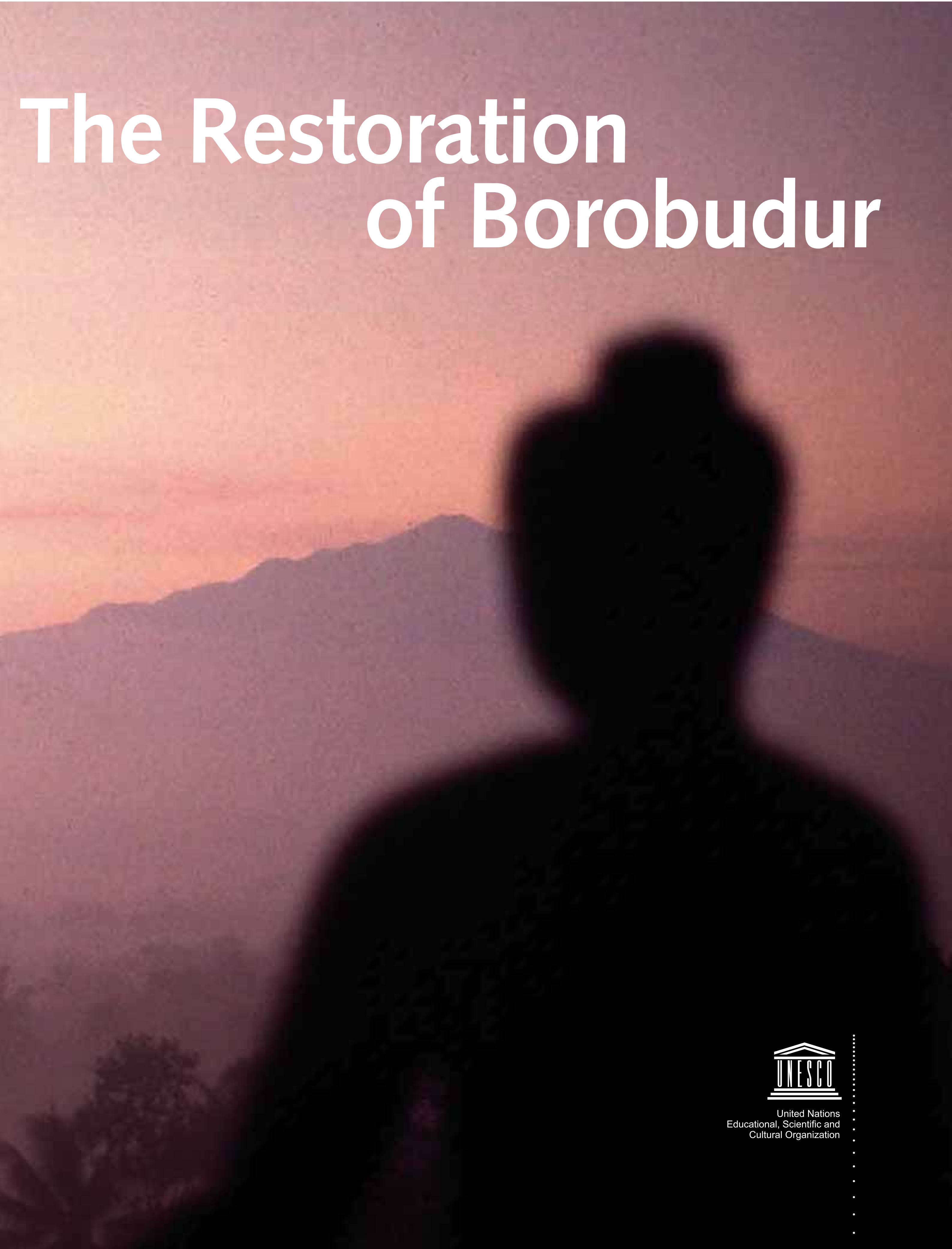
The Restoration of Borobudur



United Nations
Educational, Scientific and
Cultural Organization

The Restoration of Borobudur

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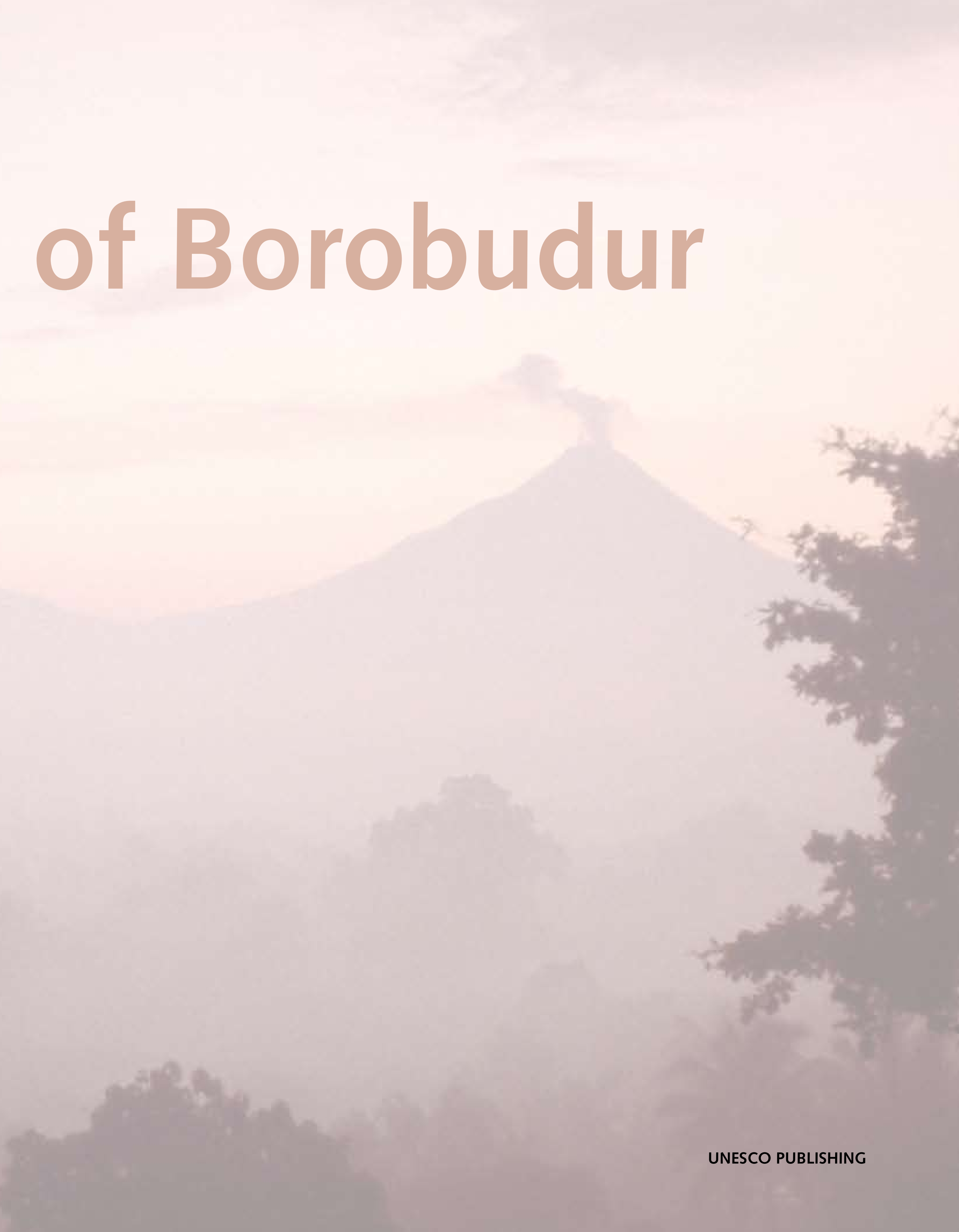

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Foreword

by Ir. Jero Wacik, SE

It is a great pleasure to write this foreword marking the auspicious launching of the Borobudur publication entitled *The Restoration of Borobudur*, published by UNESCO. It is timely to reflect on the glory and importance of the Borobudur Temple to World Heritage.

As one of the World Heritage Sites inscribed in 1991, the Borobudur Temple is not merely owned by the Indonesian but also the international community. Therefore, it is our task to safeguard Borobudur, not only in physical terms, but also from the cultural point of view, which includes the culture of the local community surrounding the site.

The restoration of the Borobudur Temple, which was successfully conducted from 1973–1983, was coordinated by UNESCO and involved the international community as part of an international awareness effort to safeguard our World Heritage, not only through a series of campaigns, but through actual measures that could not be neglected by the Indonesian community in particular and the international community in general. It is, therefore, on behalf of the Government of the Republic of Indonesia and also as the current Minister for Culture and Tourism, that I welcome and deeply appreciate the publication of this very important international event initiated by UNESCO.

I would like to congratulate all the people concerned who have made this publication possible. I sincerely hope that it becomes an important means of sharing scientific experience as well as of improving and strengthening international cooperation efforts and awareness of our World Heritage.

Jakarta, February 2005

Ir. Jero Wacik, SE
Minister of Culture and Tourism
The Republic of Indonesia

Foreword

by I Gede Ardika

It is indeed a great pleasure and honour to extend my gratitude, on behalf of the Government of the Republic of Indonesia, for the publication of *The Restoration of Borobudur*. Two decades on from the completion of the Borobudur Restoration Project, the long writing process initiated by Dr Soekmono has finally become a reality. This would not have been possible without the excellent contributions of authors from various specialities and technical backgrounds who have given generously of their time – often in spite of numerous other, pressing commitments. Many difficult challenges were met, particularly regarding the search for, and compilation, of data that was often spread widely across different areas of our country and abroad. Therefore, I would like to applaud their remarkable contribution. The importance of the role performed by UNESCO as our main counterpart for the whole process of restoration goes without saying. Their funding assistance has also played a vital part in the publication of this book. For this, acknowledgements are due both to the UNESCO Jakarta Office and UNESCO Headquarters in Paris.

The Restoration of Borobudur presents a magnificent work of art and architecture built over 1,000 years ago. As we all know, Chandi Borobudur is one of the world's greatest man-made masterpieces, a testament to a golden age. Its restoration prevented the complete loss of this monument and is considered to be the most successful endeavour of its kind ever undertaken. Hopefully, the completion of the restoration project will now be followed by further improvements in both preservation techniques and utilization of this monument that will ensure it endures for another 1,000 years. These developments, in addition to maintenance of the site, will be our challenges in the years to come, while preservation improvements will also focus on not only tangible, but also intangible culture.

Last but not least, the very existence of Chandi Borobudur is a source of great pride for our nation. Its inscription on the World Heritage List means that the monument has been acknowledged as an invaluable asset to the international community because of its outstanding and universal values. Therefore, it is our hope that this publication on Chandi Borobudur will not only enable a clearer understanding and appreciation of the values of cultural heritage, but also of universal values it represents: cooperation, peace and goodwill among the countries of the world.

I Gede Ardika
Former Minister for Culture
and Tourism of
the Republic of Indonesia

Foreword

by Koïchiro Matsuura

UNESCO has been involved in the preservation of Borobudur since 1968 when it sent a first team of experts to report on the Chandi's condition following an appeal from Indonesia. In 1972, the International Safeguarding Campaign of Borobudur was launched by UNESCO with generous financial support from a number of Member States, including Japan, West Germany, Australia, Belgium and Great Britain.

In 1991, eight years after the end of the campaign, Borobudur was inscribed on the World Heritage List. The three criteria for such an inclusion were that it represented a masterpiece of human creative genius; that it exhibited an important interchange of human values over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; and that it was directly or tangibly associated with events or living traditions, with ideas or beliefs, and with artistic and literary works of outstanding universal significance.

Thanks to the remarkable restoration of this beautiful Buddhist Chandi – the result of which is visible for all to see today – more than 2.5 million people now visit Borobudur each year.

I had the honour to take part in the Fourth International Experts Meeting on Borobudur, which took place in July 2003, marking the twentieth anniversary of the end of the restoration of the Chandi. On this occasion I encouraged the experts to formulate a tourism development programme that would also benefit the local community. I furthermore expressed my full support for the Minister for Culture and Tourism's proposal of launching a Phase II Borobudur Restoration Programme for the twenty coming years, focusing on the spiritual and educational values of the site. Work on this programme has since begun.

It is a great privilege for UNESCO to be part of this important endeavour and I am very pleased to present this book, not only recalling the fruitful cooperation between UNESCO, the international community and Indonesia during the restoration of Borobudur, but also giving precious technical, historical, archaeological, religious and cultural information on this jewel of the World's Cultural Heritage.

I hope that the close ties between UNESCO and Indonesia will long continue to exist.

Koïchiro Matsuura
Director General, UNESCO

Preface

This book honours a legacy. This legacy first and foremost marks Chandi Borobudur as a 'chandi': a religious monument immortalizing a Hindu or Buddhist king between the eight and fifteenth centuries AD. Chandi Borobudur is an outstanding example from among the hundreds of monuments in Indonesia – edifices that stand as a testament to a great tradition of religious building. The legacy is also that of Professor Dr Soekmono, Indonesia's first archaeologist, who served as project manager on Borobudur from 1971 until 1983. During this period, Borobudur underwent meticulous physical restoration with the support of UNESCO. While Professor Soekmono stands at the forefront of this legacy, many others have worked to bring this extraordinary legacy to fruition. Most notable among these are Professor Soekmono's assistants and experts from the Ministry of Culture and Tourism led by Dr Anom, who acted as editor of this book. All worked following Professor Soekmono's death to give birth to this significant work.

Chandi Borobudur is not only a monument to the past, however, but also an heirloom of special significance for the people of Indonesia. It is a symbol of the extraordinary cultural diversity that characterizes the vast archipelago of islands that form this country. Borobudur is a symbol of religious tolerance, a Buddhist monument in a predominately Muslim country also inhabited by Christians, Hindus and Buddhists.

Borobudur is also one of the three cultural World Heritage sites of Indonesia, the other two – the Hindu site of Prambanan, and the hominoid site of Java Man, Sangiran – lying within the same general geographic area. Some 2.5 million people visit the Borobudur site every year, bringing the monument to life and highlighting the context of the surrounding mountainous 'mandala' landscape in relation to which it was originally constructed. Indeed, Borobudur is now entering the second phase of its restoration, which will examine the context of this wider landscape and its peoples.

Commencing twenty years after the conclusion of the first restoration phase, the second phase began in July 2003. It has been made possible through cooperation between UNESCO and Indonesia's Ministry of Culture and Tourism with funding from both UNESCO and Japan. The focus now centers on meaning and relationships. UNESCO and the Ministry are working with local peoples, seeking to restore Borobudur's value both in terms of local understanding of its cultural and religious significance, and as source of local enterprise and income. As a Buddhist heritage monument located in a largely Muslim community, the revival of Borobudur's religious significance is being accomplished in the context of an inter-faith programme, led by a musical dialogue – an inseparable and vital part of the overall spiritual and cultural restoration of Borobudur.

Chandi Borobudur is therefore coming to life in 2005. The outstanding legacy of the first phase of restoration led by Professor Soekmono provided the platform both for the present and for the maintenance of this World Heritage site as a living, enriching presence in Indonesia. UNESCO also continues to maintain its interest in this important project. We believe that the publication of *The Restoration of Borobudur* is of considerable importance both for Indonesia and for the world, and congratulate all those whose efforts and highly valuable contributions have made it possible.

Stephen Hill
Director and Representative
UNESCO Office, Jakarta

Acknowledgements

Professor Dr Soekmono, Borobudur's project manager from 1971–83 and Indonesia's first archaeologist, commenced the writing of this publication soon after the completion of the Borobudur restoration in 1983. His main objective was to compile various reports, researches and his own observations of the comprehensive restoration. All aspects of the restoration, including the conservation process are presented in this publication as a means of providing information on these topics.

Due to his activities as professor in several universities and consultant on various restoration projects on both national and international scales, Dr Soekmono was unable to finish the manuscript. When he died in 1997, several of his assistants took his completed first draft and continued his work, researching documents related to restoration projects. With the publication of *The Restoration of Borobudur* in 2005, the hard work of Dr Soekmono and all those involved in the writing of this work, has finally borne fruit.

This book is divided into eight chapters: the Introduction, Getting Acquainted with Chandi Borobudur, Saving Chandi Borobudur, Towards an International Project, Studies on the Sources and Causes of Decay, Execution of the Project, The Post-Restoration Development Plan, and A New Perspective on Some Old Questions Pertaining to Borobudur, the last chapter contributed by Prof. (Em.) Caesar Voûte.

The publication of this work would not have been realized without both the financial and editorial assistance of UNESCO. Therefore, the Ministry of Culture and Tourism wishes to acknowledge with deep gratitude the financial assistance of UNESCO that made possible the editing and printing of the text, photos and figures. Special thanks and gratitude are due to the Technical team, who prepared the second draft, especially for their continuing interest and support of the work Dr Soekmono initiated. Our gratitude also goes to the Finalization team, who completed the manuscript based on the writings, photos, drawings and annexes of Dr Soekmono and the Technical team. All names are given on the following page.

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1. General Introduction

Chandi Borobudur is one of hundreds of monuments that mark the great tradition of building religious edifices in Indonesia. These splendid architectural achievements were erected at a variety of locations, not only in the open plains and valleys but also on the slopes and even at the summits of mountains.

These monuments, built either of stone or brick, are traditionally called 'chandis', no matter what they were originally meant for. It is not only shrines and temple buildings that are denominated chandis, but also gateways, stepped pyramids, terraces and even bathing places. The main criterion is neither the kind of building nor its function in the past, but rather the period to which these buildings belong and the Hindu-Buddhist trend underlying their construction.

Chandis are peculiar to a certain period in Indonesian history: the period between the beginning of the eighth and the end of the fifteenth centuries AD, when Hinduism and Buddhism strongly influenced the indigenous ancestor worship. Indeed, chandis were constructed to glorify kings who were considered the incarnation of a Hindu or Buddhist deity, and who after their deaths were immortalized by the erection of statues depicting their divine appearance.

For how long a period the chandi and its statues functioned as an integral part of society's religious life cannot be determined precisely. It is generally assumed that when the Indonesian people embraced Islam around the beginning of the fifteenth century, the monuments lost their function and were neglected. They were abandoned and fell gradually into oblivion. Regardless of the exact time at which the chandis ceased their function, all had to be individually rediscovered before once more becoming a part of contemporary knowledge. They were all found in a ruinous condition, and many of them were even buried or covered with dense vegetation.

For many centuries the chandi was neglected, but only in the material aspect as a tangible structural achievement. Spiritually it remained deep-rooted in the hearts of the Indonesians. The chandi and the glorious past it reflected were always remembered. The change of religion inevitably led to a gradual change in people's attitude towards the monuments, but this was not due to indifference. A kind of mysterious fear replaced the old understanding, but the spiritual value of the chandi as a cultural heritage secured the ties between the past and the present. The chandi is considered a 'pusaka'.

Left: Worn face of a bas-relief

A pusaka is an heirloom of special significance. It is held in high esteem, and possesses an intimate spiritual connection with its keeper. Ownership is determined by heredity, and may be vested in an individual or a community. Where the owner is an individual, the intimate association with a pusaka may even tend towards superstition, with magical power ascribed to it. Kerisses, daggers, spearheads and other personal belongings are believed to protect their owners from evil and to secure their well-being. In the case of communal ownership, the 'owners' see themselves only as custodians, and may in daily life often not use, see or even think about the pusaka. However, if it were in danger of theft, damage or destruction, they would do everything in their power to save it. This is, in essence, what has happened with the chandis. A chandi is regarded as a cultural pusaka. It is not owned by a single individual, or even by a group of individuals or people in the surrounding area.

The chandi is for Indonesians today a tangible witness of their glorious past and a spiritual beacon that fosters the self-confidence that will enable them to achieve their national aspirations. Alongside the struggle for independence there was, not surprisingly, an endeavour to determine the national character, to establish a truly Indonesian identity. In this context the chandis came to be regarded as part of the national heritage on which that identity was founded. They were seen to reflect the nation's pride and greatness of spirit, to embody precepts that might serve as reference points for the future. No longer objects of purely scientific or aesthetic interest, the chandis had become the cultural pusaka of the newly independent people.

This viewpoint of the Indonesians is convincingly demonstrated by the government's attitude. In 1948, only three years after the Republic of Indonesia was proclaimed and while the fight for recognition of Indonesia's sovereignty was still continuing, special attention was given to Chandi Borobudur, which was reported to be in grave danger and needing immediate action to prevent its total loss. The perpetuation of a pusaka was at stake. Apparently stimulated by the government's decision to tackle the gigantic restoration plan of Chandi Borobudur, ample funds were released in the second Five Year Plan for the conservation of cultural pusakas. Since 1975 more than 200 monuments have been restored, chandis as well as other remains of the past. Prehistoric sites have been preserved, old mosques, churches and *puras* (Hindu-Balinese temples) have been restored, old fortresses and strongholds consolidated, and palaces and royal recreational parks rehabilitated.

As far as Chandi Borobudur is concerned, special surveys and studies were carried out from 1950, as soon as the Republic of Indonesia was internationally recognized and admitted to the United Nations. Being aware of its shortcomings, particularly in the field of archaeology and economy, the state sought international assistance through UNESCO as early as 1955. However, it was not until 1975 that measures were put into effect to preserve Chandi Borobudur for another 1,000 years. The question might be raised why so much time was needed before a definite plan could be executed.

The purpose of restoring archaeological monuments is to prevent further decay (perhaps leading eventually even to total loss) of a pusaka, one of the most invaluable documents of humanity's achievements. Its implementation varies from case to case. In some instances technical precautions, confined to the strengthening of those parts that are in danger of collapse, may suffice. At other times, even partial reconstruction may be far from sufficient.

Archaeology demands that a restoration should avoid any falsification of the record. It prescribes that the authenticity of the monument be preserved as far as possible. In fact, however, any kind of restoration inevitably introduces something new to the monument. The technique of anastylosis even makes it possible for a ruinous monument to regain its former grandeur. It is, therefore, of the greatest importance that the changes projected for a planned restoration are taken into the most serious consideration far in advance.

Deciding on the technique that would be most appropriate for a particular restoration project depends heavily on three main factors: the state of decay of the monument, the available archaeological evidence, and the policy of the responsible government. In the case of Borobudur, it was essential to undertake a series of thorough studies in the most varied fields before proceeding to the decisive step: the actual restoration work. We were increasingly convinced that we were faced with a case that required an individual approach and a very specific solution.

The state of decay of Chandi Borobudur was so far advanced that mere precautionary measures could not be justified any longer. Moreover, the degradation proved to have so many and so varied aspects that it was hard to find one simple diagnosis to cure the disease the monument was suffering from. The interaction between the various destructive agents was so complex that the elimination of one single element would only invite a reaction by the other components, either individually or jointly, that might even be fatal for the edifice. The restoration would, therefore, make sense only if the entire process of decay could be arrested completely and permanently.

With regard to the availability of archaeological evidence, the restoration undertaken by Th. van Erp in the years 1907 to 1911 had preserved so much material that it was possible to carry out a thorough reconstruction, as required by the specific case we faced. It should be kept in mind that former restorations, including van Erp's, were mainly designed to prevent the collapse of the monument's walls and the total loss of the archaeological data, and were not expected to withstand natural weathering processes for centuries.

Any further such measures, however, which would only have to be repeated after a very short time, would undoubtedly do harm and conflict with the principles of restoring an archaeological object. Even worse, such work would initiate a kind of scientific vandalism. The intention therefore was that this restoration should be permanent, and the result should last into the most remote future.

The third factor mentioned above, the government's policy, is by far the most important one, at least as far as Indonesia is concerned. In this respect we only can emphasize the fact that the perpetuation of a cultural pusaka is an integral part of national aspirations. Indeed, all archaeological monuments, irrespective of their present condition, are part of the people's daily life, being the most valuable strongholds of national consciousness and the fundamental source of national identity. Each undertaking that will touch a monument has to take the deepest feelings of the people into account. It is an endless task to convince them that restoration does not automatically imply the rehabilitation of the monument's former splendour; no scientific argument can change the desire and expectation that the result should be identical to the historic original. This desire intensifies the responsibility placed on the restorers to preserve a cultural heritage for the sake of future generations.

2. Getting Acquainted with Chandi Borobudur

2.1 The site and its environment

The site for the construction of a chandi was doubtless selected for many reasons, rational as well as irrational. Since it was intended as a sanctuary area, the natural setting would not only have to be suitable for the technical execution of the project, but also – and even more important – be able to cope with the requirements of underlying religious purposes and metaphysical conceptions. In this respect the holy scripts prescribe what spots on earth are potent sites and what surroundings in the landscape draw special attention.

It is therefore no mere chance that Chandi Borobudur was erected where it is, at the very geographical centre of the island of Java. The region is known as the Kedu Plain, and is often called the Garden of Java because of its great fertility. It is a bowl-like plain fenced by mountain ranges on practically all sides. This chain of rugged peaks is marked by two sets of twin mountains that soar into the sky to an average height of 3,000 metres above sea level. The twins to the northwest consist of the dormant volcanoes Sindoro and Sumbing, while to the northeast the sky is beautified by dormant Merbabu and the very active Merapi with its wreath of smoke over its conical peak.

The undulating plain is crossed by the two main rivers of the area, the Progo and the Elo, which run nearly parallel to each other from north to south until they meet at a point not far from Chandi Borobudur. In fact, the confluence of two rivers is one of the holy spots where 'the gods are seen at play'.

The landscape surrounding this highly accessible area is completely flat, but only a few kilometres to the west the plain is inter-

Left: Head of seated Buddha
Source: UNESCO/ Dominique Roger

Photo 2.1.1
Aerial view of Borobudur
Source: Borobudur Restoration Project

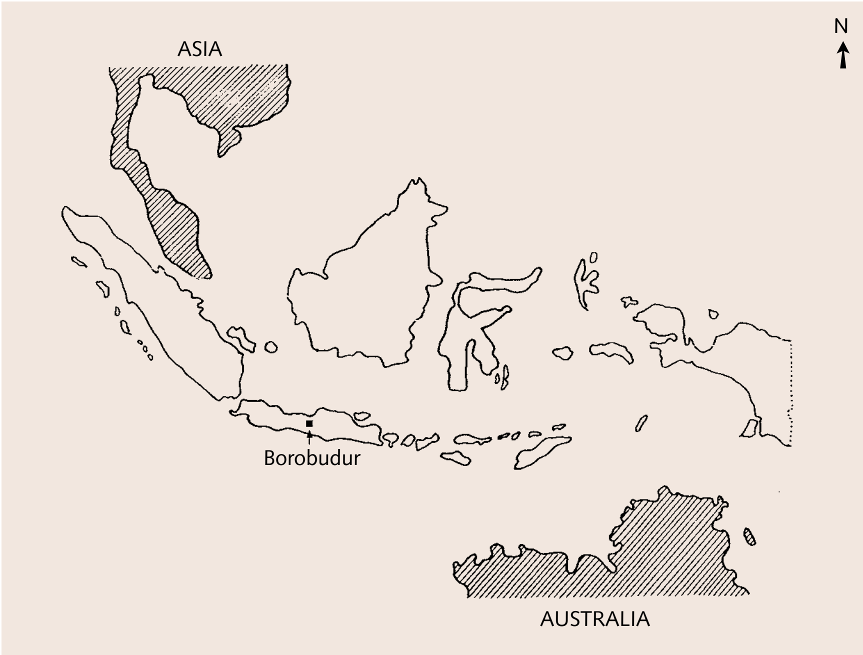


Figure 2.1.1
Map of Indonesia
Source: Borobudur Restoration Project

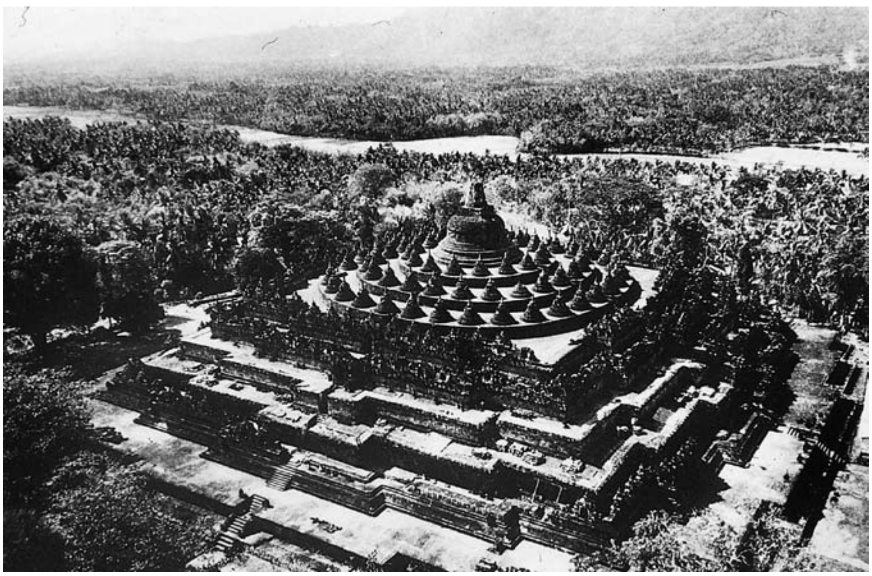


Photo 2.1.2
Borobudur
Source: Borobudur Restoration Project

rupted by a row of three small hills running from northwest to southeast, diminishing in size. It was the 15-metre-high central hill that was chosen by the creators of Chandi Borobudur.

Another very conspicuous landmark, consisting of a small rounded hill, is to be found some 15 kilometres to the north. This is the Tidar hill, which is believed to be 'the Nail of Java'. According to tradition this huge 'nail' was driven into the centre of the earth in order to fix the island of Java, which was floating in the ocean, in its present permanent position.

Another tradition relates to the architect who constructed Chandi Borobudur. It is said that one particular part of the ridge of the Menoreh mountain range, bordering the view from the monument in a southerly direction, depicts the profile of a man lying on his back. Indeed, the nose, the lips and the chin are clearly delineated. This man is considered to be the legendary Gunadharma, the monument's creator.

Chandi Borobudur is not the only monument in the area. The region was formerly strewn with temple buildings, as is evident from the fact no fewer than thirty sites have been found within a radius of 5 kilometres around it (Sub Konsorsium Fakultas Sastra dan Filsafat, 1976). It is notable that nearly all of them are Hindu. Only Borobudur, Pawon, Mendut and Ngawen are Buddhist.

It is also remarkable that not a single one of the Hindu monuments was found intact. They were all discovered in such a deplorable condition that only a few fragments could be recognized. Chandi Banon, which is situated only a few hundred metres north of Chandi Pawon, and which produced the best sculptures in the history of Indonesia was nothing but a heap of fallen rubble.

The condition of the Buddhist temples was

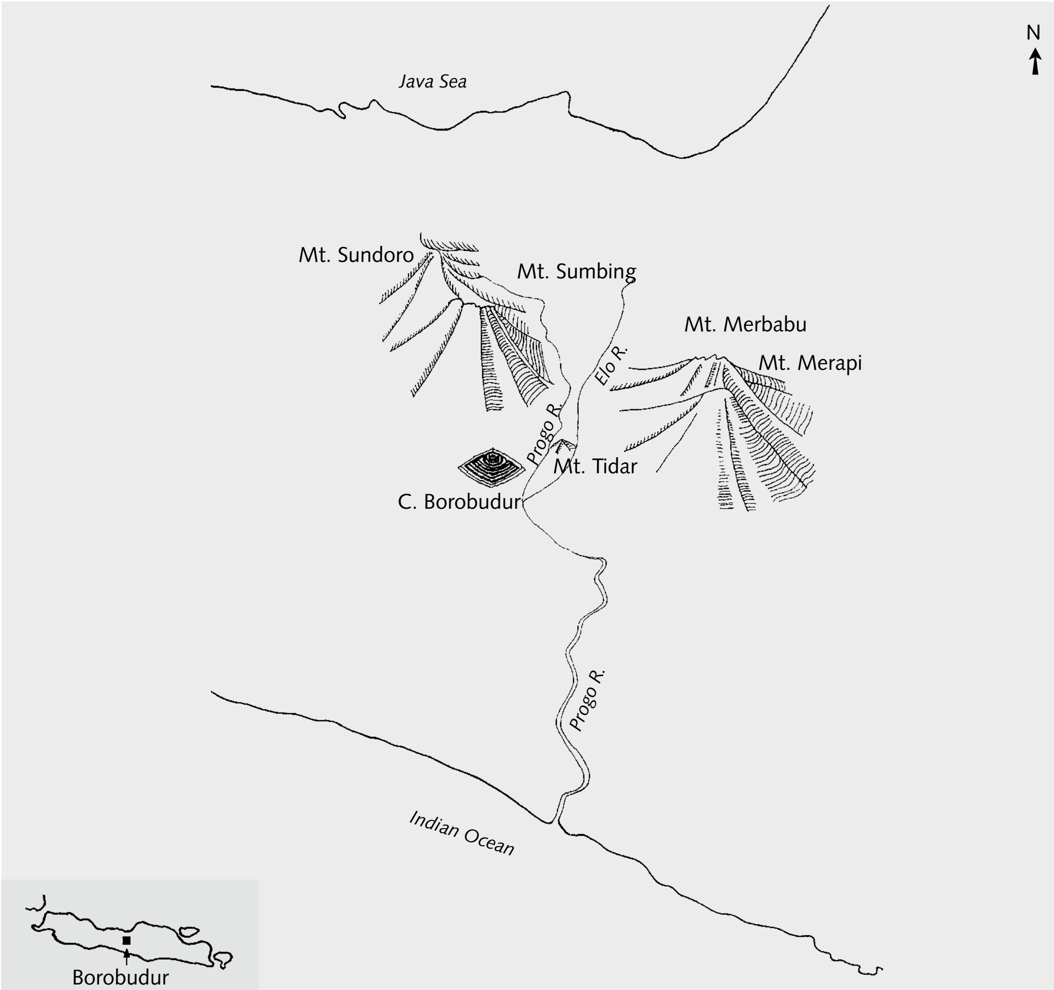


Figure 2.1.2
Location of Borobudur
Source: Borobudur Restoration Project

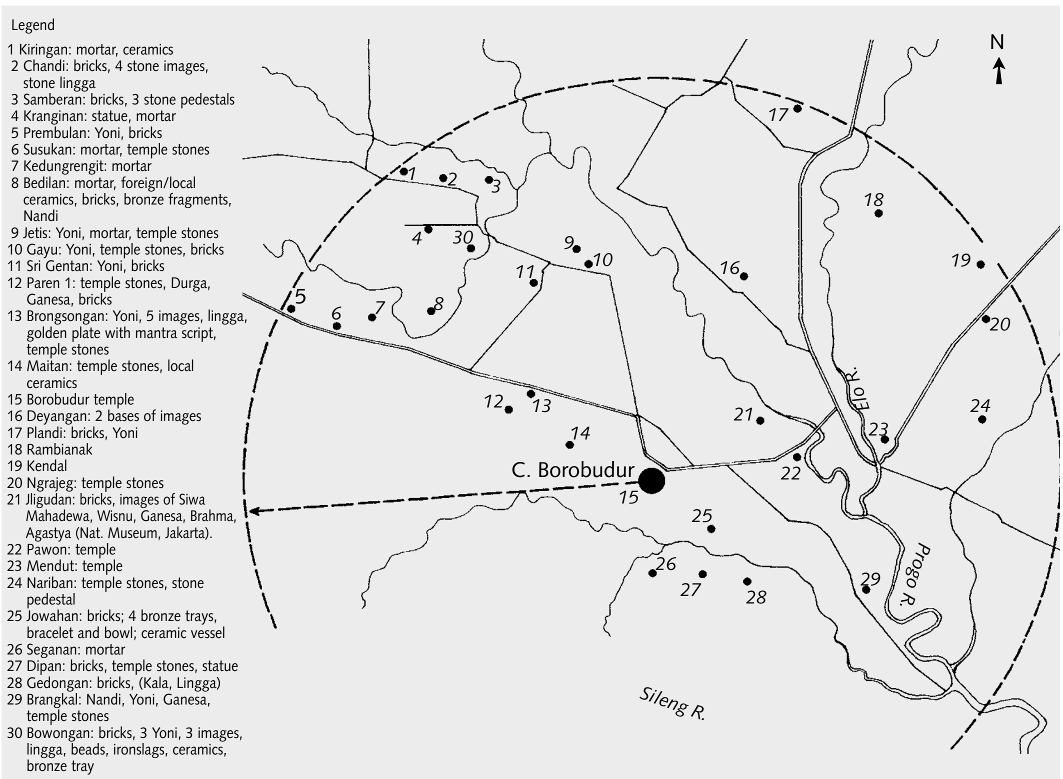


Figure 2.1.3
Monuments at a radius of 5 km around Borobudur
Source: Mundardjito

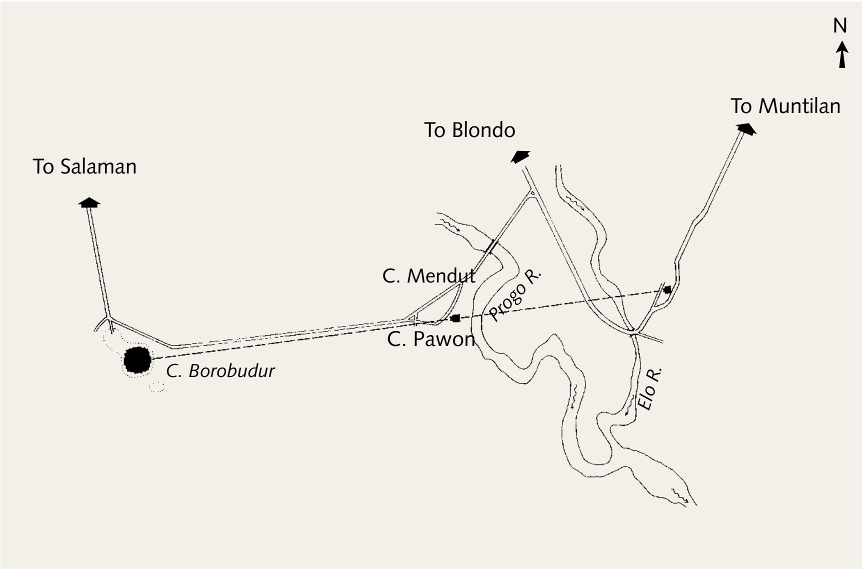


Figure 2.1.4
The triad of Borobudur, Pawon and Mendut
Source: Borobudur Restoration Project

quite different. Though their present state is the result of a restoration, they retained more than enough original material when discovered to make a reconstruction possible. In this respect the triad of Borobudur, Pawon and Mendut draws special attention, particularly because of the remarkable affinities demonstrated by the sculptural art. It is also striking that the three monuments can be connected with each other by an imaginary straight line drawn from Borobudur to Mendut through Pawon. Consequently the assumption is justified that the three monuments actually constitute one entity, representing one conception.

A chandi compound is normally laid out as a whole. The structures are built close together, the main building being clearly distinguished from the ancillary temples. A surrounding wall generally borders the common courtyards. This kind of layout, however, is not to be found at Borobudur. Chandi Mendut is some 3 kilometres from Chandi Borobudur, while Chandi Pawon is approximately half that distance away. It is hard to imagine a common courtyard covering so large an area. No traces have been found of any enclosure binding the triad together and bordering a common courtyard. Nevertheless, there is good reason to assume that the three monuments belong to one single grand design.

According to oral tradition, the triad was once linked by a paved processional path, flanked by richly decorated balustrades. Unfortunately, land and aerial surveys have so far produced no convincing evidence of this. Some hewn stones found in a field east of the village of Borobudur many decades ago are supposed to be remains of the pavement but no other indication has been found.

A special survey that included geological observations on the banks of the rivers Progo and Elo could not reveal even the scantiest remains of bridges or other means to cross the rivers.

The exceptional composition of the triad has led to much speculation about the actual relation between Chandi Borobudur, Chandi Pawon and Chandi Mendut. The most plausible link is to be sought in the religious sector, if the three monuments as a whole are interpreted in a particular way to represent one religious concept.

Photo 2.1.3
Borobudur
Source: Suparno

Chandi Borobudur has no inner space, and so does not provide a fixed place where the devotees might perform their religious duties and rites of worship. Most likely it was a place of pilgrimage, where Buddhists could seek the 'Highest Wisdom'. The passages all around the edifice, successively mounting to the uppermost terraces, are evidently suited to ritual circumambulations. Guided and instructed by the narrative relief, the pilgrim proceeds from one terrace to another in silent contemplation.

Chandi Mendut, on the other hand, does seem to have been a place of worship. In semi-darkness the Buddha is represented by a formidable monolith, seated with hanging legs on a throne and flanked by the accompanying Bodhisattvas, Avalokiteshvara and Vajrapani. The depiction of the Buddha preaching the first sermon in the deer-park at Sarnath is apparently meant to recall good conduct in life to those who seek their refuge in the Compassionate Buddha.

The very small Chandi Pawon also has an inner space, but it does not reveal which deity might have been the object of worship. Not a single statue has been found, and there is not the slightest indication that can be traced back. It is therefore impossible to identify the actual function of the temple in relation to Chandi Mendut or to Chandi Borobudur.

The assumption that pilgrims had to pass Chandi Pawon on the way from Chandi Mendut to Chandi Borobudur along the paved processional path might suggest that Chandi Pawon was a kind of way-station on the long journey; after they had been purified through the required ceremonies of worship at Chandi Mendut, Chandi Pawon allowed them to pause and reflect before proceeding on the pilgrimage to Chandi Borobudur, where a tiring series of circumambulations awaited.

The sequence followed by the pilgrim in ancient times remains the same for the present visitor. The normal route to Chandi Borobudur, either from Yogyakarta or from Magelang, passes Chandi Mendut, so that the first monument that emerges before reaching Chandi Borobudur is Chandi Mendut. Chandi Pawon, however, is to be reached by a side-way since the present road does not follow the ancient processional path.

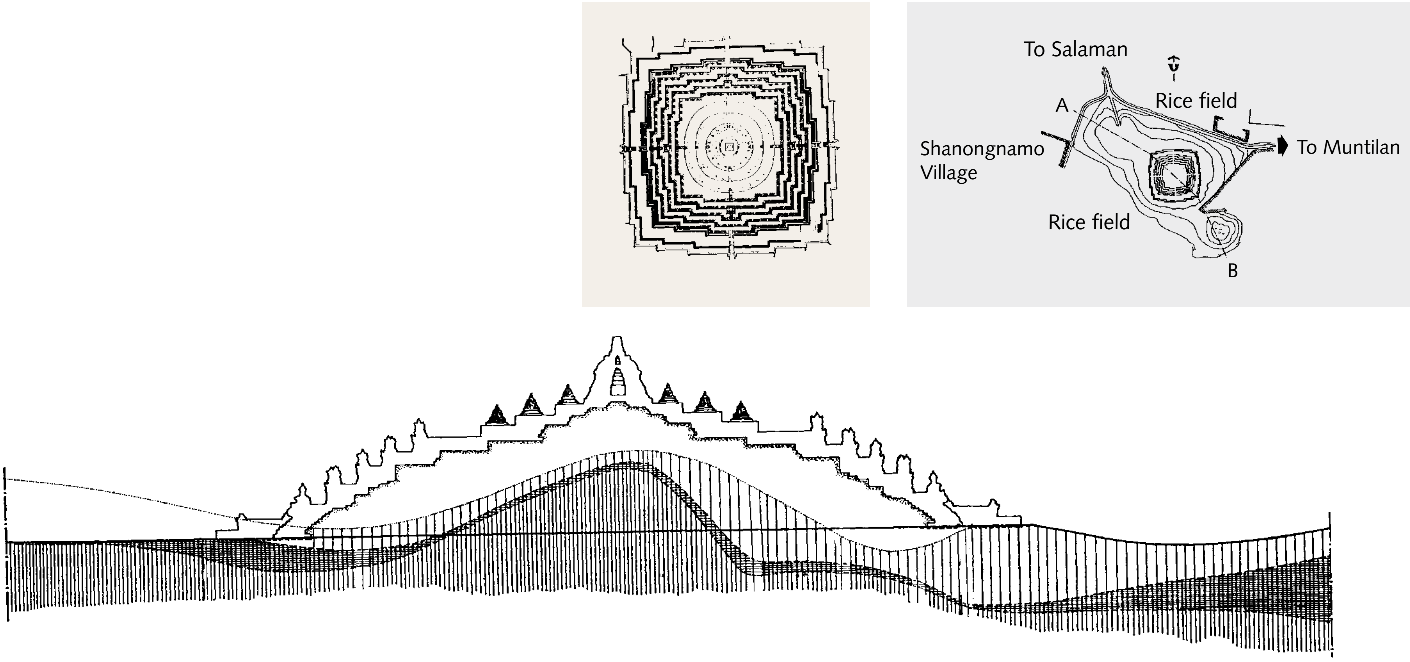


Figure 2.2.1
Top view, plan and cross-section of Borobudur
Source: Borobudur Restoration Project

2.2 The monument

Chandi Borobudur is constructed on a hill that rises some 15 metres from the surrounding plain. The top of the hill was levelled to form a plateau. The main part of this was designated as the site of the monument, while the plain and the northwestern spur of the hill provided the location for the monastery and ancillary buildings.

The erection of a chandi on top of a hill is a common feature, but to build it around the top of a hill – using it as the core of the structure and wrapping it totally in the construction – is a technique thus far only found at Borobudur. In fact, Chandi Borobudur not only differs from the conventional building technique of the chandi in being erected on a sloping surface, but even more in its architectural design. It is not a building provided with an inner space for the enthronement of the statue of a deity, but is a stepped, unroofed pyramid consisting of nine superimposing terraces, and crowned by a large bell-shaped dome. Nevertheless, a main vertical division into three parts – base, body and top – is discernible.

The base forms a square with protuberances, measuring 123 metres at the axes. The 4-metre-high walls of the base are supported by a foothold, resembling a huge plinth, 1.5 metres high and 3 metres across.

The body or middle part of the monument is composed of five terraces, which diminish in size with height. As if to emphasize the changes from one part to another, the first of these terraces stands back some 7 metres from the sides of the base, creating a broad platform right around the monument. The other terraces retreat only 2 metres at each stage, and balustrades at the outer sides convert the narrow galleries into corridors.

The superstructure is again clearly distinguished from the terraces. It consists of three re-entrant circular platforms, each of which supports a row of perforated *stupas*. Surmounting the row of *stupas*, which are arranged in concentric circles, the central dome on top of the whole monument soars into the sky to a height of nearly 35 metres above ground level.

Access to the upper part of the monument is provided by stairways in the middle of each side of the pyramid. Through a series of gates, most of which have been lost at each level, a stair leads directly to the circular platforms, at the same time intersecting the corridors of the square terraces. The main entrance is on the eastern side.

Photo 2.2.1
Jaladvara (water-spout)
Source: reproduced from Miksic, 1990

Photo 2.2.2
Lions at the entrance
Source: reproduced from Miksic, 1990

Staircases are also found on the slopes of the hill, mounting from the lower-lying plain to the elevated plateau, and linking up with the stairways of the monument by means of paved walkways. The entrances are guarded by stone lions, and so are the different levels of the pyramid, making up a total of thirty-two lion statues in all.

The builders of Chandi Borobudur apparently realized the need for a drainage system to cope with the heavy rains. Spouts were provided at the tiled corners of the mounting stages to drain off the rainwater from the galleries. All the 100 spouts are beautifully carved in the shape of *makaras* or gargoyles.

The vertical division of Chandi Borobudur into base, body and superstructure perfectly accords with the conception of the Universe in Buddhist cosmology. It is believed that the universe is divided into three superimposing spheres, *kamadhatu*, *rupadhatu* and *arupadhatu*, representing respectively the *sphere of desires* where we are bound to our desires, the *sphere of forms* where we have abandoned our desires but are still bound to name and form, and the *sphere of formlessness* where there is no longer either name or form.

At Chandi Borobudur, the *kamadhatu* is represented by the base, the *rupadhatu* by the five square terraces, and the *arupadhatu* by the three circular platforms as well as the big *stupa* (see Photo 2.2.3).

The *rupadhatu* is distinguished from the *arupadhatu* not only by the architectural features, but also by the abundance of decoration of the square terraces in contrast to the plainness of the circular platforms. The base, however, gives no immediately visible evidence of representing the *kamadhatu*. This is because it is not the original support of the monument, but an encasement that hides from the visitor's sight the real base with its series of 160 reliefs. Many of these reliefs are provided with short inscriptions, apparently meant as instructions for the sculptors indicating the scene to be carved. The inscriptions were recognized as key words from the holy Buddhist script *Mahakarmavibhangga*, which deals with the operation of karma: the law of cause and effect in reincarnation, in heaven and in hell. The reliefs depict morality on earth, showing how every thought, act and feeling results either in some happy circumstance or some terrible mishap.

The law of cause and effect is fundamentally a predominance of desire. Hence the designation *kamadhatu* is undoubtedly correct for the base and hidden 'foot' of Chandi Borobudur.

The obvious question, of course, is why the hidden 'foot' was buried, hiding the zeal and dedication of the devoted artists. The use of 12,750 cubic metres of stone to make the encasement and the sacrifice of architectural elements and reliefs seem to indicate very strongly that the soundness of the monument was at stake. As a considerable part of the gradually mounting foundations of the stepped pyramid had to rest on filled earth, some sliding probably took place, and it became necessary to wall in the base. In other words, the encasing wall was a retaining embankment thrown up on all sides to prevent further sliding and to avoid disaster.

The technical solution of an encasement had certain aesthetic and religious compensations. The broad platform provided by the additional wall smoothes the outlines. At the same time it furnishes ample space and allows the pilgrim to perform the preliminary rounds at leisure and reflect deeply again before entering the 'Narrow Path of Buddhism'.

Buddhism lays particular stress on the stages of mental preparations to be undergone before attaining the ultimate goal, which is the definitive liberation from all earthly bonds and the absolute exclusion of rebirth. The three spheres of the universe are consequently designated in similar terms.

In contrast to the openness of the broad base, therefore, the mounting stages of the monument are provided with narrow passages, thus symbolizing humanity's total freedom in *kamadhatu* and the focusing of the bodily sight and concentration of the mind. These restrictions are irrevocable when entering the narrow path leading to the ultimate salvation. Indeed, the narrow galleries of the *rupadhatu* help the faithful to achieve this in a most appropriate way.

The *rupadhatu* is at first sight bewildering. The walls are full of reliefs, and so are the balustrades. No fewer than 1,300 panels of narrative reliefs, over a total length of 2,500 metres, and a further 1,312 decorative reliefs, flank the corridors. Over the reliefs on the walls, a continuous carved frieze stretches for over 1,500 metres, and the cornices above it are embellished by 1,416 antefixes. The upper part of the walls (corresponding to the outer facades of the balustrades) consists of niches alternating with decorative reliefs. There are 432 niches around the five terraces, each containing a statue of a seated Buddha. Over and above the niches, small solid *stupas* soar into the sky. And since the walls behind the niches constitute the inner facade of the balustrades, the row of 1,472 *stupas* in turn forms the somewhat rugged skyline of the balustrades.

The bewildering abundance of forms in the *rupadhatu* has its counterpart in the narrative reliefs. The life of the Lord Buddha, from his descent from heaven until his enlightenment, is depicted on the main wall of the first gallery. It is based on the holy script *Lalitavistara*. The reliefs covering the walls of the

Photo 2.2.3
The terraces and platforms
Source: Borobudur Restoration Project

second, third and fourth galleries depict the story of Sudhana in search of the Highest Wisdom and the Ultimate Truth. The story is based on the manuscript *Gandavyuha*.

The perseverance of the principal figures of the *rupadhatu* and their tireless efforts towards each ultimate goal, despite their involvement with the extreme richness and beauty of forms, provide a model for the pilgrim who passes through the successive stages.

In striking contrast to the square terraces of the *rupadhatu*, the circular platforms representing the Sphere of Formlessness are plain: no carving, no ornaments, no embellishments. The only break in the monotony is offered by the circles of *stupas* around the big central dome. Supported by lotus cushions, the *stupas* are arranged in three concentric circles, corresponding to the three circular platforms. In all there are seventy-two *stupas*: thirty-two on the lowest or first platform, twenty-four on the second and sixteen on the third. Each of them has a kind of latticework surface, composed of stones and diamond-shaped empty spaces that partly disclose the seated Buddha statue inside.

The central *stupa* rests on a base more than 12 metres in diameter and a huge lotus cushion half a metre thick. The dome has an inner space, but no entrance was possible. It was, however, meant to represent the image of the most sublime Buddha.

The complete openness of the *arupadhatu*, and the magnificent view from it, realistically symbolize the endless widening of the spiritual horizon that the pilgrim can achieve by consistently following the devout conduct in life of the Lord Buddha. Absorbing the spirit of the *rupadhatu* offers the delight of becoming wiser, if not enlightened. And the ordinary visitor finds that the weary journey is richly rewarded.

2.3 Stages of construction

The discovery in 1885 of a carved wall inside the broad base encircling Chandi Borobudur gave rise to many problems. The questions 'why' and 'what for' have puzzled many students in archaeology and architectural history.

The general assumption is that the encasement of the foot of the monument was intended to resist a danger of slippage that threatened the monument with an eventual disastrous collapse of the construction in progress. This solution finds support in the fact that several reliefs adorning the hidden foot are left unfinished, whereas others that were already completed have been chiselled away.

The subsequent question is why so many cut stones were employed for the construction of the retaining wall. The use of no less than 12,750 cubic metres of stone material, resulting in the addition of a broad platform about 7 metres wide and 4 metres high all around the monument, seems neither logical nor in line with the high qualities of the entire construction.

A non-technical but plausible answer is also worth considering. According to this suggestion, it is essential for the completeness of Chandi Borobudur in symbolizing the universe that the *chakravala* be materially represented. The *chakravala* is the iron curtain of the horizons, which keeps the most remote realities hidden from human sight. And this is exactly the meaning of the encasing construction. A retaining embankment, if constructed only for technical purposes, might surely have been built with much less material.

It is not easy to determine which of the two solutions is most plausible. It is possible that both are right, since in chandi architecture it is quite common to come across the solution of a technical problem that is closely associated with religious concepts.

During the restoration of Chandi Borobudur by van Erp (1907–11), several other structural changes were observed, including the existence of stairways under the present ones, the modification of the gateways, and the bottom layers of a huge *ogive* or bell-shaped plinth inside the first circular terrace at the upper part of the monument.

The recent restoration project has also revealed other evidence of constructional changes in the monument. Borings through the galleries of the monument and excavations around the base of the building brought to light a series of significant new data. The stratigraphy at several pits showed the occurrence of subsidence, whereas the finding of apparently rejected structural elements and fragments clearly indicates the re-use of waste material for the foundations.

A special study on the newly obtained data conducted by Mr Dumarçay concluded that the present Chandi Borobudur is a result of a series of structural modifications. He distinguished five stages of construction.

The first stage

At first appearance, a small wall of three or four carefully edged courses formed the foundations of the monument in its first form. The foundation wall was partly buried by debris from waste stone. After the completion of the foundation wall, the next step was the definitive foot, which was somewhat set-off from the foundation wall.

As the building progressed, scaffolding became necessary. It was put into position above the first level of stone waste and the feet of the poles were gradually buried by refuse from the construction. When the walkways began to be paved, the scaffolding remained in place for some time, doubtless until the monument reached the level of the

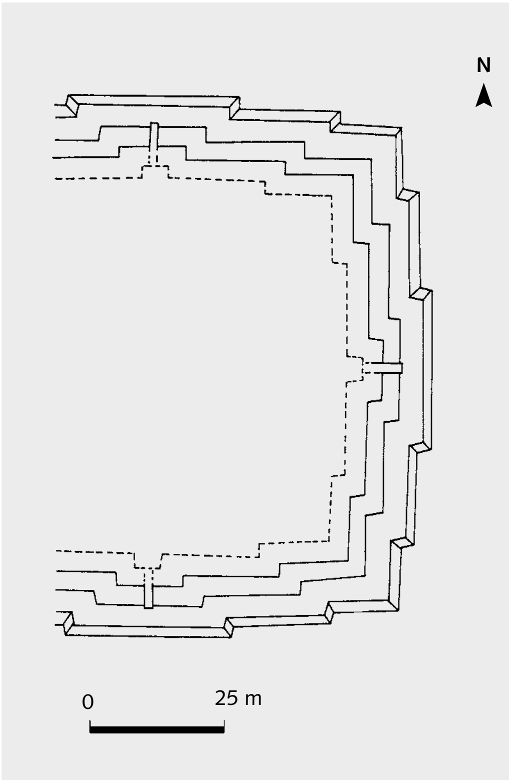


Figure 2.3.1
Plan of the first construction stage
Source: Borobudur Restoration Project

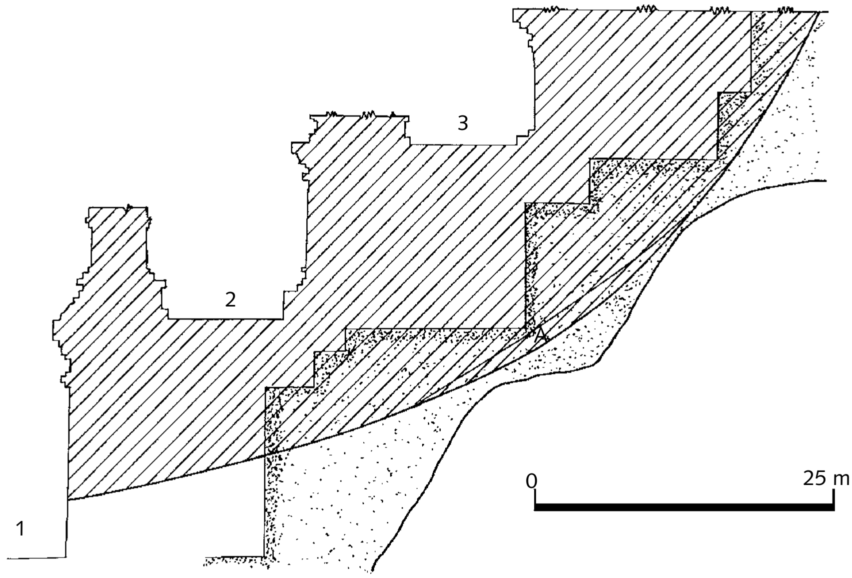


Figure 2.3.2
Limit on the northern side of the slide during the second period of construction
Source: Borobudur Restoration Project

first gallery. At this point it was taken away and the space previously occupied by the poles was filled with stone blocks.

The beginning of this construction work was not without technical problems. After the first course of the retaining wall for the second gallery had been laid, a major subsidence occurred on the west side because the fill had been poorly compacted. It was necessary to re-align the level of the base of the wall's facing. This was done with a levelling course of wedge-shaped stones, thus restoring the departure point for the wall and the paving.

The construction progressed up to the level of the third gallery where, for unknown reasons, the work stopped. Possibly the monument was at that time already complete or nearly complete but without reliefs.

The second stage

The second period of construction was a complete renewal of the building, with the insertion of new material, starting from the second gallery. At this level the wall was placed outside the one of the first stage; it appears on each side of the stairway on the southern face. On the northern face everything disappeared because of an earth movement that is especially noticeable on the eastern side of the northern face (Figure 2.3.2). The layer of stone debris slipped and a large gully appeared on the hillside. This is why, quite naturally, the supervisor rejected the parts of the structure that had been destroyed on the northern side. But a few remained where the earth movement had

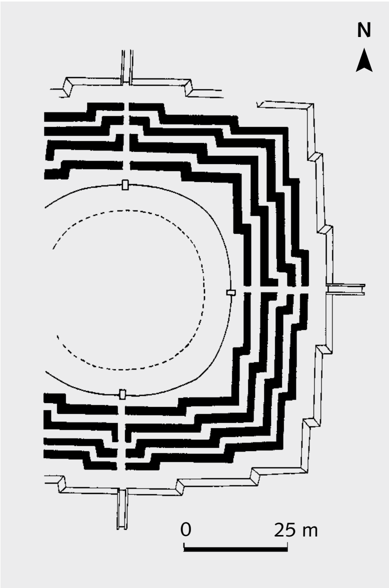


Figure 2.3.3
Plan of the second stage
Source: Borobudur Restoration Project

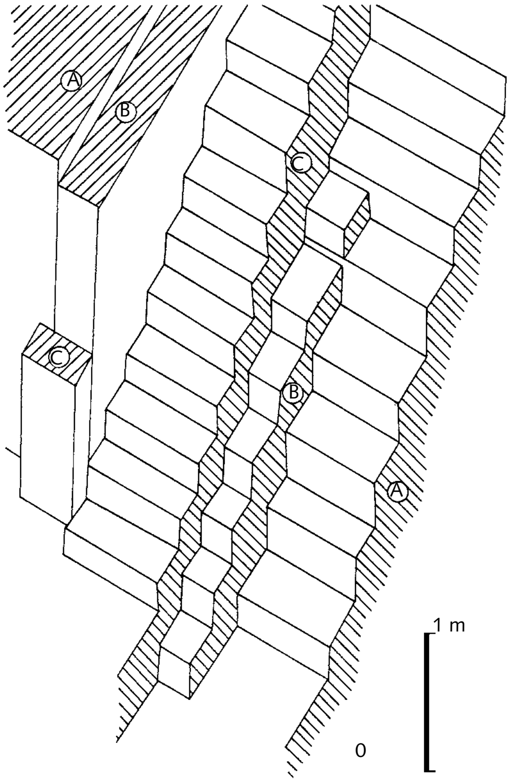


Figure 2.3.4
Stairways from the first to the second gallery
Source: Borobudur Restoration Project

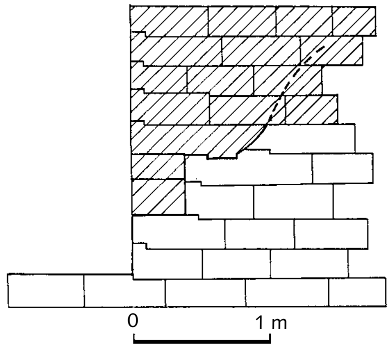


Figure 2.3.5
Section of the edge of the first circular terrace (according to van Erp)
Source: Borobudur Restoration Project

carried them, as is evidenced by the find of a small *stupa*. This is proof that the monument was nearly finished when the disaster occurred. The work, however, was started again immediately while following the same plan (Figure 2.3.3).

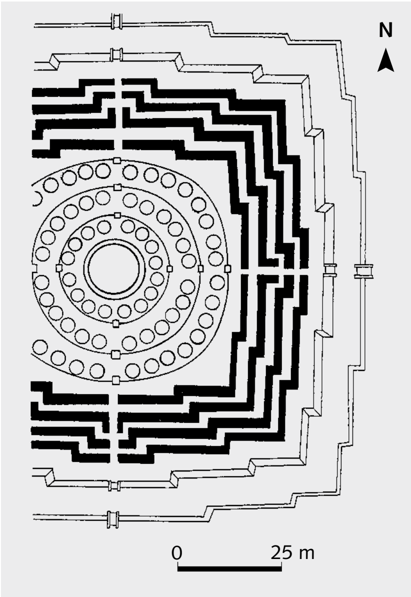
The third and fourth galleries show slight differences. The stairways had to be reconstructed (Figure 2.3.4: A first stage, B second stage, C third stage), for the earlier structure was lower and consequently the staircase was less steep.

While a fairly large circular structure was being built on the top of the plateau, the work was again interrupted. Not much can be found out about this structure, but it was probably not yet completed when the work had to be stopped. Only the beginning of the moulding of the foundation remains.

The third stage

At the base of the monument, perhaps due to a new earth slippage that stopped the work at the top, a massive foot was built, completely hiding the reliefs of the original base. On the side of the hill, a complex grading was begun, including five levels of compressed earth, interrupted by four stairways. The paving of the first stage was extended and gutters inserted to remove rainwater to the edge of the earth platform. It would seem that these gutters were extended eastwards along the length of the steps, which had begun to be dressed on the eastern side. This enormous work was only partially completed, although the two upper levels of the eastern side of the north wing were completed.

It is not known in what state the builders



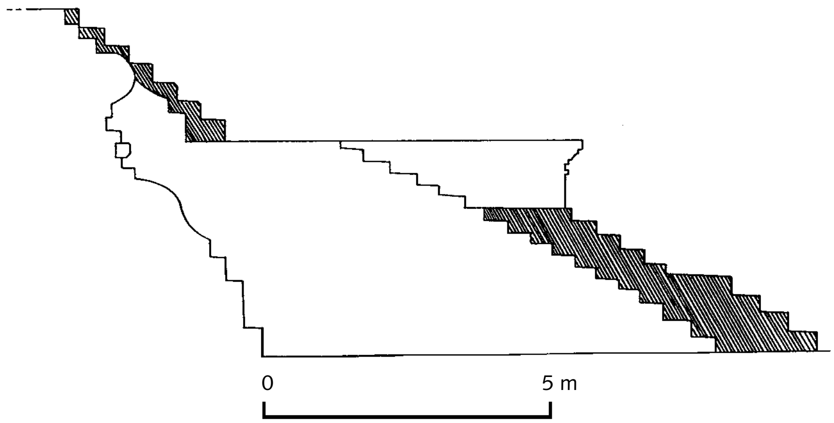


Figure 2.3.6
Plan of the third stage
Source: Borobudur Restoration Project

Figure 2.3.7
Section of the first flight of the stairway (according to van Erp). The etched part is from the fifth period of construction.
Source: Borobudur Restoration Project

of the second period left the central structure, but it is likely that it was levelled before construction work began on the new structure, doubtless utilizing the concave elements of the upper part of the moulded base of the second stage. The work of this period included the construction of the three nearly circular terraces, the pierced *stupas* and the central dome. At the same period the balustrade of the first gallery was modified by constructing niches on the curved moulding of the top of the balustrade.

To give a unity to the monument new entrance jambs (similar to those on the third and fourth galleries) were installed on the first and second galleries where the old reliefs were (Figure 2.3.6).

The fourth and fifth stages of construction

The two last periods of construction were merely improvements to the monument in the course of its existence and, in contrast with the previous periods, did not modify its plan. They included the prolongation of the massive foot on the paving of the third period, which involved an important modification of the first flight of the stairways (Figure 2.3.7). They also included blocking the space between the open niches on the balustrade of the first gallery, and the insertion of a new series of reliefs on the inside of the first gallery under the moulded top of the balustrade. These reliefs were linked with new entrance doorways.

At this time the compacted earth steps on the hillsides became eroded and the debris was thrown indiscriminately down the slopes of the levels, except on the eastern side, which was always better maintained. Construction work ceased, and upkeep was increasingly neglected, but the renovation of the reliefs continued until as late as the thirteenth century.

2.4 The historical setting

We do not know exactly when Chandi Borobudur was built. There are no records to inform us which king had the monument built or which architect it was who created this wonder. Nor are there any documents to reveal what techniques were applied to carry out such a grand design. Not the slightest idea can be gained as to how much time and how much labour were needed for the construction of this gigantic work.

Based on some bits of archaeological evidence associated with fragmentary historical data, it is generally assumed that construction can be dated to around the year AD 800, at a time when Central Java was ruled by the kings of the Shailendra dynasty. This accords quite well with Indonesian history in general and the history of Central Java in particular. The century from 750 to 850 was the Golden Age of the Shailendra dynasty, as is evidenced by the great number of chandis that were erected.

A salient feature of ancient Indonesia's Shailendra period is its great tradition of building religious edifices or chandis. A splendid series of these architectural monuments was erected, marking the highlights of the dynasty's history, at a variety of locations. Not only were the open plains and valleys strewn with chandis of varying sizes, but also slopes and even summits of mountains were beautified with these dwelling places of the gods. It may be said that the middle part of the island of Java was caught in a veritable construction boom which lasted from the early eighth until the end of the ninth century, a period commonly known as the Central Javanese period. This term however is misleading, as dozens of chandis were also constructed in East Java. Such temples were also built outside Java, though in more limited numbers. Since the distinction is actually based on chronology rather than on topography, these inappropriate terms are no longer in use. Instead, the terms 'early' and 'later classic' have been introduced, for the periods before and after the tenth century AD respectively.

In fact, there is a clear evidence of a renewed vitality of architectural construction during the period between the middle of the thirteenth and the beginning of the sixteenth centuries. It is this period that was formerly called the East Javanese period in the ancient history of Indonesia. The term is indeed appropriate, in that the building activity was concentrated in the eastern part of Java and chandis were no longer built in Central Java. Again, however, these building activities were not limited to eastern Java alone, for the monuments in Bali and Sumatra date from this period.

The chandis of the early classical period, which are chiefly concentrated in the middle part of Java, are either Hindu or Buddhist. This distinction in religious background is not apparent. The structural design is the same, consisting of a quadrangular base, a temple body enclosing a chamber for enthronement of a statue, and a roof of three tiers, diminishing in size with height. The pyramid-like roof is crowned with a spire as its finial.

It is this finial that in fact marks the distinction between the two kinds of chandi. A Hindu temple is crowned by a *ratna* or jewel, and a Buddhist temple by a *stupa*. The statues inside the temple body are also different, since

Sculpture at Borobudur Temple
Source: UNESCO/ Alexis N. Vorontzoff

they depict different deities. However, in most cases the statues have been lost, so that this particular feature is of no help. It is noteworthy that the statues cut in relief on the walls do not show any such particular features either.

The Shailendras were ardent Buddhists, but apparently there was an older generation of the dynasty that embraced the Hindu religion. The Cangal charter of AD 732 commemorates the construction of a palladium for the Shivaitic king Sanjaya. This chandi was erected on the top of a hill only about 10 kilometres to the east of Chandi Borobudur.

It is not quite clear what the relationship was between the Shailendras and the Sanjayas. The plausible assumption is that both were branches of the same dynasty. From the chandis it is apparent that the Hindu branch of the family reigned over the mountainous regions in the very centre of Central Java, while the Buddhist branch had their sanctuaries built in the Kedu plain. After 850, however, the two branches merged and became one again through the marriage of a Buddhist princess and a Hindu prince. Husband and wife jointly erected chandis in the Prambanan plain in the southern part of Central Java.

The Shailendras ceased to rule over Central Java in the middle of the ninth century, and a century later all political and cultural activities had moved from Central to East Java. The reason for this drastic change is still unknown today. It is only apparent that Central Java was abandoned: no records, no artefacts, not even a mention in one or another source, can be found to indicate the existence of Central Java with its Chandi Borobudur.

In the eleventh century the kingdom of Kadiri came to the fore, but no chandis from then until its fall towards the end of the twelfth century have survived. Indeed, no evidence of building activities can be found.

The principality of Singhasari replaced the kingdom of Kadiri at the beginning of the thirteenth century. It is from this period that a later classical chandi is known and has come down to the present day. This Chandi Kidal is reported to be a temple erected to commemorate a dead king. A century later the Majapahit empire was founded, as a continuation of the ruling dynasty of Singhasari. The two centuries of its existence witnessed another building boom. Dozens of chandis were erected in the plains and on the slopes as well as on the tops of the mountains.

It was not until the middle of the fourteenth century that a reference was made to the existence of a Buddhist sanctuary of the Vajradhara sect called 'Budur'. Since no other Budur is known to exist, it is quite plausible that the monument mentioned in the *Nagarakrtagama* (a literary work written by Prapañca in 1365) is the Borobudur we are dealing with. However, the name is only mentioned in passing, without any further detail except the religious aspect, so that we are still kept in the dark as regards its fate.

In the eighteenth century Borobudur was apparently known as a place of magical danger. According to the *Babad Tanah Jawi* (a traditional narrative of the history of Java) a certain Ki Mas Dana, son-in-law of Ki Gede Pachukilan, revolted against King Amangkurat III of Kartasura in 1709. He was defeated by the royal army and fled to the hill of Borobudur. The hill was besieged, and Ki Mas Dana surrendered. He was taken captive by the royal commander, Prince Pringgalaya, and brought to the court at Kartasura where he awaited his sentence of death.

In another chronicle, the *Babad Mataram*, it is mentioned that in 1757 the crown prince of Yogyakarta, Prince Manchanegara, had bad luck at Borobudur. He had been forbidden to see 'the thousand statues' of Borobudur, because one of the statues depicted 'a prince held captive in a cage'. It was precisely because of his feeling of pity that the prince became curious to see the unfortunate knight. The evil effect was unavoidable: the prince fell seriously ill as soon as he returned home, and he died shortly afterwards.

Thus Chandi Borobudur was buried in oblivion for about nine centuries, from its completion around AD 800 until its first reappearance about 1700. In the eighteenth century a part of the monument was unveiled, but it was the superstitious belief rather than the monument itself that emerged from the darkness. It was not until the second decade of the nineteenth century that the veil was finally lifted and the monument came under the spotlight of present knowledge.

2.5 The symbolic meaning

Generally speaking, the construction of a chandi was meant to glorify a king who had died and gone up into the realm of the gods. During his life the king was considered a god who had descended on earth to secure justice, peace and order for the people. As a human being he was therefore perfect, so that after passing away he merged directly with the god of whom he had been the incarnation.

A chandi is therefore a manifestation of human reverence towards our forefathers, and at the same time a tangible expression of a profound consciousness of religious belief. It is a place of worship in which homage was paid to the deified king as well as to ancestral spirits. The object of worship is a free-standing statue, enthroned in the chamber of the edifice. The statue depicts, on the one hand, the deity dressed in the attire of the god and provided with his attributes, and on the other hand, the deceased king in his divine appearance. Through a ceremony called *pranapratista* the statue was imbued with the breath of life, the god-king descending from heaven to communicate with his descendants. As the meeting place of the worshipper and the worshipped, of this world and the world beyond, the temple building symbolizes the entire universe. In Hindu mythology the universe is represented by the Cosmic Mountain called *Mahameru*. The chandi is its replica.

Chandi Borobudur lacks this essential part of the chandi. It has no statue to represent the king-god, no inner space to house it, and not even a roof to shelter it. Indeed, Buddhism glorifies its creed through the erection of *stupas*. When statues are to be attached to the edifice, niches are spaced along its walls. Hence the general assumption that Chandi Borobudur was conceived in the form of a *stupa*.

In Chandi Borobudur it would seem that a combination of modifications to the original *stupa* form created the present shape. If so, the big *stupa* and the top of the monument would be the main item, and the circular platforms and square terraces would represent a multiple base. The main objection to this assumption is the structural disproportion, which seems inconsistent with an achievement of quality otherwise so supreme. To accept the assumption that the big *stupa* constitutes the monument would mean agreeing that the extraordinary impressive supporting mass is of secondary importance only. And it is hardly conceivable that a design should allow the main feature and purpose to be completely overwhelmed by the ancillary embellishments.

Regarded objectively, Chandi Borobudur consists of a stepped pyramid that is surmounted by a *stupa*. Neither pyramid nor *stupa* predominates. Each have merged into a single entity. Consequently, in seeking the symbolic meaning of the monument, it cannot be considered either as just a pyramid or as just a *stupa*.

Photo 2.5.1
The ten levels of Borobudur
Source: Suparno

Ambiguity is a common feature of chandis; the statue depicting both the king and the deity is a good example. Indeed, the underlying elements of Hinduism and Buddhism can often only be properly understood in terms of ancestor worship.

The idea of a terraced mountain is obviously contained in the historic culture of Indonesia. A stepped pyramid is the particular symbol of the abode of the ancestors in the mountains, and it can plausibly be argued that ancestor worship played a significant part in the design of the monument.

Consequently, the symbolic meaning of Chandi Borobudur has obviously a twofold origin: in Mahayana Buddhism and in ancestor worship. Counting the big dome on top as the tenth storey, the ten mounting terraces of the entire structure correspond to the ten successive stages that the Bodhisattva has to achieve before attaining to Buddhahood. In terms of ancestor worship the nine terraces, counted from the top downwards, may indicate the nine Shailendra kings who preceded the reigning monarch who had Chandi Borobudur built.

In this context the Shailendra kings identified themselves with their divine patron, the Bodhisattva. Liberation from the cycle of birth and death constitutes the final goal in Hinduism. To the Mahayana Buddhist, however, it is but the start of the Path to be followed by the Bodhisattva. A Shailendra king had to do his utmost to pave the way for attaining Buddhahood. He had to accumulate as much virtue as possible during his reign. He had also to glorify his predecessors, and one of the most meritorious ways of doing so was to erect monuments dedicated to both his patron and his forefathers.

Viewed from the angle of ancestor worship, a predecessor is assumed to have reached a higher stage of perfection. The most remote forefather, who founded the dynasty, was imagined to have attained the ultimate perfection, and the other ancestors were ranked successively in precedence. This was apparently the underlying idea of the founder of Chandi Borobudur when he decided to create a monument that differed quite radically from the conventional design. And by a really fortunate coincidence, the reigning Shailendra king happened to be the tenth of the dynasty.

A stepped pyramid always consists of an odd number of terraces. Chandi Borobudur, however, has ten. The explanation may be that the designer of the monument had not only the indigenous tradition in mind, but – perhaps even more – the Mahayana path of the Bodhisattva. This daring break with tradition is a further demonstration of the high esteem of the founder of Chandi Borobudur for the forefather whom he identified with the Buddha. And a stepped pyramid with a stupa on top was a most appropriate symbol to depict the virtue the dynasty had accumulated successively along the Path of the Bodhisattva (Photo 2.5.1).

Below: View of the Buddhist temple, the terraces and stupas
Source: UNESCO/
Alexis N. Vorontzoff

3. Saving Chandi Borobudur

3.1 Rediscovery and rescue

From 1811 to 1816 Java was governed by the British. The chief of the colonial administration was Sir Thomas Stamford Raffles, who had the rank of Lieutenant Governor General. Raffles resided in Jakarta, but travelled widely throughout the island because of his intense interest in Javanese history. In 1814, while he was visiting Semarang in Central Java, he was informed about a monument that was unknown to him, called Borobudur. On hearing this news, he did not hesitate to undertake the arduous journey to the interior of Central Java to see for himself the newly reported object of his special interest. H.C. Cornelius, a Dutchman who already had experience in surveying chandis, was instructed to carry out the required investigations.

That very year Cornelius left for Borobudur, and what he found was a hill overgrown with trees and bushes. Between the dense vegetation heaps of carved stones and parts of a structure were discernible. Cornelius immediately recruited some 200 labourers from the village and started his task: trees were cut down, undergrowth was burnt, and loose stones and rubbish were thrown down the hill. The 'excavation' continued for about two months, and though the global appearance of the monument could be perceived, its details remained for the most part hidden. Indeed, several parts could not be unearthed because of the danger of collapse.

Cornelius had the insight to avoid any possible risk of structural degradation, and this proved to be a challenge for many people who were eager to know what the newly discovered monument looked like. From 1817 onward, several small-scale excavations were carried out, the results of which were never recorded. Eventually in 1835 it became evident that the monument was not merely the upper part of a hill but a real structure standing on top of a hill. The man responsible for this discovery was C.L. Hartmann, district officer of the Kedu region from 1832. Hartmann was deeply interested in the monument, and he started a clean-up of the entire structure in 1834.

In 1842 Hartmann carried out an investigation focusing on the interior of the big *stupa* crowning the monument. He was attracted by rumours that hidden treasures had been found, and that the big hole in the eastern wall of the main *stupa*, already observed by Cornelius, could be ascribed to earlier treasure hunters. His investigation was not recorded, but it was said that Hartmann had found among other things a stone Buddha statue, which later became an object of academic dispute.

The statue is the same size as the other Buddha statues at Borobudur. However it proves to be unfinished, and is of inferior quality aesthetically: its face is ugly, and one arm is shorter than the other, so that it might be a sculptural reject. On the other hand it is this imperfection that later on invited quite another opinion claiming it to be an appropriate representation of the Adhi Buddha or Supreme Buddha, whose perfection is beyond depiction.

Today, this second opinion has become the generally accepted one. Analyses and views from all possible aspects have ultimately resulted in the conviction that the so-called ‘unfinished’ Buddha in question had always been enshrined in the main dome of the monument.

Thanks to Hartmann the whole landscape around the village of Borobudur had changed. The flatness of the area had been given relief, crowned by the great monument soaring aloft over the fertile fields of the plain. The idea arose that such scenic beauty should be enjoyed by visitors, and so a bamboo teahouse was built at the top of the monument.

In the meantime, the villagers also took advantage of the availability of the huge amount of building material on the Borobudur hill. They could simply select for themselves whichever loose stones they wanted to take away for the foundations of their houses or for any other purpose. This new threat led the government to look for adequate means to save the monument from total destruction.

In 1845 a professional photographer named A. Schaefer was commissioned to record the reliefs of Chandi Borobudur for posterity. It is a great pity that the results were far from satisfactory, so that in 1849 the government sought to achieve the goal through the medium of drawings. The task was entrusted to F.C. Wilsen, a talented draughtsman of the army engineering corps. Within four years the work was completed. No fewer than 476 drawings of the reliefs, and many other drawings of the architectural parts of the monument, had been produced.

Wilsen also intended to write several articles concerning the monument, but meanwhile the government had appointed Dr J.F.G. Brumund, a brilliant art historian and talented writer, to do the job. There was apparently a misunderstanding and, to make things worse, another frustration arose in 1856 when Brumund submitted the results of his efforts.

He had expected his treatise to be published in its entirety, supplemented by Wilsen's drawings. As it turned out, however, the government intended to publish Wilsen's article and drawings, while Brumund's treatise was only meant to supplement the official publication. Brumund was very annoyed, and refused any further cooperation. The government had to turn to yet another person to overcome the obstacles. This was Dr C. Leemans, who was commissioned to compose – on an entirely new basis – a monograph on Chandi Borobudur, making free use of the articles written by Wilsen and Brumund. Wilsen's drawings were to be used to illustrate it.

Quite another kind of obstacle also had to be overcome. Several scholars doubted the accuracy of Wilsen's drawings, particularly with regard to the depiction of the main figures of the reliefs, and it was not until 1873 that the monograph – which had been entrusted to Leemans as long ago as 1859 – could be completed and printed. A French version of this Dutch monograph appeared in 1874.

With the publication of Leemans' monograph in 1873, the efforts that had started in 1845 to record Chandi Borobudur and immortalize it on paper were brought to a successful end. This work, which had taken no less than twenty-eight years, wrested Chandi Borobudur from the grip of oblivion and brought it to the limelight. It also meant that the site was saved from the danger of being once again forgotten and of falling prey to neglect forever. This danger did indeed exist.

In 1873 Chandi Borobudur was in a condition of serious disrepair. The keeper of the local government rest-house, who was in charge of its supervision and maintenance, showed no serious concern and did not even care much about the monument. This was apparent when J. van Kinsbergen – an able but slow-working photographer – was directed to Borobudur with the assignment to make a permanent photographic record of the sanctuary. The initial intention was to take photographs of the whole of Chandi Borobudur to replace Wilsen's drawings, but this plan was later modified. Van Kinsbergen was to take only a limited number of photographs that would reflect the beauty and artistic value of the monument. To do this, he had to do the necessary cleaning work, which often included excavation of the galleries.

Now that Chandi Borobudur had become known as an architectural and sculptural achievement of extraordinary quality, more and more people became interested in its fate. Nevertheless it remained neglected, so that voices were raised demanding that steps be taken to safeguard the monument. In 1882 there was even a suggestion of dismantling the entire structure and removing all the reliefs to a museum to be built especially for the purpose. The following year the government commissioned W.P. Groeneveldt of the Royal Batavia Society to carry out an *in situ* survey to clarify the situation. His reports stated that the problem was not as bad as had been feared, and so no further steps were taken.

Chandi Borobudur drew particular attention in 1885 when J.W. Yzerman, President of the newly founded Archaeological Society of Yogyakarta, announced the surprising discovery that the broad bottom of the monument was but an encasement hiding its actual base from view. Moreover, it turned out that the walls of this hidden base were carved with a series of reliefs.

In 1890 this additional base was opened up, section by section, for the photographing of the newly discovered reliefs, after which it was immediately covered up again. It appeared that the course of relief panels went all around the base of the monument, and the obvious conclusion was drawn that Chandi

Photo 3.1.1
Borobudur in 1927, view 1
Source: reproduced
from N.J. Krom, 1927

Photo 3.1.2
Borobudur in 1927, view 2
Source: reproduced
from N.J. Krom, 1927

Borobudur had undergone earlier structural modifications.

Yzerman's spectacular discovery of the hidden reliefs intensified the widely felt need for the government to take drastic measures to avert any danger that might threaten Chandi Borobudur. It was therefore absolutely outrageous that, during this very period of extreme public concern, the government should decide to present no less than eight cartloads of Chandi Borobudur masonry to the King of Siam when he visited the monument in 1896. The gift consisted of some thirty pieces of masonry with reliefs, five Buddha statues, two lion statues, a *makara* spout, a number of monster-heads from the staircases and from the gateways, and a unique guardian statue from the nearby Dagi hill.

In 1900 a government committee was set up with the special task of planning the physical protection of Chandi Borobudur. The suggestion by one member of constructing a gigantic zinc dome supported by forty iron pillars as a roof over the monument did not meet with approval. The earlier idea of putting the reliefs in a museum was also rejected.

After two years of hard work, the committee finally came to the conclusion that three measures were necessary to protect Chandi Borobudur permanently. First, the imminent danger of collapse should be averted by reinforcing the corners of the structure, straightening the leaning walls on the first terrace, and repairing the gateways, the niches and the *stupas* (including the main *stupa*). Second, it was recommended that the improved condition should be maintained by instituting strict controls and intensive care, and improving the water discharge system by repairs to the gallery floors and the gutter spouts. Third, to present a clean and undamaged appearance, the loose stonework was to be removed, the tile base freed from the covering soil, and all additional structures demolished. It was also essential to reconstruct the top of the main *stupa*.

A few years later, in 1905, the Government of the Netherlands decided to approve the committee's proposals, and earmarked the sum of 48,800 Dutch florins for expenses. Th. van Erp, an officer of the army engineering corps and a committee member who was

Photo 3.1.3
Borobudur in 1927, view 3
Source: reproduced
from N.J. Krom, 1927

Photo 3.1.4
Borobudur in 1927, view 4
Source: reproduced
from N.J. Krom, 1927

well-versed in the problems involved, was appointed to carry out the restoration work.

Van Erp started his work in August 1907. The first seven months were spent collecting as many loose stones as possible in order to have a clear picture of the extent to which Chandi Borobudur could be restored. Excavations were also carried out around the monument and on the plateau to the west of the chandi to a depth of more than 1 metre, resulting in the recovery of a great many temple stones. Among these were found many important items such as monster-heads from the gateways and spouts, two lion statues, twenty Buddha heads, fragments of narrative reliefs, ornaments from the niches, balustrade *stupas,* antefixes.

With the recovery of so many stones belonging to the monument, much more could be done than was originally thought possible. Van Erp therefore planned restoration on a bigger scale in 1908. Approval soon came with an additional budget of 34,600 florins. The restoration work was no longer restricted to a partial repair. The work included the balustrades, the walls of the first gallery, the water discharge pipes on the hill slopes, the stairs on the lower structure, some gateways and most of the niches with the matching *stupas*.

