FIRST UNESCO REGIONAL TRAINING PROGRAMME IN MINING GEOLOGY

KENYA
Report of the
First UNESCO
Regional Training Programme
in Mining Geology
16 September — 14 November 1981
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synopsis</td>
<td>1</td>
</tr>
<tr>
<td><strong>Part I: Geology and ore deposits of the Fluorite Mines Area, Kerio Valley, Rift Valley Province</strong></td>
<td>2</td>
</tr>
<tr>
<td>Geographic setting</td>
<td>4</td>
</tr>
<tr>
<td>- Location</td>
<td>4</td>
</tr>
<tr>
<td>- Accessibility</td>
<td>4</td>
</tr>
<tr>
<td>- Communications</td>
<td>4</td>
</tr>
<tr>
<td>- Climate and Vegetation</td>
<td>4</td>
</tr>
<tr>
<td>History of Mining</td>
<td>4</td>
</tr>
<tr>
<td>Previous Geological Studies</td>
<td>8</td>
</tr>
<tr>
<td>Geology of the Kerio Valley</td>
<td>10</td>
</tr>
<tr>
<td>- Lithology</td>
<td>10</td>
</tr>
<tr>
<td>- Structure</td>
<td>12</td>
</tr>
<tr>
<td>- Geological History</td>
<td>12</td>
</tr>
<tr>
<td>- The Orebodies</td>
<td>16</td>
</tr>
<tr>
<td>Kimwarer Orebody</td>
<td>16</td>
</tr>
<tr>
<td>Kamnaon Orebody</td>
<td>17</td>
</tr>
<tr>
<td>Choff Orebody</td>
<td>17</td>
</tr>
<tr>
<td>Paragenesis</td>
<td>17</td>
</tr>
<tr>
<td><strong>Part II: Kibongwa Gold Mine, East of Kisumu</strong></td>
<td>22</td>
</tr>
<tr>
<td>Location</td>
<td>22</td>
</tr>
<tr>
<td>Mining History</td>
<td>22</td>
</tr>
<tr>
<td>Geology</td>
<td>25</td>
</tr>
<tr>
<td>Workings</td>
<td>25</td>
</tr>
<tr>
<td>Geochemical Work</td>
<td>25</td>
</tr>
<tr>
<td>References</td>
<td>28</td>
</tr>
<tr>
<td>Appendix I: Geological interpretation of the Southern Kerio Valley, Kenya</td>
<td>29</td>
</tr>
<tr>
<td>Appendix II: 1. Planning of the Programme</td>
<td>33</td>
</tr>
<tr>
<td>2. Implementation of the Programme</td>
<td>34</td>
</tr>
<tr>
<td>Appendix III: 1. Programme Instructors</td>
<td>37</td>
</tr>
<tr>
<td>2. UNESCO Secretariat</td>
<td>37</td>
</tr>
<tr>
<td>3. Publication Consultants</td>
<td>37</td>
</tr>
<tr>
<td>4. Participants</td>
<td>39</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1. Participants learning to 3-point with plane table and open sight alidade. This is one of the half-day exercises done in the camp area on Saturdays. ............. 3

Figure 2. Participants and instructors gathered beside a triangulation flag reviewing the plane table map of the deposit made by one of the parties ............................................................... 5

Figure 3. Participants reviewing the mapping done at the Kimwarer No. 1 fluorite deposit watch while a structural measurement is made by one of the geologists. Massive outcrops are mostly fluorite ore. The concentration plant is visible in the background ............................................................. 7

Figure 4. View of the development at the three southern fluorite deposits. The prominent benched hill on the left is the Kimwarer No. 1 deposit that is now inactive but contains a large reserve of fluorite. The white open cut in the middle is on the Kimwarer No. 2 deposit currently being mined, and the smaller cut at the extreme right is on the inactive Kimwarer No. 3 deposit ................................................................. 9

Figure 5. Participants examining the violently erupting hot springs on the shore of Lake Bogoria during the mid-programme recreational break. White patches on the lake are formed by thousands of flamingoes that congregate near the shore ........................................... 11

Figure 6. Geological map of Kimwarer area ................................................................. 13

Figure 7. Geological cross section Kimwarer No. 2 area .............................................. 15

Figure 8. Geological map of Kamnaon area ................................................................. 18

Figure 9. Geological cross section, Kamnaon No. 1 ..................................................... 19

Figure 10. Two of the participants examining one of the drifts in the Kibongwa gold mine that was mapped by the group ......................................................... 21

Figure 11. Kibongwa gold mine, Kenya ......................................................................... 23

Figure 12. Kibongwa gold mine, Kenya ......................................................................... 24

Figure 13. Participants looking down into the large Menengai crater from its rim during the lunch stop on the trip from Kisumu back to Nairobi. The dark mass in the crater is one of many spectacular lava flows forming the floor of the crater and extending northward through a breach in the crater wall ......................................................... 27
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Production of fluorspar from the Kerio Valley deposits</td>
<td>6</td>
</tr>
<tr>
<td>Table 2</td>
<td>Kibongwa mine — production figures</td>
<td>22</td>
</tr>
</tbody>
</table>
Report of the First UNESCO Regional Training Programme in Mining Geology

SYNOPSIS

The First Regional Training Programme in Mining Geology, organized by UNESCO and funded by the Norwegian Government, was held in Kenya from 16 September to 14 November 1981. The programme was modelled after the very successful series of CENTO training programmes in Mining Geology. Sixteen young graduate geologists and mining engineers from 11 English-speaking African countries attended the programme.

The objective of this programme was to train graduate geoscientists in the multiple techniques needed to map and evaluate mineral deposits through progressive instruction and practice at known mineral deposits.

The first part of the training took place in the open cast mines of the Kenya Fluorspar Company Ltd. in the Kerio Valley, Rift Valley Province. The trainees produced maps and sections on a scale of 1:1000 for the fluorite deposits, using plane-table survey methods. Optical alidades and stadia rods were used to obtain the necessary vertical and horizontal controls. Page size reductions of these maps are included in the report. The second part of the training, consisting of instruction in underground mapping and geochemical exploration, was conducted in the Kibongwa Gold mine near Kisumu.

