REPUBLIC OF BOTSWANA

REPORT ON GEOLOGICAL SURVEY OF NORTHEASTERN BOTSWANA

PHASE III

FEBRUARY 1987

METAL MINING AGENCY OF JAPAN
JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

The Government of Japan, in response to the request of the Government of the Republic of Botswana, decided to conduct collaborative mineral exploration in an area streching over the Northeast and Central District in the northeastern Botswana and entrusted its execution to Japan International Cooperation Agency (JICA) and Metal Mining Agency of Japan (MMAJ). Between July 10 and November 22, 1981, Metal Mining Agency of Japan dispatched a survey team headed by Mr. Tamotsu Nakajima to conduct Phase III of the project.

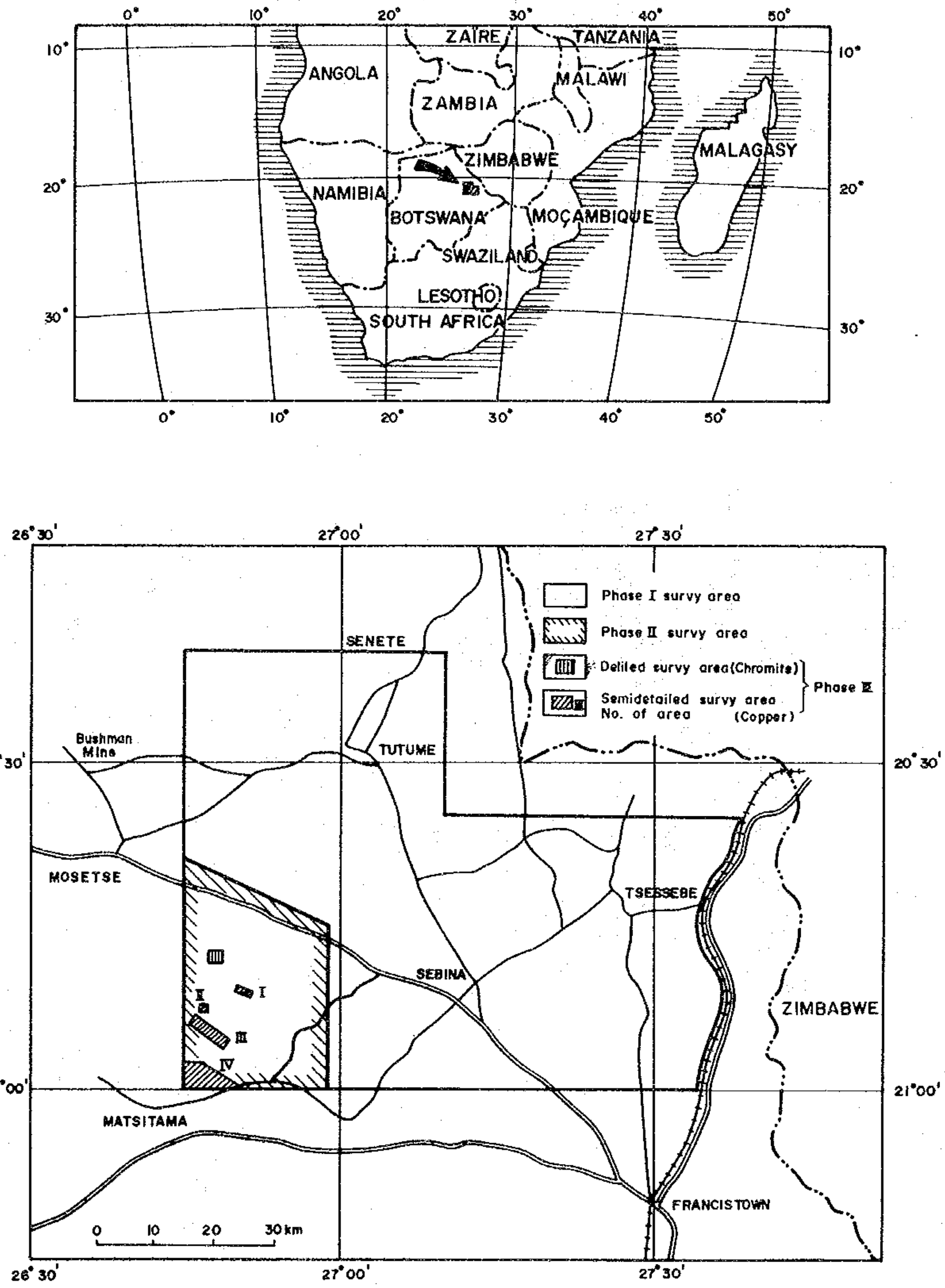
The survey had been accomplished under close cooperation with the Government of the Republic of Botswana and its various authorities.

We wish to express our appreciation to all of the organizations and members who bore the responsibility for the project; the Government of the Republic of Botswana, Mr. M.C. Tibone and other authorities and the Embassy of Japan in Zambia.

Keisuke Arita
President
Japan International Cooperation Agency

Masayuki Nishiie
President
Metal Mining Agency of Japan

Fig. 1 Location map of the survey area



SUMMARY

The purpose of the 3rd year survey in the northeast part of the Republic of Botswana consists in finding whether there is mineralization or not, the nature of ore deposits, their size, ore grade and other matters, on the basis of the results of surveys in the 1st and 2nd years, in the four areas, Areas I, to IV, in the Matsitama north area that were selected as the ones with the highest potentiality of copper mineralization and in an area where outcrops of chromite were confirmed and a more detailed survey was found necessary, to obtain the basic data for the future exploration and development.