The upper levels of the monument, consisting of the three circular terraces with the seventy-two perforated *stupas*, were completely dismantled and afterwards rearranged. A reconstruction of the uppermost balustrade wall, of which most of the stones were missing, was also attempted. The main *stupa* too was reconstructed, complete with its spire and superimposing umbrellas. These umbrellas were later removed after being photographed, since the reconstruction was too conjectural. Indeed, there was no certainty about the actual shape or number of the umbrellas. As for the imperfect Buddha statue found inside the main *stupa*, a scientific decision was made to take it out and keep it in the temple yard.

The stability of the structure was secured in two ways: first by reinforcing the hill slopes, and second by covering the gallery floors and the lower stages with layers of concrete, so that the gallery walls and the balustrades were firmly connected. The corners of the structure

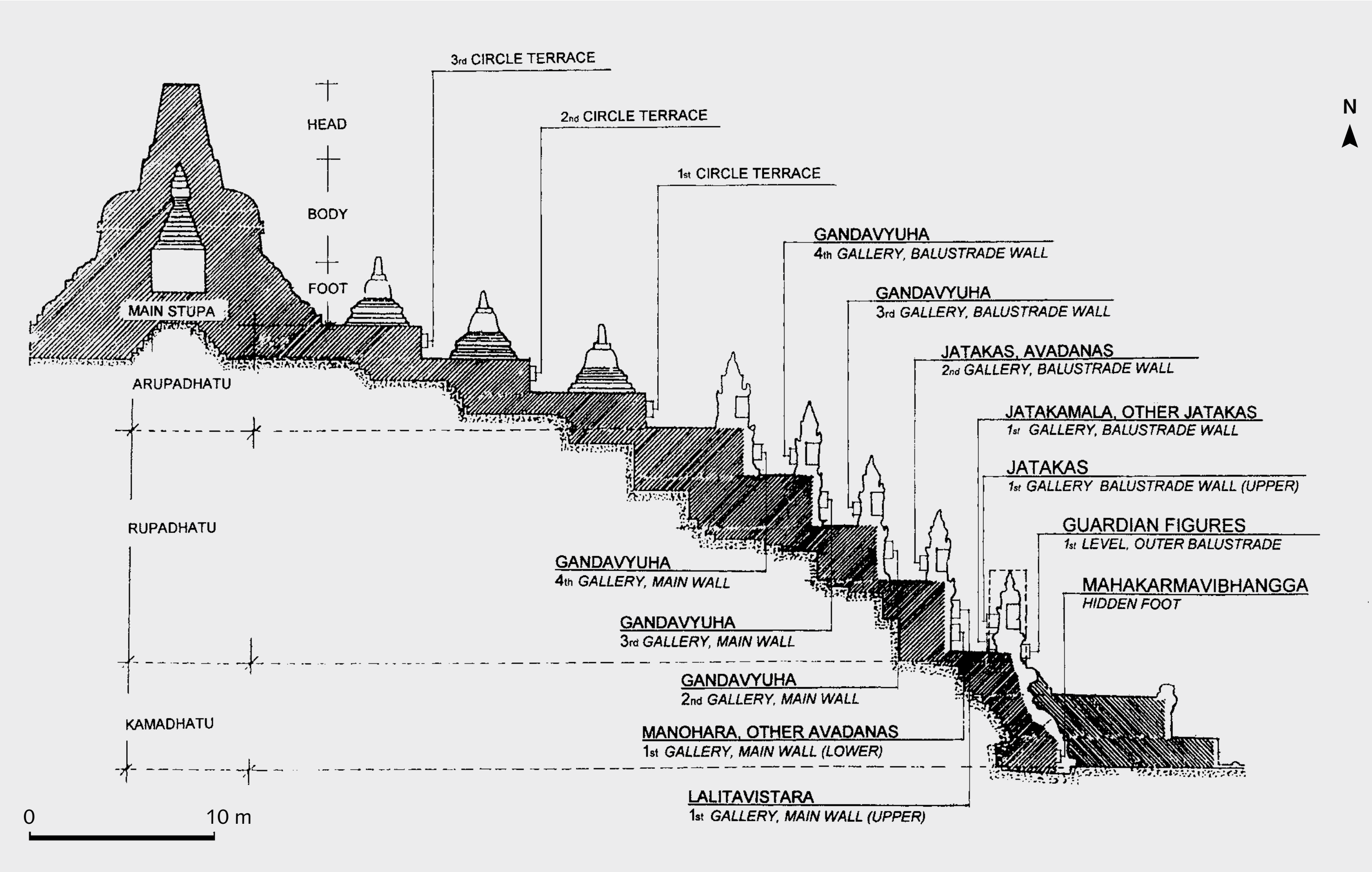


Figure 3.1.1
The correlation of architectural design and symbolic meaning
Source: Borobudur Restoration Project

and the upper parts of the walls were likewise reinforced.

Van Erp completed his restoration work in 1911. Technically speaking, Chandi Borobudur had regained its vigour to face the coming decades. The danger of collapse and ruin had been averted. Even so, not every fault could be eliminated. The first and second gallery walls were still leaning, of the twenty-four gateways only a few could be rebuilt, the balustrades were still showing yawning gaps in several places, the reliefs were far from complete, and not all the Buddha statues could be recovered and put back in their original niches.

It is worth mentioning that van Erp's efforts to save Chandi Borobudur had not been limited to the technical aspects only, but had included the establishment of photographic documentation as well. Many photographs had been taken before the restoration work was begun, showing the condition of the entire monument, and many more were taken after the restoration was completed, showing practically all details of the chandi, including every single panel of the narrative reliefs.

3.2 Towards a change in approach

Thanks to van Erp's endeavours, Chandi Borobudur had regained its splendour. To preserve its soundness, however, the strictest attention had to be given continuously to the condition of both the structure as a whole and the stones that composed it. Moreover, regular measurements had to be carried out with respect to the slant of the walls.

A tight watch over the monument proved

to be not only justified but absolutely necessary, for in January 1926 several reliefs were found to be damaged, apparently through the vandalism of souvenir hunters. The discovery of wilful destruction led to a thorough survey of the reliefs, and it turned out that many stones with reliefs showed new fissures and cracks. The question arose whether the damage was due to destructive hands or to natural processes.

Comparison of the condition of the reliefs in stone and the photographs taken about 1910 finally led to the conclusion that the greater part of the damage could not possibly be caused by vandalism. Neither could it be due to erosion by water, the growth of mosses or to vertical load pressures. The main cause proved to be the fact that the stones were being continuously subjected to rapid changes of temperature, the considerable heat during the day being immediately followed by cold during the night, with extreme heat during sunshine and considerable cold during rainy periods.

To eliminate the adverse effects of weather was a serious problem, since it meant a fight against natural processes. The fact that 40 of the 120 *Lalitavistara* reliefs were damaged gave rise to great concern. A special committee was therefore created at the beginning of 1929, and its investigations led to the conclusion that there were three kinds of deterioration: those caused by corrosion, those by mechanical effects, and those caused by load pressures.

Corrosion was caused by weather conditions and most of the problems occurred with poor quality stones. A layer of yellow ochre, previously applied to smooth the colour of the reliefs for easy photographing, appeared to have protected the hard stones but had caused the surface of the soft ones to peel off. Fungi, lichens and mosses had also brought about erosion, but the most important cause had been water profusely seeping from inside the structure through the seams between the stones and through the pores of the stones themselves.

Mechanical damage, caused by people or other forces from outside, was to be found at the delicate, protruding parts of the reliefs. Most of this seemed to have taken place before the photographs of 1870 and 1910 were taken, but a comparison of these photographs with the situation in 1929 showed the deterioration was going from bad to worse.

Damage through load pressure was manifested in vertical cracks or even breakages, mostly occurring where the walls had sagged down. In several places the stones had practically been crushed or shifted from the horizontal. This load pressure was not constant, but increased proportionally with the setting of the wall parts. This process advanced very slowly but it could be dangerous in the event of an earthquake.

The committee put forward several suggestions to cope with further danger resulting from these three causes of deterioration. Corrosion was very difficult to deal with, as natural processes were involved. Certain chemicals could perhaps be used to coat the surface of the stones, but experiments had still to be conducted to prove their effectiveness. Previous experience with the ochre layer had to be borne in mind.

Earlier efforts to reduce percolation from inside the structure had apparently been inadequate. Although the crevices between the stones of the gallery floors had been filled with concrete, the porosity of the stones themselves still allowed rainwater to penetrate into the core of the monument. Establishing a watertight layer beneath every level of the structure was out of the question, as such an operation would necessitate the total demolition of the chandi, and to use a sealant such as asphalt to cover the gallery floors would not be advisable. Thus the only possible way to arrest the destructive effects of water would be the installation of an efficient water discharge system.

To eliminate mechanical damage by human hands the committee suggested limiting the number of visitors. Large groups should be divided into parties of not more than twenty people, who should be accompanied and supervised by a special guide.

Mechanical damage due to natural causes was considered inevitable. The committee urgently recommended cleaning with the greatest care when using the *sapu lidi* (a broom made from the ribs of palm leaves) or the like.

Finally, as regards damage caused by load pressures, the committee recommended continuous observation. The fact that subsiding walls had not shown further sagging after van Erp's restoration led strongly to the supposition that other, so far unknown forces must be causing strains and pressures.

The efforts made by the committee did not result in any positive steps, however; its recommendations and suggestions to the government were pigeon-holed, since in the years to follow a worldwide economic depression set in. This period of lack of funds was followed by the Second World War, and after that by the struggle throughout the country for Indonesia's Independence.

It is a great pity that the reports of the committee were left neglected among the thousands of files heaped up in the archives of the Archaeological Service. The range of approaches that it proposed for preservation of ancient monuments might have induced the responsible experts at the Service to reconsider and eventually revise their current techniques of restoration. It could at least have helped to supplement the solely architectural view with the study of building materials. In fact, particular attention to the piecing together of loose and dislocated stones, in the attempt to arrive at the reconstruction of an edifice that had fallen into ruins, had long been a kind of tradition. However, the dilapidation of the stones – the building materials of the chandi – was still neglected, and nothing was done to counter the ongoing natural process of decay.

In the meantime another committee had just concluded its assignment and submitted its final reports to the government. This committee was set up in 1925 to study the problem of the architectural reconstruction of ancient monuments and to settle the endless dispute between the two most outstanding archaeologists of the time, Krom and Bosch.

Reconstructing monuments in danger of falling completely into ruin had enjoyed the special attention of the government since the turn of the century. The official assumption was that the techniques of preserving architectural remains applied thus far were most appropriate. The unsatisfactory reconstruction of Chandi Mendut had incurred fierce criticism, but the failure was attributed to the fact that the enterprise was one of the earliest to be attempted. Similarly, the rebuilding of the minor shrines of the Panataran temple complex in East Java in 1917 had also met with little enthusiasm. Indeed it was considered a falsification of an historical record.

From the very beginning the founder and first Director of the Archaeological Service (1913–16), Professor Dr N.J. Krom, opposed such falsification. A chandi is a tangible witness of history, and should therefore be preserved as a record and not presented as a fake through a reconstruction, by which he meant rebuilding of the edifice. A reconstruction on paper, showing the final result of the painstaking efforts to retrieve displaced stones and to match them one by one, should be sufficient and could even be considered the crown of the work. A two-dimensional reconstruction could serve the required scientific purposes perfectly, whereas a reconstructed building would run the risk of misleading the researcher.

Krom's successor, Professor Dr F.D.K. Bosch, who was Director of the Archaeological Service for twenty years (1916–36), was very enthusiastic about the unveiling of Chandi Prambanan's greatness. The retrieval of the displaced stones of the main temple and the subsequent piecing together of the disordered building material promised the eventual revival of this gigantic monument. And it was exactly this prospect that prevented Krom from agreeing with the continuation of the project. Directly opposed to his views, Bosch was of the opinion that the preservation of ancient monuments would not make sense if the retrieved stones were only recorded and stored, while the monument itself was left in a deplorable condition. The result could even be ridiculous when, for example, two fragments retrieved from the ruins that clearly constituted one and the same architectural component were kept separately in two different showcases.

After many years of dispute, no compromise proposal could be formulated. In fact, neither party was wrong, and their motives were equally justifiable. The actual disagreement lay in the question of how far the conservation of an ancient monument was feasible while paying due attention to its scientific value. The government decided in 1925 to set up an Advisory Board for the Restoration of Hindu-Javanese Monuments, in connection with the reconstruction of the Shiva temple at Prambanan. The conclusions and recommendations of this board were accepted as the basis of the government's policy in dealing with the restoration of monuments, and as the guideline for the Archaeological Service when carrying out restoration work.

The reconstruction of the Shiva temple of the Prambanan complex near Yogyakarta, which was the main source of the conflicts between Krom and Bosch in the 1920s, was successfully executed from the time that Dr W.F. Stutterheim was appointed Director of Archaeology in 1936; he enjoyed the full cooperation of the architect-restorer V.R. van Romondt. These two were the leading figures responsible for the much-disputed restoration. Respectively representing archaeological science and architectural techniques, they demonstrated in the most convincing way the justification of a far-reaching reconstruction without violating the established principles of restoring monuments.

This consistency in abiding by the rules on the one hand and allowing alternatives on the other was universally appreciated, and in some neighbouring countries was even adopted to serve as a model. For Indonesia it became a tradition that was routinely implemented, and was the main theme in the training of field technicians.

However, there was a period when this tradition fell into complete abeyance. During the years of the Second World War and the struggle for independence there was no opportunity to evaluate the implementation of the well-established principles. No wonder that the inadequacy was not felt until Chandi Borobudur was reported to be in grave danger in 1948. The traditional methods of restoration could not possibly be applied; the monument was not endangered by a techno-architectural failure, but was suffering seriously from a weathering process. This was no question of sorting and piecing together dislocated stones; the reliefs had to be rescued from further uncontrolled deterioration.

The three-year-old Government of the Republic of Indonesia was entirely right when it invited two archaeologists from India to survey the decay and to seek a remedy. Chemical archaeology had been developed for many years in India, and its implementation to counteract the weathering of the surface of the stones could be expected to be successful.

Very unfortunately, the mission's report never reached the Indonesian authorities. The documents went astray due to renewed armed conflict when the Dutch army invaded Yogyakarta, only three months after the completion of the mission.

Nevertheless, one point became apparent. Archaeology in Indonesia had to catch up. Indeed, as a scientific discipline archaeology should never stand still. It has continuously to develop, keeping pace with the progress of science and technology. Moreover, its concern is not restricted to the reconstruction of chandis. This architectural conservation is only one aspect of the preservation of ancient monuments. More is needed than piecing together dislocated stones. More is needed than a two-dimensional reconstruction on paper. Even a three-dimensional reconstruction, which involves the rebuilding of the edifice by applying the technique of anastylosis, turns out to be neither sufficient nor effective.

The Indonesian Archaeological Service had to wait for many more years before it could couple well-established architectural conservation with the newly developed chemical conservation. For the sake of the monument itself, its conservation needed to embrace many more relevant branches of science. However, it would take a considerable time before it was possible to start drawing up a new programme and updating its scope of activities, while taking into account the growing complexity of the interaction between the adjacent disciplines.

The apparent need to set up two committees to tackle two different problems in conservation enhanced awareness in the Archaeological Service that its current architectural approach and well-established techniques of restoration were inadequate. The imperative need to pay special attention to the weathering process on the building materials of the chandi might cause a reversion towards too narrow a view of the safeguarding of the monuments from total loss. The Archaeological Service was stimulated as never before to achieve a better means to preserve ancient monuments, as both the executor of a branch of science and the upholder of the national pusaka.

3.3 A twofold danger

The recognition of Indonesia's Independence, sealed by the transfer of sovereignty from the Dutch Government to the Republic of Indonesia at the end of December 1949, was the right moment for the Indonesians to achieve their sincerest wish to become full members of international society and join the efforts of humanity to build the world anew. The infant republic did not hesitate to apply for membership of the United Nations Organization and was accepted as its fiftieth Member State. Implicitly, it also became a member of the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Now that the horizon was infinitely broadened, the awareness of being left behind in the development of science and technology was felt as never before. On the other hand, new opportunities for consultation and cooperation were offered from every corner of the world. As far as the care of monuments was concerned, special attention was directed to UNESCO.

Realizing that the right moment had also come to draw international attention to the fate of Chandi Borobudur, the Director of the Indonesian Archaeological Service at once seized the opportunity to ask UNESCO's advice on the problem of counteracting weathering in monuments in Java and Bali. The following year Professor Dr C. Coremans of the former Central Laboratory of The Belgian Museum was sent to Indonesia. It was a great pity that he could spend only one month there, making his programme very tight. Nevertheless he devoted several days to surveying the decay of Chandi Borobudur, and appeared extremely interested in the condition of the monument. His conclusions were similar to those of the 1929 committee, but more emphasis was laid on aquatic problems as the chief cause of all deterioration. He used the term 'stone cancer', starkly depicting the gravity of the chronic disease affecting Chandi Borobudur.

Rainwater in itself is not harmful and does not create direct danger. The real cause of damage is rainwater draining from inside the structure, containing various kinds of minerals and chemicals from the soil that are left behind on the surface of the stones when the water evaporates. Subsequent oxidation processes cause a crust to form, coating and destroying the surface of the stones, and also lead to tiny explosions that leave the surface pock-marked with holes.

Professor Coremans could not prescribe a remedy for the stone cancer that endangered Chandi Borobudur. He suggested the possibility of spraying the stones with a special kind of polyethylene that would prevent rainwater from penetrating them while still allowing percolation from inside to evaporate. Another suggestion was to dig a tunnel under the temple foot at the northeast corner to speed up drainage. The best remedy, he suggested, might be found through a detailed study of the stones in a laboratory, and so a number of temple stones were sent to Brussels. However, several years of intensive study produced no satisfactory result.

A very significant follow-up to the mission was, however, the award of a special fellowship by the Royal Belgian Government to enable an officer of the Archaeological Service to follow a training course at the Brussels laboratory. Mr Soejono had the privilege of serving his apprenticeship with Professor Coremans during two years.

It is to be deeply regretted that neither Professor Coremans' mission nor Mr Soejono's apprenticeship were to lead to the realization of the Archaeological Service's goals. The political situation was not favourable to further attempts to seek international assistance, and financial constraints made it impossible to provide the facilities needed for the development of chemical archaeology.

While attention was focused on the problem of stone deterioration, measurements in 1961 of the settling of the northern walls on the first gallery disclosed another menace of a different nature. It turned out that the walls had developed a deviation from the earlier pattern. Previous measuring had, indeed, indicated an irregular process of slanting, but this time several parts of the leaning wall appeared to have somewhat tilted back towards their perpendicular position. Such a development was entirely unexpected, and was difficult to explain.

It took months of minute investigations to bring to light the cause of this peculiar deviation. The middle part of the wall had bulged out in such a way that the upper part of the wall had slanted backwards. The stones also appeared to have shifted somewhat. In fact, such bulges were not outside the norm and were very likely to occur. As the foot of the wall was already tightly embedded in the van Erp floor, and the upper part was also held firmly in place by the balustrade, the middle part would stay undisturbed only as long as there was no horizontal outward push from inside. Such a pressure seemed in fact to have developed, and there was every reason to assume that the cause was the presence of water-pockets behind the wall. This accumulation of water had transformed the soil into mud, expanding its volume considerably. The consequent pressure was inevitably directed towards the wall.

The bulging of the middle part of the walls had never been taken into account. No attention was paid, therefore, to its effect on the measurements and thus it had never been possible to define what dangers it might cause. It would have been quite unjustifiable merely to take this fact for granted and to keep it in mind during further observations and measurements in the following years. The speed of the development could not be estimated, but it certainly could be expected to increase. It was impossible to say how long the wall could resist these unpredictable forces.

In view of the twofold jeopardy threatening Chandi Borobudur, namely the physico-chemical and techno-architectural problems, and with the knowledge that the rate of the deterioration process could not be estimated and that it must not be allowed to proceed, it was announced in 1960 that Chandi Borobudur was in peril.

3.4 Planning the restoration

In 1960 the first preparations were undertaken for a programme to eliminate both the physico-chemical and the techno-architectural dangers that threatened Chandi Borobudur. The planners were mindful of the fact that van Erp's restoration – in spite of its technical merits and praiseworthy execution – was guaranteed to last only a few decades. In fact, it was more or less a palliative, patchwork restoration that left the fundamental cause of deterioration only half settled by improving the water discharge system.

The Archaeological Service was now determined to conduct an overall restoration that would secure the soundness of the monument for at least 1,000 years. The leaning walls were to be set upright, the subsided parts elevated and the tilting floors levelled. The most important consideration was that Chandi Borobudur should be provided with a foundation that would not only guarantee the lasting stability of the structure, but also be capable of preventing an uncontrolled flow of rainwater.

Such a total restoration would mean that the entire monument had to be altogether dismantled. The obvious consequence would be that Chandi Borobudur should be closed to visitors for a considerable period, at least during the execution of the restoration. It was therefore of the greatest importance to find ways to speed up the restoration work in order to save as much time as possible. The application of modern equipment such as electric cranes and motorized means of transportation was taken into consideration.

In this respect a comparison was made with the restoration of the main shrine of the Chandi Prambanan compound. The sorting of the stones that had fallen away from the edifice and preparation of the reconstructional scale drawings took nineteen years (1918–37). The subsequent rebuilding of the monument was completed within sixteen years (1937–53). Since the period of reconstruction coincided with the years of a worldwide depression followed by the upheaval of the Second World War, the comparison showed that the period could obviously be shortened when restoring

Chandi Borobudur. As the general conditions had changed and technology had progressed considerably, such an aim was reasonable.

Unfortunately, two years of efforts to obtain the desired modern equipment yielded no result. The work programme to be set up was restricted by having to use such equipment as was readily available. The restoration of Chandi Borobudur would be executed in the traditional manner of the Archaeological Service.

In the meantime the long-awaited government decree came out in August 1963, setting aside a special budget for the restoration of Chandi Borobudur. The technical staff of the Archaeological Service were immediately called upon to start the preparatory activities.

However, the progress of the work was seriously hampered by a continually increasing rate of inflation, which caused an ever-growing discrepancy between the work programme and its execution. Towards the end of 1965, activity had to be stopped altogether because of the political disturbances set off by the abortive coup of the PKI (Indonesian Communist Party). When peace and order were restored several months later, the suspended work was resumed, only to be interrupted once again towards the end of 1966 due to lack of funds.

In the course of two and a half years of work (mid-1963 to the end of 1966) the essential measures for the preparatory stage of the restoration programme were taken, consisting of the following items:

- measuring and drawing of the galleries;
- measuring and drawing of the deviating parts of the structure;
- photographing of the walls and their reliefs, for documentation and for reconstruction purposes later on;
- investigation of the foundation of the monument in order to obtain cross-sectional drawings through various angles;
- drillings into the soil inside as well as outside the monument to collect data on the structure and characteristics of the subsoil, and also the bearing capacity and permeability of the soil;
- designing the reconstruction plan and the reinforcement of the new concrete foundation;
- the dismantling of several parts of the balustrades at the northwest corner in order to lessen the load and the pressure on the leaning walls;
- the supply of electricity, water and means of transportation;
- the construction of a site office, sheds and other buildings for working facilities;
- the training of field technicians.

For all those preparations it was noteworthy that exceptional cooperation was established with the local government and the army. The government's top authorities joined the project as members of the restoration committee, and the commander of the engineering battalion of the army in Magelang made his entire personnel available to take part in the 'demolition' of the monument. Prior to this offer, the Archaeological Service asked if the army could help the project with moving cranes of some 10-tons capacity in order to modernize the equipment and thus shorten the work period.

With respect to the geological studies, the project enjoyed the fullest cooperation of The Geological Foundation of the Institute of Technology in Bandung, and its Department of Geology, presided over by Dr Sartono. A series of drillings and subsequent investigations into the rocks and soil, underneath as well as outside the monument (and even outside the area of Borobudur) were carried out by Dr Sampurno in 1963, 1965, 1966 and 1969. The most significant result of the studies was probably to provide information about the structure and the properties of the hill inside and underneath the monument. This was evident when the Netherlands engineering consulting firm NEDECO and the UNESCO biologist Dr Hyvert made free use of Dr Sampurno's findings as the basis for setting up the engineering design and the conservation programme respectively.

It was also on the basis of Dr Sampurno's geological studies that Mr Samingoen, Director of the Technical Department of the Archaeological Service, set out to design the engineering work of the restoration. On the principle that the dismantling of the monument, although inevitable, should be confined to a minimum, he planned a restoration to be carried out in four successive stages, corresponding to the four quadrants the structure could be divided into. Each quadrant was bordered by the staircases on the axes of the monument.

Under this plan the northwestern quadrant, on which the slanting and the subsidence of the walls were most alarming, was the first to be restored. Scaffolding was erected and the relevant balustrades were dismantled. The overall engineering design, however, had not reached its final stage when all activities had to stop completely because of the political turmoil towards the end of 1965.

The change of government policy from the earlier 'self-imposed isolation' to the 'free international intercourse' of the new order in 1967 presented an opportunity to call UNESCO's attention to the alarming condition of Chandi Borobudur. This appeal came at an opportune moment when UNESCO was intensifying its activities to safeguard the cultural heritage of humanity all over the world while utilizing those archaeological remains to promote mutual understanding among nations through tourism.

The appeal to UNESCO was supported by the twenty-seventh International Congress of Orientalists, which was held in the United States in August 1967, and which *inter alia* adopted a resolution urging UNESCO to help save Chandi Borobudur. Indeed, in the opinion of the convening orientalists, Borobudur was a cultural heritage of the whole of humanity that just happened to be entrusted to the Indonesian people and stand on Indonesian soil.

In accordance with the procedure for dealing with applications for aid outside the scheduled annual working programme, UNESCO started with the assignment of the appropriate experts to study the matter and report back. Early in 1968, two experts were assigned to Borobudur. They were Dr B.Ph. Groslier, a French expert in restoring monuments and director of the Conservation d'Angkor at Siem Reap in Cambodia, and Dr C. Voûte, a hydro-geologist of the International Institute for the Aerial Surveys and Earth Sciences in the Netherlands. Both were of the opinion that Chandi Borobudur was indeed in a worrying condition, that the steps taken by the Archaeological Service to safeguard it were appropriate, and that the main problem facing Indonesia was the lack of funds, experts or modern equipment. These factors stimulated UNESCO to continue sending experts, pending the drawing up of an overall aid programme.

It was not until January 1973 that the Contracting Agreement between the Republic of Indonesia and UNESCO was signed, indicating the real beginning of the restoration of Chandi Borobudur with international aid.

Above: The statues facing East have the same Mudra, and so have respectively the Buddhas facing South, West and North.
Source: Borobudur Restoration Project

Above: The Borobudur statues show five kind of Mudra, corresponding to the five cardinal points of the compass (East, West, North, South, Zenith), and also to the Mahayana conception of the five Dhyani Buddhas. One point of the compass is ascribed to each Dhyani Buddha, and the distinction between the Dhyani Buddha is indicated by the different Mudra.

Source: Borobudur Restoration Project

4. Towards an International Project

4.1 UNESCO's assistance

The adoption of the Convention on the Protection of Cultural Property in the Event of Armed Conflicts in 1954 encouraged the Director of the Archaeological Service of the Republic of Indonesia to take advantage of UNESCO's services. The failure to receive the expected reports from the Indian mission in 1948 and the apparent worsening of the condition of the Borobudur reliefs induced him to ask UNESCO for technical assistance.

There was a prompt response in 1956 when, as described earlier, Professor Coremans, Director of the Central Laboratory of the Institut Royal du Patrimoine Artistique in Brussels, was sent to Indonesia and diagnosed that the great monument was suffering from chronic stone cancer, the therapy for which might be found in more elaborate studies in the laboratory. Sadly, however, political conditions made it impossible to gain full advantage from this, or from the subsequent grant by the Belgian Government that funded a training fellowship in Brussels.

As soon as the political climate permitted, a second request was made in 1967, supported by the appeal from the Twenty-Seventh International Congress of Orientalists, for UNESCO to pay special attention to the fate of Chandi Borobudur. Armed with a leaflet entitled 'Save Borobudur', the Indonesian delegation was able to convince the assembly that immediate steps should be taken to save a monument of unequalled value, and appropriate experts were assigned to report on the situation.

As described in the last chapter, Dr Groslier and Dr Voûte concluded that steps should be taken immediately. They also expressed their satisfaction and appreciation with respect to the studies thus far carried out by the Indonesian experts, but suggested that additional investigations and experimental studies be made in order to gain more information to secure the success of the forthcoming major enterprise.

In order to verify the reports they submitted to UNESCO, Dr Voûte visited Borobudur for a second time a few months later. His extensive report, based upon both his visits, described in detail the alarming condition of the monument. It stated explicitly that the monument was facing imminent destruction from the advanced state of disintegration of the building stones and the doubtful stability of certain structural components. The stone decay had reached a point where it was accelerating rapidly, so that immediate steps needed to be taken to eliminate the physico-chemical and biological processes. The planned restoration of the monument should, therefore, in the first instance be aimed at reducing the foundation loads and preventing water from infiltrating. Before arriving at the final decision, however, a range of additional information was urgently needed, in the field of soil mechanics as well as stone conservation.

Voûte's mission was followed not only by other missions but also by a visit of the Assistant Director-General of UNESCO for Cultural Activities, Mr Adishesiah, in April 1969. He did not see Borobudur himself, but had a long discussion with the Indonesian Minister of Education and Culture that resulted in the signing of an *Aide Memoire*. This document was intended to secure the continuation of UNESCO's assistance to Indonesia in the field of education and culture, including the restoration of Chandi Borobudur. For this particular aim, UNESCO committed itself to send more experts in the field of stone conservation and civil engineering as soon as possible. The sum of US$6,200,000 would be earmarked for the purchase of necessary equipment. It was also agreed that the civil engineering work of the restoration would be carried out by contractors, so that the Archaeological Service could concentrate its activities on the handling of the temple stones. Such specialization was, moreover, expected to shorten the time needed for the entire enterprise from the estimated eight years to three or four. It was furthermore stated that UNESCO would soon start a limited campaign for fundraising, making an appeal to the United States, the Netherlands, Sweden, Australia and Japan. Finally it was agreed that UNESCO would coordinate the international response to the appeal, and would take responsibility for administration of the funds collected.

In conformity with the *Aide Memoire*, two missions arrived at Borobudur in August 1969, including a biologist from France, and two civil engineers from the Netherlands. The biologist, Dr G. Hyvert, was an expert in stone deterioration studies, and had assisted UNESCO with conservation projects in Cambodia, Iran and Nepal. The two civil engineers were C.C.T. de Beaufort and P.H. Deibel, representing the Netherlands engineering consultants NEDECO.

Both missions made extensive use of the results of previous studies carried out by Indonesian experts. The geological investigations into the hill supporting the Borobudur monument and the subsoil in the surrounding areas turned out to be of extreme importance, not only for engineers in drafting their design for reconstruction, but also for the biologists in determining the impact of seepage water on the deterioration process of the stones.

Working with her Indonesian counterparts, professors of the Faculty of Agriculture at the Gadjah Mada University in Yogyakarta, Dr Hyvert drew up a long-term programme on the biochemical studies, applicable to the conservation of the Borobudur stones.

The NEDECO engineers held intensive discussions with the technical staff of the Archaeological Service about the design for reconstruction, and suggested convening an international panel on the subject within the shortest time possible. They also expressed their wish to gain more soil mechanics data by carrying out additional drillings.

It was not only the safeguarding of the Borobudur monument that was taken seriously into account, but also the preservation of the surroundings and the development of cultural tourism. In April 1970 Professor Ch. Tunnard of the Department of City Planning of Yale University and Mr J.C. Pollaco of the Malta Government Tourist Board were assigned to Indonesia. With regard to Chandi Borobudur, they suggested that an area of 200 metres around the monument should be kept completely free from any kind of building activity. A protective zone was thought essential to save the monument from pollution. Indeed, without the appropriate natural setting through the preservation of the surroundings, the monument would run the risk of losing its identity and its significance.

The reports submitted by the visiting experts undoubtedly weighed in the scale in developing international opinion on the imperative need to save Borobudur. The resolution of 1968 was followed two years later by another resolution of the General Conference. This second resolution was even more far reaching as well as binding, since it authorized the Director-General of UNESCO to:

> assist Member States, at their request, in direct operations for the preservation and presentation of sites, monuments, and works of art of special significance, in particular by mobilizing international assistance to contribute to the preservation of Borobudur in Indonesia.

In the meantime Professor J. Filliozat, Director of the École française d'Extrême-Orient, visited Borobudur and offered close cooperation since both the École and the Borobudur Restoration Project were in principle dealing with the same problems. Mr J. Dumarçay, the architect who was in charge of the restoration of the Baphoun monument in Siem Reap, Cambodia, was also involved in the Borobudur Restoration Project.

In 1970 Dr Voûte visited Borobudur twice. Following his mission, which extended his study of the overall problems of the projected restoration, he suggested setting up a joint secretariat to meet the increasing need for coordination between UNESCO and the project, while anticipating the establishment of a special coordinating unit on the site. Dr Hyvert, too, came back to Borobudur in December 1970 for a six-month stay, in order to coordinate and elaborate the ongoing researches into stone conservation.

The international panel discussion, proposed by NEDECO in August 1969, was convened by UNESCO in January 1971 in Yogyakarta. It was attended not only by UNESCO representatives, NEDECO engineers and Indonesian staff members of the project, but also by experts from France, the Netherlands, West Germany, the United States, Japan and Italy.

The chief focus of the two-day discussions was the design for the restoration of Chandi Borobudur prepared by NEDECO. Though it was unanimously approved in principle, several modifications were recommended to meet the wishes of the Indonesian participants, who after all would be carrying out the undertaking. In this respect it may be noted that three points required special deliberations in order to arrive at a unanimous conclusion.

The first point concerned the hidden foot of the monument, which displayed in relief the law of cause and effect. Exposing the series of reliefs by dismantling the entire broad base encircling the monument would contravene the principles of restoring ancient monuments. Keeping them hidden from sight would mean putting aside a unique opportunity to show one of the mysteries concealed in the structure. To remove the reliefs and to store them in a museum (still to be constructed) would be prohibitively expensive. The best solution was to construct a tunnel all around the foot of the monument. This would require an extra budget, and the risk of harm to the reliefs was disproportionate to the prospective advantages.

It should be kept in mind, also, that extreme humidity and a limited degree of air circulation could not possibly be avoided, and the installation of electricity for air-conditioning and lighting could not be recommended. On the other hand, it had to be remembered that the base itself was the most stable part of the monument and there was a strong argument for leaving this component as it was. It was finally agreed that the restoration work would be limited to the middle part of the monument, in conformity with the NEDECO design.

The second point in the discussion concerned the question of whether the inner stones should be treated in a similar way to the outer stones, in the sense that they had to be put back in their previous places inside the monument when rebuilding the dismantled parts. This kind of work, involving some 32,000 cubic metres of stones, would be practically impossible to carry out. From the financial point of view it was not possible to raise an extra US$3 million for this purpose, while technically speaking it was also impracticable since it would consume too much time and energy. The point was that every single stone would have to be marked and recorded before it was taken away from the monument and stored systematically until the right moment for it to be placed back into the original setting. Without much deliberation, the participants of the panel opted for treating the dismantled inner stones as simple building material needed for the reconstruction.

The third point related to the use of chemicals for cleaning and conserving the carvings. The participants agreed in principle, but could not decide what kind of chemical could be recommended and to what extent its use was justifiable. The idea of coating the surface of the reliefs with chemicals was rejected, in view of the obvious harm done by the yellow ochre during van Erp's restoration. It was therefore unanimously agreed that further studies and experiments should be carried out.

In the meantime (20 January 1971) UNESCO assigned a team to consider the possibility of drafting a provisional agreement concerning the international aid to be coordinated by UNESCO. The Draft Agreement stated that the cost of the restoration of Chandi Borobudur was estimated to amount to US$5.5 million. When UNESCO had succeeded in raising funding of US$2 million (on or before 31 December 1972), Indonesia could start the restoration work, while leaving certain items to be executed by a contractor.

NEDECO did not want to waste time. Two months after the panel discussion, E. Hoogkamer was assigned to Borobudur to gather additional data on the bearing capacity of the soil and the stability of the structure. His cone penetration tests in eight boreholes in the second gallery of the monument apparently did not meet his requirements, so he proposed to extend the drilling programme with twelve more boreholes, anticipating the potentials of rotational sliding. The elaboration of the results gained *in situ* was conducted by the Delft Soil Mechanical Laboratory of the Institute for Building Materials and Building Constructions in the Netherlands.

In May 1971 NEDECO sent two more engineers – Th. A. Roosendaal and P.H. Deibel – to Borobudur to elaborate their previous measurements and calculations, which were needed for the completion of the reconstructional drawings that had to be modified in line with the agreement arrived at in the Yogyakarta panel discussions.

Meanwhile Dr Hyvert terminated her six-month assignment in June 1971, with a strong recommendation that special microbiological research be carried out at the laboratory of the Faculty of Agriculture of the Gadjah Mada University. She herself took samples of the Borobudur stones to France. There they were studied by the Bureau de recherches géologiques et minières (BRMG) at Orléans-la-Source to analyse the material, by the Centre expérimental du bâtiment et des travaux publics (CEBTP) in Paris to test the permeability of the stones, and by the Laboratoire de cryptogamie du Muséum national d'Histoire naturelle in Paris, which would consider the biological aspects and undertake general coordination of the activities in France.

The messages left by the NEDECO engineers and the French biologist posed the project with a dilemma in regard to their financial consequences. The annual budget had no contingency fund for such sudden additional activity. Luckily the National Fundraising Committee for the Restoration of Chandi Borobudur could defray the costs of the soil investigations by the Geological Department of the Bandung Institute of Technology and the microclimatological studies by the Faculty of Agriculture of the Gadjah Mada University.

In this way, close cooperation was established among the experts involved in the Borobudur Restoration Project. Assisted by the visiting experts, research continued into a renewed approach and an improved basis for operations. Measuring and photographing methods were modernized, not only by updating the equipment but also by applying the techniques of photogrammetry and aerial photography. Investigations of the subsoil through drillings were intensified by cone penetration tests to obtain an optimal data collection for further stabilization of the foundations. Physico-chemical, microbiological and microclimatological researches dealing with stone degradation and the arrest of the process of decay were carried out and further developed into an altogether new branch of Indonesian archaeology.

The surprise of the year 1971 was the 32-hour visit of Mr Rene Maheu, Director-General of UNESCO, to Borobudur late in the afternoon of 16 June. Accompanied by the Project Officer/Director of the Archaeological Service, he inspected the activities on the monument while gaining detailed information about the problems involved in the planned restoration work. It was getting dark when Mr Maheu descended the monument, and took a well-earned rest while enjoying the magnificent display of the copper-coloured spires of the series of *stupas*. In expressing his feelings, he stated repeatedly that he was really committed to this monument for the sake of humanity all over the world.

In Jakarta the Director-General signed an *Aide Memoire*, stating among other things that UNESCO would appoint a permanent consultant in Indonesia for a period of twenty-one years, starting from 1 July 1971. With regard to the target of raising US$2 million through international donations, UNESCO promised to intensify the fundraising campaign so that the contracting agreement for the implementation of UNESCO's assistance could be signed in October 1971. The Indonesian Government in turn agreed to UNESCO's initiative to set up an executive committee in Paris for the administration of international funds.

The promised UNESCO consultant arrived in Indonesia towards the end of July 1971. The assignee with the position of UNESCO Coordinator for Monuments and Sites was none other than Dr Voûte, the man most familiar with Chandi Borobudur and its problems, who moreover had formed cordial relationships with his Indonesian colleagues and mastered the Indonesian language during the course of his previous visit.

UNESCO's special attention to Chandi Borobudur was also demonstrated by its Assistant Director-General for Culture and Communication, Mr R. Hoggart, who paid a 21-hour visit to the monument in September 1971.

In the same month a second panel discussion was held in Yogyakarta to arrive at an overall agreement with respect to NEDECO's design, which had been modified in accordance with the wishes expressed in the first panel. The final result was the signing of a document by the responsible Indonesian and international experts: the 'Joint Conclusions and Recommendations'.

This document does not mention the deliberations over the estimated costs of the undertaking. In fact, the participants of the panel paid the most serious attention to the financial consequences of their agreement on technical matters, since the figures that emerged from the discussions showed an increase of about 50 per cent, from US$5 million to US$7.75 million. Nevertheless, this drastic change was accepted as realistic, and therefore unanimously approved.

UNESCO's reaction was to urge seriously that the budgetary estimate should be managed in such a way that it would not exceed US$6 million, in view of the fact that similar conservation projects in other parts of the world also demanded extensive fundraising campaigns.

In December 1971 a special meeting was convened with a single item on the agenda: finding alternatives in view of the objections raised by UNESCO. It turned out that the rise in cost was due to international economic and monetary conditions, and it was considered quite unfeasible to cut the budget estimate by reducing the volume of work or the time of execution. It was therefore unanimously agreed to maintain the estimate of US$7.75 million. However, it was hard to find a way to defray the balance of the sum. Keeping in mind that the project had to go ahead anyway, and that a deadlock would be fatal to the monument, the participants came up with an appeal to the Indonesian Government to cover the deficiency, should the restoration costs in fact exceed the amount of US$6 million.

The fast-growing intensity of international cooperation for the safeguarding of Chandi Borobudur made it necessary to establish a mechanism to secure close and continuous contacts between the Indonesian Government and UNESCO. Consequently the government appointed Mr Soepojo Padmodipoetro, Secretary General of the Ministry of Education and Culture and Chairman of the National Commission for UNESCO, as Permanent Delegate at UNESCO's headquarters in Paris. In his new assignment as Ambassador to UNESCO he was certainly the right man to render great service to the Borobudur project. In Jakarta and on the Borobudur site there was already the Badan Pemugaran Candi Borobudur and the UNESCO Coordinator for the Conservation of Monuments and Sites, and from now on in Paris there was the Ambassador, Permanent Delegate at the UNESCO headquarters.

The appointment of a Permanent Delegate in Paris was immediately followed by the issue of a second Draft Agreement. Conforming to UNESCO's policy when assisting Egypt with the safeguarding of Abu Simbel in Nubia, the agreement stated, among other clauses, that UNESCO committed itself to raise funds for the Borobudur project up to a maximum of two-thirds of the total amount estimated for its implementation. While the participants of the panel discussions maintained that the total budget would amount to US$7.75 million, UNESCO's commitment in appealing to its Member States was limited to fundraising of up to US$5 million. The agreement further mentioned that if, on or before 30 June 1973, UNESCO had succeeded in raising US$3 million, the Indonesian Government could start the implementation of the project by appointing a contractor for the establishment of the ancillary facilities, as laid out in NEDECO's design and work plan.

It was not until January 1973, however, that the definitive Contracting Agreement between UNESCO and the Indonesian Government was finally signed in Paris. Another document was signed at the same time by the Director-General of UNESCO and the ambassadors of donating countries, confirming pledges either in cash or in kind.

The representatives of the donating Member States, along with the Indonesian ambassador, constituted the core of the Executive Committee for the Safeguarding of Borobudur, set up by the Director-General of UNESCO to assist him in establishing the international character of the Borobudur Project, in coordinating the international activities, and in authorizing the use of the funds collected from international donations and kept in the International Trust Fund.

Another committee had to be set up not by UNESCO but by the Indonesian Government, since its assignment was to give the government technical advice on the implementation of the project. This Consultative Committee for the Safeguarding of Borobudur was composed of a chairperson from Indonesia and four expatriate members, recommended by UNESCO on the basis of their personal capacities. They all were appointed by the Minister of Education and Culture. The chair was taken by Professor R. Roosseno, chair of the Body for the Restoration of Chandi Borobudur and special adviser to the Minister of Education and Culture. The members were Professor R. Lemaire of Belgium, Dr K.G. Siegler from West Germany, Dr J.E.N. Jensen from the United States and Dr D. Chihara from Japan.

The official terms of reference were stipulated as follows:

1. The consultative committee receives the technical documents concerning the project tender documents, bids by contractors, estimates of costs and so on. The committee examines these documents and make recommendations to the Government of Indonesia.
2. The committee regularly receives and discusses reports on the progress of the work from the representative of the consulting engineers to the Government of Indonesia. The committee visits the works, receives complementary explanations and makes recommendations to the Government of Indonesia. It must give its opinion on any major modification of the programme of work.

4.2 NEDECO's engineering design

Restoring monuments has always been routine work for the Archaeological Service of Indonesia, varying from the simplest repair of broken stones to the most complicated reconstruction of monuments. Restoring Chandi Borobudur, however, turned out to be an entirely new challenge, since the monument was unique in its construction.

A chandi is usually constructed on a flat surface, and the foundations are also laid out flat. Even when the location is sloping, part of the site is dug out in order to obtain the required flat courtyard.

In contrast to the normal pattern, Chandi Borobudur was built on and around the top of a hill. Moreover, it was not erected directly on the natural soil of the hill but on layers of earthen fill. This additional soil was apparently needed to enlarge the site, horizontally as well as vertically, to make it suitable for the monument that was designed to rise step-wise while diminishing in size with height.

The unique construction of Chandi Borobudur was the reason the Archaeological Service refrained from taking steps hastily when in 1960 it declared the monument in danger. Alarmed by the previously unnoticed bulging of the section of the northwestern wall of the first gallery that leaned the most, it set up a multidisciplinary team to make a special study of the problems and the solutions so that it could plan an adequate restoration programme.

The restoration project was meant to save Chandi Borobudur from a state of advanced decay. It should be kept in mind, however, that the restoration was in no way to result in the falsification of the monument. The authenticity of the historical record was to be preserved as far as possible. Restoration of all archaeological monuments should be carried out in accordance with the archaeological codes. Current regulations and prerequisites, internationally established by the science of archaeologists, should be the sole guidelines in the preparation of a restoration plan.

In spite of strict regulations it has to be admitted that any kind of restoration introduces something new to a monument. Repairs of broken stones and consolidation of crucial points in the structure have to be accepted. Even a structural reinforcement, either inside the edifice or underneath the foundations, might be inevitable to preserve a monument in a dangerous condition. Technical interference is permissible in emergency cases. And since a restoration is in general a response to a critical condition, this technical solution is an integral part of the restoration work.

As far as the restoration of Chandi Borobudur was concerned, quite another factor required special attention. The monument had been restored previously, so that the intended restoration would run the risk of replicating earlier changes or even being misled by the cumulative changes of successive earlier restorers. In this respect the Archaeological Service was from the outset fully aware of the harm a second restoration might do. The studies therefore started with a serious effort to 'reconstruct' van Erp's activities, in order to establish the precise details of the restoration work. This knowledge was seen as a very important basis for planning the restoration, which was to be the final action to preserve for the most remote future this internationally established cultural pusaka of the human race.

The Archaeological Service lacked any information about the geological condition of the soil on which Chandi Borobudur was erected, and therefore invited Dr Sampurno of the Institute of Technology in Bandung to carry out the series of borings through and around the monument that were described earlier. Knowledge of the properties and the characteristics of the hill inside the chandi was also considered to be essential in determining the basic approach of the restoration plan.

Concurrently the Archaeological Service set up an extra programme to conduct extensive surveys on the condition of the monument, while developing ideas for attaining the very best solution for the perpetuation of Chandi Borobudur. The technical staff were instructed to transform these ideas into an engineering design.

Having identified the twofold danger threatening the integrity of Chandi Borobudur and obtained a better knowledge of the hydrogeological condition of the subsoil, the projected restoration work would in the first instance provide the monument with a reinforced concrete support. This reinforcement should at the same time provide a means to regulate water percolation. The obvious solution was to construct a dome covering the entire hill underneath the monument. At first sight this idea seemed reasonable.

However, the construction of a dome would involve the total dismantling of the monument. Moreover, isolating the hill totally from any contact with the 'outside world' would result in the drying out – and hence the shrinkage – of the soil. And, since a dome is a rigid construction, the possibility of cracks in the structure must be taken into account. It would be difficult, if not impossible, to detect the occurrence of cracks after the dome had been completely concealed under the reconstructed monument. The idea of constructing a dome was therefore abandoned.

Nevertheless, the idea of a dome-like construction remained. While keeping in mind that the monument should be kept intact as far as possible by minimizing the number of parts to be dismantled, the construction of a modified dome intersected by a series of ribs was considered. Accordingly the Archaeological Service prepared two different constructional designs.

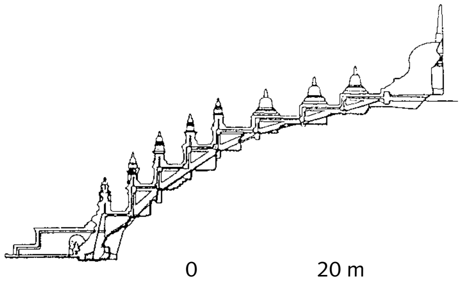
The first design was to introduce horizontal slabs to support the gallery floors at each stage, while vertical columns would reinforce the walls and the balustrades from the inside. Slabs and columns alike would rest on a series of ribs constructed at a certain distance from each other and stretching from one end of the monument to the other. The lower ends of the ribs would be attached to the base of the monument at the very ends of the hidden foot. The dismantled stones were to be put back in their original places by fixing them in front of the vertical concrete columns, and the floor stones would be arranged on the horizontal slabs.

The second design was slightly different. Bow-like ribs and horizontal slabs were omitted. Instead, horizontal beams across the galleries were to support vertical columns behind the walls of the monument. These beams and columns would occupy very little space in the monument, since they would be installed under the staircases and at the protruding corners only. In this way the dismantling of the monument was to be limited to a minimum.

The two engineering designs prepared by the Archaeological Service were of only a preliminary character, and had not advanced further than the very first stage. Indeed, they were no more than a visualization of basic ideas to determine a suitable basic approach.

When in 1968 UNESCO decided to take part actively in the Borobudur Restoration Project, the studies of the engineering designs were resumed in close cooperation with the experts of the UNESCO missions. In the meantime, the Netherlands' Government provided UNESCO with funds for the engineering consultants NEDECO to prepare an overall restoration plan, comprising an engineering design, a detailed work plan and a financial analysis.

NEDECO's plan was presented to a special international panel discussion convened by UNESCO in Yogyakarta in January 1971. The general outline of the plan met no significant objections. The main concern was over the engineering design, which was described by the NEDECO representatives as a modification and at the same time a simplification of the two designs prepared by the Archaeological Service. To a certain extent this was true, especially in terms of the basic approach. The fundamental change, however, was striking. Vertical constructions were omitted, and hinge-like joints were avoided. The establishment of horizontal slabs supported only by



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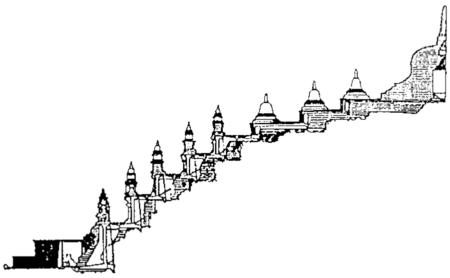
Solution I for restoration



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Solution II for restoration

Figure 4.2.1
Proposed approaches to restoration
Source: Borobudur Restoration Project

piled up loose stones was a technical solution with far-reaching consequences. Moreover, the limitation of the design to only the middle part of the edifice, while avoiding disturbance of the stable lower and upper parts, would considerably lessen the scope of work and the time needed for its execution.

The main objection to NEDECO's engineering design was that too much of the monument would have to be dismantled. The work would involve the total removal of all four stages of the *rupadhatu*. In view of the risk of a slippage of the exposed hill inside the monument, the panel suggested that special studies should be carried out and that special attention should be paid to the latent danger during the operation. With regard to the many points of difference concerning the details of the design, the panel was of the opinion that the matter should be settled by the parties involved (the Archaeological Service and NEDECO) through technical meetings to be held as often as was deemed necessary.

With respect to the base of the monument, a proposal to remove the encasement totally in order to expose the *karmawibhangga* reliefs on the wall of the original foot led to serious deliberations. The Archaeological Service had anticipated such a wish in its design by proposing the construction of a tunnel inside the encasement. Neither proposal gained the full approval of the panel, and it was suggested that an intensive study should precede any decision on the matter. It was agreed that removal of the encasement would impair the archaeological value of the monument, while the construction of a tunnel would carry the risk of creating new problems related to the unpredictable effect on the reliefs of the changed conditions.

Another point of discussion was the fate of the inner stones. If they were treated in the same way as the outer stones, the scope of work and the time and cost it would entail could not be foreseen. Even if the operation were limited to putting the stones back in their original places in the monument, a tremendous amount of energy and expense would be consumed in recording them and creating scale drawings. On the other hand, ample space in the structure needed to be reserved for the construction of the concrete slabs. Consequently, it was inevitable that a considerable amount of inner stone would have to be removed. Waste, however, was out of the question. Some of these stones would function as inner stones in the new construction, and use of others would reduce significantly the need for additional building material.

NEDECO's engineering design consisted in principle of two different constructions: the insertion of concrete slabs under the four stages of the *rupadhatu*, and the establishment of an effective drainage system. These constructions were not meant to stop water penetrating the stone layers and reaching the hill inside the monument; water would still be permitted to flow into the structure, but its course would be regulated and guided by the different layers and drainpipes.

The concrete slabs, to be laid in an unbroken layer under the four gallery walls, were designed:

- to strengthen the foundation while distributing the load on the subsoil evenly;
- to collect and disperse runoff water on the floors of the upper structure and galleries;
- to prevent the penetration of shallow percolation water;
- to distribute lateral seismic forces uniformly throughout the structure.

The slabs were to be constructed in such a way that the outer end supported the balustrade and the inner end reached the surface of the hill inside the monument. This means that the width would be from 5 to 6 metres. The thickness of the first and second slabs (counting from the bottom upwards) was 0.66 metres, and of the third and fourth 0.44 metres.

The drain system involved a filter layer, watertight layers and drainpipes. The *filter layer*, to be constructed along the slope of the bare hill, would cover the hill from under the plateau to the bottom of the hidden foot. Its function was to collect and channel deep percolation water, and to avoid the washing away of soil particles from the hill.

Layer A was to be added to the filter layer to prevent deep percolation water from infiltrating the inner stones. This barrier would suffice when the surface of the stones was coated with a suitable preparation.

Layer B was a watertight vertical barrier one stone away from the bas-reliefs of the main wall. It consisted of impregnated inner stones, coated with araldite tar and joined

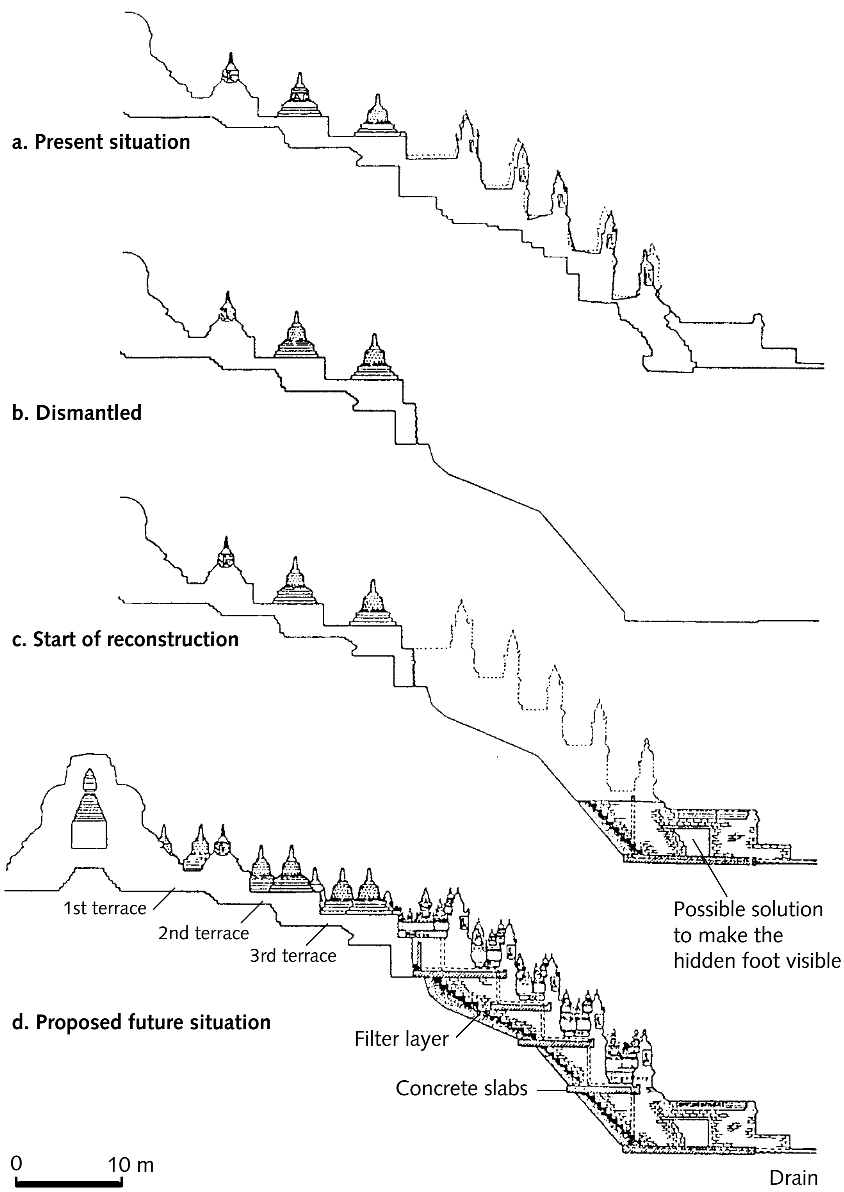
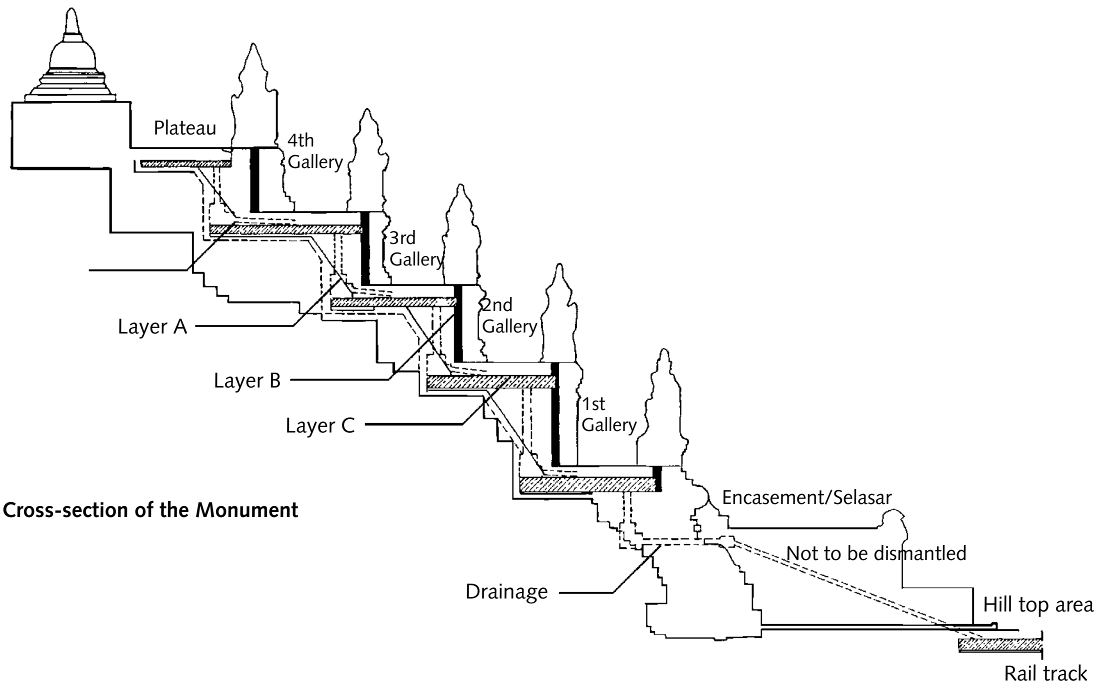


Figure 4.2.2
Restoration engineering plan
Source: Borobudur Restoration Project



Cross-section of the Monument

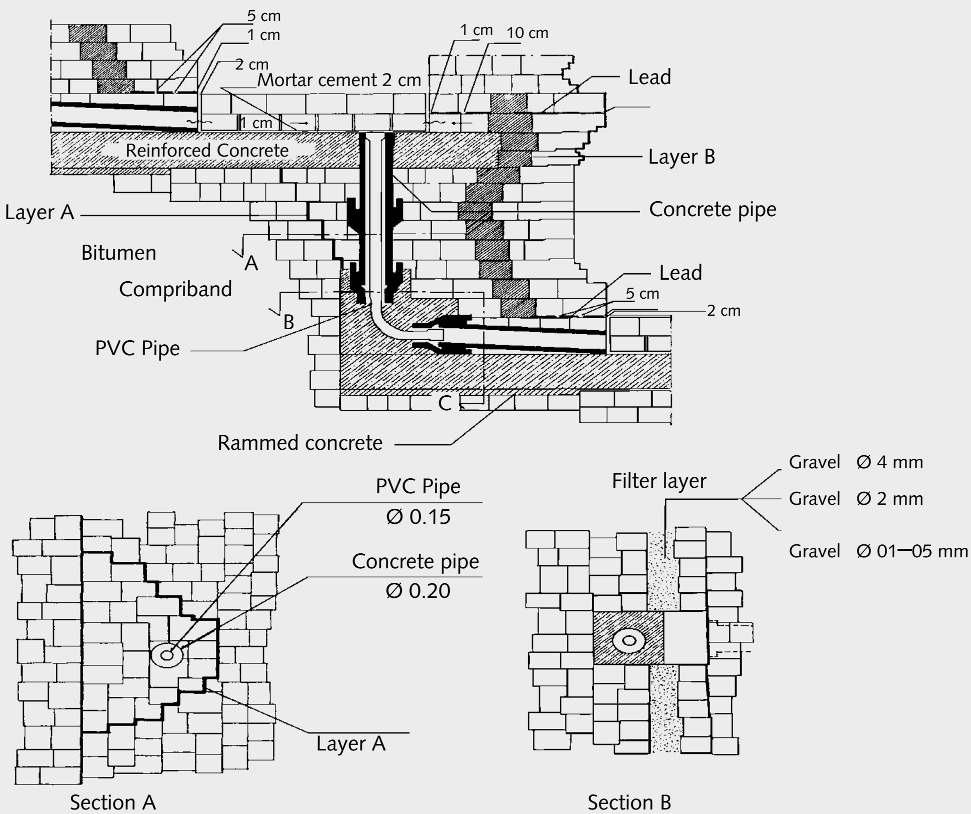
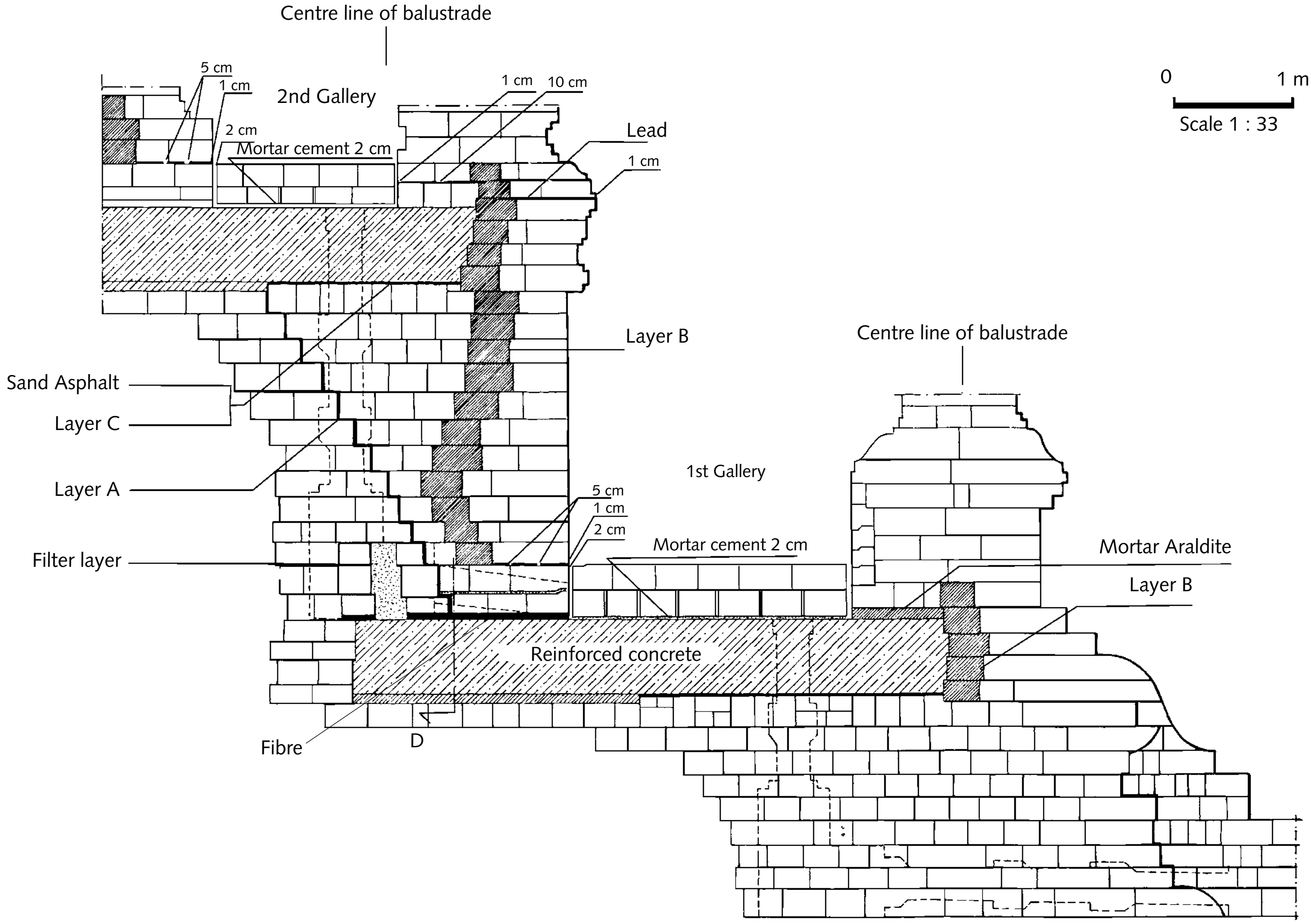
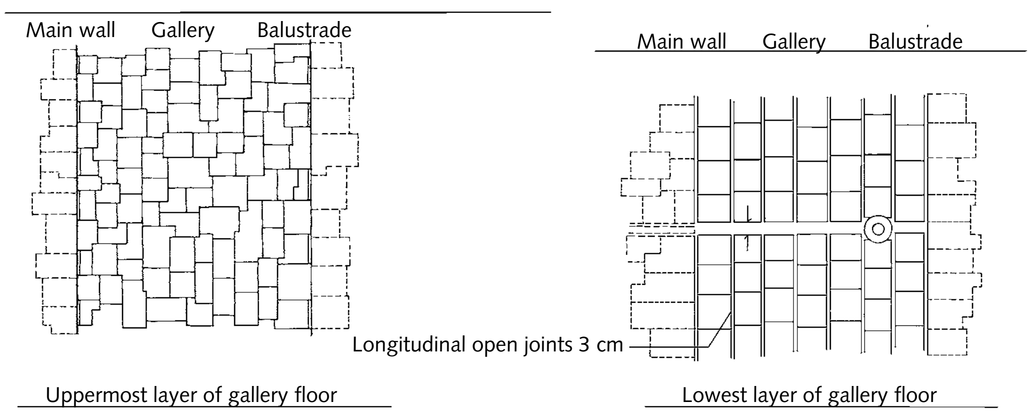
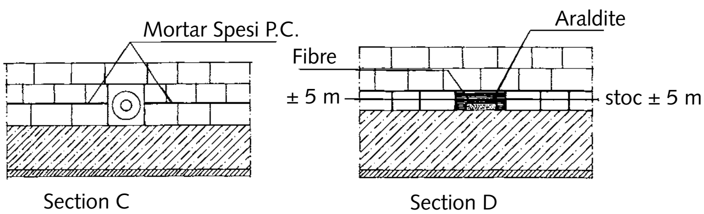


Figure 4.2.3
Drainage pipes and floor stones
Source: Borobudur Restoration Project


Centre line of balustrade
5 cm
1 cm
2nd Gallery
2 cm
Mortar cement 2 cm
1 cm
10 cm
Lead
1 cm
0 1 m
Scale 1 : 33
Layer B
Centre line of balustrade
Sand Asphalt
Layer C
Layer A
1st Gallery
5 cm
1 cm
2 cm
Mortar cement 2 cm
Mortar Araldite
Filter layer
Layer B
Reinforced concrete
Fibre
D


Main wall Gallery Balustrade
Main wall Gallery Balustrade
Longitudinal open joints 3 cm
Uppermost layer of gallery floor
Lowest layer of gallery floor


Mortar Spesi P.C.
Araldite
Fibre
± 5 m
stoc ± 5 m
Section C
Section D

with araldite mortar. This layer was intended to protect the carved stones against capillary movements of water, but at the same time to limit the accumulation of water from the outside so that a good anti-microbiological climate would be created behind the porous stones. It also constituted the last barrier against deep as well as shallow percolation water.

Layer C comprised two different constructions. The first was intended to isolate the concrete slab from the stones. Capillary seepage might occur and, when contaminated with calcium from the concrete, this water would harm the stones. The second element of layer C was an additional precaution to protect the reliefs from possible seepage through capillary action. It consisted of lead sheets installed under balustrades and under the row of reliefs of the walls.

Finally, *drainage pipes* were to be installed for the rapid discharge of water that might accumulate in the circular terraces of the monument and the square galleries below. Water collected on the concrete slabs would be passed downwards through pipes linking one slab to another, to be finally discharged outside the encasement at the foot of the temple.

4.3 NEDECO's workplan

The restoration project was to be divided into three major parts: the archaeological work, the civil engineering work, and the ancillary works.

The archaeological work was concerned with the handling of the temple stones, starting with the very first action of dismantling and ending with the return of the cleaned and chemically treated stones to their original places in the monument. It also included the rearrangement of the inner stones and the construction of layer B behind the walls. This activity involved about 1 million blocks of stones with a volume of around 29,500 m^3 (6,500 m^3 of outer stones and 23,000 m^3 of inner stones). This was the responsibility of the Restoration Project.

The civil engineering work entailed the installation of the reinforced concrete slabs under the gallery floors, including the establishment of the different kinds of filter and watertight layers. These activities were to be executed by the contractor.

The ancillary works had to provide the project with all means and facilities so that the gigantic undertaking could be executed in the best way possible. The preparation of the working areas, the construction of inner roads, the provision of equipment for transporting the stones and building material such as cranes and forklift trucks, the supply of electricity and water, the building of sheds and stores, of offices and laboratories were among the main items for the contractors' participation in the safeguarding of Chandi Borobudur.

The archaeological work could not start before the means of transport and storage were available, while the civil engineering inside the monument had to wait until the dismantling had reached the relevant space. Once these three kinds of activities had started, they proceeded simultaneously.

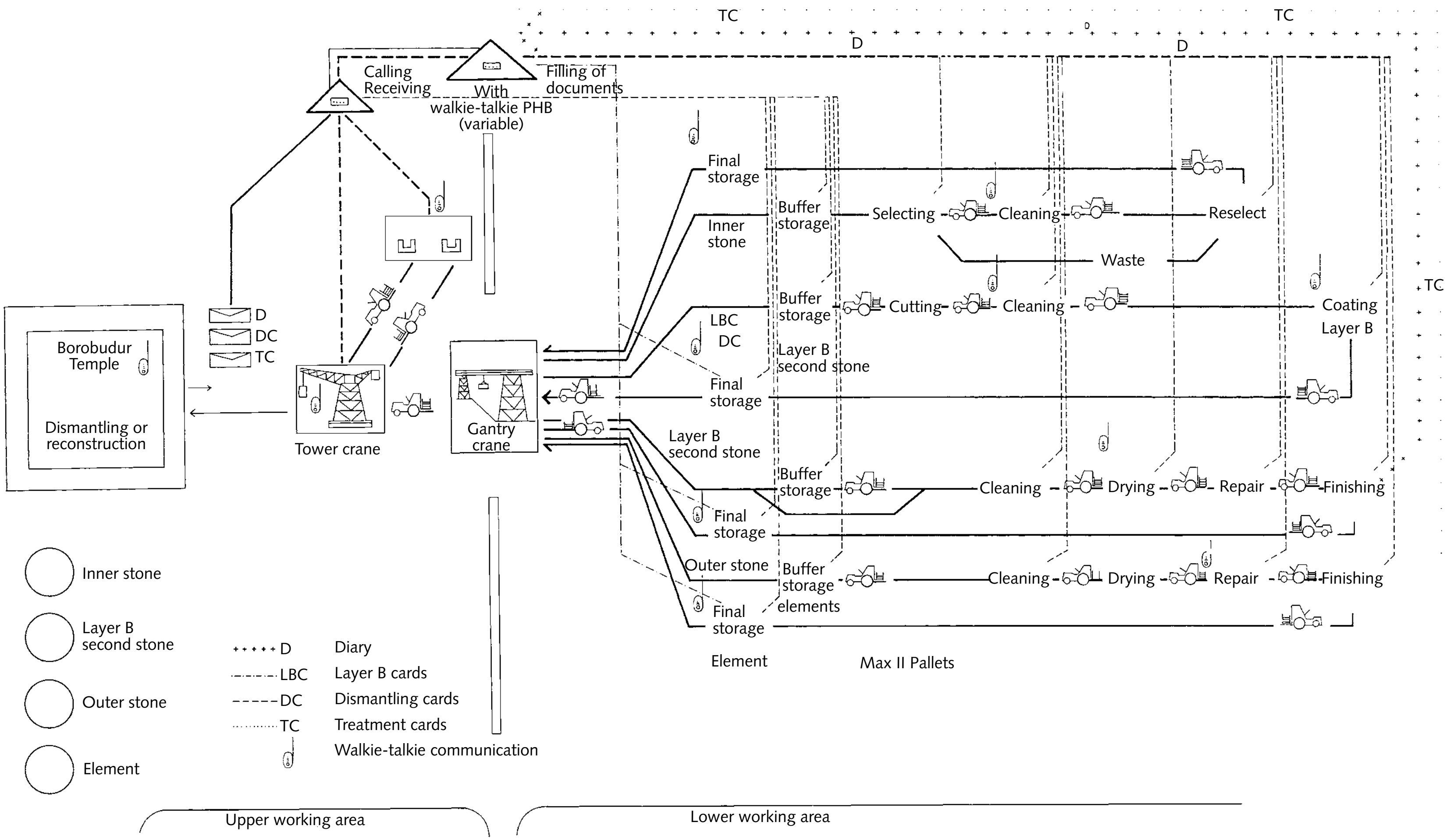


Figure 4.3.1

Chart of stone treatment

1. Flow of the stone
2. Documentation system
3. Communication system
4. Transportation system

The dismantling work was to be carried out on two sides of the monument at the same time, starting from the axes sideways and from top downwards. The most crucial part, the northern side, would be dealt with first, followed a few weeks later by the southern side. This work was scheduled to be completed within not more than three years, but the rebuilding would not wait that long. As soon as the dismantling had created the necessary space at the lowermost area for the execution of the engineering work, the rebuilding was to start. The construction of the concrete slabs and the rebuilding work would be performed from below upwards. In the meantime the exposed areas of the monument were to be sheltered by a roofing of galvanized iron to prevent any sliding of the hill slope when it rained.

With work under way at all sectors on the four sides, the entire project was expected to be completed within six or seven years.

The stones to be detached were provided with identification marks and registered on cards. One by one they were hoisted manually, and collected in wooden pallets, which each had nine compartments. A single pallet could carry nine stones, and the tower crane would bring it down to the upper working area. The gantry crane then took over to transport the pallet down to the lower working area, where a forklift truck was waiting to transport it to the buffer storage.

From the buffer storage the stones still had a long way to go. After manual cleaning, they passed to another department for chemical treatment. Broken or damaged stones were brought to a special shed for repair, before being treated chemically. The next step was the drying chamber, where the stones were dried artificially. Only then were the stones put in final storage waiting for the moment when they could be returned to the monument, a period varying from several weeks to several years. The first stone detached from the monument would be the last to reoccupy its original place, after three years.

It should be noted that during movement from one place to another, and during the treatment from one phase to another, the stones in each pallet remained together in the same pallet, which was accompanied by its pallet card all the way. Registration cards were also kept at every stop, so that the whereabouts of every single stone was recorded at the Central Registration Office. It is from this office too that overall control over the stones was exercised (Figure 4.3.1).

When setting up the work plan, NEDECO was fully aware that the Borobudur Restoration Project was a tremendous job, and its implementation would involve the most accurate calculations. It was realized from the very outset that all the planned activities were aimed at saving the fabric of the monument, so critical attention had to be paid to the fate of the stones. It was for this reason that every single stone was given an identity. It had a code number indicating its exact place and position in the monument. Statues, *stupas* and other free-standing building elements were treated separately and given their own identifications. Not a single stone escaped registration, and every single stop in the long journey was provided with the relevant registration cards.

This method of providing each stone with its own identity was developed as part of the 'registration planning'. During implementation, this system was elaborated and became a computerized Stone Registration System.

4.4 The joint statement

In January 1971 an international meeting sponsored by UNESCO was convened in Yogyakarta to discuss the proposed restoration of Chandi Borobudur, with international assistance to be coordinated by UNESCO. UNESCO was represented by the Head of the Development's Department of Cultural Heritage, Paris (Mr H. Daifuku), UNESCO'S Legal Adviser, Mr C. Lussier, and the UNESCO Chief of Mission in Jakarta, Mr J.F. McDivitt. The Indonesian team consisted of Professor Roosseno, the adviser to the Minister of Education and Culture, as Chief Delegate, Borobudur Restoration Project Officer Dr R. Soekmono, the Head of the Borobudur site office Dr Soediman, and the Borobudur staff of Experts: Mrs Sulaiman, Mr Sampurno, Mr Parmono Atmadi, Mr Jutono, Mr Soenardi, Mr Daruslan, Mr Suwandhi and Mr Ismojo. Expatriate experts attending the meeting were Dr G. Hyvert and Mr J. Dumarçay from France; Mr A.J. Bernet Kempers, Dr C. Voûte and Mr C.C.T. de Beaufort from the Netherlands; Mr Garvey from the United States; Mr D. Chihara from Japan; Mr G. Siegler from West Germany; and Mr G. Toracca from Italy.

The main topic of the meeting was NEDECO's restoration plan, which after the necessary deliberations was accepted in principle. Several problems raised during the sessions, and thus far remained unsettled, were to be further discussed by NEDECO and its Indonesian counterpart.

The second panel discussion was held in September 1971 in Yogyakarta, arriving at an overall agreement with respect to NEDECO's design, which had been modified in accordance with the wishes expressed in the first panel. The final result was the signing of the document following.

JOINT CONCLUSIONS AND RECOMMENDATIONS BY THE RESPONSIBLE INDONESIAN AND INTERNATIONAL EXPERTS

1. Work has continued and further research has been carried out since the preparation of the report published by UNESCO, dated April 1970. Many institutions have been engaged in activities on behalf of the Borobudur Restoration Project, in particular:

a. Lembaga Purbakala (Archaeological Institute): survey and detailed measurements of the monument, meteorology, on-site experiments, coordination work in Indonesia, etc.
b. Gadjah Mada University, Yogyakarta: microbiology, laboratory and *in situ* tests, water analysis and soil studies, civil engineering studies.
c. Solo Saraswati University: civil engineering studies.
d. Technical University, Bandung (ITB): drillings and soil mechanical studies.
e. Laboratoire de cryptogamie, Muséum national d'Histoire naturelle, Paris: studies of Borobudur materials, biology, coordination of work done in France.
f. Bureau de recherches géologiques et minieres, (BRGM), Orléans-la-Source: study of Borobudur materials, testing of conservation products, statistical processing of data.
g. Centre expérimental du bâtiment et des travaux publics (CEBTP), Paris: testing of conservation and restoration products.
h. TNO Institute for Building Materials and Building Constructions, TNO-IBBC, Delft: analysis of concrete aggregate and concrete.
i. Soil Mechanical Laboratory, Delft: cone penetration tests, soil mechanical studies and stability analysis.

j. Netherlands Engineering Consultants NEDECO: civil engineering studies, design of engineering works, planning transport of ornamental and building stones, coordination of work done in the Netherlands.

The results obtained from these studies have been discussed in a number of internal reports of the various institutions concerned, as well as in several discussion notes and progress reports transmitted to other institutions participating in the project. Moreover, some of the problems in matters of principle were discussed by an international committee of experts held in Yogyakarta by the Indonesian Government with the aid of a grant from UNESCO from 18 to 20 January 1971. This was followed by informal discussions and exchange of views at various times and places.

2. On 23 June 1971 the Minister of Education and Culture of Indonesia established by Ministerial Decree no. 0124/1971 the Badan Pemugaran Candi Borobudur, the Body for the Restoration of Chandi Borobudur.

The Chairman, Secretary and Principal Officers of this organization and a number of technical advisers were designated by Ministerial Decree of 31 August no. 0166/1971. Both decrees are valid retroactively from April 1971.

On 15 July 1971 UNESCO appointed, under UNDP-TA, a coordinator for the conservation of monuments and sites. His main task is to assist the Badan Pemugaran Candi Borobudur in the implementation of the project and to maintain liaison with international organizations, non-Indonesian participants and the authorities concerned.

3. From 13 to 20 September 1971 a series of meetings took place in Yogyakarta during which all of the available information was received and an analysis was made of the solutions proposed for the various problems encountered during the studies. In two plenary sessions basic aspects of the restoration project were reviewed, with emphasis on the proposed engineering works and on the budgetary consequences of various recommendations made. Agreement was reached with respect to the execution of the engineering works, on the basis of which the final design and the tender documents will be prepared. In the field of stone conservation, it was agreed that current research programmes will have to be completed before it is possible to take final decisions on materials to be used and the process adopted. It was also stated that pending the results of the stone conservation studies, the engineering works should proceed without any delay.

4. The following persons took part in the group discussions and plenary meetings:

Dr R. Soekmono, Secretary to the Badan Pemugaran Candi Borobudur (chairman of the plenary meetings)
Dr Soediman, Head of the Project Office at Borobudur
Mr Soejono, Project Office, Borobudur
Mr Soewarno, Project Office, Borobudur
Mr Maulana, Project Office, Borobudur
Dr S. Sulaiman, Adviser
Mr Samingoen, Adviser
Dr Parmono Atmadi, Adviser
Mr Joetono, Adviser
Mr Sri Hartadi, Adviser
Mr Tedjo Juwono, Adviser
Mr Soewandi, Adviser
Dr G. Hyvert, UNESCO consultant on stone conservation
Mr J. Dumarçay, special adviser to Badan Pemugaran Candi Borobudur
Mr C.C.T. de Beaufort, Netherlands Engineering Consultants NEDECO
Mr P.H. Deibel, Netherlands Engineering Consultants NEDECO

Professor Dr C. Voûte, UNESCO Coordinator, Conservation of Monuments and Sites.

5. The participants in the meeting adopted unanimously the following conclusions and recommendations, and expressed the wish that they be taken into consideration by the Government of Indonesia and by UNESCO in the implementation of the project:

a. In view of the fact that the restoration project will be financed to a large extent by voluntary contributions through the intermediary of a Trust Fund established by UNESCO, international bids should be invited; the possibility of bids submitted by consortiums consisting of foreign companies and Indonesian contractors could also be considered.

b. In view of the international character of the operation and the special requirements of the project, the Badan Pemugaran Candi Borobudur should have the authority to appoint, whenever deemed necessary, non-Indonesian supervisory staff or experts to supervise the work and advise on specific problems. Financial provisions for the appointment of such staff and advisers should be foreseen in the budget to be submitted to UNESCO and to the Indonesian Government.

c. The final design and the tender documents for the engineering works shall be worked out on the basis of the report by NEDECO, after due consideration of all amendments and suggestions proposed by the technical staff and advisers of the Badan Pemugaran Candi Borobudur during and after the panel meeting held in Yogyakarta from 18 to 20 January 1971 and during the present meetings. On the basis of these discussions NEDECO will begin the preparation of draft tender documents. The points still under consideration will be taken up in due time with the competent Indonesian authorities.

d. With respect to the 'hidden foot' it is recommended that the bas-reliefs be exposed by constructing a partly covered trench, which does not change the general outline of the monument. Such a trench would permit viewing of the bas-reliefs while at the same time ensuring relatively safe environmental conditions for their preservation. Research will be carried out on the need for additional conservation measures.

e. In the field of stone conservation the opinion is expressed that structural restoration work will greatly improve conditions for preservation. It is therefore recommended that these engineering works be carried out as soon as possible. In the meantime research continues on the need for and the technical feasibility of cleaning and of measures to preserve the bas-reliefs, statues and other sculptured stones. On the basis of the results of these studies a final decision will be taken later on the desirability of such measures. The archaeologists agree beforehand that the final responsibility to advise on such measures rests with the competent experts in stone conservation.

f. In view of the foregoing conclusion and recommendation it is advisable to have an item in the budget for stone conservation.

g. It is recommended that there should be at least one competent archaeologist, designated by the Badan Pemugaran Candi Borobudur, permanently at the site. The archaeologists should have authority to stop parts of the work temporarily if major archaeological discoveries are made. It is furthermore recommended that provision for these unforeseeable expenditures be included in the budget.

h. It is recommended that archaeological surveys be carried out in the immediate surroundings of Borobudur and at all sites where permanent or temporary work will be executed. It is recommended moreover that proposals for non-Indonesian archaeologists to participate in these investigations receive consideration.

i. A small photogrammetric section is recommended to assist in the recording of all matters of archaeological and architectural interest; this item should also be included in the budget.

j. It is recommended that a monograph should be published upon completion of the work. It should incorporate archaeological and technical data and summarize the experience gained, as this information should be disseminated to archaeologists, scientists and engineers. Moreover, continuous records shall be kept and important archaeological and technical data published whenever this would be of interest to archaeologists, architects or engineers, scientists and the general public. It is recommended that there should be a budget for this item. In this connection it is also recommended that there should be an information centre on the site during the execution of the work.

k. With the proviso of the above mentioned points the participants considered the budget submitted by NEDECO to be realistic.

l. The meeting expressed very strongly its opinion that any planning with respect to the landscaping or the tourist development of the surroundings of Borobudur should only be undertaken in close cooperation with the Badan Pemugaran Candi Borobudur and the Lembaga Purbakala, in agreement with the Indonesian Monuments Act in force and after due consideration of the forthcoming Master Plan for Tourism for Central Java.

m. Those present at the meeting expressed their wish that the conclusions and recommendations included in this report be transmitted to the forthcoming UNESCO General Assembly.