The report is prepared from the geological work carried out during this UNESCO programme and provides:

a) A permanent record of geological information gathered by the participants.
b) An attempt to analyse the information.
c) A geological interpretation of the Landsat Scene of the Southern Kerio Valley (Appendix I)
d) A summary of the conduct of the training programme (Appendix II)

The organisation of the first UNESCO Regional programme in Mining Geology was the result of the collaborative efforts of many individuals from many organisations. It was funded by the Norwegian Government through the agency of UNESCO, via the Regional Office for Science & Technology for Africa (ROSTA). Consultations were held with the Department of Mines and Geology, the Regional Remote Sensing Centre, and the Geology Department of the University of Nairobi. Special mention must be made of the Kenya Fluorspar Company which not only permitted the training programme to be held on some of the fluorite deposits in the Kerio Valley, but generously offered the facilities of the hospital building, the club for recreation, a furnished staff house and a rondavel.
Part I:

Geology and Ore Deposits of the Fluorite Mines Area, Kerio Valley, Rift Valley Province

INTRODUCTION:

This report resulted from the First Regional UNESCO Training programme in Mining Geology held at the Kenya Fluorspar Company mines during the period 17 September to 22 October 1981. It is based on the work of the trainee participants and the instructors.

There were 16 participants from 11 different countries (Ethiopia, Ghana, Kenya, Lesotho, Malawi, Nigeria, Sierra Leone, Somalia, Tanzania, Uganda and Zambia).

The three instructors were Dr. Edgar H. Bailey of the United States Geological Survey, Dr. John W. Barnes, a senior lecturer in Economic Geology from the University of Swansea (UK) and Dr. Matthew P. Nackowski, professor of Mining and Geological Engineering, University of Utah, USA. Mr. Robert Missotten was camp manager.

During the field work which lasted five weeks in the Kerio Valley, topographical and geological maps were prepared of the Kimwarer and Kanmaon ore bodies, using plane table, optical alidade and stadia rods. The fieldwork was started at each site by establishing a base line with a steel tape whose ends were tied later to the company’s established bench mark. From these base lines, mapping was extended to other secondary and tertiary resections and the geological observations added. In the afternoons and evenings reviews and discussions were held on the geology, structure and mineralisation of the ore bodies. Also exercises were carried out and lectures held which dealt with various aspects of mining geology such as ore-reserve calculations.

The Kerio Valley fluorite deposit is one of the major suppliers of acid grade fluorspar to the world market. To date it has produced more than half a million tons of acid grade, ( + 97% Ca F₂ mostly within the last seven years) and about 175,500 tons of metallurgical grade, ( + 75% Ca F₂ mostly in the year 1975 but later abandoned production). The fluorite deposits are of hydrothermal origin and of Tertiary age. They occur as replacement bodies of variable size in Precambrian calcareous bands and in fault and shear breccias, generally at an overall average grade of about 40% CaF₂. A wholly owned Kenya Government company, the Kenya Fluorspar Company Limited (KFC), is currently engaged in the mining and processing of the acid grade fluorspar for export (through the port of Mombasa after about 1,000 km of road and rail haulage). The Company operates a modern mining and processing plant capable of producing about 100,000 tons of acid grade fluorspar per annum.
Figure 1: Participants learning to 3-point with plane table and open sight alidade. This is one of the half-day exercises done in the camp area on Saturdays.
GEOGRAPHICAL SETTING

LOCATION

The Kenya Fluorspar Company Mines are situated at the head of the Kerio Valley in the Elgeyo Marakwet district of the Rift Valley Province. The area may be considered to be bounded by 0° 19' N and 0° 22' N latitudes and 35° 35' E and 35° 38' E longitudes. The Kimwarer River, a tributary of the Kerio River, originates in the escarpment headland to the south and flows past the mine site.

ACCESSIBILITY

Access to the mine site from the capital city of Nairobi is via a tarmac road to the town of Eldoret, and thence to Nyaru. An all weather road maintained by the mining company descends into the Kerio Valley, a distance of about 24 km.

The main railway line to Uganda passes through the station of Kaptagat, the nearest railhead, and provides the major outlet to Mombasa. An airstrip provides a rapid means of air charter transport.

COMMUNICATIONS

The mines area is served by a three phase power connection with the national grid, and also by telephone and telex links with the outside world.

CLIMATE AND VEGETATION

The climate and vegetation of the mine area are controlled by the terrain which, as elsewhere in central Kenya, is affected by the Rift tectonics. The present Rift morphology evolved from the last three principal pulses or uplifts of central Kenya, accompanied by the concomitant downwarps of the Rift axial zone, voluminous flooding by eruptives, and followed by spectacular fault displacements. All these events occurred within the Tertiary period. The Elgeyo Escarpment which reaches about 2700 metres at Nyaru has a temperate climate and lush vegetation, while the mines area below in the valley, at about 1350 metres, is rather warm and semi-arid with its stunted thorny bush, characteristic of most of the axial Rift zones of Kenya.

HISTORY OF MINING

A gemstone prospector by the name of Al Amin first drew attention to the fluorite deposits of the Kerio Valley in the mistaken belief that he had struck a lode of purple coloured gemstones. His samples were identified as fluorite. On realisation that a ready market existed for this mineral commodity at the Bamburi cement works, he commenced a small scale, low capital, mining operation on the high grade ores of Kamnaon in 1967. A peak production of about 400 tons per month was reported, and this was transported up the precipitous Elgeyo Escarpment using pack animals.

Meanwhile several geologists and mining engineers had made appraisals of the Kerio deposits and reported substantial tonnages at Kimwarer and Choff.
Figure 2: Participants and instructors gathered beside a triangulation flag reviewing the plane table map of the deposit made by one of the parties.
AI Amin’s hand mining company was bought out by a new mining venture called the Fluorspar Company of Kenya (FCK) in 1971. The majority equity of 51% was owned by the Kenya Government through the ICDC (Industrial and Commercial Development Corporation) and the remaining 49% was equally shared by the Continental Ore Corporation Ltd. (managing partners) and the Bamburi Portland Cement Company Ltd.