With this object in view, in the areas where copper is the target, confirmation by means of drilling principally was made of the mineral indications which were presumed to be owing to graphite or massive sulphides as the result of geophysical prospecting in the 2nd year survey, about which the main object was to confirm their charactors, and also of anomaly areas by geochemical survey, the extensions of copper indications as observed in former trenches, and other parts. In addition, a geological survey of their surroundings, geochemical survey and handy magnetic prospecting of some parts were conducted.

The survey area was divided into four, Area I to IV, the total area of them was 51 km^2. In them holes were drilled, their total length coming up to 1,405.45 m. In the following is a brief description of the result of the above-mentioned survey for each area.

Area I

Drilling (GSJ-4 and 5) was made for geophysical indications. In both holes graphite schist was found, but as to mineralization the result was only pyrite being slightly observed.

Area II

As the result of drilling (GSJ-6) made for a geochemical anomaly area, pyrite, chalcopyrite and hematite were extensively found. Partially there was a part rich in chalcopyrite, but the copper grade was low. Floats of copper ore were found at a place to the north of the drilling point.

Area III

As the result of drilling (GSJ-7, 8 9 and 10) made for geophysical indications, weak mineralization of pyrite and chalcopyrite was recognized in GSJ-9 and graphite schist in GSJ-7 and 10.

Area IV

As the result of drilling for geophysical indications (GSJ-11, 13 and 14) and for geochemical anomaly areas (GSJ-12 and 15), a very small quantity of native copper was found in GSJ-11 and dissemination of pyrite in a somewhat large extent in GSJ-13 and 14.

In an area on the west side of the area where these holes were drilled, floats containing copper minerals were sporadically found. Also as the result of geochemical survey in the said west side area, anomaly areas including anomalies of class A were picked up extensively.

In addition, by the drilling intended for the extension of copper indications in the former trench on the east side of this area (GSJ-16 and 17), mineral indications that were presumed to be the extension were confirmed. In both of these holes dolerite, altered rock originating from basalt, aplite and other kinds of rock are so complicated that the geology cannot be defined, but the copper mineral indications as seen here are presumed to derive their orgin from basalt secondary and be of a small scale.

As the result of the above-mentioned findings, Area II and the western part of Area IV offer hope of occurrence of Matsitama-type deposits and have been selected as promising areas for the future, because of the facts that copper mineralization are observed in drill holes as well as on the surface, that there are geochemical anomalies, and that both areas are within the distribution of the Matsitama schist and metasedimentary group.

The result of the drilling for the geophysical indications make one infer that most of them are attributable to graphite and part of them to sulphides. Although promising mineral indications were not found, confirmation of graphite makes one judge that there is geological environment similar to that of Bushman-type deposite.

In the area where chromite is intended, a geological survey, drilling of four holes (GSJ-1, 2, 3 and 18) coming up to 401.5 m in total length, and handy magnetic prospecting as auxiliary measures for the geological survey were carried out over an area of 2 km by 2 km centering on outcrops of chromite that were confirmed in the 2nd year.

The chromite is black, massive ore that is borne, as small-size ore bodies, irregularly in ultrabasic rock. The country rock, ultrabasic rock, has a trend of being oriented in a NE–SW direction, though limited in distribution, and it is assumed that chromite ore bodies are also concordant with this trend. However, the individual ore bodies are presumably controlled by the minor structure of the ultrabasic rock, and do not show a definite trend. The drill holes of GSJ-1 and 2 that were aimed at the lower extension of outcrops on the surface reached chromite bodies, but none of these bodies are related with the outcrops and presumed to be different ones.

Therefore, this area has the possibility that similar small-size ore bodies occur besides the confirmed ones. Because of their small size and irregular distribution, careful and detailed survey through trenching and shallow drilling is recomended for further exploration.

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GENERAL INFORMATION

1. Purpose of Survey

The purpose of this survey is to acquire the basic data for the development of mineral resources in the northeastern part of the Republic of Botswana in cooperation with the Ministry of Mineral Resources and Water Affairs of the Government of Botswana.

The survey for 1981, the 3rd year of the project, was carried out for the purpose of confirming the conditions of the minerals by means of drilling and geological survey over the areas suggesting copper ore indications and also the area where outcrops of chromite were discovered, in the north of Matsitama, which were selected as promising as the results of the 1st and 2nd year surveys.

The drilling survey was conducted principally over the anomaly areas picked up by the geophysical survey in the 2nd year, and, in addition, the anomaly areas by the geochemical survey and chromite indication area.

The geological survey consisted of a semi-detailed survey of the areas surrounding the drilling sites in the copper indication area and a detailed survey of the chromite deposit area.

2. Survey Areas

The survey areas comprise four areas covering 51 km^2 in total selected for copper ore indications and one area covering 4 km^2 for chromite, as indicated in Fig. 1.

The district including these survey areas is located in the Central District of the Republic, and the nearest town is Francistown about 100 km to the east of the survey areas. Francistown is connected with Gaborone, the capital of this country, by a trunk-road over a distance of about 400 km. There is anotehr trunk-road extending to Maun, which lies about 500 km to the west of Francistown, and the survey areas are situated approximately 10 km from this road.

The survey areas and the surroundings are situated at the eastern edge of the Kalahari Desert; their altitude is 1,000 to 1,100 m above sea level, and their topography is almost flat showing only slight undulations. Rivers in these areas have running water for only one or two weeks in the rainy season, remaining dry rivers at ordinary times.