4.5 Organization and staffing

Restoring monuments has always been part of the activities of the Archaeological Service of Indonesia, the only institution authorized to deal with the care of monuments in the broadest sense. In view of the very complicated problems emerging from the studies of the alarming condition of Chandi Borobudur, however, the traditional method of restoration could not be applied. It was apparent from the very outset that the annual budget and the very limited number of archaeologically trained technicians were far from adequate for such an enormous undertaking.

In view of the fact that Chandi Borobudur had been restored earlier, a second attempt to save it from a further degradation should aim to be final. No future repetition of the action could possibly be justified; it would risk harming rather than saving the monument.

One other point to be taken into consideration was that once the second restoration work had started it had to continue without interruption until the very end. To stop or even postpone the sequence of activities would invite a dangerous situation and might cause a fatal disintegration of the monument. As a matter of fact, the restoration would inevitably require dismantling on a large scale, and this in turn would expose the hill inside the monument. Consequently the risk of erosion

Above:
Buddhist temple, statue of Buddha and openwork stupas
Source: UNESCO/
Alexis N Vorontzoff

and an eventual sliding of the slopes of the hill should be viewed with the utmost seriousness.

When the government started with the Pelita or Five Year Development Plan in 1969, the restoration of Chandi Borobudur was designated a Pelita project. This meant that from then on special funds would be reserved and made available annually, and special regulations were issued for the implementation of the project to anticipate administrative constraints. Plans and proposals were to be submitted to the BAPPENAS or National Planning Board one year in advance, and upon approval the funds were released. Consequently the overall planning of the project had to be prepared and elaborated in such a way that a yearly progress could be projected, complete with a breakdown of the costs.

As a Pelita project, the restoration of Chandi Borobudur had to be administered separately from the bureaucracy of its mother institution, the Archaeological Service of Indonesia. Special regulations enabled the project to act outside the routine procedures, so that the enrolment of the necessary technicians and skilled labour could be carried out as desired. Office facilities and the supply of equipment were also included in the budgetary programme.

While this gave enormous advantages, the Chandi Borobudur Restoration Project had to face one big problem. It had to abide by the regulation that its Director – officially called the Project Officer – was assigned for one fiscal year only, from 1 April to 31 March of the following year. The term could be extended and the assignment renewed every year, but still the Project Officer was not authorized to act or make decisions in cases that required implementation beyond that one-year term.

As far as the Chandi Borobudur Restoration Project was concerned, Dr Soekmono had the privilege of being Project Manager from the second year of the first Five Year Plan in 1970 until the completion of the entire undertaking in 1983. It was he who, in his capacity as Director of the Archaeological Service of Indonesia, had taken the initiative to save Chandi Borobudur from further decay as early as 1955. After his reassignment in 1973 to hold the post of full professor in archaeology at the University of Indonesia in Jakarta he still enjoyed the government's entire confidence to administer the Chandi Borobudur Restoration Project. There was, therefore, continuity in the implementation of the project.

Nevertheless, when in 1971 a contractor had to be appointed and the contract signed, the Project Officer had to abide by the regulations. He simply could not do this job. To overcome the problem the Director-General of Culture decided to designate the Chairman of the Badan Pemugaran Candi Borobudur to act on behalf of the Indonesian Government. This Badan was actually set up in 1971 as a coordinating body for interdepartmental coordination and international cooperation in the implementation of the Chandi Borobudur Restoration Project. This was a good and realistic solution, because many other multi-year actions were to be expected in the further implementation of this internationally financed project. Consequently it was the Badan that thenceforward acted as the institution dealing with such cases.

As a coordinating body the Badan was not equipped with a staff and had no funds. For its operations it was entirely dependent on the Pelita project. On the other hand, although it was not directly involved in the execution of the restoration work, the project provided support for the Badan in all these respects. The Project Officer was therefore designated Executive Secretary and all the experts of the project appointed advisers to the Chairman of the Badan.

At international level the Chairman of the Badan was the direct counterpart of the UNESCO Coordinator for the Conservation of Monuments and Sites, and was also Chair of the Consultative Committee for the Safeguarding of Borobudur.

The Chandi Borobudur Restoration Project had its head office in Jakarta and a site office in Borobudur. The head office was mainly concerned with administrative matters, while the site office had to run the machinery for the technical implementation of the project. In order to achieve effective operations, the office was provided with special departments related to the special activities to be accomplished. These were:

- The directorate (DIR), which synchronized the activities of the project and of the joint contractors, and also supervised the latter.
- The Techno Archaeology Department (TA), which was in charge of the dismantling, rebuilding and other activities particularly in the technical field. Its members included Professor Soekmono, Dr Boechari, Urip Joyo, Mr Supangkat, Mr Wiratman, Dr Sampurno, Dr Soediman, Mr Soewandi, Professor Dr Parmono Atmadi, Mr I.G.N. Anom and Mr Tejo Yuwono.
- The Chemico-Archaeology Department (CA), which was in charge of stone conservation and other kinds of work in connection with the application of chemicals.
- The Central Registration Office (CRO), which was set up to keep track of the whereabouts of the stones and to prepare milestone reports.
- The Documentation Department (DOC) which was charged with recording all the activities of the project in photographs, scale drawings and situational maps.
- The Administrative Department (ADM), whose contribution was largely overlooked but which was in fact the most important part of the project, since it was here that the machinery could be kept running, in the financial field as well in the care of the personnel.

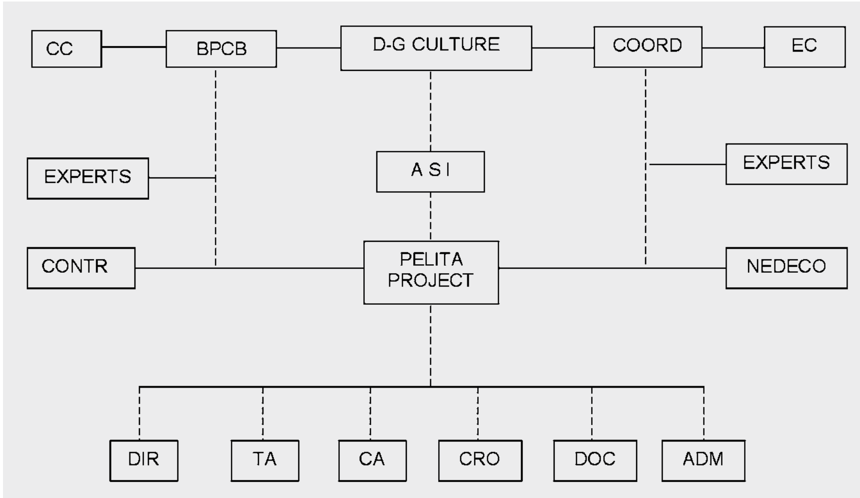


Figure 4.5.1
Diagram of the organization of the Pelita project for the restoration of Chandi Borobudur
Source: Borobudur Restoration Project

It was evident that to administer such a complicated organization adequate staffing was essential, and it was again thanks to the Pelita that the enrolment of personnel and even the training of technicians could be carried out without constraint.

The breakdown of NEDECO's restoration plan not only showed the immensity of work to be done but also the enormous number of people required for its implementation. The breakdown of activities was accompanied by the number of workers needed for each kind of work, and the total was more than 600. This figure exceeded the total number of employees

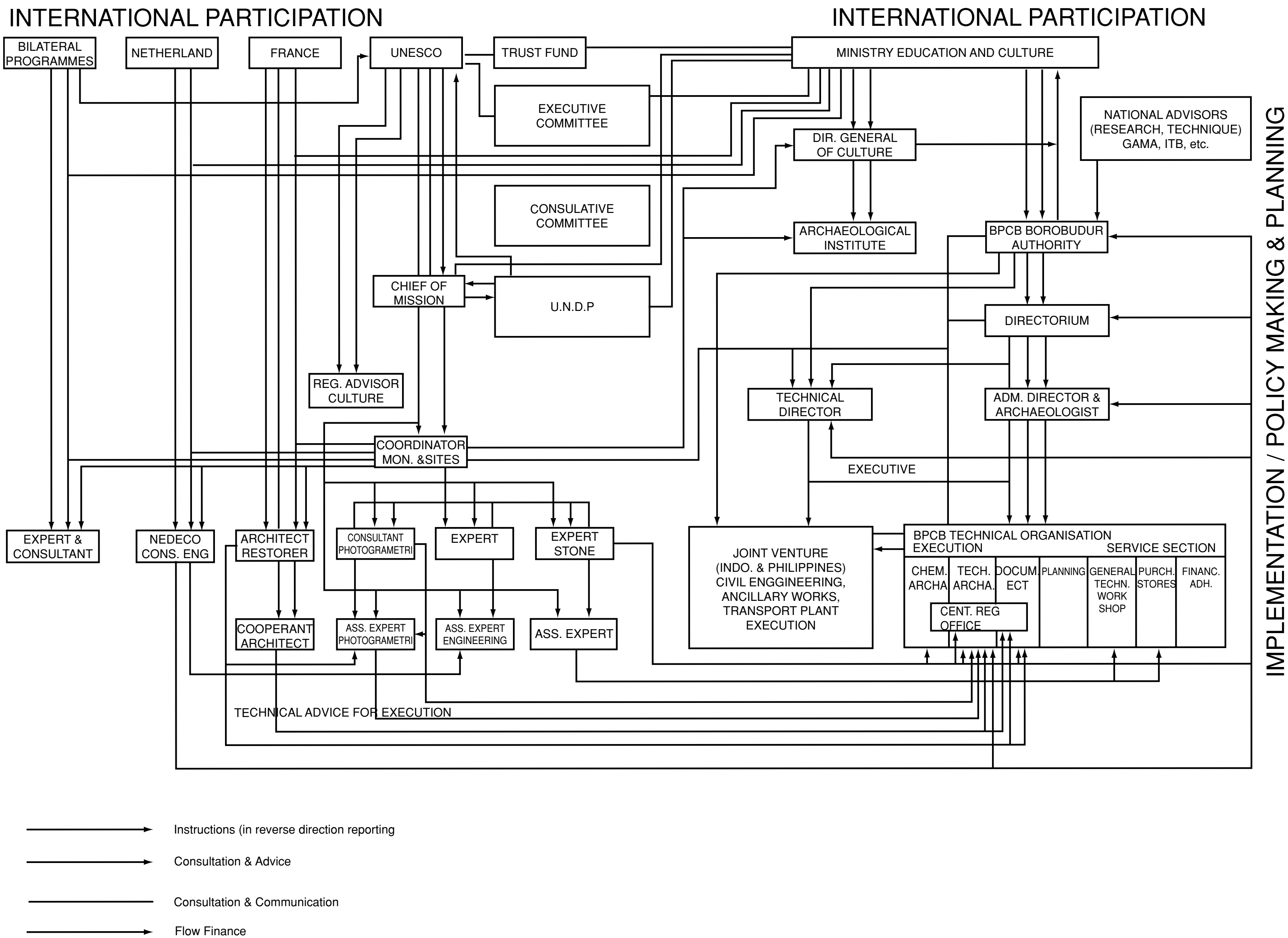


Figure 4.5.2

International participation
Source: Borobudur Restoration Project

on the entire staff of its mother institution, the Archaeological Service of Indonesia. Even to assist the project with senior officials for the leading positions was quite impracticable; the very limited number of senior personnel were fully occupied with their own specialized activities, so that it was impossible to release them. Indeed, for the first years of the project only the Director (Dr Soekmono), the Head of the Technical Department (Mr Samingoen), the Head of the Financial Department (Mr Soetjahjono), and the Head of the Prambanan Branch Office (Dr Soediman) were engaged to run the enterprise, while still keeping their permanent positions at the Archaeological Service. Some archaeological assistants from the Head Office and the Prambanan branch office were also engaged, on an alternate basis, while retired senior technicians proved eager to join the project as instructors in the field.

Since it was apparent that the project could not possibly reckon on the facilities of its mother organization, appropriate provisions were made when preparing the Pelita programme. In this respect the need for a workforce of 600 or even more did not necessarily create problems. The real problem was to be found in quite another field. Whereas the necessary experts could be provided by the different universities through close cooperation, and the unskilled labour through normal recruitment, the acquisition of technicians at intermediate level had to be realized through a special training programme.

As early as 1971 the project started a solid training programme. Diploma holders from general secondary schools majoring in physics and chemistry were enrolled for training in chemical archaeology, and those with technical secondary school diplomas majoring in construction and architecture were selected for the course in technical archaeology.

The training programme was scheduled to last three years. The enrolment was to be continued annually, until the minimum required number of technicians had been reached. The teaching staff, consisting of experts attached permanently to the project, were responsible for the academic courses. The practical training, involving the trainees in the daily activities of the project, was conducted by retired technicians of the Archaeological Service.

According to the prevailing regulations, a Pelita project was not authorized to run courses. The trainees were therefore designated full employees of the project. Their performance, however, was to be preceded by a special training programme.

The curriculum of this training programme was set up in such a way that all the trainees had to follow general courses alongside the special courses reserved for their specialized studies. The general courses consisted of English language, an introduction to archaeology and the cultural history of Indonesia. The special subjects to be followed by the trainees in techno-archaeology were civil engineering, history of the architecture of Indonesia and soil mechanics. The special subjects reserved for the chemico-archaeology course were chemistry, microbiology, soil science and petrography.

Additional courses were also given on an irregular basis. Practical training consisted of archaeological excavations, recording and registering, cutting and carving stones, jointing and bonding broken stones, and other kinds of relevant activities to provide the necessary skill and experience in preparation for full participation in the restoration work.

The first alumni of this ‘Borobudur Academy’ turned out to be not only ‘ready for use’ but also able to assist and even to represent their teachers in the joint studies with the expatriate experts.

5. Studies on the Sources and Causes of Decay

5.1 Water: the main source of destructive processes

Close observations and intensive studies made it clear that Chandi Borobudur was endangered by a twofold destructive process: the techno-structural deformations of the building components, and the physico-chemical deterioration of the building material.

The primary source of both kinds of danger turned out to be water. It was water that had disturbed the bearing capacity of the subsoil and hence caused the subsidence and leaning of the walls and the tilting of the floors. It was water that made possible the growth of mosses, lichens, algae and other micro-organisms, and hence the disintegration of the stones. For this reason, a special study on the properties of water was conducted by the advisers of the Badan, Mr Jutono and Mr Sri Hartadi of the Faculty of Agriculture, Gadjah Mada University (Jutono and Hartadi, 1973).

The heavy rains deluging the monument continuously during the wet season were not being discharged rapidly enough through the original drainage system. The 100 spouts at the corners of the different stages of the monument did not function appropriately, so a considerable amount of water was penetrating the stone layers and accumulating in the hill underneath the chandi as deep percolation water. Another quantity found its way along the slopes of the hill downwards to accumulate behind and between the stones of the walls as shallow percolation water.

The deep percolation water saturated the subsoil, causing an increase in its volume and a decrease in its bearing capacity. Simultaneously, fine particles of the soil were translocated. These particles, saturated with soil salts and minerals, seeped through the seams and pores of the stones and were finally deposited on the surface of the carved outer stones when the carrying water evaporated.

Shallow percolation water saturates the stones and flows through the open joints and the pores of the stones to the surface of the walls, causing a constant moistening of the surrounding air. This microclimatic condition intensifies the biological attack on the surface of the outer stones by stimulating the growth of mosses, lichens, algae and other micro-organisms.

It is apparent that there is a close interaction between runoff water and percolation water. Indeed, water is the most potent weathering agent in nature. It not only has several important reactions with other substances, but also strongly promotes the occurrence of other reactions. Hydrolysis and hydration are the two processes in which water reacts as a

Photo 5.1.1
Runoff water
Source: Borobudur Restoration Project

chemical compound. Hydrolysis is the major reaction in weathering, by which even the most complex and resistant compounds will gradually be decomposed. Dissolved carbon dioxide, acids and bases tremendously increase the hydrolyzing power of water.

The dipole structure of water molecules gives water the ability to hydrate various compounds. Hydrated compounds tend to be softer and more easily dispersed, so hydration facilitates the disintegration of materials. It also influences the physico-chemical relations between materials electrically. Strongly hydrated particles are apt to be dispersed due to their increased zeta-potentials. Disintegration diminishes the size of particles, and the total surface area per unit of volume or weight that is exposed to the chemical environment becomes much larger. This will accelerate or intensify chemical reactions.

Dissolution is another important geochemical aspect of water. Almost everything is to a greater or lesser degree soluble in water, which is why it is called the universal solvent of nature. The further the disintegration of a solid matter proceeds, the more soluble it becomes, or the faster it goes into solution. Water-soluble substances are not only readily transported, causing matter transfer from one place to another; they are also more liable to chemical alterations such as carbonation, oxidation, reduction, silicification, desilicification, transformation into new compounds or the liberation of constituting elements from their original compounds.

Water always contains dissolved oxygen and carbon dioxide in varying amounts, derived from the air or from reactions producing these gases, especially from those associated with life. In prolonged stagnant water, rich in unreadily oxidizable organic matter, oxygen may be lacking or entirely absent, and in this sort of environment reduction will prevail. In normal situations, however, an essential part of the total processes of carbonation and oxidation that take place in nature proceed in a watery medium. To a certain degree reduction brings about greater solubility: for instance, ferrous compounds are more soluble than when the iron is in the ferric state. Thus reduction adds to the mobility of elements.

Mobility and transportation lead to the deletion of elements in one portion of the weathered mass and the subsequent enrichment of those elements in another. Whenever the conditions for precipitation or deposition prevail, leaching and precipitation occur if a solution is translocated. In the case of suspensions the two consecutive processes are called elutriation and deposition. The transferred matter will ultimately form sequi of alluvial zones in the weathering mass.

Another crucial point is that water has a low viscosity and relatively high surface tension. Consequently, it is a fast-moving transporting medium and has a great ability to penetrate tiny pores and fissures. The characteristics of water imply that it has a far-reaching influence upon matter. Under the general range of air temperature and barometric pressure as manifested in the daily and seasonal patterns of weather, water is the only matter in abundance that can exist in its three phases: solid, liquid and gas. The mechanical force that develops through the increase in volume when confined water changes from its liquid into its solid phase tends to crack the walls of pores and fissures. This is also true when liquid water evaporates, due to the increase in vapour pressure.

Water affects soil consistency by modifying the degrees of cohesion and adhesion within the soil mass, and by shifting the balance of these two forces from one to the other. The degree of change depends upon other factors, such as clay content, clay mineralogy, nature of the exchangeable actions, organic matter content and the degree of decomposition of the organic matter. But whatever the other factors are, a moist soil is softer or more friable, while it becomes harder or harsher when dry. Saturation or excessive wetness over extended periods causes a weakening of the rigidity of soils.

Rock or soil solutes are sources of plant nutrients. Therefore, the growth and development of organisms, especially of microbes, will be greatly promoted by the existence of rich solutes, provided that the other essential growth factors are equally favourable. One of these is the microclimate, comprising air humidity and solar radiation. Air humidity is controlled by the temperature of the air and by the amount of liquid water in contact with it, and is also influenced by air movements. In shaded places and where obstructions or restrictions prevent air from flowing freely, the air tends to be more humid and also somewhat cooler than in open spaces. Shading also decreases the intensity of solar radiation. This kind of microclimate is preferred by many micro-organisms, particularly fungi, algae, lichens and mosses. As soon as these organisms establish themselves, the weathering mass enters an advanced stage of deterioration as biochemical reactions will now play an active part in the whole chain of weathering processes. Beyond this point, the process goes on with a much greater intensity, leading to the removal of metal ions in the form of organic chelates. Chelation renders metal ions soluble even in a chemical environment that otherwise advances the precipitation of the free ions. Carbon, nitrogen and sulphur cycles are essential parts of the biological decomposition. Humification is the consequence of the combined carbon and nitrogen cycles. The carbon cycle increases the rate of carbonation by producing more bicarbonate ions, while the nitrogen and sulphur cycles speed up hydrolysis and solution through the formation of nitric and sulphuric acids, respectively.

The ample solutes available throughout the year in and around the stones of Borobudur, in conjunction with the existence of a favourable microclimate, have made the monument an excellent habitat for micro-organisms. In order to study the effect of water on its dilapidation, four classes of water have been recognized. First is rainwater itself. The second is runoff water, or surface flow, which flows out along the gallery floors and is collected from gargoyles. It is considered to be water that has only limited contact with the stones. The third is drip water from the down-facing side of the protrusions of gallery floors. This water is assumed to have a longer contact with the stones, and so more opportunity to react with them. The fourth is drainage water seeping from the pores and spaces between the panels of the walls. This is considered the water that has been in the most intimate contact with the stones. It might contain water that has been flowing through the subsoil of the monument. A portion of the rainwater percolates deeply into the subsoil and could be considered a fifth class of water. Its effect on the stability of the supporting hill of Borobudur was assessed by determining the mechanical and some chemical properties of the subsoil.

All four classes of water were collected continuously over three months of the rainy season (December 1970 to February 1971). Twice a week, water that had been collected during the preceding days was taken to the laboratory for analysis. The results of this investigation can be seen in Annex Table 1.

The lowest pH was found in rainwater, and the highest in drain water. This was also the case with silica. The contents of HCO_3, Ca, Mg and SiO_3 increased sharply in drip drain water. This was true also for EC

(Electrical conductivity = total soluble salt content). These facts indicated that solution and leaching became much more intensive when there had been longer contact between water and stones. The increase in HCO_3 content could account for the increase in pH, which in turn led to more silica going into solution. The Ca and Mg contents could also be related to pH. The significantly higher average figures for OM and mineral nitrogen in water that had been in contact with the stones, as compared with rainwater, indicated that accelerated biological activities on and around the stones had occurred. This acceleration was very likely the consequence of a chemical concentration brought about by the liberation of bases from the stones following the attack by water.

No iron or sulphate could be detected in the investigated water. Some Al was affected by weathering. The figures for Na, K, PO_4 and Mn were inconclusive. Taking into account the zero figures of SO_4 it can be concluded that the sulphur cycle was absent in Borobudur. This finding was backed by microbiological analyses elsewhere. When considered together the figures of CO_2, HCO_3 and the ratios of free CO_2/aggressive CO_2 (to some degree also the figures of CO_3) clearly suggested that carbonation had been active. The molecular ratios of earth alkali to alkali cations and that of Ca to Mg could indicate that the earth alkalis were more mobile than alkalis and that, among the former, Ca was more readily released than Mg. It showed the common phenomena encountered at the first stages of weathering in a tropical environment. The leaching of Cl was pronounced, which was not surprising since chlorides are very soluble in water.

Table 5.1.1 shows more clearly the processes of carbonation, decalcification and desilicification that, in conjunction with active microbial processes, affected the stones and reliefs. The degree of attack was not uniform throughout Borobudur. This could be related to differences in microclimate and the amount of runoff and seepage water. When the mean value of each constituent is taken as 100, the pH varied most in drip and least in runoff. The range of free and aggressive CO_2 was greatest in drain, and smallest in drip. The greatest variation of HCO_3, Ca and SiO_2 was in rainwater, and the least in runoff. OM had the largest variation in drip, which was approximately the same as in drain, and the smallest in rain. If the variability of the chemistry of rainwater was not taken into account, runoff was almost invariably the least affected by the site factor. In half of the cases, drip had the greatest variability in chemical properties, whereas in the other half drain was the most variable. This means that weathering was far from uniform throughout the body of Borobudur.

Table 5.1.1 Index numbers of selected constituents of runoff, drip and drain water

Water	*pH*	*CO_2 free*	*CO_2 aggressive*	*HCO_3*	*Ca*	*SiO_2*	*Organic Matter (OM)*
Rain	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Runoff	120.2	210.5	205.3	267.3	1,316.7	330.8	285.7
Drip	117.9	226.3	205.3	625.2	2,966.7	1,161.5	202.9
Drain	124.3	184.2	157.9	623.4	2,566.7	1,353.8	205.7

Based on the respective components of rainwater = 100.

Range of index numbers of each from different localities were:
Rain water: pH: 98.8–105.1; free CO_2: 89.4–178.8; aggressive $C0_2$: 89.4–178.8; HCO_3: 86.0–167.2; Ca: 0.0–350.0; SiO_2: 76.8–153.9; OM: 88.6–120.6.
Runoff water: pH: 99.5–100.5; free CO_2: 65.0–152.5; aggressive CO_2: 64.1–156.5; HCO_3: 99.6–100.0; Ca: 84.7–117.5; SiO_2: 80.3–118.6; OM: 82.0–122.0.
Drip water: pH: 87.4–108.0; free CO_2: 65.1–123.3; aggressive CO_2: 56.4–128.2; HCO_3: 66.7–139.6; Ca: 52.8–194.9; SiO_2: 68.5–115.9; OM: 78.9–141.0.
Drain water: pH: 96.7–103.2; free CO_2: 5.7–145.7; aggressive CO_2: 3.3–146.7; HCO_3: 75.4–135.7; Ca: 65.6–162.3; SiO_2: 55.1–119.6; OM: 69.4–130.6.

Table 5.1.2 Average composition of drip and drain water from locations with different moisture conditions

Water	Site condition	pH	CO_2 (ppm) free	CO_2 (ppm) aggressive	CO_3 ppm	HCO_3 ppm	Cl ppm	Ca ppm	Mg ppm	Na ppm	K ppm	SiO_2 ppm	Organic Matter ppm
Drip	wet	6.99	4.7	4.3	0.0	58.9	2.1	15.9	0.7	2.1	3.0	31.7	8.0
	moist	7.34	3.8	3.3	0.0	77.3	3.4	20.6	0.7	3.2	1.7	28.1	5.8
Drain	wet	7.52	3.4	2.9	0.6	66.3	3.2	14.8	1.1	3.7	3.3	35.5	7.2
	moist	7.53	3.8	3.2	0.3	68.2	3.4	17.3	1.0	3.5	2.9	34.1	7.5
	dry	7.73	3.2	2.2	1.6	90.5	2.8	25.0	0.8	0.9	–	32.1	5.5

On site available only. Al_2SO_4 were zero.

Table 5.1.2 shows the average figures from wet and moist spots respectively. Drip water from wet spots was lower in pH, HCO_3, Cl, Ca and Na, but higher in CO_2 (free and aggressive), K, SiO_2 and OM, than that from moist spots. MG was the same in both. Drain water from wet sites was lower in CO_2 (free and aggressive), HCO_3, CL, Ca and OM, higher in CO_3, MG, Na and K, and had the same pH as that from moist patches. Dry conditions tended to increase pH, CO_3, HCO_3 and Ca, but decrease CO_2 (free and aggressive), Cl, MG, Na, SiO_2 and OM. Generally speaking, drier conditions led to slower microbial growth, leaching of bases and desilicification, while enhancing calcification leading to the liberation and translocation of Ca.

Ferallitization had occurred as the main weathering process in wet locations. In drier spots classification with or without silicification was more likely to have occured.

The following section presents an abstract from a study on the influence of deep percolating water upon subsoil conditions. The moisture content of the fill at the time of sampling indicates that percolation water had accumulated in the lower layers of the supporting fill. The degree of saturation also increased with depth, ranging from 42 per cent. Since samples were taken in the middle of the dry season, this shows the very poor internal drainage of Borobudur, and that much water had been percolating into the subsoil. The very low permeability of the subsoil material could be estimated from surplus values: these were all negative, and in many cases very negative, ranging from -1.67 to -29.71 (surplus = sticky point – liquid limit; Badan Pemugaran Candi Borobudur, 1974, pp. 242–63).

5.2 The subsoil underneath the monument

A great number of borings into the core of Chandi Borobudur were carried out to provide the necessary information concerning the soil that supports the monument. The samples were taken at different places and different depths, not only throughout the structure but also in the immediate surroundings of the monument.

The series of borings was carried out in three phases (Sampurno, 1969). The preliminary phase took place in 1963 and 1965. The second phase was directed to more intensive investigations of the morphology and stratigraphy of the subsoil. This was executed in 1966 and 1969 (Sampurno, 1969), and the third phase in 1971–74 (see Table 5.2.1).

Table 5.2.1 Location and depth of boreholes

No.	*Year*	*Code*	*Location*	*Depth (N)*	*Total depth*
1	1971	B V/71	Rupadhatu II-ES	5.00	
2		B V/71	Rupadhatu II-SE	3.50	
3		B V/71	Rupadhatu II-SW	4.60	
4		B V/71	Rupadhatu II-WS	4.60	
5		B V/71	Rupadhatu II-WN	7.00	
6		B V/71	Rupadhatu II-NW	2.00	
7		B V71	Rupadhatu II-NE	6.60	
8		B V/71	Rupadhatu II-EN	4.00	37.30 m
9	1974	B VI/74	Rupadhatu I-WN	6.20	
10		B VI/74	Rupadhatu I-NW	10.00	
11		B VI/74	Rupadhatu I-NE	10.00	
12		B VI/74	Rupadhatu I-NW	10.00	
13		B VI/74	Rupadhatu II-NE	10.20	
14		B VI/74	Rupadhatu I-NE	4.50	
15		B VI/74	Rupadhatu II-NE	10.50	
16		B VI/74	Rupadhatu II-NW	11.00	
17		B VI/74	Rupadhatu III-NW	10.10	
18		B VI/74	Rupadhatu III-NE	10.10	
19		B VI/74	Rupadhatu III-NE	10.60	
20		B VI/74	Rupadhatu IV-NE	10.00	113.20 m

Note: Depth measured from the base of chandi's foundation

Boring through the stone layers of the galleries and the circular terraces of the monument also provided significant data about the thickness and structure of the stone foundations. It turned out that the number of stone layers supporting the different parts of the edifice varied from place to place, even at points on the same structural level.

The boreholes revealed that the maximum thickness of the stone foundation was to be found at the eastern side of the second gallery: more than 3 metres, composed of no fewer than twenty layers. The minimum thickness was found at the northeastern corners of the first gallery and the first circular terrace, measuring no more than 0.6 metres and consisting of only three layers.

In spite of the considerable discrepancy between the maximum and minimum thickness of the stone layers supporting the monument, a certain uniformity in the whole construction of the different levels could be observed. The average thickness at the first gallery is 2.3 metres (max. 3.24, min. 1.02), and at the third gallery 2.95 metres (max. 3.15, min. 2.75). The floor where the square terraces end and the circular platforms begin shows a remarkable feature. Near the southwestern corner, where the average thickness is 2.50 metres, the foundation has a thickness of 2.8–2.95 metres in the direction of the cardinal points of the compass (North, East, South and West); towards the other corners, however, the thickness is only 0.65–0.08 metres. At the topmost platforms the average thickness is 1.66 metres, with a maximum of 1.80 metres and a minimum of 1.50 metres.

The reason for this inconsistency in the construction of the foundations must lie in the morphology and stratigraphy of the soil beneath the monument. This soil, which consists of constantly moist/humid fine tuff, sometimes mixed with small stone fragments, is part of the hill on which Chandi Borobudur was to be constructed. Furthermore, the figures indicate a certain regularity, in the sense that the hill was deliberately reshaped in accordance with the requirements of the construction to the desired dome-like shape.

Studies following the borings revealed that Chandi Borobudur was built on and around the top of the hill, which is itself situated between two other hills: a bigger one to

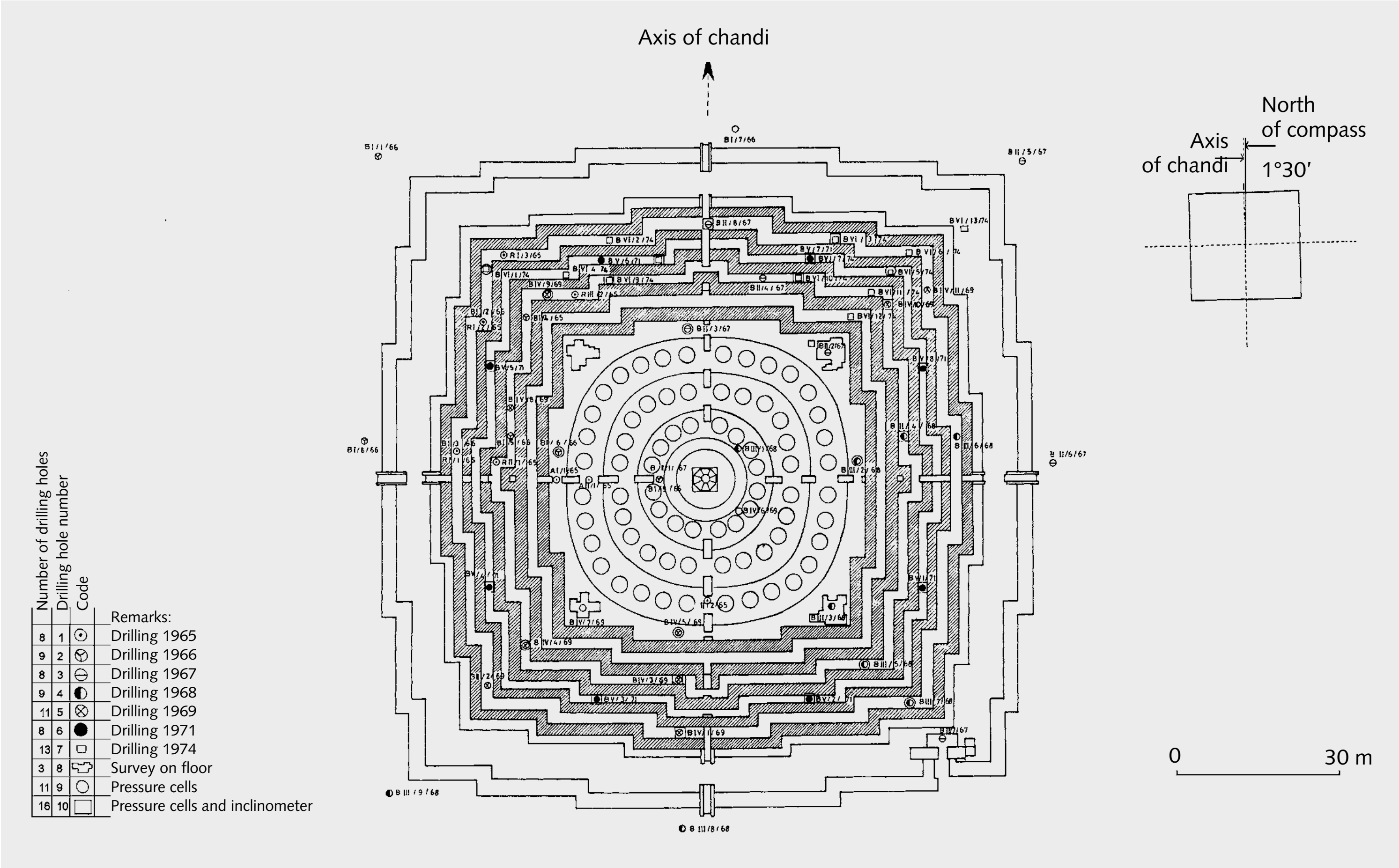


Figure 5.2.1
Distribution of drilling holes

Source: Borobudur Restoration Project

the northwest (known as the Dagi hill) and a smaller one to the southeast. The Dagi hill has a strikingly flat top, and borings did not come across an artificial layer. Horizon A is also lacking. The obvious conclusion is that the upper part of the hill was cut off to fill the low-lying plain at its southeastern side. This is entirely compatible with choosing to site the monument on the central hill, which occupies only the southeastern part of the spur, leaving considerable open space on the northeastern slope. Filling up this open terrain with earth from the Dagi hill created an ideal site for the adjacent monastery and its ancillary buildings. The foundations of these religious buildings were excavated in 1952.

Apparently the central hill did not fully meet the requirements for the planned construction of the monument so it had to be recontoured, mainly by enlarging it both horizontally and vertically. Consequently, the soil underneath the monument can stratigraphically be divided into two layers: the artificial fill or artificial soil, and the original terrain or the natural hill. The natural hill from top to bottom can further be subdivided into three horizons: horizon A, horizon B and horizon C (Sampurno, 1969).

The distinction in horizons of the natural hill is mainly based on the intensity of the weathering. In this respect the uppermost horizon (A) shows the highest intensity, when compared to the lower two. The thickness of the horizons is different, and so are the properties and characteristics of the respective soil types. Although borings down to a depth of 13.5 metres and more did not fix the exact bottom line of horizon C, it is reasonable to assume that this lowest horizon represents the bedrock of the hill (Table 5.2.2).

Table 5.2.2 Horizons of subsoil

Stratum	*Thickness (metres)*	*Soil*
Fill	0.5–8.5	Sandy clay, dark brown sand, frequently containing fragments of andesite, spiky or rounded 2–6 cm in diameter
Horizon A	2–3.5	Sandy clay or clayey sand, colour ranging from dark brown to blackish, sticky and soft, sometime friable, high permeability
Horizon B	0.5–3.5	Sandy clay, reddish or yellowish brown in colour, rather sticky and soft, very low permeability
Horizon C	> 7.5	Whitish yellow medium grain size tuff, neither sticky nor soft, containing igneous rocks

The builders, as we have noted, seem to have transported soil to increase the height of the natural hill and provide the shape and dimensions required for the construction of the monument. This artificial layer functions directly as the supporting layer of the structure. It has been interpreted as being artificial fill because it is not homogeneous and has the characteristics of a mixed soil, sometimes sandy, with gravel and andesite chips. The presence of these chips suggests that the building stone blocks were cut to size on the site and that the chips were thrown away.

The fill was found below the floors of the galleries, and also behind the walls of the monument. It consists of sandy clay or sand, dark brown to blackish in colour, sometimes in a mixture with a yellowish soil. Its consistency varies depending upon texture and water content: in some places non-sticky and non-elastic, in others sticky and elastic. In general, permeability was medium but varied with composition and was high in some places.

The thickness of the fill varies from one point to another, even on one and the same gallery. The minimum thickness is half a metre, and the maximum is 8.5 metres. The latter was observed at location B III/5, below the floor of Rupadhatu III-SE.

At a number of spots the fill consists of loose sand containing a large number of angular and vesicular andesite stones, measuring 2–6 cm across. Bigger andesite fragments (6–10 cm) were sometimes also found. These broken stones correspond in composition with the stones of which the monument was built.

Further down into the fill the soil consists of sandy clay or clayey sand that is dark brown to blackish in colour. It is often difficult to distinguish the artificial fill from horizon A of the natural soil. The boundary between the two layers is often apparent only from the lowest lying andesite fragments at the bottom level of the fill.

Judging from the cross-sections made through the monument and the surrounding hills, it is very probable that not only was the part of the hill allotted for the construction of the monument enlarged by fill, but also other parts on the northern, eastern and southern sides.

The physical characteristics and the soil mechanical features of the artificial fill can be summarized as follows. The water content is reasonable, with an average of 39.75 per cent. However, the plasticity index is relatively high: 32.04 per cent. Porosity is in general fairly high, with an average of 57.91 per cent. This is acceptable, since the material contains sand and andesite fragments in many places, so that the permeability rate is also high. Further analysis revealed that the grain size is D 60, thus indicating sand or silt. It also showed that the average bearing capacity is reasonable (1.47 kg/cm^2), and the maximum figure is high (3.15 kg/cm^2). The angle of internal friction, with an average of 16.3, can also be considered high.

The natural hill forms a dome with an oval base stretching in an east–west direction. The summit of the hill, which is approximately 16 metres above the plateau surrounding the temple building, lies northeast of the central part of the monument rather than precisely under it. In other words, the southeastern part of the monument is mainly constructed on fill. It is at this part of the hill, indeed, that the fill is thickest. Below the first gallery it is 7 metres, below the third gallery 8.5 metres, and below the circular terrace 7 metres.

The three horizons vary in accordance with the weathering profile revealed by percussion borings. There was, indeed, an obvious difference in the physical as well as in the mechanical characteristic in almost all boreholes.

Horizon A varies in thickness between 1.5 and 13.5 metres, and is composed of sandy clay, which has a dark brown to blackish colour. The minerals found in the sand components are feldspar, pyroxene, amphibole and magnetite. The average size of the sand grains is 2 mm.

The soil in general has the properties of being non-sticky, and non-elastic to reasonably elastic, depending on its texture and water content. This low elasticity was closely related to its composition: 10 per cent clay, 35 per cent silt, and 45 per cent sand. The blackish colour and the absence of fragments of fresh rock indicate that the soil has undergone an advanced process of weathering and leaching. Compared to the two other horizons, it has a very high degree of permeability. Along the bottom, it merges gradually into the next horizon.

Analysing the physical characteristics of the soil, the investigation revealed that horizon A has the highest water content of the three horizons (45.96 per cent), and the lowest plasticity index (26.15 per cent). This feature can occur in sandy soil of a high porosity. Horizon A in fact also has the highest degree of porosity among the three: 60.19 per cent. The sandy nature of the horizon can also be deduced from the relatively low bearing capacity and the angle of internal friction, respectively 1.13 kg/cm^2 and 14.3.

Horizon B has a thickness of 0.3–4.5 metres, and is distinguished from horizon A by its colour: brick-red, reddish brown or yellowish brown. Its mineral composition is striking: the whitish patches show the weathering product of feldspar, while the dark brown patches are due to iron hydroxides resulting from the weathering of magnetite and other ores. Numerous grains of fresh rock, 5 mm in diameter, are also found.

The soil is quite sticky and elastic, and has a fairly compact consistency. Consequently it has a very low permeability, and is even nearly waterproof. Grain size analysis has revealed, indeed, that the clay component of horizon B is larger than that of the two other horizons: 31 per cent clay, 44 per cent silt, and 23 per cent sand.

Compared with the other layers, horizon B displays the lowest water content (38.39 per cent) and also the lowest porosity (51.56 per cent), but the highest plasticity index (35.5 per cent). This is in accordance with the sticky and elastic nature of the material. Garnishee on the whole is of silt dimensions or D 60. The horizon, as noted above, has the lowest permeability of the three levels. Its elasticity is indicated by the values for bearing capacity and angle of internal friction, which are respectively 2.98 kg/cm^2 and 21.10. Both values are the highest observed for all horizons.

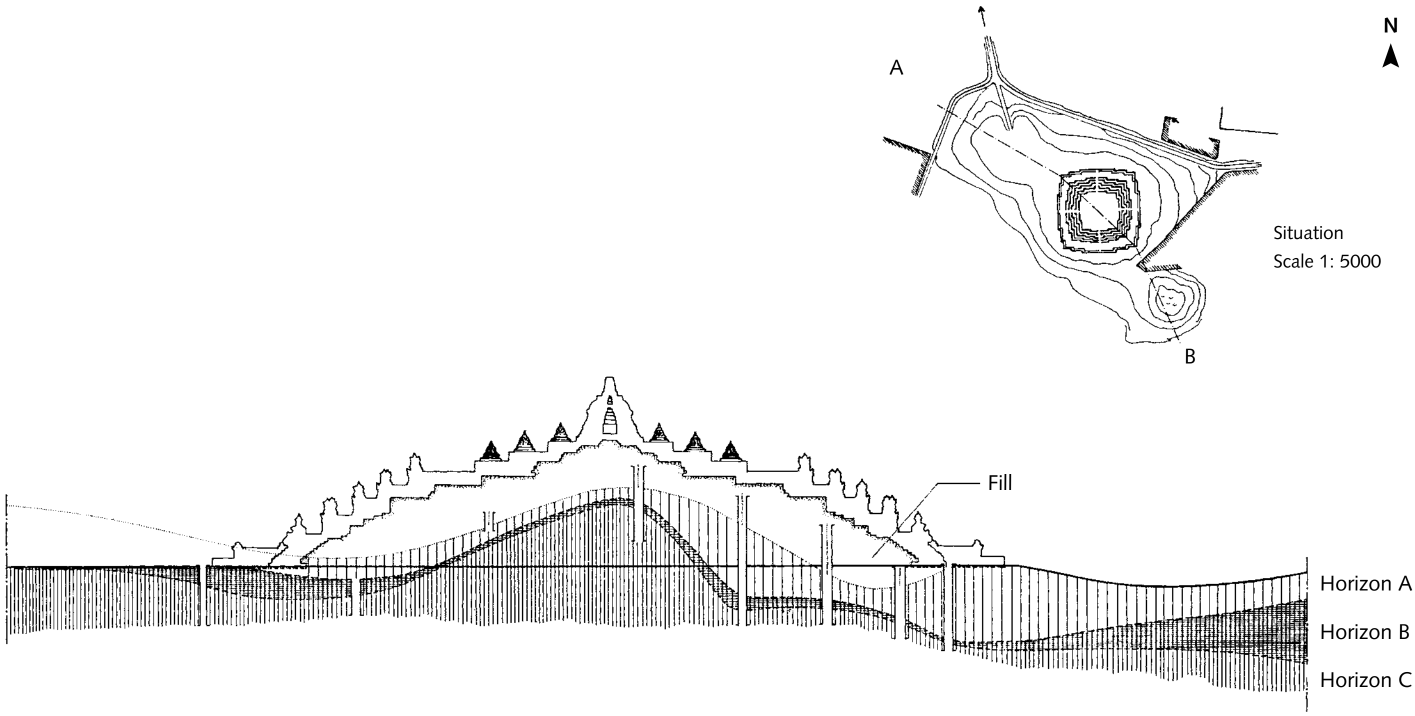


Figure 5.2.2
Stratigraphy of Borobudur
Source: Borobudur Restoration Project

Horizon B acts as a transitional zone between horizon A, which shows intensive weathering and leaching, and horizon C, which consists in general of only slightly degraded fresh rock.

Horizon C, with a thickness of 7.5 metres or more, consists of sandstone tuff of medium grain size, and is yellowish to whitish in colour. The soil is in general non-sticky and non-elastic, with a sandy consistency. Rather weathered tuffaceous sandstone of somewhat sticky and elastic character was also found. The proportions of the elastic components are: 26 per cent clay, 51 per cent silt and 20 per cent sand. In the components with the grain size of sand the following minerals are to be found: feldspar, pyroxene, amphibole and ores. At various places there is also hard rock, possibly a volcanic breccia occurring in the tuffaceous sandstone.

Although borings down to a depth of 13.5 metres could not precisely define the lower boundary of the horizon, the discovery of fresh rock justifies the assumption that the investigation had already reached the bedrock of the entire Borobudur hill. It is a pity that the exact thickness of the horizon remains unknown.

As far as the physical characteristics are concerned, the relevant studies showed that the water content of horizon C is reasonable (40.65 per cent), with a remarkable plasticity index varying between 14.68 and 44.31 per cent. At certain places the soil is quite sticky, unlike the rather sandy and loose material found elsewhere. The porosity is reasonable, and so is the bearing capacity (respectively 53.88 per cent and 1.66 kg cm^2). It is also remarkable that the angle of internal friction varies from a minimum of zero to a maximum of 250, with an average value of 13.60.

Table 5.2.3 Physical characteristics and soil mechanics

Characteristics	*Fill*	*Horizon A*	*Horizon B*	*Horizon C*
water content wn (%)				
minimum	42.31	35.50	32.20	31.82
maximum	63.50	66.76	52.10	52.13
average	39.75	45.96	38.39	40.65
plasticity Ip (%)				
minimum	17.69	17.12	22.83	14.68
maximum	39.19	38.76	43.05	44.31
average	32.04	26.15	33.50	28.21
porosity n (%)				
minimum	55.75	54.71	45.92	48.21
maximum	63.34	64.99	57.95	58.54
average	57.91	60.19	51.56	53.88
bearing capacity qu (kg/out)				
minimum	0.23	0.58	0.37	0.45
maximum	3.15	2.28	5.83	4.60
average	1.47	1.13	2.98	1.66
angle of internal friction 0°				
minimum	9.00	8.50	9.00	0.00
maximum	23.00	23.30	30.00	20.50
average	16.30	14.30	21.10	13.60

The results of the soil studies make it clear that the bearing capacity of the Borobudur hill plays a very significant role in maintaining the stability of the monument. The lowest rate recorded for the artificial fill is 0.23 kg/cm^2. This means that the soil cannot carry the burden of a stone wall higher than 1.15 to 1.43 metres, assuming that the specific gravity of the stone is between 1.6 and 2.0. The investigations, however, have shown that at many places the maximum height of the walls is greater than this. Most are of more than 8 metres, while at the centre of the monument the stone layers supported by the earthen fill even exceed 15 metres. The obvious result is that deformations occurred in the soil structure.

A stone wall with a height of 8–15 metres can be carried by the artificial fill if its bearing capacity is at least 1.28–1.60 kg/cm^2 or 2.4–3.00 kg/cm^2, depending on the specific gravity of the building material.

Deformations of the fill, which can also affect the horizon, can dislocate the walls of the monument. This is evident at the base of the walls, which are in direct contact with the fill layer. The greater part of the walls has subsided, causing distortions and tilting of the floors of the galleries. It turned out that such settlement has occurred not only in the square Rupadhatu section but also in the circular Arupadhatu platforms. This discovery is in complete accordance with the very low values at the upper part of the monument, which vary from 0.80 to 1.65 kg/cm^2.

Besides the relatively low bearing capacity at many places, the consolidation of the fill and the horizons demonstrates the fairly large potential of a variation in void ratio, in relation to the load to be borne.

Percussion borings for research on the permeability of various types of soil and different horizons in the field were carried out either by direct measuring on the surface of the soil or by first drilling boreholes down to the desired horizon. The measuring instrument comprised a pipe of 10 cm diameter and 10 cm height, into which water was permitted to infiltrate. The test showed that horizon A has the highest permeability, followed by horizon C. Horizon B turned out to be lowest in permeability. Indeed, horizon B contains soils and rocks that are almost impervious, and water can only infiltrate with great difficulty. Consequently, water that had already penetrated the artificial layer and horizon A is effectively prevented from flowing further downwards, and has to seep away along the surface of horizon B. If this surface happens to form a basin, as is indeed the case on the southern slope of the natural Borobudur hill, a local accumulation of water can be expected. Thus, the practically waterproof horizon B caused a high degree of water content in horizon A.

Finally, it can be stated that the water found in all the above-mentioned types of soil is situated in the aeration zone above the saturation zone. It is probable, therefore, that the presence of water is caused by capillary processes.

5.3 The subsoil around the monument

All the drillings into the different layers of the hill supporting the monument stopped before reaching groundwater. Bearing in mind that water is indispensable for all kinds of activities related to the projected restoration work, it was deemed necessary to determine whether or not groundwater could contribute to the water supply. However, Dr Sampurno's hydro-geological studies in the area around the Borobudur hill were not designed to establish the level of the groundwater but rather to gain information with respect to the properties of the soil and the rocks under the ground surface (Sampurno, 1969). While the presence of subsoil water can be deduced from the surveys of various wells in the Borobudur area, it has no apparent impact on the condition of the monument. A well to the southwest of the monument showed a depth of 51.70 metres, while a well to the east was 7.50 metres in depth, and one to the north 9.50. This means that the average depth of the wells is around 8 metres (which is more than 20 metres when measured from the courtyard of the monument).

The soil studies were carried out with the aid of vertical electrical soundings followed by supplementary experimental drillings, which could simultaneously be used as a kind of check on the accuracy of the geo-electric prospecting. These tests involved an area to the southwest of the monument measuring 300 square metres. Penetration tests were also made at eight locations near the temple base, and another four in the plain to the south.

The geo-electric prospecting southwest of the monument was primarily aimed at gaining information about the distribution and properties of the subsoil layers. By distribution was meant the horizontal extension and the depth of the interface of the layers from the surface. The properties of the rock layers, based on the specific resistivity, help to determine the zones of water saturation and the groundwater pattern. The flow of the groundwater is influenced by factors such as the shape of the natural environment, the type of rock, the fracturing pattern of the rocks and the thickness of the covering layer, which mainly consists of weathered bedrock.

The area chosen for the application of the geo-electrical method was too close to villages and ditches, which inevitably caused disturbances in the recording. The physical condition of the terrain, however, was highly suitable in view of the expectations that at least a distinction could be made between the covering layer, which was thought to be very conductive, and the bedrock, which is both more compact and of a higher specific resistivity.

The interpretation of the specific resistivity of the rock, deduced from the vertical electrical soundings and taking into account the general properties of rock in relation to electrical currents, leads to a number of conclusions.

The geological feature of the subsoil in the area south of the monument is characterized by a bottom layer of rock with a very low specific resistivity at a considerable depth. At location P4 the depth is approximately 12.5 metres. The rock can be interpreted either as a type full of hollows saturated with water or as clayey or silt rock, which is impervious. The type of rock can be considered to be bedrock. Its configuration shows the presence of a basin, which deepens nearer to the monument.

On the bedrock are found several layers of rock with a relatively high specific resistivity, but with striking variations at different places and different depths. This phenomenon can be interpreted as indicating that the layers alternate between coarse and fine-grained material (varying from coarse sandstone to gravel with clay or silt). The most plausible assumption is that there is an interfingering between the layers. The top layer was formed by products washed down from the hill on the north.

The groundwater table could be identified by a sudden drop in the specific resistivity. At location P4 it is estimated that the table lies at a depth of 5.50 metres, but further south it becomes gradually less.

Assuming that the bedrock forms the basis of the higher layers and that it has the shape of a basin, it is reasonable to suppose that this basin provides a good reservoir of groundwater. In view of the fact that the wells near the foot of the Borobudur hill and the spring of the Sileng River have a very small discharge, the discharge at location P4 cannot be expected to be different.

Supplementary drillings were carried out some 270 metres to the southwest of the monument, in the low-lying area where the vertical electrical soundings had been executed earlier. The supplementary studies were aimed at obtaining more detailed information on the geological structure of the subsoil, and also more data on the groundwater pattern as well as on the availability of water.

The land surface, which slopes gently in a southerly direction, consists of soil containing fine-grained sandy clay of a dark brown colour. The groundwater level lies at a depth of 6.10 metres, and thus practically at the same level as the well west of the drilling site. The drillings were performed down to a depth of 59.81 metres.

Almost all the layers below a depth of 6 metres contain groundwater. Starting from a depth of 14.90 metres, a semi-artesian condition was even encountered, in the sense that the groundwater at that depth rises up to a height of 4.50 metres below ground surface.

Table 5.3.1 Groundwater levels and lithology

Groundwater level	*Depth of boreholes*	*Lithology*
-4.50	14.90	Sandy clay
-3.80	31.26	Sandy gravel
-3.50	35.44	Sand and gravel
-4.00	40.24	Sand and gravel
-4.45	46.90	Clay and silt
-2.04	59.10	Sandy gravel

During the drillings, water samples were also taken at three different depths: 14.50, 43.50 and 69.81 metres. Chemical analysis produced very interesting results: fresh water was found at the first level, but salt water at the other two. As to the quantity of water that may be expected from the groundwater, tests at the three different levels have shown that the discharge is very small: between 8.18 and 18.00 litres per minute.

A number of conclusions can be drawn from the data on the lithological log and the groundwater level and type.

Fresh water is found in relatively recent layers, where no impact of formation water is observed; salt water is found in older beds where formation water is developed. If this conclusion is correct, the older beds can be interpreted as bedrock and the younger beds as alluvial deposits (alluvial rivers).

The boundary separating the bedrock from the more recent deposits is very probably situated at a depth of either 23.34 or 43.5 metres. The first interpretation is in agreement with the results of the vertical electrical sounding method, while the second is based on the sudden change from relatively compact clay and silt layers to relatively loose sand gravel beds.

Sounding tests were also carried out at several places around the base of the monument and in the plain southwest of it, at eight and four locations respectively. The depth prescribed for each sounding, in cases where no hard rocks were encountered, was 15 metres. In fact the soundings varied considerably in depth with a minimum of 5.6 and a maximum of 25.6 metres. Soundings stopped when the desired depth was reached or if the rocks encountered resisted a pressure of more than 150 kg/cm^2. If there was any doubt about the results – for instance if apparent large differences were observed with respect to the depth of a certain horizon, or if hard rock was encountered at too shallow a depth – the soundings were repeated. This happened at location 4 to the east of the monument and at location 9 to the northwest.

The sounding tests showed on average a low conus resistance, varying from 10 to 20 kg/cm^2 for the uppermost layer. The thickness of this layer is relatively large, but at location 4 to the east and location 9 to the northwest it appears to be small: respectively 5.8–9.2 metres and 10.80 metres. At these depths the conus resistance suddenly increased to over 150 kg/cm^2, followed by the lifting up of the sounding apparatus itself. At other locations this high conus resistance is only reached at a depth of 18.6 to 24.8 metres.

A hard layer was frequently found between the soft layers at the upper part and the hard beds below, with a relatively high resistance (20–40 kg/cm^2), which sometimes showed a sudden increase to 100 kg/cm^2.

By comparing the results of the soundings with the bore log of the previous drillings on the site of the monument, a certain parallel could be observed. The soft layer of the upper part is comparable with the artificial fill, the relatively hard layers with the sandy material of horizon B, and the very hard layers of weathered rock below that form the bedrock of Borobudur hill represent horizon C.

Finally, it can be observed that generally speaking all the sounding locations show a high value of friction resistance. In particular, at locations 7, 8 and 9 a friction resistance of more than 100 kg/cm^2 was recorded at a depth of 11 metres.

5.4 The structural deformations

The structural deformations of Chandi Borobudur involved the leaning and subsidence of the main walls and the tilting and settlement of the gallery floors. The clearest danger of collapse could be seen at the northwestern part of the monument, especially at the first gallery. The corner to the immediate west of the northern staircase was leaning as far as 10°, while the sagging had reached a depth of more than half a metre. In fact, the entire northern wall of the first gallery was leaning forward, to an extent that varied from place to place. It could also be seen that the wall of the second gallery was leaning seriously, but in the opposite direction: it was leaning backwards.

The base of the monument, and also the upper part, were in good condition, in the sense that no particular structural irregularities could be observed. Very precise analysis showed that the circular terraces had undergone a slight subsidence, but thanks to van Erp's restoration these had become one of the most stable parts of the edifice.

Studies of the leaning of the walls and the tilting of the gallery floors had led to the conclusion that they were caused by several technical failures. Most obvious was the inadequate bearing capacity of the subsoil on which the monument had been constructed. The foundations were very probably laid in conformity to the horizons of the soil layers, so that there was an apparent irregularity in the number of stone layers. Opening up the floors to make possible the borings for soil investigations had revealed that the number of stone layers supporting the monument varied from place to place. It was also apparent that the tilting of the layers was due to the subsidence of the walls, so that the floor stones tended to slope downwards in the direction of the foot of the wall. Irregularities in the horizontal position of the floors were also observed at many places.

It was probably not only the characteristics of the subsoil that caused the deformation of the monument, but also the inadequate building techniques and construction methods used by the engineers of more than 1,000 years ago. The stepped construction of the foundations inevitably entailed the occurrence of weak spots, especially where the supporting stone layers were not adequate for the burden they had to bear, so that a hinge-like connection was created after some time. This was observed, indeed, exactly at the point where the wall was leaning forward to the greatest degree.

The technique of simply piling up stone blocks without using mortar, ensuring the grip between the stones by indentations, also promoted the occurrence of uneven stresses and pressures among the various components. This process was exacerbated by the striking difference in thickness of the supporting stone layers, which varied from three to twenty layers.

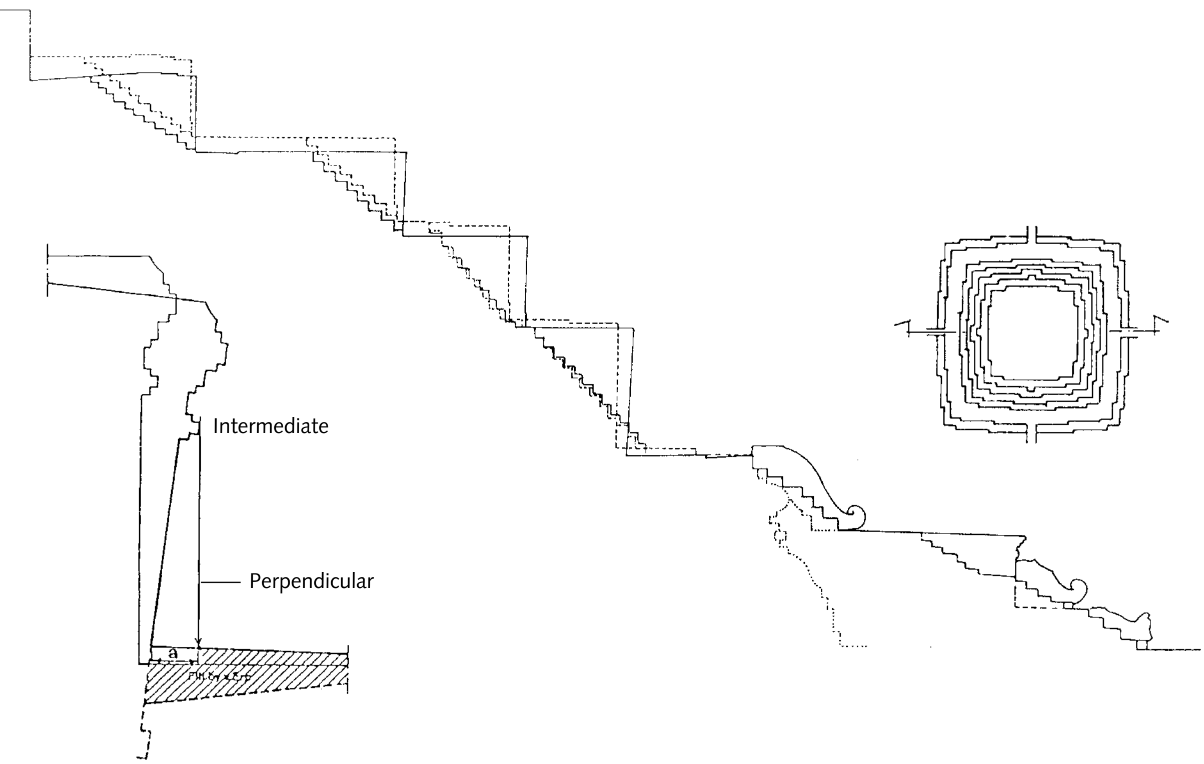
Another destructive factor was the presence of soil particles containing inappropriate chemical elements that had been leached from the inside of the monument, which was almost always moist. These particles inevitably enhanced the deformation processes.

Apart from identifying the possible causes of the structural deformations of the monument, the study continuously monitored the leaning of the northern wall of the first gallery and checked the degree of slanting from time to time.

Checkpoints on the stones of the wall and on the floor were established for easy measuring purposes. This was done in the simplest possible way: by using a plumb line, lowered from the extreme edge of the intermediate listing point to the marked point on the floor. The base of the resulting triangle, showing the distance from the foot of the wall to the checkpoint, was used as the parameter of the degree of slanting.

Measurements over a period of nearly fifty years did not reveal alarming symptoms with respect to the process of slanting of the continuously observed wall. However, the alternations between increase and decrease undoubtedly indicated the occurrence of movement, and could therefore not be ignored. It was not improbable that the movement

Figure 5.4.1
Cross-section of eastern staircase
Source: Borobudur Restoration Project



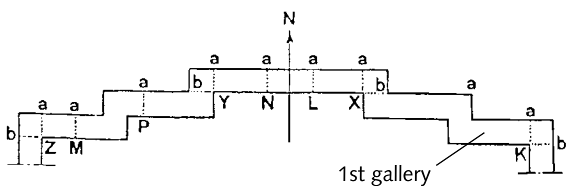


Photo 5.4.1
Walls
Source: Borobudur Restoration Project

Photo 5.4.2
The angle of deformation
Source: Borobudur Restoration Project

took place behind the wall and that the cause was the alternating swelling and shrinkage of the subsoil.

When in 1959 a suspicious bulging was detected in the middle part of the wall under observation, indicating that there was not only movement in the subsoil but even a push from behind the wall, the Archaeological Service was faced with the risk of being taken by surprise by a sudden collapse. To establish the actual danger of the bulging process through continuous observation would take years and probably even decades. Since it was impossible to predict the moment when the bulging would create immediate danger, the Archaeological Service could no longer take responsibility for the safety of this national pusaka, recognized as a monument for all humanity.

5.5 The biodeterioration of the stones

All climatic factors like sunshine, temperature, rainfall, wind and humidity play an important part in the deterioration of Chandi Borobudur's building material. The

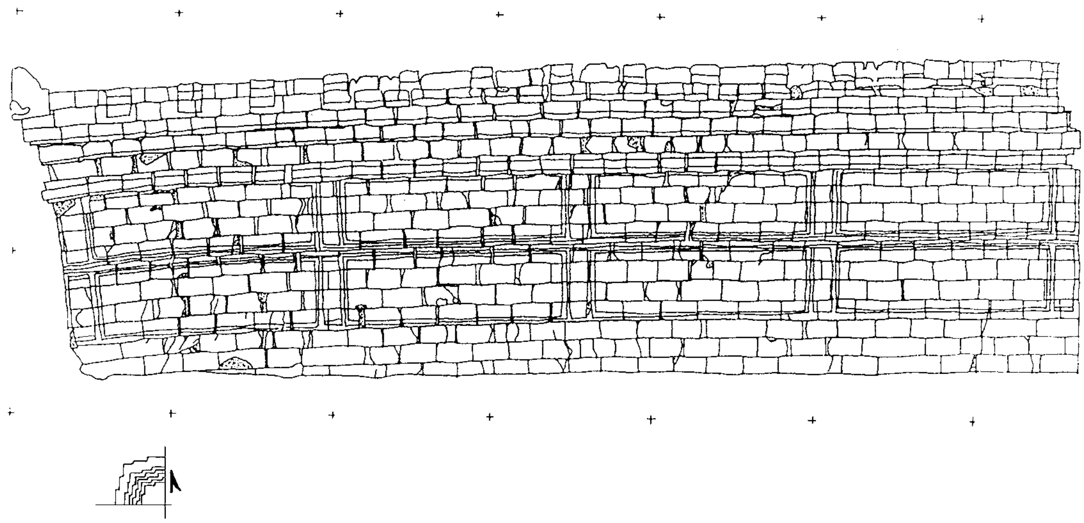


Figure 5.4.2
Tilting of main wall
Source: Borobudur Restoration Project

constantly moist stones form an ideal environment for the growth of mosses, lichens and higher plants. These organisms not only spoil the appearance of the bas-reliefs and other carvings but are also active agents that accelerate the corrosion and disintegration processes. Thus the tropical climate enhances the intensity of the microbiological activity very significantly.

The Borobudur area has a fairly temperate tropical climate, with irregular monsoons. It has two distinct seasons: the wet season from October to April with dominating northwest winds and more rainfall, and the dry season from April to October with southeast winds and less rainfall. The distinction between the seasons is not very marked, since it can be wet in August and dry in December.

The annual rainfall around Borobudur is fairly high, with an average of around 2,200 mm. Daily rainfall of 65 mm is normal and it is not exceptional for the figure to rise to 100 mm. The highest daily figure recorded is 201 mm (17 August 1960), followed by a figure of 194 mm for one day in January 1937. At the height of a downpour the rainfall is estimated to be 15 mm per minute. There are also, however, years with an almost total absence of rain. A drought lasting for three to five months is not exceptional.

Rainwater affects the stones of the Borobudur monument in two ways. First, runoff water causes erosion of the stone surface. Trickling water increases the action of various organisms, and in general leaches away the coating together with the detached fragments of the rock. Second, the water easily penetrates the porous rocks, transforming the hill underneath into a kind of water reservoir. This became apparent when in the course of the borings on the topmost platform of the monument, after a three-month drought, saturated rocks were found in addition to muddy clay. It also expl ains, though only partially, why the walls with the reliefs are constantly damp – and sometimes close to saturation point – during the dry season. In the process of evaporation this water rises up through the rocks to the surface, bringing with it fine particles of clay and other dissolved material. It is the presence of these substances, rich in micro-organisms and remaining stagnant in the pores or fissures of the rocks, that gives

Photo 5.5.1
The base of the monument measures about 118 m, the top stands at present 36 m above the foot of the monument. The pinnacle of the central stupa is incomplete.
Source: Borobudur Restoration Project

rise to the majority of the biological agents observed.

The atmospheric humidity recorded in the direct vicinity of the monument varies from 50 to 85 per cent in the rainy season, and from 66 to 88 per cent in dry seasons (de Beaufort et. al., 1970, p. 117).

The average air temperature is between 20 °C and 36 °C in the rainy season, and between 20 °C and 33.5 °C in the dry season. In this respect it is worth noting that special observations during the rainy season in 1969 revealed differences of 10 °C to 15 °C between 7 o'clock in the morning and 12 noon of the same day. Considerable differences in temperature were observed when measured on the surface of the stones, not only at different times but also at different locations. This is apparently due to the texture and geographical position of the stones, and also to the presence or absence of certain organisms such as algae, lichens and mosses.

An extensive study of micro-organisms like algae, lichens and mosses occurring throughout the monument as a result of constantly moist stones was conducted by Mr Jutono and Mr Sri Hartadi of Gadjah Mada University in 1971 in cooperation with the UNESCO experts, particularly with Dr Hyvert.

In this study special attention was paid to the identification of the micro-organisms and their spread over the different parts of the monument. It turned out that mosses, lichens and algae were to be found practically everywhere.

Mosses were distributed profusely, though unevenly, over all the stones of the monument, spoiling their aesthetic appearance. *Hepaticeae* are most frequently found on weathered rocks containing little clay, particularly in humid zones. This type of organism is further affected by the moistness of the stone. *Haplozia javanica* was found most frequently on rocks that had already

Photo 5.5.2
Staircases In the middle of each side of the edifice give access to the upper parts and galleries of the monument.
Source: Borobudur Restoration Project

undergone a slight surface deterioration. It usually grows alone – unlike the other organisms, which are always found in association – and in the form of small bulbs of varying size (the average is 1.2 cm in diameter). The leaching products are fixed on the surface of these bulbs and cause them to adhere to the rock. Underneath the bulbs a slight corrosion of the rock was sometimes observed. Atmospheric humidity and a few minerals from either the clay or the rock were all they needed to ensure growth.

Several other types of *Musci* could be identified, but *Barbula javanica* drew special attention, since it was frequently associated with algae. It was to be found in particular in the hollows of reliefs where there was a large quantity of clay. The types of *Musci* that were recorded are: *Hyalophyla involuta*, *Acngtroemia orientalis*, *Bryum coronatum*, *Ectropothesium monumentum* and *Barbula javanica*. *Barbula javanica* was frequently associated with algae (*Nosctoc minustissimma* and *Anabaena anomala*).

Many types of lichens were identified. These organisms were among those found in the largest quantity on the monument. Crustaceous lichens were mainly observed on the surface of the reliefs and the statues, and foliaceous lichens at the base of the monument. The principal factor for their growth and development is moisture: rainwater, capillary water, or simply atmospheric humidity. Apart from their adverse effects on appearance, the lichens also have destructive effects on the rocks. Their biochemical action through the secretion of acids increases the erosion of the surface of the stones. The pH of certain types of lichens showed significantly high acidity. The following specimens were found at various places on the monument: *Laboria pulmonia*, *Placynthium nigrum*, *Endocarpon fusitum*, *Bacidia rosella*, *Perina fafinea*, *Biatoria immersa*, *Verrucaria rupestris*, *Rocella fuciformis, Thermuthis velutina,* *Ephebe pubescens, Peltigera malaccea* and *Septrotrema pseudoferemula*.

The abundant growth of algae is promoted by the fairly high degree of atmospheric humidity in the immediate vicinity of the monument. This fact is closely related to condensation in the stones bearing the bas-reliefs, the presence of clay and traces of coating in the pores and the fissures of the rock, and also the runoff. These cellular cryptograms were also frequently found in calcareous concretions, usually associated with lichens, fungi, mosses and bacteria.

Members of the Cyanophyta (blue-green algae) were found in greater abundance than others. These included:

Familia: *Nosctocaceae: Nostoc calcicola, N. microscopcum, N. ellipsosporum, Nostoc sp. Anabaena anomala*.

The *Nosctocaceae* are usually confined to watery places (seepage water). *Nosctoc minutissima, N. calcicola* and *Anabaena anomala* are the blue-green algae, which are found also in association with *Barbula javanica* (*Musci*).

Familia: *Scytonemataceae: Tolypthrix conglutinata, T. campylonemoides, Auslosira fertissima, Scytonema julianum, Scytonema mirabile*, and *Scytonema sp*.

The *Scytonemataceae* is found in damp sites. *Tolypothrix conglutinata* is characterized by its brownish and slimy appearance. *T. Campylonemoidea* has a slimy and blackish appearance as has *Aulosira fertilissima*. *Scytonema spp*. are also the specific organisms on the runoff channel.

Familia: *Entophysalidaceae*: *Heterohormogonium spp. Entophysalis spp*. is observed occasionally in postulae or stone wraths

Familia: *Stigonemataceae: Stigonema hormoides* and *S. minutum*.

These organisms are found on damp sites.

Familia: *Chroococcaceae: Cloeocapsa punctata, G. magma, Aphanothecea castagnei, A. pallida, Synechocystis aquatilis*.

These types of algae can be found on every site, in damp as well as watery places. Their cells are intermingled with other algae cells, or in quite pure colonies (e.g. *Synechocystis aquatilis* can be recognized easily by its greenish appearance in watery places).

Other kinds of algae, for instance the *Chlorophyta*, are found in small quantities. The *Chlorophyta* that have been identified include *Gonggrosira sp., Oocystis sp., Trentopohlia sp*. and *Chlorococcum humicola*.

The algae are found on watery places, in the fissures and on very weathered rocks.

The presence of diatoms inevitably presupposes the existence of runoff and seepage water, or the proximity of stagnant water. In this respect the condition of the carved walls provides an ideal situation. In most cases layers of diatoms alternate with layers of silica and coating.

Species that can be identified in various samples are: *Pinnularia leptosom, P. interrupta, P. mesolepta, P. intermedia, P. borealis, P. hemiotera, Caloneis bacillum, Navicula minima, N. breakkaensis, N. mutica, Cymbella ventricosa, Nitzschia amphybia, N. denticula, N. frustulu* and *Achnautes lanceolata*.

Formations of stone wraths on blocks that are already weathered are the result of the association of algae and mosses. Protonema of moss may be attached to a substratum of either clay or artificial remnants of coating, forming a green edging of algae. The upper part is covered with limestone mixed with silica dust, which may come from the leaching of the coating. These pustules adhere closely to the rock and cause it to deteriorate both underneath and around the edges.

The algae identified from stone wraths are: *Gloeocapsa, Gloeotheca, Entophysalis, Pleurococcus, Scytonema, Aphanothece, Anacystis, Synechoeystis, Gloeodinium, Oocystis, Gongrosira, Trentopohlia, Schizothrix, Cosmarium* and many kinds of diatoms. Almost all stone wraths contain a protonema of moss. Details of the microbiological analysis can be found in Jutono and Hartadi (1973).

Observations of the growth and population of micro-organisms on the stones of Chandi Borobudur led to the general conclusion that the deterioration was mainly caused by mosses, lichens and algae. The multitude of colours of these organic growths was responsible for the disfiguring of certain parts of the monument and the blurring of the details of the reliefs. Thus the change in appearance was brought about by the luxuriant cryptogamic vegetation growing on both weathered and seemingly sound rocks. The various kinds of surface deterioration of the carved stones were closely related to the different physico-chemical and biological processes.

Special observations of the biological processes on the sculptured main walls led to the identification of one zone suffering from runoff water and another zone exposed to seepage water and partial runoff. The first zone showed the dominance of the growth of algae. The organisms attacking the second zone consisted of algae, *Musci*, *Hepaticeae* and an association between *Musci* and *Nostoc spp*. or *Anabaena*.

Stone wraths were also observed at many parts of the reliefs, particularly at those spots where the weathering process had reached an advanced level. The wraths were formed by the association of algae with mosses.

Observations of the carved stones of the balustrades showed that mosses and lichens dominate the organic growth. Algae are also found, but much less frequently. Striking differences in the composition and the population were also observed, mainly due to the difference in moisture conditions.

The results of the studies of the organic growth on the surface of Chandi Borobudur's stones can be seen to reflect the type of damage and the physico-chemical condition of the relevant sites. It is an established fact that under any kind of circumstances and climatic conditions, the weathering of stones (and particularly of soil formations) is caused by various kinds of micro-organisms and various types of compositions, dominated by lichens and mosses.

The exact composition of the dominant organisms apparently depends on several other factors beside moisture and the salt content of the water. Seemingly, however, a composition consisting of algae and *Musci* is very common. It is interesting to note that the growth of mosses apparently starts in the hollows in the stones and thence extends to the surrounding parts of the surface.

For a good understanding of the characteristics of the different organisms, microbiological analyses were carried out in the laboratory. The counting of the number of specific organisms (micro-organisms) was carried out with the aid of a method adapted by Krumbein. Stone and soil samples were collected from several sites. Two types of soil samples were analysed: one taken from the foot of the hill of the temple and the other from between the stone layers of the temple.

The results of the analysis of the soil as well as the stone samples can be seen in Annex Table 2. It can be concluded that the activities of the organisms of the sulphur cycle are negligible (Jutono and Hartadi, 1973, p. 9).

Some of the organisms, particularly fungi and actinomycetes, were isolated in pure culture. The species of isolated fungi (identified by the Laboratoire de cryptogamie du Muséum national d'Histoire naturelle in Paris) were:

Aspergillus niger van Tieghem
Aspergillus flavus Link
Aspergillus elegans Gasp
Cladosporium cladosporoides (Fres) de Vries
Cladosporium sphoerospernum Penzig
Cunninghamella echinulata Thaxter
Curvularia lunata (Walker) Boed
Fusarium roseum Suyd and Hans
Gliocladium virens
Penicillium lilacinum Thom
Penicillium multicolor G.M. and P.
Rhizopus arrhizus Fischer

Fifteen strains of *Streptomycetes* were also isolated. Many of these micro-organisms are able to form organic acids from several carbohydrates, and some of them might be active in the process of heterotrophic nitrification (Jutono and Hartadi, 1973).

Some of the fungi strains are capable of forming citric acid and oxalic acid of a significant concentration from certain carbohydrates.

Data for the evaluation of the ammonification rates revealed that the ammonification rate for soil samples ranges from two to nine days, while for stone samples the range is from four to fourteen days.

Microbiological analysis has led to the conclusion that the aggressive compounds produced by the sulphur cycle (H_2S and H_2SO_4) should not be identified as primary weathering agents. No such indications have been found and their action can be considered negligible. On the other hand, the organisms of the C and N cycles seem to play a very important role in the biodeterioration process.

The climatic conditions of the area where Borobudur is situated are characterized by a high annual rainfall without a pronounced dry season, high air humidity throughout the year, and a moderately high air temperature with only slight yearly fluctuations and minor differences between day and night temperatures. From the point of view of soil genesis, this kind of climate favours the process of laterization. This is facilitated by parent materials that contain enough bases that are released during the first stage of soil formation, and a relief that, in cooperation with the structure of the parent material, provides good drainage to the area. Andesitic material is one such parent material. The better-developed soils in the surroundings of the Borobudur monument show the typical results of laterization.

The very porous and quite permeable stones of the monument can easily be penetrated by air and water. Moreover, the building's location on top of a hill enhances the downward seepage of water into the pores of its material. The loose joints between the stones assist this moisture penetration to a considerable extent. The obvious assumption, therefore, is that a laterization process has been taking place continually and that this activity is to be blamed as the principal weathering process.

Detailed investigations have firmly established that the microclimatic factor plays the most important role. In this respect Chandi Borobudur can be divided into locally drier parts and locally moist to wet ones. At the drier parts the process of laterization seems to be modified into a process that has the characteristics of calcification. This latter process in its purest form will lead, in the case of soil formation, to the building of so-called pedicels. In this way carbonates, especially those of calcium, magnesium and iron, are deposited at the surfaces and in the cracks of the stones. The dirty white deposit that effervesces with strong mineral acids is known as *mendmilch*. Laterization results in the formation of pedicels. Iron and aluminium react to form oxides and hydroxides as residual compounds after the bases and other soluble salts have been leached out. These residual materials can easily be seen on the surfaces of the stones where the microclimate is moist or wet (Notohadiprawiro and Soekodarmodjo, 1975).

In both weathering processes (laterization and calcification) CO_2, in the form of gas and of carbonic and bicarbonic acids in the infiltrating and percolating solution, is the primary agent.

To elaborate both kinds of weathering processes, Mr T. Notohadiprawiro of the Gadjah Mada University conducted special research into the physical and chemical aspects of deterioration. Soil samples were taken from boreholes III-6 (underneath the first terrace, east side), III-4 (underneath the third terrace, east side), III-2 (underneath the fifth terrace, east side), III-3 (underneath the fifth terrace, southeast corner), and III-1 (underneath the third circular terrace, northeast corner).

The results of the physical analysis are summarized in Tables 5.5.1 and 5.5.2.

The moisture content at sampling time (Pw) indicates that water accumulates in the lower portion of each observed profile. The series as a whole also shows that water collects in the lower part. These facts can easily be seen by comparing the average figure of a profile with the corresponding individual ones of each layer, and the average figure of the whole series with that of each profile (Table 5.5.4). In order to assess the degree of saturation the percentages of PW_t to maximum water holding capacity (MWHC) was calculated (Table 5.5.3). The percentages reach the highest values at the lower parts for the series as a whole as well as for each profile. Since the samplings took place in the driest part of the year, it may be assumed that a great deal of water had penetrated the inner part of the chandi during rainy periods and that the internal drainage condition is very poor.

The Pw was considerably higher than the PL (Plastic Limit), especially in the lower layers of the profiles and the lowest profile in the series. Generally speaking, the PL can be seen as the critical bearing point, and above it the soil could easily be compressed. Furthermore, many of the layers have a Pw that is close to or even above the LL (Liquid Limit). This means that shearing effects or tangential stresses are more marked. Thus it may be concluded that under the heavy load of the building:

- The upper part of the supporting soil at site III-2 is apt to undergo compression, while the lowest sampled layer is affected by shear: the third layer, which contains a 10-cm sand layer and where the silt and clay particles are in a high degree of stable aggregation, is the most stable owing to the much better drainage condition.
- At site III-4, the supporting soil bears the effect of compression; here the middle sample, which coincides with a considerable degree of silt and clay aggregation, is the most stable.
- At site III-6, the supporting soil as whole is likely to be affected by shear.

Table 5.5.1 Physical characteristics of each sampling site

Sampling site No.[1]	*Depth cm*	*Pw air dry sample (%)*	*Pw$_t$ (%)*	*MWHC (%)*	*Particle size distribution (%)* sand 2.0–0.05 mm	silt 0.005 –0.002 mm	clay < 0.002 mm	*Textural class*[2]	*Degree of stable aggregation of silt and clay (%)*	*Notes on sampling*[3]
III–1	600–650	12.36	nd	64.86	22.92	14.83	62.25	Clay	62.44	
	700–750	11.18	nd	74.27	54.35	25.03	20.62	Sandy clay loam	50.79	
III–2	A	11.12	39.38	64.21	43.60	16.41	39.99	Clay loam	57.99	Underneath 3rd–6th stone layer: many platy stones.
	B	8.29	33.60	52.79	44.54	25.55	29.91	do.	59.78	do. 6th–10th stone layer: many smaller stones, not platy.
	C	6.28	18.57	44.22	42.22	6.48	51.30	clay	64.86	do. 10th stone layer: with a sand layer of 10 cm thick.
	D	6.74	46.61	50.23	29.04	21.48	49.98	do.	63.12	do. 13th stone layer
III–3	0–20	7.40	34.42	49.58	61.28	16.78	21.94	Sandy clay loam	46.66	The sampling started from underneath the 3rd stone layer.
	20–80	6.10	52.39	45.48	46.74	13.28	39.98	Sandy clay	66.14	
III–4	A	6.93	36.11	49.43	53.80	12.99	33.21	Sandy clay loam	36.76	From fissures between stone of 6th to 10th layer.
	B	9.96	37.14	64.36	31.00	23.21	45.79	clay	72.80	Underneath 13th stone layer and lower.
	C	11.37	39.27	60.69	44.54	22.34	33.12	Clay loam	72.72	Between 15th and 16th stone layer.
III–6	0–25	13.79	54.93	73.95	48.45	18.20	33.35	Sandy clay loam	71.79	First sample from underneath 3rd stone layer.
	25–60	17.14	58.33	69.94	40.13	16.17	43.70	Clay	70.32	
	60–80	14.08	58.18	71.51	32.49	12.21	55.30	do.	59.85	
	80–110	15.60	67.56	74.21	50.57	10.08	39.35	Sandy clay	71.65	
	110–125	14.60	63.42	77.94	74.93	8.27	16.80	Sandy loam	52.45	
	125–165	16.48	59.86	84.03	60.06	14.65	25.29	Sandy clay loam	73.21	
	165–175	17.96	68.78	84.04	43.42	24.39	32.19	Clay loam	88.32	

Notes:

1. Refer to Plate 3 of Voûte (1969)
2. According to USDA
3. The average thickness of a stone layer is 20 cm

Table 5.5.2 Atterberg values of each sampled layer

Sampling site No.	*Depth cm*	*Liquid limit %*	*Sticky point %*	*Plastic limit %*	*Colour changing point %*	*Plasticity index (LL-PL)%*	*Surplus (SP-LL) %*	*Shrinkage %*	*Degree of heaviness (range 1–10) (1)*
III–1	600–650	62.52	43.64	36.69	15.07	25.83	-18.88	5.9	8
	700–750	59.40	43.51	39.37	17.05	20.03	-15.89	5.8	8
III–2	A	55.91	41.09	39.21	12.36	16.70	-14.82	3.2	7
	B	41.08	33.69	31.56	13.53	9.52	-7.39	3.2	6
	C	35.03	30.06	26.55	7.40	8.48	-4.97	4.3	7
	D	41.41	30.53	27.88	9.03	13.53	-10.88	4.3	7
III–3	0–20	35.13	32.06	28.75	10.04	6.38	-3.07	3.2	6
	20–80	33.57	31.83	26.57	8.64	7.00	-1.74	5.7	7
III–4	A	57.91	28.20	28.15	27.73	29.76	-29.71	2.0	8
	B	59.54	43.49	28.15	18.20	16.27	-16.05	8.2	7
	C	49.55	35.48	43.27	20.15	14.08	-14.07	5.7	8
III–6	0–25	56.48	49.50	46.03	44.39	10.45	-6.98	6.9	7
	25–60	62.17	48.02	47.96	24.36	14.21	-14.15	4.6	7
	60–80	50.15	48.48	45.05	15.08	5.10	-1.67	7.4	8
	80–110	55.59	45.65	45.51	18.70	10.08	-9.94	4.7	7
	110–125	61.83	47.97	42.76	13.16	19.07	-13.86	5.1	7
	125–165	59.14	53.98	45.18	20.63	13.96	-5.16	2.7	5
	165–175	66.25	56.63	52.23	24.81	14.02	-9.62	5.6	5

Table 5.5.3 Comparisons of percentage of Pw_t to MWHC with the average figure for each site and with the whole series

Sampling site No.	*Average Pw_t /MWHC × 100* Site	Series	*Individual Pw_t to site mean: higher +; lower –*[2]	*Sites means to series mean: higher +; lower –*[2]
III-1	nd	72.45[1]	nd	nd
			nd	
III-2	65.34		-	-
			- - -	
			+++	
III-4	64.49		+	-
			-	
			+	
III-6	80.65		-	+
			+	
			+	
			+	
			+	
			-	
				+

Notes:
nd = not determined.
1. Without site III-1.
2. Differences less than 10 = single sign; 10–20 = double sign; more than 20 = triple sign.