The FCK began the production of metallurgical grade fluorspar from the Kamnaon and Choff deposits and established a crushing and gravity separation (jigging) plant in 1971. To haul the mineral product up the Elgeyo Scarp, to the nearest railhead at Kaptagat, road construction began. This road now winds up over an altitude of about 1350 metres in a distance of about 24 kilometres.

Four diamond drilling exploration programmes began on the Kimwarer deposits, and it was established that there were fluorite deposits which could support large-scale production of acid grade material. The International Mineral and Chemical Corporation (new partners of FCK) carried out the beneficiation research and, through a contract with the Denver Equipment Company, a concentrator plant able to produce 100,000 tons per year was erected and brought into production by 1975.

However, it is thought that, in operating both the metallurgical and acid grade production plants, the company began to experience a series of serious technical, managerial, financial and stringent market-created problems, which culminated in the company being put into receivership. In May 1979 the Government of Kenya acquired full control through the purchase of the remaining assets of the FCK and launched a new company called the Kenya Fluorspar Company Ltd. (KFC) in September 1979.

The company’s immediate future now appears bright and at the present rate of acid grade production of some 100,000 tons per year, the mines have a life span in excess of 10 years (see table 1 - official figures of fluorspar production)

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation/Company</th>
<th>Acid-grade(1)</th>
<th>Metallurgical-grade(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967-70</td>
<td>Hand-mining</td>
<td>—</td>
<td>3,400*</td>
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<tr>
<td>1971</td>
<td>FCK</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1972</td>
<td>FCK</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1973</td>
<td>FCK</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1974</td>
<td>FCK</td>
<td>54,644</td>
<td>—</td>
</tr>
<tr>
<td>1975</td>
<td>FCK</td>
<td>85,365</td>
<td>172,100*</td>
</tr>
<tr>
<td>1976</td>
<td>FCK</td>
<td>103,356</td>
<td>—</td>
</tr>
<tr>
<td>1977</td>
<td>FCK</td>
<td>72,695</td>
<td>—</td>
</tr>
<tr>
<td>1978</td>
<td>FCK &amp; KFC(3)</td>
<td>93,377</td>
<td>—</td>
</tr>
<tr>
<td>1979</td>
<td>KFC</td>
<td>96,025</td>
<td>—</td>
</tr>
</tbody>
</table>

Total 175,500 tons

(1) Grade + 97% CaF₂
(2) Grade + 75% CaF₂
(3) KFC commenced operation on 1st September 1979.
(*) Annual production data unreliable.
Figure 3: Participants reviewing the mapping done at the Kimwarer No. 1 fluorite deposit while a structural measurement is made by one of the geologists. Massive outcrops are mostly fluorite ore. The concentration plant is visible in the background.
PREVIOUS GEOLOGICAL STUDIES

Walsh, in the official reconnaissance geological report of the Eldama Ravine area, has cited 12 references on the general geology by various scientists visiting Kenya. The dates of publication range from 1896 to 1956. Most of the comments deal with the spectacular faulted nature of the Elgeyo Escarpment and its displacement which exceeds 1.3 kilometres.

Walsh's report on the area was revised by the East African Geological Research Unit (EAGRU) under the direction of Prof. B. C. King. Several theses have been written on the area but only the maps are available in Kenya.

The relevant EAGRU map differs in two ways from that of J. Walsh:

i. A single fault, buried below the Kerio sediments is shown to be responsible for the Elgeyo Escarpment. Walsh mapped several branching and coalescing faults. Also Walsh's east-west faults are not mapped.

ii. The Precambrian rocks, as mapped by S.J. Lippard, are mostly hornblende-biotite gneisses with discontinuous lenses of marbles and quartzo-feldspathic gneisses. Walsh's reconnaissance map shows these as continuous bands.

Several unpublished reports by I.S. Loupekine, J.E.P. Halse, N. Segura and S.H. Rhentulla, among others, exist in the archives of the company, but these are now outdated.

Two publications on the Kerio Valley fluorite deposits resulted from two Masters' theses by Í.O. Nyambok and S.J. Gaciri. The first of these describes the general geology and the structural control exerted by the fault and shear breccias on the formation of the fluorite deposits. The second deals with the paragenesis of the mineral deposits and tries to elucidate the relations between colour, temperature and relative age of crystallisation. Owing to the repeated pulsed nature of the mineralisation occurring over an extended period in Tertiary times, the picture is not clear.
Figure 4: View of the development at the three southern fluorite deposits. The prominent benched hill on the left is the Kimwarer No. 1 deposit that is now inactive but contains a large reserve of fluorite. The white open cut in the middle is on the Kimwarer No. 2 deposit, currently being mined, and the smaller cut at the extreme right is on the inactive Kimwarer No. 3 deposit.
GEOLOGY OF THE KERIO VALLEY

The Kerio Valley is an elongate, cone-shaped Tertiary tectonic graben within the Gregory Rift of Kenya. Its narrow southern tip straddles the highest culmination of the Kenyan dome of uplift, volcanicity and faulting. Towards the north, it fans out into a broad, shallow, alluvial-filled depression that contains the Lake Turkana inland drainage basin.

The western wall of the rift, standing at about 2700 metres in the south, is represented by the Elgeyo Escarpment. To the east lies a complex igneous horst which forms the Tugen Hills (average altitude 2500 metres) and whose valley floor stands at about 1300 metres in the south, and slopes northwards to Lake Turkana.

The Kerio Valley is unique in that it forms a window in the greatest pile of the rift volcanics, to reveal the foundation metamorphic rocks. These rocks have an important bearing on the concept of global tectonics. These foundation metamorphic rocks are mineralised by the Tertiary hydrothermal fluids directly related to the genesis of the Rift Valley.

LITHOLOGY

The crystalline, reworked, metamorphic rocks are seen as outcrops in the foothills of the Elgeyo Escarpment. These are assigned to the Basement System of the Upper Precambrian age; they were affected by the last orogenic cycle, termed the Mozambiquian event.