Belonging to the semi-dry areas of the tropics, the summer lasts from October to April and the winter from May to September; the amount of rainfall, about 440 mm a year, concentrates in the summer.

3. Contents of Survey

The semi-detailed survey was made by making reconnaissance between the survey lines which were set for the geochemical survey in the 2nd year survey so that the 1981 survey along the lines, which have 500 m intervals, are complemented.

For the detailed survey, survey lines were laid out at 100 m intervals in the north-sourth direction and reconnaissance was made along these lines.

The contents of the field works and laboratory tests are summarized in the following tables:

Table 1. Contents of survey

Item	Amount of work	Remarks
Drilling	18 holes, 1,800 m	All coring, vertical
Geological survey	Semidetailed survey, 51 km^2 (127 km*) Detailed survey, 4 km^2 (40 km*)	Geochemical survey (12 km^2) Geophysical survey, Trench

* Length of survey route

Table 2. Laboratory test item

Kind of test	Amount of work			Remarks
	Geological survey	Drilling core	Total	
Microscopic observation of thin sections	40	34	74	
Microscopic observation of polished sections	12	12	24	
Chemical analysis (Copper ore)	189 (561)	51 (167)	240 (728)	Cu, Pb, Zn, Au, Ag
Chemical analysis	40 (202)	5 (27)	45 (229)	Cr_2O., T. Fe, Al_2O_3, MgO Sio_2.

( ): No. of components

4. Organization of Survey Team

Japan side planning and negotiation

Akira Takahashi	(Metal Mining Agency of Japan)
Toyo Miyauchi	(Metal Mining Agency of Japan)
Nobuhisa Nakajima	(Metal Mining Agency of Japan)

Botswana side planning and negotiation

G. C. Clark	(Geological Survey Department, Botswana)
C. Black	(Geological Survey Department, Botswana)
D. G. Hutchins	(Geological Survey Department, Botswana)

Japanese Survey Team

Leader	Tamotsu Nakajima
Geological survey	Iwao Uchimura
Geological survey	Takehiro Sakimoto
Drilling work	Sakari Kon
Drilling work	Hisao Ataku
Drilling work	Akemichi Saito
Drilling work	Mutsuo Saito
Drilling work	Mitsuo Nagata
Drilling work	Koichi Ito

Botswana Survey Team

B. Aboneng	(Geological Survey Department, Botswana)
M. Kgomoesele	(Geological Survey Department, Botswana)
M. Ditlhogo	(Geological Survey Department, Botswana)

The Japanese team conducted the survey as shown in Table 1 from July 15th 1981 to November 20th 1981 in Botswana.

5. Acknowledgement

The survey team is most grateful for their continued beneficial advice and assistance in conducting the field work following the survey in 1980 to Mr. M.C. Tibone, Permanent Secretary of the Ministry of Mineral Resources and Water Affairs of the Government of the Republic and Dr. J.C. Brower, Adviser to the Ministry.

The team members wish to take this opportunity to tender their thanks to Dr. C. Kim, who serves in Jubilee Hospital of Francistown, and his family for their kind care for the team members' health during the working periods.

DETAILED REMARKS

Part I. Geological Survey of Copper Indication Area (Semi-detailed Survey)

I-1 Introduction

The north of Matsitama area, which was selected as promising as the result of the survey in the 1st year, is overlain by the Matsitama schist and metasedimentary group which is possible to bear metasedimentary copper deposits.

Also the result of the geophysical prospecting in the 2nd year provided a great number of anomalies in this area which are considered to be owing to graphite or massive sulphides, and some copper anomalies were picked up by the geochemical survey.

Consequently, the 1981 survey was primarily directed to confirmation of these anomalies according to the geophysical prospecting by means of drilling and in addition to finding in more details the geology of their surroundings and mineral indications through conducting reconnaissance survey.

The zone including the survey area is situated at the eastern end of the vast desert of Kalahari, and is a flat savanna area with slight undulations, hardly showing outcrops except for the parts along river systems where only little outcrops are seen. Accordingly, the results of the geological survey and the drilling in 1981 do not include any facts that may largely change the geological map made in the past, though a little readjustment was found necessary.

I-2 Geological Survey

I-2-1 Stratigraphy

The geology of this area, lying in the northeastern portion of the Mosetse-Matsitama Area Geological Map (Bennett 1970), is formed primarily of a basement complex and besides younger igneous rock and sediment.

Bennett, in 1970, divided the basement complex into the Mosetse river gneiss group and Matsitama schist and metasedimentary group. In the following the stratigraphic unit are described with their names as given by Bennett (1970) and mentioned in the 1980 M M A J report.

(1) Mosetse River Gneiss Group

Outcrops are only scattered in the beds and on the banks of such major rivers as the Lepashe river, the Mosope river, and its tributaries, namely, the rivers of Mukulwane, Chadeche and Mapatse; in flat areas outcrops are only scarcely found and floats seen very little.

This group is widely distributed occupying the eastern half of this area. It is composed of gneiss for the most part, and in the northeast part porphyroblastic gneiss is found. In addition, amphibolite – amphibole schist, feldspathic quartz schist, quartzite, limestone and others are also distributed in lenticular to thin layer forms.

The gneiss is medium-grained rock of light-gray to gray or light reddish brown to reddish brown colors. When it has been weathered, its gneissic structure becomes distinct. The rock forming minerals are quartz, plagioclase, potash feldspar and mica (more biotite than muscovite), accompanied by a small quantity of amphibole. Most of the gneiss is granitic paragneiss.