Table 5.5.4 Comparisons of Pw_t with the mean figure of each profile (site) and with the whole series

Sampling site No.	*Mean Pw_t Site Series*	*Individual Pw_t to site mean: higher +; lower –*[2]	*Sites means to series mean: higher +; lower –*[2]
III-1	nd	48.03[1]	nd nd nd
III-2	34.54		+ - - – - - ++
III-4	37.51		- - -
III-6	61–58		- ++ - - + + - +

Notes:
nd = not determined
1. Without site III-1
2. Differences less that 10 = single sign; 10–20 = double sign; more than 20 = triple sign.

The LL and Ip (plasticity index) of III-1 are both high. III-2 has a medium LL and low to medium Ip. The LL and Ip of III-4 are high and medium, respectively. The LL of III-6 is high and its Ip low to medium. A large negative value means that the inherent permeability is low. Small negative or positive values are proper to soils with medium to good permeability. On the basis of this classification and calculating the weighted averages of each profile (weighted by the thickness of each layer), the permeability of III-1 is poor (S = -17.4); III-4 is also poor (S = -1.42); and III-2 is moderately permeable (S = -6.9). In the calculation of the mean value of S for III-4 the first layer is not taken into account because it existed as material in fissures of the stone layer.

Although the profile of III-6 has the smallest negative value of S, it had the highest moisture content at sampling time and also the highest in relation to its MWHC, LL, and PL. It seems that more water had been entering the interior of the temple than its systems could deal with. This excessive amount of water had only a very limited chance to drain away.

As a result, the base of the chandi had become unstable. To control excessive water infiltration, the provision of an effective drainage system inside the body of Chandi Borobudur had to be given due consideration.

The texture of soil ranges from sandy loam with 75 per cent of sand (fifth layer of III-6) to clay with a little more than 62 per cent of clay (first layer of III-1). The most frequently encountered texture is clay, followed by sandy clay loam and clay loam (both at the same frequency). Taken as a whole the series has a moderately fine to fine texture. Two different parts can be recognized. First, a part in which the silt content varies in proportion to that of sand

Table 5.5.5 Chemical properties of each sampling site (I)

Sampling site No. +	*Depth cm* ++	*Soil reaction*			*Organic matter*			*Nitrogen (%)*	
		pH H_2O	*pH KCl*	*d-pH x*	*C (%)*	*N % xx*	*C/N*	*Total*	*Inorganic*
III-1	600–650	7.15	5.61	1.54	0.674	0.023	29.3	0.024	0.001
	700–750	7.18	5.82	1.36	1.436	0.113	12.7	0.114	0.001
III-2	A (60–120)	7.32	5.75	1.57	2.508	0.105	23.9	0.107	0.002
	B (120–200)	7.29	5.76	1.53	0.693	0.125	5.5	0.127	0.002
	C (200+)	7.22	5.88	1.34	0.765	0.069	11.1	0.070	0.001
	D (260+)	7.10	5.98	1.12	1.916	0.085	22.5	0.086	0.001
III-3	6–80	7.40	6.25	1.15	1.039	0.023	45.2	0.024	0.001
	80–140	7.28	6.15	1.13	0.780	0.046	17.0	0.047	0.001
III-4	A (100–200)	7.45	6.02	1.43	1.418	0.053	26.8	0.055	0.002
	B (260+)	7.21	5.85	1.36	0.772	0.031	24.7	0.033	0.002
	C (280–320)	7.20	5.68	1.52	2.314	0.023	100.6	0.024	0.001
III-6	60–85	7.00	6.05	0.95	2.055	0.083	24.8	0.084	0.001
	85–120	7.12	6.01	1.11	2.116	0.193	10.7	0.198	0.000
	120–140	7.05	5.92	1.13	1.513	0.058	26.1	0.059	0.001
	140–170	7.25	5.87	1.38	0.684	0.109	6.3	0.110	0.001
	170–185	7.11	5.97	1.14	1.063	0.200	5.3	0.203	0.003
	185–225	7.08	5.85	1.23	0.268	0.067	4.0	0.068	0.001
	225–235	7.05	5.92	1.13	0.698	0.060	11.6	0.061	0.001

Notes:
+ Refer to Plate 3 of Voûte (1969).
++ Measured from surface of terrace floor.
x pH (H_2O) – pH (KCl).
xx Organic – N = (total – N).
– Inorganic – N.

but in inverse proportion to the clay content. Second, where the silt varies in proportion with the clay but in inverse proportion to the sand (Notohadiprawiro and Soekodarmodjo, 1975).

A chemical analysis was also carried out alongside the physical analysis. The two analyses are complementary, since major physical behaviours of soils are interconnected with several of their chemical properties.

The results of the chemical investigations are listed in Tables 5.5.5 and 5.5.6. Graphs were constructed to depict the depth function of some of the chemical properties. Ratio figures are used supplementary to absolute values.

These ratios are more practical for detecting relative translocations of elements or matters in the profile. Their significance does not lie chiefly in the absolute or individual changes of the soil constituents; changes in their respective proportions are more useful indicators for atomic or molecular changes are much more important than weight changes.

As Notohadiprawiro and Soekodarmodjo note – drawing on Polynov and Joffe (1949) and Lutz and Chandler (1946) – Ca apparently has a greater relative mobility than Mg. This means that soil magnesium is less readily available than calcium, which accounts for the tendency of Ca to be more easily leached out and lost in the drainage water. This commonly results in a higher concentration of Ca than Mg in fresh water streams and lakes (Den Berger and Weber, 1919;

Table 5.5.6 Chemical properties of each sampling site (II)

Sampling site No. +	*Depth cm* ++	*CEC me %*	*Equiv. $CaCO_3$*	*Extractable in 25% HCI (%)*			*Molecular Ratio*			
				CaO	*MgO*	*SiO2*	*CaO/MgO*	*CaO/SiO_2*	*MgO/SiO_2*	*CaO+MgO/SiO_2*
III-1	600–650	37.30	3.11	0.054	0.610	0.131	0.07	0.44	6.98	7.42
	700–750	nd	3.34	0.055	0.457	0.112	0.09	0.53	6.12	6.65
III-2	A (60-120)	38.98	1.66	0.054	0.402	0.272	0.10	0.21	2.22	4.35
	B (120-200)	nd	2.12	0.062	0.428	0.235	0.10	0.28	2.73	3.01
	C (200+)	nd	4.65	0.050	0.403	0.160	0.09	0.33	3.78	7.13
	D (260+)	21.53	1.82	0.053	0.404	0.107	0.09	0.54	5.66	10.99
III-3	60–80	25.94	3.62	0.054	0.441	0.323	0.09	0.18	0.18	3.83
	80–140	24.01	3.48	0.055	0.454	0.248	0.09	0.24	2.75	5.13
III-4	A (100–200)	25.68	2.25	0.061	0.055	0.220	0.06	0.27	4.45	7.12
	B (260+)	38.29	3.41	0.061	0.678	0.174	0.07	0.38	5.85	9.52
	C (280–320)	37.53	2.99	0.060	0.528	0.125	0.08	0.51	6.34	11.47
III-6	60–85	38.35	2.85	0.079	0.524	0.437	0.11	0.19	1.80	3.73
	85–120	56.71	0.82	0.074	0.520	0.441	0.10	0.18	1.77	3.56
	120–140	43.12	0.24	0.065	0.450	0.387	0.10	0.18	1.74	1.95
	140–170	44.34	0.57	0.067	0.476	0.412	0.10	0.17	1.73	1.91
	170–185	43.65	4.02	0.062	0.492	0.307	0.09	0.22	2.40	2.62
	185–225	47.93	3.02	0.079	0.441	0.376	0.13	0.23	1.76	1.84
	225–235	51.62	1.18	0.062	0.447	0.269	0.10	0.25	2.49	2.74

Lutz and Chandler, 1946). Many analyses show that the amount of Ca relative to Mg in soils and weathered layers is smaller than in the parent rocks (Jeny, 1941; Mohr and van Baren, 1954; Soil Classification, 7th Approximatus, 1960). Calcium is much more abundant than magnesium in sedimentary rocks (Hem, 1959). Therefore, the ratio of Ca to Mg in soil extracts could be used as an index of the degree of weathering or leaching that has taken place in the soil (Jeny, 1941).

The difference between pH (H_2O) and pH (KCl) indicates the proportion of positively charged exchange complexes to negatively charged ones in the soil, or the content in the soil of neutral salts. Thus it could be employed to signify the degree of leaching and the extent of liberation of iron, aluminium and silica to form secondary minerals (Notohadiprawiro and Soekodarmodjo, 1975).

The soils are neutral in reaction in terms of the pH–H_2O, apart from the first sampled layer of III-3 and III-4, which are mildly alkaline. This could be expected from the figures of equivalent $CaCo_3$ which indicate that the soils are rather calcareous. We have as yet no way of knowing whether this is an inherent characteristic of the soil material or is due to some mixing with lime-containing building material.

The d-pH shows a preponderance of silicate clay minerals (negatively charged particles) over free hydrated iron and aluminium oxides (positively charged particles). This indicates that the process of weathering or soil formation had not gone so far as to produce very strongly weathered oxide layers. In profiles III-1, IIII-2 and III-3, and to a certain extent also in III-4, the d-pH decreases with depth. The weighted average of d-pH at each site fluctuates slightly in the sequence III-1, III-2, III-4 (1.45, 1.51, 1.45) and decreases sharply in III-6 (1.17). This may point to leaching of neutral salts from the upper parts and the subsequent deposition of a portion of them in the lower end of the sequence.

This phenomenon seems to be consistent with the vertical distribution of soil moisture at the time of sampling.

The organic-C profiles show two maximals, one in the upper layer and the second in the lower part of the profile. These were probably not due to podzolization. The pH is too high for podzols or podzolic soils. Also the vertical distribution of SiO_2 shows no similarity to that of podzols.

Excluding the extreme value of III-4C and the values of III-3 (the latter is outside the sequence under the present investigation), the C-N ratios range from 4.0 to 29.3 with an average of 16.4. The very low figures in the range (III-2B, III-6 : 140–225) suggest that there is an occlusion of NH_4 ions in the crystal lattices of the silicate clay minerals. They may also indicate that the organic matter in those layers consisted predominantly of microbial tissues. The higher values in the range are the result of less effective decomposition (III-1 : 600–650, III-2 A and D, III-4A and B, and III-6 : 60–85 and 120–140). The other values may be considered normal for soils.

There is a tendency for the depth variation of C-N to be positively correlated with that of the ratio (CaO + MgO)-SiO_2. This is especially so in the top part of the supporting hill (sites III-1 and III-2). It seems that in places where the organic matter is more actively broken down, bivalent bases are more leached compared with silica.

From Table 5.5.6 the following may be postulated. Ca and Mg had undergone considerable leaching. There was some leaching of Bi in III-1, whereas in the same profile no leaching of Mg could be detected. Leaching was more pronounced in III-2, less so in III-4, and even less in III-1. The degree of leaching or translocation could be related to the general slope of the surface of the Borobudur hill, the distance of the sampled profile above the surface of the original hill, the general slope of the surface of the original hill, and the distance of the sampled profile from the surface of the plateau on which the monument stands today. A simplified surface of the original hill along the cross-section II-1 to III-6 is constructed on the bases of the bore figure (Voûte, 1969, Plate 6) and of the present surface of the plateau (Voûte 1969, Plate 4).

Leaching has been more intensive in III-2, first because of its greater height above the surface of the original hill and, second, because it is situated at a point where the slopes of the Borobudur hill and of the original hill become clearly steeper from left to right. In addition, compared with III-4, III-2 is located at a distinctly higher level than the present ground level. These are all factors that would enhance the percolation of rainwater through the fill material.

The sampled profile of III-1 is the least leached of the three profiles III-1, III-2 and III-4, because it is closer to the surface of the original hill, and the surface of the natural hill is nearly flat at that point.

Ca is leached more extensively than Mg, except in III-2 where both elements have about the same degree of leaching. It is probable that in III-2 the process of leaching has been so intensive that even the constituents that are ordinarily less mobile were carried away at the same speed as the more mobile ones. In III-1, Si has been translocated rather than Mg.

The figures of III-6 present some difficulties in interpretation. Apart from the ratio of CaO-MgO, all ratios here are distinctly the lowest. The opposite is true for the ratio of CaO-MgO, which is the highest. The greatest percentages of SiO_2 are found in III-6; here some increase in the percentages of CaO can be seen (Table 5.5.6). III-6 is at the bottom end of the sequence. Its uppermost and lowermost sampled layers are only about 205 cm and 30 cm respectively below the present ground level. It is about as close as III-4 to the surface of the natural hill. Furthermore, from this point on towards the east, the slope of the original hill decreases markedly. Since the natural hill has a lower permeability than the mass of fill, this change in slope may conceivably slow down the sub-surface runoff through the fill. The accumulation of moisture in this portion seems to support this interpretation.

There is reason to believe that the accumulated salts and bases, especially Ca, in III-6 have favoured the release of silica from its less soluble compounds. Coincidentally this profile has the highest CEC of the series. The organic matter content of III-6 shows no difference from that of the other profiles. It is suspected that the higher CEC may be correlated with the occurrence of high SiO_2-Al_2O_3 ratio type of silicate clays (Notohadiprawiro and Soekodarmodjo, 1975).

5.6 Anticipating earthquakes

All the studies of the causes of decay have underpinned the general assumption that water is to blame as the primary source of the dilapidation. It is water that penetrates the stone masonry and affects the building material as well as the supporting hill underneath the monument. The physico-chemical and biological processes attacking the surface of the stones come about through the action of water.

Another natural force, however, should not be overlooked: earthquakes. Though thus far no damage can be ascribed explicitly to this source, the danger is there and cannot possibly be neglected if the restoration is meant to last into the most remote future. The success of this gigantic undertaking should be secured not only from the destructive effects of water but also from possible deformations or even ruin by an earthquake, not only during the present restoration project but also for the perpetuation of the restored monument. Consequently, seismic studies have been carried out to support the planned work.

Chandi Borobudur is situated in a major earthquake zone that follows the Indian Ocean coasts of Sumatra and Java. Some of the earthquakes are purely local phenomena related to volcanic activity, which in general do not affect too large an area; their influence is restricted to their immediate surroundings. The active Merapi volcano, which is located not far from Borobudur, has shocked the area around it many a time. Significant effects on the monument, however, have neither been observed nor reported. Volcanic activities do not appear to be a serious source of danger.

Tectonic earthquakes, which are associated with the major geological structure of the Indonesian Archipelago, are regional phenomena that can affect large areas. Moreover, this kind of earthquake can attain such a high intensity that it should always be counted as a possible destructive force.

Studies of the seismic risk at Borobudur had to face one serious constraint: no real data were available, while damage to the monument already caused by earthquakes could not be proved. The absence of precise information on the magnitude, intensity and frequency of earthquakes in the Borobudur area needed to be tackled by carrying out relevant studies, but this was not possible since it would involve continuous observation and regular measurements over an indefinite period. The studies thus far conducted have, therefore, been confined to theoretical concepts and possibilities. Conclusions, if any, can only be drawn from interpretations and analogies. In this respect the estimated values had to be based on the maximum acceleration to be expected, while building in a sufficient margin of safety.

Reports of the Institute for Meteorology and Geophysics for the period 1905–70 showed that the seismicity of Java is that of a typical island structure. Large surface earthquakes occur about one degree or more to the south of the Java coastline, some intermediate depth earthquakes under the island, and deep earthquakes to the north in the Java Sea. Sporadic shallow-focus earthquakes with epicentres on the island are also reported. The largest magnitude of an earthquake recorded in Java was 6 on the Richter scale.

There are several scales for measuring earthquakes. Estimates are made by comparing the degree of destruction and the instrumental records of the acceleration obtained during the tremor. For this purpose several formulae are used, and the results differ considerably from one to another.

For the magnitude of an earthquake, the Richter scale from 1 to 10 is generally used, denoted by the capital letter M followed by the number. The intensity is measured according to the Rossi-Forel scale, which also varies from I to X (modified as the Mercally Intensity Scale I to XII, commonly denoted by the character g for gravity acceleration). When applying these scales, an earthquake is moderate when it is valued at M = 5–6 (Richter) or at MM = VII–VIII (Mercally), or approximately at 0.03 g–0.30 g.

Chandi Borobudur is situated just between a zone with a maximum ground surface acceleration of 0.07 g–0.15 g and a zone with a maximum of 0.15 g–0.3 g. This means that a design acceleration of 0.15 g is reasonable. In other words, the monument is liable to moderate damage in the case of an earthquake with an intensity of VII–VIII on the Rossi-Forel scale.

In December 1924, an earthquake occurred in Wonosobo, causing considerable damage in the area, mainly through landslides. Its magnitude was reckoned to be less than 6.5 on the Richter scale, which means that the intensity was no more than IX on the Rossi-Forel scale. On the basis of these figures, the earthquake cannot be counted as a major one. It was rather a shallow-focus earthquake, similar to those in Java that have been observed instrumentally during the last sixty-five years.

Wonosobo is only some 50 kilometres to the north of Borobudur. Nevertheless no damage to the monument that could be ascribed to the earthquake was observed.

Damage that was positively caused by an earthquake was reported in 1961. Two earthquakes took place within one month, but apparently of very slight intensity. Several stones of the leaning wall may have been displaced, and new cracks and fissures were observed, thanks to the wet condition of the stones after a rain. These extremely slight cracks and fissures are hardly detectable when the stones are dry. It is to be regretted that this event could not be recorded adequately, simply because of the absence of the proper instruments.

The absence of accurate and reliable data on earthquakes in the Borobudur region, and the lack of reports of observed damage to the monument, raised doubts about whether NEDECO's engineering design for the restoration of Chandi Borobudur was justified. The dismantling of the major portion of the monument meant a considerable reduction of the load exerted on the hill, which might endanger its seismic resistance.

For engineering purposes, only earthquakes with magnitudes larger than M = 5 are generally considered, not only because smaller magnitudes are usually non-destructive (provided that they are not very shallow) but also because their records are often inaccurate and incomplete. Earthquake intensity is expressed as a physical parameter of ground motion such as maximum acceleration, velocity or displacement. These parameters may be obtained directly from instrument readings, analysed on the basis of visco-elastic models or statistically evaluated from earthquake records (seismic risk analysis). Whatever the method followed to obtain the physical parameters of ground motion, the results serve as the input for any kind of structural mechanics to analyse the effects of seismic action on engineering structures.

Reviewing NEDECO's restoration plan in order to secure its implementation, Mr Wiratman of the Institute of Technology in Bandung was invited to carry out a special study of the matter (Wiratman, 1979, pp. 91, 112). After studying NEDECO's proposed solution carefully, he reported as follows.

EXTRACT FROM THE WIRATMAN REPORT

A careful study of the causes of dilapidation of this monument will lead to the conclusion that the original cause is solely the seepage of water into the body of the stone structure and into the hill beneath, causing a series of other destructive processes, such as stone deterioration by physiochemical and biological processes due to an excessive degree of humidity in the capacity of the subsoil, resulting in the washing away of soil particles from the layers beneath the structure and high moisture content in those layers.

Thus, any solution to the restoration of this monument must face the conditions present in the soil. In addition, the solution must also have a reasonable resistance to earthquakes, since the region is liable to earthquake ground surface acceleration up to 0.2 g. Above all, the execution of the plan must be technically and economically feasible.

If we summarize, the restoration of this monument faces the following four problems:

1) drainage
2) inadequate soil bearing capacity
3) earthquake resistance
4) execution.

From the engineering point of view it is apparent that only a complete dismantling can assure the installation of a proper drainage system and waterproof layers to prevent further seepage. These facts are indeed the basis of NEDECO's proposed engineering solution.

1. The problem of drainage

In NEDECO's proposal a drainage layer is constructed against the bare hill. It is to be a filter layer that will prevent the soil under the foundations being washed away and will lessen the flow of water from within the hill to the walls. The concrete slabs under the balustrades and walls will form a watertight barrier to rainwater, so that further seepage to the underlying layer may be prevented. Drainage water and surface water will further be carried off by means of internal drainage pipes.

As far as the drainage problem is concerned, NEDECO's proposal may be considered adequate.

2. The problem of inadequate soil bearing capacity

As mentioned earlier, the settlement of the stone structure is caused by a reduction of the bearing capacity in several places. Another cause is the existing uneven pressures on the subsoil caused by the lack of load distributing elements, resulting in differential settlements.

Increasing the bearing capacity of the ground by chemical injections seems to be impossible, because the nature of the grain size and grain distribution do not permit such operations. The only way to prevent differential settlements is to distribute the gravity loads evenly to the ground layers that still have adequate bearing capacity. This is only possible by inserting a reinforced concrete slab system under the stone structure.

Thus, to overcome future differential settlements and release weakened soil layers from overstress, NEDECO's proposal of using a reinforced concrete slab system seems to be inevitable.

3. The problem of earthquake resistance

A careful study of NEDECO's proposed slab system has led to the conclusion that such a construction will certainly not prevent deformations in the stone structure required for earthquake energy absorption. The absence of rigid vertical elements, such as walls or columns supporting the slabs, will allow the numerous joints to deform when subjected to earthquake shocks. On the other hand, these slabs will increase the shock-absorbing capacity of the stone structure, through better distribution of lateral earthquake force among the various parts of the structure. The slabs will act as horizontal rigid diaphragms, allowing all parts of the structure, from the smallest to the largest element, to respond simultaneously to the earthquake motion. It is evident that the shock-absorbing capacity is most effective when all parts of the structure can respond at same time.

Another requirement is to secure the several parts of the stone structure against being overturned when subjected to lateral earthquake forces. The turnover phenomena of balustrades and other parts have been carefully studied and checked by NEDECO, and it can be concluded that the horizontal slab system will increase rather than decrease the earthquake resistance of stone structure.

4. The problem of execution

The execution of the proposed restoration project must, of course, be performed with a complete knowledge of the subsoil. Particular consideration should be given to the swelling characteristic of the soil as a result of altered overburden pressure and a change in moisture content, and also to the possibility of slides during partial dismantling of the stone structure.

If the above-mentioned properties of the soil have not been ascertained from the soil survey already carried out, then additional soil investigations should be performed to eliminate as many unpleasant surprises as possible.

A basic principle to be followed in the execution of the project is the step-by-step process of dismantling and rebuilding the monument. Only thus can eventual influence from swelling and other unwanted properties of the soil, as a result of altered overburden pressure, be eliminated.

The proposed stages of reconstruction are an evident demonstration that the above-mentioned possibilities of soil behaviour have duly been taken into consideration. The step-by-step reconstruction principle is to be followed, and if necessary each step can be adjusted to the characteristics of the subsoil.

Reviewing the several problems to be overcome simultaneously by any method of restoring Chandi Borobudur, the only plausible conclusion is that NEDECO's proposal is to be considered adequate.

Elaborating on the problem of seismicity and stability while anticipating the occurrence of an earthquake, Mr Wiratman carried out a special study of the seismic risks to Chandi Borobudur, starting with the statement that the definition of 'risk' is purely mathematical. It implies the probability of an undesirable event in a certain period of time.

For the seismic risk analysis of Chandi Borobudur, he considered shallow earthquakes with focal depths of up to 65 kilometres to be those with Richter magnitudes of M = 5 and above, within a radius of 500 kilometres. In total nine source areas were considered, numbered I to IX. Mr Wiratman included earthquake data on dates of occurrence, coordinates of epicentre, depths and magnitudes over a period from 1897 to 1977, supplied by the Meteorological and Geophysical Institute. The source areas governing the seismicity of the Borobudur site are all located south of Java in the Java Sea; shallow earthquakes with hypocentres further away than 500 km

Table 5.6.1 Source area characteristics for Chandi Borobudur

Source area	M_0	M_1	*Depth (km)*	*b*	*A*	*a'*	a_1'	$N_1 (M \geq M0)$
I	5.0	6.25	49.0	0.768	5.326	5.078	3.209	0.257
II	5.0	8.10	44.0	0.772	5.276	5.024	3.154	0.215
III	5.0	6.50	31.0	0.496	3.293	3.235	1.366	0.081
IV	5.0	6.75	48.7	0.628	4.498	4.338	2.469	0.230
V	5.0	8.10	43.4	0.401	3.098	3.133	1.263	0.189
VI	5.0	7.20	49.8	0.564	4.051	3.938	2.069	0.189
VII	5.0	6.50	39.3	0.704	5.076	4.886	2.997	0.324
VIII	5.0	7.25	48.6	0.748	5.052	4.816	2.947	0.176
IX	5.0	6.50	50.3	0.914	5.928	5.605	3.736	0.162

Table 5.6.2 Annual risk and mean return period for the occurrence of earthquake intensities at Chandi Borobudur

Annual Risk (%)	*20*	*10*	*5*	*2*	*1*	*0.5*	*0.2*	*0.1*
Mean ret. Period (year)	5	10	20	50	100	200	500	1 000
Peak gr. accel (cm/sec^2)	15.52	25.27	41.16	65.89	88.91	119.03	172.51	225.14
Peak gr. accel (g)	0.016	0.026	0.042	0.067	0.091	0.121	0.176	0.230

Table 5.6.3 Risk of the occurrence of earthquake intensities at Chandi Borobudur during the seven-year restoration period

Peak ground Accel (g)	0.016	0.026	0.042	0.067	0.091	0.121	0.176	0.230
R7 (1>)	79.0	52.2	30.2	13.2	6.8	3.4	1.4	0.7

need not be considered, since their influence is negligible. It is noteworthy that between source areas IV and V there is a seismically 'quiet' area, that is, an area free from hypocentres. This interesting feature seems to be consistent with the quarternary tectonics of the area, where no indication of tilting or warping has been observed.

In Table 5.6.1 the characteristics of the nine source areas are listed. The lower-bound magnitude (m_0) is 5, while the upper-bound magnitude (m_1) is taken as the largest magnitude ever recorded in the source area. This does not mean that larger magnitudes are to be excluded. There is good reason to believe that Indonesian earthquake magnitudes tend to be low. As regards the focal depth, this varies in each source area. Generally, small magnitudes are accompanied by shallow foci, and vice versa. It is therefore reasonable to take the average focal depth as the source area characteristic. The constants b, a, a' and a_1' of the Gutenberg-Richter magnitude frequency equation have been calculated for each of the source areas and the results are listed in Table 5.6.1.

In order to find the peak ground accelerations, a special computer program was prepared to compute the annual risks. With the source area characteristics as input data, peak ground accelerations at Chandi Borobudur have been obtained, for which the annual risks are successively 20, 10, 5, 1, 0.5, 0.2 and 0.1 per cent, corresponding to mean return periods of successively 5, 10, 20, 50, 100, 200, 500 and 1,000 years.

The peak ground accelerations associated with the given mean return periods and annual risks are shown in Table 5.6.2.

The results of the computer analysis listed in Table 5.6.2 can be interpreted in different ways. Considering, for example, the past 1,000 years of the monument, it becomes apparent that the probability is that the monument had experienced a peak ground acceleration of, say, 0.042 g fifty times, one of 0.091 g ten times, one of 0.176 g twice, and one of 2.230 g only once. Assuming that the earthquake source characteristic will not change in coming centuries, then the same probabilities of occurrence could be given for the next 1,000 years of the monument's lifetime.

These figures clearly show that during its lifetime the monument has experienced several strong tremors (with peak ground acceleration of 0.1 g or more), which must have caused some damage to the structure. This is evident from damage found along continuous horizontal joints on the four faces of the third and fourth terraces, strongly suggesting the effect of seismic action.

Considering a shorter period in the history of the monument, say the seven-year restoration period, it was possible to calculate the risk of various earthquakes of particular intensities affecting the site. The results of this calculation are listed in Table 5.6.3. It can be seen that the probability of strong shaking with peak acceleration of more than 0.1 g during the restoration period was less than 6.8 per cent, and thus to be considered as very unlikely. However, the occurrence of very mild tremors with peak accelerations in the order of 0.01 g was more than 79 per cent. Such intensities have a mean return period of less than five years (see Table 5.6.2). In fact, one of such intensity occurred at Borobudur during the restoration. This was felt on 15 February 1976 at 3.30 p.m. According to the Meteorological and Geophysical Institute the intensity was MM IV, associated with a peak ground acceleration of approximately 0.01 g. This tremor was also felt on the site, but did not cause any harm to the monument. Such intensities with short recurrent periods could have been expected to recur before the completion of the restoration project.

Seismic stability had been analysed on the basis of a maximum expected peak ground acceleration of 0.15 g. From Table 5.6.2 it can be seen that this intensity has a mean return period of 200–500 years, which means it is an intensity that might happen once in every three centuries. It has been found that the average safety factor of stability during such an earthquake is 1.4 g, so the safety margin is more than adequate.

In conclusion, it can be asserted that Chandi Borobudur is able satisfactorily to resist strong ground tremors that could occur once in every several centuries. It could be damaged by very strong tremors with a probability of occurrence of, say, once in 1,000 years. Even in such cases, however, it is evident from its past history that the monument as a whole will remain stable (WW, 1979, pp. 91–112).

6. Execution of the Project

6.1 Preparatory work

6.1.1 Collecting the missing stones

Missing stones are blocks and fragments that are detached or have fallen from the structure of the temple. Many of them were found on the surface around the temple site, buried beneath the soil or used as foundations for house dwellings, staircases or floors, or for mortar for *padi*, among other purposes. Some have been found underground during routine archaeological excavations, and many more sculptured fragments have been discovered around the temple complex. The stones were dislocated from their original places by natural or anthropogenic causes. The process of matching the missing stones entailed two major activities: first, the general classification of all the missing stones and stone fragments and, second, the matching up of certain specific types of missing stones, for example, the broken Buddha heads and the crowns of antefixes.

The project of collecting the missing stones was initiated in 1970–71 and continued up to 1973–74. As many as 2,234 blocks were collected and categorized, and 739 blocks successfully relocated to their original places.

Table 6.1.1.1 Replacing the missing stones into the monument (number of blocks)

		Location				
No.	*Wall side*	*north east*	*south*	*west*		*Total*
1	Main Wall 0	3	1	–	–	4
2	Gallery 1	65	33	56	60	214
3	Main Wall 1	–	7	1	–	8
4	Gallery 2	60	29	32	65	186
5	Main Wall 2	–	4	–	6	10
6	Gallery 3	23	42	47	84	196
7	Main Wall 3	–	–	–	4	4
8	Gallery 4	28	29	12	25	94
9	Main Wall 4	1	–	–	–	1
10	Gallery 5	2	4	16	–	22

6.1.2 Drawings

Drawings were made before starting the process of dismantling so that the measurements of each joint and each layer could be taken into account. They served to make up the working plans and were known as the 'series drawings' (drawings for the rebuilding) in the work description. The three different kinds of series drawing, A, B and C, are described below.

Series A drawings. These were designed to ensure the correct remounting of the

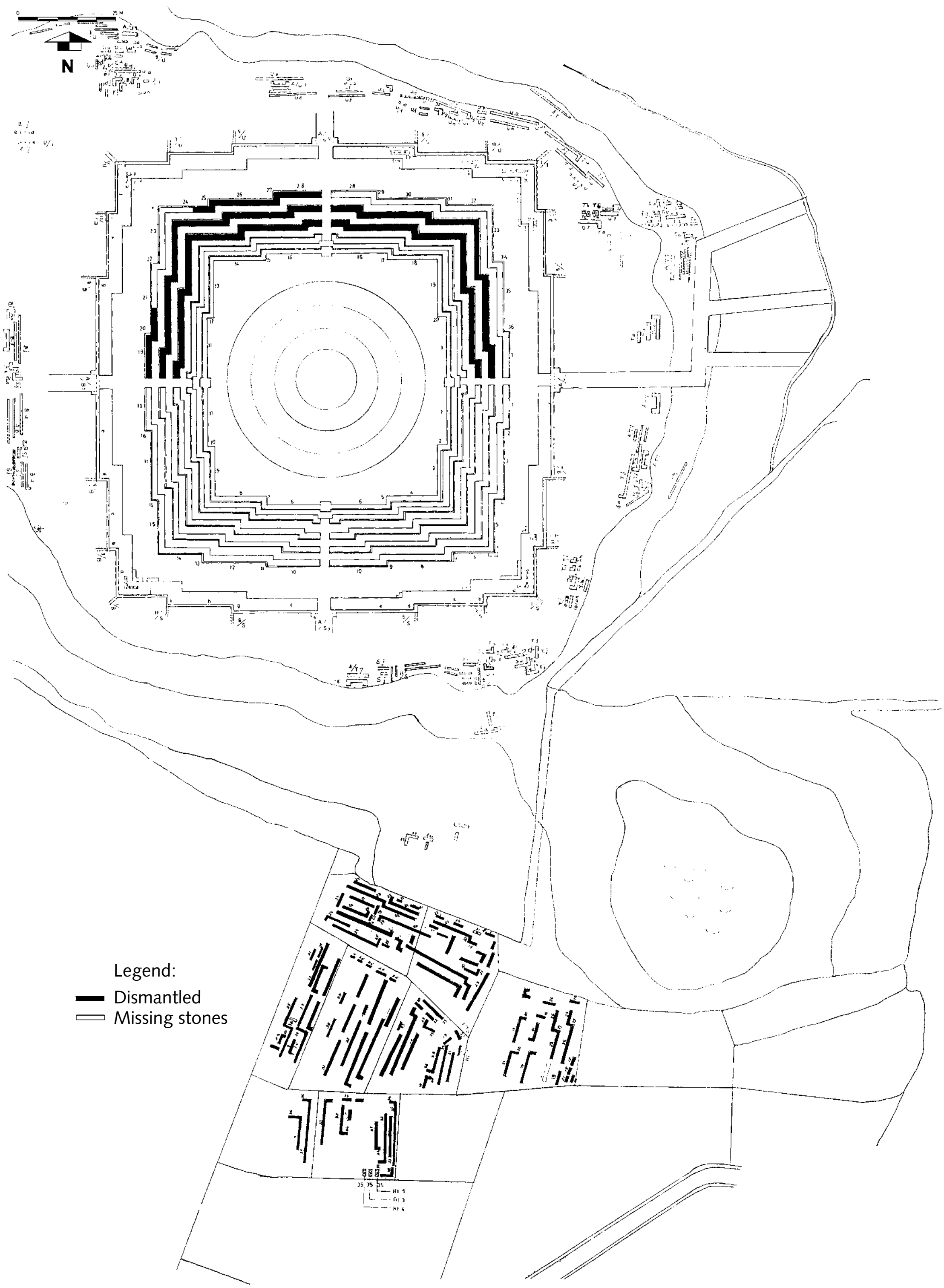


Figure 6.1.1.1
Placement of dismantled stones and missing stones
Source: Borobudur Restoration Project

monument stone in its original place when rebuilding. They contained data on the coordinates of the stones in three dimensions as guidelines.

The coordinates given in such a drawing were not precise, but served as a rough approximation of the location; the exact location was identified after measuring using a standard system, that is, in centimetres. In the serial drawing the following data were entered: which face of the monument the stone came from, the gallery/stage, main wall or balustrade, outside or inside face, layer, series number (the stones in each section were numbered in series, beginning from the centre and proceeding sideways), dismantling or rebuilding area, and section.

From the series A drawing it was possible to establish the correct place of the stone according to the coordinate plans x, y, z, in which x represented the length, y the width of the section and z stood for the gallery (Figure 6.1.2.1).

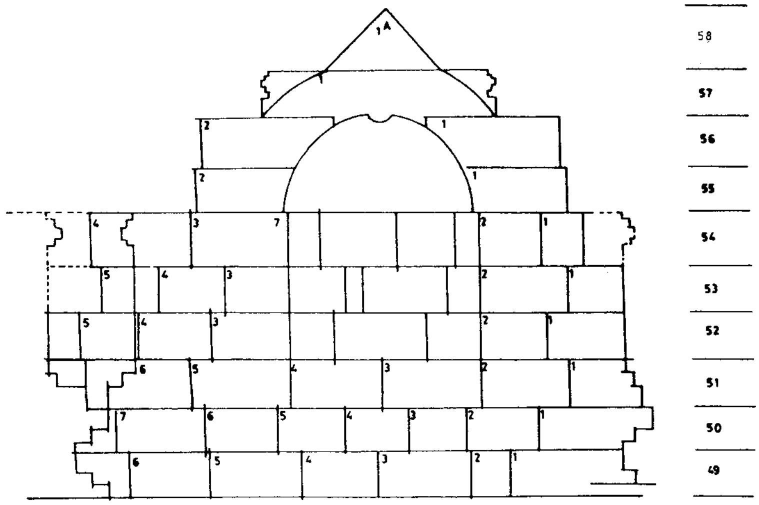


Figure 6.1.2.1
Series A drawing
Source: Borobudur Restoration Project

Series B drawings. These, like the series A drawings, were prepared for the purpose of placing the stones in position, according to the sequence directed in the series drawing, in which the pallet numbers were specified so as to fix the location of the stones.

The series B drawings were made during dismantling by filling in the pallet number and selecting the stones to be loaded in the pallet bearing that number. With the help of this drawing, a pallet card was composed and the necessary data recorded in triplicate, the original to be attached to the pallet containing the stone, and copies going to the Techno-Archaeology Section for plotting and to the Operations Room for the programming of further activities.

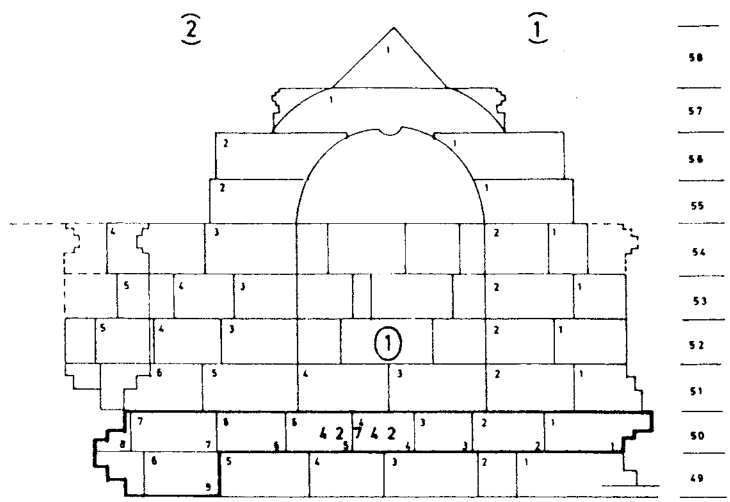


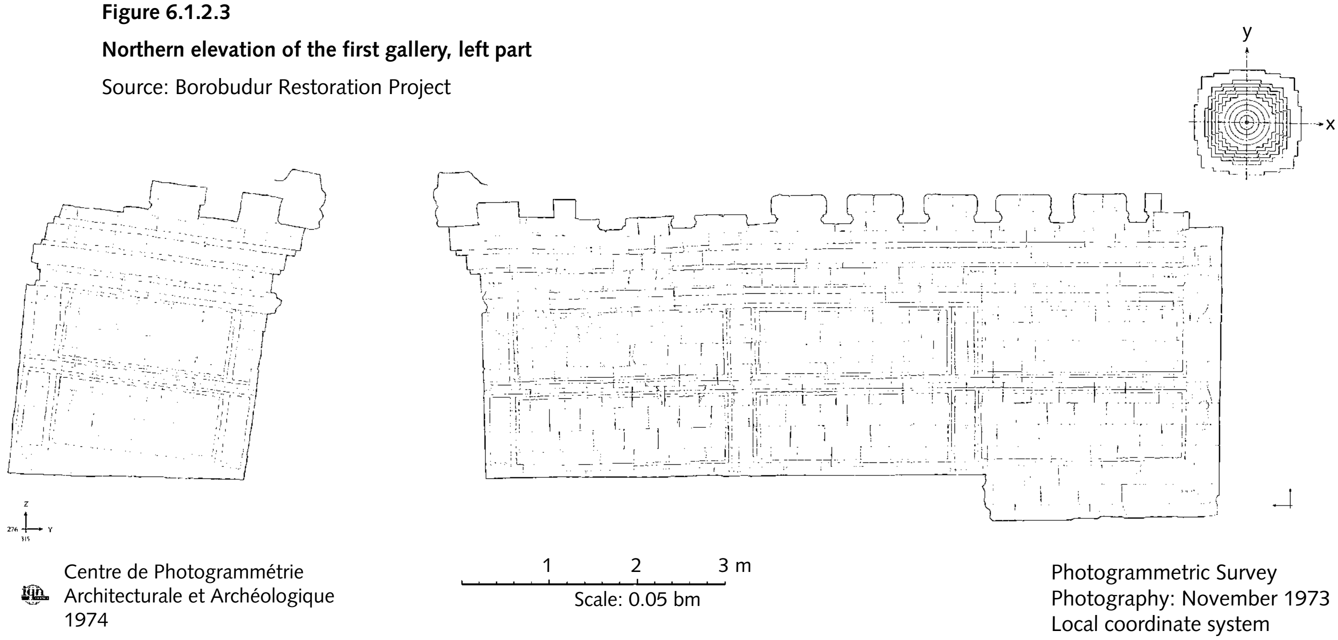
Figure 6.1.2.2
Series B drawing
Source: Borobudur Restoration Project

Remarks:
4: West
2: Balustrade 2nd gallery
7: Left-hand side of the stairs
: h section
4–2: The ordinal number of the pallet of one section

Figure 6.1.2.3

Northern elevation of the first gallery, left part

Source: Borobudur Restoration Project



Series C drawings. These were special drawings, copied from the series A versions, with directions about any particular 'disease' suffered by the stones. This served as a recommendation for treatment of the problems, which was carried out by the Chemical Archaeology section in the treatment shed.

Photogrammetry. In addition, photogrammetrical pictures were taken prior to dismantling, with particular attention being given to the relief panels.

The resulting pictures were later used to ensure that the rebuilding of a panel or any other part had been done correctly, and that if mistakes were made they could be corrected as soon as possible.

The rebuilding teams were also instructed to produce photographs of the rebuilt sections in order to monitor eventual growth on the stones.

Calculation. Absolutely precise results could not be expected from the calculations, but the data obtained were approximately correct. Computations regarding the east and the west faces were more reliable, due to the experience gained during the restoration of the north and south faces, and also because the damage on the east and west faces appeared to be less than that on the south, and especially the north, faces.

The calculations were very important in producing a time schedule that would give reliable estimates and targets. In practice, the working methods also affected progress. A decisive factor was the number of stones to be dismantled and rebuilt.

Details. For the pouring of concrete slabs, a well-prepared area was needed that would allow the smooth execution of rebuilding work. The length of the area was determined by the length of the steel reinforcement bars – 11 metres – and was one or more times that length (with an extra metre added to allow for each junction of the bars in the longer areas).

On the various sections of a gallery these lengths might vary. Thus, if a multiple of 11 metres could not be achieved, it might be necessary to cut the bars, but this had to be done as economically as possible. For this purpose, technical drawings had to be provided that allowed the efficient placing of reinforcement steel while making it possible to set the main wall stones on top of the concrete slabs in the various areas of the sections.

For each section of a main wall, one detailed drawing was made and for each balustrade two drawings: one each of the inside and outside faces.

In addition, it was necessary to make detailed drawings of the stone layout for the top surface of the balustrades, the stairways, the arches, the platforms and plateau, so that if necessary they could be reconstructed in what was assumed to be their original state. The scale of the drawings was 1:20, this scale being such that each stone could be individually marked while the drawings were of a size that was not too unwieldy for on-site use. For main walls and balustrades the drawing's height would be 29 cm, this being sufficient to accommodate even the highest main walls (those of the first gallery). The length of each drawing depended on the length of the individual sections; the largest required a maximum drawing length of approximately 90 cm.

The section reference, a possible serial number and any other information was always placed in the lower right-hand corner. This uniformity was necessary to enable drawings and prints to be easily sorted. The following information could be found on each drawing:

- the peripheral line of the section;
- the stone layout;
- the contours of the reliefs;
- the layer numbering outside the section on the right-hand side;
- the numbers of the reliefs and statues; outside the section at the bottom.

At this stage a minimum of three negatives for the series A, B and C were made. The master drawing was then filed so that it could always serve in the future as a basis for other detailed drawings. The negative for series A was to be used for stone identification on the principle that the series number was indicated in the top left-hand corner of each stone, each layer and section commencing with 1 at the side situated the closest to the central stairway.

Detail on series A drawings. The series number of the stone was only recorded on the drawing series A, as repetition of this on other drawing series could have caused confusion. It was nevertheless necessary (primarily for the completion of the pallet cards) to read the serial and layer numbers of the stone, the pallet number and the desired treatment in an efficient manner. The layer number presented no problems in this regard as it appeared in all series. To enable the serial number and pallet number to be read simultaneously, a negative of series A could be placed on a similar print from series B, and in the same way a combination of series C and series A would give both the serial number and the desired treatment.

This method was only practical if the various references were so arranged that they did not overlap each other confusingly, therefore there had to be a standard coding pattern. This was arranged as follows:

- The series number was situated in the top left-hand corner (series A);
- The number of the pallet compartment into which the stone was to be placed was recorded in the bottom right-hand corner (series B);
- The reference for the treatment could appear anywhere on the area except the top left-hand corner (series C).

Photo 6.1.3.1
Photogrammetry
Source: Borobudur Restoration Project

Photo 6.1.3.2
Measuring stupa on balustrade
Source: Borobudur Restoration Project

Detail on series B drawings. The details on series B drawings indicated which stones were to be loaded together on to a pallet, which pallet that was and in which compartment of the pallet each stone was placed. The ground rules for determining the pallet limits were as follows:

- Both dismantling and reconstruction commenced with the section of each gallery directly adjacent to the staircase.
- Within a section, both dismantling and reconstruction were executed in lengths of approximately 7 metres.
- Dismantling and reconstruction had to be possible at a slope of 1:2.

Stones destined for the same pallet would ideally come from a single layer. However, only two pallets could be accommodated on the scaffolding during dismantling and reconstruction, so one pallet might take stones from two layers, but no more. The ground rules for determining the pallet numbering were as follows:

- Within one working length of 7 metres, the dismantling took place layer by layer as far as possible, and similarly for the reconstruction.
- Within a length of 7 metres, the reconstruction was executed layer by layer where possible, to minimize the possibility of 'closure errors'.
- Positioning was in descending sequence of the pallet numbers: thus, pallet number 399 was positioned first followed by pallet number 398 and so on. This system had the advantage that personnel in the storage areas only needed to check for the highest numbered pallet of a given section. This was then the first to be transported, eliminating the need to consult reconstruction schemes and drawings.

Each pile of four pallets was also stored so that the highest numbered pallet was at the top, to avoid unnecessary movement of pallets.

Detail on series C drawings. These drawings indicated the prevailing corrosion, fouling and other defects of the stone, and the phases of treatment to be carried out. Any temporary repairs that were carried out also had to be specified.

Three-quarters of the surface of the drawings was available, as previously mentioned, for the indication of this information. Only the top left-hand part had to remain blank.

The correct coding system to be used for both known corrosion and specified phases of treatment was established by the stone conservation experts. It must be borne in mind that the pallet cards could not be fully completed until this coding was determined and the stones were classified.

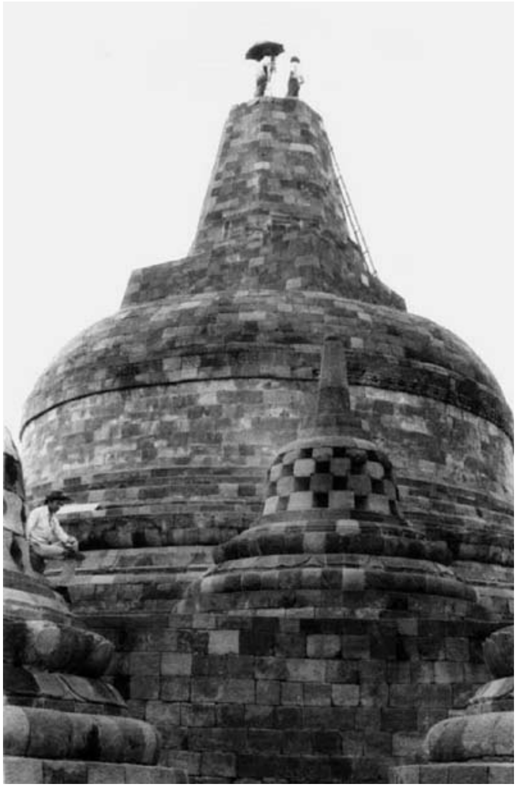


Photo 6.1.3.3
Measurement of ground plan
Source: Borobudur Restoration Project

6.1.3 Measurements and dimensions

Dumarçay pointed out (1974, p. 225), the monument was not in its original form. It had been altered many times during its history, and there had been at least two stages of restoration (Dumarçay, 1974, p. 225). While the previous work was done with care, it had not always taken into account the exact dimensions of the monument. For example, in sections B and D of the north face, first gallery, a restoration had added new stones to complete the cornice, which follows an inclined line, but did not pay regard to the deformation joints (all joints are closed). In the section of the first gallery of the west face, the wall is inclined to the south but the new cornice, created in a previous restoration, is horizontal. It was very clear to us that these stones should not be replaced.

The structure was to be re-levelled on the basis of four reference lines defined in October 1973. They were chosen with the agreement of Dr Soekmono, General Secretary of the project. These four lines were to be horizontal after reconstruction; for the first gallery the reference line was the lower line of the median decorative band and, for the second, third and fourth galleries, the reference line was the edge of the plinth. For the first gallery the reference line had a height of 277.91 metres, for the second a height of 280.77 metres, for the third a height of 283.31 metres, and for the fourth gallery 285.88 metres.

The height given per section in Figure 6.1.3.1 is of the planned floors; each long section had an intermediate point as requested in the work description (issued October 1972; see Annex Table 3–10)

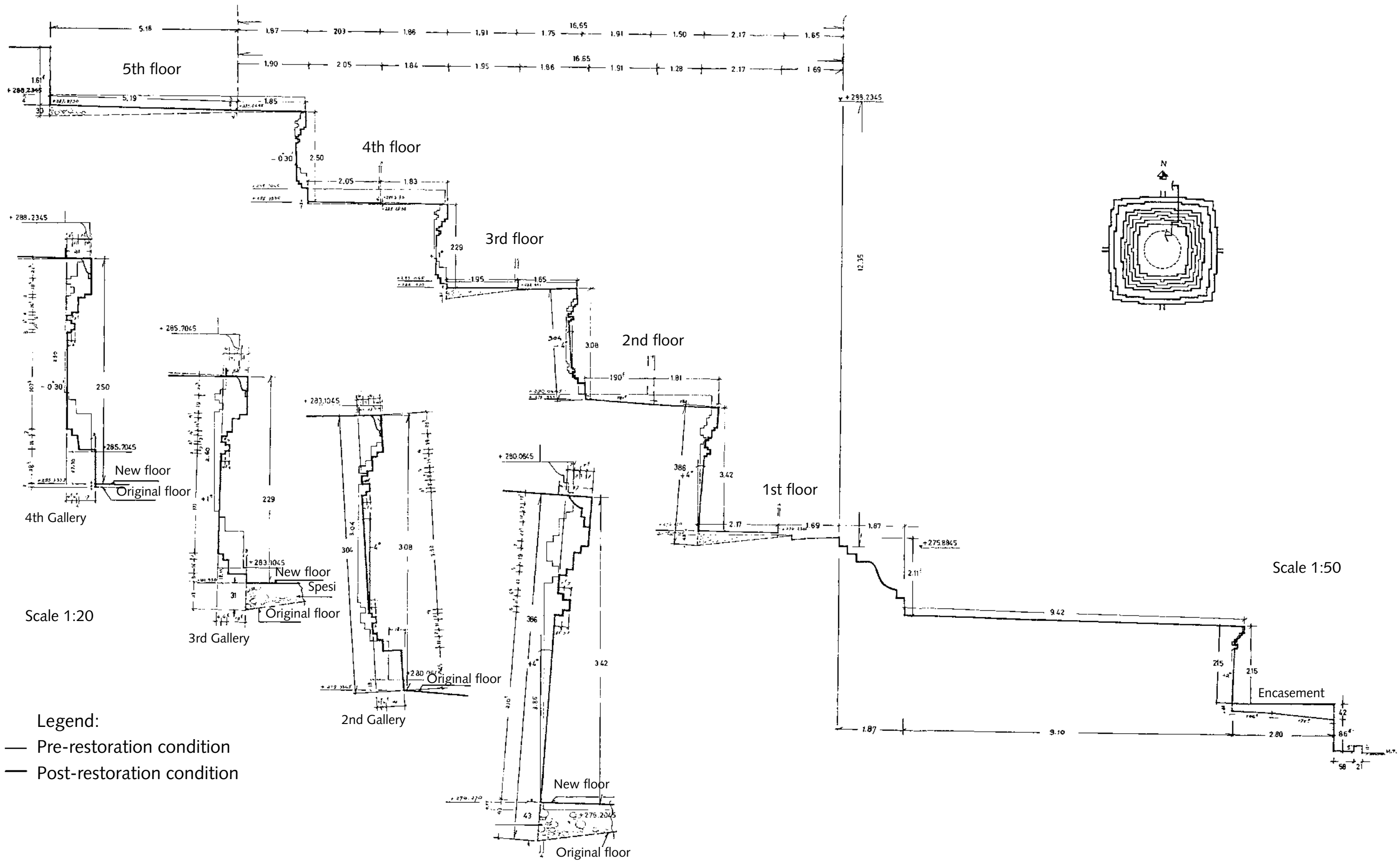


Figure 6.1.3.1
Cross-section of east section, north gate
Source: Borobudur Restoration Project

With regard to the method of determining the new dimensions of the monument, it should be noted that all calculations were made with the proviso that the lines of the hidden foot and of the first plateau should not be touched.

The monument was originally envisaged with vertical walls, but it seems that during construction these walls were set at a slight inclination. In fact, if we set all the walls vertically we would not match the actual width of the galleries. Consequently, after having calculated the dimensions to take this into account, we allowed for a small regular inclination of 1.5° for the main walls, while the respective balustrades were kept vertical.

The longitudinal dimensions of the first and second galleries were obtained by rotation, negative in the first gallery and positive in the second. In our calculations we did not take into account the open joints between the stones, because these joints were not only caused by longitudinal deformation of the walls but also by bulging under the influence of seismic shocks or badly compensated earth pressures. It was clear that these deformations did not change the distance between two corners. The dimensions of the third and fourth galleries were unchanged; the walls were vertical.

Before we started to calculate the coordinates for the construction, it was important to check our method and results, because any change of the method would make it necessary to completely revise them. (Coordinates are given in the Annex ,Tables 3–17.)

Remeasuring the west and east sides

Mr Ismijono stated that in the course of time earth pressure induced by the body of the temple hill pushed the walls forward and down, causing the joints between the stones to widen (Ismijono, 1979).

During the rebuilding of the north and south sides the stones were placed exactly against each other. Consequently the walls regained their original length, which turned out to be substantially less than before the restoration.

With the end corners of the walls in their new places as fixed points for the rebuilding of the east and west sides, the design coordinates for these sides were calculated anew.

Lines and points of reference

The central line of the band between the higher and the lower panels was taken as the reference line for the first gallery. For the second, third and fourth galleries, the line of the plinth – the upper edge of the stones of the second layer above the floor – was taken as reference. Corner points were situated on these reference lines.

Design coordinates, north and south sides

The design coordinates of the reference lines were obtained in the following manner. The forward tilting faces of the wall were returned to the vertical position, with a line 60 cm below the floor surface as rotation axis. During this rotation, the reference line travelled a certain distance (Figure 6.1.3.2). The wall was then shifted backwards – towards the inside of the hill – by a quarter of that distance.

The Z coordinate of the reference line was the elevation of the highest point of that line before dismantling.

Since the reference line for the first gallery line was much higher than that of the others, the backward shift of the first gallery wall was the most substantial. The shift for the other walls was practically negligible.

The execution

During the process of rebuilding, it was observed that there were discrepancies between the designed coordinates and the end result. This, of course, was caused by the elimination of the wide joints. Outer corner points were found to have shifted in the direction of the staircase, whereas inner points had shifted towards the outer corners.

Design coordinates for the east and west sides

The design coordinates for the east and west sides were laid out as follows:

1. The length of each wall section was calculated, taking into account the elimination of the wide joints. The length of the wall sections was measured as follows:
   i. The total length of the wall section was measured before dismantling (L).
   ii. The length of each individual stone was measured (S).
   iii. The width of each joint was measured (W): see Figure 6.1.3.4.
   The design length was taken as: SS + (L – SW)/2.
   All measurements were taken twice.
2. The walls were shifted backwards in accordance with the decrease in length of the walls on the south and north sides.
3. The staircase was shifted backwards, but remained on the same east–west axis.
4. The width of the staircase was kept constant.
5. The corner points were laid out, beginning from the staircase.
6. In repositioning the walls, the angle of the outer corners was kept constant. The

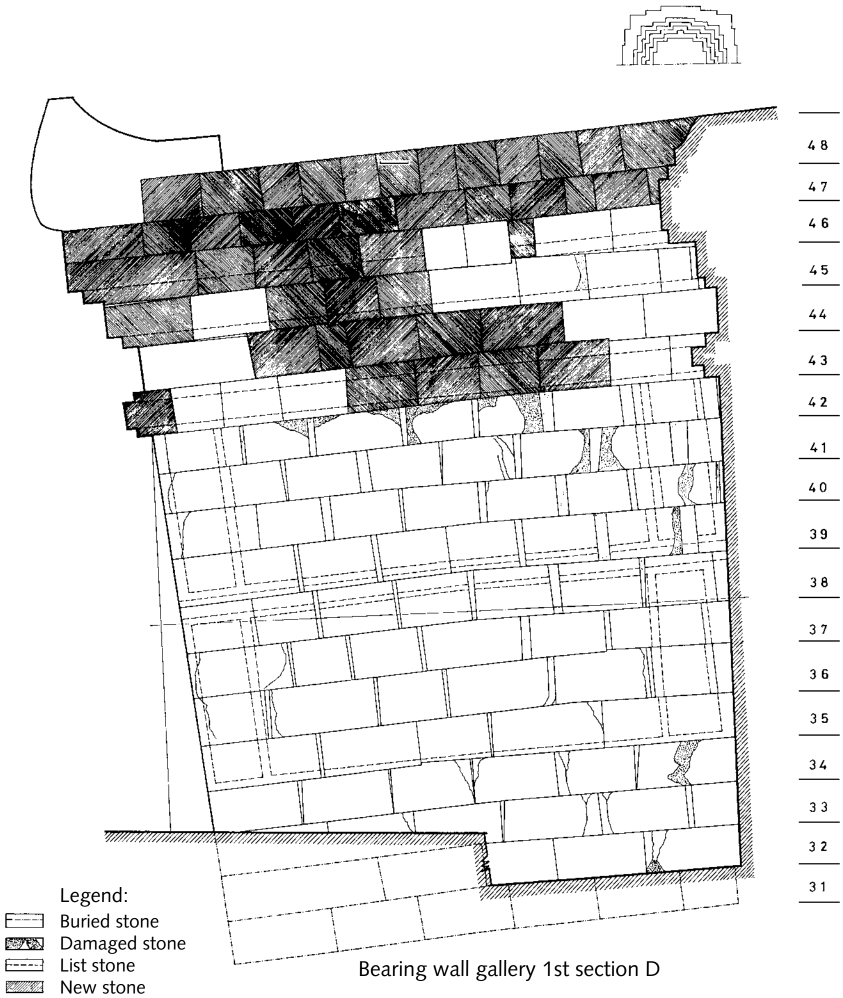


Figure 6.1.3.2
Rotation of tilting walls
Source: Borobudur Restoration Project

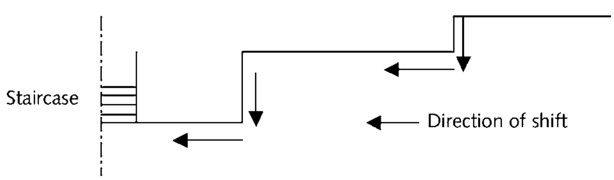


Figure 6.1.3.3
Direction of shift
Source: Borobudur Restoration Project

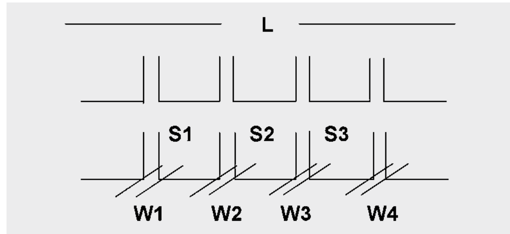


Figure 6.1.3.4
Width of joints

difference in backward shift of the corners was taken care of by slightly manipulating the angle of the inner corners.

In order to accommodate any final discrepancies at the main corners, the end parts of the walls of the north and south sides were rebuilt at the same time as those of the east and west walls (Coordinates are given in the Annex, Tables 3–17).

6.1.4 Registration system

Before the dismantling could begin, a series of preparatory operations had to be carried out. The most important thing was to ensure that all the temple stones had been accurately measured, registered and adequately recorded in drawings and photographs. Moreover, every single stone had to be provided with a code giving its individual identity. The details of the notational and coding system used in the Stone Registration System are as follows:

Sides

A one-character code was used to denote the side of the temple:

U for Utara (North)
S for Selatan (South)
T for Timur (East)
B for Barat (West).

Gallery

A one-digit code defined the gallery of the temple (see Figure 6.1.4.1):

0 for foot
1 for first gallery
2 for second gallery
3 for third gallery
4 for fourth gallery
5 for plateau.

Sections

Each gallery was subdivided into a number of sections. For main walls, the sections ranged from A to J, and for balustrades from A1 to J1 (for inner sides) and from A2 to J2 (for outer sides). In the case of top galleries, however, there were fewer sections and they were designated from A to F. This is shown in Figure 6.1.4.2.

For staircase and arches, special sections were designated by T (central) and Y or Z (sides).

It should be noted that although in most cases one character sufficed to denote the section (two in the case of balustrades), some stones belonged to more than one section, as for example with the corner stone at the junction of sections D and E. In such cases more than one character was used to designate the sections.

Layer numbering

The layer number depended on the gallery and also whether it was a main wall or balustrade as shown in Table 6.1.4.1. For section T, the layer number always started from 1 upwards for each gallery.

Pallet numbering

A pallet was designated by a five-digit number. This coding system was made use of in printing various output reports. Table 6.1.4.2 shows the pallet numbering system for gallery 0, and Table 6.1.4.3 shows the system for the other galleries.

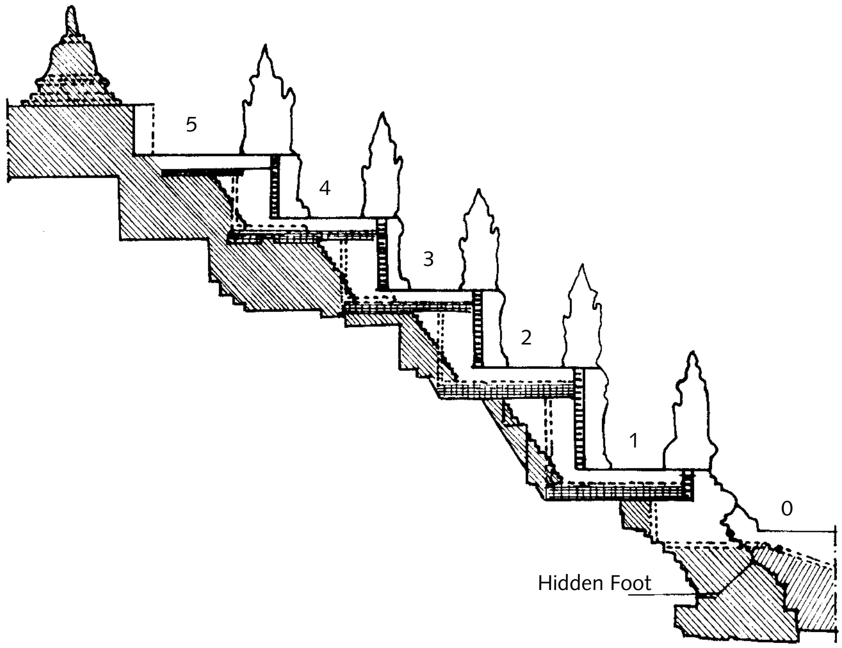


Figure 6.1.4.1
Levels of construction
Source: Borobudur Restoration Project

Table 6.1.4.1 Numbering of stone layers

Gallery	Layer Number for	
	Main wall	Balustrade
0	1–29	–
1	30–48	30–48
2	49–63	49–63
3	64–76	64–78
4	77–90	77–91
5	–	91–104

Table 6.1.4.2 Numbering of pallets, gallery 0

Dismantling side	*Pallet number*
U	00000–02499
S	02500–02499
T	05000–02499
B	07500–02499

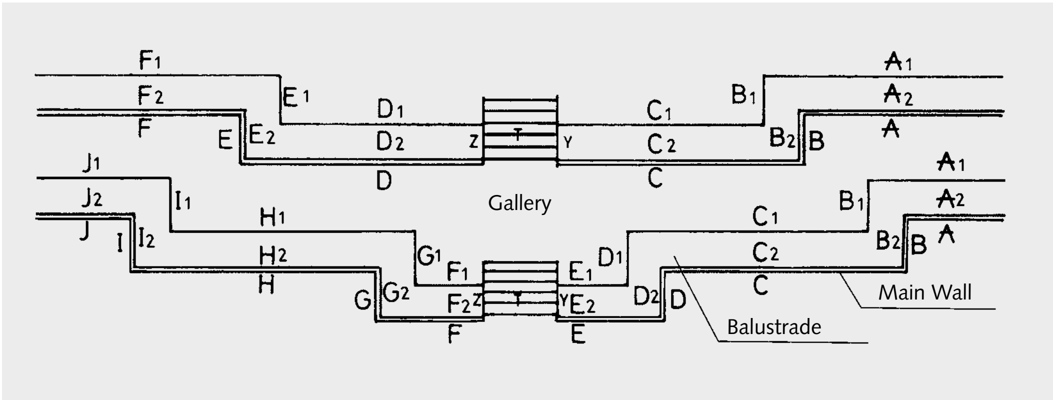


Figure 6.1.4.2
Sections of galleries
Source: Borobudur Restoration Project

Stones were not only identified in relation to their positions at the monument, but also classified by their type and their function in the forthcoming reconstruction.

- *Outer stones* were stones constituting the surface of a wall.
- *Layer B stones* were the two stones directly behind the outer stones (numbers 2 and 3 in the inward direction), which would function as the watertight layer protecting the outer stones against possible seepage of water from the inside of the monument. These stones were in fact inner stones, and were categorized as such in the technical reports since they could be replaced by another inner stone where they did not meet the prescribed requirements, such as size, quality and condition.
- *Inner stones* were stones numbered 4 or more behind the outer stones. They were not put back in their original places but served various purposes. The construction of new floors, an additional watertight, for example, layer A, filter layer, and the fill between layers A and B all required a considerable amount of stone.
- *Element stones* were architectural elements such as *stupas*, gargoyles, Buddha statues and lions.

Table 6.1.4.3 Numbering for other galleries

Gallery, Main wall/Balustrade	Pallet Number	
	Dismantling Area Right	Dismantling Area Left
Gallery 5 balustrade	x0000–x0499	x0500–x0999
Gallery 4 main wall	x1000–x1499	x1500–x1999
Gallery 4 balustrade	x2000–x2499	x2500–x2999
Gallery 3 main wall	x3000–x3499	x3500–x3999
Gallery 3 balustrade	x4000–x4499	x4500–x4999
Gallery 2 main wall	x5000–x5499	x5500–x5999
Gallery 2 balustrade	x6000–x6499	x6500–x6999
Gallery 1 main wall	x7000–x7499	x7500–x7999
Gallery 1 balustrade	x8000–x8499	x8500–x8999

Note:
the value of x is given by
1 for side U.
2 for side S.
3 for side T.
4 for side B.

The division into these categories was necessary in view of the different kinds of treatment and conservation of the stones, and also because of the use of pallets for their transportation from the monument to the workshops.

The pallets were wooden boxes measuring 2.4 x 1.0 x 0.4 metres, provided with iron rings at the ends for the hooks of the hoisting crane. The pallet was divided into nine compartments, each intended to contain one dismantled stone. Thus, nine stones could be transported together from the monument to the buffer storage in the lower working area.

The pallet, when ready to function on the site, was further provided with its own identification number painted on one side. The stone to be dismantled was assigned two numbers: the five-digit number of the pallet, and a single-digit compartment number ranging from 1 to 9. These numbers were also engraved on the 'layer B' stones – the second and the third stones behind the outer stone – since they also would be returned to their original places in the monument where possible.

To simplify the engraving of the numerals on the surface of the stones, the symbols shown in Figure 6.1.4.3 were used.

The traditional method of marking the stones was also followed and proved to be of great help, especially in identifying the connection between the outer stones and the layer B stones. This approach, inherited from former restorations, consisted of a symbol carved across the seam between two neighbouring stones. The symbol, of whatever shape, marked the sides of the relevant stones. When the stones were put back together during the rebuilding work, the two separate parts of the symbol ensured the right match of the stones.

Accompanying the pallets were the Series A drawings and the pallet cards. Series A drawings were the scale drawings of parts of the wall depicting the boundaries of the areas to be dismantled and the boundaries of the planned rebuilding area. They also gave other information concerning the exact data on the stones.

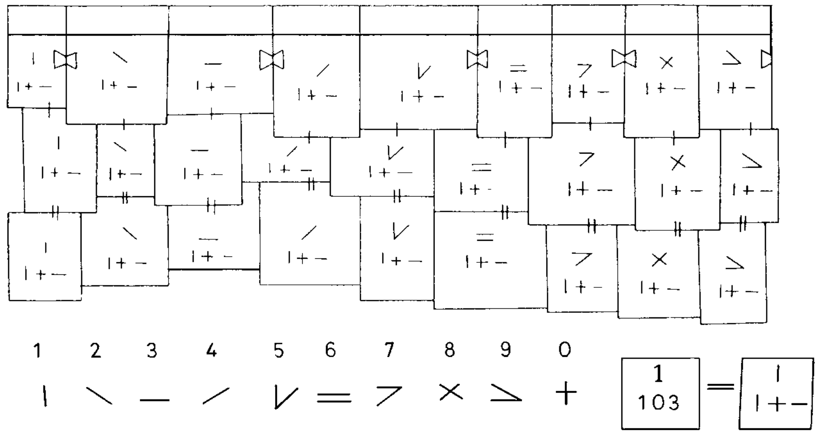


Figure 6.1.4.3
Numbering and marking of outer and inner stones
Source: Borobudur Restoration Project

There were also the series B drawings, which consisted of series A drawings that were filled out with the new data derived from the rebuilding programme. These drawings provided guidance when carrying out the reconstruction work.

No less important was the pallet card, which recorded all data concerning the stones, not only their full identification but also their condition when they were dismantled (if damaged or broken), and the treatment undergone at the various stations. This card accompanied the pallet and the stones all the way from the monument when dismantled and back to the monument again when they were replaced. To ensure that the card would not go astray, it was issued in three copies. Copy I was sent to the drawing section for the preparation of the series B drawing. Copy II was kept by the Central Registration Office, and copy III was fixed to the pallet.

Photo 6.1.5.1
Deterioration or surface erosion
Source: Borobudur Restoration Project

Photo 6.1.5.2
White deposit
Source: Borobudur Restoration Project

6.1.5 Mapping the deterioration of stones

Prior to restoration, mapping the deterioration of the stones was an important step designed to provide quantitative and qualitative data about deteriorated stones. These data were the main source for developing a work plan and deciding on the staff needed as well as the conservation material. Mapping was also useful to document the condition of the monument before restoration.

Mapping was carried out by direct observation of every stone, and the details were recorded on a drawing on a 1:10 scale. The observation focused only on the relief walls and balustrades. At this level, the aim was to identify the causes of decay, specifically the physical-mechanical, chemical and biological processes.

Deterioration caused by physical-mechanical processes includes erosion on the surface of the stone, cracking and breaks. These processes are influenced by various factors: fluctuations of temperature and humidity, seepage water, radiation, air pollution and the nature of the minerals in the stone. Chemical processes are predominantly caused by salt deposits. Deterioration caused by biological processes are mainly due to the growth of micro-organisms on the surface. Other processes are caused by rainfall and humidity.

The mapping process included three types of observation:

- general observation
- restoration observation
- biological observation.

Each type of survey was listed with a particular code, as shown in Tables 6.1.5.1, 6.1.5.2 and 6.1.5.3.

Table 6.1.5.1 General observation

No.	*Type of deterioration*	*Code*
1	Deterioration or surface erosion	Dd
2	Ochre	De
3	White Deposit	Dw
4	Alveoles	Da
5	Clean Stone	Dn

Table 6.1.5.2 Restoration observation

No.	*Type of deterioration*	*Code*
1	Missing part	Ra
2	Fissures	Rb
3	Fissures fill with artificial deposit	Rc
4	Superficial Scaling	Re
5	Superficial Scaling fill with deposit	Rf
6	Efflorésceae	Rd
7	Postules	Rp

Table 6.1.5.3 Biological observation

No.	*Type of deterioration*	*Code*
1	Algae in the hollow of the relief	Ba_1
2	Algae in the runoff water	Ba_2
3	White crustaceae lichens	Bc_1
4	Other types of crustaceae lichens	Bc_2
5	Foliaceae lichens	Bf
6	Mosses on the surface	Bm_1
7	Mosses in the hollow of the relief, fissures or in the joint	Bm_2

Table 6.1.5.4 Deterioration of stone reliefs on the main walls

No.	*Description*	*Gallery*				*Remarks*
		1st	*2nd*	*3rd*	*4th*	
	Total Blocks	5741	6132	4828	4442	
1.	Missing Part (Ra)	3415	3030	2967	3136	
2.	Fissures (Rb)	1052	1248	1422	1361	
3.	Fissures Filled (Rc)	91	189	232	240	
4.	Efflorescences (Rd)	3601	1263	1361	1270	
5.	Superficial Filled (Re; Rf)	2229	2242	2319	1713	
The total block						
6.	Postules (Rp)	2716	920	1539	1097	
7.	Algae (Ba_1 & Ba_2)	5639	4264	4773	3904	
8.	Crustaceae Lichens (Bc_1 & Bc_2)	2810	3295	2474	2640	
9.	Mosses (Bm_1 & Bm_2)	3576	2302	2573		

6.1.6 Trial conservation of the deteriorated stones

Close observations had revealed that the decay of the reliefs in the lower galleries had reached serious proportions, and that the process was accelerating alarmingly. From the relevant studies it was evident that it was once again water that was the main cause of decay. Alongside seepage water, the moist atmosphere in the galleries enhanced the process of corrosion and erosion of the stones. A well-defined regulation of water percolation, however, could not possibly cure the disease that the stones were suffering from. In fact, the planned technical implementation of an adequate drain system was directed to the future care of the monument rather than to solving the existing problem.

The fight against the micro-organisms attacking the Borobudur stones needed to have a curative as well as a preventative character. Curative measures involved a total cleaning of the stone and preventative work meant the introduction of strict regulation of water percolation. Consequently, a well-planned conservation programme needed to be set up to give the necessary firm basis for the entire undertaking of treating the stones. This in turn called for experiments that could ensure the right remedy for each particular disease.

Remains of yellow ochre, formerly used as a coating for photographic purposes, were found at several places. After so many decades this ochre had apparently functioned as a protective layer; in several places the coated parts of the surface of the stones were still in good condition. Closer observation, however, showed that it was the quality of the stone rather than the yellow ochre coating that was responsible for this resistance to the weathering process. Serious damage was found on many sections that had been coated.

The observed failure of yellow ochre as a protective agent had discouraged ideas of using the method of coating, even with other chemicals. It was felt that the elimination of water should have priority in the stone conservation programme. In due course, however, full attention was to be paid to the chemical treatment of the individual stones.

The conservation of stones on monuments by means of chemicals had not been introduced until 1968. The traditional approach was confined to the cleaning of the surface of the stones by hand, or with brooms

Photo 6.1.5.3
Labelled stone
Source: Borobudur Restoration Project

Photo 6.1.5.4
Fissures
Source: Borobudur Restoration Project

Photo 6.1.5.5
Superficial scaling
Source: Borobudur Restoration Project

Photo 6.1.5.6
Effloresceaes
Source: Borobudur Restoration Project

Photo 6.1.5.7
Algae in the hollow of the relief
Source: Borobudur Restoration Project

Photo 6.1.5.8
Algae in the runoff water
Source: Borobudur Restoration Project

Photo 6.1.5.9
White crustaceae lichens
Source: Borobudur Restoration Project

6.1.5.3

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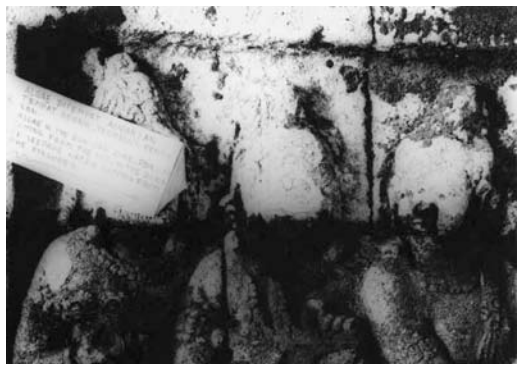
6.1.5.7



6.1.5.8

6.1.5.9

or brushes. Another method of dealing with individual stones during restoration work was to bury them in the courtyard of the temple for two or three months. In this way the organic growth on the surface of the stones would be decomposed, so that traditional mechanical cleaning was easy and the risk of damaging the stone was avoided.

The chemical conservation programme began with a survey of the effect of chemicals on the organic growth on the surface of uncoated Borobudur stones. Selected chemicals were brushed or sprayed on to the surface of a number of selected stone blocks, and the effects on the organic growth observed. To verify the results a laboratory test was carried out, applying chemicals directly to organisms that had been taken from the stone surface.

The laboratory experiments showed the different effects of chemicals on the pure culture of algae, actinomycetes and moulds. It was also evident that the use of chemicals at low concentrations was less effective, and it took ten or more days before the results could be observed.

Experiments in the field included several kinds of activities: tests of the effect under field conditions of chemicals followed by a combination of mechanical and chemical treatments, and the use of clay paste and mixtures of clay paste and chemicals.

The chemicals used during the tests were: Nabasan, Quat, Formol, Noranium and Sodium hydroxide. Nabasan and Quat proved to be effective at killing two types of foliaceous lichens when applied at a concentration of 0.5 per cent over a contact period of one week. Three kinds of crustaceous lichens, however, were not affected.

Musci were also killed by Nabasan at the same concentration within one week of contact, but regrowth was observed as soon as the moisture conditions were reintroduced. The 'black algae' populations comprising *Seytomene pasceri, Plectonema spp., Aulosira yertilissima* and *Tolypothrix campylonemoides* were also killed by Nasaban or Quat (0.5 per cent) within one week of contact.

Formaldehyde (Formol) applied at 1.0 per cent concentration on mechanically cleaned surfaces could prevent the growth of organisms for five weeks as long as the treated stone could be kept dry.

Noranium at 3–5 per cent was apparently more effective and could keep the stone surface clean for a longer period. Regrowth of mosses and algae, however, was observed after six months when moisture conditions permitted. The fact that the stones became discoloured also had to be taken into account. A yellowish, grey or brownish colour appeared on the surface of the treated stone after seven days of treatment.

Sodium hydroxide at 5–25 per cent, hot or cold, could facilitate the cleaning of all kinds of organic growth, but also had a discolouring effect. This kind of chemical is very corrosive and will leave a whitish deposit. Regrowth of mosses and lichens occurred after nine months when moisture conditions permitted.

Mechanical cleaning was carried out by using plastic brushes and wooden sticks with the following results. *Hepatica*e are easy to clean away by brushing and rubbing in either dry and wet states, whereas *Musci* are easier to clean off when wet.

Algae can easily be removed when dry. Some types of *Nostocaccae* scale off easily when dry. Lichens of the crustaceous types were difficult to clean.

The time taken by mechanical cleaning ranged from one and a half to five and a half hours per square metre of stone surface. It was also observed that the speed of the operation depended on the properties of the stone surface.

Mechanical cleaning followed by chemical treatment was applied to a number of selected stones. After cleaning, the chemical treatment was not started until the stones were dry. The treatment involved seven kinds of chemicals: Formal (2 per cent), Quat (1 per cent), Algicide Proven (1 per cent), Preventol PN (1 per cent), Preventol liquid (1 per cent), Benzalkon (2 per cent) and Kermex (1 per cent), (Jutono and Hartadi, 1973).

The tests showed that no chemicals could remove lichens of crustaceae type and protonema mosses that remained on the stone surface after the mechanical cleaning; however, Quat, Karmex and Benzalkon could kill the other kinds of mosses and it protonema.

The application of clay paste to the surface of stones covered with organic material was found to facilitate the cleaning operations considerably. *Hepatica*e were killed within one week (*Musci*, however, would grow on the surface of the paste). In fact, both *Musci* and *Hepatica*e were easy to remove without pre-treatment with clay paste. Aligal cells decomposed after being covered with paste. White lichens (crustaceous types) were also easy to clean after contact with clay paste for one week.

The use of admixtures of clay and chemicals to combat lichens of the crustaceous type was only effective when the chemical component consisted of Quat at 5 per cent and the contact time was twenty-four hours. The white lichens were affected by Quat, Algicide Proven, Preventol liquid and Karmax within five hours, while the effects of Formol and Benzalkon became apparent after forty-eight hours.

The best results in combating white lichens and mosses were obtained from an admixture of clay and AC 322 (25 per cent). However, mosses started to appear again on the cleaned surface of the stone five days after the cleaning operation (for further discussion of the use of AC 322 see Section 6.2.2).

The experiments in using chemicals to facilitate the cleaning of the stone surface from organic growth showed them to be effective for a short period only. It also became apparent that the use of chemicals in the form of paste – composed of a sticky material such as clay mixed with chemicals – was more effective. The paste would intensify the contact of the chemicals with the surface of the stone to be cleaned, so that low concentrations of chemicals sufficed for the operation. Furthermore, evaporation and photo-reactions could be reduced considerably. One point, however, drew special attention: the weathering process is a very complicated natural phenomenon, and we cannot expect cleaning the stones and preventing harmful organic growth in the future to be a simple undertaking.

The building material of Chandi Borobudur consists of volcanic stone of the andesite type that is in general very porous. Consequently, when saturated with water it provides a very fertile field for the growth of mosses and other micro-organisms. Since the stones are practically humid all the time due to the microclimatic conditions, the process of deterioration cannot be prevented.

The deterioration process can be classified into three different types: mechanical, chemical and functional ('soiling').

The mechanical process, usually called corrosion, can be divided into a biotic and an abiotic process. Organisms, as biotic factors, produce corrosive substances like organic acids that can dissolve free lime or calcium carbonate present in the material. More dangerous is the sulphuric acid produced by bacteria. Abiotic processes occur when water carrying dissolved substances – either organic or inorganic salts – permeate through the stones.

Table 6.1.6.1 Chemicals used in the field experiments

No.	*Name of chemical*	*Concentration used*	*Method of application*	*Duration of contact*	*Remarks*
1.	AC-322	10–25%	As admixture of clay paste and the chemical	2–48 hours	Very effective for cleaning the organic growth of the stone surface.
2.	Benzalkon	1–10%	ditto	5–48 hours; 6 days	Slight effect on crustaceous lichens.
3.	Curitan	0.5–1.0 promil	As solution	—	—
4.	Formol	1–30%	As solution, as admixture of clay paste and chemical	5–48 hours	Effective for algae as admixture of clay and Formol 30%
5.	Hyver X	1–2%	ditto	1–6 days	Effective for *Musci* and Black Algae
6.	Karmex	1–5%	ditto	1–6 days	Slight effect on *Musci*
7.	Muslick	Concentrates	As solution	6 days	Effective for *Musci*
8.	Nabasan	1–5%	As solution	6 days	ditto
9.	Noramium	3–5%	As solution	6 days	Slight effect on lichens
10.	Preventol L (liquid)	1–10%	As admixture of clay paste and chemical	5–8 hours; 6 days	—
11.	Preventol O extra	1–2%	As solution	6 days	Effective for *Musci*; *Hepaticae*, Brown algae
12.	Preventol PN	1–2%	As solution as admixture of clay paste and chemical	6 days	ditto
13.	Preventol ON	1–2%	As solution	6 days	ditto
14.	Proven	3–5% 20%; Conc.	As solution As admixture of clay paste and chemical	7 days	Effective for mosses and algae
15.	Quat	1–20% 50%; Conc.	ditto	5–48 hours; 6 days	Effective for white lichens (crustaceous) and *Musci*
16.	Sodium hydroxide	5–25%	As solution		Effective for cleaning, but very corrosive.
17.	S-66	0.5–1.0 promil	As solution	6 days	Slight effect on lichens

Table 6.1.6.2 The adhesives used in experiments

No.	Type of adhesive		Composition		Pot life	Drying time	Type of experiment	Result of experiment
	Resin	Hardener	Resin	Hardener				
1.	Akemi Normal Stein U. Marmorkitt Universal	Paste HS	100	3	5 minutes	40 minutes	bonding filling bonding with anchor	good good good
2.	Akemi Extra Schnell Hartend Stein U. Marmorkitt Universal	Paste RS	100	3	4 minutes	15 minutes	bonding	good
3.	Akemi Universal Transparent water Clear No. 1	Harter Flussig B	100	3	15 minutes	1 hour	bonding	good
4 .	Sinmast P.203	P.203	3	1	100 minutes	5 hours	bonding filling bonding with anchor	good good
5.	Araldite AW 106	HV.953.U.	1	0.8	170 minutes	8 hours	bonding bonding with anchor	Material crack Stone crack
6.	Araldite XB 2697	HY 2962	2	0.66	130 minutes	7 hours	bonding	Adhesive Material crack
7.	Araldite GY 257	X.157/2401	100	18	50 minutes	3 hours	bonding bonding with anchor	good good
8.	Epasfill PT.521 SL	PT.521 SL	3	1	180 minutes	9 hours	bonding bonding with anchor	good good
9.	Davis Fuller 614 (A)	DF.614 (B)	4	1	2 jam	4 hours	bonding filling bonding with anchor	good good good
10.	Davis Fuller 609 (A)	DF.609 (B)	1	1	2 jam	5 hours	filling	good
11.	Instant Resiweld Part A	I.R. (B)	1	1	3 minutes	13 minutes	bonding filling	good
12.	Durox 628 (A)	D. 628 (B)	147	53	3 jam	14 hours	bonding bonding with anchor	Adhesive Material crack Stone crack

The presence of organisms on the surface of the stones, even if they do not cause observable damage, has a disfiguring effect on the carvings. The stains constitute a functional degradation of the stones. This is known as the soiling process.