The bulk of the crystalline rocks are pelitic gneisses, that is hornblende, and hornblende-biotite gneisses. There are numerous intercalations, generally narrow and lenticular, of calcareous and psammitic gneisses such as marbles and quartz-feldspar granulites and quartzites.

The hornblende and hornblende-biotite gneisses are generally dark, coarse grained and show poorly developed foliation. There is a tendency in these rocks for the light components of feldspar and quartz to segregate from the dark minerals such as hornblende and biotite. It is apparent, on crushing the dark grains, that the biotite has formed from hornblende, which probably formed from pyroxenes.

The quartz-feldspar gneisses and quartzites are generally light in colour to almost pure white, but are frequently iron stained to reds and browns. The grains are coarse and show poor foliation, the texture frequently approaching that of granulites. There are almost always a few flakes of mica between the grains of quartz. Only very minor amounts of crystalline limestone are encountered in the southern part of the mines area, but further north they become more pronounced. When seen, they range in colour from pale white and pink to mottled browns and black. They are generally fine grained, but recrystallization results in granular textures. These Precambrian metamorphic rocks are overlain by Tertiary sediments, which are conglomeratic at the base, passing upward into finer members, through
Figure 5: Participants examining the violently erupting hot springs on the shore of Lake Bogoria during the mid-programme recreational break. White patches on the lake are due to thousands of flamingoes that congregate near the shore.
grits to sands and silts. The latter are generally well lithified, creamy to pale buff in colour, and obviously derived from the older metamorphic rocks. However, in the upper members of the fine grained sediments, some tuffaceous material is also present. These sediments in turn are overlain by Tertiary lavas and pyroclastics. The Elgeyo volcanic sequence passes underneath the Tugen Hills and is composed of a similar and correlated sequence of basalts, phonolites and trachytes.

**STRUCTURE**

The structure of the Precambrian rocks is essentially simple. That is, rocks strike generally north-northwest and dip steeply to the east, commonly over 60°. However, to the south, the strike swings in a gentle arc to the northeast.

On a meso scale, the structure is seen to be composed of plunging antiforms and synforms. If it is assumed that the structure is consequent to the deformation and homologous on all scales, then it may be presumed that the inlier of the Precambrian rocks represents part of a dome.

The Tertiary structure consists of updoming and downwarping of the rift zone, flooding by volcanic debris and lavas, and faulting. Faulting in the Kerio is seen in the boundary fault, or group of faults, on the Elgeyo Escarpment.

Essentially the Tertiary faults almost always trend north-south. However, in the vicinity of the Kerio, a few east-west trending faults have been mapped. The north-south faults on the Elgeyo Escarpment all dip to the east and one group forms a synthetic step structure.

**GEOLOGICAL HISTORY**

Briefly the geological history can be summarised as follows:

1. The formation of Precambrian metamorphic rocks from sediments folded under stress.

2. Between the Precambrian and the time before the Miocene, successive uplifts and denudation of the metamorphic rocks resulted in the formation of a sub-Miocene peneplane.

3. Sub-Miocene domal uplift and axial downwarp of the rift region with flooding by fissure eruptions was followed by faulting. This phase is represented by the Elgeyo Volcanics and the Elgeyo fault scarps. The Kimwarer sediments represent a pocket formed before the eruption of the volcanics.

4. The above cycle was repeated at least twice, represented by Pliocene faulting and Pleistocene grid faulting, associated with increasing volcanicity which was confined to the narrower grabens formed with each cycle.

The fluorite mineralisation presumably commenced towards the waning phase of the Elgeyo volcanic period as the Elgeyo Basalts mineralised, and continued with later cycles. The dominant mode of mineralisation is caused by replacement of limestone to form fluorite, but fracture and fissure filling is also present.
Figure 6:
GEOLOGICAL MAP OF KIMWARER AREA
KENYA FLUORSPAR CO.LTD., KERIO VALLEY

EXPLANATION

TOPOGRAPHY & GEOLOGY

Logo: Kenya Flouorspar Co. Ltd.

Topo. & Geology by participants in First UNESCO Regional Programme in Mining Geology

Topo. & Geology by participants in First UNESCO Regional Programme in Mining Geology

- Triangulation point showing altitude line
- Secondary triangulation point
- Kenya Fluorspar Company triangulation point
- Contour of five metres interval
- Road
- Road abandoned
- Track
- River
- Determined stream
- Top or cut
- Base of cut
- Digg
- Waste (rubble)
- Building

GEOLOGIC SYMBOLS

- Alluvium
- Gullies
- Dyke
- Fluorescent rock
- Granite, hornblende biotite
- Quartz-Feldspar rock
- Marble
- Mixed rock/Marble and Quartz-Feldspar rock
- Contact, dated where concealed
- Fault, dated where concealed
- Strike and dip
- Foliation with plunge
- Tunnel showing dip
- Tunnel vertical
- Lineation with plunge
Figure 7:

GEOLOGICAL CROSS SECTION KIMWARER NO. 2 AREA
SECTION ALONG LINE A - A
KENYA FLUORSPAR COMPANY LTD.
KERIO VALLEY - KENYA
SAID ALJABRI (KENYA) - UMARU WURIE (SIERRA LEONE) - R.S. MSHALI (MALAWI) - K.S. KETE (GHANA)
THE OREBODIES

The fluorite ore bodies occur in a tract of country some ten kilometres long and about three kilometres wide, lying at the foot of the Elgeyo escarpment, and stretch from Kimwarer ridge to Muskut. That the mineralisation (introduction of fluorite, silica, iron ores etc.) was fault controlled is indicated by its Tertiary age, the parallelism of the line of ore deposits, and the location of the source in the waning phase of an igneous cycle. However, the localisation of conformable deposits suggests that replacement of lenticular limestone bodies occurred.

It has been suggested that fracture and fissure filling may have taken place during the phase of mineralisation, but a more detailed study of the east-west aligned Choff deposits is required to substantiate this theory.

The diamond drilling programme has shown that the deposits narrow with depth, and the maximum depth at which fluorite was encountered was at Cheberen (50 metres). The highest stratigraphic formation, which shows mineralisation of fluorite, is found in the Elgeyo Basanites, overlying the Kimwarer sediments.