The porphyroblastic gneiss has the same component minerals as the above-men-mentioned gneiss, it is distinguished by containing porphyroblasts of potash feldspar, 5 to 20 mm in size. The result of the dating of such granitic gneiss according to the K-Ar method indicates the age of 1810 to 1890 m.y. (MMAJ reports, 1980 and 1981).

The amphibolite-amphibole schist is distributed in the form of thin strata. It is a dark green rock generally consisting of common amphibole, plagioclase, quartz and epidote in a small quantity. As for its contact with other kinds of rock, it distinctly bounds on surrounding rocks in some cases, while in other cases the quantity of amphibole gradually decreases to change into other rocks.

Under the microscope sphene is found in a film or veinlet form in some samples. According to the result of dating, the age is 1755 m.y. (MMAJ report 1981).

The quartzite – quartz schist is light-gray to dark-gray or light-brown to light-purplish brown, or rarely light-green; it is generally formed of fine grains. Such rock is composed of quartz grains for the most part, but occasionally contains small quantities of feldspar and mica. On rare occasions banded hematite is recognized.

The limestone, which is white to gray, is crystalline. This group is largely divided into the upper and lower strata by its lithofacies. The lower one primarily consists of gneiss and porphyroblastic gneiss and is interlaid with quartz schist – quartzite and amphibolite – amphibole schist. The upper one is similar to the lower in lithofacies, but as compared with the lower, amphibolite – amphibole schist is dominant and also it is interlaid with limestone at places.

(2) Matsitama Schist and Metasedimentary Group

This group is distributed in the southwest and west parts of the survey area. Outcrops are found only along the Mosope river, and in the other parts very small quantities of floats are scattered. It conformably overlies the lower Mosetse river gneiss group, partly being in contact with the latter with faults.

The rock consist principally of various kinds of schist, quartzite, and amphibolite – amphibole schist, and small quantities of limestone and phyllite are recognized therein.

The schist, generally leucocratic, has the principal components of quartz and feldspar, and some contains dark-green amphibole. It is classified into feldspar-quartz-schist, biotite-feldspar-quartz-schist, muscovite-feldspar-quartz-schist, amphibole-feldspar-quartz-schist, epidote-amphibole-feldspar-quartz-schist, hematite-quartz-schist to amphibolite, etc.

The quartzite, formed of fine grains, is mostly leucocratic, but one of dark-gray, brown, purplish brown, or green color is seen at times. The main component mineral is quartz, but is often accompanied by feldspar or a small quantity of colored minerals.

The amphibolite-amphibole schist is distributed in a belt form with a maximum width of 2 km on the geological map, but this is a collective indication of alternate strata with various rocks, and as a single stratum it has a maximum width of only about 100 m.

Its component minerals are mainly amphibole, feldspar and quartz, and in addition it is often accompanied by epidote and a small quantity of sphene.

As for its boundary with other rocks, it distinctly bounds on surrounding rocks in some cases, while in other cases as the amphibolite decreases it changes into some other rock.

The amphibole consists mainly of common amphibole, but at times actinolite, tremolite and anthophyllite are recognized; it often has been epidotized.

This group is divided into the upper and lower strata in terms of the combination of lithofacies. The upper is distributed in the southwest part of the survey area and has the characteristics that it has a distinct lineation principally in the northwest direction as seen in an aerial photograph, that it bears copper ore beds, that felsitic rocks are dominant there, and that phyllite – macaceous rock is often seen. In the lower stratum, amphibolite – amphibole schist is dominant.

According to the result of dating, some indicated the age of 1,764 m.y. (M.M.A.J. report in 1980).

(3) Quarternary

The Quarternary consists of soil, pebbles and calcrete.

I-2-2 Igneous Rock

The igneous rocks that have developed in the survey area are classified into acidic, basic and ultrabasic rocks.

Outcrops are very scanty and their conditions of occurrence are unclear, but the following can be considered from the floats and outcrops.

The acidic rocks occur as small-scale dykes of pegmatite, granite and syenite.

The basic rocks consist mainly of dolerite and in addition small quantities of gabbro and basalt. All of them are in a dyke form and most of them have principally a NE strike.

Some of the rocks comprise serpentinite and contains a large quantity of magnetite and a small quantity of chromite. Under the microscope the greater part of it is serpentine – chlorite and talc, and at times a very small quantity of olivine. In addition, it is accompanied by magnetite, and small quantities of carbonate minerals and chromite.