Algae and lichens can be of particular importance in the soiling process, provided that water and light are present. Fungi, however, which can grow on a small amount of organic substance, can also produce disfiguring stains on the stones when humidity is high enough. Other disfiguring effects are stains and efflorescence, caused for example by iron compounds or the crystallization of salts from water that dissolves these substances and then permeates through the stones and subsequently evaporates.

The fundamental process of biotic damage is the same as the underlying abiotic damage, because the stone does not provide an organic carbon source for the growth of organisms. The presence of water – or at least a significantly high relative humidity – is of decisive importance for the biotic as well as the abiotic deterioration.

In order to identify the appropriate type of adhesive to be used in bonding the stone, research was carried out in the early stages of restoring Borobudur. The goal of this research was to determine the type of adhesive that was most suitable for the tropical climate, had sufficient strength for the weight of the construction, and would have no negative impact on the stone.

The research used inner stone found around the site as the sample for experimentation, specifically the andesite stones. The stones used as samples for the research were classified into:

- dark compact stone;
- light compact stone;
- dark porous stone;
- light porous stone.

Each type of stone was bonded with the adhesive for an appropriate setting time. Tests of each stone type and adhesive type were made in several series for comparison. The adhesive research included an 'ageing test' and a 'compression test'. In the 'ageing test', stones were heated up to 70 °C then cooled to 15–20 °C. After the test, the stones were placed in the open air or outdoors to monitor their liability to weathering. This cycle was repeated at least ten times and each time the stones remained outdoors for twenty-four hours. This research also studied stones that had been physically bound with bronze, zinc or iron anchors. In each case, the stones were observed over a month and then at weekly intervals to monitor the results.

The 'compression test' was conducted by the laboratory of the Faculty of Civil Engineering at the University of Gadjah Mada. Stones to be tested were shaped into cubes measuring 7 cm on each side. The experiments took place in three series: the first series studied the bonded stones (F1; F2; F3), the second related to stones whose pores had been filled (H1; H2; H3), and the third series served as control experiments (C1; C2; C3). The types of stones used in the research were compact and porous stones.

The average results from the compression test were: bounded compact stones, 229,1 kg/cm^2; bounded porous stone, 157.8 kg/cm^2; filling compact stone, 230.7 kg/cm^2; filling porous stone, 199.0 kg/cm^2; compact stone for control, 207.0 kg/cm^2; and porous stone, 193.8 kg/cm^2. The adhesive used was Davis Fuller 614, as shown in Table 6.1.6.3 (for further details see Section 6.2.2).

Table 6.1.6.3 Compression tests on stones

No.	*Code Number*	*Compress. stress at first crack*	*Compress. strength at failure*	*Control*
1	I C_1	113.7	144.6	
2	I C_2	–	285.4	Control
3	I C_3	159.8	190.9	
4	I H_2	135.6	206.2	
5	I H_3	167.8	198.2	
6	I H_4	172.7	287.6	
7	I F_1	157.5	209.2	Davis
8	I F_2	154.5	176.4	Fuller
9	I F_3	186.1	301.6	614
10	II C_1	129.6	226.6	
11	II C_2	140.2	185.5	
12	II C_3	109.1	169.3	Control
13	II H_2	79.3	–	
14	II H_3	121.1	130.8	
15	II H_4	258.1	267.3	Davis
16	II F_1	67.4	183.5	Fuller
17	II F_2	129.7	205.9	614
18	II F_3	52.6	84.0	

6.1.7 The computer-based system

Thousands of finely sculptured stones, statues and fragments were missing from Borobudur, most of which were found around the temple site. Attempts have been made to restore them but without success.

As a solution to this problem, a computerized system based upon sound analytical principles has been devised. The process involves a number of steps.

1. Classification of all possible types of stones in as many categories as possible. For the types of stones and fragments found in Borobudur the following criteria were adopted for the classification structure:

- archaeological description
- petrographic code
- physical size
- shape of the broken surface.

2. Establishing classification codes for all individual missing stones.
3. Organizing this massive amount of data with the help of the computer in category and sub-directory sequences and printing classified directories.
4. Determining the match with the help of these computer printed reports.

The Stone Registration System (SRS)

The system was designed as a control system encompassing maintenance of up-to-date records of stone pallets at the various stages from dismantling to rebuilding. At regular monthly intervals a number of useful reports were printed to enable the project management to keep effective control of operations. A salient feature of SRS was 'exception reporting', whereby only those situations that needed attention were highlighted. This cut down unnecessary paperwork and speeded up remedial action.

The following were some of the benefits of SRS:

- Ensuring proper treatment of stones. The monthly Outer Stones Treatment Ordered/Treatment Completed report pinpointed those stones that had not been treated as ordered. Necessary action could be taken to ensure their complete and proper treatment.
- Efficiency Analysis. Smooth and successful execution of the project required all the operations to be executed smoothly and with planned speed. The Teamwise Dismantling Analysis indicated the speed of dismantling for each dismantling team. Cases of excessively low and high speeds were considered as potential trouble spots. After finding out the reason for these discrepancies, corrective action could be taken. Other analysis

reports, such as the Teamwise Cleaning Analysis and the Teamwise Rebuilding Analysis, similarly helped coordinate and control activities.

- Proper coordination between different restoration operations. As outlined earlier, strict control was required over the movement of the stones through different operations so that interruptions to work were avoided. This was achieved with the help of a concise report: the Pallet Movement Summary. This gave the number of pallets moved from one stage to another each month. Figures for the past six months were printed out, showing at a glance the pattern of stone movement from month to month. If these figures indicated an abnormal rise or fall in the speed of certain operations, suitable action could be taken after determining the cause.
- Planning for rebuilding. Before rebuilding a certain area of the temple, it was essential to ascertain that all the stones required for that area were ready and had been given complete restorative treatment. This was particularly difficult as the rebuilding areas were not identical to the dismantling areas. To help in this, a Rebuilding Planning Report was prepared by the system. This gave layer-by-layer pallet requirements for each rebuilding area. Details of the pallets that were not ready for the rebuilding and their current whereabouts were also printed. This report would be prepared for each area a few months before rebuilding was scheduled, and if any pallets were not ready they could be processed without any last minute rush.
- Proper documentation. The reports mentioned above, together with several other reports like the Outer Stones Dismantling Report, the Outer Stones Rebuilding Report and Pallet Movement Report, provided complete, up-to-date and methodical documentation of the restoration work.
- Error checking. Before preparing this report, the system rigorously checked and highlighted mistakes in reporting such as wrong or duplicate numbering of pallets, missing pallet cards, incorrect location of pallets, invalid gallery numbers and the like. All such errors were automatically detected by the computer, thus ensuring the accuracy of the monthly output reports. The errors could then be investigated and corrected, thereby avoiding unnecessary confusion at the later stage.

Project Control System (PCS)

The system is a very simple yet scientific technique for planning, monitoring and controlling a project using a computer. It was used to monitor the Borobudur Restoration Project on a regular basis. Every month, a number of useful reports were printed out to enable the project management to maintain effective control over operations. The following were some of the benefits obtained from the PCS:

- Identification of potential problem areas. Monitoring of critical activities (those where any mistiming could have the greatest impact on the whole operation) gave timely warning of operations that either were causing or might cause a delay in the completion of the project. Proper action taken on these helped eliminate undesired slippages and meet schedules.
- Resource optimization. Reports such as the Resources Utilization Report gave a projection of manpower requirements taking into account the latest status of the project. This report assisted in achieving

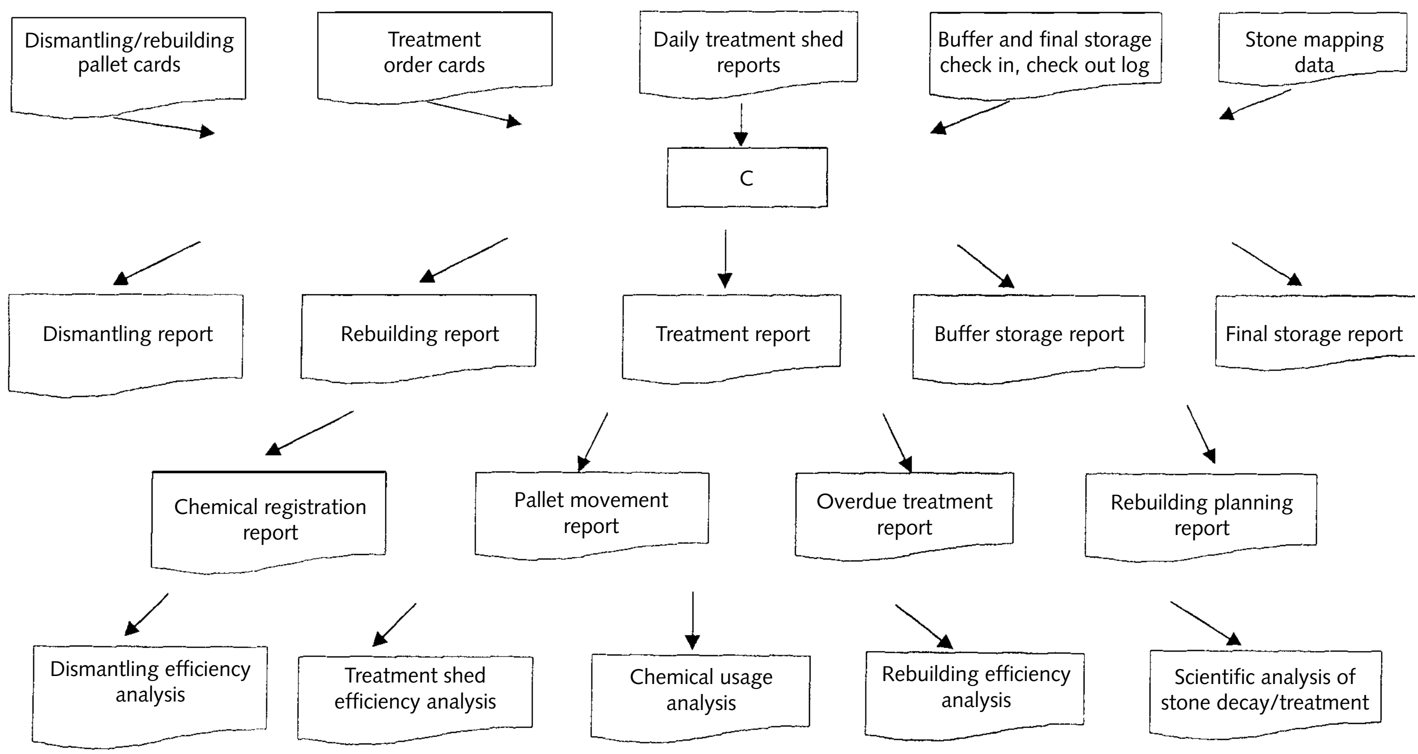


Figure 6.1.7.1
Stone registration
Source: Borobudur Restoration Project

more balanced manpower distribution rather than swinging between high-pressure and slack periods.

- Defining what needed to be done. Documents like the Schedule Report printed out activities that should commence over the coming weeks. This eliminated guesswork in project execution and helped maintain the schedules.
- Continuous timely progress reporting. The Work Status and Progress Report and regularly updated bar charts depicted the current status of the project, the latter in chart form. Each new chart was prepared by the computer to take into account the latest progress of the work.
- Uniform reporting system. Reports such as the Milestone Report provided a uniform and regular way of reporting the progress of the work to various people who, though not present on the site, were deeply involved in the project.
- Better communication. Although different types of output reports went to different people concerned with the project, it should be kept in mind that they were all based upon the original project network and periodic progress information given to the computer every month. This eliminated any possibility of discrepancies in information between any two project reports for the same reporting period. The project status understood by different people through different reports was the same, thereby eliminating ambiguity and achieving improved communication.

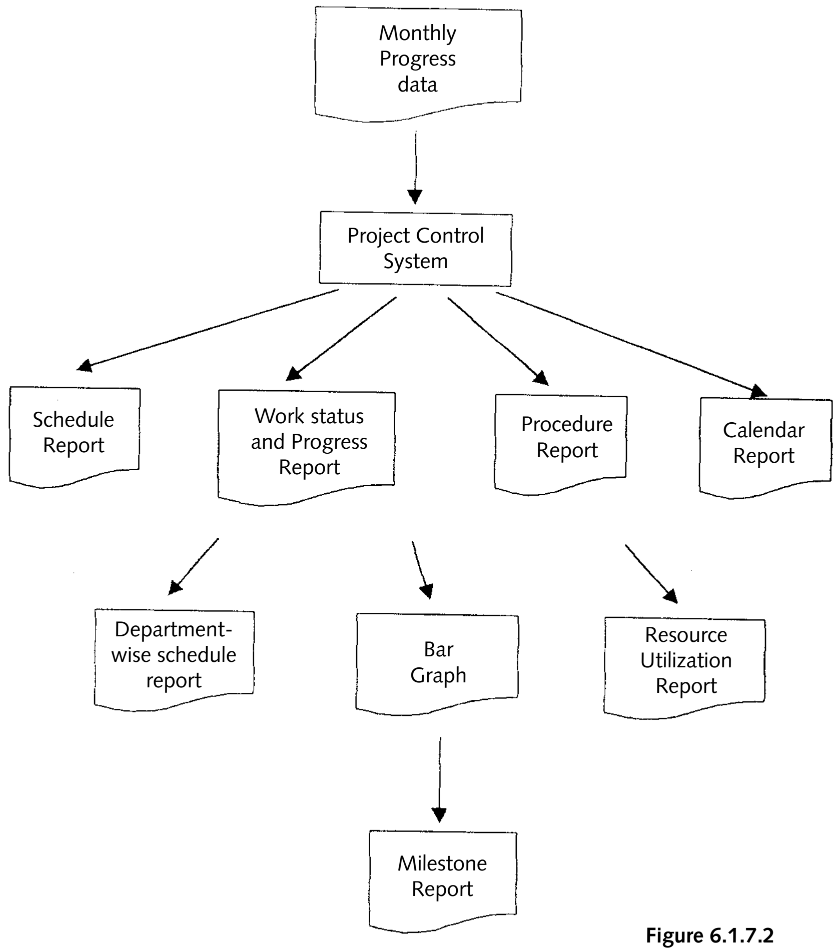


Figure 6.1.7.2 Borobudur Project Control System
Source: Borobudur Restoration Project

A general flow chart of the PCS showing the input and the end-user reports is given in Figure 6.1.7.2. As is evident, different reports were used by different levels of management to control the project.

As a contribution to the restoration of Chandi Borobudur, IBM assigned its programme specialist, Dr V.K. Khandelwal, to the project for two years (1975–77). His assignment was to assist the work with the necessary computer services. After having studied the work plan and surveyed the activities involved in the implementation, he arrived at the conclusions described below.

The restoration of Borobudur involved dealing with a major portion of the temple and over 1 million stones, determining and giving proper chemical and other restorative treatment to these stones to prevent further deterioration, and finally reconstructing the temple. Although seemingly straightforward, the complexity of this project was evident from the following:

- Of the stones dismantled, more than 500,000 blocks of important stones like outer stones and layer B stones had to have individual identification numbers engraved on them while dismantling. These numbers would be used to report the movement of these stones from one place to another and finally for rebuilding. The accuracy of the reporting system was therefore of utmost importance as any inaccuracy in identification number or reporting might not only lead to wrong chemical treatment or storage of stone in the wrong place but would result in the loss of the stone's identity.
- The restoration treatment required – manual cleaning, chemical cleaning, drying, repairing and so on – was determined on a stone-by-stone basis. The treatment of each stone depended on its state of deterioration and whether it was a sculptured or a non-sculptured item. Further, to ensure proper restoration of the temple, it was essential that no stones were left partially and incompletely treated before rebuilding.
- The speed of dismantling was always regular, while the average treatment capacity was constant. For this reason, some stones had to await treatment in the buffer storage area. It is estimated that the number of stones lying in this area was at times as high as 40,000. With such a large number of stones awaiting treatment, it was essential that an appropriate

system be maintained to provide details of their status and enable their quick and easy retrieval when needed.

- The stones dismantled first would be the last to be rebuilt, so a final storage (after treatment) was required. The stones were stored here for a period ranging from two months to several years before they were required for rebuilding. It was essential that the location of each stone in the storage was precisely and accurately known to avoid frequent interruptions to rebuilding.
- The dismantling areas of the temple were not the same as the rebuilding areas. In other words, the sequence in which the stones were required for rebuilding was not necessarily the reverse of the sequence in which they were dismantled. To facilitate reconstruction, the order in which the stones would be required for building had to be known well in advance so that they could be stacked in the final storage area accordingly.
- The capacity of different operations – dismantling, treatment and rebuilding, as well as the buffer and final storage – was limited. This required close coordination of the movement of stones through the various stages. Lack of proper coordination could have led to serious impediments in the project execution. For example, if treatment slowed down or dismantling speeded up, the buffer storage would soon reach its capacity and hinder further dismantling work.

It is evident from all this that successful execution of the project required very strict vigilance over the movement of stones. To achieve this, a computerized stone registration system was evolved encompassing maintenance of up-to-date records of stones and pallets throughout the various stages of their movement from dismantling to rebuilding. A salient feature of this system was Exception Reporting: warning reports that referred only to those situations that needed attention. This cut down unnecessary paper work and speeded up the implementation of remedial action.

The input documents required for the stone registration system – dismantling and rebuilding pallet cards, treatment order cards and many others – already existed, so no new documents needed to be prepared to produce the computer output reports. In this respect it is worth mentioning that the computer proved not only to facilitate greatly the registration work, but also to verify earlier registrations carried out manually.

Another programme of at least equal significance was the project control system, which enabled the project officer to exercise full control over the various activities and to anticipate possible constraints.

The restoration of Borobudur was a colossal project involving more than 600 people, working together on the multidisciplinary activities of this complex project. These activities ranged from dismantling stone blocks and pouring concrete slabs to chemical cleaning of the sculptured stones. Yet all these diverse activities were interlinked and dependent upon one another; a delay in one activity would affect others and, ultimately, the completion of the project. Unless such delays were given proper and immediate attention, they might have extended the duration of the project and eventually increased costs very significantly.

For such a project to be successfully executed it was essential that the utmost attention be devoted to planning and control. The initial project planning had to be done on a sound scientific basis. Once the work started, it was important that any hold-ups or delays were immediately brought to the attention of management. It was because of these requirements that it was decided to utilize the PCS for the Borobudur Restoration Project.

A typical modern project not only consists of hundreds of complex multifarious activities, each interlinked with and dependent upon the others, but also involves enormous sums of money. Inefficient planning of such projects could result in the loss of thousands or millions of dollars. In such cases it becomes increasingly important to control the different aspects of the work effectively, but at the same time it is more and more difficult to do so using ordinary techniques. The PCS has been found to be of enormous benefit in the control of such projects.

The technique used most extensively for planning, control and scheduling of projects is the Critical Path Method (CPM). This is one of the most powerful, efficient and widely used tools that the computer has made available for construction projects. In this technique, the project is first broken down into its component activities, arranged graphically as a network so that the sequential relationships among them are clear. Any path through the network traces a series of activities that can be performed only in that order. Allowing for the fact that no given activity can begin until all its prerequisites have been completed, which is the path through the network, from beginning to end, that will take the longest to complete? That path when found is the critical path, in the sense that a delay in any activity along it will cause a corresponding delay in completing the entire job, while shortening the activity time along that path will permit earlier completion of the whole. Activities along non-critical paths, on the other hand, have varying 'float' times; that is to say, they can be postponed or completed more slowly without delaying the completion of the project.

Once the work on the project starts, the information about the work performed on different activities is reported to the computer every month. This is called the work progress data. On the basis of this data and the initial project plan, the computer calculates, and prints in a report, updated schedules for the whole project. This report therefore incorporates not only the initial project plan but also the work completed since the start of operations, and is thus an up-to-date report reflecting the current status of the project. The monthly progress data form the basis of the monthly updating of the project plan. A number of comprehensive reports such as the Schedule Report, the Work Status and Progress Report and the Milestone Report are produced, keeping the different levels of the project management up to date on the current status of the project.

In the course of implementation of the project, modifications and changes to the original plan are deemed necessary from time to time. It is almost impossible to keep on modifying the plan and analysing the effect of the changes manually. However, in the computerized PCS, all that is needed is periodic information on the completion status of the current activities, and such changes can be incorporated in the original project plan there and then. This ensures that the project status reflected in the latest computer output report reflects the current situation of the project site rather than the original theoretical plan, which is no longer relevant to the changing conditions.

Besides helping in monitoring and controlling a project, the PCS also helps in the initial planning. For each of the many activities involved, there will be in general more than one set of figures for time, cost and labour, ranging from a 'crash' programme of high resources, high cost and minimum time to a more economical one using fewer resources but taking a longer time. Under these conditions, appropriate decisions to optimize the entire project can simply not be taken without the help of a computer. With the computerized PCS, the different sets of combinations can be modelled and the best one chosen.

The PCS, based on a method commonly known as network planning, was used as a planning and control system to monitor the Borobudur project on a regular basis and, as previously noted, its monthly reports enabled the project management to maintain effective control of operations.

6.1.8 Archaeological research

Excavation of the west courtyard of Chandi Borobudur in 1951–53 unearthed the brick foundations of two square buildings, a big bronze bell, a large number of bronze nails and many religious objects. The number of nails led to the obvious assumption that the excavations had revealed the remnants of wooden structures, presumably the long-sought *vihara*. The large bell provided strong support for this theory.

It is indeed impossible to imagine a temple without the dwellings of monks and temple attendants in the surrounding area. It was these officials who had the duty of attending the ceremonies at certain times and maintaining the temple and accessory buildings. The inscriptions give us ample evidence of the various kinds of ceremonies to be held at particular times: daily, monthly or otherwise.

The restoration project, covering the plateau on the Borobudur hill and a considerable area around it, presented a unique opportunity to carry out extensive archaeological research. It would in any case have been desirable to conduct such investigations.

From 1970 excavations were carried out on the hill immediately around the temple, on the slopes of the hill, on the plain south and southwest of the hill where the sheds and the workshop were to be erected, and east of the temple where in future the approach to the monument would be located. The opportunity was seized to train students in archaeology from both the Gadjah Mada University in Yogyakarta and the University of Indonesia in Jakarta.

The diggings on the hill east of the temple revealed remnants of a foundation, presumably of a wall, running from north to south for 53 metres, located 28 metres east of the eastern stairs of the temple. A similar formation of stones was also found north of the temple, extending for 50 metres from east to west. However, we cannot interpret the two formations as remnants of the surrounding wall of Borobudur since the types of stone and the distances from the temple are different. The formation on the north side is 20 metres from the northeast stairs. A formation of bricks, ranging from two to six layers, was found on the northwest corner of the temple, running from southwest to northeast. It is difficult to speculate about its function in the past.

Excavations on the western slope of the hill in 1970, on the site for the installation of the water reservoir, yielded the find of a bronze *prabhamandala* (the back of a seat) and a bronze *vajra*, only 1.2 metres from the surface.

To the southeast of the two bronze objects, four Chinese ceramic vessels and fragments, all dating back to the Tang Dynasty of the ninth century, were found.

The plain below the hill, southwest and west of the temple, also yielded interesting finds. Unfortunately the process of buying the land took so long that there was not enough time to make a thorough and meticulous archaeological investigation when at last the area was purchased by the project. Only trial trenches without adequate recording could be made, yielding a wealth of local potsherds and Chinese ceramic fragments. Some trenches uncovered formations of brick, cut stones and small river boulders (presumably remnants of building foundations), pieces of charcoal, and animal teeth and bone fragments. They indicated that the area had been inhabited for some time before being inundated or struck by a lava flow, as testified by a layer of sand and ashes in a large number of the trenches.

Only some small sites were excavated properly. In 1973 students of the University of Indonesia led by Mundardjito excavated four sites. On the supposition that there must have been a surrounding wall, excavations were undertaken on the southern axis of the temple. Six trenches were dug to a depth of 5 metres, but without any results. Four other trenches, set more to the west on the basis of geo-electric prospecting, were excavated, but again without results. Another site was tried, on the theory that since the layout of a temple compound is usually symmetrical, we would expect remnants of a building due south of the remnants of the *vihara* on the hill. Five trenches were excavated, but also in vain.

The fourth site was a success. It was chosen according to indications from aerial photographs. From this site five delicate earthenware pots, presumably used for ceremonial purposes, and a formation of irregular river stones were excavated. Unfortunately there was no time to extend the excavations to the adjacent areas. And it was not far south of this site that the most important discovery of this area was made, as discussed below.

The fifth site, excavated in 1974, was on the hill southeast of the monument. Results here were very poor: only some potsherds, iron slag and a few pieces of charcoal were found.

Excavation at site 33-II revealed a formation of stones running from northwest to southeast, interspersed with brick and river stones, at a depth of 100 cm from the surface. On the same level and above, to a depth of 50 cm, a wealth of local potsherds, a few pieces of Chinese ceramic fragments, pieces of charcoal and a number of animal teeth were recovered. Some of the ceramic remnants could be dated from the Tang period. Many of the local potsherds are decorated with incised and impressed patterns. A piece of a handle is decorated with a laughing human face. Unfortunately the bulldozers were already moving in on the heels of the excavators, and excavations had to be stopped before a clear picture of the area in the past could be gained. It can only be presumed that it might have been an inhabited site. In some of the trenches a 30 cm thick layer of sand was detected, at a depth of 50 to 70 cm.

The area west of the temple was purchased in March 1974 and trial excavations were immediately undertaken. A number of trenches revealed formations of cut stones, brick and small river boulders, local potsherds and Chinese ceramic fragments. In trench 35-III a rolled piece of lead-bronze was recovered, which later on turned out to be an inscription containing a kind of *dharani*, a very interesting text. Boechari was able to read and transcribe the text, but was so modest as to refrain from interpretation. He left that to more competent Buddhologists. Nevertheless, he draws special attention to a reference in the text mentioning a building of *mahasasana* located on a hill in the southern region (*daksinapathasyaparvvatasthala*). Does this refer to Chandi Borobudur? Boechari regretted that the script of the epigraph showed the irregular and careless hands of the royal scribe.

From the general forms of the characters, he concluded that the text mentioned above could not be older than the ninth century.

At the foot of the hill, about 100 metres to the west of the temple, an important discovery was made. However, the site was recognized only after a bulldozer struck off the upper part of two stone statues. The levelling of this area was immediately stopped and a special team started excavations. They soon uncovered a Bodhisattva image and a smaller Buddha image, of which only the lower part from the waist downwards was preserved. Both fragments were made of stone.

The most important find at this site, which ran about 100 metres from southeast to northwest, comprised a great number of votive stupas and votive tablets with Buddha images made of unbaked clay. Also found here were five delicate terracotta pots, four rolled silver plates, which could not be straightened out, and a number of potsherds. A little distance to the south two rolled silver plates were found on the surface, apparently dragged away from their locations by a bulldozer. After they had been straightened out in the site laboratory they turned out to contain a one-line inscription in old Javanese script. The two silver platescontain nearly the same *dharani* text. The longer one is 10 cm long and 1.5 cm wide, whereas the shorter one is 7.5 cm long and 1 cm wide. The script on both plates is 1.5 mm high and irregularly written. According to Boechari the text of the longer plate reads:

> *sitakula sitakula sitakula kada kada kada kada manda suryya*

and the shorter plate gives the reading:

> *sitakula takula takula nanda suryya.*

It is very regrettable that this site was disturbed, and that the excavations had to be carried out in a hurry, so that the stratigraphy was not adequately recorded. Moreover the excavators did not immediately recognize some layers that contained clay artefacts, because in the rainy season in which the excavations had to be made, the unbaked clay of the votive *stupas* and tablets easily dissolved into the earth.

Dr Boechari of the University of Indonesia, who carried out a special study of these finds, mentioned that from the site above no fewer than 2,307 small clay *stupas* or '*stupikas*' and 252 votive tablets had been brought to light, either whole or fragmentary. Apparently, they had been deposited in a pit, along with five terracotta pots: one in each corner and one at the centre. There are several other sites in Indonesia that have yielded similar finds: Jongke and Kalasan near Yogyakarta, Jatikalangan near Semarang (Central Java), Pejeng in Bali, Banyuwangi in East Java and Palembang (South Sumatra). Such finds have also been reported from the mainland of southeast Asia: Burma (Myanmar), Thailand and Malaysia.

Stupika. The small clay *stupas* of these assemblages are of varying forms and sizes. However, no detailed description of them has yet been made. It is therefore necessary to classify them; a type-variety classification of this material may give further information, on account of its time, space and contextual dimensions. After examining all the collections at other places more closely – those at the National Museum and Research Centre of Archaeology, the Sonobudoyo Museum in Yogyakarta, the office of the Archaeological Reserve in Prambanan (Central Java), the Mpu Tantular Museum in Surabaya (East Java), the Bali Museum in Denpasar, Rumah Bari in Palembang (South Sumatra) – it is expected that the classification will be able to produce a more refined grouping or even lead to a typology.

The classification is based on the form of the *anda*, since all known moulds are designed only for the *anda* with the *harmika* and *yasti*. The base was apparently shaped by hand and its form depended arbitrarily on the amount of clay, which still shows the marks of the potters' hands. On the reliefs of Borobudur we can find several small *stupa* forms, distinguished by the shape of the *anda*. On this basis, three types can be distinguished: type I, small *stupas* with bell-shaped *anda* and sloping underpart (Figure 6.1.8.1); type II, similar to the *stupas* on the three circular terraces of Borobudur, small *stupas* with a more laced-in *anda* (Figure 6.1.8.2); type III, comparable to the *stupas* crowning the balustrades of Borobudur, that is, small *stupas* with a more elongated *anda* surrounded by eight subsidiary *stupika*s (Figure 6.1.8.3). The classification is also based on variations in the cross-section of the base of the *stupika*, which may be circular, quadrangular, hexagonal or oval (see Figures 6.1.8.4 and 6.1.8.5).

The third criterion relates to the size of *stupas* including the base, classified as large (l), medium size (m), and small (s), as shown in Table 6.1.8.1. It should be noted that the measurements are chosen arbitrarily; this criterion would not be valid for the Banyuwangi collections, for instance, since they contain much bigger specimens than the Borobudur collection, and the smallest *stupas* of Banyuwangi would fall into the medium size category of Borobudur.

Among the 2,312 small *stupas*, sixty-three (2.7 per cent) are large, 2,195 (95 per cent) are medium sized, and fifty-four (2.3 per cent) are small. The surfaces of 107 specimens (4.6 per cent) are inscribed with a shortened *ye-te* formula. Only 1,422 out of the 2,312

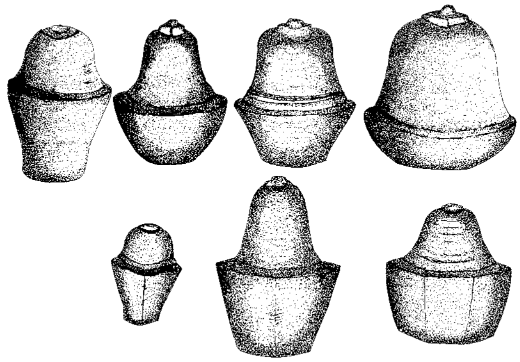


Figure 6.1.8.1
Small *stupas* with bell-shaped *anda* and sloping underpart
Source: Borobudur Restoration Project

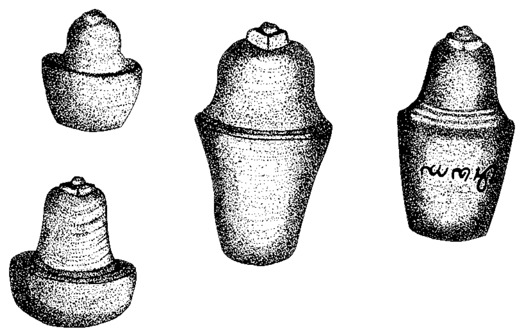


Figure 6.1.8.2
Small *stupas* with a more laced-in *anda*
Source: Borobudur Restoration Project

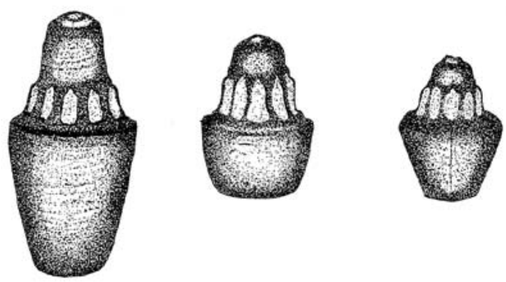


Figure 6.1.8.3
Small *stupas* with a more elongated *anda* surrounded by eight subsidiary *stupikas*
Source: Borobudur Restoration Project

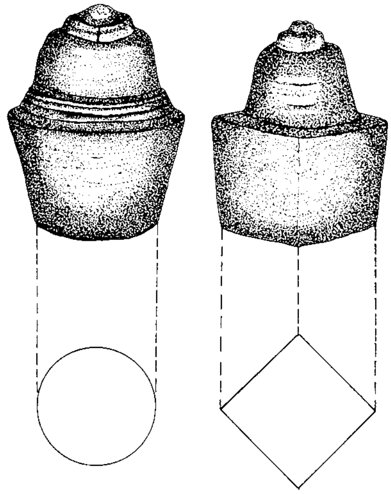


Figure 6.1.8.4
Cross-section of *stupika* base (1)
Source: Borobudur Restoration Project

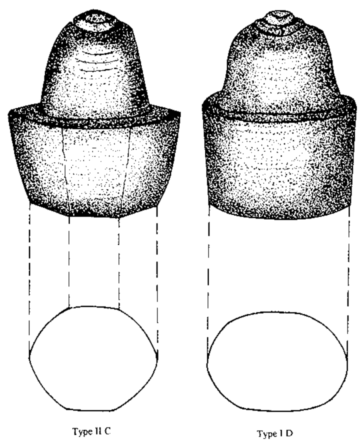


Figure 6.1.8.5
Cross-section of *stupika* base (2)
Source: Borobudur Restoration Project

small *stupas* can be subjected to formal classification, since the *anda* of the others are damaged beyond recognition. Tables 6.1.8.2 and 6.1.8.3 show the quantitative distribution of each type.

The material of the small *stupas* was also analysed at the Borobudur Laboratory and compared with the clay from areas around Borobudur. The results shown in Table 6.1.8.4 indicate that the basic material of the *stupika*s was yellowish-brown clay, which is also found within an area up to the Menoreh hills, tempered with sand and a small amount of quicklime. It is thus very likely that the small *stupas* were produced at Borobudur's ceremonial site. The total absence of moulds so far, however, suggests that we should treat this conclusion as at best provisional.

It can be seen from Table 6.1.8.4 that type III is dominant (54 per cent) and so is that of the Pejeng votive small *stupas*. A mould in the National Museum and another in the Archaeological Reserve Office of Prambanan very probably belong to that type of small *stupa*. This is very interesting since only one monument consists of a central *stupa* surrounded by eight smaller *stupas*, namely the Chandi Bungsu at Muara Takus (Eastern Sumatra). Similar structures to Chandi Bungsu – but with more than eight surrounding smaller *stupas* – are found only in the roof structures of certain temples such as Chandi Kalasan, Sewu and Mendut (Central Java). There is only one example on the relief of Borobudur that shows a temple with such a roof.

A similar arrangement of *stupas*, but with a central *lingga* surrounded by eight similar *linggas*, is found at the bathing place of Jalatunda on the western slope of Mount Penanggungan in East Java. This arrangement reflects a cosmic mountain, the Mahameru (Stutterheim, 1937) seen in the shape of Mount Penanggungan, which consists of a nearly perfect cone surrounded by eight smaller peaks. It was considered to be the Cosmic Mountain of the East Javanese kingdoms (Stutterheim, 1926).

To decide whether the popularity of type III in the Borobudur sample has a religious significance or not, it is necessary to investigate the votive small *stupas* from other sites using similar methods of classification and quantitative analysis. Then a seriation technique must be applied in order to identify whether or not the area distribution of each type of *stupika* also has temporal connotations.

On the base of a number of the *stupas* are inscriptions in Old-Javanese script, containing the abbreviated form of a formula

Table 6.1.8.1 Classification based on the size of the *stupika*

Measurement of	*Large*	*Medium*	*Small*
Diameter of *anda*	7.10–9.26 cm	6.00–7.50 cm	3.64–6.00 cm
Height of *anda*	3.80–6.32 cm	3.20–4.40 cm	1.93–3.70cm
Height of base	4.62–6.86 cm	2.15–7.60 cm	1.20–1.50 cm
Diameter/length of *anda*	4.00–7.00 cm	3.10–4.50 cm	1.83–3.00 cm
Length of *harmika*	1.80–2.50 cm	1.80–2.20 cm	0.83–2.00 cm

Table 6.1.8.2 Uninscribed *stupikas*

Type	*A*			*B*			*C*			*Total*
	l	*m*	*s*	*l*	*m*	*s*	*l*	*m*	*s*	
I	41	238	13	2	5	3	–	2	–	304/23%
II	7	167	3	9	69	11	–	1	–	267/20%
III	–	745	6	–	–	1	–	–	–	752/57%
Total	11	1,150	22	11	74	15	–	3	–	1,323/100%

Table 6.1.8.3 Inscribed *stupikas*

Type	*A*			*B*			*C*			*D*			*Total*
	l	*m*	*s*	*l*	*m*	*s*	*l*	*m*	*s*	*l*	*m*	*s*	
I	10	–	–	1	–	–	–	–	–	–	–	–	11/11%
II	–	47	14	–	4	2	1	–	1	–	1	1	71/72%
III	–	17	–	–	–	–	–	–	–	–	–	–	17/17%
Total	10	64	14	1	4	2	1	–	1	–	1	1	99/100%

of the Buddhist creed: *om ye te swaha*. The formula is usually stamped on a clay tablet, and concealed in the body of the *stupas*.

It is rather difficult to date the *stupas* accurately on the evidence of palaeography, because the formulae were not written by the royal scribes and so cannot be compared with the script of dated royal charters. Since the script on different *stupas* varies, it can be assumed that the devotees had a clay *stupa* stamped, and wrote the formula with their own hands, or had them written by one of the many monks present at the ceremony. Judging from the general form of the characters (although they are irregularly written), with a characteristic small 'flag' on top of each foot of the *akshara*, the *stupas* cannot be later than the second half of the ninth century AD.

The votive tablets also show a great variety in size and in the figures stamped on them. The biggest specimen has a diameter of 12 cm, and the smallest 6 cm. The figures stamped on them represent a seated Buddha with different kinds of *mudra*, namely *vitarkamudra*, *abhayamudra*, *bhumisparsha* or *varamudra* (it is not clear whether the palm of the hand is turned downwards or upwards) but no *dharmachakra* or *dhyanamudra* can be distinguished. Sometimes the Buddha is depicted sitting in a niche, surrounded by *stupas*. Only a small number represent a *Tara*.

We are fortunate in having come across

Table 6.1.8.4 Laboratory analysis

Type	*Sample no.*	*Colour*	*Sand %*	*Calcium %*	*Microscopic polarization of clay*
I A	131	Yellowish brown	35.62	0.065	Mont-morillonite
	707	Yellowish brown	32.56	0.059	Mont-morillonite
I B	274	Yellowish brown	29.63	0.064	Mont-morillonite
	294	Yellowish brown	36.36	0.066	Mont-morillonite
II A	163	Yellowish brown	28.98	0.070	Mont-morillonite
	310	Yellowish brown	37.37	0.064	Mont-morillonite
II B	787	Yellowish brown	29.93	0.062	Mont-morillonite
	1548	Yellowish brown	39.21	0.067	Mont-morillonite
II D	2277	Yellowish brown	37.27	0.067	Mont-morillonite
III A	459	Yellowish brown	34.43	0.065	Mont-morillonite
	404	Yellowish brown	31.29	0.065	Mont-morillonite
	169	Yellowish brown	32.61	0.065	Mont-morillonite
	903	Yellowish brown	30.53	0.067	Mont-morillonite
	18	Yellowish brown	36.35	0.062	Mont-morillonite
	200	Yellowish brown	27.99	0.058	Mont-morillonite
	61	Yellowish brown	32.80	0.060	Mont-morillonite
	49	Yellowish brown	30.65	0.063	Mont-morillonite
	631	Yellowish brown	32.33	0.064	Mont-morillonite
	1559	Yellowish brown	35.35	0.068	Mont-morillonite
Clay from the Borobudur Hill					
	5	Reddish brown	26.44	0.16	Mont-morillonite
	2	Yellowish brown	19.40	0.03	Mont-morillonite

a reference to the function of such votive tablets. In Burma, for instance, such votive tablets usually have an inscription either on the back or under or around the Buddha figure. The inscriptions inform us that the tablets were offered by dignitaries and for the sake of attaining perfect Buddhahood, either for themselves or for other people. It not too bold a surmise to assume that the Indonesian votive tablets had a similar function.

We thus have evidence of a religious ceremony near the Borobudur temple in the past. And although the material of the *stupas* and votive tablets is just unbaked clay, this does not mean that the devotees leaving these testaments of religious activity were humble people without means, as is demonstrated by the Burmese specimens.

Summing up the result of his studies, Boechari once again regretted his inability to determine the chronological relationship of these very important finds and the Borobudur monuments, since their stratigraphic position could not be accurately known. He had to be content with no more than a typological classification of the clay *stupas* and the inscribed seals, and an effort to demonstrate that religious ceremonies were apparently not performed on the monument but rather at a fixed site somewhere below it.

On the other hand, the epigraphic data give us a general picture: a temple usually had temple lands in the form of whole villages, wet rice fields, dry fields, grasslands, parks, gardens, plantations, woodlands, marshes and riverbanks. It also becomes evident that

Photo 6.1.8.1
Broad-shouldered pots
Source: Mundardjito

Photo 6.1.8.2
Broad-based pots
Source: Mundardjito

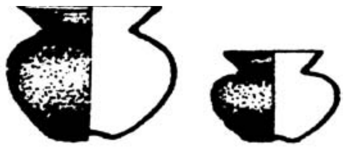
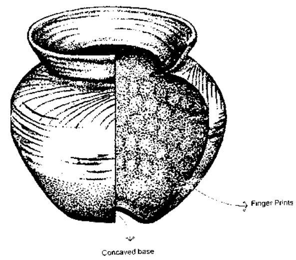


Figure 6.1.8.6
a) Broad-shouldered pots

b) **Broad-based pots**



c) Interior of pot showing fingerprints

Source: Borobudur Restoration Project

there were people – priests, monks, peasants, artisans and temple servants – living in the immediate neighbourhood, in charge of the religious ceremonies and the management of the temple and its lands. Moreover we can imagine people going there at certain times to bring offerings, hold religious ceremonies and celebrate temple festivals.

These people certainly left testimony of their behaviour in the past. We have indeed found it around Borobudur, but in such a deplorable condition that any plausible reconstruction of former life around the monument is out of the question.

In the southwestern part of the lower area of the Chandi Borobudur site, ten undamaged earthenware pots have been discovered: five were excavated in 1973 by the University of Indonesia, and five in 1974 by the Borobudur Restoration Project. Beside these, there are also approximately 14,000 potsherds discovered in the same area during a rapid emergency excavation during 1974 by the same Restoration Project. From a formal analysis of these artefacts, it has been possible to identify at least nine types of pottery found at Chandi Borobudur, as briefly described here (Mundardjito, 1982).

Pots. The pots found at this site are generally small in dimension, with streaky burnished patterns on their exterior surfaces. These pots are of two forms: broad-shouldered pots, with reducing lower dimensions (Figure 6.1.8.6a), and broad-based or onion-shaped pots (Figure 6.1.8.6b). Interestingly, both types are concave

Figure 6.1.8.7
Neckless paddle-marked cup
Source: Borobudur Restoration Project

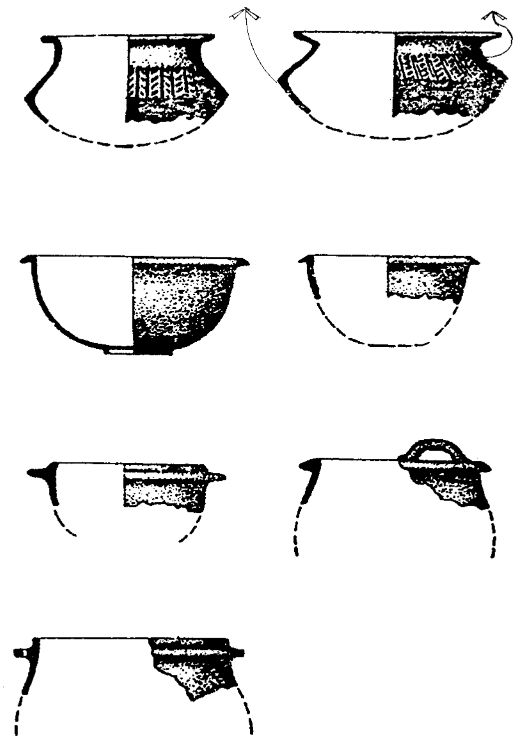


Figure 6.1.8.8
a) Long-neck paddle-marked bowl

b) Short neck paddle-marked bowl

c) Footed bowl

d) Flat based bowl

e) Outflanged rim bowl

f) Outflanged rim bowl and holes on the rim

g) Bowl with handle

Source: Borobudur Restoration Project

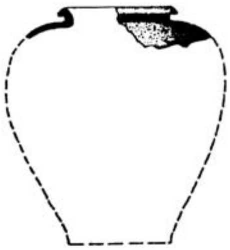


Figure 6.1.8.9
Tempayan
Source: Borobudur Restoration Project

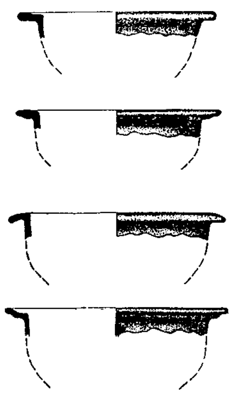


Figure 6.1.8.10
Basins with variety of rims
Source: Borobudur Restoration Project

at the base. Of the ten specimens, one is of a small or mini size, 7 cm high and 10 cm wide, while the biggest measures 15 by 20 cm. Fingerprints on the inside wall show how the woman potters of that age used their fingers as 'anvils' when they built the vessel's wall (Figure 6.1.8.6c).

Cups. The cups take the form of open and rather upright vessels, with outflared rims and carination at the lower parts. Mouth and neck diameters are about 10 cm, carination 16 cm, and they are 6 cm in height. The upper portions have carved paddle marks in chevron patterns (Figure 6.1.8.7).

Bowls. Four types of bowls have been found at the Borobudur site: (1) paddle-marked bowls, (2) plain bowls, (3) outflanged rim bowls, and (4) bowls with handles. Bowls of the first type are paddled with chevrons and carinated, with a wall thickness of 0.50 cm, mouth diameter of 20–24 cm, and height of 12–12.4 cm (Figures 6.1.8.8a and b). Bowls of the second type are plain bodied, either with or without a foot rim (Figures 6.1.8.8c and d), having a mouth diameter of 20–25.2 cm and a height of 10–10.8 cm. The third type have outflanged rims (Figure 6.1.8.8e) or holed rims (Figure 6.1.8.8f), a mouth diameter of 21.2 cm–26 cm, and a wall thickness around 0.60 cm. Their height could not be measured. The fourth type has a handle (Figure 6.1.8.8g).

Tempayan. The Borobudur *tempayan* is a vessel with a lower rim and tends to be a more closed, round-shouldered *tempayan* (Figure 6.1.8.9). There are also two types of rim: low rim, with the opening and fold oriented rim downwards; mouth diameter is 20.4 cm and estimated height around 40 cm.

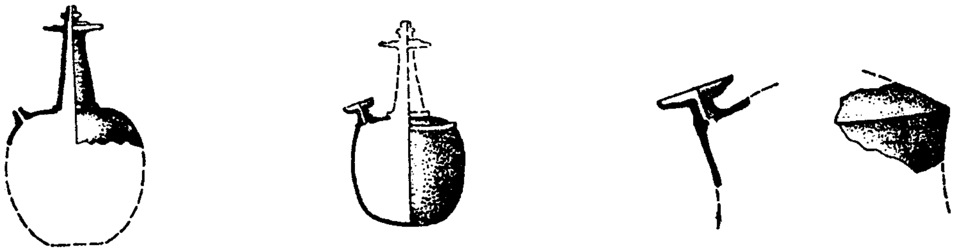


Figure 6.1.8.11
a) Rounded body form *kendi*

b) Rounded body form *kendi* with trumpet-shaped spout

c) Waisted body form *kendi* with trumpet-shaped spout

Source: Borobudur Restoration Project

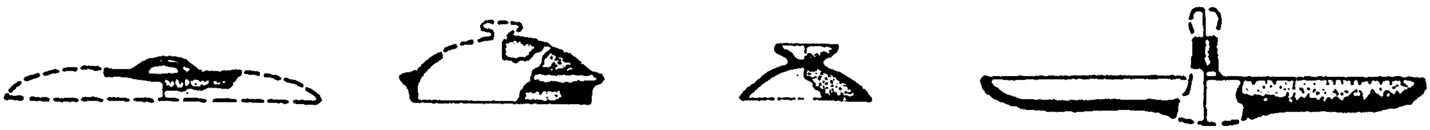


Figure 6.1.8.12
a) Convex lid

b) Convex carinated lid

c) Convex simple lid

d) Concave lid

Source: Borobudur Restoration Project

Basins. Generally, these vessels have a form similar to the first type of bowl (the open bowl with a flat, outward-curving rim edge). Their diameter varies from 40–44.4 cm, and wall thickness from 3–4 cm. The estimated height of these vessels is about 25 cm and it is highly probable that the base was flat (Figure 6.1.8.10).

Kendi. These water pitchers have widening necks and the upper part is equipped with two umbrella-shaped lids. The body portion is one of two forms: a somewhat rounded body form (Figure 6.1.8.11a and b), or a waisted form up to the carination (Figure 6.1.8.11c). Likewise, there are two forms for the spout: either pointed or funnel/trumpet-shaped. The flared spout is found on both the round-bodied (carinated) and the waisted carinated *kendi*, whereas the pointed spout is only found on the round-bodied type. The height of the round-formed *kendi* is 25–35 cm, and the diameter is from 15–35 cm, with a wall thickness of about 0.5 cm.

Lids. Overall, there are two lid forms: the first is convex, elliptical (Figure 6.1.8.12a) and generally dome-shaped (Figure 6.1.8.12b and c), while the second is a concave and open hemispherical form (Figure 6.1.8.12d). The first (convex) type has three kinds of handle, knobbed, flared-ring or looped. Edge diameters are 12–25 cm, and the height from the edge to the upper part of the handle is about 5 cm, and the average thickness is 0.6 cm. The second (concave) type of lid is oval-shaped. Lid height is about 3 cm and edge diameter 28 cm.

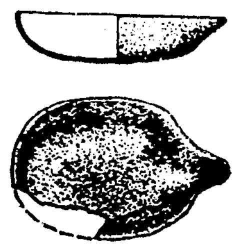


Figure 6.1.8.13
Oil lamp
Source: Borobudur Restoration Project

Oil lamps. These are in the form of low shallow cups (Figure 6.1.8.13), small in size with an elliptical circumference of about

100 cm in diameter. The height is only about 2.0 cm, with a thickness averaging 0.6 cm. The base is relatively flat. At one end, there is an open spout for placing a wick.

Decoration

Of the 14,000 potsherds found, only about 5 per cent were decorated. We can classify them into three groups according to the decorating techniques: impressed, incised and burnished. In the first group, the most abundant and interesting decoration from the artistic point of view is the paddle-marked type. This is produced by stamping a carved paddle on to the vessel's body when it is still damp ('hard leather' condition).

The result is a rather high relief with patterned decorations. We can recognize themes such as ladders, fish bones, chevrons, *tumpal*, stars, slots, nets and spider webs. It is evident that the potters had their sense of art just as the artists who made the reliefs of the Borobudur temple did. This paddle-mark decoration was impressed on only two types of containers, the bowls and the water jars, on the body, shoulder and base. This suggests that these types of container may have been used for special purposes.

Decoration by the incised technique is very rare and is found only on the spouts of water pitchers. Decoration made by burnishing is found on several types: pots, bowls, water jars, pitchers, dishes and lids. There are two kinds of burnish decoration: streaky and patterned. There are also decorations on the carinations, especially the bumping ones, made by the impressed technique, either with a tool or with finger and nail.

Paste and temper

To determine whether all the terracotta vessels found at the Borobudur site came from one or several pottery-making villages, it was necessary to investigate the raw material used: clay and mineral temper. The data required are mainly the colour and mineral structure of the clay, and the granulometrical form of the temper. The samples investigated consist of thirty potsherds selected from fragments known to belong to certain types of containers already recognized. Thus the data obtained can be used to differentiate the existing types and varieties.

The inspection was carried out with two kinds of microscopes: a binocular microscope for the specimen itself (40 × magnification), and by a polarized one for the sections (30 and 50 × magnification). Although there were technical problems, like the difficulty of making thin sections, this investigation (the first in Indonesia for this purpose) was successful.

From the point of view of archaeological method, it is interesting that observation by the naked eye gives a different result from observation by microscope. For example, potsherds perceived by the naked eye as belonging to one group were in fact found to belong to two groups when observed through the microscope. Conversely, we found that potsherds thought to belong to two groups proved to be of one group on microscope investigation. Thus, classifications based only on the naked eye – usually made by archaeologists – are not accurate enough for an investigation of whether a group of potsherds came from one or more pottery-making villages.

From observation of the thirty selected samples by the above methods, we can conclude that there are two groups of potsherds. The first consists of compact red clay vessels (as many as seventeen samples), and the second group consists of uncompact brown clay (thirteen samples). For convenience of classification we could call them the 'redware' and 'brownware' groups. Thus it is evident that the pottery used at the Borobudur site came from at least two pottery-making villages.

From the investigation we also know that almost all the samples in both the redware and the brownware groups used a kind of breccial mineral temper. There is only one sample in each group that used a conglomerate mineral temper mixture. With so small a sample, it is impossible to draw any further conclusions except that, since the source of the conglomerate temper is volcanic, it came from somewhere near a volcano.

It is also interesting to note that some potsherds are coated with a kind of red slip made of clay different from the clay used for building the body, as seen from the samples of water jars, water pitchers and bowls. This kind of red slip pottery is used on the brownware group. It seems that this special kind of pottery was made by a small group of potters or meant for a specific purpose.

Dating

It is quite difficult to date the potsherd samples we have because the 1974 emergency excavation was carried out in such a hurry that it was impossible for us to observe the stratigraphy of all sections of the 285 pits in detail. It is not surprising, therefore, that the 14,000 potsherds were not grouped according to the strata where the artefacts were deposited. In other words, the potsherds do not have a spatial stratigraphical dimension. Due to this lack of investigation, we decided to consider the collection as one component or unit of analysis, without trying to sort or group the assemblage stratigraphically, or even to date each sub-unit of the potsherds.

On the basis of Chinese ceramic finds, we can date the whole collection from between the seventh and the tenth centuries. From the 500 Chinese ceramic samples, we know that fragments of water jars, plates, bowls and the like were from the early, middle and late Tang until the early Sung period. As the early Tang started in the seventh century, we can date the finds as being from after that century, say 100 years later. So to be on the safe side we could date those samples from between the eighth and the tenth centuries, within a range of 200 years. And this is the case with our local ceramic samples. We can also date the terracotta potsherds through palaeographical study of the *stupika*s and the inscriptions. Boechari was able to date them from the second half of the ninth century AD, a date compatible with the period suggested above (Boechari, 1976, pp. 9–10). Based on this assumption, it seems that after the tenth century the Borobudur site was not used for religious ceremonies. This accords with the theory that Mataram's centre of government shifted from Central to East Java (Boechari, 1976).

Borobudur reliefs

On the reliefs of the Borobudur temple we can observe various containers that give a useful comparison with the forms of containers found in the excavations. The depicted containers not only help us to reconstruct the fragments that were found, but also to know what forms were most common at the time that Borobudur was still functioning. These reliefs can also explain how each container was used by various people under particular circumstances. For our purpose we consider the forms of the containers depicted on the *Kamadhatu* reliefs, which we take as reliefs depicting scenes from daily life, so that it may be assumed that the containers depicted on them were derived from forms in existence at that time.

It is interesting that there are reliefs showing the technique of making pottery in ancient times. We can also see from the reliefs how the clay was transported, the technique

Photo 6.1.8.3
Scenes on relief
Source: Reproduced from N.J. Krom, 1927

Photo 6.1.8.4
Relief
Source: Reproduced from N.J. Krom, 1927

of making pottery and the preparations for firing the vessels. It is also shown that there was division of labour among the people. The men carried the clay, while the women did the shaping and modelling of the pottery, as the people of Nglipoh do at present. Concerning the technique, we can see that the pottery was made by the so-called paddle-anvil technique that is also used today in villages like Nglipoh.

Ethnographical data

As well as collecting archaeological data, the research was expanded to gain information through ethnographical data. Research was done in Nglipoh village, about 3 kilometres from Borobudur, where most families were active in making pottery and the tradition had been passed down through the generations.

Through the data collected, Mundardjito found that there are two techniques for making pottery. Samples were taken from two jars with the same form, one decorated with burnish technique and the other plain. These suggest that the jars were made and used by communities that had different ways of carrying them. The burnished technique correlates with people carrying the jar with a shawl around its body so that it could not slip free despite its smooth surface; the plain type would be used by people who carried them with a shawl fastened round the neck of the water jar.

Other evidence has shown that there were other potters active in producing pottery around the Borobudur site. Petrographical analysis shows that the Borobudur pottery came from two or more pottery-making villages. The analysis was very useful in revealing the marketing pattern or the economy of pottery in general in ancient times.

Surveys conducted in 1975–76 by a sub-consortium of the Faculty of Literature and Philosophy, organized by the University of Indonesia, attempted to locate other sites within a radius of 5 kilometres. Through an intensive three-month survey, the team found thirty sites from nearly the same period as Chandi Borobudur. Their results showed that Chandi Borobudur was not isolated but surrounded by a community.

The archaeological finds at the Borobudur site undoubtedly confirm the assumption that

Photo 6.1.8.5
Carrying a burnished water jar
Source: Mundardjito

Photo 6.1.8.6
Carrying a plain water jar
Source: Mundardjito

the temple building is but one component of a bigger integrated archaeological unit: the temple building itself as the focus, but with settlement sites, ceremonial sites and perhaps other kinds of components.

6.1.9 Preparing the working areas

For the execution of the restoration project of Chandi Borobudur two working areas were prepared: the upper and the lower working areas. The upper area occupied the western end of the plateau on which the monument stands, and the site office of the Chandi Borobudur Restoration Project was located there. The lower working area was assigned the newly purchased land of the low-lying plain to the west and south of the hill.

Several parts of the plateau were used for temporary storage of thousands of loose temple stones. Some of these stones had been there for a long time, some had been retrieved from the surrounding villages, and others came from the dismantling of the northwest balustrades in 1963–65. All of these stones had to be removed to make room for the construction of offices and other facilities for the joint contractors, and also for the construction of the reinforced-concrete crane track around the monument.

This gave an opportunity to sort the stones and identify their possible provenance. It turned out that no fewer than 739 stone blocks could be put back at their original places in the monument (see Table 6.1.1.1 above).

The loose stones that could not be identified were brought down the hill and stored in open spaces to the north and south of the foot of the hill. As far as possible the stones were grouped according to their specific features. A few could in fact be pieced together to constitute particular structural components, but their original places in the monument are so far unknown.

With regard to the stones of the dismantled balustrades it is worth mentioning that, in line with the current tradition of the Archaeological Service, they were arranged according to their original places at the monument but piled upside down. In view of the fact that these stones were part of the restoration project and therefore were to be included in the forthcoming rebuilding programme, the newly established procedures were applied in full for handling them. A special place in the lower working area was reserved for them.

Apart from the need to remove loose stones spread over the plateau and the slopes of the hill, the corners of the very base of the monument had to be dismantled to make space for the construction of the crane track. At those corners the track was to make a turn so that the lower crane could be moved to any side of the monument.

Special care was also required when removing the stones of the pavements in front of the staircases of the monument and the stones allowing for water percolation from the monument to the hill slopes.

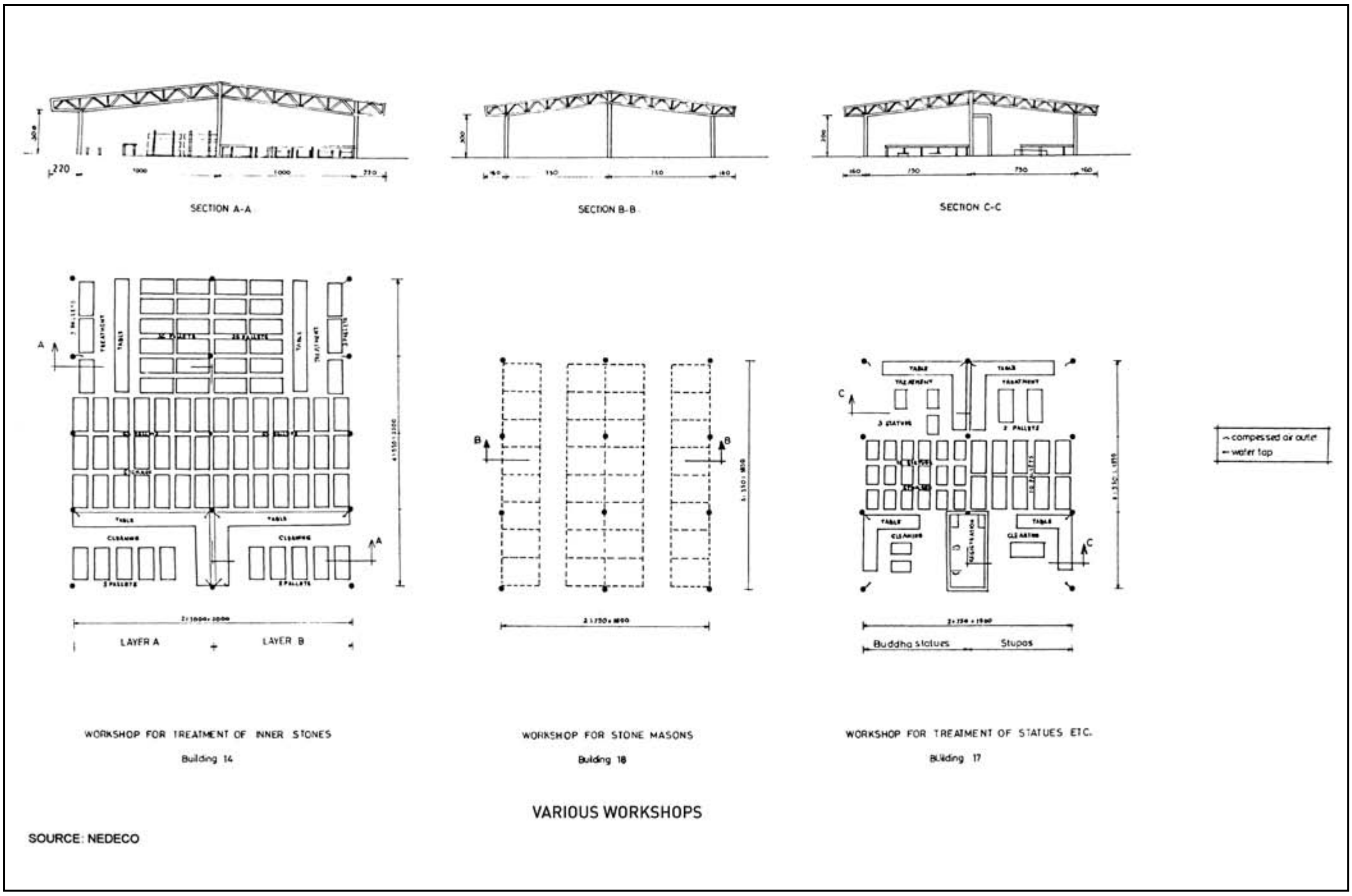


Figure 6.1.9.1

Various workshops

Source: NEDECO

Loose stones collected from the bore-holes in the different galleries also had to be removed. Since they consisted of inner stones, which were not to be put back in their original places when rebuilding the monument, there was no problem in collecting them in one of the stores in the lower working area.

The lower working area consisted of fields purchased in stages by the project. It sloped slightly from north to south, so it had to be levelled before the construction of stores and other working facilities could begin. As discussed earlier, the procedure of buying the land unfortunately took so long that it had to be used as a working area as soon as the purchase was finalized. This left no time for systematic archaeological research, yet never again will there be any such opportunity to reveal Borobudur's past through diggings in the area all around the monument.

Excavations were carried out, indeed, but hastily and only in random trial trenches. Even these rescue excavations were confronted with the rapidly progressing work of the bulldozers that the joint contractors used for levelling the area. It was deeply ironic that the most significant archaeological find was an accident that was due to the bulldozers, which unearthed the lower parts of the two statues and the clay *stupas* and seals only a few metres from where the archaeologists were digging.

As well as being identified in relation to their positions at the monument, the stones were also classified according to their type and function.

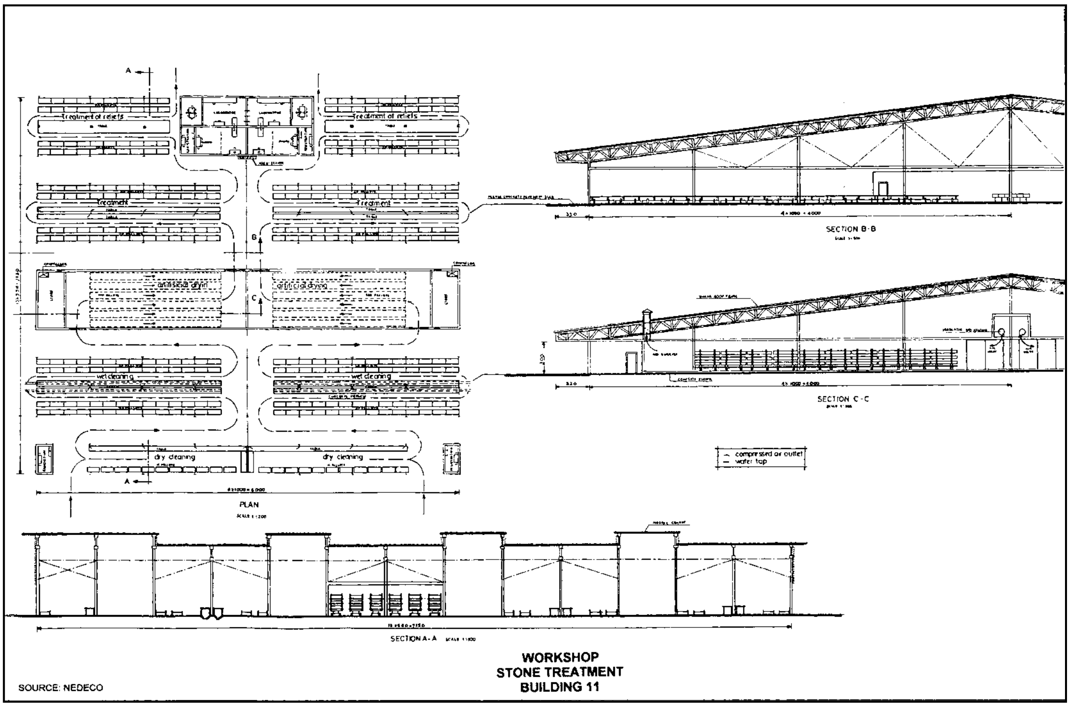


Figure 6.1.9.2
Stone treatment workshop
Source: NEDECO

6.2 Dismantling and reconstruction

6.2.1. Dismantling

The first step in dismantling was the marking of the stones. In principle no outer stone was to be removed before its pallet and area number had been indicated on its top surface. The exceptions to this rule were of course stones whose top surface would be visible and so could not be marked; in these cases the only option was for the markings to be placed on the underside.

A copy of the relevant detail drawing of series B (see Section 6.1.2) was taken to the place where dismantling was under way so that the correct number could be read from it. The outer stones were then carefully loosened from their position and placed in a pallet. Removable scaffolding was used to assist in the work and where a stone was too heavy for two men to lift, a scaffold crane was available at each work point.

As noted in Section 6.1.4, the pallets were wooden crates with nine compartments. If a stone was too large to be contained in one compartment, one or more compartment dividers could be removed. The pallets were designed to be easily picked up by a crane and easily stackable in both loaded and unloaded states.

With the help of a tower crane (one per side) empty pallets were brought to the monument and loaded pallets transported to the upper work level, to await the next stage of their journey. The inner stones (which were left unmarked) were carried in pallets with no compartment dividers.

The workface took on quite an erratic appearance. The dismantling began from the middle (the stairway) on all galleries and the plateau at both the north and south sides.

Photo 6.2.1.1

Rail track of the tower crane

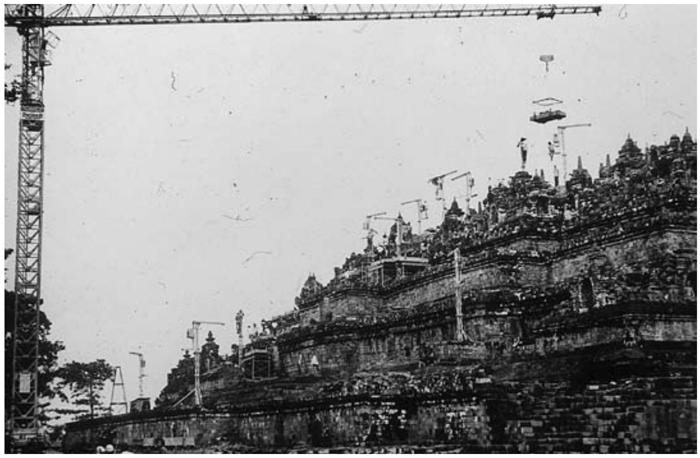


Photo 6.2.1.2

Tower crane

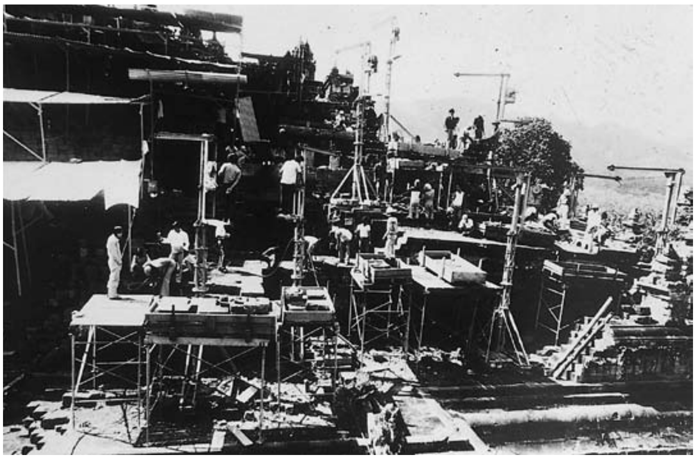


Photo 6.2.1.3

Dismantling activities

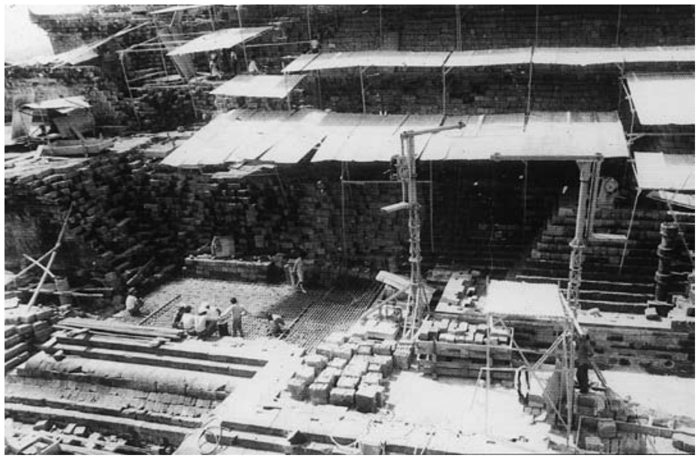


Photo 6.2.1.4

Rebuilding

Source: Borobudur Restoration Project

When enough of the balustrades had been removed, work began on removing the outer stones of the main wall – once again from the middle – followed soon afterwards by the inner stones. The slope of the workface during dismantling was 2:1 (2 vertical to 1 horizontal).

The danger of disturbing the equilibrium of the subsoil set a limit to the amount that could be done at one time. The main wall of a gallery could not be dismantled over a greater length than the dismantled length of the main walls above. In practice this meant not only that the workface of the main wall of one gallery had a slope of 2:1 but that the complex work front from plateau to hidden foot had approximately this same slope. Reconstruction work began approximately one year after the start of dismantling.

The dismantling of the north and south side took approximately two years and was followed by work on the east and west sides.

As far as registration is concerned, the prior identification of the pallet systems meant little essential work had to be done on site. In accordance with the dismantling schedule, the empty pallet with the correct number and the already completed pallet card were brought to the monument at the appropriate moment. The information contained on the pallet card was then checked, and only remarks pertaining to the enclosed fragments, missing stones or any other points coming to light during the dismantling were added to the card.

At the work point a record was made of which pallets had been loaded. This information was passed on to the central archive on a daily basis so that it could maintain a complete and up-to-date record of the work results. One of its important functions was to plan revisions to the dismantling schedule.

The dismantling was not carried out on all four sides of the monument simultaneously, but confined to two sides at any one time. The north and south sides were dealt with first, and immediately afterwards the east and west. The dismantling of the walls had of course to wait until all the balustrades had been removed.

The dismantling work was to be carried out in five stages for each of the sides of the monument, and every stage covered several working areas. The basic starting point was at the middle of the staircase, and the working areas extended to the right and to the left.

The sequence of activities can be illustrated as follows.

- Stage 1 covering thirteen working areas
- Stage 2 consisting of ten areas following immediately after completion of stage 1
- Stage 3 with ten areas
- Stage 4 with eight areas
- Stage 5 comprising twelve areas.

The length of each dismantling area was fixed at about 7 metres by the need to have sufficient space to lay out the concrete slab. For every working area a team of five men was employed, consisting of one specially trained leader, two assistants and two unskilled labourers.

The dismantling of the north side was started in February 1975 and was completed in July 1977. It involved a total of 45,307 outer stones and 176,853 inner stones. The dismantling of the south side was carried out from May 1975 to June 1977, and dealt with 48,835 outer stones and 147,644 inner stones.

The dismantling of the west side took place from August 1978 to September 1979, removing 39,690 outer stones and 134,657 inner stones. From the east face 37,012 outer stones and 102,073 inner stones were dismantled between September 1978 and September 1979 (layer B stones have been included in the number of inner stones here).

The exposed parts of the monument were protected with galvanized iron plates after the dismantling. This was needed to prevent heavy rains saturating the bare parts of the hill, which could have led to an earth slippage.

During the dismantling special attention was paid to the possibility of coming across archaeological evidence. A few finds were indeed made, consisting of:

- two staircase structures under the present staircase between galleries 1 and 2 (earlier touched upon by van Erp in his study of the hidden foot)
- a small *stupa* under the wall of gallery 3 on the north side, east of the staircase
- a length of stone with a number of niches in it, which had no apparent connection with the structures alongside it
- a wall-like structure in the floor of the base of the monument, to the right as well as to the left of the northern staircase
- a similar structure to the right and left of the staircase between galleries 1 and 2.

Unfortunately the search for a sacred deposit did not yield any result, in spite of meticulous investigations at the magically vulnerable spots at the four corners of the structure and the four ends of the axes at every stage of the monument.

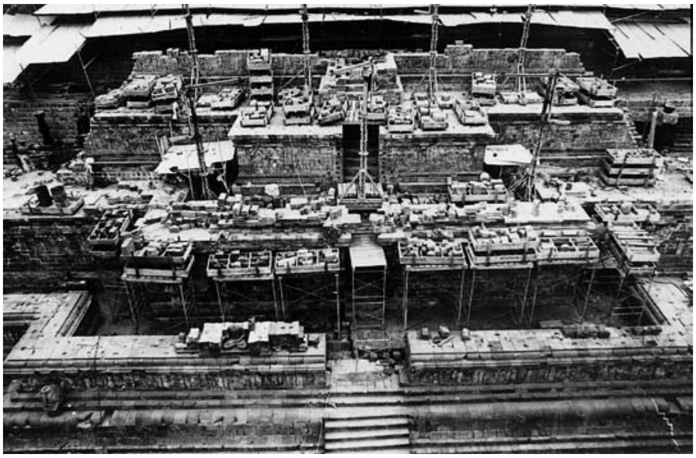


Photo 6.2.1.5

Rebuilding work on the east side, on both sides of the stairs

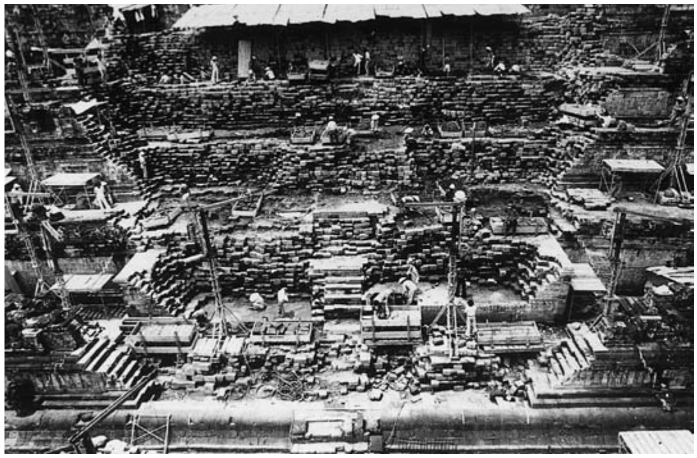


Photo 6.2.1.6

Dismantling of stones on the west side

Photo 6.2.1.7

Buffer storage

Source: Borobudur Restoration Project

6.2.2 Stone treatment

The dismantled stones were brought to the workshops for cleaning and further treatment, which depended on the type of stone and its function on the monument. Outer stones, inner stones and element stones were stored separately.

Each relief stone was thoroughly cleaned, manually or chemically, through dry or wet cleaning, as described in Section 6.1.6. Other sculptured stones and loose elements such as statues were cleaned in the same way, the specific cleaning methods depending on the type of deterioration.

Dry cleaning comprised the following activities:

a. Removing van Erp's cement and clayish deposits on the sides of the stones, using compressor-driven tools or hand tools. The deposits were carefully removed in order not to damage the stones.
b. Removal of organic growth, that is, higher vegetation such as spermatophyte, pteridophyte or moss by wooden spatula or by hand.

Wet cleaning involved washing the stones manually, using brushes and a great deal of water to remove dust, remains of clay and several kinds of organic growth like algae and mosses which could be easily removed without the use of chemicals.

After the manual cleaning, remains of lichens, algae, mosses and salt deposit were generally still present on the stones. Even the most rigorous manual cleaning was apparently not enough to remove them, especially the remnants of lichens. Chemical treatment was used only when it was deemed necessary, but a certain mixture of chemicals was usually used to remove these organic remains. This mixture, commonly called AC 322 and developed by P. Mora and L. Mora from Italy, is composed of:

- Ammonium bicarbonate: 30 gr.
- Sodium bicarbonate: 50 gr.
- Carboxymethyl cellulose: 50 gr.
- Disodium salt of EDTA: 25 gr.

Photo 6.2.1.8
Hidden foot
Source: Borobudur
Restoration Project

Photo 6.2.2.1
Workshop for stone treatment

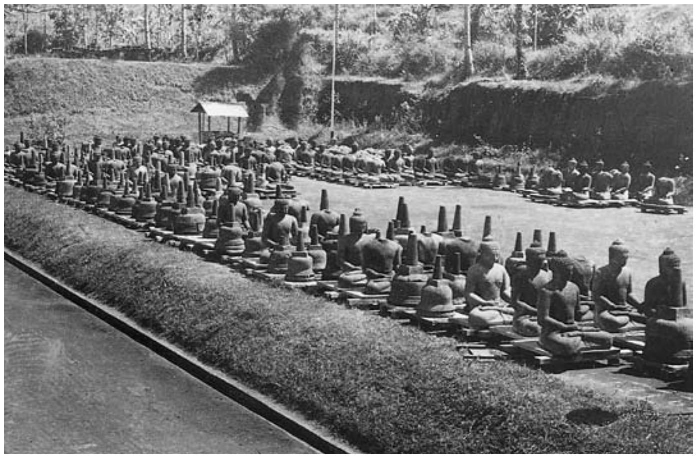


Photo 6.2.2.2
Final storage of the elements
Source: Borobudur
Restoration Project

- Disinfectant: 3 cc.
- Add water until the volume reaches 1,000 cc.

Clay was added to the mixture of these chemicals to make a paste. This was brushed on to the surface of the organic remains to a thickness of approximately 0.5–1 cm and left there for twenty-four hours. It was then removed by means of a spatula and the surface was brushed and rinsed thoroughly. To ensure that no more chemicals were left on the stone, the pH of the washing water was checked. If the pH measured 8 or higher, the cleaning was continued until the pH had become neutral. Treatment with AC 322 could be repeated up to a maximum of three times if necessary. The organic growth and other remains had to be totally washed away to prevent the recurrence of biological deterioration of the stones.

Photo 6.2.2.3
Stone bonding
Source: Borobudur
Restoration Project

Photo 6.2.2.4
Stone treatment

Photo 6.2.2.5
Electromagnetic scan

Source: Borobudur Restoration Project

Photo 6.2.2.6
Elimination of rhizomes of mosses in the pores of the stones using a fine needle
Source: Borobudur Restoration Project

Some difficulties were often faced in eliminating salt deposits and rhizomes of mosses that had penetrated the pores of the stones. This required special steps depending on the petrographic type and the weathering stage of the stones.

It is known that mosses are among the biological factors that play a dominant role in the deterioration of stones. In the mosses' generative phase stones are attacked by a very short stem with ramifications that bear leaves and rhizomes. Rhizomes, which form very fine fibres, often penetrate the pores of stone to a depth of up to 5 mm.

The cleaning methods described above made it possible to brush the rhizomes of mosses off the surface but some still remained in the pores. To eliminate these, a fine needle was inserted carefully into the pores of the stone, taking care not to scratch the stone surface. These methods of removing them were carried out as often as possible but despite all efforts some of the rhizomes could not be entirely eliminated. The advanced stage of stone weathering made it inadvisable to use more drastic measures.

Salt deposits were found on the surface of the reliefs, in cracks and at the joints of the stone blocks. Sometimes the deposits appeared to have covered up the coating van Erp had applied. Deposits, mainly consisting of salt of silicate and carbonate, were complicated by chemical or biological processes. At some places they had formed concretion, efflorescence and efflorescence.

Total cleaning of the salt was not possible. Since it is much more compact and harder than stone, cleaning would be technically very difficult and could harm the stone itself. On the other hand, it was important to reduce the salt deposits, especially where they were totally covering the surface and plugging up the pores so as to prevent the evaporation of moisture.

The salt concretion was removed by means of a spatula or other tool, until only a very thin layer remained. At that point the cleaning had to stop, to avoid damaging the stone itself. This treatment was similar to the dry cleaning described earlier.

To remove soluble salt several methods were used. The first, which had a double function, was again the use of AC 322. Experiments conducted by P. and L. Mora showed that it would make the salt more soluble so that it could easily be washed away.

Another method was the use of paper pulp, or demineralization through a water bath. Paper pulp was used on stones that could not be immersed in water. The pulp, containing aquadest of demineralized water, penetrated the pores of the stone where the water dissolved the salt. This salt was further absorbed into the paper pulp through evaporation processes. This process took several days to yield the desired result. When the pulp had dried, it would be removed and replaced by another layer of paper pulp if necessary.

Removal of the soluble salt by dipping the stone in a bath of normal, osmotic or demineralized water was the other method used. All the pores of the stone were pervaded by the water which dissolved the soluble salt. Sometimes the water was agitated to facilitate the dissolution. After some days the water could be replaced.

After all cleaning operations had been conducted, the stones were stacked in the drying chamber or 'oven' where an artificial drying process was developed. In this airtight room the stones underwent a drying process for two to three weeks at a temperature of 40 °C.

From the 'oven' the stones were transferred to the repair department. There they were checked one by one to see which needed repair and what kind of further work was required.

There were several different operations for stone repair. Bonding and glueing were used to attach stone fragments to their 'mother' block. If the broken stones had been temporarily bonded with thermoplastic adhesive UHU they had to be parted from one another by means of Acetone solvent which removed the bonding agent.

The most widely used thermosetting adhesives were Davis Fuller 614 and Akemi Normal Stein U. Marmorkitt Universal.

The choice of adhesive depended on the volume of the broken stone. Small stone fragments were glued with Akemi, which set in forty minutes. Davis Fuller 614 took three or four hours to set, since it could not have pressure applied through a carpenter's press. Large stone fragments were bonded with Davis Fuller because the operation took a longer time to perform.

Another method, rather similar to bonding, was riveting. This method was used to join big pieces of stone, for instance when one stone block was split into two pieces, where the reinforcement of a stainless steel rivet was considered necessary.

A filling technique was also sometimes used. In some cases holes had formed on the surface of the reliefs, through either a process of corrosion or dissolution of some minerals by water action. In such a case the holes had to be filled up to prevent further deterioration of the stone, using resin mixed with stone

Photo 6.2.2.7
Stone pallets
Source: Borobudur Restoration Project

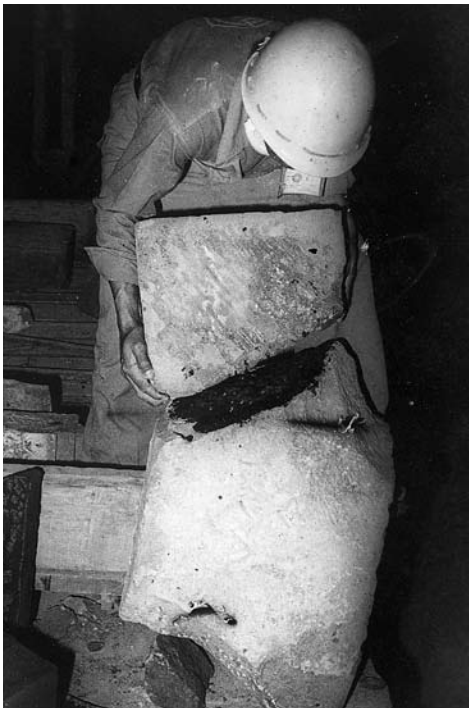


Photo 6.2.2.8
Stone binding
Source: Borobudur Restoration Project

Photo 6.2.2.9
Buddha head bound with iron key
Source: Borobudur Restoration Project

powder. At the same time, a 'camouflage' operation was performed on the surface of the stone, as discussed below.