Thus the fluorite deposits taper with depth and appear to have been formed by metasomatic replacement of marble, and hydrothermal alteration of fault and fissure breccias under an impervious cover of early Tertiary lavas.

KIMWARER OREBODY

The Kimwarer orebody is by far the most important and the largest, containing some 3 million proven tons of fluorite, with a similar probable tonnage (1981). It has produced the bulk of the acid grade concentrate for export to date. It is the southernmost body and stretches north across five hillocks over a distance of more than a kilometre.

It consists of 3 lenses, 10 metres, 15 metres and 50 metres thick, with the 50 metre lens occurring in the southernmost hillock called Cheberen. However, beyond this hillock only one vein persists for the remainder of the distance. The orebodies dip at about 50° to 60° to the east in conformity with the structure of the host rock.

The orebodies are tabular near the surface but taper to a lensoid shape at depth. They consist of buff to brownish-yellow coloured fluorite, intimately mixed with silica and iron ores. The texture is granular and the rock as a whole is resistant to weathering. From a study of the aerial photograph it can be seen, that the fluorite deposits occur in areas of positive relief.

Figure 6 shows the maps prepared in the field while figure 7 is a cross section.

During the course of mapping, a footwall fault was discovered by Dr. E. Bailey which stretches from hills 1 to 3 and limits the mineralisation in depth. Minor structures associated with the faults are fault striae, gangue and slivers of displaced rocks. The fault dips at a high angle and its trace appears as a sinuous line on the
map. The section illustrates the mineralisation of this area.

In other places, the footwall rock is commonly hornblende biotite gneiss, rarely unreplaced carbonate and contacts are sharp. The hanging wall contact is diffuse with increasing content of silica which finally gives way to pegmatised quartz-feldspar gneisses.

KAMNAON OREBODY

This is the northernmost orebody, and was worked during the initial stages of mining. It is a high grade ore-body occurring in brecciated zones and marbles, striking northwest and dipping to the west at a steep angle.

The orebody is formed of masses of fluoritized marbles and breccias of which the principal one has a strike length of about half a kilometre and an aggregate width of about 100 metres. Several veins cluster together, ranging in thickness from 5 to 15 metres.

The ore is typically granular, fine grained and friable, ranging in colour from grey brown or black to purple. The gangue includes silica, limonite, calcite and graphite.

Parts of the orebody which are wedged between unreplaced marbles show thinning. Elsewhere kaolinisation of feldspar is a notable feature. The footwall, which has been replaced completely, is biotite gneiss passing in depth to quartz-feldspar gneiss, while the hanging wall tends to be hornblende-biotite gneiss.

About two-thirds of the 1972 estimate of about 910,000 tons has been mined. The geological map and the section prepared by the group are shown in figures 8 and 9.

CHOFF OREBODY

At Choff, a series of small but high grade deposits occur in an east-west line of fault breccias. Individual deposits are some 100-200 metres in length and 10-20 metres in width. A reserve estimate (1980) stands at about 500,000 tons.

PARAGENESIS

On a mega-scale it is clear that the largest deposit with the most extensive and complete replacement of marble, together with mineralisation of breccia to a minor extent, occurs at Kimwarer. Here several parallel deposits are developed. Northwards, the deposits become smaller, narrower and unreplaced marbles become dominant. It has been suggested that the source material of mineralisation may have originated somewhere south of Kimwarer, in the highest culmination of the domal uplift, and migrated along the fault zone to be ultimately fixed in the marbles by chemical reaction.

It is also noted that the fluorite bodies are generally paler in colour in the south and progressively darker northwards. The friable fluorite occurs in the north while the more massive bodies which are more resistant to erosion occur in the south. This
Figure 8: GEOLOGICAL MAP OF KAMNAON AREA
KENYA FLUORSPAR CO., LTD. KERI VALLEY, OCT. 1981

Topography and Geology by First UNESCO Regional Programme in Mining Geology

EXPLANATION

Lithologic Symbols
- Recent
  - Alluvium
  - Colluvium

Geologic Symbols
- Tertiary
  - Fluorite Rock
  - Green Hornblende, Diotlite, Graphite
- Pre-Cambrian
  - Quartz Feldspar Rock
  - Marble
- Geologic contact showing dip above, plunge below
  - Fault, showing dip
  - Fault plane, showing dip
  - Fault, vertical
  - Joint, showing dip
  - Lineation
  - Healed a-k fold

Cartographic Symbols
- Gully
- Triangulation point showing altitude (m)
- Secondary triangulation point
- Point at known altitude
- K.F.C. triangulation point
- Contour line Vertical interval 5m
- Road / abandoned road
- Trail
- Building / Concrete slab
- River
- Fence
- Top of cut/Bottom of cut
- Dump
GEOLOGICAL CROSS SECTION, KAMNAON NO1, KENYA FLUORSPAR CO. LTD.

GEOLGY AND TOPOGRAPHY BY:
D.P.M. HADOTO, M.B. MANSARAY, LT. MOLAPO, NJ. VIBETTI.
Friable nature of the fluorite suggests the presence of unreplaced marble or some other reactive matrix attacked by the agents of erosion.

The occurrence of darker fluorite in joints, fractures and geodes suggests the late arrival of mineralising fluids, relative to the older material. These field observations suggest the order of mineralisation.

No additional quantitative data is available on silica, limonite, calcite or feldspar of low temperatures. However, the empirical observations appear to be in conformity with the field relations. It is obvious that mineralisation occurred in more than one pulse, judging from the observation of repeated layered structures, and it continued outwards for an extended period in proportion to the loss of heat from a sub-surface magmatic body. The detailed nature of the paragenesis needs more careful geochemical, mineralogical and geological study. For instance, it would be significant if the source or magmatic body were located in the immediate vicinity, or if it could be established whether or not the marble bodies buried below the Elgeyo alkali basalts are mineralised.
Figure 10: Two of the participants examining one of the drifts in the Kibongwa gold mine that was mapped by the group.
Part II:

Kibongwa Gold Mine, East of Kisumu

The instruction in underground mapping and geochemical exploration was conducted during a period of 9 days at the Kibongwa Gold Mine and its vicinity. This small underground gold mine, formerly called the Equatorial mine, is one of several small mines in the Kibigori mining area. The mine as of 1957, was described in report number 50 of the Geological Survey of Kenya, “Geology of the Kericho Area” by F.W. Binge, and further described in an unpublished report by P.C. Benedict, on file in the Geological Survey. The limited work contributed to a geological map showing the extent of open workings in 1981 (figure 11).