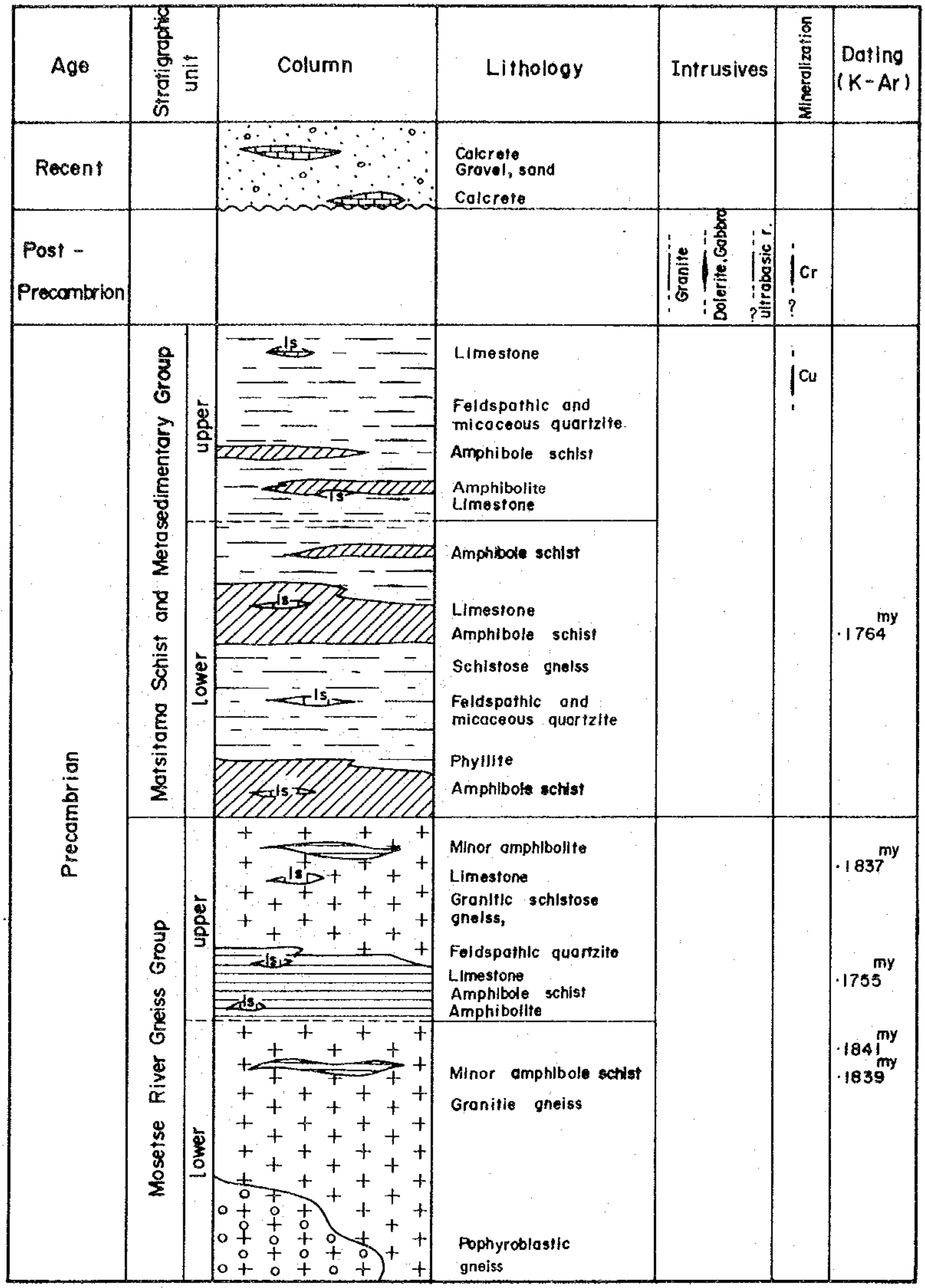
I-2-3 Geological Structure

The strata distributed in the survey area are classified, by their lithofacies, into the Mosetse river gneiss group and the Matsitama schist and metasedimentary group, but these two grade into each other and their boundary is not always clear.

These strata have been subjected to such techtonic movement as folding and faulting. Viewed broadly, they are located in the north wing of the Matsitama fold as mentioned by Bennett (1970). While repeating some folds, they are in a monoclinal structure with a NW-SE strike and a W dip.

As for a major fault found in the survey area, a fault in the NW-SE direction is presumed to the south of the Lepashe river.

Fig. 2 Generalized stratigraphic column



Most of intrusive rocks (dykes) are in the directions of WNW-ESE to E-W. From aerial photographs and Landsat images, lineaments in the NW-SE and E-W directions, as conspicuous ones, are picked up.

From the above-mentioned, the directions of fracture systems dominant over this area are assumed to be those of NW-SE, WNW-ESE and E-W.

I-2-4 Mineralization

As copper indications, boulders containing copper minerals have been confirmed at several places, and also such indications are recognized in trenches that were prospected before. As a result of the geochemical survey also, copper anomaly areas were picked up centering on the southwest part of the survey area.

These copper mineral indication areas are situated about the northeast edge of the Matsitama deposit group which was prospected by the A.A.C. group before, and part of the prospecting work extends into the survey area.

This Matsitama deposit group is metasedimentary deposits accompanied by mainly copper ore and small quantities of lead and zinc which are borne in strata of calcareous quartz schist – calcareous quartzite, mica schist, amphibole schist, phyllite, etc. in the Matsitama schist and metasedimentary group; the deposits are disposed comformably in the strata as a group of many deposits in the said group. The ore minerals, in the oxidization zone which extends to a depth of about 60 m under the surface, are oxidized minerals composed of mainly malachite, chrysocolla and azurite and accompanied by a small quantity of tenorite. Below this zone the ore minerals consist of chalcopyrite, bornite, chalcocite, pyrrhotite, pyrite and small quantities of lead, zinc and silver minerals. (Baldock 1977)

About 40 km to the northwest of the survey area, there is Bushman mine which is being prospected by Falconbridge Co. This mine comprises a copper ore deposit borne in the country rocks of graphitic quartzite to quartz schist and phyllite in siliceous limestone or dolomite that has been taken into the fracture zone of a major tectonic line running in the north-south direction near Bushman mine, called the Bushman lineament. This deposit has the characteristics that it has been structurally controlled in the N-S direction, that graphite schist is seen in the country rock, and that the mineralization is closely related with graphite concentrating in the fracture zone.