Further steps might be necessary to restore damaged stones. In exceptional cases the missing part of a stone was replaced by a new piece. Such a falsification was only justified when technical consideration showed it to be necessary.

An injection technique was used to eliminate fine and very fine cracks in the stone without causing immediate danger of disintegration. This operation entailed filling up a hole, previously drilled into the crack, with a very low viscosity resin injected by means of a syringe.

The dry cleaning method was used for a second time to eliminate the last remains of salt concretion on the surfaces and at the edges of the stone blocks, while securing a perfect and seamless jointing.

One final repair technique should be mentioned. This was the application of camouflage to eliminate inappropriate appearances such as pocks and seams that contrasted with the neighbouring stone surface. For this purpose

Photo 6.2.2.10
Camouflage
Source: Borobudur Restoration Project

the resin, the stone powder and the colouring agent were carefully selected while performing the necessary tests in the laboratory.

Once the stones had been cleaned and repaired in full accordance with the diagnosis, they had to undergo the third and final stage of treatment. This was implemented by the application of Algicide Proven, Herbicide Hyvar X Liquid or Fungicide Quat at a concentration of 1–3 per cent. This was intended to protect the stones from organic regrowth during the year or more that they were kept in the final stage of storage.

It was only then that the stones were ready to resume their long journey from dismantling at the monument back to their final resting place when rebuilding. The different stages along this route were necessary to ensure that they were in the best condition to form the building material of the reconstructed Chandi Borobudur.

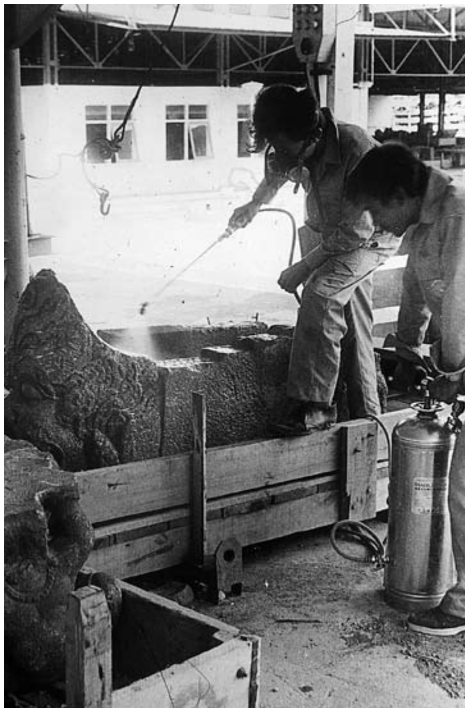


Photo 6.2.2.11
Protective treatment by chemical pesticides with low concentrates
Source: Borobudur Restoration Project

6.2.3 Structural reinforcement

The aim of the structural reinforcement or engineering design is to prevent subsidence in the future, to improve drainage and to regulate the passage of water within the monument. The structural design consists of the following parts:

1. Broad concrete slabs laid in an unbroken layer under the four gallery floors and the adjacent wall. These concrete slabs provide:
   - a first water barrier
   - support to the weak points in the stone piling
   - distribution of the irregular load
   - better cohesion in case of earthquakes.
2. A filter layer against the core of the layer hill; this layer will intercept possible water movement to the outer stones.
3. A drainage system of glazed ware piping, to carry off rainwater and water from the filter layer.

4. A watertight layer A, of filled bitumen, to prevent the water collected in the layer from seeping into the piled up stones.
5. A watertight layer B, consisting of a layer of stones treated with bitumen and with their joints sealed with bitumen; this layer is designed to reduce to the minimum the reservoir from which moisture is transported to the outer stones, and also forms a second barrier to moisture or other matter from the core of the hill.
6. A watertight layer C, also composed of a layer of filled bitumen; this is to prevent water which may have been in contact with concrete seeping through cracks in the concrete slabs.
7. A roof to the gallery, created around the hidden foot; the roof is to be of concrete slabs with air vents.
8. All technical, organizational and administrative measures necessary for the execution of works (1) to (7).

Balustrades, main walls, stairways and a proportion of the inner stones were dismantled stone by stone. This work was executed from above (the plateau) to below (the hidden foot) to prevent the danger of rotational slide in the hill.

The inner stones were left in place; when parts of the core of the hill were exposed, they were immediately covered with inner stones to prevent the soil washing away or drying out. The subsoil was tested at specific points for hollows or weak places.

Other stones were removed for cleaning and, in the case of outer stones, any necessary repair and/or treatment. Inner stones only required cleaning. Both types needed to be stored for some time before they would be used in the reconstruction, which was carried out from below upwards. The watertight layers, inner stones, concrete slabs, filter layers, and finally the outer stones, balustrades and gallery floor stones were built up successively according to the methods laid down. The *stupa* terraces and the main *stupa* were not dismantled.

6.2.4 The rebuilding

The replacement of the stones required the most accurate calculations since they had to be put back in the right position. It should be understood that these were not the original places that they had occupied before dismantling. The rebuilding process itself changed the condition of the monument, and the position of the stones had to be adjusted to the new circumstances. The formerly leaning and sagging walls had been reconstructed in an upright position and lifted up; previously tilting gallery floors had been levelled. Moreover, as the stones were fitted in place tightly together, there were now no seams between them, which meant that the dimensions of the walls were smaller than they had previously been. As a result, the position of the corners of the edifice had to change.

Since it was intended to keep intact the base and the circular terraces, the surface line of the encasement and the base line of the first circular terraces served as the fixed lower and upper boundaries for the reconstruction work. The space in between had to be calculated in such a way that the restored parts of the monument would fit precisely into it.

To position the reconstructed walls and balustrades correctly, certain points and lines were fixed as references. The reference line for the first gallery was fixed at the centre line of the band separating the upper and lower rows of relief panels, at a height of 277.191 metres. For the second, third and

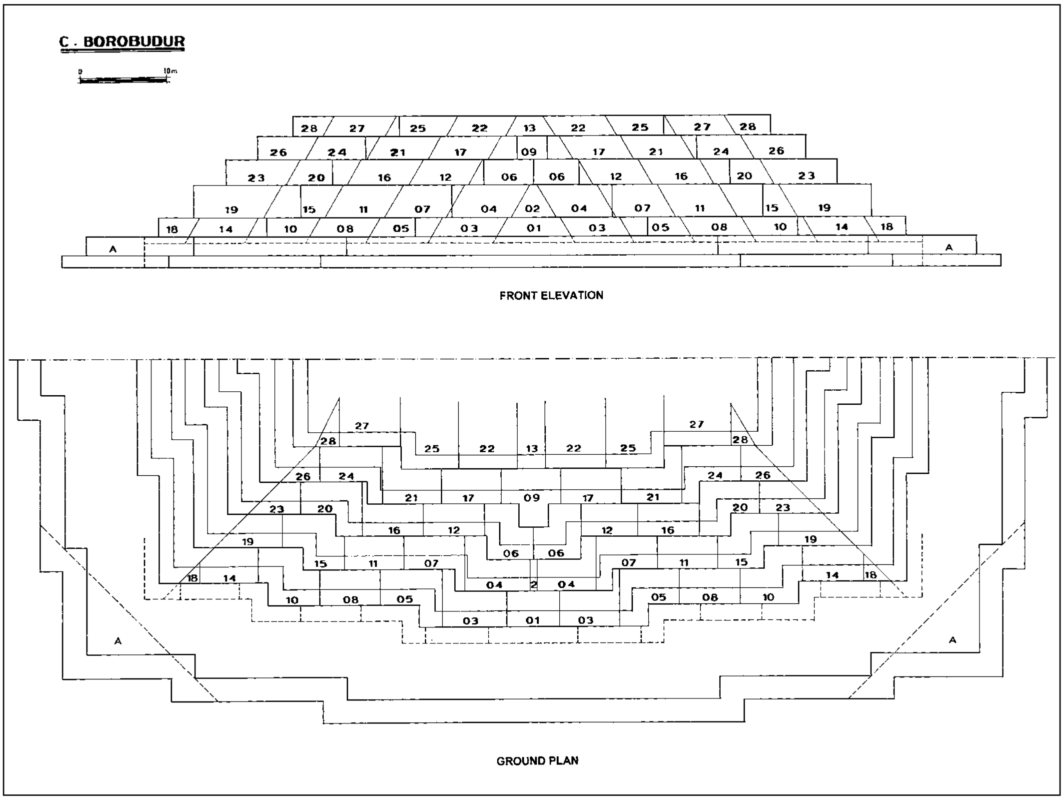


Figure 6.2.4.1
Rebuilding scheme North/South
Source: Borobudur Restoration Project

fourth galleries the line of the plinth – the edge of the stones of the second layer above the floor – was fixed as reference at respectively 280.77, 283.31 and 285.88 metres. Corner points were situated on these reference lines.

With respect to the corner points it should be added that the rebuilding at the north and south sides resulted in a substantial shift due to the decreased length of the walls. This change was anticipated in the reconstruction design, particularly when planning the rebuilding of the east and west sides. What was not anticipated, however, was the remarkable way that the outer corners tended to shift towards the staircases and the inner corners towards the outer corners.

In fact, it was accepted that the rebuilding might not exactly conform to the precisely calculated plans that had been made. The individual stones demanded different solutions and a discrepancy of a few centimetres was within the limits of tolerance.

The process of dismantling and rebuilding at the north and south sides of the monument was extremely instructive, in the sense that the experience gained provided a solid base for the reconstruction design of the other sides. These east and west sides posed fewer difficulties since no significant structural deviations had been observed, and thus no drastic changes were required. Nevertheless, the design coordinates did need to be revised.

The rebuilding work on the north and south sides caused several changes in the overall plans. The schedule for rebuilding one side, expected to take thirty-nine months with a workforce of eight members per team, could not be realized. The working areas were not spacious enough to permit more than five

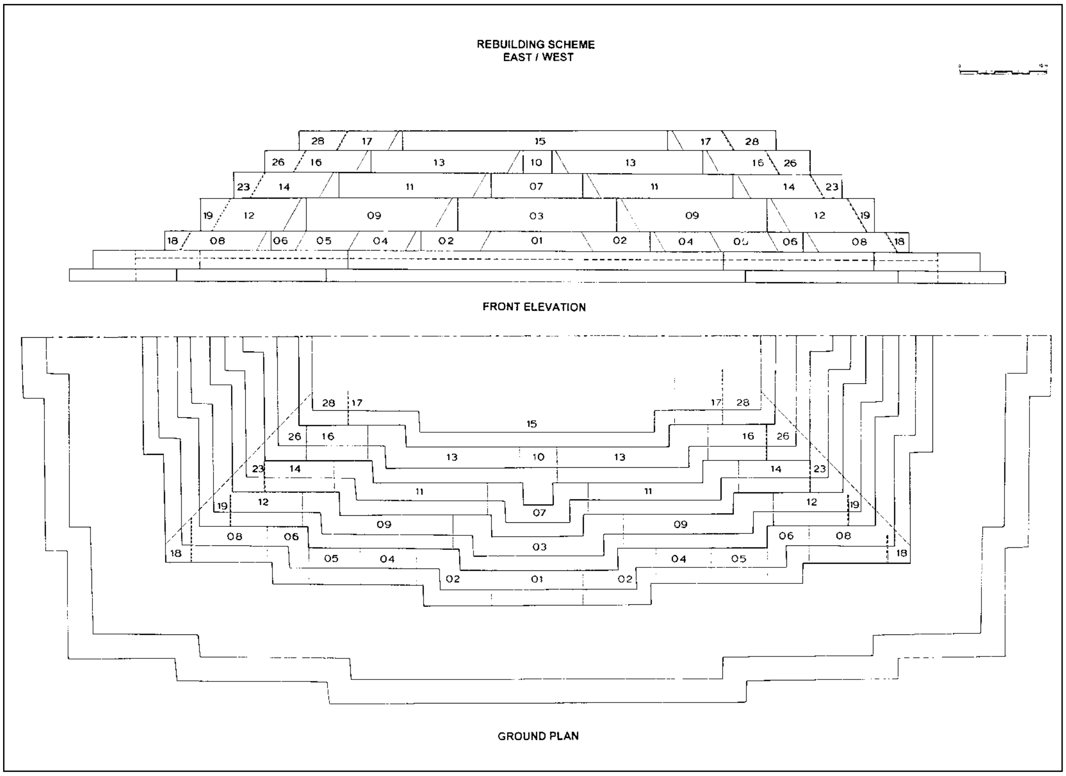


Figure 6.2.4.2
Rebuilding scheme East/West
Source: Borobudur Restoration Project

people to work simultaneously. Moreover, since the rebuilding was in fact only part of a complicated series of activities in a network of planned operations, the constraints that were experienced provided a sound basis for revising the work schedule and reorganizing the work teams.

In view of the exceptional case at the northern part of the monument, where the walls of the first gallery were leaning forwards and those of the second gallery backwards, a review of the entire rebuilding plan was deemed necessary. The rebuilding work was in fact not restricted to returning the dismantled stones to their fixed places at the monument, but included a series of activities to strengthen its foundations. These included:

- The subsided foundations were levelled and covered with rammed concrete, and layer B was laid out.
- A water discharge system was created through the different stages of the monument, involving the partial dismantling of the encasement at the foot of the monument.
- Layer C was laid out so as to allow the concrete slabs to be installed.
- Layer A was constructed, complemented by the installation of the filter layer and the coating with araldite tar of its stones, and the placing of joint-bends in the water discharge pipes.

After the different stages of preparatory work had been completed, a trial rebuilding was felt necessary. One difficulty was caused by the adoption of the band between the upper and the lower rows of relief panels of the northern wall of the first gallery as the reference line. To ensure that this band was properly horizontal, the wall had to be rebuilt up to that level

Photo 6.2.4.1
Rebuilding scheme
North/South
Source: Borobudur Restoration Project

Photo 6.2.4.2
Rebuilding scheme
East/West
Source: Borobudur Restoration Project

before proceeding with the following stage. If the trial rebuilding showed an irregularity in the course of the band, as it usually did, the correction had to be repeated. This involved dismantling the reconstructed wall, which consisted of seven or eight layers of stone. This procedure had to be repeated many times.

The rebuilding consisted of:

1. Laying out of the lead sheets on the base of the wall
2. Reassembling the outer stones
3. Reassembling the second stones (immediately behind the outer stones)
4. The reconstruction of layer B
5. Arranging the inner stones in between layers A and B.

Whereas the dismantling had started with removing the stones of the balustrades, the rebuilding had to start with the reconstruction of the walls in order to obtain the necessary working space on the terraces. The later stages of work, however, were similar in that the sides were divided into stages and every stage into working areas. The reconstruction of one stage was carried out at several working areas simultaneously.

In fact rebuilding and dismantling were carried out at practically the same time. As soon as the first stage of dismantling was finished and the second was due to start, the first stage of rebuilding commenced.

A basic reference for rebuilding was the series B drawings showing the pallet number and compartment, and the number of stones for each area of rebuilding, while the reference line had been prepared beforehand.

The rebuilding at the north side started in February 1976 and was finished in November 1978. In total no less than 35,164 outer stones and 85,680 inner stones had been put back in the reconstructed monument. At the south side the rebuilding started in February 1976 and was completed in August 1978, replacing a total of 35,901 outer stones and 94,504 inner stones.

The rebuilding of the west side was started in February 1979 and was completed in March 1982, involving 51,019 outer stones and 111,130 inner stones. The rebuilding of the east side was begun in March 1979 and was terminated in March 1982, involving 49,442 outer stones and 114,772 inner stones.

It is worth noting that the changes in position of the reconstructed walls entailed changes in the galleries; the passages of the first and the second galleries became narrower. This change did not create serious problems. The real difficulty involved the increase in height of the reconstructed mounting stages in relation to the first circular terrace. According to the calculations, the reconstructed plateau marking the upper limit of dismantling and reconstruction would reach the same level as the first terrace. Though it was already known that the upper structure of the monument had subsided by more than 1 metre, it was considered stable enough not to require work in the restoration programme. Consequently, to prevent this upper part from being absorbed by the reconstructed plateau, the height of each of the different galleries had to be lessened by several centimetres. Even so, the vertical proportions could not be entirely preserved and the first circular terrace had to become lower in comparison with the floor of the plateau.

6.3 The Consultative Committee and progress evaluation

The Consultative Committee for the Safeguarding of Borobudur (for convenience called the CC) was an advisory body set up by the Indonesian Government in January 1973 in compliance with UNESCO's wishes. The members were appointed in accordance with the proposal of the Director-General of UNESCO, each in his personal capacity. They were Dr Chihara of Japan, Dr Raymond Lemaire from Belgium, Dr Karl G. Siegler from the Federal Republic of Germany, and Dr Johannes E.N. Jensen of the United States (who retired in 1975 and was succeeded by his fellow countryman Mr W. Brown Morton III). Professor Roosseno from Indonesia was appointed Chairman of the Committee; he had earlier presided over the coordinating body for the Restoration of Chandi Borobudur (known as Badan, for short).

The CC met at least once a year in Indonesia (Jakarta, Yogyakarta or Borobudur) in accordance with the terms of reference, to evaluate the progress of work so far accomplished and to lay down a programme for the next phase. Reports on the progress of work were prepared and presented to its annual meetings, and subsequent action reflected the deliberations at the sessions and the decisions made by the CC. NEDECO's work programme, and indeed all the other programmes, were liable to modification whenever the committee deemed it necessary.

The first CC meeting. At the very first meeting of the CC in February 1973 a serious objection to NEDECO's engineering design was launched by Dr Lemaire, in particular with regard to the planned large-scale dismantling of the monument. In his view a restoration that involved the demolition of a sound monument could not be justified. Other ways and other means should be found to carry out the work without damaging the monument to be restored.

However, the evolution and evaluation of NEDECO's design had taken many years and involved many experts. A total revision would not only mean that the planning had to be started anew but also that an endless repetition of former deliberations would take place with little prospect of reaching a solution that would satisfy all the parties concerned. Furthermore, marking the fifth year of the inclusion of the Chandi Borobudur Restoration Project in the Five Year Development Plan, the Indonesian Government was determined to start the restoration work in August 1973. For this purpose the President of the Republic of Indonesia was invited to inaugurate this national event and to announce the firm intention of the Indonesian people to save their cultural pusaka. With this programme in mind, there was not much time for setting up a totally new restoration plan.

At its closing session the CC unanimously adopted a report, drafted by an ad hoc commission, noting with much appreciation the results of the extensive technical studies and research undertaken over a period of more than five years by Indonesian and international experts and consultants. With respect to the archaeological investigations, the CC noted with satisfaction the efforts already made and those to be made in the areas that were intended to be used for the crane track, the work sheds, the storage areas and other ancillary works. It also expressed its satisfaction with the intensive search for missing architectural and sculptural fragments in the surroundings of Borobudur, which had led to the discovery and identification of large numbers of important elements, thus making possible a more complete reconstruction of the monument than during the first restoration at the beginning of the century.

In fact, the CC recognized all the qualities and merits of the various studies for the restoration and preservation of the monument, which had created a solid basis for the elaboration and the implementation of the project.

On the other hand the CC members also recognized the great responsibility entrusted to them in advising the Indonesian Government on the proper performance of the project. It was therefore the committee's recommendation that the following procedures be instituted in preparing the tenders submitted to potential bidders:

1. That since the aim of restoration was to preserve *in situ* as far as technically possible all the original parts of the monument, and as this seemed possible for several parts of the sanctuary, continuing studies should be developed to realize that objective throughout the entire implementation of the project.
2. That the tenders be reworded so that the maximum flexibility in the performance of the contract would be a basic philosophy underlying the work.
3. That tenders for the contracts be submitted immediately.

Finally the CC was of the opinion that the tender documents and the detailed description of work, with the above provisos, formed a sufficient basis to proceed with the international invitation for bids in accordance with the time schedule.

The second CC meeting. The second CC meeting was held in the same year, from 2 to 6 July 1973, in Yogyakarta. In his opening address the Director-General of Culture pointed out that, as the first session had primarily set out to establish a solid foundation for further international cooperation for the safeguarding of a monument of universal value, the second session was expected to appoint the appropriate contractor so that the actual work could be started. Special attention should be paid to the participation of the local government in the execution of the project, in particular with respect to the development of the Borobudur area. In fact, the governor was the supervisor of any Pelita project located in the province.

The deliberations of the second meeting were concerned mainly with the budgetary consequences for tendering of the instability of international currency rates and the continuing inflation of the rupiah.

The CC also examined a document submitted by Mr Lemaire suggesting possible alternative solutions by which further studies could be made and which could allow more conservation *in situ* and less danger to the monument.

The CC recommended, among other things, that:

1. The contract should be concluded with the lowest bidder, and that its clauses be drafted in a way that would allow the later adoption of alternative solutions.
2. Dismantling of the monument should begin on the first or second lowest terrace of the northern side, taking all necessary precautions against sliding and after slope metres had been installed. The dismantling should be combined with reconstruction of these terraces, part by part, in accordance with the technique proposed in the present plan.
3. During the dismantling of the northern side and on the basis of the experience acquired as well as of the more precise data collected during this operation, studies should be made of alternative solutions for preservation and restoration *in situ* of the parts of the monument that would seem not to require dismantling.
4. These studies should be submitted to the third session of the CC with an evaluation of the cost.
5. The third session should be convened as soon as:
   a. Enough experience had been gained of the dismantling-reconstruction technique.
   b. The appropriate studies concerning alternative solutions had been completed, but not later than June 1974.

Summarizing, the CC recommended that the development of the project be closely watched and every opportunity be taken to introduce technical modifications that might result in an optimal realization of the objectives of the restoration project, an improvement of the quality of the work and a reduction of costs.

The CC was also unanimous in considering that an appropriate development of the area and its people should be an integral part of safeguarding the cultural value of Borobudur, and that all means should be attempted to prevent cultural pollution through inappropriate modernization and improper tourist promotion. In view of the fact that landscaping is not only concerned with providing a good view of the monument, but also with enhancing the natural view from the monument towards the surrounding areas, the zone of 2.5 kilometres radius from the monument proposed by the local government was considered insufficient. Consideration should be given to providing a progressive system of zoning: a nearby area with a radius of 200–300 metres, a second zone extending to a range of 2.5 kilometres, and a wider third zone. It was also important that the zoning be planned by taking into account the changes to be expected in the area over the coming thirty to fifty years.

The third CC meeting. The debate over dismantling a major portion of Chandi Borobudur as an integral part of the restoration project was resolved when the CC at its third meeting, held in March 1974, accepted the dismantling of all four square galleries as the basic solution for the safeguarding of the monument. In this respect the CC recommended that the elaboration of detailed plans for the execution of the project be continued in a way that gave the greatest possible chance of finding the best solutions for a number of crucial problems.

The CC further proposed that the future activities be directed mainly to five groups of problems that required either continued studies or special attention during the implementation of the project:

- the static and dynamic stability of the monument
- the dismantling-reconstruction sequence and techniques
- stone conservation measures
- the partial exposure of architectural elements and bas-reliefs of the hidden foot
- the establishment and implementation of a master plan for the development of the surroundings of Chandi Borobudur.

The CC was very concerned about the static and dynamic stability of the monument, and urged that additional borings should be carried out. This survey was designed to produce more complete information on the constitution of the subsoil of the monument and its soil mechanical parameters, including the soil moisture content. It was considered desirable that part of the new data be ready for analysis and assessment before dismantling began at the particular galleries concerned. Furthermore, a review should be made of the current static solution in the light of the new survey's results, and the relevant data should be transmitted to the laboratories and institutions that had submitted the earlier stability calculations. They would be invited to prepare revised computations based on new and more complete data and assumptions adjusted to the observed data.

If the new boring and testing programme on the north face revealed serious hazards, the CC recommended the installation of a network of instruments for *in situ* measurements of soil deformations throughout the monument. In this unfavourable case, the purpose of the network would be to monitor movements that might occur during dismantling and reconstruction and give an early warning of dangerous developments. Anticipating the occurrence of serious stability hazards during the course of the work, it was recommended that the plan for the north face of the monument be supplemented with contingency planning.

The static and dynamic stability of the monument was of primary concern to the CC members. Stability calculations and stability analysis had been carried out as early as 1971 by the Delft Laboratory for Soil Mechanics when NEDECO set up the restoration programme for Chandi Borobudur. A new and more elaborate study based on additional data was carried out in 1973. This report was presented to the CC at its third meeting.

The meeting also discussed the report on seismic stability prepared by Professor N.N. Ambrasseys of the Imperial College of Technology in London. In his report he expressed concern, based on seismic considerations, about an early start on the north face of the monument. However, since his study was based on a seismic intensity that the Institute for Meteorology and Geophysics in Jakarta and the Institute of Technology in Bandung considered too high, and for a large number of other technical reasons, the CC concluded that starting the work on the north side would be the best option. Nevertheless the CC found it necessary to issue a strong recommendation that extreme care and caution be exercised, so that as dismantling progressed the necessary precautions could be taken to ensure the safeguarding of the monument.

The fourth CC meeting. The fourth session of the CC was held from 16 to 19 June 1975. It was attended not only by the CC members, the UNESCO representatives, the staff and advisers of the Badan and the expatriate experts and consultants, but also by the Chair of the Executive Committee and a delegation from the provincial government of Central Java.

In his opening address the Minister of Education and Culture drew special attention to the socio-psychological impact of the inauguration of the project by the President of the Republic of Indonesia nearly two years earlier and the expectations of the Indonesian people that they would see their national pusaka sound and safe in the shortest time possible thanks to international cooperation. Keeping in mind that the actual implementation of the project was far behind schedule, any further delay would also cause considerable increases in cost. Finally, he made an appeal to keep to the schedule, without sacrificing quality by endless consideration of detail.

It should be noted that when the start of the restoration work was officially announced on 10 August 1973, it was symbolized by removing a few stones from the northwestern corner of the encasement at the foot of the monument. A year and a half elapsed before the dismantling of this and the northeastern corner, was carried out in order to create the necessary space for the construction of the tower crane track. It was May 1975 before the two tower cranes finally began operations, marking the real start of the project.

The technical discussions were mainly concerned with the stability studies resulting from the additional borings. In general the results confirmed previous conclusions. The stability of the monument was to be maintained safely during the dismantling sequence from top to bottom (which did not include the encasement of the hidden foot). It was also pointed out that the degree of saturation was an important factor influencing the cohesion value. Consequently it was important to maintain the degree of saturation in the capillary zone at as constant a level as possible. Piezometer readings were also considered important. In this respect the use of a computer might be very helpful for calculating the safety factors for any value of the pore pressure at any time. Thus a diagram could be prepared, in which pore pressure would be the variable parameter.

Much attention was also paid to the report elaborating on the cost estimate and the increase of the realistic budget from US$7.75 million in April 1972 to US$16.1 million in April 1975. It should be borne in mind, however, that this amount did not represent the total cost of the project, as the elements that were not included in the earlier estimate were also omitted from the new one. Excluded were, for instance, the salaries of the employees and overhead costs of the Pelita project.

In this respect Mr Suyama, Chairman of the Executive Committee, noted that the CC in its previous session had advised against uncovering the hidden foot of the monument, a recommendation that would substantially reduce the total cost and duration of the restoration. The Executive Committee had also recommended the previous year that no time extension should be considered. Mr Roosendaal was also of the opinion that not uncovering the hidden foot could save an estimated Rp 100 million, but that it would not reduce the duration of the project, since the date of completion had slipped through delays that had already occurred. Elucidating the rupiah aspect of the project costs, Dr Soekmono pointed out that the restoration project had been incorporated in the Indonesian Five Year Plan which meant that all costs of the Badan Pemugaran Candi Borobudur would be defrayed by the government. He said that the increase of the budget was actually a logical effect of worldwide inflation and elaborated further on the various stages of the increase in the budget since 1973.

He then explained that the government had been aware of this continuous increase. The chairman made some remarks on the dollar sectors and the rupiah sectors in the budget. Work done by contractors was mostly in the dollar sector so that the increase due to inflation was only about 70 per cent. The rupiah sectors, such as salaries paid internally in Indonesia, showed an increase of more than 250 per cent. The causes of delay were beyond the control of the government. As a consequence of the oil crisis, equipment from France arrived two and a half months late. The problem of soil investigation had not been considered at the outset and it had taken a long time to reach a final decision. The chairman said that from now on there would be no more reasons for delay. In all sectors work would be accelerated.

The fourth CC meeting closed by adopting recommendations for the landscaping of the surrounding of Chandi Borobudur and the conclusions drawn from its deliberations. The recommendations for landscaping were as follows:

1. It goes without saying that Chandi Borobudur constitutes not only a national Indonesian monument, but also one of the most valuable monuments of humanity's cultural and historical heritage. For this reason all endeavours should be made to preserve its value for future generations.
2. These are the very reasons why the monument is being restored at present with an appeal for international solidarity.
3. In order that the restoration project may achieve its aims, it is necessary that the planning should not be restricted to the preservation of the monument as such, but that the interrelationship between monument and environment be given full weight, since these are so essential to understanding its full meaning.
4. It is therefore recommended to the government that all measures be taken to create a protective zoning for the entire area surrounding the axis Borobudur-Pawon-Mendut. It will not be sufficient to limit action to the establishment of a sound master plan based on the designation of a sufficiently large protective zone. In the opinion of the members of the Consultative Committee, options should be studied to bring the entire area mentioned under the protection of special regulations in addition to the provisions of the current Antiquities Law.
5. With respect to the intention to build large-scale tourist facilities on the Dagi Hill, including a restaurant, bar, swimming pool, tennis court, accommodation, recreation grounds and a camping site, the members of the Consultative Committee were of the opinion that the plan should be revised so as to fulfil the intentions of the campaign for safeguarding Borobudur, because it endangered the very values that should be protected.
6. In the opinion of the members of the Consultative Committee the distance between the proposed buildings and

facilities and the monument is too short, and this cannot be compensated for by screening the construction from the direct surroundings of Chandi Borobudur.

7. The members of the Consultative Committee wish to point out that they have no intention of interfering in internal Indonesian matters. Their advice is solely motivated by their concern that the proposals brought to their attention for comment and advice may have very negative effects on the fundamental values of the Borobudur monument. Furthermore they consider it their duty to transmit their views to the government which had honoured them by inviting them to assist the responsible authorities as advisers.

The following points are the conclusions of the sessions.

1. From the results of additional soil investigations, it can be concluded that the static and dynamic stability of the monument during the dismantling work is sufficiently secured. However, every means should be considered to keep the degree of saturation of the subsoil as constant as possible, as this has an appreciable influence on stability, and to make use of any necessary protection against rainwater during the operations.
2. The installation of *in situ* instruments, consisting of forty pore pressure indicators and sixty casings for the inclinometers, is fully justified. In this way, optimum utilization of the instruments should be achieved so as to create an effective warning system.
3. The basic dimensions of the present design should not be modified, which means that the extension of the reinforced concrete slabs inwards need not be considered. As for the outward extension of the reinforced concrete slabs, they should be arranged so that the centre-of-gravity lines of the balustrades always lie inside it.
4. The replacement of the original layer A, consisting of prefabricated pipe asphalt plates, by a layer of similar construction to layer B, with stepwise jointing using Araldite tar epoxy as adhesive, should be adopted.
5. Layer B should be kept at the same position as in the present design. However, the stones should not be cut on their horizontal faces, as indicated in the work description, but should be laid at their original thickness with a thin Araldite tar epoxy coating in between, to avoid a different bearing capacity on the composing parts of the wall. However, the vertical joints should be filled with the same Araldite tar epoxy indicated in the work description.
6. The drainpipe system should be modified into a double pipe system, to allow easy repair of the inner pipes in case of damage, if such modification proves to be feasible in terms of technical possibility, cost implications and construction time.
7. To achieve a maximum bearing area, it might be useful to use a thin layer of fine sand between the horizontal stone layers.
8. The Consultative Committee expresses the highest appreciation for the work performed by the IBM organization and recommends accepting this organization's offer to continue supporting the project with its facilities as a donation to the Borobudur Restoration Project.
9. The Consultative Committee, having received the relevant documents on the

work executed in the period March 1974 to March 1975 and the revised estimate of costs, expresses its concern at the slow rate of progress and the financial consequences of this. It advises the government to take, as far as is possible, all necessary measures to ensure the accomplishment of the objectives of the enterprise, which are to respect fully the cultural values of the monument and to accomplish its restoration within the limits of the present time schedule. Such measures may include, if deemed useful, an improvement of organization and management of the operations.

10. The Consultative Committee recommends that the government should continue studies to develop and finalize a master plan for the whole area surrounding Borobudur, Pawon and Mendut. The members of the Committee considered the proposal for developing tourist facilities on Dagi Hill and expressed their view that this proposal should be revised in order to fulfil the intentions of the campaign to safeguard Borobudur. It is their opinion that any such proposal to erect constructions at the presently planned location in the neighbourhood of the temples is incompatible with the true safeguarding of these exceptional monuments and the cultural value of the site.
11. The Consultative Committee also recommends:
    a. That UNESCO make budgetary provisions for the purchase of complementary accessories for the pore pressure indicators to enable the measurement of negative pore pressures, as these are important for a clear understanding of the stability of the monument.
    b. That UNESCO invite Dr Ambrasseys of Delft Soil Mechanics Laboratories to prepare additional diagrams as an extension of his previous ones, in which water levels derived from pore pressure readings should be introduced as a new parameter. In addition, cohesion values up to 0.4 kg/cm^2 should be included. The cases to be considered should be the present situation and all the dismantling stages from top to bottom (the four galleries including the five balustrades).
    c. That the special duties of Professor Murayama should be defined in accordance with the assignment of Professor Ambrasseys, especially in the field of ensuring soil stability during the dismantling and reconstruction works.

The fifth CC meeting. The fifth CC meeting was held at Borobudur from 27 to 29 April 1976. The main topic of discussion was the stability of the monument, about which the members had expressed their concern at the previous meeting.

Mr Wiratman submitted his special report on the subject and gave the necessary explanations. He pointed out that the long-term stability of Chandi Borobudur, with a safety factor of 1.7 for k=0 and the present average value of cohesion C'=0.3 kg/m^2, was reasonably secure. This safety factor was greater than the minimum of 1.3 required for long-term stability. At a safety factor (k=0) of less than 1.3, there was a high probability that stress levels higher than the upper yield value would occur, generating continuous strains leading to creep failure. This minimum safety factor was derived from the fact that creep failure would occur at stress levels approximately 70 per cent of the strength obtained from conventional strength test (stress-controlled), so that the minimum safety factor was 1:0.70=1.3. The safety factor for the long-term stability of the monument could be expected to increase after completion of the restoration work due to the improved drainage system, which would produce lower groundwater levels and consequently lower phreatic levels.

For the case of complete dismantling at k=0 and the present average value of cohesion C' = 0.3 kg/cm^2, the safety factor of 1.45 was adequate. However, if the cohesion dropped to a lower value such as C'= 0.2 kg/cm^2, the safety factor would fall to 1.25, which was rather low. This indicated that it was most important during dismantling and rebuilding to keep the degree of saturation of the subsoil as constant as possible, so as to keep the average value of the cohesion at the same value of C'=0.3 kg/cm^2. The state of complete dismantling would only be a temporary one, since rebuilding would follow as soon as the concrete of the foundation slabs had hardened. During this brief period, rather low safety factors were acceptable.

The recommendations concluding the fifth session of the CC read as follows:

1. Since a delay in the work will cause a considerable increase in the construction cost, every effort should be made to reduce the delay now anticipated in the completion date, as indicated by the latest Milestone Computer Report.
2. Great care should be taken when rebuilding the monument, and all necessary means adopted to avoid any excessive concentration of stresses in the decorative wall stones.
3. The Government of Indonesia is encouraged to develop the Master Plan for Borobudur simultaneously with the current restoration project. Thus the two efforts can come to maturity together and the current presence of so many highly qualified professional persons and skilled artisans can be most efficiently utilized.
4. The existing instrument readings should be provided and evaluated as soon as they are available, according to schedule, so as to have up-to-date information about the stability of the monument at all stages of the project. These readings should be treated as an effective early warning system, not be used merely to document possible failures.

The sixth CC meeting. The problem of the stability of the monument was once again the main topic of the sixth CC meeting, which was held at Borobudur from 31 May to 3 June 1977. The question of the possible shrinkage of the soil inside the monument had been raised at the previous meeting. In the present session Mr Wiratman submitted his report on this special topic, while emphasizing his earlier answer. In his explanation he convinced the CC members that no shrinkage or swelling of the soil had ever been observed. Not the slightest indication of such phenomena had been found in any of the previous investigations based on laboratory tests while applying theoretical and empirical considerations. The damage to the stone structure was solely the result of uneven settlements due to a drop in bearing capacity of the subsoil resulting from the washing away of soil particles by seeping water. It could be safely accepted that site investigations had confirmed the non-active character of the Borobudur soil.

With respect to possible shrinkage or swelling in the future, Mr Wiratman informed the meeting that such an occurrence was very unlikely. The results of the laboratory tests on the properties of the Borobudur soil had shown that it could be classified as immune to volume change. Tests on the site had shown that the water content in the subsoil was approximately constant throughout the year. The obvious conclusion was that neither shrinkage nor swelling in the course of time need be taken into consideration.

In fact, in the final stage of rebuilding the concrete slabs and stone layers that would completely cover the foundation soil would act as a protective layer against changes in water content, thus providing even more security from changes in the volume of the soil.

A possible cause of decrease in water content that should be kept in mind was evaporation of pore (capillary) water from the voids by a process of drying out. This, however, was also very unlikely since in the final stage of the rebuilding the subsoil would be completely covered and during the restoration work only a small part was exposed to open air. The obvious final conclusion was, therefore, that there would be no problem of shrinkage or swelling endangering the stability of the monument, either during or after completion of the restoration.

At the opening session of this sixth meeting the Director-General of Culture read out the Minister of Education and Culture's address. This noted that the restoration work was behind schedule, but everything possible was being done to make up for the delays. The Indonesian Government would take full responsibility for the completion of the project. He further imparted the exhilarating news that the Chandi Borobudur Restoration Project had been entrusted by SEAMEO (the South East Asian Ministers of Education Organization) with the establishment of a SPAFA-SEAMEO Project on Archaeological and Fine Arts (Subcentre for the Preservation and Restoration of Ancient Monuments).

The session closed with the following points:

1. The high quality of the work carried out since the fifth meeting of the Consultative Committee is greatly appreciated, especially the extremely delicate task of rebuilding.
2. In the rebuilding process it is recommended that the upper and lower surface of all the outer stones of the walls and the balustrades be checked during the treatment procedures to ensure a uniform flat surface so that dangerous point stresses will not occur.
3. It is recommended that the use of chisels and other sharp tools be prohibited in cleaning the sculptured surfaces of the stones so that the decoration will not be over-cleaned or damaged.
4. It is recommended that the expert who developed the stone conservation programme for the project be requested to conduct an on-site review of the stone conservation work being carried out at this time.
5. It is recommended that the recent patching of the pavement of the extended foot on the north and south face be re-pointed to match the existing pavement on either side.
6. Prior to installing the pavement of the galleries every effort should be made to model the work on original examples of paving; it should be noted that original paving stones ought to be replaced wherever possible.
7. It is recommended that the placement of the bearing stones of the under layer of the gallery pavement be adapted to allow more flexible evacuation of water.
8. The Consultative Committee wishes to reiterate its recommendation, made at the third session of March 22–27 1974, that the hidden foot shall be partially revealed at the southeast corner of the monument to a greater extent than at present, so as to show this important

stage of the historical development of the monument and to display the beautiful profiles and reliefs of the hidden foot. For this purpose, dismantling of the encasement between sections i and j of the east face and a and b of the south face should be considered. Studies should be made to provide for staircases and drainage.

9. A new time schedule should be developed taking into account all the present on-site experience including the reasons for delays, so that a reliable estimate of the time required to complete the project can be projected. In any case the first priority of the project must be the quality of the work executed.
10. Since the members of the Consultative Committee rely on the monthly Milestone Reports to evaluate the progress of the work, it is recommended that the format of the Milestone Reports be revised according to the new time schedule to show a comparison of the actual and estimated progress of work in a clear graphic form. When there is a significant difference between the actual and estimated schedule, the reasons for this should be given.
11. In order to safeguard the traditional appearance of the landscape, the traditional land uses and forms of architecture should be preserved, while at the same time providing for the social and economic development of the area. It is recommended that the Government of Indonesia develop and implement new interim controls regulating all new construction in the immediate vicinity of Chandi Borobudur, the village of Borobudur and on either side of the principal road leading to Borobudur over a distance of 10 kilometres. Such new controls would regulate the design, height, materials, function and location of all new construction, and would be modified upon the adoption of a comprehensive master plan for the landscaping and development of Chandi Borobudur and the Borobudur region.
12. It is recommended that all new construction for the Borobudur Project itself or for the purpose of tourism be located outside the immediate project area in locations of no archaeological significance and not within view of Chandi Borobudur itself.
13. It is recommended that archaeological research using contemporary scientific methods be carried out prior to the implementation of any master plan for the area.
14. The Consultative Committee expresses its great appreciation for the work achieved by NEDECO and also expresses the wish that NEDECO engineers be made available for consultation for the further execution of the project.
15. The Consultative Committee expresses its high appreciation of the helpful assistance given to the restoration of Chandi Borobudur by IBM, in particular for the well-organized computer program and the training of the staff members of Badan.

The seventh CC meeting. The seventh meeting of the CC was held at Borobudur from 5 to 8 April 1978. In his opening address the Chairman informed the meeting that since the work on the north and south faces was nearing completion, a careful plan for the east and west sides had been drawn up in which experience gained so far was taken into account.

The concern of the members with regard to the stability of the monument was addressed by Mr Wiratman. Summarizing the results of the investigations he pointed out that:

- Pore pressure readings and the phreatic level of the groundwater gave grounds for optimism.
- The results of level measurements before and after the dismantling showed that settlement of the upper part (the circular terraces) did occur, but only to a very small extent (2–15 mm). The settlement was partly due to the reconsolidation of the made fill and partly due to minor deformation of the terrace floor.
- The stability of the southeast corner had been analysed to ensure that a limited exposure of the hidden foot would not endanger the monument.
- Seismic activity during the previous two years had been much below the design intensity.

A study of the pottery found on the Borobudur grounds, carried out by Mr Mundardjito of the University of Indonesia, was also presented. The main conclusions he arrived at were:

- After reconstruction, some of the potsherds showed certain similarities with pots and vessels depicted on the reliefs of Chandi Borobudur. This might cast a light on customs and ceremonies that had been conducted over the centuries.
- In some pits the finds indicated two kinds of pottery: the lower and higher level pottery. Analyses were made of the form, decoration and temper of the potsherds.
- The ceramological survey suggested the very significant possibility that a large area stretching far around the monument should be considered as an archaeological site. Consequently as many archaeological excavations as possible should be carried out before starting the landscaping of the area.

With respect to the planned Borobudur Archaeological Park, the Director-General of Tourism took the opportunity of providing the CC with the necessary information and explanations.

The seventh CC meeting concluded with the following points.

1. The Consultative Committee congratulates the directorate, the professional staff and all the teams on the outstanding work carried out during the last ten months. In particular the Consultative Committee applauds the quality as well as the quantity of work achieved following the revised work programme.
2. Now that the reconstruction of much of the north and south faces of the monument has been achieved, it appears that there exists a substantial difference between the actual measurements of the reconstructed terraces and the measurements calculated in the final work programme. This has led to certain problems pertaining to the reconstruction of the east and west faces. The Consultative Committee recommends that detailed plans be developed for the reconstruction of the east and west faces that will solve the problems caused by the dimensional changes on the north and south faces, and that these detailed plans be thoroughly checked and evaluated by the directorate before reconstruction work begins on the east and west sides.
3. The Consultative Committee expresses its concern about the proposed design for the gallery paving system. Because

visitor safety requires that the joint between the paving stones be kept narrow, it is probable that the joints will soon fill up with dirt and cause problems for the drainage of water. The Consultative Committee recommends that the design be modified to create more generous openings for water evacuation along the edges of the gallery pavement than those presently identified in the design. The Consultative Committee also reaffirms the sixth recommendation made at the sixth meeting that 'original paving stones ought to be replaced wherever possible'.

4. The Consultative Committee recommends that for the safety of visitors the broken and worn steps of the monument's stairways be replaced where necessary with new steps of the appropriate form and dimensions.
5. The Consultative Committee agrees with the proposal to expose the southeast corner of the hidden foot. The length of wall exposed should coincide with a division between the sculptured relief panels and not be less than 5 or 6 metres. The Consultative Committee also recommends that the design of the area where the encasement will be removed and modified be given further study to develop a design more compatible with the spirit of the monument.
6. In view of the tremendous symbolic and architectural importance of the relationship between the uppermost square gallery and the first round terrace, and in view of the current problems related to the level and exact design of the reconstructed uppermost square gallery and stairway, the Consultative Committee recommends that a detailed study be made of the original or traditional relationship between these two areas and that a final design project be prepared for review at the next meeting of the committee. Temporary access to the upper terraces should be provided in the interim.
7. Since the completion of the Chandi Borobudur Restoration Project is scheduled for October 1982, the Consultative Committee recommends that steps be taken by the Government of Indonesia in cooperation with UNESCO to recover by donation or exchange those original sculptures of the monument currently in private and public collections around the world.
8. Since the conservation of an historic monument both during and after project work requires systematic scientific observation, it is recommended that measurement of the levels of both the upper terraces and lower gallery floors be carried out at least every three months and also that a system to monitor and record any movement in the reconstructed areas be developed and initiated.
9. A more complete understanding of the basic architectural concept of Chandi Borobudur and a more certain starting point for any future intervention could be achieved if the basic measurement system used in the original construction of the monument were known. Therefore, the Consultative Committee recommends that the necessary study to discover or identify this basic system be undertaken without further delay.
10. In recommendation 11 of the sixth Consultative Committee meeting the members expressed their concern for the protection of the landscape and environment of Chandi Borobudur. It is self-evident that the preservation of the

full integrity of the historic and artistic content of a monument depends not only upon the responsible preservation of the monument itself but also upon the preservation, to the fullest extent possible, of the traditional surroundings of the monument. For this reason the Consultative Committee congratulates the Indonesian authorities upon the efforts made for development of the Borobudur region. Nevertheless the committee would like to express some reservations about certain aspects of the proposed master plan. It should be kept in mind that every preservation project should respect the fundamental historic, artistic, cultural and natural values that characterize the actual site. It seems to the committee that the entrance axis anticipated in the master plan for the eastern side of the monument is not consistent with the basic composition and design of the monument, nor with the traditional relationship between the monument and its setting. Therefore the proposed entrance could be a dangerous intervention into the equilibrium of the site. For this reason it is recommended that further studies be undertaken to discover the fundamental components of the natural and historical landscape and that, for example, the significance of the existing axis that links Mendut, Pawon and Borobudur should be given its full value and status. It is also recommended that a comprehensive survey be carried out to identify sites of potentially high archaeological value so that these sites will not be disturbed as a result of any new construction.

11. The committee welcomes warmly the recent new appeal issued by the Director-General of UNESCO to the community of nations with the view of mobilizing international funds and moral support for the completion of the restoration of Borobudur.
12. The Consultative Committee expresses the wish that NEDECO engineers continue to be made available for consultation for the further execution of the project.

The eighth CC meeting. The eighth session of the Consultative Committee was held at Borobudur from 23 to 27 April 1979.

The main point of discussion was the application of lead sheets to be inserted at the bottom of the main walls and the balustrades. For the sake of proper positioning when rebuilding the monument, both main wall balustrades had to be raised so that a supporting stone layer could be added. This additional layer was constructed by using inner stones fixed with cement mortar. The lead sheets were meant to prevent direct contact of the bottom layer of the walls and balustrades with the cement of the supporting layer.

Another topic of interest was once again the risk of an earthquake. Mr Wiratman explained that the definition of 'risk' that he used was purely mathematical. It implied the probability of occurrence of an undesirable event in a certain period of time. His review of the application of probability theory in calculating the earthquake risk for Borobudur brought him to the conclusion that the occurrence of a disastrous earthquake was very unlikely.

The earthquake force adopted for the control calculation of the stability of the monument left a margin of safety, so it could be concluded that Chandi Borobudur was capable of satisfactorily resisting strong ground tremors that might occur once every several centuries. Even in such cases, the history of the monument gave surety that it would remain erect as a whole.

Finally, the urgent desire of the CC members to obtain more information about the development of the archaeological park was met by the Director-General of Tourism, who presented a clear report on the final progress.

The recommendations marking the end of the eighth meeting read as follows:

1. The Consultative Committee congratulates the directorate, the professional staff and all the teams on the excellent progress achieved during the last year. In particular the committee recognizes the quality of the reconstruction work on the north and south faces of the monument, and the especially difficult task of reconstructing the third and fourth galleries. The committee urges that the greatest possible care be given to the problems of reconstructing the third and fourth galleries of the east and west faces during the coming year, in view of the deformation of the monument throughout its original construction period.
2. The Consultative Committee requests that the full text of the Progress Report for the ninth meeting of the Consultative Committee be translated into English and transmitted to the members of the committee no later than four weeks prior to the meeting.
3. The Consultative Committee requests once again that the monthly Milestone reports be presented in a clear format and accompanied by a graphic representation of the overall progress being made.
4. The committee requests that the Progress Report for the ninth meeting of the Consultative Committee include a full explanation of the reasons for not reusing the original or early paving stones of the gallery floors.
5. The committee requests that a report be developed by the directorate for the ninth meeting of the Consultative Committee concerning the method used for marking each new stone so that it cannot be confused with original work in future years.
6. The Consultative Committee urges that greater attention be given to the use of chemicals in the cleaning and maintenance of the monument to ensure that no further environmental damage ensues.
7. The Consultative Committee strongly urges the directorate to prepare large-scale measured drawings of the correct position of the first layer of stones of the walls of the east and west galleries prior to reconstruction so as to ensure the most accurate possible placement of the stones and the best possible integration with the north and south walls already in place.
8. The committee congratulates the UNESCO expert, the scientific staff of the Badan and Tokyo Research Institute of Cultural Properties for the excellent analysis and report on the problems of the use of lead sheets in proximity to cement mortar. The committee strongly recommends that the following modifications in the project design be executed in the reconstruction of the east and west faces of the monument.

   a First balustrade: no lead sheets will be used in this location and layer B will be raised by one layer of stone above the reinforced concrete slab.

   b. First main wall and second balustrade: lead sheets to be lowered two layers with attention being paid to the position of the lead sheets, layer B stones and the cement mortar. At the level of the foot of the first main wall to lay the lead in strips with 5 cm between them over a layer of Araldite and for the layer of the cement mortar to be one layer of Araldite and for the layer of cement mortar to be one layer of stone underneath the lead and Araldite between the first and second stones. The utmost attention must be paid to leaving the vertical joints open between the stones and underneath the spaces between the lead strips so that water can drain easily.

c. Second, third, and fourth balustrade and main wall: the same system described for the foot of the first main wall in paragraph (b) above will be applied to the foot of the second, third, and fourth gallery main walls, except that there will also be a layer of Araldite mortar to even out the upper surface of the second layer of stones, and that the balustrade level of imperforated lead sheets will be placed one layer down.

9. The Committee has received with great interest the status report of the Director-General of Tourism on tourist development and the protection of the Borobudur area. The Committee appreciates the effort being made by the Indonesian government to protect this site, especially in the light of the worldwide effort to protect a site of this importance. However, the Committee would like to call the attention of the government once again to the recommendations made in past years about this matter, particularly in the sixth and seventh Consultative Committee meetings. The Committee hopes that it will have the honour of being informed about the detailed plans for the application and execution of the government's programme at the ninth meeting of the Committee.
10. The Consultative Committee expresses its appreciation for the work achieved by NEDECO and expresses its wish that the NEDECO engineers continue to be made available for consultation for the further execution of the project.

The ninth CC meeting. The ninth CC meeting was held from 15 to 19 April 1980. In his opening address the Minister of Education and Culture informed the meeting that the Indonesian Government's expenses for the Borobudur restoration was nearly 70 per cent of the entire budget that was needed each year. He further expressed the government's gratitude for UNESCO's aid and campaigns that had resulted in attention and assistance from all over the world. He conveyed the government's gratitude to the Belgian Government for the return of two Buddha heads.

Responding to the questions raised by the CC members concerning the pore pressure cells and the inclinometer, Mr Wiratman explained that during the first two years since installation of the warning devices a watch had been kept on the monitoring and reading of the data. Diagrams were made to check the stability of the monument. The readings had always indicated very low pressures, or none at all, through all kinds of weather, during the dry as well as the rainy season. None of the resulting data had ever indicated any significant problems.

The inclinometers had from the very beginning been difficult to handle and had never really been used as a means for checking.

Responding to a question about the estimated date of 4 October 1982 produced by the computer as the date for the completion of the whole restoration, Dr Soekmono explained that the computer output should be understood as indicating the terminating date of the rebuilding work.

It should be noted that two kinds of work had to be completed by then: the extension of the crane track in order to get a full circle of concrete slab all around the monument, and the exposure of the hidden foot at the southeast corner. The first item was designed to avoid the extra work of demolishing the very solid track on the one hand, and on the other hand to use the existing construction as an additional reinforcement. For this purpose, however, the intended plan was not yet included in the programme. The second item was already included in the programme, and was projected to be carried out in the first or second half of 1981.

It was not until then that a new project would be started: the clearance of the upper as well as the lower working area.

The final task of the meeting was the adoption of its recommendations, formulated by a special working team and reading as follows:

1. The Consultative Committee congratulates the directorate, the professional staff and all the workers and craftsmen on the excellent work carried out in the last year. In particular the committee recognizes the high quality of the work achieved to re-establish the corners of the monument. The committee urges that great care be taken in the remaining months of the project to maintain an appropriate balance between the pressure to remain on schedule and the need to take great care to minimize damage to the stones.
2. The Consultative Committee requests that quarterly Milestone Reports and a simple bar graph showing the progress of work accomplished be posted by registered mail to all members of the committee on a regular basis.
3. The Consultative Committee requests that a report evaluating the technical and cost effectiveness of the use of chemicals on the stones of the monument to retard or prevent the growth of algae, mosses and micro-organisms be prepared for discussion at the next meeting of the committee.
4. The Consultative Committee fully appreciates the important study of the stability of the soil of the hill undertaken at the initiative of the chairman, and further recommends that the technical monitoring of the stability of the monument and the soil of the hill be carried out on a regular basis both during the restoration project and after the work has been completed. Specific proposals for carrying out the ongoing technical monitoring should be developed and distributed to the committee with the next quarterly report.
5. The committee expresses the wish to be informed at the next meeting of the Consultative Committee about the plans for the removal of buildings, structures, cranes and other machinery from the project site on completion of the restoration work.
6. The committee has learned with pleasure of the proposal to establish a National Centre for Stone Conservation and a Centre for Borobudur Studies.
7. The Consultative Committee has received with great interest the current status report of the Director-General of Tourism on the development of the Borobudur National Archaeological Park and surrounding area. The committee would like to bring to the attention of

the Director-General the following concerns:

a. That the plans and design for the National Archaeological Park should respect the sensitive scale, the deep spirit and the rich historical and archaeological quality of the site so as to avoid the possibility that the new construction will be disproportionate.

b. That the greatest care possible to identify and conserve important archaeological sites and landscape features should be taken prior to any new construction.

c. That all zoning decisions should be based upon the quality and importance of the existing archaeological features and the existing and proposed landscape features, so that all planning concepts will be in perfect harmony with important aesthetic and historical values already present at the site.

8. The Consultative Committee expresses its appreciation for the work achieved by NEDECO engineers and hopes they will continue to be made available for construction for the further execution of the project.

The tenth CC meeting. The tenth meeting of the CC was held at Borobudur from 11 to 15 May 1981. In his opening address the Minister of Education and Culture pointed out that the restoration of Chandi Borobudur was progressing on schedule. He expressed the hope that the work would continue at the same pace and would be finished by the end of 1982 as scheduled, and that Chandi Borobudur would reappear in its former splendour as the fruition of combined national and international efforts.

He reminded the meeting, however, that the completion of work on the monument itself would not mean the end of the entire restoration work since there would remain other tasks to be taken in hand, such as the clearing of the sanctuary's surrounding area, which were expected to take another six months. Accordingly, the inaugural celebration ceremony could be expected to take place only in early 1983.

The minister also touched upon the establishment of public cooperation in managing the archaeological park. This park would also include Borobudur's Hindu counterpart, the temple compound of Prambanan.

Finally, the minister made an appeal to the Consultative Committee members to continue for some years to come to give advice on the construction of the national park, which in the past had given rise to some misgivings on the part of the Consultative Committee, which feared that too many efforts in the tourist field might endanger the cultural objectives.

Quite another matter was then announced by the chairman: that the master-contract concluded between the Badan and the joint contractors had expired at the end of the previous April, and that the execution of the remaining extension of the contract had to be made on a lease-lend basis, effective as of 1 May.

The evident deep interest of the CC members in the future stability of the monument again stimulated reassuring explanations from the two Badan advisers from the Institute of Technology in Bandung. Mr Wiratman explained that the successful dismantling and rebuilding of the chandi stones was due to two main factors: careful and rigorous theoretical stability analyses carried out beforehand, and continuous checking of the stability levels during restoration based on readings of *in situ* instruments.

He therefore recommended the installation of a new monitoring system, consisting of piezometers and clinometers (as previously implemented) to control future stability levels. In addition he also recommended installing accelerometers to monitor future strong seismic movements.

Elaborating on Mr Wiratman's explanation, Mr Aziz pointed out that special attention had been paid to the southwest part of the hill slope, because at this side the chandi is located very close to the edge of the slope. The soil investigations, which consisted of fieldwork and laboratory testing of samples, had shown that there was no homogeneity of the soil in terms of its strength properties. Two combinations of soil strength properties had been chosen for the stability calculation, namely:

$\varnothing = 24$
$C = 0.3\ kg/cm^2$
$\varnothing = 26$
$C = 0.2\ kg/cm^2$
→ both for slope angle of 28°

The stability calculation was based on the simple assumption of circular shape failure surface. This was consistent with the assumption of average shear strength taken. The ratio of resting moment to driving moment gives SF with respect to a certain point of rotation. Two-dimensional analysis indicated the minimum SF was 1.7 with no seepage, while with seepage the minimum SF was 1.11.

Taking into consideration the three-dimensional effect it was found that the SF3 ~1.2 x SF2 approximately. Even though it is stable, there may be low SF because of heavy rain when water can penetrate and seepage develops. It is therefore necessary to protect the slope from deep penetration of rainfall, for two reasons: first, water will cause seepage, and second, it will reduce the strength of the soil.

Both seismologists were also of the opinion that a review of the geological analysis of the natural hill was important in order to look more deeply into the soil layers and rocks and to analyse faults or any other geological input affecting stability that was not covered by the soil survey.

In conclusion the seismologists emphasized the extreme importance of maintaining the existing slope. Excavation of earth around and near the toe should be prevented or at least carefully supervised to avoid disturbing the stability of the soil. Attention should also be given to preventing surface disturbance of the slope at present and at any time in the future.

The session closed with the following recommendations:

1. The Consultative Committee congratulates the directorate, the professional staff and all workers and craftsmen on the extensive work carried out in the past year. The committee notes, however, that some of the rebuilding work in the upper gallery of the east and west faces does not appear to be of the same very high quality as the rebuilding work on the north and south faces. The committee urges the directorate to exercise the highest possible degree of quality control over the rebuilding work yet to be carried out.
2. The Consultative Committee recognizes the important role of appropriate maintenance for Borobudur. The committee also believes that the experts and craftsmen who restored the monument are the best qualified to develop the ongoing maintenance programme for it. Therefore the committee recommends that the directorate develop a preliminary draft of the following information for review and comment by the committee at the next meeting:

- general maintenance policy for Chandi Borobudur and the sanctuary area
- standards for all maintenance activities to be carried out at Chandi Borobudur and the sanctuary areas.

The CC also notes that the US National Park Service's publication *Cyclical Maintenance for Historic Buildings* or other publications in Japan and Germany may be helpful in developing a maintenance programme for Chandi Borobudur.

3. The Consultative Committee previously recommended that the floor stones be placed so that the joint between them would be wide enough to permit free drainage and ventilation of water between the stones. The experience of the project staff has shown that leaving wide joints between the stones allows the stones to move when they are walked upon. Therefore wide joints have not been used in the work on the monument. The committee recommends that additional drainage and ventilation openings be constructed at the edge of the floor stones and the balustrade so that approximately 50 per cent of the length of the joint between the walls and the floor stones will be left open, in so far as a perfect stability of the floor stones can be ensured.
4. To ensure the future stability of the monument and the hill, it is considered necessary to monitor several geotechnical quantities so that appropriate action can be taken to maintain or increase current conditions of stability. The quantities to be measured should be:
   - pore water pressure and groundwater level, as well as precipitation and pore water pressure change with rainfall
   - the performance of the drainage system
   - triangular survey, levelling surface extensometer, multipoint settlement meter and clinometer
   - seismic activity.

   To carry out these measurements, the committee recommends that the equipment necessary to do the work be selected and installed under the supervision of a geotechnical consultant expert retained especially for this purpose.
5. The Consultative Committee recommends that the directorate conduct a field test on the monument of the remedial solution suggested by NEDECO at the tenth CC Meeting. If this measure (applying mortar in an even slope between stones of the first layer) is a success it should be carried out wherever the floor stones have not yet been installed.
6. To prevent the continued growth of mosses, algae, lichens and other unfavourable organic matter on the monument, the committee recommends continuing the carefully controlled use of chemicals as part of the ongoing maintenance programme. The continued effectiveness and environmental acceptability of such measures should be evaluated. Some chemicals fail to perform satisfactorily and new chemicals have been thoroughly field-tested to ensure they meet all the project's maintenance standards.
7. It has been suggested by NEDECO that the absence of many of the original balustrade stones may cause future static problems with the concrete slab. The committee recommends that potential problems be thoroughly studied by the directorate and NEDECO and that a report be made to be next meeting of the CC.
8. The Consultative Committee recommends to the Minister of Education and

Culture that the committee hold its next regular meeting in early May 1982 and that it meet again in 1983 immediately prior to the inauguration ceremonies for Chandi Borobudur. The committee would be honoured to meet again following the inauguration in order to evaluate the project work and to provide whatever other assistance or advice it can.

9. The Consultative Committee recommends that UNESCO be invited to prepare a publication or documentary film on the Borobudur restoration project in honour of the inauguration of the monument in 1983.
10. The members of the committee wish to express their deepest regret at the deaths of the representative of the Republic of Indonesia to UNESCO, Ambassador Dr Partomo M. Alibazah and the consultant of UNESCO, Dr Achmad Ali. We have lost two esteemed colleagues whom we will always hold in great respect.
11. The Consultative Committee wishes to express its appreciation for the work achieved by NEDECO and expresses its wish that NEDECO engineers be made available for consultation.

The eleventh CC meeting. The eleventh meeting was held at Borobudur from 8 to 10 June 1982.

In his opening address the Minister of Education and Culture informed the meeting that the Grand Celebration was scheduled for the end of February or the beginning of March 1983. He further pointed out that although the Borobudur and Prambanan Archaeological Park Inc. had been established, the monuments would remain the full responsibility of the government.

Touching on the eleventh session itself, which was to be the last formal meeting, the minister expressed the hope that a special session would be convened prior to the Grand Celebration to which he would also like to invite the Director-General of UNESCO and representatives of donor countries.

Looking to the future of the restored monument, Mr Samidi, Head of the Chemico-Archaeological Department, informed the meeting that the necessary preparations had been made to ensure the required supervision and maintenance. An elaborate work plan had been drawn up, using the invaluable experiments of the last ten years of conservation work at Borobudur.

The central concern of the CC members with regard to the stability of the monument remained the focus of the discussion. Mr Aziz was invited to present his paper (written together with Mr Wiratman) on the Final Review of the Long-Term Stability of the Monument. He admitted that some statements in the report Doc. CC/XI/4/1982 might not be clearly formulated. He then explained that the writers of the report would like first of all to point out two different phenomena involved: time-dependent deformation (or long-term settlements caused by the consolidation process) and the problem of soil stability.

Time-dependent deformation takes place over a much longer time than the construction period and the rate of deformation will depend on the permeability of the soil and of course the boundary condition.

On the other hand, stability, including bearing-capacity problems, is categorized as a shear failure problem that can occur very rapidly. Thus the statement, which had given rise to comments, should be viewed in the light of the two different phenomena mentioned and is meant to distinguish between stability and consolidation processes. At the start of the restoration, the consolidation caused by the stone load had long been achieved, since the load had been there for a very long period. The restoration is, in fact, a process of unloading and reloading and recompression of the soil underneath.

The critical state would not come from consolidation deformation during the restoration, but from the stability problem: in this case the stability of the hill slope. The measures so far taken, as shown in the CC Documents of 1976 and 1978, had been to analyse the risk of slope failure caused by water infiltration. This process usually occurs in a relatively short time, in comparison with the consolidation settlement, and the danger would come from a sudden failure of the slope caused by infiltrating water (known as seepage), especially during the restoration period.

Mr Aziz further stated that the important influence of the infiltrating water had been understood from the beginning of the restoration. The matter had been mentioned in previous reports, with recommendations that the water content should be kept as constant as possible to avoid disturbing the important strength parameter of the soil, especially during the restoration. It was also suggested that as a warning system, piezometers and inclinometers be used. Piezometers were not only important during restoration, but could also be used to predict time-dependent deformations through pore water pressure readings.

Concerning the inner soil mass, additional settlement could only happen if there was a change of load. As restoration is the process of unloading and reloading or recompression of the soil, back to about the same load intensity, the final settlement will not vary or change. Furthermore, according to the field data obtained so far, no groundwater table had ever been found in the Borobudur soil, which meant that the compression characteristics of the inner soil could be expected to be constant, because no soaking condition had ever been experienced by the inner soil. The infiltrating water is seeping water and mostly goes through the upper part of the soil layers.

Finally, Mr Aziz informed the meeting that both he and Mr Wiratman fully agreed with the earlier CC recommendation to install instruments such as piezometers in order to gain data on the behaviour of the soil layers, including the inner soil. Those instruments when installed would give a range of benefits:

- monitoring of the behaviour of the soil layers, their movement if any, variation of pore pressure and so on
- information to compare the actual behaviour of the chandi with the predictions given by theory
- constant information about the true safety of the monument in terms of soil stability.

It should be noted that the piezometers to be used must be of the kind able to pick up negative pore pressure existing in the ground. The use of the existing boreholes should be explored but the objective of future instruments must be remembered and distinguished from the objective of the earlier measures, which was to check stability during restoration.

The eleventh meeting of the CC closed with the following recommendations:

1. The Consultative Committee recommends that the Indonesian Government pay attention to the problem of long-term monitoring of the soil conditions of the interior of the monument.
2. The Consultative Committee congratulates the directorate on the fine report by Mr Samidi about the future maintenance of the monument and recommends that the maintenance programme be equipped and implemented in phases so that no gap occurs between the completion of

the restoration project and the opening of the archaeological park.

3. The Consultative Committee recommends that the degree of cleaning and the type of tools used for maintenance be such that the aesthetic appearance of the monument will not be adversely affected by over-cleaning.
4. The Consultative Committee recommends that a visitor circulation study be made of the monument to evaluate the most efficient traffic pattern for visitors who wish to climb it. The committee also recommends that the design of the new stairs for the hidden foot shown in the drawing be modified so that:
   a. The reliefs are protected
   b. The stairs are not visible on the east or south elevation
   c. The stairs are no wider than the stairs between the Rupadhatu terraces
   d. The dismantled ends of the extension are left at 90° to the hidden foot and with the unfinished masonry open to view. Two panels of the Kamadhatu reliefs will be visible on both the east and south sides. This will permit traditional *pradakshina* circulation.
5. The Consultative Committee has noticed with pleasure the ongoing work to identify and conserve the loose temple stones. It is recommended that the policy be continued of replacing the loose temple stones on the monument whenever their original location has been definitively established.
6. The Consultative Committee wishes to express its appreciation for the continuing and thoughtful development of the master plan for the archaeological park, and to express its support for the basic goals and objectives of the plan, which so carefully balance historical, cultural, natural and human considerations.
7. The Consultative Committee wishes to express its appreciation to NEDECO for its valuable contribution to the success of the Borobudur Restoration Project.
8. The Consultative Committee wishes to congratulate the Government of Indonesia, the directorate, the professional staff and all the craftsmen and workers for the work carried out in the past years to bring this project to a successful completion.

6.4 Final stage

6.4.1 Opening the southeast corner

The issue of dismantling the southeast corner of the hidden foot or *Karmawibhangga* of the temple was first discussed in 1977 at the Consultative Committee meeting. In the event, on the basis of the CC meeting recommendation of 1982, serious consideration had to be given to this, in particular in view of the dismantling of the east and west faces. The decision needed to be based upon adequate knowledge and research of the scope of the intended dismantling, the estimated cost, available manpower, time schedule and the stability of the monument.

It was first thought that dismantling of too large an area would affect the stability of the monument as a whole. The proposed dismantling would create an open space of 12 metres in both directions with no counter pressure, which would cause a cantilever bending movement on the concrete slab.

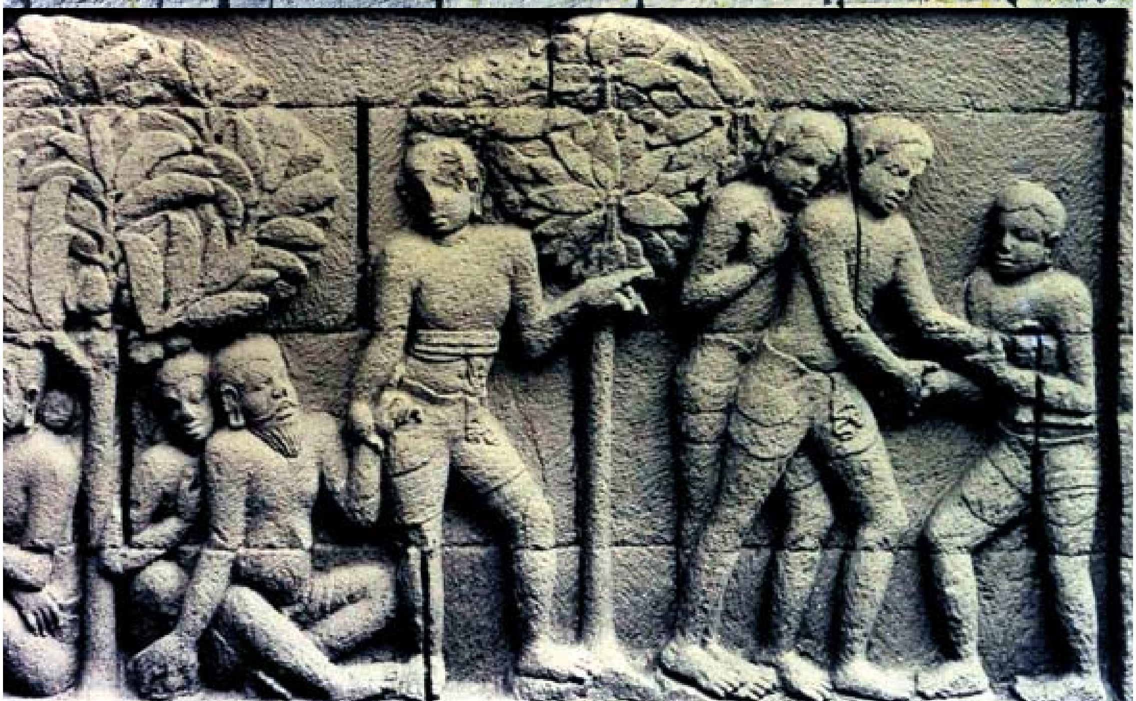
It was estimated that this method would result in the additional dismantling of about 800 m^3, in addition to the 245 m^3 of already dismantled stones. Further consideration of this plan led to a decrease of the dismantling area to a distance of only about 5 metres from the corner. However, the quantity of stone to be dismantled (about 500 m^3) was still considered too large.

Following consultations with the NEDECO consultant, a third plan was agreed. The area to be dismantled was reduced, by following the line of the dismantling area, cutting the corner and adjusting it to the dismantled encasement wall. For this purpose, a quantity of only 361 m^3 of stone had to be dismantled. From the technical point of view, this called for a modification of the drainage system and also the levelling of the so-called platform.

6.4.2 Setting up the hill belt

With a view to ensuring greater stability of the supporting hill, it was proposed that use should be made of the reinforced concrete structure that had served as the foundation of the tower crane rail track. After removal of the rail tracks, the concrete foundation was not broken up, but served instead as an additional means of strengthening the hill. Both ends of the concrete structure were connected to one another so as to form a massive ring encircling the foot of the hill. This ring was further strengthened by prestressing the concrete, through a method devised by Professor Roosseno.

Part of the Rupadatu, a main wall relief from Borobudur.



Part of the Kamadatu, a story from Karmawibhangga. Monks delivering doctrine in a quiet place.

Part of the Kamadatu, a story from Karmawibhangga. Noblemen and their people watching acrobats performing music and dance.

7. The Post-Restoration Development Plan

In his inauguration speech on the completion of the Borobudur Restoration Project on 23 February 1983, the President of the Republic of Indonesia guaranteed the maintenance of Borobudur by the people and Government of Indonesia as our national historical monument and now as part of the world's cultural heritage. He further emphasized that the inauguration did not mark the end of our attention to Borobudur, but the beginning of an even greater task: the long-term maintenance and protection of the monument.

It was with this objective that the government, through the Ministry of Education and Culture, had set up the Borobudur Conservation Project to carry on the work, taking over the maintenance, observation and protection of Borobudur from the Restoration Project, which had conducted these tasks since 1983, with the agreement of the National Planning Board (Bappenas).

The project's conservation laboratory with its appropriate equipment and technicians was also used for training courses on conservation and restoration of historical monuments at national as well as international levels. By 1994, no fewer than fourteen national training courses had been held in Borobudur. Each four-month course was attended by twenty-five participants, who were selected field officers of the Provincial Archaeological Offices from various provinces all over Indonesia. Meanwhile, nineteen regional training courses in Borobudur were attended by more than sixty technicians from Thailand, Philippines, Malaysia and Indonesia. UNESCO participants from Burma, Bangladesh, Vietnam, Norway and Pakistan were also given a chance to undertake comparative studies between 1987 and 1994. Deep thanks are due to UNESCO, which has stimulated the development of conservation and restoration technology in Indonesia through the training of personnel and improvement of the sophisticated laboratory equipment.

The activities and results of the project were reported through the first and second International Meeting of Experts from 4 to 8 August 1986 and 7 to 11 August 1989, to which the experts submitted valuable follow-up recommendations. The experts' meeting of 1986 recommended (in point E) a new permanent institution for the long-term conservation and care of the monument and as a centre for stone conservation research. Such a body was to develop, disseminate and supplement specific guidelines and standards for all the maintenance and conservation activities of Borobudur and other archaeological/historical monuments in Indonesia.

According to the original plan, developed from 1970 onwards, Borobudur would be served not only by the Centre for Stone Conservation but also the Centre for Borobudur Studies.

The government, through the Ministry of Education and Culture, had set up the permanent institution for Borobudur: the Borobudur Study and Conservation Institute (MOEC decree no. 0605/01/1991, dated 30 November 1991). It was established as a third echelon operation (at the third administrative level of the Indonesian civil service) with only a limited structural organization: Head Office, Secretariat, Chief of Technical Section and functional groups. The scope of its operation was not restricted to Borobudur itself but also covered the study of conservation problems at other historical monuments. The institute is also expected to develop conservation technology in Indonesia.

Apart from these tasks, the institute will have a close relationship, and in some cases collaboration or joint projects in related fields of study, with other national and international institutions. Thus, coordination with UNESCO would have to be strengthened. The institute needs to be assigned to a higher echelon, the second echelon, to enable it to conduct these affairs. Thus, it will become the Borobudur Studies and Conservation Centre instead of the Borobudur Study and Conservation Institute in the third echelon.

7.1 Borobudur Training Centre

From 1971 the Borobudur Restoration Project functioned unofficially as a training centre for technicians in the restoration and conservation of archaeological monuments. This new generation was badly needed, as the few technicians that the Archaeological Institute had at its disposal were already committed to ongoing restoration activities in the Prambanan area.

Intensive three-year training courses were started in 1971 and continued until 1974, enrolling candidates annually. When the restoration work started in 1975 by dismantling the north and south sides of the monument, the project's execution relied on these young technicians. This gave them a unique opportunity to put into practice the techniques they had mastered and to become acquainted with the responsibilities involved.

On the initiative of SEAMEO (South East Asia Ministry of Education Organization) in Bangkok, SPAFA (the SEAMEO Project on Archaeology and Fine Arts) was set up to establish three sub-centres providing technical and educational facilities. Indonesia was selected as the SPAFA sub-centre for the Preservation and Restoration of Ancient Monuments, and the National Project for the Restoration of Borobudur was designated as host institution for SPAFA activities, including not only training courses for architects, restoration technicians, chemists and other scientists but also a workshop for specialists in monuments in Indonesia (SEAMEO, 1978, pp. 113–15)

The SPAFA sub-centre activities benefited from the new techniques, modern scientific equipment and expert services available at Borobudur. The laboratories include photography and photogrammetry workshops, a laboratory on stone diseases and a workshop for treatment of stones. The office site of the Borobudur Restoration Project accommodated all SPAFA participants.

During the period 1978–81 the SPAFA sub-centre in Indonesia proposed the following training programmes for both graduate and technician levels:

1. Training course in restoration of monuments (nine months), October 1978 to June 1979 and October 1979 to June 1980.
2 Technician training course in restoration of monuments (six months), October 1978 to March 1979 and October 1979 to March 1980.
3 Technician training course in survey of restoration of monuments (six months), October 1979 to March 1980, April 1980 to September 1980, and December 1980 to May 1981.
4 Training course in conservation of monuments (four months), October 1978 to January 1979 and July 1980 to October 1980.

The successful training courses, and particularly the training opportunities presented by the ongoing restoration of Chandi Borobudur, drew the special attention of the education ministers of southeast Asia. Borobudur was then appointed sub-centre for the Restoration and Conservation of Ancient Monuments in the SPAFA. Eight training courses were conducted between 1978 and 1981, attended by participants from Thailand, the Philippines, Malaysia, Singapore, Brunei Darussalam and the host country, Indonesia.

Meanwhile, four-month training courses at national level were also held at Borobudur, even after the completion of the restoration. Between 1977 and 1986 no fewer then eleven courses were conducted. The participants, who were selected field officers of the Directorate for the Protection and the Development of Historical and Archaeological Heritage, came from all twenty-seven provinces of Indonesia. As a result, we can now rely on well-trained personnel for the safeguarding of the monuments scattered all over the country.

In addition, the Borobudur technicians, who in the meantime had become officers of the directorate, were often sent to render technical assistance to restoration and conservation projects in various provinces. Thus there was a two-way traffic of increasing knowledge and experience.

The Borobudur Conservation Project, as the embryo of the forthcoming permanent body, did its utmost to carry forward the three kinds of activities described above. The archives of the restoration project were kept separately, while the Conservation Project's own archives were administered in the same way. The library was extended by new acquisitions and the photographic documentation reorganized in a way that could better serve the current needs.

The techno-archaeological activities in the meantime changed from dealing with reconstruction to observation and monitoring of the position of the different architectural components of Chandi Borobudur, using the checkpoints established earlier. The chemico-archaeological activities, in turn, were no longer confined to the cleaning and treatment of loose stones. Experiments with new methods using sophisticated equipment were conducted, in addition to daily observation of the effect of former treatments and the current state of the stones. The application of newly developed chemicals on plain stones of the monument and the use of steam for cleaning were among the experiments with the newly acquired equipment, and the results were very promising.

Finally, training of field officers from the various provinces continued regularly. The administrative implication was that the setting up of a new permanent body for the safeguarding of Borobudur, while rendering services to scholars and researchers as well as to restoration projects elsewhere, would have a formal or official character rather than a technical one. In the end the problem concerned finance. Under the existing regulations it would be a hard struggle to get the necessary funds from the government, even though the new organization had been founded as a government body.

Nevertheless, the task had to be carried out for the sake of the perpetuation of a monument like Borobudur for all humanity, and also of years and years of hard work involving hundreds of workers and millions of dollars. The more difficulties, the greater the challenge for the success of the undertaking. The Conservation Project would serve as the basic model of the proposed centre, so that the change would in effect be merely a change in status.

7.2 Borobudur Study Centre

When we carried out the feasibility studies around the year 1959 to find out what would be the best way of saving Chandi Borobudur from total collapse, we were unable to obtain the details of van Erp's activities during his restoration of the monument. No records whatsoever could be dug out from the archives of the Archaeological Institute. The only reference was *The Archaeological Description*, which was the second volume of the famous Borobudur monograph by Krom and van Erp, supplemented by three albums of photographs and drawings.

The later rediscovery, in 1965, of the original floor of the gallery on the first stage was a great surprise that enabled us to gain some idea of what van Erp actually did to keep together the main wall and the balustrade. When dismantling the north side of the monument ten years later we came across a series of stones marked with red paint, which helped us to reconstruct to some extent the way van Erp carried out the restoration work. In the course of the further dismantling many more items were revealed, which individually would not have surprised us but for the fact that there was no record of the earlier work. Such puzzles could only be solved if all the activities involved in the restoration were accurately recorded, in writing as well as in drawings, and the records kept in the archives and made available as reference for later similar efforts.

This experience convinced us that, as executors of the latest restoration of Chandi Borobudur, we must do our utmost to prevent any repetition of such problems. Consequently every single detail of technical or administrative activity was to be recorded, and monthly reports compiled to provide the necessary overall information on the progress of the undertaking, and for eventual use in the future. In relation to this, the aim developed from 1970 onwards to set up a Centre for Borobudur Studies as the permanent government agency for keeping the archives and other records of the project.

The Centre for Borobudur Studies was not only intended to keep the archives, scale drawings, photographic documentation and all other files recording the activities of the Borobudur Restoration Project, but would also be provided with an extensive library of books, articles, newspaper clippings and other kinds of publication from all over the world about Chandi Borobudur, the cultural history and historic archaeology of Indonesia, and also about Buddhism and Hinduism.

The main duty of the institute involved two aspects: study/research and conservation/maintenance, as its name implied. The details of the job description were as follows:

- to carry out the archaeological study of the Borobudur site and its surroundings

- to undertake civil engineering and studies of the architecture of Borobudur and other archaeological/ historical remains
- to carry out the conservation study of Borobudur and other archaeological/ historical remains
- to preserve and safeguard Chandi Borobudur and other archaeological collections
- to report and publish the documentation of the institute's activities
- to manage the secretariat and internal affairs of the institute.

Essentially, this job description could be classified into four technical scientific areas:

- maintenance of the Borobudur monument and the collections of the site museum
- conservation and restoration studies
- architectural and engineering studies
- documentation, publication and training.

The divisions performing these roles were divided into subdivisions to meet relevant objectives and to clarify their job descriptions.

- Architecture and Engineering Studies
  - Civil Engineering Studies
  - Architectural Studies
  - Environmental Studies
- Documentation and Publication
  - Library and Documentation
  - Publication
  - Training
- Administration/Secretariat
  - Personnel
  - Facilities
  - Finance
  - Public Relations.

Finally, to assist researchers and scholars, domestic as well as foreign, with a special interest in uncovering Chandi Borobudur's secrets, a kind of guest house and a room for seminars would be attached to the Centre.

7.3 Borobudur National Archaeological Park

7.3.1 Archaeological survey

One of the basic philosophies of the park development is the preservation and conservation of archaeological remains, since from the archaeological point of view it is highly probable that much still lies undiscovered underground.

An archaeological survey was conducted as part of the consultants' engineering services in order to make proper plans and prevent destruction of those undiscovered remains. However, the area of the survey was very limited and too few points were covered. In the opinion of Indonesian archaeologists, it was never adequate in the light of such great possibilities of discovery.

The project for a park of worldwide significance had to take into consideration the need to safeguard those undiscovered remains. A new archaeological survey was thus essential for the development of the archaeological park.

Two survey methods were used. The first used a standard excavation pit 2 metres across and in most cases up to 1 metre deep. Second was the hand boring method applied where large trees were to be planted, carried out immediately before the planting.

The excavation method was used for the proposed facility area, particularly in locations of heavier structures and deeper earthwork areas; about 10 per cent of building floor

Table 7.3.1.1 Number of excavation and boring pits

Areas of excavation	*Calculation*	*No. of pits*
Building area	9,016 Sq. l-m x 10% = 901.6 Sq m : 4 Sq.m =	225
Heavier paving area	30,000 Sq.m x 1% = 300 Sq.m : 4 Sq.m =	75
Septic tank	30 tanks	30
Other areas	Approximately	50
Total		380

coverage was surveyed as well as 1 per cent of the heavily paved area. Deeper underground structures and possible areas of archaeological interest were surveyed regardless of the proposed facility location.

The survey lasted ten months and was integrated into the total implementation project. The excavation surveys were conducted prior to the start of construction. The surveys using the boring technique were carried out after completion of landscaping and immediately before tree planting.

The result of the survey and the considerable amount of research accumulated indicate that the chandis are 1,000 years old, and will last for many years more. There is a consensus of opinion that park and protected-area construction should not be overimpressive, remarkable or permanent, so as not to draw attention away from the monument. Even though we have a great deal of data on spots already surveyed, the area covered is far less than that covered by the proposed parks. Therefore there is still a good possibility that following generations will discover more about the chandis and may solve eventually the riddle of their existence.

Taking this into account, the construction should not make drastic changes. It should retain the existing topographical condition as far as possible and avoid creating heavy structures needing deep foundations at places where archaeological remains have been found and probably will be found in the future.

Another archaeological consideration is that the existing monument is the predominant (and, needless to say, the essential) element in the park and protected area. Therefore no new structure should be built that would compete with the monument in size and grandeur. If new structures need to be bigger to function efficiently, they should be located well away from the monument or hidden by tall trees.

It is also important that places where heavy structures are to be built should be investigated again before and during the construction so as to avoid damaging undiscovered archaeological treasures.