LOCATION

The Kibongwa Gold Mine lies about 7 kilometres north-northwest of Kibigori, which in turn is 33 kilometres east of Kisumu on the Kisumu-Muhoroni tarred road. It is near the west end of the Kibigori mineralised area which, further east on the same structure, contains the multiple ore deposits of the small Rock Corry Mine. The deposits lie in low foothills of the Kibigori scarp just above the alluvial filled valley of the Nyando River in an area of moderately deep soil, poor rock exposure, and dense vegetative cover. Gold lodes were first recognised here in 1945 and the Rock Corry (Kibigori) Gold Mine was worked from 1949-1955 yielding in that period 15,161.87 oz of gold from 16,990 tons of ore. Recovery was made by table concentration followed by flotation and cyanidation in a mill erected about 6 kilometres east of the mine.

MINING HISTORY

The Kibongwa claims were first registered in 1948 by E.N. Mantheakis who apparently did only a limited amount of prospecting. In 1951 the Safari Exploration Company of South Africa controlled the ground and did extensive exploration consisting of 24 diamond drill holes, having a total length of 1,225 metres, and underground work totalling 170 metres under the direction of P.C. Benedict. The property was transferred in late 1951 to Chemilil Sisal Estates Ltd. and in 1953 a small mill to process the ore was erected at the sisal factory 17 kilometres from the mine. The production during this active period is given by F.W. Binge as follows:

<table>
<thead>
<tr>
<th>YEAR</th>
<th>TONNAGE MILLED</th>
<th>GOLD (OZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953</td>
<td>850</td>
<td>647.76</td>
</tr>
<tr>
<td>1954</td>
<td>2,950</td>
<td>1,144.59</td>
</tr>
<tr>
<td>1955</td>
<td>2,031</td>
<td>2,236.45</td>
</tr>
<tr>
<td>1956</td>
<td>4,853</td>
<td>4,130.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>10,685</td>
<td>8,159.18</td>
</tr>
</tbody>
</table>

Table 2: KIBONGWA MINE — PRODUCTION FIGURES
Figure 11:

KIBONGWA GOLD MINE, KENYA

Geology & workings mapped by participants of
First UNESCO Regional Programme in Mining Geology
Nov. 1981

EXPLANATION

- • Survey point with altitude at floor
- - - - Mine workings. Dashed where
--- - Inaccessible
--- - Outline of stope. Querried where
--- - Inaccessible
///// Stoped
- - - - - - Timbered
>>> - - - Incline workings. Chevrons point
down at 2m vertical interval.

- Top of winze
- - - - Vein with dip
- - - - Nyanzian metavolcanic rocks
- - - - Strike and dip of bedding or banding
- - - - Horizontal bedding or banding
- - - - Strike and dip of joint
- - - - Strike of vertical joint
Figure 12:

KIBONGWA GOLD MINE, KENYA
GEOCHEMICAL ORIENTATION SURVEY

Mercury

cxHMI

Traverse with sampling points

Adit Portal
The time of cessation of mining and milling is not known but, as the tonnage reported is roughly equal to the quantity removed from the stopes as they exist now, it is believed the operation terminated in 1956 or 1957. In recent years, villagers living near the mine have screened fines from the stope fill and recovered a little additional gold.

**GEOLOGY**

The Kibongwa mine is developed on a single siliceous zone that dips northward at 20°—30° through metamorphosed volcanic rocks assigned to the Precambrian Nyanzian System. Most of the rocks in the area of the mine are mafic, apparently originally basalts, but, according to P.C. Benedict, nearby drill holes penetrated extensive flows of rhyolite. The ore zone is dominantly a band of sugary quartz varying in width from near zero to 1 1/2 metres but with vague gradational boundaries to silicified metabasalt. The band essentially parallels the layering of the country rock and it was not clear whether it represented silicification along a crush zone or was a replaced tuff layer that was originally more siliceous than the bordering rocks. The quartz-rich zone contains pyrite, locally in excess of 1% and Binge also reported the presence of chalcocite, chalcopyrite, pyrrhotite and possible sphalerite. Fine-grained gold is distributed in varying amounts throughout the quartz zone and lesser amounts are also found in the silicified wall rocks. The average gold content is very close to 1 oz per ton.

**WORKINGS**

The mine is developed chiefly through an inclined shaft following the vein down 15 metres and a second incline, offset 10 metres to the west, extends down an additional 16 metres to where the workings are flooded (see figure 11).

At the foot of the first incline, drifts have been run eastward 75 metres and at least 25 metres to the west. A second drift has been run from the other incline 13 metres below the upper drift, and apparently there is a third level which was inaccessible because it was below the water level. Much of the area between the two accessible levels has been mined in a large, though shallow stope having a length of more than 100 metres and a length down the dip of 40 metres. Owing to the hard and competent character of the wall rock the back of the stope required and received very little support over its expanse. The estimated tonnage of ore taken from the stope is about 10,000 tons.

The Kibongwa mine proved adequate for the instruction and practice in underground mapping. The map produced is shown in figure 11. The previous reports giving details of the exploratory drilling provide the most complete data on the ore deposit. Calculations of the total reserve before mining by Mr. Missotten using the drill data gave 10,000 troy ounces gold in 35,797 tons of ore. From this initial reserve, a residue of about 25,000 tons, containing about 8,203 troy ounces gold, is assumed. With the greatly increased value of gold that now prevails, revitalising the Kibongwa mine is worth serious consideration as the drilling has not delimitil the extent of the mineralisation in this promising area.