The survey area is divided into the following four areas, which are named Areas I to IV from the north.

Area I	Within the extent of a 2 km^2 area which includes anomaly area M-23A by the result of the airborne geophysical prospecting in the 2nd year survey, two holes were drilled, aiming at the indications by the ground geophysical prospecting conducted over this anomaly area.

This area lies at the axis of a folding structure having a NE-oriented axis in the Mosetse river gneiss group and comprises amphibole schist, quartz schist to quartzite, limestone, and calcrete.

This area offered some hope because Zn anomalies were recognized in the geochemical survey as well as the geophysical prospecting and it has conditions that are likely to make a ground for an ore deposit to be borne as viewed from the point of geological structue. The geological survey, however, resulted in only partial revision of the geological map, and mineral indications were not found. The result of the drilling, which is described later, disclosed only a little pyrite.

Area II	This area is an area of 1 km^2 centering on class A anomalies that were picked up as a result of the geochemical survey in the 2nd year survey. Drilling was made aiming at the anomalies.

The Matsitama schist and metasedimentary group is distributed in this area. About 1 km to the east of the area there remain drill holes and cut lines made by the A.A.C. group before. Near them small outcrops and floats containing copper minerals are observed. Also, as a result of the drilling, copper mineralization was extensively recognized though at a low grade of copper.

Particularly, the facts that chalcopyrite has been recognized as the result of the drilling, that the country rock is amphibole schist of the Matsitama schist and metasedimentary group, and that mineralization including pyrites and other minerals extends widely, raise one's hopes for the future prospecting, including the relations with the Matsitama deposits.

Area III	This area, located near the boundary between the Mosetse river gneiss group and the Matsitama schist and metasedimentary group, is an area of about 14 km^2 including the anomaly areas of M-7A, M-7B, M-7C, and M-10 by the airborne geophysical prospecting. For the mineral indications by the ground geophysical prospecting conducted over these anomaly areas, drilling was made. The drilling points are all within the distribution of the Matsitama schist and metasedimentary group.

On the surface small pieces of calcrete, limestone, quartzite, and amphibolite are seen only here and there. As the result of the drilling, mica schist, quartz schist, amphibole schist, quartzite, graphite schist and basalt were recognized.

As the cause for the indications by the geophysical prospecting, some massive sulphides or graphite was conceived, and the result of the drilling revealed that the cause was graphite.

Since graphite is easy to pulverize, it was not found at all on the surface in the form of floats or outcrops.

Graphite being the country rock of the Bushman deposit, mineralization was hoped for, but none of it was found.

Area IV This area, located in the southwest part of the survey area in the 2nd eyar, covers an area of about 36 km^2. It is the most promising area where promising anomaly areas were picked up by the geochemical and geophysical prospecting, and on the surface too mineral indications are seen sporadically. Drillings were made for the class A anomaly area by geochemical survey and the indication by ground geophysical prospecting that was carried out on anomaly area M-3 and M-4 by airborne geophysical prospecting drilling was made also at the side of a former trench excavated by the A.A.C. group. Besides, a geological survey was made over the surroundings of the former trench, and geochemical survey was conducted over some part.

In this area the Matsitama schist and metasedimentary group is widely distributed. As a result of an on-the-surface survey, floats containing copper minerals were discovered at several places. Among them, samples of S-6 (X2.00 Y1.02) are fist-size mica shist containing malachite with copper content of 8.14%.

Also some of soil samples from the geochemical survey showed the following values: 423 ppm (Sample No. 59), 338 ppm (No. 103), 705 ppm

(No. 105), and 1,060 ppm (No. 144).

According to the result of the drilling, very small quantities of native copper were found, and pyrite in a disseminated form was found widely scattered.

The above-mentioned mineral indications exist in the western half of this area, and mineral indications on the east side are restricted to the surroundings of the former trench made by A.A.C. In this trench there are two layers of copper mineralization with green copper minerals principally (M M A J report, 1980), and drilling and trenching were made aiming at the extensions of this mineralized zone.

Two trenches were excavated in parallel with the former trench 20 m and 40 m respectively away from it on its east side, aiming at the extension of the above-mentioned mineralization zone in its strike. In both trenches, however, the pebble layer and calcrete stratum were found extremely weathered and in some rock its original rock was unknown, and no mineralization was confirmed.

At a place about 600 m to the north of the former trench, drilling had been made some time ago according to local people, and in its neighborhood floats containing copper mineals were seen. As a result of drilling of two holes that was made on both sides of the former trench, copper indications were recognized in some extremely altered rock whose original rock seemed basalt. From such conditions of occurrence, these mineral indications are surmised to originate in basalt.

I-3 Drilling

I-3-1 Purpose of Drilling

On the basis of the results of the surveys in the 1st and 2nd years, fourteen drill holes, each 100 m deep, were made in the 3rd year for the anomalies by the geophysical prospecting primarily and by the geochemical survey secondarily, for the purpose of prospecting for copper ore deposits.

The geology of the parts where drilling was made, the results of the geophysical and geochemical prospecting there, and the result of the drilling are shown in Table 12, the location map of drilling in Fig. 8, the core log in Apex. 1, the geological profile of drilling in Fig. 4, the list of microscopic observation in Apex. 4 and 5, and microphotographs in Apex. 6.