7.3.2 Evaluation of the master plan

Basically the redesign of the surroundings of the Borobudur National Archaeological Park followed the concept and analysis of the design produced by the JICA Team, especially as far as certain considerations of concepts and principles of spatial arrangement are concerned.

The main difference is perhaps in the performance of the final plan, which in this redesign focused more on taking advantage of environmental conditions and laid stress on the regional identity. It also aimed to reduce those development components that were considered less important, thereby avoiding excessive cost. There were also different views and understandings of various social aspects which the plan had to define more fully.

Thus in all matters pertaining to the general redesign, reference was made to stipulations about the borders of zoning areas, consideration of condition values, problems and potentials of the park's surroundings, data related to the number and classification of visitors, and projections studied and forwarded by the JICA Team.

In order to perfect the design and analysis of the existing condition of the environment, the basic policy for the design of the surroundings of the Borobudur National Archaeological Park had to follow the guidelines below:

- The Land Use Plan aimed to use existing material and potential as much as possible in order to preserve the archaeological remains. It developed a land use system that is tourism oriented while preserving existing agricultural conditions.
- For the site plan, it was necessary to consider criteria for choosing where activities should be developed, including a set of principles for the spatial arrangement and the activities, the connection between the location of activities and the monument, roads for the tourists, existing use of the site, topographic conditions and existing spatial conditions.
- The facility plan had to incorporate the following aims:
  a. To create a spatial arrangement that is harmonious for both the natural and human environment, and to preserve the traditional archaeological conditions as much as possible through restraint in the development of new facilities.
  b. To make use of typical regional approaches to the creation of spatial arrangements and the environment, although the introduction of certain facilities will entail use of the latest systems.
  c. To consider the hierarchy of scale between facilities to be developed and the existing monument.
  d. To study and evaluate the possible existence of archaeological remains whose locations are not yet known.
  e. To establish an interrelation between the facility sites that would result in a compactness and a system of service appropriate for visitors as well as for the respective facilities.

Using these guidelines, a proposal for the redesign of the surrounding area of the Borobudur National Archaeological Park was developed for the following elements:

- Land use: from the viewpoint of gardening and landscaping as much use as possible should be made of rice fields and coconut.
- There should be a grouping of similar supporting facilities in one location; the public area comprises a service area for the public and there are special private areas for non-public activities, with semi-public areas in between.
- The proposal on infrastructure in the park allowed for:
  a. a concourse or road from the gate directly to the monument
  b. a parking area for various main transport facilities in the park such as *andong/sado* or bicycles and local transport
  c. a special route for pedestrians
  d. a road for services/operational activities
  e. a traffic terminal and parking for tourist buses and private cars.
- Proposals for the landscape plan:
  a. Utilize rice fields and coconut plantations as park components.

b. Eliminate the ponds that are merely decorative and replace them by non-permanent fishponds.

c. Maintain the plant components in the landscape plan that function as: formal components in the concourse area; decorative plants in areas that need special attractions such as gardening and flower gardens; vegetation to provide shade along the roads and in the parking area; edge vegetation in the buffer zone; screening vegetation in areas that need ground cover; artificial forest for areas that because of their nature need special attractions.

- Various protected areas of Zone 1 in the Borobudur National Archaeological Park are not yet defined in the plans.
- The proposal for the redesign of the Borobudur National Archaeological Park is an overall design that integrates land use, the site, facilities, transportation, utilities and the landscape.

7.3.3 The integrated zoning system

The integrated zoning system is a means of passing on to the future the historical environment of this area, which has been formed over a period of centuries. The system encompasses the goals of both preservation and development as two extremes and aims at systematic land control. It consists of five zones as follows, each with its own particular purpose:

Zone 1

This zone is established to protect the physical environment of the archaeological monuments.

The zone covers an area with existing monuments of great historical value that is to be designated as a protected area. Its land is to be nationalized, and the monuments and their surroundings are to be permanently protected.

Zone 2

This zone offers the provision of park facilities for the convenience of visitors and preservation of the historical environment.

This will incorporate the area around the Borobudur Temple, one of Indonesia's most representative historical monuments, be provided with various facilities to accommodate the growing number of visitors and function as a park. Its land will be gradually nationalized, its environment will be improved and facilities will be built for maintenance and park control.

Zone 3

This zone allows for regulation of land use around the parks and preservation of the environment by controlling development in areas surrounding them.

It consists of the area around the park zone in which there is a concentration of existing monuments. Its purpose is to introduce a system of land use regulation involving some restriction of regional development and partial freezing of the present state of land use, as well as of taking measures for environmental preservation over a wider area as means of passing on the present desirable environment to future generations.

Zone 4

This zone is designed for the maintenance of the historical scenery and prevention of destruction of the landscape.

It is a wider area than Zone 3. As an area of high historical and scenic value that will be seen by many visitors, it is selected for maintenance and improvement of the scenery. A system of scenic controls will be introduced to prevent development that might lead to deterioration of the environment.

Zone 5

This zone facilitates the undertaking of archaeological surveys over a wide area to prevent the destruction of undiscovered archaeological monuments.

It covers that part of the Kedu Basin where the Shailendra and Mataram dynasties of the Central Java Period centred, including all of the existing archaeological monuments and areas where it is likely that other unexcavated monuments exist. Archaeological surveys and excavation work will be undertaken and all necessary steps will be taken to ensure that development activity does not lead to the destruction or damage of any unexcavated monuments.

7.4 UNESCO and Borobudur since the restoration

Close links have been maintained between Borobudur and UNESCO. In December 1991 the site was inscribed on the World Heritage List, on the grounds that 'the monument of Borobudur is the biggest Buddhist monument of the eighth to ninth century in Indonesia and has a unique architecture'. Thus Borobudur was officially recognized as one of the outstanding representations of human creative genius in the world.

The Borobudur Study and Conservation Institute was formed in 1992, and in 1993 the Director-General of UNESCO, Federico Mayor, paid a visit to the site and the Institute, as well as to the palace/monastery site of Ratu Boko. It was during this visit that the Director-General made a special donation of US$40,000, which was subsequently used by the government in collaboration with the UNESCO Office in Jakarta to purchase a portable computerized theodolite for the institute. Its portable nature allows the instrument to be used at any archeological and restoration site in Indonesia. The purchase was executed early in 1995.

Also in 1995 the third International Experts Meeting was held in Borobudur. During the meeting it was reiterated that:

> The Borobudur Study and Conservation Institute is responsible for the preservation of the Monument as well as for conducting research in developing restoration and conservation methodology and for delivering training both nationally and regionally.

The same document also stated, however, that:

> The present status of the Institute is not adequate to support such a national task, because of the lack of necessary experts and technicians. In addition, some of the equipment is old and needs to be replaced.

With these observations in mind, the UNESCO Office in Jakarta carried out a monitoring mission in collaboration with the Indonesian Government in late 1995. The mission aimed to formulate recommendations, and a list of the equipment and repairs required. One of its recommendations was that 'technical assistance is needed for maintenance and future development of Borobudur's conservation laboratory'.

With the assistance of the UNESCO Office in Jakarta, and following the suggestion that the surplus budget from the Borobudur Trust Fund could be put to use, the recommendation resulted in a decision by the Indonesian Government to renew the photogrammetry equipment in the Institute, which dated back to 1974 and for which no spare parts were available. This decision was discussed in Paris and accepted. The problem of finding suitable bidders for new digital equipment made the exercise very slow and difficult, the major problem being to find qualified suppliers among local companies. This is of crucial importance for the Indonesian Government in case repair or replacement is needed. Solutions have however been found and the old equipment will soon be replaced by the latest portable 3D laser scanning system.

A Borobudur on-site promotion meeting, supported by the World Heritage Centre, was organized between 12 and 14 January 1999 as a collaborative operation of the Indonesian Government and the UNESCO Office, Jakarta. During the meeting decisions were made on issues related to the improvement of the promotion of the World Heritage site and the following recommendations were made.

- Promotion for Borobudur and Prambanan as World Heritage sites should be intensively implemented at all levels of the community, particularly among junior and senior high school students.
- Tourism promotion for Borobudur and Prambanan should be consolidated in a single package and should become part of the student curriculum.
- The promotion strategy for Borobudur and Prambanan should be improved in a way that would attract more interest among tourists; it was noted that conservation and restoration activities could be utilized as one of the tourist attractions.
- Public awareness should be improved through programmes to explain the significance of our cultural heritage/ world heritage for the next generation.
- The special interest of providing specific and scientific information should be used to develop tourist programmes.
- Inter-sector coordination in promoting Borobudur and Prambanan as World Heritage sites should be improved.
- Leaflets or pamphlets on Borobudur and Prambanan should be distributed in East and West Java; these should be attractive and well prepared.

These leaflets were subsequently printed with the assistance of the World Heritage Centre.

In late 1999, it was also decided that the Indonesian Government, in close collaboration with the UNESCO Office in Jakarta and the Paris headquarters of the Cultural Heritage Division, would finalize a publication on the restoration campaign of Borobudur, a decision that has borne fruit in the present document. It was also proposed that a final meeting of the international experts was to be held in June 2003 on the twentieth anniversary of the restoration campaign to bring together everybody involved in the restoration process.

All this serves to illustrate the strong relation UNESCO continues to have with the Borobudur site and so with the Indonesian Government, especially since 1995 through its Culture Sector field representation in the UNESCO Office in Jakarta.

8. A New Perspective on Some Old Questions Pertaining to Borobudur

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with important contributions by ***Mark Long*** and ***Jeffrey Sundberg***

The earlier chapters have provided an extensive technical overview of the restoration efforts of the Borobudur Restoration Project. The purpose of this chapter is to explore the many mysteries and questions that continue to surround the site. In 1969 Dr Soekmono, the internationally recognized expert on Borobudur, published an article with the revealing title 'New Light on some Problems of Borobudur', which appeared in the *Bulletin of the Archaeological Institute of Indonesia*. Similarly, when the famous expert A.J. Bernet Kempers published his own work on Borobudur in 1976, he entitled it *Ageless Borobudur: Buddhist Mystery in Stone – Decay and Restoration – Mendut and Pawon – Folklore in Ancient Java*.

I therefore feel honoured to be invited to add an additional chapter to this otherwise technical book and discuss some of the archaeological mysteries and questions that remain to be answered. The discussion that follows builds upon a number of observations and archaeological discoveries that were made during the preparatory research stage of the Borobudur Restoration Project, during the implementation of the technical project, and over the two decades since it was completed. Although some of these findings were unintended by-products of the technical reconstruction project, they proved to be highly relevant to understanding Borobudur, and were therefore followed up in considerable detail thereafter. This was done in a large part in consultation with colleagues in Indonesia and abroad, and especially with the late Professor Dr Soekmono himself, to whom the following paragraphs are dedicated.

The findings that are presented below highlight the more interesting recent developments, which will be presented in detail in a forthcoming book entitled *Borobudur: Pyramid-Mountain of the Cosmic Buddha*, to be published in 2005. For brevity's sake, readers are referred to the extensive bibliography that will appear in that volume.

Within the framework of the present chapter the interpretation of the relevant observations and discoveries concerning the mysteries of Borobudur, and the conclusions to be derived from them, are grouped in the following sections under three separate headings:

1. Borobudur and its Javanese-Buddhist historical context
2. Borobudur and its international Buddhist historical context

3. The temple, its surroundings and its connection to the local environment.

Many of the facts discussed in two of these sections are characterized by the important consequences of two major historical discontinuities that took place in and around Java, one in the sixth and the other in the tenth to early eleventh centuries CE. These were probably provoked by fundamentally different natural events, and had different political, religious, economic and socio-cultural effects.

Strangely, the first of these major historical discontinuities, in 535–36 CE, has attracted only limited attention from archaeologists working on the history of Java and Sumatra. This is all the more astonishing when one considers the nature and duration of the event and its consequences, the extent and intensity of which were observed worldwide over the following decades. The effect outside Indonesia has already been the subject of several scholarly works. By contrast, the second historical discontinuity, which was primarily restricted to Central and Eastern Java, has been the subject of intensive discussions for more than eighty years, and has involved Indonesian and foreign archaeologists as well as national and foreign earth scientists.

8.1 Borobudur and its Javanese-Buddhist historical context

To gain a good understanding of the Hindu–Buddhist period of Javanese history (seventh to fourteenth centuries CE) one has to delve much deeper into the past, going back to the third to fifth centuries, or perhaps even earlier, when the first phase of the Hinduization of maritime Southeast Asia took place. This early period is extremely interesting because the historical development of maritime Southeast Asia and its relations with continental South and Southeast Asia are characterized by widely diverging processes and trends.

Basically, the Javanese Hindu-Buddhist historical context can be subdivided into four main periods: Java before the seventh century CE, Java between the seventh and tenth centuries (the Classic Javanese period), Java from the tenth century until the advent of Islam, and finally the modern history of Java since the advent of Islam (which was quite soon followed by the Dutch colonial period). Of these four main periods the first and the second, and to a limited extent the third, are of direct interest for a study of Borobudur and its Javanese-Buddhist historical context.

Very little is known about the local Hindu-Buddhist Javanese history before the seventh century CE, in particular in Central and East Java. The situation in West Java is somewhat different, as five inscriptions dating from the fifth century were found near present-day Bogor and Jakarta. However, there is little other information, such as religious or architectural remains, and the history of West Java is still poorly known. Thus far, only five temple sites have been found there: Chandis Cangkuang, Garut; Chandi Ronggeng, Pamarican; Chandis Pananjung, Ciamis; Cibuaya, Karawang; and Batujaya.

Of these, the Batujaya site in Karawang regency is by far the largest, and with regard to the Hindu-Buddhist Javanese history from before the seventh century perhaps the most relevant. First examined by experts in 1984, the complex lies in an area of 5 square kilometres, comprising more than twenty structural remains buried in what locals call *unur*. Ongoing excavations by archaeologists since 1984 have uncovered seventeen *unur*, of which three are in the form of pools. Preliminary research at the site found that the Batujaya complex was built between the fifth and sixth centuries. 'This is based on the inscriptions found on numerous votive tablets discovered in the area. This at least signifies that the temples were in use between the fifth and sixth centuries', said Hasan Djafar, project leader on the Batujaya excavation (quoted by Tantri Yuliandini in the *Jakarta Post*, 16 August 2003). It is unclear, however, whether Tarumanagara's famous King Purnavarman, who lived in the fifth century CE, built the complex.

The votive tablets are small clay pieces used in prayer, with inscriptions and pictures of Buddha. The finds upset an earlier theory of several Indonesian archaeologists that the state religion of Tarumanagara was Vedic, an earlier form of the present Hinduism, whose religious ceremonies were conducted in open fields and hence left no temple remains. Besides the votive tablets, another indication that the complex was Buddhist came with the floor plan analysis of two structures – Chandi Jiwa and Chandi Asem – which showed that they were once Buddhist *stupas*, believed to have been constructed between the second and fourth centuries CE.

The finding of the large number of votive tablets at the Batujaya complex warrants thorough future investigations because such discoveries are very rare in the Buddhist history of Java. This is mirrored by the similar discovery of more than 2,000 votive *stupas* and more than 250 votive tablets of unburned clay, some with short inscriptions, at the west side of the base of the Borobudur hill in Central Java, which could be dated from the eleventh century. These discoveries suggest two important questions to which no answers can yet be given.

The first obvious question is whether the finding of these votive *stupas* and tablets near Borobudur represents a return in eleventh-century Mahayana Central Java to an older tradition, one that had first emerged between the fifth and sixth centuries CE in the Tarumanagara Buddhist society in West Java. Are we dealing with a sheer coincidence, or do these discoveries prove the existence of a direct link between the Buddhism of West Java in the fifth to sixth centuries and the eleventh-century Mahayana Buddhism of Central Java?

The second question relates to the locations where these votive tablets were found: in Batujaya in Tarumanagara in West Java and at Borobudur in Central Java. The report in the *Jakarta Post* of 16 August 2003 only mentions that numerous votive tablets were discovered within the 5 square kilometre area of the Batujaya complex, without any indication of their location. Were they found spread over different places or had they all been found together at a single relatively small site, like the find at the foot of the Borobudur hill? If the former is the case we may be dealing with votive tablets deposited by pilgrims during their visits to the holy sites of Batujaya and Borobudur to pay homage, meditate or participate in religious ceremonies; the tablets would then have been found at various sites at these sanctuaries. The other possibility, which appears more logical at Borobudur where all votive tablets were found grouped together outside the sanctuary itself, is that the finds are an indication of the place where they were manufactured, not deposited. In that case it appears more logical that they were produced *en masse* for the pilgrims to take home with them as memorabilia of their journey, in much the same way as Buddhists on the Southeast Asian mainland still do today.

Unfortunately, we do not have precise information on the dating of these early Buddhist remains discovered in Tarumanagara, or on the form of Buddhist beliefs and practices they represent. Thus we cannot yet say whether there were any relations at that time with Hinayana Buddhist settlements, which Lokesh Chandra suggests could have existed further north in Sumatra. Recently Lokesh Chandra postulated the theory that the ancient seventh-century Kingdom of Shrivijaya in South Sumatra had its origin as early as the third century in Shrivijayapuri (the present-day Andhra Pradesh in India), from where he believes that this Hinayana Buddhist Shrivijaya expanded in the fourth century through the Malaysian Peninsula into the Island of Sumatra, centuries earlier than accepted thus far.

Another even more recent discovery in West Java could perhaps become equally relevant to Hindu-Buddhist Javanese history before the seventh century. In August 2002, a previously unknown Hindu temple was discovered in Bojongmenje, Cangkuang Rancaekeke, which is about 25 kilometres southeast of Bandung in West Java. The temple yard consists of a main shrine that is surrounded by a number of smaller buildings. An archaic column found on the site suggests that the temple predates Borobudur and may even prove to be the oldest monument ever discovered on the island. The Indonesian archaeologist Djubiantono, according to a newspaper interview, believes that the site of Chandi Cangkuang was abandoned in the seventh century after the collapse of the Taruma Kingdom. If this hypothesis proves to be correct, a thorough site analysis may eventually help archaeologists to reconstruct critical missing parts of West Javanese history.

The inscriptions and temple sites are proof that during the fifth century CE there existed in the Sunda region – the westernmost part of the Island of Java – the Kingdom of Taruma (Tarumanagara). It prospered during the reign of King Purnavarman, who compared himself in a number of Sanskrit inscriptions in Pallava script with the God Vishnu. King Purnavarman is best known for a large canal that he ordered dug to evacuate floods near Tugu to the northeast of present-day Jakarta. In addition, two four-armed images of Vishnu have been discovered on the banks of the Tarum river east of present-day Jakarta, which present features in common with early Pallavan sculpture, another indication of early Indianization.

With the exception of the few facts mentioned above we know precious little about the history of Tarumanagara. In his newspaper interview Djubiantono refers to this when stating that we have just the Kebon Kopi inscription in Bogor, which was written in the ninth century and which says 'Let us revive the glory of Sunda'. He added that we have yet to find proof that there was an important Sundanese Kingdom of Tarumanagara before it collapsed in the sixth century and dissolved into smaller kingdoms like Galuh, Pakuan, and Pajajaran.

The Taruma Kingdom lay in the area of the Sundanese cultural sphere, which has certain affinities with Southeast Sumatra but is different from the Javanese cultural sphere which dominated and still dominates in Central and East Java. The boundary between these two cultural spheres corresponds roughly with the boundary between the present Sundanese and Javanese languages, a boundary that runs approximately north–south from the harbour town of Cirebon on the north coast across the island to the south coast which borders the Indian Ocean. During this period there still existed in South Sumatra an important and widespread prehistoric megalith-building warrior culture, the Pasemah. It should be noted that the emergence in the Sundanese region of West Java of the short-lived Hindu-Buddhist kingdom Taruma was the first time that (South) Sumatra and (West) Java followed separate historical developments, a trend that was to continue during the later parts of the Hindu-Buddhist Javanese history.

The new discovery at Chandi Cangkuang may also help to bridge the wide historical gap that lies between the construction of the Buddhist Jiwa Temple in West Java in Batujaya, Karawang regency between the second and fourth centuries CE and the Hindu temples on the Dieng Highlands in Central Java. Although the earliest inscription from the Dieng area dates from the mid-ninth century, studies of the architectural elements of the buildings there indicate that they were built at around the same time as Borobudur and other Buddhist sanctuaries dating from the eighth century. It is for instance as yet unknown what relations, if any, had ever existed between fifth-century Tarumanaga and its Hindu and Buddhist communities and the very active and prosperous Hindu and Buddhist communities that emerged in Central Java in the seventh to eighth centuries. Was the Tarumanagara Buddhism represented at the Jiwa Temple at Batujaya similar to the esoteric Buddhism of Borobudur, or are we dealing in Central Java with a separate wave of Indianization and of the introduction of Hinduism and Buddhism?

These discoveries and the recognition of the wide historical gap of at least a century between the temple constructions in Tarumanagara in West Java and those in Central Java would confirm an important working hypothesis elaborated in detail in *Borobudur: Pyramid-Mountain of the Cosmic Buddha*. In view of the great importance of this historical discontinuity for the Hindu-Buddhist history of Java it deserves also to be discussed at some length in this chapter.

No traces of the West Javanese Tarumanagara are found after the fifth or sixth centuries. Major temple complexes like the newly discovered Chandi Cangkuang and Buddhist Chandi Batujaya in Karawang regency, found somewhat earlier, were apparently abandoned at around the same time. This could possibly be explained by the tremendous havoc caused by the presumed submarine volcanic mega-eruption of 535–36 CE in the Sunda Strait, which caused not only the destruction of the political structures of the kingdom but also the total collapse of society in the Sunda region. It was not until 1,000 years later that the Islamic sultanate and trade centre of Banten emerged in the area. This was followed shortly afterwards by the founding of the harbour city/trade centre of Sunda Kelapa on the north coast of West Java, which was visited by Portuguese and Dutch sailors and traders. This was followed again somewhat later by the founding of the Dutch fortifications and trade centre of Batavia at the site of Sunda Kelapa – the Jakarta of our days.

The prehistoric Pasemah culture in South Sumatra also lost much of its importance after the fifth century. It was only in the seventh century that another Buddhist kingdom, Shrivijaya, emerged in South Sumatra, on the other side of the Sunda Strait, characterized by a number of inscriptions written no longer in Sanskrit but in Old Malay. It was also only in the seventh century that Hindu and/or Buddhist states emerged in Central Java and that the main period of construction of Hindu and Buddhist sanctuaries began.

It is curious that the important historical sixth-century discontinuity in West Java and the absence of Hindu-Buddhist archaeological finds before the seventh century in South Sumatra and Central Java have received very little attention from historians and archaeologists. This is the more remarkable since the sixth-century historical discontinuity is of such fundamental importance in many other parts of the world as well. It was presumably provoked during the years 535–36 CE by extraordinary meteorological events, whose impact and aftermath were felt for many decades and locally even for centuries.

As to the causes of these extraordinary meteorological events, the opinions of the various experts vary between truly giant dust storms (the mechanisms of which are yet to be explained), the impact of an asteroid or comet on the Earth's surface (probably in an oceanic area), or a volcanic mega-eruption (most probably of a submarine volcano located in the Sunda Strait between the islands of Sumatra and Java). Whatever the cause of the extreme meteorological conditions, their effect was to carry huge amounts of very fine dust particles, aerosols and water vapour high into the atmosphere and most probably far into the stratosphere. They are supposed to have remained suspended in the atmosphere and stratosphere for many months or even several years, obscuring the sky for very long periods and thereby considerably reducing the solar radiation reaching the Earth's surface. This would have upset the heat balance of the atmosphere and caused a global cooling of unusual magnitude.

These phenomena would have resulted in a prolonged period of perhaps several decades of very cold weather, as can be deduced from the systematic analysis of tree ring chronology in many different regions. In several parts of the world these extreme events with respect to climate were recorded in ancient chronicles in connection with the occurrence of famine, epidemics and social, economic and political turbulence and chaos. We as yet know little about the long-term psychological and social effects, and the resulting changes in religious attitudes, of extreme geophysical events that involve changes to climate such as presumably occurred in the years 535–36 CE. They would certainly have been far-reaching and it may have taken more than one generation to reach a new equilibrium. It appears acceptable and logical to speculate about what probably did happen in the sixth to eighth centuries in the islands of Sumatra and Java.

The first attempt to analyse and explain the tremendous physical damage caused by the 535–36 CE submarine volcanic mega-eruption and the resulting depopulation of the area, as well as social, economic and political chaos on both sides of the Sunda Strait, was the result of research by David Keys and other experts. A brief summary of his findings in ancient Javanese records is given below.

David Keys' book *Catastrophe: An Investigation into the Origins of the Modern World* is based on extensive research covering all continents, in which he was assisted by more than eighty specialists in many different fields, some of whom were specially commissioned to carry out specific investigations. Part of the author's field research in the Sunda Strait area was funded by the United Kingdom's Channel 4 television, which broadcast a special documentary on this issue in the United Kingdom on 27 July and 3 August 1999. With regard to the specific events in the Sunda Strait in 535–36 CE, David Keys refers to a surviving copy from 1869 of an ancient Indonesian chronicle, the *Pustaka Raja Raja Purwa* (the Book of Ancient Kings). Two slightly different versions of this book are kept in the *Susana Pustaka* Library of the *Kraton* (Royal Palace) of the *Susuhunan* (King) in Surakarta, as copies dating from 1869 and from the mid- to late 1880s. Nancy Florida of the University of Michigan, an American specialist in Javanese literature, translated passages from the 1869 copy from Javanese into English. Some passages from the 1880s version, which might have been influenced by the 1883 Krakatoa eruption, were translated by the Dutchman C. Baumgarten and quoted in a letter of Professor Judd published in *Nature* on 15 August 1889.

But with the exception of these few translated parts the *Pustaka Raja Raja Purwa* has apparently never been the object of detailed scientific studies.

These surviving manuscripts were compiled at two different dates in the nineteenth century by a Javanese intellectual Ranggawarsita III, a leading literary personality at the royal court of Surakarta. His ancestors, many of whom are known by name, had held similar high posts at court for at least 300 years. Some of them had apparently compiled versions of parts of the same manuscripts in 1745 and probably also much earlier. There is some evidence to suggest that all these texts were at least partly based on very ancient Javanese chronicles written on palm leaves. Many such palm-leaf texts still survive in collections in Java and in Europe and the United States. However, as emphasized by David Keys, these texts, unfortunately, have almost never been the subject of thorough scientific analysis.

The two nineteenth-century versions of the *Book of Ancient Kings* give quite a detailed description of a volcanic eruption in the Sunda Strait. They mention various characteristic features that we know also from the 1883 Krakatoa eruption, but which of course would have been unknown to the Javanese author of the 1869 version. For these and other reasons, David Keys considers the account of the ancient volcanic mega-eruption as probably at least substantially true. There is one problem: the manuscripts date the mega-eruption as having happened in the Shaka Calendar year 338, which would correspond to 416 CE. This chronological error could easily have happened in the successive phases of copying of the chronicles.

According to the *Book of Ancient Kings* the mega-eruption occurred at Mount Batuwara (now called Pulosari), causing great floods which flowed eastward as far as Mount Kamula (now Mount Gede) and westward to Mount Rajabasa in southern Sumatra, killing the inhabitants of the entire flooded area. From the ancient descriptions it would also appear that during one phase of the eruption pyroclastic flows consisting of boiling hot tidal waves of steam, sulphur, air, carbon dioxide, carbon monoxide, ash and rocks spread in all directions away from the volcano. This was followed by the collapse of the volcano and the sinking of the surface below sea level, creating a large, permanently flooded submarine caldera.

The Sunda Strait volcanic eruption was located on an extensive and relatively narrow belt with very active volcanoes that passes through the Indonesian archipelago. Some of the volcanic activity in this belt is of a very explosive nature, and highly explosive and intensive eruptions occurred repeatedly during the Pleistocene and Holocene parts of the Quaternary, as well as during prehistoric and historic periods, resulting in many cases in the formation of volcanic collapse structures or calderas. A typical example is the huge depression of the Lake Toba caldera, which during its eruptions about 30,000 and 75,000 years ago produced volcanic ashes that covered a large part of the Malay Peninsula.

In the same volcanic belt are situated the caldera formed by the 1883 Krakatoa eruption in the Sunda Strait, the presumed 535–36 CE mega-eruption also in the Sunda Strait, the very scenic Holocene Mount Tengger near Malang in East Java, and the enormous Tambora eruption of 1815 in the western part of the island of Sumbawa. The highly active Merapi volcano near Borobudur with its very explosive eruptions is located in the same volcanic belt.

Returning to the history of Hindu-Buddhist Java between the seventh and tenth centuries CE, insufficient attention has been given to the reasons behind the sudden emergence of Hindu and Buddhist kingdoms in Central Java at around the same time that Shrivijaya's own star was rapidly rising over South Sumatra. The waning of West Java's Taruma Kingdom not only provided local rulers in the island's interior an excellent opportunity to expand the boundaries of their domains but also gave them the time they needed to develop their own state governments without fear of outside interference. Starting from almost nothing, Central Javanese civilization reached a phenomenal degree of maturity within a period of just 200 golden years, during which time the area's rulers established a sphere of influence that would eventually encompass West Java, Sumatra, Bali and the Malay peninsula as far as the trading centre of Chaiya in the north. The burst of artistic and architectural effervescence, and the related intensive construction activities, which radiated outward from the island's centre between the eighth and tenth centuries, ultimately culminated in the building of some of the most beautiful and awe-inspiring temples to be found anywhere in the world, which is why the entire period is generally known as the *Classic Age* of Javanese Hindu-Buddhist culture.

The extremely destructive events which apparently took place in 535–36 CE and their long-lasting effects on the stricken populations may explain the mysterious and apparently sudden emergence in the seventh century in South Sumatra of a Mahayana Buddhist Kingdom known as Shrivijaya, which had its centre around present-day Palembang, the existence of which is confirmed by some early seventh-century inscriptions. In general archaeologists have taken the existence of Shrivijaya for granted, without questioning the reasons for its emergence at that period. During the seventh century, it grew rapidly as a Mahayana kingdom, and after absorbing the Kingdom of Malayu (Jambi) developed equally rapidly into an important political and maritime power, before starting to decline in the second half of the eleventh century. We have also to take into consideration that the rapid emergence of this new kingdom was accompanied by a profound change in Buddhist doctrine from Hinayana Buddhism to esoteric Mahayana Buddhism.

Equally little attention has been paid to the fact that at about the same time in the seventh century other Hindu and Buddhist kingdoms emerged almost as suddenly and miraculously in Central Java, flourished in the same way and showed a remarkable cultural and architectural development, resulting in the construction between the seventh and tenth centuries of numerous and often very large temples and other religious buildings. The two scholars Daigoro Chihara and Lokesh Chandra are important exceptions to this general lack of interest. They have speculated as to how and why Central Java, starting from almost nothing, reached in the seventh century these 200 years of golden maturity, a civilization that radiated to a certain degree to western Java and Sumatra and beyond as far as Chaiya on the northeastern coast of the Malaysian Peninsula, and eastward to Bali. This period is generally identified as the Classic Age of Hindu-Buddhist Javanese culture and architecture.

All of these developments appear less mysterious when we entertain the theory of a major catastrophe with a worldwide impact during the mid-sixth century, and in particular that of a volcanic mega-eruption in the Sunda Strait in the years 535–36 CE. As mentioned in the previous section, this event resulted in depopulation and social, economic and political chaos on both sides of the Sunda Strait, which caused the decline of the Pasemah society and the collapse and disappearance of the Kingdom of Taruma and from which the Sundanese society in West Java only recovered very slowly. It also resulted in a considerable reduction of international maritime trade through the Strait of Malacca between China, India, the Arab world and the Roman and Byzantine empires, and in a diminishing of politico-economic development along the west coast of the Malay peninsula, as exemplified by the diminished number of tribute missions from the trade centres of the Malay peninsula to China.

In a personal communication, the Malaysian geologist T.T. Khoo, has arrived at a date for the catastrophe based on his further analysis of a compilation of tribute missions from the Thai-Malay peninsular to the Chinese Emperor (Wheatley, 1980, p. 118). Khoo believes that the catastrophe probably took place after the tribute mission had left P'an p'an following the end of the N.E. monsoon in February and most likely at the beginning of the S.W. monsoon in May or June 536 CE on its way for China. He concludes this from the fact that in those days sailing trips were controlled by the monsoons. There were tribute missions every year from 529 to 536, but there was then a four-year gap until 540 CE, after which the tribute missions became less regular, reflecting the tremendous disruption to the port-city economies of the Southeast Asian states as a result of the presumed eruption.

The psychological and social effects of extreme climate changes and geophysical events would certainly have been far-reaching and may have taken more than one generation to reach a new equilibrium, as discussed by Joel D. Gunn (Editor) and his co-authors in their book *The Years without Summer: Tracing A.D. 536 and its Aftermath*.

During the seventh century, the stricken populations gradually recovered from the aftermath of the catastrophe of 535–36 CE and the worldwide social, economic and political chaos that had followed in the wake of the event itself. The local indigenous societies appear to have been revitalized by an event that may have liberated the potential for the development of new creative forces. In this context it is significant that the Shrivijaya inscriptions in Pallava script found in the Palembang region, dating from 683, 684 and 686 CE (thus all from about 150 years after the catastrophe) are all written in Old Malay, whereas we find Sanskrit in the earlier inscriptions in the Kedah area on the Malay Peninsula, the Taruma inscriptions in West Java and the Kutai inscriptions in the Mahakam valley in East Kalimantan. However, it is important to emphasize that these inscriptions were public proclamations rather than religious documents.

The international maritime trade through the Strait of Malacca must also have resumed during the seventh century. Simultaneously the second period of Indianization of maritime Southeast Asia got a fresh start. The Palembang area in South Sumatra, situated very favourably on a gulf at the mouth of the Musi River and outside the region of direct physical destruction in the Pasemah area in southernmost Sumatra, was in a good position to profit from this international trade. Lokesh Chandra reminds us that the South Indian (Tamil) Vajrayana Buddhists were rich multinational merchants who at that time carried out intensive trade with China and formed colonies of rich Buddhist traders (called *sambara* in Tamil) along their trading routes.

The void left by the disappearance in the sixth century of the former Taruma Kingdom in West Java following the extreme events of 535–36 CE also permitted Central Java to profit from the international maritime trade, which found a new foothold in some harbours on the central part of the north coast of Java. Reliefs at Borobudur depicting traders at their business and large, probably Javanese, merchant ships and their crews amply illustrate the importance of this international trade.

Another important aspect of international relations during the seventh century is that they apparently extended much further beyond mere conventional trade relations than had been the case during the fifth century and before. Religious, political and cultural relations became more prominent and played a bigger role, especially in the development of the Central Javanese states. In the seventh to tenth centuries they also had a significant influence on Central Javanese religious and cultural matters. Moreover, we should not overlook the probability that the long-lasting memory of the 535–36 catastrophe had made the populations more sensitive to certain religious and cultural influences, especially when they took the form of esoteric and/or Tantric concepts and practices.

As to the Sunda region and the former Taruma Kingdom in West Java, the local population could have recovered only very slowly from the almost total socio-economic collapse and the extensive physical havoc caused by the volcanic mega-eruption, which had devastated the region as far eastward as Mount Gede, or Mount Kamula as it was known in ancient times. This created an excellent opportunity in Central Java for the Javanese cultural sphere, which had suffered less harm, to develop independently, politically and economically as well as culturally, as is illustrated by the explosion of religious creativity which led to the construction of world famous Borobudur and large numbers of other important Buddhist and Hindu temples.

Lokesh Chandra believes that the Shailendras had come to Java carrying the beliefs and cultural traditions of Shri Shailam in South India, where Vajrayana Buddhism had once existed side by side with practices dedicated to Shiva. As can be seen at Nagapattinam in South India, the Vajrayana Buddhists were great builders of sanctuaries and *stupas* as visible landmarks. Whatever the case, in the seventh century this Shrivijaya kingdom rose swiftly as a Mahayana state, absorbed the Kingdom of Malayu and developed equally rapidly into an important political and maritime power that prospered until the second half of the eleventh century.

In *Borobudur: Pyramid-Mountain of the Cosmic Buddha*, Mark Long and I discuss a number of the more important Hindu and Buddhist temples and sanctuaries constructed in Central Java. However, our primary focus is on the building of Borobudur, including the reasons for selecting the site on which it was constructed, the significance of the various building phases and many other essential aspects of this unique monument. In particular, our joint work refers to the many other publications of the last several decades which deal with the numerous Hindu and Buddhist monuments and sanctuaries in Central Java and with the various inscriptions relating their construction to certain Hindu and Buddhist kings.

Located in Central Java's northern highlands, the 'Nine Temples' at Chandi Gedong Songo on Mount Ungaran, together with a second temple group to be found in the general vicinity at Dieng, demonstrate that a centre of Javanese civilization had begun to take root in the area during the eighth and ninth centuries CE Although the area's first dated inscription comes from the mid-ninth century, the Chandi Gedong Songo and Dieng temple complexes display a number of architectural characteristics which suggest that construction had begun at the two sites during the mid- to late-eighth century. Did the survivors of the catastrophe that brought West Java to its knees during the sixth century build these Hindu temples? Excavations that are currently under way at the seventh-century Chandi Cangkuang temple site near Bandung may eventually allow us to answer this question.

With regard to the many Buddhist monuments and sanctuaries in Central Java, it appears clear from many publications that they often represent different Mahayana Buddhist concepts and practices, and we also know the names of several of the kings who probably commissioned their construction. Likewise, the different construction phases at Borobudur appear to reflect the prevalence at one time or another of changing religious concepts and the introduction of new construction techniques. Thus, there is no reason to repeat here the discussion of Borobudur and of these other Buddhist temples and sanctuaries in Central Java, which will just be briefly enumerated.

Beginning in the late eighth century CE, the Shailendra kings embarked upon an ambitious temple-building programme that not only featured the construction of a large number of entirely new religious foundations but also involved major renovation efforts at a number of existing sites. Historians generally credit the Shailendra with commissioning more than a dozen Buddhist temples and monasteries within the short period of just fifty years, several of which are among the finest examples of Buddhist architecture that the world has ever known.

What little we know about the inspirational forces that impelled the Shailendra to create such a large number of wonderful temples comes from their inscriptions. Discovered on the Prambanan plain in the vicinity of the Buddhist temples of Sewu, Lumbung and Bubrah, the *Stone of Kelurak* (782 CE) celebrates the installation of a holy image of an esoteric form of the Bodhisattva Manjushri called Manjugosha. It must have been a particularly magnificent image for the composer of this inscription continually showers it with torrents of high praise. Located to the south of Mount Merapi on the Prambanan plain, Chandi Sewu initially consisted of just five small buildings. The *Stone of Kelurak* appears to commemorate this first construction phase. Later on these five buildings were combined to form a single structure with a cruciform ground plan. The resulting central sanctuary was in turn surrounded by a total of 240 additional shrines laid out in five distinct tiers, and the entire temple yard enclosed by a walled perimeter with two stone images of temple guardians placed before each of its four gates.

In 792 CE, King Samaratungga of the Shailendra founded a Buddhist monastery called Abhayagiri at the hilltop site of Ratu Boko overlooking the Prambanan plain to the north. He was aided by Buddhist monks from Sri Lanka who had come from the original Abhayagiri monastery, which maintained the holy tooth relic of the Buddha that was the palladium of the ancient Kingdom of Anuradhapura. Once again we find evidence of how easy it was for the Shailendra to bring important foreign visitors to Java by ship. Studies continue of inscriptions found at Ratu Boko and of the site itself, making good use of the discovery of some of the hitherto missing parts of these inscriptions. We will encounter King Samaratungga hereafter again when discussing his connections with Sri Lanka.

Recent research by Jeffrey Sundberg (*Bijdragen*, April 2004) presents the evidence for identifying these ninth-century Sri Lankan ascetic wilderness monks as the ones who not only cultivated the Yoga Tantras but were also responsible for mentoring Amoghavajra and his delegation. This same doctrine was, we must presume, accepted and sponsored by Samaratungga. Sundberg's paper on the Abhayagirivihara monastery at Ratu Baka, promises to remove much of the mystery and obfuscation that has previously obscured activities on the Ratu Boko plateau.

Other important Buddhist temples, near which was found another Shailendra inscription, are the Chandis Plaosan Lor (north) and Kidul (south), Buddhist temples. They too are located on the Prambanan plain less than 2 kilometres east of Chandi Sewu. Like the Kelurak inscription before it, the Plaosan Shailendra inscription also commemorates the consecration of a sacred image. Located to the west of Prambanan is the Hindu temple Chandi Sambisari, which was deeply buried under Merapi volcanic debris after the thirteenth century.

Yet another Buddhist temple in the neighbourhood of Chandi Kalasan is based on the same tripartite plan used in the building of the two central shrines at Chandi Plaosan Lor, but faces east instead of west. An analysis of the building's components suggests that Chandi Sari was constructed a few decades earlier than either of the Plaosan temples. Archaeologists also suspect that, like Chandi Plaosan, Chandi Sari had formerly been surrounded by a number of smaller shrines but that their stones had been removed by people living in the surrounding area and used for constructing homes and other buildings.

In 824 CE, the same Shailendra monarch King Samaratungga and his daughter Princess Pramodavarddhani (Increase of Joy) installed the images of deities at a Buddhist monastery called the Venuvana (Bamboo Forest), undoubtedly named after the famous retreat in northern India where the Buddha had formerly resided each year during the rainy season. We do not know with certainty just which temple foundation this important record commemorates because the inscription's discovery place is no longer known. However, the opening lines of the Kayumwungan inscription suggest that it might have been the foundation charter for a religious foundation that was located in the vicinity of Borobudur.

The combination of a temple-mountain with a monastery complex in the neighbourhood suggested to some that the Buddhist temple of Chandi Mendut might have been the original site of the Stone of Kerengtengah. Located 2.9 kilometres to the east of Borobudur's summit, Chandi Mendut was originally surrounded by a walled perimeter measuring 50 × 110 metres. Although this brick wall is no longer in evidence, the surrounding yard also contains the stone foundations for a number of buildings as well as several commemorative *stupas* that may have originally contained the remains of monks and perhaps of other pious persons. Although the supporting evidence is entirely circumstantial, Chandi Mendut is currently the best-known candidate for fulfilling various elements that are found in the Kerengtengah inscription. However, the only inscription discovered at Chandi Mendut to date is a rendition of the well-known Buddhist creed that had once graced the interior of the temple's main shrine.

Several other Buddhist temples were erected in Central Java during the ninth century CE, including Chandis Sajiwan, Ngawen and Pawon. Although no inscriptions have been found that would allow us to tie them directly to the Shailendra, the overall architectural style of the three temples suggests they were all built during the first half of the ninth century. All these temples display makaras that have small lions standing in the mouths. According to an eleventh-century inscription found in southern India, the Shailendra monarch at that time used the makara as the emblem on his standard.

Located to the north of Ratu Boko at the southern end of the Prambanan plain, the layout of Chandi Sajiwan reflects a complex architectural plan that combines certain features also found at Chandi Plaosan Lor and Chandi Mendut. Its overall plan is similar to that of Chandi Plaosan Lor, with two distinct enclosures, each of which features a central structure surrounded by a large number of smaller shrines and *stupas*. However, the central shrine in Chandi Sajiwan's southern complex has a ground plan that is more like the one used at Chandi Mendut. The central cella also features a number of small reliefs that portray episodes from the ancient *Tantri* fables of southern Asia as well as scenes from the past lives of the Buddha called *Jatakas*. In terms of location, size and layout, this series of reliefs is similar to the one found on the inward-facing balustrade at Chandi Mendut.

Located 7.5 kilometres to the east of Borobudur on the way to the present town of Muntilan, Chandi Ngawen consists of five shrines that collectively form a line in the north–south direction with their doorways all facing east. These five shrines may have contained statues of the five Jinas. Two headless Jina statues can still be seen there today. However, this was in all probability not the original function of this temple complex. Three of the shrines (I, III and V) appear to have been constructed later than the other two (II and IV), which feature standing lions at each of their four corners. The discovery of a yoni platform nearby suggests that the temple may have originally been a Hindu temple that was later changed to a Buddhist one. Certain architectural elements suggest that this conversion might be connected with the construction of Borobudur and Chandi Mendut.

Located 1.75 kilometres to the east of Borobudur's summit, Chandi Pawon consists of a single cella that had originally held three images: a central image that faced the northwestern horizon and two smaller ones in singular niches on side walls. None of the three images has survived into modern times. The archway over the door features the images of *Richis* who are engaged in the act of bestowing riches upon the heads of all who pass over the threshold. The outer walls of the central cella are also decorated with the images of goddesses, Bodhisattvas and *kinnari*. In addition, there are scenes of pilgrims paying homage to wishing trees on the sidewalls of the staircase balustrade.

Many scholars have considered Borobudur to be closely linked with Mendut and Pawon, the three probably having been connected by a processional road crossing the Progo River. However, neither aerial photographs nor terrain investigations have shown any traces of the paving of such a road, nor of any structures that might have been expected to have bordered it. On the other hand, the same aerial photographs have shown traces that apparently reflect the ground plan and hidden foundations of a fourth building near Bojang village, opposite Chandi Pawon and just across the Progo River. This building, which has almost entirely disappeared over the course of time, is very similar to Chandi Pawon in dimensions and shape, and might be its twin. The two may have been designed to guard the crossing of the Progo, which especially during the rainy season can be very dangerous due to sudden flash floods. Later on, more will be said about the probable astronomical meaning of the Borobudur-Pawon-Mendut alignments.

The next ruler of Central Java to be prominently mentioned in association with a Buddhist temple is the monarch Rakai Garung (829–47 CE). Due to the length of his reign, he undoubtedly played a major role in the early stages of the construction of Chandi Loro Jonggrang, also called Prambanan, Central Java's largest Hindu temple complex just to the south of Chandi Sewu, where Roy Jordaan and others note Buddhist influences on a typical Hindu sanctuary. King Garung's and his court's names are also linked to the shrines surrounding Plaosan Lor.

When constructing such a vast temple complex as Chandi Plaosan Lor, it would have been natural to begin at the centre and work outwards, in which case the surrounding courtyard would have remained entirely free of any obstructions. If the two main temples at Chandi Plaosan Lor were constructed first, then it is not beyond the realm of possibility that the Shailendra monarch Samaratungga was the initial sponsor. Since the auxiliary temples were only constructed much later, it would explain why his name has not been found on the foundations of these other buildings.

Chandi Loro Jonggrang (or Prambanan) is not the only Hindu temple constructed in the neighbourhood of Buddhist sanctuaries. The entire area around Borobudur is packed with small Hindu shrines and temples. Within a radius of 5 kilometres, no fewer than thirty additional sanctuaries have been found and registered, and new finds are still being reported from time to time. In 1974, Caesar Voûte and Soekmono participated in an inventory that identified the foundations and other remains of several newly discovered Hindu temples. Although built of fired bricks of good quality, these ruins were badly damaged and incomplete because the local villagers had been mining them for construction materials. Borobudur was constructed in the extremely fertile and densely populated Kedu area in the midst of dozens of small Hindu temples dedicated to Shiva (the *Mahaguru* or Great Teacher), Vishnu, Agastya, Durga, the elephant-headed Ganesha, and many others. The presence of such a prominent Buddhist sanctuary as an 'island' amidst a sea of Shaivaite temples is all the more remarkable because the site is so far from Ratu Boko, where many archaeologists presume that the royal *kraton* of the Shailendra formerly existed. By comparison, other important Hindu and Buddhist temple complexes such as Prambanan, Sewu, Kalasan, Plaosan and Sari were all constructed in close proximity to Ratu Boko. Although some authors suggest an antagonism and even a competition between the two religions, there are other indications that Hinduism – in this case Shivaism – and Buddhism existed peacefully side by side, even influencing each other. If Chandi Loro Jonggrang reflects some Buddhist influences, Borobudur in some of its reliefs shows Hindu elements, including the appearance of Shiva.

The huge scope of the Buddhist temple building activities that took place in Central Java between 778 and 824 CE must have taxed the resources of the Shailendra dynasty to the limit. Borobudur alone accounts for more than 3 million cubic metres of stone that had to be quarried, transported and hewn into shape at the site. No wonder that the temple building aspirations of the Shailendra are often blamed for causing the dynasty's fall from grace in Java; the effort must have depleted their treasury as well as demanding the unceasing efforts of the local population. However, it may also be said that Herculean efforts on the part of a society can at times be beneficial to their growth, as was the case in America where the mammoth industrial effort required during the Second World War was followed by a post-war boom period. Therefore, economic reasons alone cannot explain the mysterious decline of the Shailendra in Java.

For reasons that continue to be fiercely debated among archaeologists and earth scientists, the Classic Age of Javanese Hindu-Buddhist civilization came to an abrupt end during the tenth century CE. This led Eiji Hattori to ask a question that is very relevant in the context of this chapter: why was esoteric Mahayana Buddhism so shortlived in Southeast Asia? The last known Central Javanese inscription bears a Shaka date equivalent to 928 CE. At some point between 928 and the opening years of the following century, the Old Mataram Kingdom transferred both its political and economic power base to the eastern end of the island. Simultaneously, the Javanese interest in esoteric Mahayana Buddhism began to decline in the ninth and tenth centuries, and the highly Indianized culture of Old Mataram was eventually replaced by an even stronger East Javanese Hindu-inspired culture that increasingly promoted various elements of the island's older indigenous traditions.

This second historical discontinuity in the Hindu-Buddhist history of Java dates from the tenth and early eleventh centuries CE, and concerns mainly Central and Eastern Java. It has been the subject of intensive discussions by scholars dealing with the Indonesian archaeology and history for about eighty years. The debate has involved not only Indonesian and foreign archaeologists but national and foreign earth scientists such as geologists, geomorphologists and vulcanologists.

The ongoing debate about this mysterious event centres on certain ancient Hindu-Javanese Sanskrit texts that attribute the apparent destruction of Old Mataram in the Shaka year 928 (equivalent to 1006 CE) to an unnamed, probably natural, calamity of horrific proportions (*mahapralaya*). For two centuries following the event itself, the ancient sources remain absolutely silent about the state of affairs in once flourishing and densely populated Central Java, while a new kingdom emerged in East Java which found its apogee in the fourteenth century in the empire of Majapahit. Why had the rulers of Central Java abandoned the magnificent temples and holy shrines that their ancestors had so painstakingly constructed at great cost? And what happened to their subjects?

It was generally assumed that the *mahapralaya* was caused by an enormous volcanic eruption. D. Van Hinloopen Labberton first published the volcanic cataclysmic theory in 1921. It has remained very popular among Indonesian archaeologists and scholars from other countries as an explanation for the apparently sudden eclipse of the Old Mataram Kingdom. The Indonesian archaeologists Soekmono and Boechari were convinced that they had found further evidence of a volcanic catastrophe when several of the archaeological trenches dug in Borobudur's vicinity from 1973 onward revealed the presence of an ash layer that ranged from a few millimetres to a few centimetres in thickness. The fact that a 30-cm layer of sand was also found there, below which lay a 1 metre-thick layer of occupational soil containing many potsherds of Indonesian and Chinese manufacture, was sufficient proof that we were dealing here simply with outwash of volcanic products transported over large distances and not with the direct impact of a major volcanic eruption.

In the early 1980s, Irvan Bahar carried out a detailed geological and vulcanological study of the entire Merapi area. Contrary to the argument that 'a geological investigation cannot be exact in terms of centuries', Irvan Bahar was able to date with precision many eruption phases at Merapi, together with their associated lava flows and volcanic debris. To accomplish this task, he analysed their sequence, duration and overlap in terms of time and space as well as variations in mineral composition. He also measured the time-dependent decay of certain radioactive mineral grains found in various lava flows.

His observations, results and conclusions confirmed that the period of intensive activity at Merapi, as well as the ensuing collapse of the volcano, dates from the late Quaternary. He concluded that a main phase of intensive volcanic activity had taken place in early prehistoric times. However, he found no evidence whatsoever of the occurrence of any cataclysmic eruptions during historic times.

The volcanic cataclysmic theory was nevertheless repeated (nearly eighty years after it was formulated in the early 1920s) in 1999 by David Keys, although it had been refuted by Irvan Bahar in the 1980s as well as by Caesar Voûte and Jan Nossin in the period 1985–86. During their fieldwork in 1985–86, Nossin and Voûte systematically analysed the drainage characteristics of the whole area around Borobudur. The results reveal various anomalies in the course of several rivers and valleys, apparently due to fault-line control by active faults. The local rivers in the area have incised deep meandering paths into the bottom of the prehistoric lake, which points to the occurrence of uplift movements on either a regional or a local scale. The faulting as well as the uplift, which could very well have been associated with intensive volcanic activity, took place during the Quaternary and at the latest during prehistoric times in three successive, major and distinct phases, but once again long before the kingdom of Old Mataram had come into existence.

Whatever the evolution of the Merapi volcanism over the millennia prior to the emergence of Hindu-Buddhist kingdoms in Central Java, and whatever the actual reasons for the shift of the capital of Old Mataram to East Java, one fact is certain. No huge volcanic eruption ever occurred during historical times that even approached the magnitude and destructive power of the Tambora or Krakatoa eruptions, or that could be compared with the Vesuvius eruption that buried the Roman towns of Pompeii and Herculaneum. Therefore, we should not expect to find some day a large town that has been buried below deep layers of volcanic ash and lahar flows in Central Java, not to speak of *kratons* and large temple complexes as others have previously suggested.

Yet another new theory may help to account for the eclipse of the Old Mataram Kingdom in Central Java. Developed by the Russian environmental geologist Vartanyan, this is based on recently acquired knowledge about specific natural phenomena and processes that are fully capable of triggering psychological reactions in humans that can lead to violence and turbulent mass actions. The new theory may allow earlier historically known cycles of social disturbances to be correlated with recorded instances of powerful earthquakes in other parts of the world, which the affected societies may have interpreted as a punishment by the Gods for their sins.

Recent Russian research demonstrates that a variety of natural phenomena often accompany the preliminary processes that lead to seismic events. In the Caucasus region in 1987–88 and again in 1991, Vartanyan and his colleagues observed alternating cycles of social violence that were followed by disastrous earthquakes. Some of these precursor events and processes appear to have involved the release of increased concentrations of various chemical compounds, in either a liquid or a gaseous state. These releases may, in fact, be responsible for neurological reactions in the human brain that can affect the collective social behaviour of entire societies. The well-known anomalous behaviour of various wild and domesticated animals prior to an earthquake may be due to similar processes. According to Russian scientists, the identification of links between human behaviour and the complex geophysical processes that occur in advance of major earthquakes may eventually help to explain political and social events known to have taken place in the decades leading up to cataclysmic events in Romania and Iran, Armenia, Georgia, North Caucasus, Tajikistan and other areas throughout history.

Java appears to be a good candidate for testing the merit of Vartanyan's hypothesis. It might help to shed new light on questions concerning the *mahapralaya* mentioned in the Airlangga inscription and explain why the political and religious apparatus of the Hindu-Javanese state and the *kraton* disappeared from Central Java in favour of their establishment in Eastern Java. Assuming that Vartanyan is correct in his analyses of precursor phenomena related to seismic and volcanic activity, such as the release from faults and fissures of poisonous liquid and gaseous compounds, his theory might help to explain the social disruptions known to have weakened the Old Mataram state toward the end of Central Java's Classic Age. In this particular context, it is interesting to note the wars of succession that are known to have followed the reign of Rakai Kayuwangi Pu Lokapala (885–94 CE).

The Vartanyan hypothesis becomes even more relevant to Central Java when we consider that the fault lines associated with the northern portion of the so-called Bantul graben pass in the vicinity of the Loro Jonggrang and Chandi Sewu temple complexes at Prambanan before cutting into the western part of the Ratu Boko plateau to the south, the site where many archaeologists presume that the royal *kraton* of Old Mataram had been located. The recent archaeological finds at both Sambisari and Sitimulyo strongly suggest that tectonic movements involving both the graben and its associated faults occurred during the critical period that immediately preceded the *kraton*'s relocation to East Java. Mount Merapi – together with its reservoirs of gas-rich magma in the deep underground – is situated on the northward extension of some of these faults, which leads us to wonder whether poisonous liquid and gaseous emanations might not have passed through them, possibly venting in close proximity to Old Mataram's political and religious centres on the top of the Ratu Boko plateau and on the Prambanan plain below it.

The entire Yogyakarta area, including Borobudur, is located within a major tectonic earthquake zone that follows the Indian Ocean coastlines of both Java and Sumatra. This zone is crossed by an active fault system that passes through the Bantul graben area as well as the mountains of Merapi and Merbabu. Indeed, the seismic studies that were made within the framework of the Borobudur Restoration Project all indicated that the earthquakes that took place in 1937 and 1961 were not particularly destructive, which also proved to be the case with nearly a dozen minor earthquakes that have affected the Yogyakarta area since 1990. The earthquakes known to have occurred in 1549 and 1867 were somewhat stronger and are therefore likely candidates for having caused the collapse of several ancient monuments in the Prambanan area east of Yogyakarta.

The Vartanyan theory might also help to explain the strange and disturbing character of the final phase of Hindu-Buddhist culture in Central Java. The Hindu temple of Chandi Sukuh is located on top of Mount Lawu near the city of Surakarta (Solo). Two inscriptions (1416 and 1456 CE) discovered at this site demonstrate that the construction dates from the first half of the fifteenth century. The temple itself looks so much like a Mayan pyramid that early Western explorers wondered whether there had been prehistoric contact between the two societies. It was only later, when the temple inscriptions were translated, that it became apparent that the very similar Mayan and Javanese structures had occurred too far apart in time to have been connected in the way that early Western visitors initially thought.

Although the bas-reliefs and stone statues at Chandi Sukuh are still recognizably Javanese in their character, there is a twisted style to their portrayal that suggests that something peculiar may have happened here. Although the Indonesian tourist bureaus often tout the site as Java's erotic temple, there is nothing titillating about the images of masturbating temple guardians, a *lingga* with four protruding balls or a relief of the union of a penis and vagina that appears on a flagstone at the front of the monument. Early on, some Western scholars dismissed the site as an example of the degenerate fall of the local population into tantric Hindu practices that were ultimately swept away by the rising popularity of Islam.

But perhaps the most bizarre images are those of giant men with bulbous heads and widespread wings. In fact, one of the temple's inscriptions is carved on the reverse side of one of the winged statues at the site. They are very similar to a winged creature dubbed the Mothman that was responsible for a wave of mass hysteria that gripped the West Virginia town of Point Pleasant in the United States during 1969. What is interesting about the Mothman sightings is they may have been a precursor event. Less than two years later, southern West Virginia was hit by an earthquake. Although by California standards it was relatively puny, only 4.3 on the Richter scale, it was the strongest earthquake on record for this part of the United States. Another wave of Mothman sightings occurred in the Mexico City area during the days leading up to the 1985 earthquake that devastated the capital.

It is nothing short of incredible to think that the release of a poison gas or a liquid chemical could end up causing large numbers of people to have similar hallucinations in places so far distant from each other as West Virginia, Mexico City and Chandi Sukuh in Central Java. However, similar phenomena have been observed in other parts of the world that lend a modicum of support to the hypothesis. In *Plants of the Gods* (1992), Harvard biology Professor Emeritus Richard Evans Schultes and Dr Albert Hoffman of Sandoz Research Laboratories observe that South American Indians ingesting a powder made from a close relative of the Datura plant universally reported visions involving specific symbols, which led the two researchers to conclude that certain psychoactive substances can indeed produce mental experiences involving specific symbols that can be commonly found across populations. When it comes to Central Java, the fact is we know so little about the phenomenon that we cannot simply dismiss it out of hand. This is yet another area that cries out for future research.

More light on these phenomena is shed by very recent research concerning the functioning of the Delphic Oracle in Ancient Greece, with due regard to the description of the behaviour of the Pythia (the priestess who spoke the oracles) by important contemporary Greek and Roman authors. We may refer here in particular to the very convincing article in the August 2003 issue of Scientific American's *Archaeology* magazine on 'Questioning the Delphic Oracle' by the archaeologist John R. Hale, the professor in geology Jelle Zeilinga de Boer, the chemist Jeffrey P. Chanton and the toxicologist Henry A. Spiller. It is entirely convincing from a geological/hydro-geological point of view and with regard to special applications of petroleum geology. It explains clearly the nature of the gases escaping from geological fracture systems underground and also their toxic and/or hallucinatory effects. In this respect it is interesting to note the ancient testimony that on some occasions the Pythia was seized by a powerful and malignant spirit, causing a frenzy in which, instead of speaking or chanting as she normally did, she groaned and shrieked, threw herself about violently and eventually rushed at the doors, where she collapsed. The descriptions remind one of the frightening hallucinations of the Mothman. And indeed, to return to Java, here we have an island with major fracture systems and a geological pattern that in many areas produces natural petroleum and/or its derivatives, leading to the exploitation of a number of oil and natural gas fields. In addition there are various volcanic gases that may also contain carbon and/or sulphur components. The bas-reliefs at Sukuh described above suggest different forms and degrees of hallucination, which could have occurred side by side or successively.

What we now know about the Delphic Oracle brings to mind the legend surrounding the construction of Chandi Gedong Songo, which also refers to a 'fragrant smell like flowers' that parallels the 'sweet smell' produced by volcanic venting at Delphi. The version of this legend that appears in the brochure of the Government tourist office of the second regency of Semarang includes the following:

> And then Kihajar Selakantara went to the top of Suralaya at Queen Simha's command to build the temple. And on the way to the summit, Kihajar Selakantara smelled a fragrance like flowers, and prayed to Sang Hyang Widi (the god) in that place to give him help and courage. He wondered if this was the place that Queen Simha meant. For this reason, that place is still today called Ndarum (Gondo arom), or 'fragrant smell of flowers'.

Other explanations have been put forward for the transfer of the royal seat of power to East Java. They include hypotheses put forward in 1919 by Van Stein Callenfels, subsequently supported by Krom (1931) and de Casparis (1958). Different theories have been proposed by Schrieke (1957) and de Casparis (1958) as well as by Satyawati Suleiman. They are all based on the various and entirely different interpretations of what the term *mahapralaya* was intended to mean.

The most recent working hypotheses emphasize that economic considerations may also have played an important or even essential role in the shift of the capital. From a purely economic point of view, East Java was much more suitable to the Hindu successors of King Sanjaya, who were actively involved in international trade. No deep-water harbours existed along the north coast of Java, which is characterized by extremely shallow coastal waters as well as marshy mud flats. Moreover, the entire coastline has been continuously shifting northward over the course of the last 10,000 years due to the rapid deposition by rivers that carry considerable sediment loads.

The coastline of the Jakarta bay area is known to have advanced several kilometres in precisely this manner since the time of Central Java's Classic Age. A similar shift occurred further to the east in the region of Semarang. The Indonesian historians Budiman and Widodo have recently suggested that the harbour of Bergota, at present more than 6 kilometres from the coast, had been an important harbour for the Old Mataram Kingdom during the eighth century CE. They concur with Van Bemmelen's earlier description of the Ngarang (or Garang) River as the source of the abundant sediment that has led to the rapid accretion of the coastal area in the general area of Semarang. During the Classic Age of Hindu-Javanese civilization, the harbour of Bergota was located at the most northerly situated Bergota hill in the southern sectors of Semarang town, which are today known as Chandi Lama (Old) and Chandi Baru (New).

Roy Jordaan has suggested the possibility that the Old Mataram *kraton* may have been temporarily located at the legendary capital of Medang Kamulan on Java's northern seashore when the site was still an important harbour on the mouth of the river Lusi. In particular, he refers to a 1967 study by Soekmono presenting a geographical reconstruction of the northeastern area of Central Java that also suggests potential locations for Medang. Soekmono has placed it in the Grobogan district to the east of Semarang where a number of small villages are found today (Medang, Medang Ramesan, Medang Kemit, Medang Kemulan and others), together with a river that bears the name Medang. This inland location today lies to the south of Mount Muria and to the east of the town of Purwodadi. In 1940, E.W. van Orsoy de Flines systematically collected ceramics in the Grobogan area that subsequently proved to be from the eighth to the tenth centuries CE. These finds were all discovered in the area's hills above the 25-metre contour line that appears on present-day topographic maps. By contrast, the finds that dated from more recent time periods were all discovered in lower-lying areas along the river valleys or along the area's alluvial plains.

In deference to the prior work of Van Bemmelen, Soekmono assumed that Mount Muria had formerly been an island off the north coast that was separated from the main part of Java by the Semarang-Rembang Strait, a down-warped area that had been flooded by the eustatic rise in sea level during the late Quaternary. Thus a gulf was formed that penetrated as far east as the upper course of the Lusi River. Siltation had apparently begun there and eventually led to the infilling of the Semarang-Rembang Strait. By linking up the places where the older ceramics were found, Soekmono was able to define the coastline as it existed during the eighth to tenth centuries, which followed the hilly regions that we see today, from the Bergota hill at Semarang eastward to Purwodadi and the Medang area. It then curved around a promontory constituted by chalk hills before proceeding eastward to Rembang. Medang had thus been situated on the Gulf of Purwodadi and in communication with the Semarang-Rembang Strait, a most favourable location for a harbour as well as the capital of a maritime trading state. This situation dramatically changed for the worse once the estuary of the Lusi became silted up with alluvial deposits and Mount Muria had become linked with the main island.

It is not clear what, if any, relations had formerly existed between the harbour and interim capital of Medang Kamulan and the Old Mataram harbour of Bergota in the southern sector of Semarang town. Did the Old Mataram state have two harbours on Java's north coast, or only a single main harbour, either at Medang or Bergota? Whatever might have been the case, various authors and scholars have attributed the decline of the Mataram state at least in part to the coastline siltation that had eventually led to the total loss of the kingdom's harbour facilities followed by a hiatus in its international trade relations, a hypothesis with which Mark Long and myself fully concur. The situation was aggravated by a general lowering of the sea level in many parts of East and Southeast Asia prior to and during the tenth century. Under these conditions the East Javanese harbours were the only suitable alternative that would have allowed the Javanese to maintain their profitable trade relations with China. In addition, the opening of new harbours in East Java would have furthered trading relations with the islands of the eastern archipelago, from whence came the spices and timber that were in high demand in both India and China according to one eleventh-century East Javanese inscription.

It is unlikely to be a mere coincidence that the royal *kraton* moved to East Java at approximately the same time that the harbours on Java's north coast had ceased to be usable. The loss of trade centres such as Bergota and Medang Kamulan obviously put an end to the inflow of the pilgrims and missionaries, priests and gurus who in the past had greatly influenced the religious and cultural development of Central Java. For reasons that remain obscure, they did not simply book passage to the new harbours in East Java in conformance with shifting trade patterns. It appears that they visited each succeeding new capital in East Java with less frequency than before. This helps to explain why Javanese interest in Mahayana Buddhism began to decline in the ninth and tenth centuries CE, as well as why the highly Indianized culture of Old Mataram was eventually replaced by an even stronger East Javanese one that increasingly promoted various elements of the island's older indigenous traditions. The arts and architecture of the later East Javanese kingdoms both graphically display the steady decline of the influence of India as well as a preference for local Javanese traditions.

Under these conditions the next two historical periods of Java – from the tenth century CE until the advent of Islam, and the modern history of Java from that time onwards – are of very limited relevance for the history of Borobudur and its Javanese-Buddhist historical context. It will be sufficient to refer to the various comments on these last two Javanese historical periods in our new book. Here we need mention only the more interesting facts that led to a cyclic change in Javanese history. Continued sea level fluctuations and ongoing siltation along the north coast of Java facilitated, at a somewhat later stage, a new human occupation of the erstwhile coastal marshes and a reactivation of the abandoned harbours or the establishment of new ones on the north coast, and a shifting back of major trade routes from East Java to North Central Java. This in turn facilitated the advent of Islam and the establishment of Islamic states in Central Java.

8.2 Borobudur and its international Buddhist historical context

In the preceding section references have been made to Borobudur and its international Buddhist historical context. It has long been known that there existed century- and even millennia-old trade and other relations between Java, Sumatra and other areas in the archipelago, extending to other parts of Asia, the Near and Middle East, East and West Africa and the Mediterranean world, and even, astonishing as it might appear, across the Pacific Ocean as far as the Maya culture in Central America. Some famous Borobudur reliefs depict quite large merchant ships, which apparently were used for maintaining the maritime communications involved. Of particular importance, in this respect, are the connections that existed with the Nalanda Monastery in Bihar (India) and the Abhayagiri Monastery in Sri Lanka, as well as with South India.

In recent decades many authors have published their own views, comments and conclusions devoted to this subject, including the role of the Shailendras and of Shrivijaya in this context; see for instance a number of articles published by Roy Jordaan since 1997, by Eiji Hattori in 2000 and by Lokesh Chandra in 1995, and the 1996 book by Daigoro Chihara, *Hindu-Buddhist architecture in Southeast Asia*.

Let us first consider a personal communication to Eiji Hattori, made a few years ago by Roland Silva of the Archaeological Survey of Sri Lanka and President of the International Council of Monuments and Sites (ICOMOS). Roland Silva mentioned that in the ruins of the Abhayagiri Monastery a drawing had been found which apparently represented the ground plan of Borobudur shaped as a lotus flower. He added that the Buddha statues at the Abhayagiri Monastery have a great resemblance to those of Borobudur. However, in an article entitled 'Kantarodai Buddhist Remains: A Sri Lankan Borobudur Lost for Ever?' (*Midweek Review*, Sri Lanka, 14 August 2002) Sri Lankan scholar D.G.B. de Silva said that the claim that the *stupa*'s lotus-shaped ground plan reflected that of Borobudur had been too hastily made. Nevertheless, he believes that there is very strong circumstantial evidence that the builder of Borobudur had been fully versed in Mahayana and Tantric beliefs and concepts and had been a person with a fertile imagination. Furthermore, he wishes to see if a link could be established between Borobudur on the one hand, and the Abhayagiriya and Buduruvagala sites in Sri Lanka on the other. In the latter case there may be connections in regard to the name and the Vajrayana-inspired concepts and themes of its sculptures, which are otherwise found only to a limited extent in Sri Lanka. To this de Silva adds another question, namely whether Gunadharma, the legendary builder of Borobudur, had been a Sri Lankan monk well versed in Mahayana/ Vajrayana lore.

One may even ask whether Gunadharma, the legendary builder of Borobudur, proceeded to the Shailendra Kingdom because in Sri Lanka there was no patronage but only opposition to his concepts of construction, since the Mahavihara, the principal monastery with its close links with the King's court at Anuradhapura, was a strong supporter of Theravada Buddhist doctrines and vehemently opposed to Mahayana teachings. Kantarodai, as it presents itself to us today, is but a poor imitation of Borobudur in scale, dimensions and detail.

An article by Rohan L. Jayatilake called 'The antiquity of Kantarodai Vihara of Jaffna' appeared in the 23 July 2002 issue of the Sri Lankan *Daily News*. In his article he quotes the late Dr S. Paranavitana at length. Paranavitana believed that the Kantarodai remains may not be simple burial monuments of leading Buddhist monks. He pointed to a link with concepts of *stupas* that were developed in Central Java and other places in the Malay archipelago. That would mean it was a centre where Vajrayana was practised, as at Borobudur.

Both De Silva and Jayatilake have noted that, even with a brief glance at pictures, one cannot miss the similarity of the cluster of small *stupas* at Kantarodai (8.5 to 12 ft in diameter, with a larger, 24-ft *stupa* in the centre) with those on the three terraces at Borobudur surrounding the larger central *stupa*, each of which contained an image of the Buddha (Vairocana/Aksobhya). While we may doubt Paranavitana's account of a 'Minister of Yamadvipa' who built Kantarodai, there is no question about the value of his work in its essential aspects, with clear intuition guided by unparalleled knowledge. He should have followed up with a scientific comparison of the remains of the two places but that stage seemed to have passed when he wrote, and he based his material, perhaps, on his imagination. In any event, he produced the only attempt to explain the Kantarodai Buddhist remains at Kantarodai, which include the series of *stupas*, badly damaged Buddha and Bodhisattva images, and a stone with a *Buddha-pada*.

Further scientific work is certainly called for in this particular area. To assist in this task we have a vast resource of knowledge about parallel monuments in other parts of the world for comparison, and also a wealth of Mahayana and Vajrayana Buddhist lore to identify the source of inspiration for these monuments. Contemporaneously with Borobudur, similar Vajrayana-inspired centres existed in Bengal where Tantric Buddhism prospered under the Pala kings, and also in Tibet and Nepal. Jacob Kinnard has written several articles in which he has quite convincingly demonstrated that the Palas were Mahayana conservatives who controlled the historical sites of Buddhism, while the less conservative Vajrayana theories came from further away in Southern India, the Himalayas and Sri Lanka, as Sundberg also suggests in his paper on Abhayagirivihara. One also notes that the powerful Shailendra rulers of Central Java had close contacts with the Pala rulers of Bengal around the ninth century. Balaputra, a grandson of a Shailendra ruler of Yavabhumi, built a temple for those of his people who went to Nalanda to study, and the Pala king donated five villages for its upkeep. This shows how close the relations of the Shailendras were with the Pala kings of Bengal and the monastery at Nalanda, with that great Buddhist university a source of inspiration for the Central Javanese Buddhist enterprise. That influence could not have passed Sri Lanka by, particularly since the Shailendras are believed by some scholars to have been of South Indian origin. Archaeological evidence from the Tiriyaya-Kuchchivele-Anuradhapura triangle confirms the influence of Tantric Buddhism.

According to both Dr Paranavitana. and Rohan Jayatilake, the Shailendra King Samaratungga, having ascended the throne in the year of Shaka 707 (785 CE), died after reigning for thirty-seven years, during which he constructed many temples in Central Java. His son Samaragravira, who succeeded him, received his father's kingdom as well as other principalities including Yavadvipa, Bali, Tayamara Burumaranasta and many other islands.

During this period a prince from the Sinhaladvipa (Sri Lanka) by the name of Dappula went to Yavadvipa, met King Samaragravira and informed him that he would remain a vassal of Yavadvipa if Sinhaladvipa was conquered on his behalf with the help of Yavadvipan forces. King Samaragravira was happy to grab the opportunity of bringing the Sinhala Kingdom under his sway and forthwith sent a fleet of seventy-seven ships under the command of his minister to conquer the Sinhala Kingdom for Prince Dappula, so as to retain his allegiance.

When King Agrabodhi of Sri Lanka heard of the landing of Yavadvipan troops, he ordered his son Mahendra, the Commander-in-Chief, to take his army to Nagadvipa and thwart the invaders. Prince Mahendra defeated the Yavadvipan forces and chased them back to their ships.

Yavadvipa's minister sent a message from his ship to Prince Mahendra stating his willingness to enter into a friendly treaty between the two kingdoms (Sinhaladvipa and Yavadvipa). He also sought permission to stay for seven months in Nagadvipa (Jaffna Peninsula) for the purpose of constructing a Buddhist *vihara* at a spot specified for the purpose by the Sinhalese monarch.

Having received his father's consent, Prince Mahendra informed the Yavadvipan minister that he could construct a *vihara* at Nagadvipa near the village Sulanagama sitem, where he could remain with his army for seven months until the work was completed. The minister returned after having constructed a *vihara* at Kanterodai (Kadurugida or Kandavurugoda) that resembled the *stupas* on the uppermost platform of the Barabudur Mahastupa (Indonesia).

The *stupas* at Kantarodai should not be lightly dismissed as mere burial *stupas* of prominent monks on the island. The date assigned to them also may need revision if evidence reveals that the edifices are Vajrayana-inspired. The punch-marked coins, the *Lakshmi* types and debased Roman coins found at the site certainly belong to an earlier strata than the eighth century CE, probably when Vajrayana made its impact in Southeast Asia and had an impact on this former seaport site as well. Far more attention needs to be given to the remains of Kantarodai. They could, perhaps, reveal the missing link in Sri Lanka's contribution to the traditions of the Vajrayana school. In the *Culavamsa* and *Mahavamsa* the Sri Lankans make it clear that they had expelled heretics including Vajrayanists. This is an indication of a previously little understood Southeast Asian phase in Sri Lanka's history, with links to South Indian, Bengali and Javanese religious developments: in other words, a Vajrayana phase of contribution to the evolution of forms of worship and monuments in Sri Lanka. The importance for Borobudur and its international Buddhist historical context is that it is an excellent example of the way that religious and cultural encounters and exchanges often flow in both directions.

The third case to be recorded here concerns a very interesting news item published in the 'Radar Yogya' section of the newspaper *Jawa Pos*, Minggu Kliwon, 8 July 2001, p. 7, stating that an ancient temple was recently found at Kesariya in Bihar, India, which very closely resembles Borobudur. After a request to the Archaeological Survey of India, a set of four photographs of the Kesariya *stupa* was received in November 2001 from Mr Muhammed, Superintending Archaeologist at the Agra Circle of the Archaeological Survey of India, together with two short reports on the subject: an Interim Report on the Excavations at Kesariya (1998–2001) and Mr Muhammed's report for the general public entitled 'Discovery: Kesariya – the Tallest ever Excavated *Stupa*', in which he makes comparisons with Borobudur. The four photographs are: one of the Kesariya *Stupa* Mound before the start of the excavations, two taken during the excavations and one side view of the partial excavated *stupa*, showing the results of its partial conservation and restoration.

It appears that this is not really a new discovery, the Kesariya *Stupa* hill having been known for many centuries, albeit under other names. According to age-old local traditions the hill is known as 'Raja Bena Ka Garh', King Bena (or Vena) being a famous mythical Chakravartin Raja of the Puranas. His queen's palace is believed to be at the Mound Ranivas, half a kilometre northeast of Kesariya hill. This tradition is also quoted by the seventh-century Chinese pilgrim Hiuen Tsiong in his travel records, where he refers to the *stupa* as one of the principal Buddhist sanctuaries of the region. It is also mentioned by the famous Chinese traveller Fa Hien and in several ancient Sanskrit Buddhist texts.

Following the indications in Hiuen Tsiong's records, Colonel Mackenzie of the Madras Engineers made a first archaeological exploratory gallery to the core of Kesariya *Stupa* Hill in 1814. The results were published in 1835 by Hodgson and later details were described in 1861–62 by General Alexander Cunningham, who also carried out excavations at Mound Ranivas where he identified several small cells and a shrine with a colossal Buddha statue, identified as a Buddhist monastery linked with the Kesariya *Stupa* hill. In 1911–12 Dr Spooner carried out some conservation works at Kesariya. The *stupa* was very seriously damaged in the 1934 earthquake. In 1936 the Kesariya *Stupa* hill, situated on the road to Kushinagara where the historical Lord Buddha died at the age of 80, was declared a National Protected Monument by the Archaeological Survey of India.

Since 1998 the Archaeological Survey of India has carried out detailed excavations at Kesariya combined with partial conservation and restoration works, which constitute a turning point in the Archaeological Survey of India's working methods. The excavations are supervised by an important team of archaeologists under K.K. Muhammed, Superintending Archaeologist at Agra. Work is still continuing in order to determine the complete design and detailed chronology of the sanctuary and is expected to last several years. It is planned that the Kesariya site and its surroundings will be developed as a major tourist centre.

It was at Kesariya that Lord Buddha handed his begging bowl to his followers from Vaishali, en route to Kushinagara where he died. In commemoration a small mud *stupa* was built, later rebuilt in brick in the Maurya, Sunga and Kushana periods. During the sixth-century Gupta period it was further enlarged and embellished and the *stupa* encloses hundreds of cells with life-size Buddha statues of clay and stucco, some resembling Nalanda Buddhas. The Buddhas are seated in *padmasana* posture and a few statues represent the Bhumisparsha-*mudra* well known from Borobudur. Only a very few of the statues, which are very severely damaged by erosion, have preserved the right hand illustrating this *mudra*. Further repair works were carried out in the late Gupta period.

Mr Muhammad makes important comparisons with Borobudur. The terraced Kesariya *stupa* is slightly larger than the Borobudur one, making it the largest *stupa* in the world. Its height before the 1934 earthquake was 123 feet, but in its pristine state during the Gupta period it was 150 feet, as compared to 138 feet for Borobudur. The diameter of its circular base is about 123 metres, almost exactly the same width as the Borobudur square base.

The monument must have been known to all foreign visitors and pilgrims coming to Nalanda, and a number of well-known *stupas* in Kashmir, Bhutan, Tibet and Burma were inspired by it, including Tisseru (Kashmir), Chorten Kora (Bhutan), Cherten of Toling (Tibet), Shwesadan pagoda (Bhutan), Mingalu Cheti (Burma) and Mingala Zedi (Burma). They all followed the same pattern. However, according to K.K. Muhammed the final culmination of the inspiration of Kesariya is Borobudur in Java, constructed 200 years later. That most probably places the construction of the Kesariya *stupa* immediately after the 535–36 CE mega-catastrophe, which would explain why at that very moment the reigning King Bena felt obliged to confirm his Chakravartin kingship by contructing the biggest *stupa* in the world. It could also explain why the Kesariya s*tupa* got so much attention in the Buddhist world, becoming one of the sources of inspiration for several other sanctuaries, including Borobudur.

The expression 'inspired' is well chosen by K.K. Muhammed since each of these other *stupas* enumerated by him has its own particular features, reflecting what Professor Edi Sedyawati of the Indonesian Ministry of Education and Culture and of the Indonesian Archaeological Survey in a recent publication calls 'the local genius'. On the basis of the general similarities and considerable differences between the Kesariya *stupa* and that of Borobudur, one should certainly hesitate to call the former a prototype of the latter.

In his notes Mr Muhammed refers to the ancient local traditions linking the Kesariya *Stupa* Mound to the Chakravartin King Bena or Vena of the Puranas. According to the various studies on the nature and significance of the *stupa* made by Lokesh Chandra and his sister Sudarshana Devi Singhal, one of the meanings of a *stupa* in many cases is that it is a symbol of Chakravartin kingship, the universal kings who dominate all surrounding kingdoms as well. As Borobudur can be interpreted (very generally, among other meanings) as a symbol and expression of ancestor worship by the Buddhist Shailendra kings of Central Java, it seems plausible to interpret Borobudur as a *stupa* and as such simultaneously as a symbol of Chakravartin kingship, signifying that the Shailendras had also adopted this Indian Buddhist Chakravartin kingship model along with many other Indian Buddhist concepts. It is known that the Shailendras maintained many relations with Nalanda and they were certainly also informed about this other meaning of the Kesariya *Stupa* in relation to Chakravartin kingship.

Seen from a distance, as illustrated by photographs, the side views of both sanctuaries appear rather similar, with their strongly emphasized horizontal subdivisions, the rows of cells or niches with the Buddha statues, and the same appearance of a flattened *stupa*. This flattened aspect is noticed by many visitors to Borobudur, and one of the consequences is that at Borobudur the upper circular terraces and the central crowning *stupa* are invisible when one stands at the base of the monument, an apparently intentional perspective effect. The dimensions are almost equal; both have six terraces with numerous Buddha statues; both have a pradakshina path or *pradakshina-patha* on each terrace level; both are crowned by a large central *stupa*.

This is not the place to discuss in detail the various similarities and differences between the Kesariya *stupa* and Borobudur. It will be sufficient to mention that the Kesariya *stupa* encloses hundreds of cells with life-size Buddha statues made of clay and stucco, described earlier. They are placed in groups of three on each terrace, separated by stellate arms or petalled designs. The outer face of the cells contains the usual *kumbha*-type moulding and decorative niches, characteristic of the Gupta and late Gupta period. The total number of cells and of Buddha statues is as yet unknown, pending the completion of the excavation works. No indications have been found so far of a systematic use of a number symbolism in the numbers of statues and/or the number of terraces.

The cells measure 220 × 180 cm with an opening of 75 cm. The maximum height of the cells is 225 cm because of the pradakshina paths on the next higher terrace. In each cell there is a pedestal 180 × 100 cm and 25 cm high, on which a life-size Buddha statue was seated. In each group of three, the pedestals of the eastern and the middle cells contain side niches, those of the middle cells being empty while those of the eastern cells all house an image of a lion. These side niches in the pedestals were all plastered over at a later period. The notes on the Kesariya *stupa* do not mention any presence of narrative bas-reliefs depicting scenes from the life of Lord Buddha or other texts, in contrast to the many narrative bas-reliefs which characterize Borobudur.

At Borobudur the life-size Buddha statues are seated in niches on top of the main walls with their famous bas-reliefs. They are wide open to the outside. There are 504 of these statues, and depending on terrace level and orientation in the cardinal directions, they have different *mudras*. Their facial expression is unique and one immediately recognizes a Borobudur Buddha statue. A similar statue was apparently found at the Abhayagiri Monastery in Sri Lanka. Some authors also make comparisons with the Gupta style. The number of Buddha statues and the number of terraces are apparently an expression of the systematic use of a form of numerology.

Borobudur consists of a square base surmounted by square terraces crowned by a circular central *stupa* on a circular base. One finds there an almost perfect transition from a square at the base to a true circle at the central crowning *stupa*. Structurally, and with regard to the narrative bas-reliefs and sculptures, there are also many other transitions. Furthermore, Borobudur is characterized by four sets of staircases leading from the base to the central *stupa*, on the north, south, east and west faces, emphasizing the cardinal axes. Moreover, the diagonals are also very strongly emphasized, marking the southwest–northeast and northwest–southeast axes. These strongly emphasized axes not only determine the structure and architecture of Borobudur but also very clearly link the sanctuary with a number of important landmarks in the landscape. Together with the fact that Borobudur is constructed on an artificially enlarged hill, filled up in such a way that the axis of the hill is shifted horizontally in order to establish these links with landmarks in the landscape, they are clear proof that the location of Borobudur was carefully selected on symbolic and/or religious grounds. To achieve their ends the builders did not hesitate to carry out massive preparatory earthworks.

Kesariya, however, consists of a circular base surmounted by circular terraces crowned by a circular central *stupa* on a circular base. Thus far only one staircase has been found on the southwest corner, connecting the two upper terraces. No evidence has been given of structural elements linked with the cardinal and diagonal directions, or of an orientation or site selection related to landmarks in the region.

Apart from the structural and architectural differences there is also an important difference in construction techniques. Both are constructed on an earth-fill, causing some of the damaging slides and subsidence. Borobudur, however, is constructed entirely of stone with very typical stone masonry techniques, probably imported from India, which vary from one construction phase to the other. Kesariya is constructed entirely of bricks with a clay mortar and is therefore much more prone to severe erosion and other types of damage.

Finally there is the question of whether or not the upper part of Borobudur, constructed during the third main construction phase, represents a huge mandala, another aspect which is not found at the Kesariya *stupa*.