**GEOCHEMICAL WORK**

The exploratory geochemical work done by the group at the Kibongwa Gold Mine consisted of sampling soil along a traverse that crossed the ore zone and analysing
the samples for traces of heavy metals and mercury (figure 12). As F.W. Binge had reported chalcocite and chalcopyrite in the ore, it was speculated that testing for heavy metals in the soil zone would reveal the presence of the gold vein. If so, this geochemical technique could be used in the search for additional soil-covered veins, but unfortunately the test yielded very low values which did not correlate with the projected outcrop of the vein. Because mercury accompanies gold in small amounts in some areas, the soil samples were also checked for their content of this element. The mercury detector used was very sensitive and indicated the soil had normal trace amounts of mercury with no appreciable increase over the vein zone.
Figure 13: Participants looking down into the large Menengai crater from its rim during the lunch stop on the trip from Kisumu back to Nairobi. The dark mass in the crater is one of many spectacular lava flows forming the floor of the crater and extending northward through a breach in the crater wall.
REFERENCES


APPENDIX I:

GEOL0GICAL INTERPRETATION OF THE SOUTHERN KERIO VALLEY KENYA

By Jean-Claude Rivereau, Ministry of Environment & Natural Resources for UNESCO Regional Field Training Course in Mining Geology — Nairobi September-November 1981

This false colour print is an enlargement of part of Landsat Scene 181/60 of 25 January 1976 over the southern portion of the Kerio Valley in Rift Valley Province of Kenya. It is at a scale of 1:125,000.

PHYSIOGRAPHY

The area can be divided into four physiographic units, from west to east:

1. The eastern edge of the Uasin Gishu Plateau and its extension to the south standing at an altitude between 2,400 and 2,700 metres. This is a region of large farms and plantations (cereals) with some forest-reserves such as the Kaptagat and Metkei forests which appear in a continuous deep red tone on the picture.

2. The Elgeyo Escarpment face, a steep slope to the Kerio Valley, which lies below 1,200 metres. The escarpment is an area of mixed agricultural and remnants of indigenous forests.

3. The Kerio Valley proper, a subarid area with poor thorn scrub utilized for cattle grazing.

4. The Kamasian-Tugen Hills unit. Agriculture here is primarily maize production in small farms with remnants of indigenous forests on the slopes.

GEOL0GY

The Kerio Valley is an arm of the Kenya Rift Valley system, separated from the main valley by the Kamasian/Tugen Hills horst. It is characterized by a major fault running along its western flank which is responsible for the Elgeyo Escarpment (1,500 m) with a geological downthrow that may exceed 1,000 metres (see below). One geological peculiarity of the Kerio Valley is that this major fault suddenly dies out only about 10 kilometres to the south where the Metkei Plateau joins the Uasin Gishu Plateau.

Lithology — the main formations encountered are:

- The basement system, which consists of metamorphosed sediments (hornblende and quartz-felspathic gneiss and crystalline limestones) and is exposed at the foot of the Elgeyo Escarpment.
- A series of volcanic or volcano-sedimentary formations, which extend, from Miocene to Pleistocene in age and include basalts (Samburu, Elgeyo), phonolites (Uasin Gishu, Tinderet), trachytes (Kabarnet), and intercalations of tuffs, silts and diatomites.
- Quaternary deposits, alluvium and red soils, which form the floor of the valley.

Tectonics — the area is controlled by roughly north-south normal faulting facing east on the western side and west on the eastern side of the valley. There is controversy about the magnitude of the Elgeyo Escarpment fault system which exceeds 1,000 metres if it assumed that the Samburu basalts, which occur at 1,200 metres in the Kerio Valley, were laid down on a plane surface of gneiss. The basalts are presently at an altitude of 2,000 metres in the escarpment. Other evidence suggests that the basaltic series was progressively deposited when the downwarping and faulting process was already taking place, thus indicating that the magnitude of the fault may be of lesser extent.

To the south and to the east, the area is characterized by an uplift and downthrow system of faults arranged "en echelon".

Two 1:125,000 scale geological sheets are available in this area, published by the Mines and Geology Department of the Ministry of Environment and Natural Resources. One is by J. Walsh in 1960 and the other by P.H. Truckle in 1978. There are considerable differences between the two sheets in both stratigraphy and tectonics, which illustrate the difficulty of mapping in volcanic areas.

LANDSAT INTERPRETATION

The Landsat interpretation was carried out on scene 181/60 of 25 January 1976 along with scene 182/60 of 16 May 1979 of the adjacent orbit. Together these images permit a stereoscopic view of the area because it is in the area where the orbits overlap. Through texture and tone analysis, the main physiographic and related geologic units can be delineated. This is the case for the Uasin-Gishu volcanic plateau and the Elgeyo Escarpment where the basement rocks clearly stand out with a peculiar light-coloured rough surface. The Quaternary sediments composing the floor of the valley are also easily recognized, appearing as a light-to-blueish-toned smooth surface. The mottled pattern developed over the Tugen Hills can also be identified and discriminated from the rest of the picture.

However, one could not expect to differentiate in detail between the various volcanic units because there is very little difference between basalt and phonolite and also because stratigraphy in volcanic areas is usually very complicated.

The various units interpreted from the Landsat image are in reasonably good agreement with the geological maps, although some discrepancy may occur on the delineation of these units.

Unit A corresponds to the Quaternary and Recent deposits of the Kerio Valley.

Unit B is the basement metamorphosed series.

Unit 1 and 2 are related to the Uasin-Gishu series which consists of phonolites, tuffs and basalts.

Unit 3 corresponds to the Kabarnet trachytes. This unit has a peculiar light-toned flat surface aspect which might be confused in places with the escarpment.

From the structural and tectonic standpoint, the Landsat image provides excellent data. The roughly north-south network of normal faults can be readily and accurately analysed, especially in the southern and eastern part of the image. The interpretation gives a clearer definition of the fault pattern than is shown in previous geological works. In particular these new structural trends, north-east and north-west in direction, clearly appear. The north-east trend of faulting is particularly well expressed to the south of the image (fluorspar mine valley and south) with both vertical and horizontal offset. It appears that it is along these faults the rifting process dies out to the south.