The purpose of drilling in the areas are described as follows:

Area I The drilling of GSJ-4 and 5 was made in an area, on an NE-oriented fold in the Mosetse river gneiss group, where amphibole schist, quartz schist-quartzite, limestone and large quantities of calcrete are distributed. In this area, as the result of the geophysical prospecting in the 2nd year, M-23A, which is an anomaly by the airborne geophysical prospecting suggesting existence of graphite, was found, but no geochemical anomaly was recognized. Since it was also considered to be favored with geological structure and environment that are likely to present a ground for a deposit to be borne, the drilling was made.

Area II GSJ-6 was drilled for a strong geochemical anomaly in the stratum which belongs to the Matsitama schist and metasedimentary group and is accompanied by amphibole schist and secondary calcrete.

There are anomalies by the airborne geophysical prospecting: M-32 to the north of GSJ-6 and M-12 to the south of the same. About 800 m to the north of this hole threre are old drilling site by the A.A.C. group; at a point about 1,000 m to the north-northeast of the same hole there is a small outcrop of quartzite accompanied by green copper (0.7 m in width and Cu content of 0.36%); also at a point about 1,250 m to the southwest of the same hole floats of amphibole schist accompanied by green copper were found.

Area III GSJ-7, 8, 9 and 10 were drilled for parts where there are the airborne geophysical anomalies of M-7A, M-7B, M-7C and M-10 and geochemical anomalies of class B in the Matsitama schist and metasedimentary group, primarily aiming at the geophysical anomalies. The results of the airborne and ground geophysical prospecting had made one infer existence of graphite or sulphides. This existence of graphite is one of the important indications of the Bushman copper deposit which lies about 50 km to the northwest of the 1981 survey area.

The surface is widely distributed with black soil and forms a savanna zone covered with low trees and grass.

Area IV The drilling area is divided into (1) the central part where the anomalies by the geochemical and geophysical prospecting concentrate, and (2) the neighborhood of the former trench in the east.

Area IV-(1) GSJ-11, 12, 13, 14 and 15 were drilled for the airborne geophysical anomalies of M-3 and M-4 and the geochemical anomalies, in the Matsitama schist and metasedimentary group. Out of them GSJ-11, 13 and 14 were drilled for the geophysical anomalies suggesting existence of sulphides, while GSJ-12 and 15 for the geochemical anomalies of Class A.

Area IV-(2) GSJ-16 and 17 were drilled to confirm the lower extension of the mineral indications of green copper as seen in the trench. The strata here belongs to the Matsitama schist and metasedimentary group.

I-3-2 Result of Drilling

The rocks seem in the cores as the result of the drilling of the 14 holes are: quartzite, mica schist, mica quartz schist, black schist, graphite schist, mica amphibole (quartz) schist, green schist, amphibole schist, limestone, gneiss, pegmatite, aplite, granite, quartz veins, basalts, and altered products originating from basic rock.

The quartzite is generally leucocratic, hard, and often accompanied by small quantities of feldspar and mica.

The mica schist and mica quartz schist look white, gray, brown or yellow-green according to the kind and quantity of contained mica (muscovite and biotite) and the quantity of contained quartz; when the quantity of mica is small and that of quartz is large, they are difficult to discriminate from quartzite.

The mica amphibole (quartz) schist is mica schist or mica quartz schist mixed with amphibole, with varying quantities of amphibole. As for mica, more biotite is contained than muscovite.

The green schist is a rock containing chlorite and amphibole, often accompanied by considerable amount of biotite.

The amphibole schist is the schist mainly formed of amphibole and fedlspar; the quantity and grain size of amphibole change.

The black schist has the appearance of black quartz schist or phyllite; some of it look like shale and pelitic rock, but generally the schistosity is distinct.

The graphite schist resembles black schist, but there is luster, though little, on the schistosity face. When touched with a finger, it soils the finger black, and it is said to show electric conductivity, though slight, when a tester is applied to it, so that it has been classified as graphite schist. Partly, as seen near the 53.75 m depth of GSJ-10, there is high-grade graphite, but generally the quantity of graphite is extremely small.

The limestone, which is white to grayish white, has been subjected to wallastonitization and silicification.

The gneiss is formed of granitic paragneiss, varying from fine to coarse in grain size; as mafic minerals, it contains biotite and amphibole, but generally their quantities are small. In lithofacies where there are small quantities of mafic minerals, it is hardly distinguishable from aplite, quartz schist or quartzite in some cases. Part of the gneiss contains the porphyroblasts of feldspar.

The pegmatite, aplite and granite occur as veinlets or dykes; among them the aplite is seen most widely. There are not a few cases in which the aplite, quartz and quartzite are undistinguishable from each other.

The quartz is widely seen in the form of vein or veinlets. Most of them are barren, but as the case of GSJ-6 they are occasionally accompanied by hematite, chalcopyrite and pyrite.

Basalts are divided into basalt which is accompanied by the phenocrysts of feldspar, 7 to 30 mm in size (GSJ-7, 8, 9 and 17), and dolerite which is not accompanied by them (GSJ-7, 10, 16 and 17). The former, excluding the case of GSJ-7, has strong talc carbonate alteration, but the latter generally is fairly fresh except for the case of GSJ-10 in which there is the possibility of having altered due to the effect of weathering. For these two rocks, which show difference from each other in lithofacies and alternation, it is unknown whether the two have different origins, whether, supposing that their origin is the same, they have just different lithofacies, and when the intrusion took place.