Coming to the fourth case, it has long been known not only that Hindu-Buddhist

Java was exposed to Indian and other foreign influences, but that the Shrivijaya and Shailendra Kingdoms in Sumatra and (Central) Java often also radiated important political and cultural influences abroad, for example in the northern part of the Malay Peninsula, South Thailand and the Khmer Kingdom in Cambodia. However, most people do not realize that the Sumatran and Javanese as well as Indianized Malay cultural influences occasionally radiated much further and in other directions, perhaps extending even as far eastward as Central America.

Therefore, the fourth case meriting mention here concerns recent discoveries of possible early contacts across the Pacific Ocean during the first centuries CE between Southeast Asia and Central America, which probably had a considerable impact on the Meso-American Indian Maya culture. The evidence appears in a study presented by Professor Eiji Hattori at a meeting of the International Society for the Comparative Study of Civilizations (ISCSC) at Reitaku University, Japan, published in Japanese in a recent 2002 issue of the *Journal for the Comparative Study of Civilization* under the title 'Did the Dragon Cross the Pacific Ocean?'. Hattori has formulated an acceptable working hypothesis about the outside influences on the emerging civilizations in Meso-America, including the Maya culture, in particular with regard to the importance of trans-Pacific navigation, trade and cultural exchange during the early centuries of the Common Era. His theory is that the Maya civilization in Central America was strongly influenced by Southeast Asian cultural and religious Hindu and Buddhist elements, such as stepped pyramids, mountain-top sanctuaries, *kala-makara* symbolism and winged dragons. To this must be added the growing realization among scholars of the many similarities between the Javanese language and folktales and those found on the other side of the Pacific.

Eiji Hattori suggests that Malaysian sailors from the archipelago crossed the Pacific during the first few centuries CE. Thus this would apparently have happened during the third to fifth centuries, high days of the prosperous Hindu-Buddhist Tarumanagara state in West Java, as well as during the existence of a proto-Shrivijaya Hinayana Buddhist Kingdom. The latter, according to Lokesh Chandra, had its origin as early as the third century in Shrivijayapuri in present-day Andhra Pradesh in India, from where Hinayana Buddhist Shrivijaya expanded in the fourth century through the Malaysian Peninsula to the Island of Sumatra. It would also presume a certain astronomical knowledge, which would have been essential to navigate safely across this huge expanse of ocean.

This chronology of the Southeast Asian cultural influence on the Meso-American Maya culture would more likely have occured before the worldwide catastrophe of the volcanic mega-eruption in the Sunda Strait between Sumatra and Java in 535–36 CE, the 'Years without Summer' mentioned earlier in this chapter. It could well be that the trans-Pacific contacts between Southeast Asia and Meso-America, which shaped the Maya culture, were broken as a consequence of this catastrophe. It appears equally possible that, for one reason or another, they were not resumed after the emergence in the seventh century of the important Mahayana Shrivijaya Kingdom with its extensive international trade which had its capital in Palembang in South Sumatra as well as the near simultaneous emergence of the equally important and dynamic Mahayana Shailendra in Central Java.

Whatever the case, Long mentions in a personal communication that a few years back Mayan scholar Michael Coe (author of

Breaking the Maya Code) said in an interview that if we want to understand ancient Mayan society we should go to Bali, and proposed that a Mayan scholar conference be held in Bali for this purpose. Of course Coe was not suggesting direct contact, but rather that the two societies were similar in many respects, thus confirming broadly the possibility of a Southeast Asian cultural influence brought about through Malaysian sailors.

Coe's comments prompted a further investigation of the topic by Mark Long, who confirms that the Balinese continue to use a dual calendar system that is in some respects similar to the ancient Maya system, including a divinatory almanac (the Maya almanac being 260 days, the Balinese Pawukon being 210 days). He found that some Meso-American archaeologists believe that the Mayan almanac originated through astronomical observations around the latitude of Copan, where the number of days between the two sun zenith events each year equals the number of days in the Mayan almanac.

8.3 The temple, its surroundings and its connection to the local environment

The question of the selection of the particular site of Borobudur by the ancient builders does not seem to have received as much attention from archaeologists as it merits. Soekmono and some other authors concluded that the site must have been selected for reasons, both rational and irrational, but without being more specific. To borrow an expression of Soekmono: 'These are potent sites, places where a presence is felt to dwell. In such places the Gods are seen at play. And there are plenty of places like this in Java' (Soekmono et al., 1990, p. 22). However, a careful consideration of all factors that must have been taken into account for the selection of the site and for the planning and design of Borobudur's ground plan and architectural structure provides ample evidence that matters are not as simple as that.

In the 1970s, during my UNESCO posting at the Borobudur Restoration Project, I never ceased to be fascinated by the spectacular landscape that surrounded me. From the early 1970s I was able to see for myself what the archaeologists had discovered after digging exploratory boreholes and pits into and underneath Borobudur's foundations. These produced the evidence that the hill upon which the monument rests had been artificially constructed. It was placed on top, and to one side, of a much smaller natural hill that had originally been only 25 metres in height. The entire top of the original site had also been levelled to create a wider space to the northwest where archaeologists discovered the remains of a dwelling for monks.

I was amazed to learn that the Javanese builders had elected to move 80,000 cubic metres of soil in order to raise the original hill to 40 metres in height. I wondered why they would have gone to such great lengths when there were other hilltop sites to the southeast and northwest that they could have used without undertaking such a Herculean effort. But when archaeologists dug exploratory trenches on both nearby hills they could find no evidence that these areas had ever been inhabited, whereas in the lowlands to the southeast of Borobudur they unearthed ample evidence of human occupation. For all these reasons, I could only conclude that there must have been a very good reason why the builders of Borobudur had gone to such great lengths to reshape the site upon which the monument was to be constructed. I gradually came to the conclusion that its relations to a number of important landscape elements determined the selection of the site. This was broadly confirmed during follow-up studies, in particular by Long, although on closer inspection he found that astronomical observations and considerations in combination with the presumed relations of important landmarks had proven to be the decisive factors for the site's selection. Since these astronomical aspects constitute an entirely innovative element in the Borobudur studies, they will be discussed in great detail in our joint publication.

Borobudur's architectural plan is more or less oriented to the points of the compass, with each of its four sides forming a right angle with respect to one of the cardinal directions. According to earlier observations by Krom, Kempers and van Erp, however, the north–south axis of the monument's ground plan had been deflected 1.5° to the west of true north, a finding that remains to be confirmed through the use of modern survey equipment. Kempers accounted for this small deflection by suggesting that the architect had been unable to observe the pole star and therefore would have had no way to determine precisely the direction of true north. The island's location in the southern hemisphere does indeed currently prevent Javanese stargazers from ever catching a glimpse of the pole star, but this was not the case during the eighth century CE, when the pole star still appeared on Java's northern horizon from time to time. The reason it can no longer be seen today is due to small changes in the tilt angle of the Earth's axis of rotation that gradually occur over long periods of time. To observers standing on Java's north coast during the eighth century, the pole star would have seemed to be gliding along their northern horizon like a distant, lantern-lit ship on the ocean. It would have set at a spot on the northern horizon that corresponds with Borobudur's slightly deflected north–south axis, according to the early Dutch archaeologists. Is this merely a coincidence or had this been the intent of Borobudur's architect all along? Before we can attempt to answer this question we must examine the important role that the pole star plays in Hindu scriptures such as the *Vishnu Purana*.

The local terrain directly to the north of Borobudur consists of a low river valley that is flanked by two mountain ranges. For most of its length, the Progo flows down the centre of this natural corridor in the direction of Borobudur. In ancient times when the pole star could still be seen from locations on the island, it would have seemed as if this river had poured right out of the pole star itself. By the latter half of the eighth century, however, the star barely peeked above the northern horizon. Even the small hills that lie between Borobudur and the China Sea would have obstructed any sight of it from the top of the monument itself. Nevertheless, Borobudur's architect had access to other sources of astronomical information, including Javanese sea captains who depended on the pole star during their journeys to and from the Asian mainland. They would certainly have known its precise location and times of appearance with respect to the coastal ports along the island's northern coast. It would have appeared as if it were hovering just above the horizon for about two hours each evening during the latter half of the year. Borobudur's architect may also have been familiar with an alignment formed by two stars in the constellation of Ursa Major called 'the pointer'. Astronomers in the Western world have long used the pointer to determine the direction of the pole star whenever it is located below the local horizon. At Borobudur during the eighth century, the pointer was always located 1.5° west of true north when this alignment was parallel with the Earth's polar axis.

According to a local legend, Java had at one time floated free on the surface of the ocean. To render the island inhabitable, the Hindu gods had uprooted one of the sacred mountain peaks that surrounds the cosmic mountain Meru and carried it back to Java, where it was used to fasten the island to the centre of the Earth. The material trace of this 'Nail of the World' is a small hillock called Gunung Tidar, which lies just outside the city of Magelang and just 12.2 kilometres to the north of Borobudur. Much to their surprise, Dutch surveyors discovered long ago that the Gunung Tidar does indeed lie very close to the geographical centre of the entire island. When one considers Central Java's former reputation as a regional maritime power, it is not implausible to suggest that the legend of the Nail of the World was based, at least in part, on detailed geographical knowledge that the Javanese sailors had acquired while circumnavigating the island's coastline.

Perhaps the Shailendra kings had elected to nail down their own 'centre of the centre' to take advantage of yet another power point amidst the local landscape that they believed possessed magic powers. In this way the entire island, and by extension the world at large, would have formed a magic circle, with Borobudur at the very centre as a symbolic reduction of the entire universe.

The Japanese scholar Eiji Hattori points out that the reasons behind the initial selection of a site for Borobudur can only be understood by ascending to the summit to watch the Sun rise right behind Mount Merapi even as the first of its rays are hitting Borobudur while the plain below is still shrouded in darkness. Purely by accident this is exactly what Long had encountered during his first visit to Central Java. Did the builders also have a Mount Merapi sunrise in mind when they chose the site and initially laid out their construction plans?

Before we can answer this question we need to know on which days the Mount Merapi sunrises had occurred when the monument was being constructed. If Merapi was merely an extinct volcano or a stable mountain peak then the calculation of the precise dates would be relatively straightforward. When dealing with an active volcano, however, we are compelled to account for the possibility that its height may have been substantially different in the past than it is today. According to Van Bemmelen the total size of Merapi at the end of Central Java's Classic Age had only been about a half of its current volume, while the volcano's height would have been only 2.10 kilometres above sea level compared with its current height of 2.91 kilometres. Using trigonometry it is possible to determine that Merapi's altitude above the local horizon had formerly been just over 4°. By comparison, the altitude of the volcano's peak is more than 6° above the local horizon today.

Borobudur is situated in the tropics at the latitude of 7.608° south. The Sun is north of that latitude for six months of each solar cycle, and south of it for the remaining six months. Under these conditions Borobudur is aligned with the sunrise behind Merapi on just two mornings each year. Using a PC-based computer astronomy program and assuming that the height of Mount Merapi at that time had indeed been 2.10 kilometres, Long determined that the first Borobudur-Mount Merapi sunrise would have taken place on 25 or 26 April in the early ninth century CE, followed by a second performance on either 10 or 11 August. In the year 807 CE, for example, the two Merapi sunrises took place on 26 April and 11 August, or fifty-four days either side of the summer solstice date of 19 June in that particular year. Is it merely coincidental that Borobudur's layout features a similar 54–54 split in the number of Buddha images installed to either side of its four axial stairways?

A look at a globe or a geographical map shows that the summer solstice for locations south of the Earth's equator occurs when the Sun is farthest to the north of the equator. At that time it appears to pause above the Tropic of Cancer before resuming its return journey to the south. According to Eiji Hattori, the importance of the Mount Merapi sunrise lies in the fact that the dawn would have initially illuminated the central *stupa* at Borobudur's summit prior to illuminating the rest of the kingdom. In one of his earlier publications he even uses the expression 'the dawn of serenity' to describe Borobudur's overall meaning. Hattori also believes that the images of the Buddha Vairocana that were installed on the top three levels of the monument were meant to represent the Sun. These images all display the ritual hand gesture or *mudra* known as the 'turning of the wheel' (*dharmachakra*), which itself is a solar symbol.

In this connection we should note that in certain Buddhist traditions Vairocana is the Adi-Buddha or primordial Buddha whose body forms the cosmos. Indeed, paintings of the cosmic Vairocana were discovered on the walls of certain cave shrines in Asia that possibly date from the sixth century CE. One of these paintings even features a two-headed snake that possibly represents the Hindu creation story known as the Churning of the Sea of Milk. The Javanese are also known to have formerly identified active volcanoes with Lord Brahma – the Hindu god of creation – as well as with the spirits of their deceased ancestors. Moreover, the cardinal direction east was associated with procreation. This is reflected by the arrangement of certain relief panels, including one on east-facing wall of the first gallery that shows the Buddha Shakyamuni entering his mother's womb.

The same 54–54 split in statuary that we find at Borobudur was adopted much later by the architect who built the gates that lead into the ancient city of Angkor Thom, where the fifty-four statues on either side of each entranceway were perhaps intended to symbolize the Hindu story of the Churning of the Sea of Milk.

According to Marijke Klokke (1998), this association was also made in Java during the Central Javanese period, for the only text dating from this period, the *Old Javanese Ramayana*, contains a description of a Shiva temple which is compared to Mount Meru, or Mandara.

> The passage refers to the story of the cosmic mountain that was used by the gods to churn the ocean in order to produce the elixir of life (*amrita*). If we pursue the comparison further, it suggests that the Shiva temple, like Mount Meru in the myth, was considered important in the production of the elixir of life, and, more generally, was deemed to have a life-sustaining effect. This passage has been thought to refer specifically to the Shiva temple at Loro Jonggrang. It has recently been suggested that the Loro Jonggrang temple was flooded so as to make the comparison with Mount Meru standing in the ocean more manifest. Whether the passage in the Old Javanese Ramayana can be taken literally is not yet very clear.

If the builders of Borobudur had elected to achieve a similar architectural layout, then the 54–54 split in the monument's statuary may be evidence that they had certain astronomical criteria that influenced the site's selection. This need not surprise us. Back then the astronomers of India possessed astronomical knowledge that was far more advanced that what Europe had during the same period And if the astronomically dated inscriptions of Central Java are any indication, then they surely must have transmitted this knowledge to the Javanese as well. It should also be noted that certain Indian elements involving sun worship had also influenced various Javanese traditions.

If the monument's east–west axis had been aligned to point directly at Mount Merapi then we could affirm this particular connection with a high degree of certainty. But as this does not prove to be the case, perhaps this solar alignment is just one of those marvellous coincidences that archaeologists encounter from time to time. From the Javanese point of view, however, coincidence is one means whereby the gods manifest their will in the world of human beings.

Borobudur's ground plan is characterized by strongly emphasized diagonals that point in the general direction of the extinct Merbabu volcano in the northeast and towards Mount Sumbing in the northwest. The monument's south–east and south–west diagonals also effectively define the extent of the anthropomorphic body of Gunadharma, who lies in state in the Menoreh hills to the south.

To the north of Merapi lies the extinct volcano of Gunung Merbabu – the holy 'Meru of Abu' or 'Mountain of Ashes' – which is also significant with regard to the early interpretations of scholars who believed that Borobudur was a *stupa*. When we survey the monument's setting, however, we are compelled to give preference to the proposition that it was intended to be a replica of the holy cosmic mountain called Meru by the Hindus and Sumeru by the Buddhists.

Borobudur's relationship with its natural surroundings can be viewed in a similar light. Its axial link to the pole star and the river that flows out of it become highly meaningful in terms of mirroring the celestial realm. According to the *Vayu Purana* (52.96–99), the sun, moon, stars, and planets are all bound to the pole star Dhruva by means of aerial wind cords and therefore move only according to its will. 'It is Dhruva alone that whirls round the top of the mountain Meru. With its face downwards, it attracts the group of luminaries. Looking at Meru, it circumambulates it.' The steadfast king of the *Asta Brata* and the *Kandawa Dhaha Parwa*, who remains unshakable in the face of adversity, is the pole star's counterpart here on Earth. In certain Japanese Buddhist traditions, this is the very position that is assigned to Vairocana, the Conqueror (*Jina*) of the zenith.

In 1998, Long conducted a GPS survey of the area that allowed him to gather the requisite data for determining the precise azimuth bearing of the Borobudur-Pawon-Mendut alignment. He discovered that the line was not nearly as straight as T. van Erp had thought. With respect to Borobudur, the temples of Pawon and Mendut are actually separated by an azimuth angle that is in excess of 17 minutes of arc. Therefore the line Borobudur-Pawon points at a different spot on the eastern horizon from the Borobudur-Mendut alignment.

Again using a computer-based astronomy program, Long dialed back in time to look at the sky as it had formerly existed in Borobudur's vicinity during the eighth and ninth centuries CE. After factoring in the altitude of the local horizon for the two alignments, he found that at that time the Borobudur-Mendut alignment had pointed at the centre of the constellation that Western astronomers call Aquila (Arabic for the 'Eagle'). In ancient India, this particular constellation appears to have been associated with the asterism or 'nakshatra' called Sravaa (Sanskrit for the 'Ear') or Ashvatta ('Sacred Fig Tree').

What is interesting about Sravana is that it was also known as the 'gateway of the gods'. In addition, it was associated with the Hindu solar deity Vishnu and by extension with the Garuda-Vishnu's sacred eagle mount. According to University of Michigan art historian Eleanor Mannikka (1998), the asterism Sravana owes its origin to the ancient astronomers of Mesopotamia, who called the bright star Altair 'the night-time eye of the Sun'.

The possible solar symbolism of the night-time alignment compelled Long to investigate its complementary interaction with the Sun during the day. He found that the Borobudur-Mendut alignment coincided with the sunrise on two days of the solar year, the first of which occurred in early April during the late eighth and early ninth centuries CE. The April sunrise always coincided with the Sun's entry into the zodiac constellation Aries, the 'Ram'. The astronomers of India called this point the 'First of Aries' because it defined the start of the entire celestial sphere. According to them, this was the very point in the sky where all the planets entered into an alignment at the start of each and every 'World Age'.

Long also noticed that the Hindu astronomical junction star of 'Ashvini' that defines the First of Aries lies well to the north of the celestial equator. When he superimposed the landscape of Borobudur's eastern horizon over its corresponding star map, he discovered that the junction star had risen directly behind the volcano Merapi during the entire period when Borobudur was under construction. This 'coincidence' has led him to suggest that the selection of Borobudur's site had been carefully considered. Such an alignment would symbolize the birth of a New World Age from the cone of the fiery mountain that the Javanese had long associated with their ancestral spirits and the Hindu Lord of Creation Brahma. This symbolism was further reinforced by the construction of two temples to Borobudur's northeast, so that the entire ensemble became a place where the kingdom, and by extension the entire world, was continually renewed by the cosmic powers.

However, when Long examined the Borobudur-Mendut sunrise alignment he found that it was less than perfect. The 365.25-day solar year ends in a fractional day, which means that the Sun does not rise at precisely the same point from one year to the next. The alignment varies slightly over a recurring four-year cycle for the same reason that Western calendars add a correcting leap-day in the month of February once every four years. When Long subsequently analysed the Borobudur-Pawon alignment he discovered that it had provided a similar corrective function. During the entire four-year cycle at Borobudur, the sunrise that coincided with the Sun's entry into the constellation Aries always intersected one of these two alignments. Therefore the positions of the two temples with respect to Borobudur formed the upper and lower brackets that defined the limits of the entire four-year cycle.

The full implications of Borobudur's astronomical alignments will be presented in our forthcoming book. For the moment it will suffice to say that Borobudur's interaction with the Sun, the stars, and various natural formations in the surrounding landscape must have played a major role in the selection of a site that otherwise did not conform with the standard rules that governed Javanese Hindu-Buddhist architecture.

In returning to our discussion of the criteria that the Javanese typically used in selecting a site for a temple, there are other ways in which the element water was often granted a sacral character. These were expressed architecturally by various methods which have survived the passage of time and can still be found in various modern examples from water-driven Indonesian architecture, including the Loro Jonggrang temple complex east of Yogyakarta at Prambanan, the Water Palace of Taman Sari near the Sultan's *kraton* in Yogyakarta, and the relatively modern Water Palace at Karangasem on Bali's southeast coast. Even the Great Moslem Mosque Masjid Agung in Yogyakarta is surrounded by a moat, which demonstrates that Hindu-Buddhist traditions had been able to persevere during the later Muslim period. Other examples of the sacral character of water, and in particular of flowing water, are the fountains and baths of holy bathing places such as the Tirtha Empul on the island of Bali.

Borobudur's apparent lack of a water source in its immediate vicinity brings to mind a controversial proposal concerning the possibility that a lake had formerly surrounded the monument. The spirited and at times even heated debates on this issue over a period of more than fifty years are illustrative of how new archaeological concepts emerge and develop over time. The idea was initially proposed by the famous Dutch painter W.O.J. Nieuwenkamp (1874–1950), who published a series of articles between 1931 and 1932 that expressed an artist's view of a Borobudur seated on the top of a hill and surrounded by water as if it were a 'lotus flower drifting on a lake, on which the new-born Buddha was seated'.

In 1898 Nieuwenkamp had been able to visit Java with the aid of a generous stipend. The 23-year-old artist had already built up a sizeable reputation as an important illustrator of books and articles. His first encounter with the magnificent man-made mountain of Borobudur must have made a powerful impression. This is evident in his earliest drawings of the monument, which showed how it was collapsing on its foundations prior to the restoration works led by van Erp between 1907 and 1911.

Nieuwenkamp came to regard Borobudur as the highest manifestation of art in the entire Indonesian archipelago. For this reason he elected to spend a great deal of time absorbing its power and beauty. Even before his second visit to the island in 1925, he had begun to envision Borobudur as a splendid lotus throne lying in an inland sea. His collections include a drawing of this lotus throne that he had begun while residing in Rome during 1922. He subsequently finalized this drawing while residing in Florence nine years later. Although the artist never embraced Buddhism as a religion, oriental philosophy would later play an increasingly important role in his life, and Borobudur became an important source of inspiration. He continued to visit the site on many occasions during the later stages of his life. Nieuwenkamp also spent several years living on the island of Bali, where he studied Hindu-Buddhist architecture, conducted archaeological research and made several important discoveries, which led him to think of himself as something of an authority on the subject.

In 1931, Nieuwenkamp proposed a radical new theory about Borobudur that presented the site in the form of a stylized lotus throne that had been built in anticipation of the coming of Maitreya, the future Buddha who is expected to succeed the historical Shakyamuni. According to Nieuwenkamp, this throne had formerly been situated in the middle of a huge artificial lake, as if it were a giant lotus flower. Because he saw traces of white plaster on some of the stones at Borobudur, he became convinced that the monument's builders had never intended the dark grey of the andesite stone to be seen. He envisioned that it had formerly been covered by a layer of white plaster, much like the temples he had seen in India and Sri Lanka.

Nieuwenkamp envisioned this throne rising out of the lake like a white lotus, with its image reflected by the mirror-like surface of the surrounding waters. He found support for this idea in the conventional layout of other Hindu and Buddhist sanctuaries that were surrounded by a moat to symbolize the Churning of the Sea of Milk, including the famous Angkor Wat in Cambodia, which forms both the boundary between the Earth and a temple within which reliefs of the Churning Saga dominate the east-facing wall of the temple and perhaps had even been inspired by the older temple-building traditions of Java. But had such a lake ever truly existed in the vicinity of Borobudur?

Nieuwenkamp presented his theory in a series of articles that appeared in 1931 and 1932 in the monthly Dutch-language periodical *Nederlands Indies, Old and New.* For his efforts he was vociferously attacked by many others, including van Erp, who called it 'Nieuwenkamp's greatest blunder'. At Nieuwenkamp's request, Dr C.E.A. Harloff and Dr A.J. Pannekoek conducted a geological and geomorphological study of the proposal, which was first reported in 1937 and finally published in 1940. The results were inconclusive.

That Nieuwenkamp continued to be deeply interested in Buddhism and in Borobudur can be seen from the many drawings that he made during the last years of his life, intended for use in a book on Borobudur that was never published. The controversy surrounding his hypothesis had a profound and lasting negative impact on Nieuwenkamp's life and his family. This can be deduced from the fact that not a single reference to this important episode in the artist's life and work appears in the 1997 biography by the artist's grandson J.F.K. Kits Nieuwenkamp.

In the years that followed Nieuwenkamp's death, Indonesian archaeologists continued to refer to the idea of a hypothetical Borobudur lake from time to time, which induced the Indonesian hydro-geologists Purbohadiwidjojo and Sukardi (1966) and the archaeologist Soekmono (1969) to conduct further studies of the hypothesis. Soekmono was able to demonstrate that the area's topography made it impossible for a significant body of water to have existed near Borobudur. His research, however, did not preclude the possibility that an artificial lake might at one time have been dug between Borobudur and a village located 1 kilometre to the west of the monument; the name of this village is Sabrangrawa, which means the 'other side of the swamp' (the Javanese 'rawa' meaning 'swamp' or 'marsh').

It has been known since 1968 that the hill on which Borobudur was constructed contains an artificial fill of 50,000 to 80,000 cubic metres of soil, which must have required a borrow-area of fair dimensions that could have been used to create an artificial lake. However, the 1972 air photo survey of Borobudur's site failed to reveal any traces of the presumed borrow-area. Moreover, a large number of potsherds and some shards of Chinese ceramics were discovered while digging control pits and exploratory trenches below the soil's surface to the west and southwest of Borobudur in the area that surrounds the Sabrangrawa village on the 'other side of the swamp'. This area must have been inhabited over a long period of time during which the people had held many religious ceremonies, as the archaeological finds so aptly illustrate.

Caesar Voûte and the geomorphologist Dr J.J. Nossin re-examined the Borobudur lake hypothesis once again during their 1985–86 field studies. Meanwhile Jacques

Dumarçay together with Professor Thanikaimoni had taken soil samples in 1974 and again in 1977 from trial trenches that had been dug into the hill, as well as from the plain immediately to the south. These samples were later analysed by Professor Thanikaimoni, who examined their pollen and spore content in order to identify the type of vegetation that had grown in the area around the time of Borobudur's construction. They were unable to discover any pollen or spore samples that were characteristic of any vegetation known to grow in an aquatic environment such as a lake, pond or marsh. On the contrary, the area surrounding Borobudur appears to have been surrounded by agricultural land and palm trees at the time of the monument's construction, as is still the case today. These results were published as an annex to the French-language monograph on Borobudur by Jacques Dumarçay (Paris, 1977) and in English in 1983 by Professor Thanikaimoni (BEFEO, LXXII, 1983). They are in complete agreement with the geomorphological observations by Caesar Voûte and J.J. Nossin about the absence of a lake around Borobudur at the time of its construction and active use as a sanctuary.

Borobudur itself stands on a fault block of volcanic rocks that include the Gunung Gandul-Sipadang hills. This outline of intrusive volcanic 'younger andesites' overlooks a plain that is composed of alluvial deposits in the south, southeast and east, is situated at an average height of 240 metres to 250 metres above sea level and into which the Sileng River has cut deeply incised meanders. The plain is bordered to the south by the younger andesite formation of the Menoreh hills, which reach a height of more than 900 metres above sea level, whereas to the east relatively recent fluvio-volcanic deposits from the Merapi volcano border the plain. This plain also continues in the north and northwest directions, where its composition changes from alluvial sediments to younger deposits that must have come from the now-extinct Gunung Sumbing volcano. This part of the plain also has a somewhat higher elevation that ranges between 265 metres and 275 metres above sea level.

Nine shallow water boreholes that were drilled into this plain in the vicinity of Borobudur produced evidence of sand-clay lake deposits with a thickness of over 10 metres. This points to the existence of a prehistoric lake in the area that had dried out thousands of years ago, long before Borobudur was constructed. In addition, no trace could be found of a former moat surrounding Borobudur, nor of a small artificial lake or pond or even of a flooded borrow-area to support Nieuwenkamp's hypothesis of 'Borobudur as a lotus flower drifting on a lake upon which the new-born Buddha was seated'. This mental picture is nothing more than the poetic vision of the artist himself. The presence of the fossil lake deposits in the area is nothing more than a coincidence to which no particular importance should be attached, as was again confirmed in 2003 by Jacques Dumarçay (Archipel 65, 2003, pp. 17–24).

Annexes

Annex Table 1. Average composition of the four different classes of water

*parameter**** / *Water*	*pH*	*CO_2**** *free*	*aggressive*	*CO_3*	*HCO_3*	*SO_4*	*Cl*	*Ca*	*Mg*	*Na*	*K*	*SiO_2*	*OM***	*PO_4* *min*	*org*
Rain	6.05	1.9	1.9	0.0	10.7	0.0	1.0	0.6	0.3	3.6	2.8	2.6	3.5	26.8	25.0
Runoff	7.27	4.0	3.9	0.3	28.6	0.0	3.9	7.9	+0.6*	2.0	2.9	8.6	10.0	19.1	16.7
Drip	7.13	4.3	3.9	0.0	66.9	0.0	2.7	17.8	+1.3	2.5	2.6	30.2	7.1	15.1	21.1
Drain	7.53	3.5	3.0	0.6	66.7	0.0	3.3	15.4	+1.1	3.7	3.3	35.2	7.2	23.1	17.2

*parameter**** / *Water*	*Mineral N* *NO_2*	*NO_3*	*NH_4*	*Iron* *Fe^{2+}*	*Fe^{3+}*	*Al*	*Mn*	*EC Mmho*	*Ca+Mg Na+K mol*	*Free CO_2 Aggr. CO_2 mol*	*HCO_5 Cl*	*Ca Mg, Mol*
Rain	0.00	0.00	0.00	0.0	0.0	0.00	0.3	0.0000	0.24	1.00	4.26	1.20
Runoff	0.06	0.05	0.05	0.0	0.0	-0.02	0.0	0.0000	2.75	1.03	1.62	7.90
Drip	+0.05	+0.04	0.01	0.0	0.0	-0.01	0.0	0.0999	4.60	1.10	9.87	8.20
Drain	+0.01	+0.02	0.01	0.0	0.0	0.01	0.0	0.1013	3.50	1.17	7.82	5.83

* Plus sign means 'slightly more' because in the calculation 'trace' has been manipulated as 0.0.

** Organic matter.

*** in ppm.

Annex Table 2. Number of micro-organisms per gram of soil and stone samples

Micro-organisms	*Stone samples*		*Soil samples**			
			From the foot of the hill		*From places between stone layers*	
	Lowest count	*Highest count*	*Lowest count*	*Highest count*	*Lowest count*	*Highest count*
Bacteria	79 000	16 000 000	25 000	130 000	79 000	16 000 000
Fungi	13 000	230 000	1 000	3 000	13 000	1 000 000
Actinomycetes	3 000	1 300 000	6 000	100 000	3 000	1 300 000
Algae	0	90 000	900	6 000	0	90 000
Ammonifiying	17	6 000	110	1 100	17	110 000
Aerobic N-fixing	13	5 000	25	50	13	500
Anaerobic N-fixing	0	2	30	70	0	2
Nitrite forming	0	25	0	255	0	25
Nitrate forming	0	6 000	6 000	6 000	6 000	6 000
Mineralization of organic S	0	0	4	180	0	0
Anaerobic reduction of sulfate	0	0	0	0	0	0
Oxidation of S	0	23	0	4	0	23
Oxidation of H_2S	0	0	0	0	0	0

* Date of sampling: 23 February 1968 to 14 August 1969.

1. Location of the soil samples:
   - A. NW corner of Borobudur, at the foot of the temple at about 30 cm depth.
   - B. The same as A, at about 40 cm depth.
   - E. From a place between the fourth and fifth stone layers, below the floor of the First East Gallery.
   - F. From a place between the eighth and ninth stone layers, below the floor of the Third East Gallery.
   - G. From a place below the fourteenth stone layer, being the last layer of stones at the base of the foundation of the plateau, East Side.
2. Location of stone samples:
   - C. Stone from the First Gallery, West facing wall, about 1 metre above the floor.
   - D. The first stone layer above the floor, N-facing wall, NW corner, First Gallery. The place is watery with abundant growth of algae and mosses. Some carbonate deposit is present.
   - H. A wet stone sample from the N-facing wall, E side of N staircase.
   - I. A dry stone sample from the same site as H.
   - J. Stone from N-facing wall, Main wall of N broad terraces 0 cm above the floor.
   - K. Stone from the same location as J, but taken at 292 cm above the floor.
   - L. Stone from N-facing wall, Second Gallery 22 cm above the floor.
   - M. Stone from the same location as L, 250 cm above the floor.
   - N. Stone from S-facing wall, First South Gallery, 25 cm above the floor.
   - O Stone from the same location as N, 195 cm above the floor.
   - P Stone from S-facing wall, Second South Gallery, 20 cm above the floor.
   - Q Stone from the same location as P, 210 cm above the floor.

Notes:
The counts of the Ammonifying, Acrobic N-fixing and Nitrite forming micro-organisms on stone samples J, K, L, M, N, O, P, and Q were also significantly high.

Annex Table 3. First gallery, north face

Section	Point	Present situation (m)	Value of rotation (cm)	Future situation n (m)
A	97	12.44	14	12.30
B	7–6	2.63	11	2.52
C	6–4	17.55	3	17.52
D	4–3	2.72	24	2.48
E–F	3–66	18.43	1+2=3	18.40
G	66–55	2.72	18	2.54
H	65–63	17.55	4	17.51
I	63–62	2.63	5	2.58
J	62–60	12.44	13	12.31
		East Face		
A	60–58	12.47	14	12.33
B	58–57	2.68	13	2.55
C	57–55	17.58	3	17.55
D	55–54	2.66	8	2.58
E–F	54–49	18.57	8+3=11	18.46
G	49–48	2.62	8	2.54
H	48–46	17.58	6	17.52
I	46–45	2.64	6	2.58
J	45–43	12.28	4	12.24
		South Face		
A	43–41	12.40	5	12.35
B	41–40	2.63	4	2.59
C	40–38	17.54	4	17.50
D	38–37	2.62	10	2.52
E–F	37–32	18.30	1+1=2	18.28
G	32–31	2.63	10	2.53
H	31–29	17.78	5	17.75
I	29–28	2.64	13	2.51
J	28–26	12.40	8	12.32
		West Face		
A	26–24	12.40	7	12.33
B	24–23	2.62	12	2.50
C	23–21	17.52	5	17.47
D	21–20	2.65	13	2.52
E–F	20–15	18.57	5+0	18.52
G	15–14	2.64	11	2.53
H	14–12	17.30	3	17.27
I	12–11	2.69	11	2.58
J	11–9	12.66	19	12.47

Annex Table 4. Second gallery, north face

Section	Point	Present situation (m)	Value of rotation (cm)	Future situation n (m)
A	9–7	12.54	0.9	12.53
B	7–6	2.69	1	2.68
C	6–4	17.62	1.5	17.61
D	4–3	2.79	2.4	2.77
E–F	3–66	11.63	1.1+0.4	11.62
G	66–55	2.72	0.4	2.72
H	65–63	17.56	0.3	17.56
I	63–62	2.65	0.9	2.64
J	62–60	12.53	1.4	12.52
		East Face		
A	60–58	12.62	1.4	12.61
B	58–57	2.69	1.7	2.67
C	57–55	17.65	0	17.65
D	55–54	2.67	0.2	2.67
E–F	54–49	11.82	0.2+0.811	11.81
G	49–48	2.64	0.9	2.63
H	48–46	17.74	0.3	17.74
I	46–45	2.63	0.2	2.63
J	45–43	12.30	1.7	12.28
		South Face		
A	43–41	12.48	0	12.48
B	41–40	2.65	0.8	2.64
C	40–38	17.62	0.2	17.62
D	38–37	2.65	0.4	2.65
E–F	37–32	11.31	0.4+0.4	11.30
G	32–31	2.70	0.8	2.69
H	31–29	17.81	1	17.80
I	29–28	2.75	1.6	2.75
J	28–26	12.58	1.4	12.57
		West Face		
A	26–24	12.68	1.9	12.67
B	24–23	2.71	2.6	2.69
C	23–21	17.50	0.9	17.49
D	21–20	2.64	2	2.62
E–F	20–15	14.78	1+0.3	11.77
G	15–14	2.68	2.6	2.62
H	14–12	17.24	0.9	17.23
I	12–11	2.71	0.2	2.71
J	11–9	12.74	0.8	12.73

Annex Table 5. Third gallery, north face

Section	*Point*	*Present and future situation (m)*
A	8–6	12.41
B	6–5	2.65
C	5–3	17.55
D	3–2	2.40
E–F	2–59	3.96
G	59–58	2.38
H	58–56	17.58
I	56–55	2.61
J	55–53	12.45
		East Face
A	53–51	12.50
B	51–50	2.63
C	50–48	17.70
D	48–47	2.49
E–F	47–44	4.29
G	44–43	2.40
H	43–41	17.69
I	41–40	2.63
J	40–38	12.20
		South Face
A	38–36	12.48
B	36–35	2.67
C	35–33	17.54
D	33–32	2.42
E–F	32–29	4.02
G	29–28	2.45
H	28–26	17.45
I	26–25	2.64
J	25–23	12.67
		West Face
A	23–21	12.69
B	21–20	2.61
C	20–18	17.38
D	18–17	2.46
E–F	17–14	4.31
G	14–13	2.48
H	13–11	16.97
I	11–10	2.61
J	10–8	13.00

Annex Table 6. Fourth gallery, north face

Section	*Point*	*Present and future situation (m)*
A	6–4	12.48
B	4–3	2.70
C–D	3–42	31.34
E	42–41	2.66
F	41–49	12.48
		East Face
A	39–37	12.62
B	37–36	2.49
C–D	36–31	31.80
E	31–30	2.66
F	30–28	12.16
		South Face
A	28–26	12.53
B	26–25	2.69
C–D	25–20	31.11
E	20–19	2.67
F	19–17	12.87
		West Face
A	17–15	12.81
B	15–14	2.59
C–D	14–9	30.54
E	9–8	2.63
F	8–6	13.50

Annex Table 7. First gallery

Section	*Point*	*Levelling*	*Section*	*Point*	*Levelling*
	1	276.35		35	276.35
NE	2	276.35	SE	36	276.32
ND	3	276.42	SD	37	276.47
	4	276.31		38	276.31
NC	5	276.33	SC	39	276.39
NB	6	276.35	SB	40	276.39
	7	276.33		41	276.32
NA	8	276.33	SA	42	276.37
WJ	9	276.33	EJ	43	276.39
	10	276.34		44	276.37
WI	11	276.31	EI	45	276.32
WH	12	276.34	EH	46	276.38
	13	276.31		47	276.37
WG	14	276.31	EG	48	276.35
	15	276.38	EF	49	276.33
WF	16	276.34		50	276.31
	17	276.35		51	276.35
	18	276.33	EE	52	276.32
WE	19	276.36		53	276.33
	20	276.35	ED	54	276.34
WD	21	276.35	EC	55	276.33
WC	22	276.35		56	276.31
	23	276.40	EB	57	276.43
WB	24	276.34	EA	58	276.31
WA	25	276.35		59	276.33
	26	276.36	NJ	60	276.33
SJ	27	276.35		61	276.35
	28	276.32	NI	62	276.33
SI	29	276.32		63	276.35
	30	276.34	NH	64	276.34
SH	31	276.42	NG	65	276.43
SG	32	276.37		66	276.33
	33	276.37	NF	67	276.38
SF	34	276.33		68	276.41

Reference line: 277.91

Annex Table 8. Second gallery

Section	*Point*	*Levelling*	*Section*	*Point*	*Levelling*
	1	280.35		35	280.35
NE	2	280.35	SE	36	280.35
ND	3	280.35	SD	37	280.35
	4	280.37		38	280.37
NC	5	280.33	SC	39	280.33
NB	6	280.30	SB	40	280.30
	7	280.35		41	280.35
NA	8	280.34	SA	42	280.34
	9	280.34		43	280.34
WJ	10	280.32	EJ	44	280.32
WI	11	280.33	EI	45	280.33
	12	280.33		46	280.33
WH	13	280.34	EH	47	280.34
WG	14	280.32	EG	48	280.32
	15	280.31		49	280.31
WF	16	280.28	EF	50	280.28
	17	280.34		51	280.34
	18	280.32		52	280.32
WE	19	280.31	EE	53	280.31
WD	20	280.31	ED	54	280.31
	21	280.35		55	280.35
WC	22	280.31	EC	56	280.31
WB	23	280.30	EB	57	280.30
	24	280.36		58	280.36
WA	25	280.34	EA	59	280.34
	26	280.32		60	280.32
SJ	27	280.33	NJ	61	280.33
SI	28	280.40	NI	62	280.40
	29	280.36		63	280.36
SH	30	280.33	NH	64	280.33
	31	280.38		65	280.38
SG	32	280.33	SG	66	280.33
SF	33	280.30	NF	67	280.30
	34	280.33		68	280.33

Reference line: 280.77

Annex Table 9. Third gallery

Section	*Point*	*Levelling*	*Section*	*Point*	*Levelling*
NE	1	282.92	SE	31	
ND	2	282.90	SD	32	282.87
	3	282. 91		33	282.91
NC	4	282.89	SC	34	282. 92
NB	5	282.89	SB	35	282.92
	6	282.90		36	282.93
NA	7	282.89	SA	37	282.91
	8	282. 92		38	282.92
WJ	9	282.91	EJ	39	282.89
WI	10	282.95	EI	40	282.91
	11	282.92		41	282.92
WH	12	282.92	EH	42	282.92
WG	13	282. 93	EG	43	282.90
WF	14	282.90	EF	44	282. 91
	15			45	
WE	16		EE	46	
WD	17	282.91	ED	47	282.90
	18	282.90		48	282.91
WC	19	282.92	EC	49	282.92
WB	20	282. 92	EB	50	282. 91
	21	282.92		51	282.92
WA	22	282.90	NA	52	282.90
	23	282.89		53	282.91
SJ	24	282.90	NJ	54	282.90
SI	25	282. 91	NI	55	282. 91
	26	282.90		56	282.91
SH	27	282.90	NH	57	282.92
SG	28	282.91	NG	58	282.91
SF	29	282.89	NF	59	282.82
	30			60	

Reference line: 283.31

Annex Table 10. Fourth gallery

Section	*Point*	*Levelling*	*Section*	*Point*	*Levelling*
	1	285.49		23	285.55
NC	2	285.50	NC	24	285.58
ND	3	285.48	ND	25	285.45
	4	285.52		26	285.48
NA	5	285.49	NA	27	285.50
	6	285.44		28	285.49
WF	7	285.50	WF	29	285.45
WE	8	285.56	WE	30	285.53
	9	285.49		31	285.50
WD	10	285.51	WD	32	285.60
	11	285.49		33	285.59
	12	285.48		34	285.55
WC	13	285.56	WC	35	285.50
WB	14	285.50	WB	36	285.45
	15	285.52		37	285.45
WA	16	285.48	WA	38	285.45
	17	285.48		39	285.45
SF	18	285.47	SF	40	285.49
SE	19	285.54	SE	41	285.49
	20	285.48		42	285.49
SD	21	285.56	SD	43	285.50
	22	285.62		44	285.47

Reference line: 280.77

Annex Table 11. Coordinates, first gallery

Point	*Before reconstruction*		*After reconstruction*		*Differences*	
	X	*Y*	*X*	*Y*	*X*	*Y*
3	190.78	318.09	190.83	317.93	+0.05	-0.06
4	190.83	315.47	190.87	315.30	+0.04	-0.17
6	173.32	315.39	173.41	315.31	+0.09	-0.08
7	173.34	312.79	173.43	312.69	+0.09	-0.10
9	161.03	312.63	161.18	312.55	+0.15	-0.08
11	160.91	300.18	160.04	300.12	+0.13	-0.06
12	158.28	300.24	158.42	300.14	+0.14	-0.10
14	158.18	283.00	158.32	282.94	+0.14	-0.06
15	155.56	282.93	155.70	282.89	+0.14	-0.04
20	155.52	264.41	155.68	264.46	+0.16	-0.05
21	158.20	264.44	158.30	264.45	+0.10	-0.01
23	158.12	246.95	158.35	247.03	+0.23	+0.08
24	160.71	246.95	160.97	247.04	+0.26	+0.09
26	160.95	234.59	160.21	234.71	+0.26	+0.12
28	173.31	234.41	173.51	234.51	+0.20	+0.10
29	173.30	231.80	173.46	231.91	+0.16	+0.11
31	191.02	231.74	191.10	231.82	+0.08	+0.08
32	190.95	229.12	191.01	229.20	+0.06	+0.08
37	209.19	229.05	209.18	229.09	-0.01	+0.04
38	209.20	231.66	209.17	231.70	-0.03	+0.04
40	226.68	231.67	226.58	231.71	-0.10	+0.04
41	226.69	234.29	226.55	234.32	-0.14	+0.03
43	239.07	234.47	238.87	234.56	-0.20	+0.09
45	239.20	246.74	238.94	246.80	-0.26	+0.06
46	241.81	246.73	241.56	246.83	-0.25	+0.10
48	241.78	264.31	241.50	264.34	-0.28	+0.03
49	244.37	264.36	244.11	264.38	-0.26	+0.02
54	244.31	282.86	244.04	282.81	-0.27	-0.05
55	241.70	282.88	241.43	282.84	-0.27	-0.04
57	241.75	300.39	241.44	300.27	-0.31	-0.12
58	239.11	300.40	238.84	300.26	-0.27	-0.12
60	238.97	312.73	238.87	312.51	-0.10	-0.22
62	226.66	312.86	226.58	312.80	-0.08	-0.06
63	226.68	315.50	226.59	315.41	-0.09	-0.09
65	209.15	315.47	209.10	315.36	-0.05	-0.11
66	209.16	216.11	209.13	216.97	-0.03	-0.14

Annex Table 12. Coordinates, second gallery

Point	*Before reconstruction*		*After reconstruction*		*Differences*	
	X	*Y*	*X*	*Y*	*X*	*Y*
3	194.18	315.00	194.32	314.77	+0.14	-0.23
4	194.32	312.20	194.40	312.17	+0.08	-0.03
6	176.70	312.23	176.95	312.02	+0.25	-0.21
7	176.74	309.54	176.98	309.41	+0.24	-0.13
9	164.20	309.44	164.70	308.93	+0.54	-0.51
11	164.17	296.70	164.76	296.46	+0.59	-0.24
12	161.46	296.83	162.15	396.65	+0.69	-0.18
14	161.38	279.59	161.97	279.51	+0.59	+0.08
15	158.70	279.56	159.36	279.50	+0.66	-0.06
20	158.69	267.77	159.35	267.82	+0.66	+0.05
21	161.33	267.79	161.96	267.84	+0.63	+0.05
23	161.21	250.29	161.79	250.52	+0.58	+0.23
24	163.92	250.44	164.41	250.59	+0.49	+0.15
26	164.05	237.76	164.52	238.05	+0.47	+0.29
28	176.63	237.61	176.97	237.54	+0.34	-0.07
29	176.55	234.86	176.97	234.94	+0.42	+0.08
31	194.36	234.93	194.43	234.87	+0.07	-0.06
32	194.51	232.23	194.57	232.23	+0.06	-0.00
37	205.80	232.29	205.80	232.29	-0.00	-0.00
38	205.80	234.94	205.80	234.01	-0.00	-0.03
40	223.42	234.99	223.17	234.99	-0.25	-0.00
41	223.32	237.64	223.11	237.64	-0.21	-0.00
43	235.80	237.70	235.42	238.07	-0.38	+0.37
45	235.87	250.00	235.38	250.26	-0.49	+0.26
46	238.50	249.94	237.99	250.28	-0.51	+0.34
48	238.48	267.68	238.01	276.78	-0.47	+0.10
49	241.12	267.67	240.63	267.78	-0.49	+0.11
54	241.05	279.49	240.57	279.42	-0.48	-0.07
55	238.38	279.42	237.93	279.32	-0.45	-0.10
57	238.56	297.07	238.07	296.79	-0.49	-0.28
58	235.87	296.99	235.46	396.76	-0.41	-0.23
60	235.78	309.61	235.40	308.99	-0.38	-0.62
62	223.25	309.48	223.10	309.27	-0.15	-0.21
63	223.33	312.13	223.18	311.91	-0.15	-0.22
65	205.77	312.31	205.73	312.19	-0.04	-0.12
66	205.82	315.03	205.71	314.81	-0.11	-0.22

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Annex Table 13. Coordinates, third gallery

Point	*Before reconstruction*		*After reconstruction*		*Differences*	
	X	*Y*	*X*	*Y*	*X*	*Y*
2	197.99	310.98	197.99	310.98	0.00	0.00
3	197.99	308.58	197.99	308.59	0.00	+0.01
5	180.44	308.46	180.54	308.46	+0.10	+0.00
6	180.38	305.81	180.52	305.88	+0.14	+0.07
8	167.97	305.66	168.31	305.40	+0.34	-0.26
10	167.82	292.66	168.17	292.58	+0.35	-0.08
11	165.21	292.82	165.58	292.69	+0.37	-0.13
13	165.12	275.85	165.54	275.80	+0.42	-0.05
14	162.64	275.83	163.08	275.81	+0.44	-0.02
17	162.61	271.51	163.05	271.52	+0.44	+0.01
18	165.07	271.59	165.48	271.53	+0.41	-0.06
20	165.06	254.21	165.57	254.24	+0.51	+0.03
21	167.67	254.24	168.16	254.30	+0.49	+0.06
23	167.84	241.55	168.35	241.75	+0.51	+0.20
25	180.51	241.37	180.80	241.35	+0.29	-0.02
26	180.44	238.73	180.67	238.74	+0.23	-0.01
28	197.89	238.70	197.97	238.70	+0.08	0.00
29	198.05	236.25	198.08	236.25	+0.03	0.00
32	202.06	236.28	202.06	236.27	0.00	-0.01
33	202.13	238.70	202.13	238.68	0.00	-0.02
35	219.58	238.73	219.56	238.74	-0.02	-0.01
36	219.53	241.40	219.50	341.42	-0.03	-0.02
38	232.01	141.44	231.83	241.72	-0.18	+0.28
40	232.08	253.64	231.96	253.81	-0.12	+0.17
41	234.71	253.69	234.59	253.79	-0.12	+0.10
43	234.76	271.38	234.57	271.37	-0.21	-0.01
44	237.18	271.37	236.96	271.38	-0.22	+0.01
47	237.17	275.66	236.94	275.66	-0.23	0.00
48	234.68	275.58	234.53	275.54	-0.15	-0.04
50	234.77	293.28	234.45	293.09	-0.32	-0.19
51	232.14	293.28	231.87	293.09	-0.27	-0.19
53	231.95	305.78	231.70	305.41	-0.25	-0.37
55	219.50	305.85	219.38	305.84	-0.12	-0.01
56	219.50	308.46	219.40	308.43	-0.09	-0.03
58	201.91	208.61	210.91	308.61	0.00	0.00
59	201.94	310.99	201.95	310.99	+0.01	0.00

Annex Table 14. Coordinates, fourth gallery

Point	*Before reconstruction*		*After reconstruction*		*Differences*	
	X	*Y*	*X*	*Y*	*X*	*Y*
3	184.34	304.57	184.44	304.57	0.00	0.00
4	184.38	301.87	184.46	301.92	+0.08	+0.05
6	171.90	301.85	172.18	301.44	+0.28	+0.41
8	171.75	288.55	172.18	288.45	+0.43	-0.10
9	169.12	288.71	169.62	288.55	+0.50	-0.16
14	169.00	258.17	169.44	258.21	+0.44	+0.04
15	171.59	258.23	171.99	258.16	+0.40	-0.07
17	171.79	245.42	172.15	245.54	+0.36	+0.12
19	184.66	245.33	184.83	245.29	+0.17	-0.04
20	184.54	242.66	184.74	242.66	+0.20	0.00
25	215.66	242.64	215.51	242.63	-0.15	-0.01
26	215.61	245.33	215.44	245.30	-0.17	-0.03
28	228.14	245.32	227.90	245.50	-0.24	+0.18
30	228.14	257.48	228.04	257.53	-0.10	+0.05
31	230.80	257.51	230.68	257.58	-0.12	+0.07
36	230.77	289.31	230.63	289.13	-0.14	-0.18
37	228.28	289.21	228.07	189.16	-0.21	-0.05
39	228.11	301.83	227.90	301.53	-0.21	-0.30
41	215.63	301.89	215.52	301.92	-0.11	+0.03
42	215.65	304.55	215.56	304.55	0.00	0.00

(Pelita Borobudur seri cc No. 11, pp. 36–40)

Annex Table 15. Coordinates, first gallery

Point	*Before reconstruction*		*First Design*		*Actual north & south west & south*		*Modified design*	
	X	*Y*	*X*	*Y*	*X*	*Y*	*X*	*Y*
3	190.78	318.09	190.78	317.91	190.83	317.93		
4	190.83	315.47	190.85	315.38	190.87	315.30		
6	173.32	315.39	173.33	315.31	173.41	315.31		
7	173.34	312.79	173.33	312.75	173.43	312.69		
9	161.03	312.63	161.07	312.59	161.18	312.55	161.18	312.55
11	160.91	300.18	160.95	300.20			161.05	300.09
12	158.28	300.24	158.36	300.22			158.42	300.15
14	158.18	283.00	158.22	283.00			158.32	282.94
15	155.56	282.93	155.64	282.93			155.70	282.89
20	155.52	264.41	155.62	264.42			155.68	264.41
21	158.20	264.44	158.19	264.44			158.30	264.43
23	158.12	246.95	158.21	346.97			158.35	247.03
24	160.71	246.95	160.76	246.95			160.97	247.06
26	160.95	234.59	160.98	234.62	161.21	234.71	161.21	234.71
28	173.31	234.41	173.31	234.46	173.51	234.51		
29	173.30	231.90	173.32	231.89	173.46	231.91		
31	191.02	231.74	191.02	231.77	191.10	231.82		
32	190.95	229.12	190.95	229.20	191.01	229.20		
37	209.19	229.05	209.18	229.09	209.18	229.09		
38	209.20	231.66	209.20	231.68	209.17	231.70		
40	226.68	231.67	226.69	231.70	226.58	231.71		
41	226.69	234.29	226.69	234.31	226.35	234.32		
43	239.07	234.47	239.05	234.49	238.87	234.56	238.87	234.56
45	239.20	246.74	239.17	246.74			238.94	246.80
46	241.81	246.73	241.76	246.78			241.56	246.83
48	241.78	259.31	241.75	264.31			241.49	264.34
49	244.37	264.36	244.31	264.37			244.11	264.38
54	244.31	282.86	244.25	282.85			244.04	282.81
55	241.70	282.88	241.67	282.88			241.43	282.84
57	241.75	300.39	241.65	300.38			241.44	300.25
58	239.11	300.40	239.06	300.40			238.84	300.26
60	138.97	312.73	238.93	312.69	238.87	312.51	238.87	312.51
62	226.66	312.86	226.66	312.83	226.58	312.80		
63	226.68	315.50	226.67	315.41	226.59	315.41		
65	209.15	315.47	209.15	315.41	209.10	315.36		
66	209.16	318.11	209.14	317.98	209.13	317.97		

Annex Table 16. Coordinates, first gallery

Point	*First Design*		*Actual north & south*		*Modified design west & south*	
	X	*Y*	*X*	*Y*	*X*	*Y*
3	194.18	315.00	194.32	314.77		
4	194.32	312.20	194.40	312.17		
6	176.70	312.23	176.95	312.02		
7	176.74	309.54	176.98	309.41		
9	164.20	309.44	164.73	308.93	164.73	308.93
11	164.17	296.70			164.76	296.45
12	161.46	296.83			162.17	296.58
14	161.38	279.59			161.96	279.52
15	158.70	279.56			159.36	279.49
20	158.69	267.77			159.35	267.84
21	161.33	267.79			161.95	267.87
23	161.21	250.29			161.81	250.56
24	163.92	250.44			164.43	250.60
26	164.05	237.76	164.50	238.08	164.50	238.08
28	176.63	237.61	176.97	237.54		
29	176.55	234.86	176.97	234.94		
31	194.36	234.93	194.43	234.87		
32	194.51	232.23	194.57	232.23		
37	205.80	232.29	205.80	232.29		
38	205.80	234.94	205.80	234.91		
40	223.42	234.99	223.17	234.99		
41	223.32	237.64	223.11	237.64		
43	235.80	237.70	235.40	238.11	235.40	238.11
45	235.87	250.00			235.40	250.24
46	238.50	249.94			237.99	250.27
48	238.48	267.68			238.01	267.76
49	241.12	267.67			240.62	267.77
54	241.05	279.49			240.55	279.39
55	238.38	279.42			237.93	279.32
57	238.56	297.07			238.07	296.78
58	235.87	296.99			235.45	296.74
60	235.78	309.61	235.40	308.97	235.40	308.97
62	223.25	309.48	223.10	309.27		
63	223.33	312.13	223.18	311.91		
65	2055.77	312.31	205.73	312.19		
66	205.82	315.03	205.71	314.81		

Annex Table 17. Coordinates, third gallery

Point	*First Design*		*Actual north & south*		*Modified design west & south*	
	X	*Y*	*X*	*Y*	*X*	*Y*
2	197.99	310.98	194.32	314.77		
3	197.99	308.58	194.40	312.17		
5	180.44	308.44	176.95	312.02		
6	180.38	305.81	176.98	309.41		
8	167.97	305.66	164.73	308.93	164.73	308.93
10	167.82	292.66			164.76	296.45
11	165.21	292.66			162.17	296.58
13	165.12	292.82			161.96	279.52
14	162.64	275.85			159.36	279.49
17	162.61	275.83			159.35	267.84
18	165.07	271.51			161.95	267.87
20	165.06	271.59			161.81	250.56
21	167.67	254.21			164.43	250.60
23	167.84	254.24	164.50	238.08	164.50	238.08
25	180.51	241.55	176.97	237.54		
26	180.44	241.37	176.97	234.94		
28	197.89	238.73	194.43	234.87		
29	198.05	238.70	194.57	232.23		
32	202.06	236.25	205.80	232.29		
33	202.13	236.28	205.80	234.91		
35	219.58		223.17	234.99		
36	219.53		223.11	237.64		
38	232.01		235.40	238.11	235.40	238.11
40	232.08				235.40	250.24
41	234.71				237.99	250.27
43	234.78				238.01	267.76
44	237.18				240.62	267.77
47	237.17				240.55	279.39
48	234.68				237.93	279.32
50	234.77				238.07	296.78
51	234.14				235.45	296.74
53	231.95		235.40	308.97	235.40	308.97
55	219.50		223.10	309.27		
56	219.49		223.18	311.91		
58	201.91		205.73	312.19		
59	201.94		205.71	314.81		

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Glossary

Abhayagiri monastery
: Buddhist monastery in Sri Lanka with which the *Shailendras* entertained relations and from where monks built a branch on the *Ratu Boko* plateau in Central Java. *Gunadharma*, the legendary architect of Borobudur, if an actual historical personality, could have been one of these monks. The monastery had many relations with northwest India and the Gandhara region. As early as the third century, it was a centre for adherents of Vaipulya (Buddhist teachings such as the Avatamsaka sutra), which could perhaps explain Vaipulya influences in Java during the reign of the Shailendras. The Abhayagiri monastery may have been the source place from which *Amoghavajra* obtained many of the 500 tantric tests which he brought back to China.

abhayamudra
: Hand gesture indicating 'Fearless' or 'Dispelling Fear'.

Adi-Buddha
: The 'Primally Awakened one', the personification of the enlightenment that is shared by all *Buddhas*; also a synonym for the knowledge of the five Buddhas.

agung
: (Indonesian) high, that is, 'important'

Airlangga
: The son-in-law of King Dharmawangsa Teguh who, according to the 'Airlangga inscription', escaped the *mahapralaya* calamity of the *Shaka* year 928 (AD 1006 or AD 1016), and under the name of King Airlangga, supposedly moved to East Java and founded the kingdom Daha (Kediri). Also written as Erlangga.

Akshobhya
: One of the five *Buddhas* or 'Dhyani-Buddhas', usually shown in *bhumisparsha-mudra*, facing east.

Amoghavajra

Amoghavajra (AD 705–74) and Vajrabodhi
: (AD 671–741) from Kanchi in South India were two of the first propagators of *Esoteric Buddhism* in China. One tradition locates their first meeting in Java in AD 718, where Amoghavajra had accompanied his uncle on a trade mission, thereafter becoming the disciple of Vajrabodhi. Amoghavajra arrived at Loyang in China in AD 720. After the death of Vajrabodhi he went to Sri Lanka and finally in 746 returned to T'ang China, where one of his disciples was

Huiguo, the teacher of Kukai, the founder of Japanese *esoteric* Shingon Buddhism. Amoghavajra and Vajrabodhi translated many of the important tantric Buddhist texts into Chinese. Along with their contemporary, Shubhakarasimha, they laid the foundations of *Vajrayana* in East Asia.

anastylosis
: The technique of carefully fitting together loose building stones and parts of sculptures, lying scattered on the soil, and taking into account the details of their shape in order to achieve an authentic reconstruction. This technique has been applied with much success in Java over many decades of restoration and conservation of ancient monuments.

anda
: The 'egg', cupola or dome of a stupa.

andesite
: Volcanic stone composed largely of plagioclass, pyroxine, hornblende and smaller quantities of quartz.

andong
: Traditional Javanese vehicle, pulled by horse.

antefixes
: Ornaments made of terracotta or stone which were placed above the cornice, at the end of each row of tiles on a roof of a temple (chandi).

arupadhatu
: The Sphere of Formlessness, said to be represented by the three circular platforms and the crowning *stupa* of Borobudur.

Avalokiteshvara
: The great *bodhisattva* of compassion, also known as Lokeshvara, renowned for his tremendous powers of relieving suffering, which result from his vow to withhold enlightenment until all sentient beings are saved. In Chandi *Mendut*, he is depicted with the left hand in the position of *vitarkamudra* and the right hand in the position of *varamudra*.

babad
: (Indonesian) middle and modern Javanese, a kind of local history.

Badan Pemugaran Candi Borobudur
: Council for the Restoration of Chandi Borobudur.

BAPPENAS
: National Planning Board

bhumisparsha-mudra
: A sacred handpose and finger gesture meaning 'Calling the Earth to Witness'.

Bodhisattva
: *Buddha*-to-be; a being who is to become fully enlightened or to possess bodhi (Enlightenment).

Brahma
: Hindu God, one of the three gods Brahma, *Vishnu* and *Shiva* who form the Hindu Triad Trimurti.

Buddha
: The Historical Buddha, and also the title meaning 'having attained bodhi' for all who have achieved Ultimate Enlightenment and have entered nirvana (the attainment of perfect knowledge and the extinction of all desires).

Buddhahood
: *Buddha* as the universal essence pervading all worlds with one body, hence universal Buddhahood.

caldera
: Volcanic depression formed by intensive and often extreme explosive volcanic activity followed by the collapse of the volcano

candi
: see *chandi*

carbonation
: A carbon cycle process which produces bicarbonate.

carination
: The edge part of a stone-ware container.

cation
A positively charged ion; an ion that is attracted to the cathode in electrolysis.

cella
The internal space of a temple, often containing a statue.

CC
Consultative Committee for the Safeguarding of Borobudur

chakra
Wheel or circle; discus. Also written as cakra.

chakravala
An enclosed world system; particularly, the mountain ranges which define the limit of the world; also written sakravala.

chandi
(Indonesian) Javanese term for a Hindu-Buddhist temple or a pre-Islamic ruin dating from the eighth to fifteenth centuries AD, abbreviated as c. Also written *candi* or tjandi in older publications.

chelation
The process by which a chelate is formed. A chelate is (usually) an organometallic compound containing a bonded ring of atoms including a metal atom.

clinometer
An instrument used for estimating the height of a building or other feature using a vertical angle and a distance (determined by taping or pacing).

cohesion value
The cohesion value refers to the strength with which the particles out of which a geological material is composed are attached to one another.

conus resistance
A stone's resistance capacity to a bore

decalcification
Process resulting in the decrease or loss of calcite minerals.

desilicification
Process resulting in the decrease or loss of silicate minerals.

dharani
A kind of mantra (a spell, mystical formula, or sacred invocation) in *Mahayana* Buddhism.

dharmmachakra
Also known as the 'Wheel of the Law', representing the wheel of the *Buddha*'s teaching, with eight spokes symbolizing his eightfold path to enlightenment.

dharmachakramudra
A sacred handpose and finger gesture meaning 'Turning the Wheel of the Law', the handpose of *Shakyamuni* (Gautama *Buddha*) formed while preaching his First Sermon in the Deer Park of Varanasi (the present-day holy city of Benares, India).

dhyanamudra
A sacred handpose in which hands are placed in the lap overlapping one another, signifying immersion in meditation.

EC
Electrical conductivity (measure of total soluble salt content).

esoteric
(Of philosophical and religious doctrines) hidden or closed to non-initiates.

Esoteric Buddhism
A development of Mahayana Buddhism which teaches techniques of rapid Buddhist enlightenment by the assimilation of the self with Buddhist deities through ritual and meditative means that include uttering their characteristic mantras (spells, mystical formulas or sacred invocations), forming their signature *mudras*, and calling their presence into one's own body. Also known as mantrayana.

ferallitization
A soil-forming process causing chemical enrichment in iron and aluminum.

finial

Architectural ornament finishing off an apex or roof, gable; the topmost part of a tower, towercorner.

five Buddhas

Collective name for the core meditation *Buddhas* of the Diamond *Mandala*, which represents the Sphere of Diamond-like knowledge (Vajradhatu-mahamandala). The five are *Vairocana*, *Aksobhya*, Amitabha, Ratnasambhava and Amoghasiddhi, and are also known as Dhyani Buddhas, Tathagatas or *Jinas*. These five gnostic Buddhas preside over the four cardinal directions of the compass and the centre. As a whole they are known as the *Adi-Buddha*. Although the standard group comprises five Buddhas, six are thought to be represented at Borobudur. Borobudur, itself, is thought by some to represent the Diamond *Mandala*.

free CO_2/aggressive CO_2

One of the elements occurring in rain, runoff, drip.

friction resistance

Capacity to resist any condition.

Gandavyuha

The Gandavyuha, the last part of the Avatamsaka sutra, narrates the spiritual journey or pilgrimage of the young *Sudhana*, son of a rich merchant, who meets several *Bodhisattvas*, including *Maitreya*, the *Buddha* of the Future, *Shiva* and Samantabhadra. These are illustrated in a series of bas-reliefs at Borobudur, followed by panels based on the Bhadracari scripture, in which Sudhana pledges to follow the example of the *Bodhisattva Samantabhadra*. The Avatamsaka sutra and the Gandavyuha texts in their Chinese translations were influential in China, Japan and Central Asia at the end of the eighth century.

Ganesha

Elephant-headed Hindu god

geo-electric prospecting

Subsurface research conducted by measuring the electrical resistivity of the soil.

geo-electrical resistivity

Electrical measurements made between two poles placed at a certain distance, permitting the measurement and calculation of electrical properties (resistivity) of different soil and rock layers underground without drilling. In archaeology, such measurements may indicate the presence, dimensions and forms of foundations and other traces of ancient buildings, the surface parts of which have long since disappeared.

geophysical soundings

Physical measurements taken to determine the position and properties of different soil and rock layers underground without drilling. These include seismic surveys (making use of artificial vibrations penetrating the underground) and *geo-electrical resistivity* measurements.

graben

Depressed zone in the Earth's crust bordered by faults formed by geological movements and tectonic downwarping.

grain size analysis

To analyze size of granule in the soil research by using sifter.

Gunadharma

The legendary architect of Borobudur, about whom no historical evidence has been found. However, if an actual historical personality, he could have been a monk from the *Abhayagiri monastery* in Ceylon and the master builder responsible for the main third construction phase of Borobudur, almost certainly based on a *mandala* model.

gunung
(Indonesian) mountain, abbreviated as G.
Gupta Kingdom
A kingdom in Central India from which religious and artistic (the art of Sarnath) influences are found in Central Java.
guru
teacher, spiritual instructor
harmika
The crowning stone or cube atop a *stupa*, from which the central pinnacle rises.
Hinayana Buddhism
Buddhism of the 'Lesser Vehicle', the creed which professes to maintain the original doctrine preached by the historical *Buddha, Shakyamuni*, and rejects all teachings of the *Mahayana*. Today the only surviving school of the Hinayana is the *Theravada*, as followed in Sri Lanka, Burma, Thailand, Cambodia and Laos.
humification
Process of biological decomposition through the production of carbon, nitrogen and sulfur.
jaladvara
water spout
jataka
Stories of the *Buddha*'s previous lives.
JICA
Japan International Cooperation Agency
Jina
'Victor or conqueror', referring to a cosmic or heavenly *Buddha*, often also called Dhyani Buddha or Tathagatas. The Jina group is the central group in *Mahayana* Buddhism representing the Triratna, the 'Three Jewels', comprising the *Buddha* (the Enlightened Himself), the Dharma (Law) and the Sangha (the Order).
kala-makara
Motif representing 'devouring time' that frequently surmounts the door(s) and niche(s) of a temple (*chandi*). It is located at the apex of the niche and consists of a an upper kala-head connected with a pair of *makara*s below.
kamadhatu
The 'Sphere or World of Desire', and also the 'World of Earthly Life'.
karma
action, the law of universal cause and effect
Karmavibhangga
Ancient Indian text, or *Mahakarmavibhangga*, on the 'Law of Cause and Effect', showing blessings obtained by good deeds and the punishment of bad deeds. The teachings of the text are depicted in a series of bas-reliefs at Borobudur.
Kedu
Very fertile and extremely densely populated plain in Central Java around and north of Borobudur.
kendi
water pitcher
keris
(Javanese/Indonesian) dagger
kraton
Javanese word for the royal palace complex of a Javanese king; the political and cultural centre during the Hindu-Buddhist Javanese period, often also a major religious centre of the country.
kumbha
jar, water pitcher, water pot
lahar
Volcanic mudflow, an (international) geological term derived from the Indonesian word for volcanic mudflow.
Lakshmi
The Goddess of Wealth and Prosperity, consort of Vishnu.
Lalitavistara
The Lalitavistara scripture recounts the life of the historical *Buddha, Shakyamuni*,

omitting his parinirvana (His death and His entry into the nirvana), and ending with the 'First Sermon in the Deer Park of Varanasi' (Benares). Borobudur features a series of bas-reliefs illustrating the Lalitavistara. In Nepal it is considered one of the nine great Vaipulya sutras, possibly inspired by Gandhara and Vaipulya traditions from Northwest India that had their origin in the Balkh region. The Buddhist monks of Balkh inherited the convergence of Iranian (Zoroastrian), Hellenic (Gandhara) and Buddhist traditions.

laterization
: A soil-forming process occuring in warm and moist climates under broadleaf evergreen forests. Soils formed by laterization tend to be highly weathered with high iron and aluminum oxide content.

Lembaga Purbakala
: Archaeological Institute

lingga
: Phallic representation of *Shiva*, also written linga or lingam.

liquid limit (LL)
: The moisture content at which a soil changes from the liquid state to the plastic state.

maha
: (As a prefix) 'great, exalted'; for example, Mahadeva – the Great God, another name for *Shiva*; Mahaguru – the Great Teacher, also another name for Shiva; *Mahameru* – the exalted holy mountain *Meru*; *maharaja* – the great king. Also used in modern Indonesian, for example, mahasiswa – university student (higher or more advanced than siswa, student at a primary or secondary school).

Mahakarmavibhangga
: An ancient Indian text of the *Karmavibanga* on the 'Law of Cause and Effect', showing blessings obtained by good deeds and the punishment of bad deeds. The text is depicted in a series of bas-reliefs at Borobodur.

Mahameru
: Another term for *Sumeru*, holy Mount *Meru* in the Himalaya mountains.

mahasasana
: A ground plan in which the whole is divided into 225 equal squares.

mahapralaya
: A natural calamity of terrible proportions, the end or dissolution of a cycle of aeons.

maharaja
: great king

Mahayana Buddhism
: Buddhism of the 'Greater Vehicle', which emphasizes the importance of salvation and compassion for all, the correct understanding of reality, and the worship of enlightening beings who offer liberation either directly or by example. Mahayana is the form of Buddhism traditionally practiced in China, Japan, Korea, Central Asia, Tibet, Mongolia and Nepal from the first millennium onwards including in particular various *esoteric* Mahayana doctrines. Many teachers or founders of esoteric Mahayana Buddhism travelled along the maritime silk road between India, Sri Lanka, *Shrivijaya*, Central Java, China and Japan, including in particular *Amoghavajra* and Vajrabodhi and many Chinese pilgrims. Others like Shubhakarasimha followed the land road through Central Asia.

Maitreya
: The *Buddha* of the Future, also considered a *Bodhisattva*, who is said to reside in the Tushita Heaven awaiting his time to emanate on Earth.

makara
: A mythological acquatic beast, corresponding to the zodiacal Capricorn,

usually depicted as a composite of an elephant and a fish or crocodile. In architecture, the figure of the makara may be combined with a kala head (as a *kala-makara* ornament) or as a *jaladwara* (water spout).

mandala
: A 'circle' or sacred diagram; in *Esoteric Buddhism*, a schematic representation of the domain and inhabitants of a specific *Buddha*, *Bodhisattva* or other deity.

Manjushri
: The youthful *Bodhisattva* of knowledge, consulted by *Sudhana* during his pilgrimage as described in the *Gandhavyuha*.

Mataram
: Old Mataram: a designation used by the Hindu-Buddhist Central Javanese Kingdom of the eighth to tenth centuries; Mataram (or New Mataram): Islamic Central Javanese Kingdom from the fifteenth to the eighteenth centuries.

Mendut (Chandi)
: Buddhist temple which lies approximately a kilometre east of Borobudur. Together with Borobudur and C. Pawon, Chandi Mendut is thought by some to represent the Garbhadhatu *mandala*.

Medang Kemulan
: The legendary capital of Old *Mataram*, most probably located on the Lusi River to the east of Purwodadi and to the south of Mount Muria on the southern shore of a side branch of the former marine Semarang-Rembang Strait, now entirely silted up.

Meru
: The mythical mountain supporting the world, the sacred Mount Meru in the Himalaya mountain range.

mudra
: A sacred handpose and finger gesture.

MWHC
: maximum water holding capacity

Nalanda
: India's most illustrious monastic university of the late first millennium, where the *Mahayana* and *Esoteric Buddhism* was taught. It was patronized by Pala kings, who venerated the Buddhist goddess *Tara*, and with whom the *Shailendras* maintained close relations.

NEDECO
: Netherlands engineering consultants for the Borobudur project.

numerology
: The symbolic value of numbers and the expression of symbolism in art and architecture by the systematic use of numbers with a symbolic value. At Borobudur the use of numerology is based on an *esoteric, tantric* way of thinking and *tantric* practices, as exemplified in *tantric mandalas* and yantras (abstract diagrams or 'device's representing divine energies).

ogive
: bell-shaped plinth

OM
: organic materials formed through sedimentation. The remains of living organisms are gradually consolidated into rock over time.

paddle marks
: Decoration on pottery made by stamping a carved paddle on to the damp clay.

padi
: rice plantation

padmasana
: Lotus position, sitting with legs crossed right over left.

Pala Kingdom
: Kingdom in Bengal (*Vangala*) with which the *Shailendras* maintained close relations and where the *Nalanda* monastery was located.

Pawon (Chandi)
A small Buddhist temple located in the vicinity of Borobudur. Thought to belong to a single group that includes Borobudur and *Mendut*. The role of Chandi Pawon is still very unclear and the subject of conflicting theories.

PCS
Project Control System

pedicels
Small stalk-like structure in plants.

Pelita
Five Year Development Plan

percussion boring
Bore containing explosive powder that explodes when the bore hits an object.

pH
Value which represents the acidity or alkalinity of an aqueous solution.

photogrammetry
The use of photography for surveying.

piezometer
An instrument for measuring the magnitude or direction of pressure.

Plastic Limit (PL)
The moisture content of a soil at which it becomes too dry to be plastic.

Plasticity Index (IP)
A numerical measure of the plasticity of a soil. It corresponds to the range of moisture contents, expressed as the percentage of water by dry weight of soil, within which the soil has plastic properties. The Plasticity Index is calculated by subtracting the *Plastic Limit (PL)* from the *Liquid Limit (LL)*.

podzol
Soil with minerals leached from its surface layers into a lower stratum.

prabhamandala
Nimbus of light, halo of radiance that shines from behind the head of a deity.

pradakshina
Circumambulation (of a sanctuary) in clockwise direction, with one's right side turned respectfully to the centre of the sanctuary.

pradakshinapatha
Wide processional path around a sanctuary for performing *pradakshina* circumambulation.

pranapratistha
Consecration by 'infusing life' (prana) into a statue, temple or other religious object (eg. *stupa*), or by writing mantras (spells, mystical formulas or sacred invocations) on a slab of gold or stone and placing them in front of the object of veneration.

pura
Javano-Balinese temple, usually Hindu

pusaka
Heirloom, treasured by an individual, group or nation.

PW_t
Moisture content at sampling time.

pyroclastic flow
A deadly, scalding-hot, heavy volcanic cloud consisting of a mixture of boiling hot steam, sulphur, air, carbon dioxide, carbon monoxide, ash and rocks, flowing down the slopes of a volcano during some types of volcanic eruption and often spreading in all directions away from the volcano.

raja
King, also written as radja.

Ramayana
Ancient Hindu epic narrating the history of King Rama, his spouse Sita and the liberation, with the aid of the monkey King Sugriva and the monkey hero Hanuman, of Queen Sita from the villain King Ravana of Lanka. The story, illustrating the battle between 'good' and 'bad', remains popular throughout

Southeast Asia and is illustrated on a long series of bas-reliefs at the Hindu temple complex of Loro Jonggrang at Prambanan.

ratna
: Jewel, crowning a Hindu temple; also a pyramid-shaped stone ornament.

Ratu Boko
: Also known as *Kraton* Ratu Boko. An eighth to tenth century complex consisting of several terraces on a plateau to the south of Prambanan, on which are ruins of various buildings, now partly restored, gates, a cremation place and baths. The function of the complex is still uncertain, though it was known to house the Javanese branch of the Sri Lankan *Abhayagiri monastery*. It could have been either the main royal palace, a place where a king would retire to meditate, or a group of monasteries, or a combination of these.

resistivity
: See under *geo-electrical resistivity* and *specific resistivity*

rupadhatu
: The 'Phenomenal World'; also the 'World of Higher and Godly Life' and 'the World of the Heavens'.

sado
: Traditional cart pulled by two horses.

Sanjaya
: Hindu king and his successors of the Central Javanese Kingdom. They reigned during the seventh century and from the ninth to tenth centuries and later moved the capital and *kraton* to East Java.

sapu lidi
: A broom made from the ribs of palm leaves.

SEAMEO
: South East Asia Ministry of Education Organization

SF
: Safety Factor

Shailendra
: Dynasty of uncertain origin reigning in Central Java from the eighth to the ninth centuries, mainly adhering to the Buddhist (*Mahayana*) faith, including its vajrasana form. They reigned over *Shrivijaya* in Sumatra after they were driven out of Java. They maintained relations with the *Abhayagiri monastery* in Ceylon and with different parts of India, in particular with Bengal (Vangala) ruled by *Pala* kings, and with the *Nalanda* monastery situated in that state. Some authors presume that the *vajrayana* Buddhism of the Shailendras was derived from Southern India. They were the builders of Borobudur and many other Buddhist sanctuaries.

Shaiva
: Of the Hindu God *Shiva* – hence Shaivism, the Hindu religious system in which Shiva is the highest God, who manifests Himself in the world in different forms including Mahadeva and Maheshvara.

Shaka
: An era in Indian time reckoning; a dating system commonly used in Indonesian Hindu-Buddhist inscriptions. To convert a Shaka year into a year AD, 78 years must be added to the Shaka year date. Also written as Saka.

Shakyamuni
: Name taken by Siddharta Gautama, the historical *Buddha*, after he renounced worldly matters – the Manushi-Buddha or the Human Buddha. Often depicted with *dharmacakra-mudra*, facing all directions.

Shiva
: The third god of the Hindu trinity Trimurti, the Destroyer, and in *Tantrism* the Consciousness manifesting as the male principle in union with Shakti, the female principle. See also *Shaiva*.

Shri-Shaila
A mountain in Andhra Pradesh, South India, which was a centre of *Mahayana* Buddhism as well as of Shivaism, and from where according to some experts the *Shailendra* dynasty on Java originated and from which they derived their name.

Shrivijaya
(Mainly Buddhist) kingdom extending from Sumatra to the Malayan Peninsula, from the sixth to the tenth centuries and later. They were the main antagonists of the Central Javanese kingdom.

Shrivijayapuri
Ancient town in Andhra Pradesh, South India, and former capital of a local kingdom from which a descendant went to Sumatra and founded the Kingdom of *Shrivijaya*, possibly as early as in the fifth century.

soil mechanics
The science and technology to measure physical properties of soils and use these measurements to calculate the behaviour of soils when exposed to different loads or horizontal and vertical forces, and to predict the loads and forces under which permanent deformations and accidents and failures will occur.

soundings
see under *geophysical soundings*

SPAFA
SEAMEO Project on Archaeology and Fine Arts

specific resistivity
The resistance in ohms offered by a unit volume of a substance to the flow of electric current. Resistivity is the reciprocal of conductivity. A substance that has a high resistivity will have a low conductivity, and vice versa.

sticky point
A condition of consistence at which a soil barely fails to stick to a foreign object.

stupa
Buddhist reliquary or monument; a memorial of the *Buddha* that enshrines physical remains or, in *Esoteric Buddhism*, is synonymous with the body and mind of a Buddha; consists of a base surmounted by the hemispherical reliquary proper (*anda*), surmounted by a cubic pavilion (*harmika*) and pinnacle. Also known as caitya.

stupika
A little stupa; a dome-like or pot-shaped *finial.*

Sudhana
The son of a rich merchant whose spiritual journey is narrated and expressed in the series of bas-reliefs based on the *Gandavyuha* text of the last part of the Avatamsaka sutra.

sumeru
Name of the sacred mountain at the centre of our world-system, surmounted by the heavens in which the Gods reside; also a name of a sanctuary formed by a terraced pyramid crowned by a temple, constructed as a replica of the sacred Mount *Meru*.

tantra
Esoteric scripture or holy text which contains special religious teachings that are often available only to the initiated.

Tantrism or Tantric Buddhism
Esoteric Hindu or Buddhist doctrines; a developed form of Hinduism and *Mahayana* Buddhism in which magic or yogic rites and techniques play a major role; the system of physical and psychological exercises by which a person aims to achieve unison and fusion between one's human existence and the highest reality.

Tara
Buddhist goddess and *Bodhisattva*, whose name means 'the Saviouress'.

tempayan
large jar

temper
Material inclusions mixed into clay for pottery and brick making, in a form of sand granule, pottery powder, rice husk, etc.

Theravada Buddhism
A form of *Hinayana* Buddhism.

tuff
Sedimentary stones containing quartz materials.

tumpal
triangular-shaped motif

UNDP-TA
United Nations Development Program - Technical Assistance

Unfinished Buddha
An unfinished *Buddha* statue of unknown origin and uncertain meaning found during the last century in or near the main *cella* in the central *stupa* of the Borobudur Temple. The Unfinished Buddha has been the subject of many hypotheses and theories, but the most probable is that the statue was discarded in an unfinished state because of errors made by the sculptor.

unur
A high mound of earth (in Sundanese).

Vairocana
One of the five *Buddhas* or Dhyani-Buddhas, usually shown with *vitarkamudra*, facing all directions. He is the Lord of the centre. Vairocana is sometimes called Mahavairocana when representing the totality of all Buddhas. Vairocana is also an ancient Indian name for the sun.

vajra
Thunderbolt or diamond, symbol of indestructibility and of the unborn, imperishable truth that represents the Buddhist absolute.

Vajradhara
The 'holder of the *vajra*' and thus the 'indestructable', lord of mysteries, matter of all secrets, is an *esoteric* representation of *Adi-Buddha* and in this form is believed to reign over the Eastern-Quarter. Some Lamaists identified him as Vajradhara, while others identified him as Vajrasatwa.

Vajrapani
A *Bodhisattva* who acts a leader of *Esoteric Buddhist* practitioners and defender of Buddhist doctrine, sometimes described as a reformed 'demon' (*yaksa*). Traditionally Vajrapani is depicted carrying a *vajra*, thunderbolt, symbol of indestructibility and ultimate truth, in his right hand.

Vajrayana Buddhism
The *esoteric* or tantric form of *Mahayana* Buddhism, propagated in China by Vajrabodhi from Kanchi in South India, *Amoghavajra* from Central Asia, and their contemporary Shubhakarasimha from South India. Some authors suggest that the Vajrayana Buddhism of the *Shailendras* was derived from Southern India.

varamudra
Or varadamudra, a sacred handpose and finger gesture indicating the bestowal of boons the giving of blessings and benefits.

vihara
Buddhist monastery

Vishnu
The second God of the Trimurti, the Hindu triad of gods consisting of *Brahma*, Vishnu and *Shiva*.

vitarkamudra
A sacred handpose and finger gesture meaning 'augmentation'.

yasti
The 'mast' or pole that forms the central shaft of a *stupa.*

yoga tantra
'Tantra of Meditative Union'; a Buddhist classification of tantric texts that prescribe visualization of, and meditative union with, a chosen deity.

Index

One of the most successful restoration projects of the twentieth century.

With its 123-metre axis and central dome rising 35 metres above its base, Indonesia's Borobudur Temple stands proud amidst the high mountain ranges of the island of Java. A symbol of extraordinary cultural diversity and religious tolerance, and a tangible witness to a glorious past, Borobudur is now one of the most visited monuments in Indonesia. But the path to restored glory has been far from easy.

The Restoration of Borobudur is inspired by, and honours the legacy of, Professor Soekmono, Indonesia's first archaeologist and project manager of the Borobudur restoration project. Following the professor's death in 1997, historians, researchers and archaeologists began to document one of the most important restoration projects of the last century.

Divided into eight chapters, the book traces the temple's history from its uncertain beginnings and eventual rediscovery in 1814, to the various excavations and geological studies that culminated in its successful restoration in 1983. It focuses particular attention on the decade of restoration that included some twenty-seven countries and began in earnest with the UNESCO campaign for its restoration in 1972. It covers the various aspects of the process, including the long and painstaking task of logging the position of the stones; the studies that revealed the underlying sources of decay; and the important archaeological finds that provided clues to the temple's spiritual past. Many of the original drawings and photographs taken from the restoration project archives serve to illustrate the book throughout.

It also explores some of the great mysteries and spiritual traditions surrounding Borobudur. Most notably, the question of its position: why did the ancient Javanese choose this particular site? Why did they go to such Herculean lengths to move 80,000 cubic metres of soil when other sites could have been used?

This book draws to a conclusion many years of research and writing that capture the successful restoration of Borobudur – a monument of architectural brilliance.

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