In this small proportion of Landsat data for the Kerio Valley the large fault bordering the western wall of the valley is not seen because it lies under the Quaternary sediments. When the full Landsat frame is examined the fault is well expressed by the wall of the escarpment, which extends for more than one hundred kilometres.

REGIONAL REMOTE SENSING FACILITY
NAIROBI KENYA
P.O. Box 18332 Phone: 556400 ext 203
GEOLOGICAL SKETCH MAP OF
KERIO VALLEY FROM LANDSAT DATA

KEY:

🪴 Fault, linearment
📍 Geological boundary
נחל River

🪗 Escarpment
🏠 Alluvium
acionales Kabernet trachytes

есс Tenderet volcanics (phonolites)
Basement system

Uasin Gishu series (phonolites, tufts, basalts)
APPENDIX II:

This appendix is added in the hope that the experience gained in the organisation of the first UNESCO Regional Training Programme in Mining Geology, held in Kenya, might be of benefit to the organisers of similar projects in other African Countries in the future.

I. PLANNING

UNESCO initiated an early exploratory contact with Dr. E.H. Bailey, Director of many CENTO field training programmes in geological mapping techniques held in Asia. Dr. Bailey assisted UNESCO by providing all the available information on the previous training projects and also visited Kenya between 25 March and 11 April 1981.

During his visit, consultations were held with officials of the Department of Mines and Geology, Geology Department of the University of Nairobi, Regional Remote Sensing centre, the Norwegian Embassy and the office of the Kenya Fluorspar Company. Out of these discussions evolved the proposed elements of the programme, which were:

1.1 To hold the training programme at the mines of the Kenya Fluorspar Company in the Kerio Valley.

1.2 To map all the deposits of fluorite in the area of the mines and to carry out a regional geological survey.

1.3 The Fluorspar Company of Kenya kindly agreed to provide housing, together with other facilities including catering at the club for the group of trainees and instructors.

1.4 The course would be of eight weeks duration.

1.5 An invitation document was prepared outlining the structure and content of the course, and this was circulated to African Countries of the Sub-Saharan Region.

1.6 A list of 124 items including instruments, field equipment, and other equipment necessary for the conduct of the course, was prepared.

1.7 A detailed budget was prepared.

1.8 The detailed budget was also submitted to UNESCO Headquarters in Paris for modification and approval.

1.9 The Norwegian Government agreed to fund the programme.

2.0 The Kenya Government agreed to host the programme.
2. IMPLEMENTATION OF THE PROGRAMME.

2.1 The ceremonial opening of The First Regional Training Programme in Mining Geology was held in the conference room of the UNESCO Regional Office in Nairobi on 16 September 1981, at 11.30 a.m. It was performed by Hon. A. Omanga MP, the Minister of Environment and Natural Resources. It was also attended by officials of UNESCO, officers of the relevant ministries, the Norwegian Government representatives and also by instructors and trainees.

After the ceremony, the participants were briefed on the training programme and the schedule for the following day, when the group would depart for the Kerio Valley, the site of Fluorspar Company's mines.

2.2 The party of three instructors, seven participants and the camp manager left the following morning in two minibuses, followed by a large truck carrying personal luggage, technical equipment and essential camp furniture (canvas beds, chairs etc.). The party reached the mine site of the Kenya Fluorspar Company in the late afternoon.

2.3 The participants were housed in an old hospital building, the three instructors and the camp manager in a furnished house, and the drivers in the mine workers' camp. One female student was accommodated in a private rondavel. The accommodation was adequate and comfortable. A large central room in the hospital was converted into the classroom. The adjoining club-house not only provided the dining and recreational facilities, but also helped relieve the congestion in the hospital washrooms.

2.4 After five weeks in Kerio Valley, the party moved to Kisumu for underground mapping in the Kibongwa Mine and were housed in a Kisumu hotel which was excellent. A large ballroom on the second floor was easily converted into a suitable classroom.

2.5 The final week of the course was conducted in Nairobi. The lectures were conducted at the facilities of the Regional Remote Sensing Centre.

2.6 The training programme was officially closed on Friday 12 November 1981. Many senior officials of various African Governments were present, together with representatives of the Norwegian Government (who sponsored the programme) and the local United Nations officers. Short speeches were delivered by Chief Olu Ibukun, Director of the UNESCO Regional Office for Science and Technology for Africa, and the Permanent Secretary in the Ministry of Environment and Natural Resources of Kenya. Mr. V.P. Kahr, the Specialist in Earth and Marine Sciences of the UNESCO Regional Office thanked the many individuals and organisations that had helped to make the programme so successful. Certificates for successful participation in the programme were awarded to the participants.
The opportunity was taken to arrange a display of materials prepared by the group, including maps, sections and geochemical plots.

We would like to make the following comments, with the benefit of hindsight, for the possible improvement of future courses:

1. The duration of the course should have been ten weeks (to permit greater achievement in the laboratory, with report writing and in the preparation of maps etc.).

3. The number of instructors and trainees participating in this programme proved to be adequate. (Four instructors including the camp manager worked with sixteen trainees). It was felt that by using some local instructors and by increasing the number of participants, the cost of mounting such a programme might be significantly reduced. There should be a maximum age limit for the participants, say 32 years.

4. It is important to allow at least four months following the announcement of such a programme in Africa. Unfortunately candidates kept arriving up to two weeks after the programme had commenced in the field.

5. There were persistent requests for the books maintained in the field library either as free grants or for sale to the trainees. It is felt that a future programme should prepare a list of modern text books and their publishers for issue to participants and, in addition, provision could be made to sell some textbooks to the trainees.

6. Acquisition of stores and equipment proved to be a problem. Eventually, items were acquired from Nairobi, Paris and the US Geological Survey. Not all the equipment arrived in time. There were also delays due to procedure restrictions. In the end almost all the items were on hand for the conduct of the field mapping, but only after considerable trouble and delay. Once again, the trainees made requests for the grant or sale of items such as Brunton compasses, aluminium clipboards, geological hammers and other equipment.
APPENDIX III

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— Ends —