The altered products originating from basic rock have presumably altered from the above-mentioned basalt; they are altered products accompanied by primarily talc and carbonate minerals, and besides amphibole, chlorite, and small quantities of epidote and garnet. Usually they feel greasy and have the color of reddish brown, pink, green, gray or white (GSJ-8, 9, 16 and 17).

In addition to the above, at the parts where basalt was replaced by aplite, such minerals as amphibole, epidote, diopside, and garnet occur with colors varying from white to green according to the extent of replacement.

As for the mineralization, primary and secondary mineralization is recognized. In the case of primary mineralization, the ore minerals are chalcopyrite, pyrite and hematite, which are found in a disseminated state (GSJ-6, 9, 11, 13 and 14), in veinlets (GSJ-4) or contained in quartz veinlets (GSJ-6, 9 and 14).

In the case of secondary mineralization, the ore minerals are bornite, chalcocite, chalcopyrite, pyrite, malachite (GSJ-16 and 17) and native copper (GSJ-11). The secondary copper minerals in GSJ-16 and 17 were presumably formed when copper in basalt was extracted and deposited secondarily, while those in GSJ-11 were probably formed when copper in amphibole schist was extracted and likewise deposited.

In the following the result of drilling is described for each drilling area.

Area I — In GSJ-4 and 5 the rock was hard on the whole, resulting in the largest consumption of diamond bits, which is accounted for by the siliceousness of the rock on the whole, existence of quartz veins, and silicification.

GSJ-4 — The rock consists of muscovite schist from a 2.20 to 17.6 m depth; the lower portion up to a 45.8 m depth comprises biotite schist, including porpyroblasts, primarily formed of garnet 7 mm at max. in size. Its lower portion consists first of graphite schist (?) containing a little graphite (?), and then in the extent from a 50.40 m depth to a 70.25 m depth, of crystalline limestone with a considerable quantity of wollastonite and silicification.

Below this limestone the rock is biotite gneiss up to a 100.20 m depth.

In the limestone, which has thin layers of graphite schist, pyrite is found, in a 1 to 2 mm width and nearly in parallel with the shistosity, sparsely as a whole and densely in some parts, but copper is not contained practically. There are many quartz veins in this hole, but they are barren.

GSJ-5 — From a 1.70 m depth to a 12.85 m depth the rock is biotite schist, black schist and muscovite schist, and the lower portion up to a 31.5 m depth is crystalline limestone including wollastonite; this limestone is interlaid with thin layers of graphite (?) schist. The part between a 31.50 m depth and a 44.75 m depth comprises biotite amphibole schist and gneiss.

The portion between the 44.75 m depth and a 100.40 m depth consists of gneiss, locally including porphyroblasts of feldspar.

Quartz veins in this hole are barren.

In this hole no mineralization is recognized, except four thin layers of pyrite between a 30.80 m depth and a 30.85 m depth.

As above-mentioned, no copper mineralization has been found in both holes of GSJ-4 and 5 except a little pyrite recognized.

The limestone seen in the two holes seems to belong to the same limestone stratum, and GSJ-4 is thought to have been drilled from a slightly upper horizon than GSJ-5.

Area II

GSJ-6

The rock consists of amphibole schist of fine to coarse grains. Epidotization is recognized, but it not strong. Between a 20.00 m depth and a 101.50 m depth, pyrite, chalcopyrite and hematite mineralization is recognized. These minerals, singly or together, occur impregnated in the country rock or being included in quartz veinlets.

Locally, there are parts rich in chalcopyrite as observed with the naked eye, but the rock is of low grade as a whole, for Cu content is not more than 0.1% except Cu content of 0.228% between a 94.00 m and a 97.00 m depths and 0.178% between a 26.00 m and 29.00 m depths.

Admitting that copper mineralization is weak in this hole, however, the area around GSJ-6 is a promising target area in view of the facts that pyrite and other minerals are widely disseminated and that there are copper indications and geochemical anomalies around this hole.

Area III

GSJ-7

The rock from a 2.00 m depth to a 19.00 m depth consists of muscovite schist and black schist. The lower portion up to a 81.90 m depth is formed of muscovite schist and graphite schist, excluding two layers of weakly altered basalt and a dyke of dolerite. The portion between the 81.90 m depth and a 100.20 m depth consists mainly of muscovite schist and green schist.

No mineralization has been found in this hole.

GSJ-8

The part between a 1.50 m depth and a 39.50 m depth is formed of rocks that are thought to have been formed by replacement of basic rock (probably basalt) by aplite, with some of the basic rock remaining without being replaced, that is, the rocks of aplite, green schist, talc carbonate rock, rock seeming mica schist, rock seeming quartzite, and rock seeming quartz schist. The part between the 39.50 m depth and a 48.90 m depth is formed of talc carbonate rock originated from basalt. This has just the same appearance as the talc carbonate rock that is seen in GSJ-16 and 17. The part between the 48.9 m depth and a 62.0 m depth consists of basalt. The portion between the 62.00 m depth and a 100.30 m depth is formed of aplite with considerable amount of relict of strongly aplitized basic rock. The extent of this replacement by aplite is 5 to 95%.

No mineralization is found in this hole.

GSJ-9

The rock mainly consists of amphibole schist except for quartz schist, talc to carbonate rock, and basalt which are found partly. This talc carbonate rock, found between a 64.85 m depth and a 66.45 m depth, is thought to be the alteration product of basalt.

The basalt is recognized in two portions, one between a 84.00 m depth and a 84.70 m depth and the other between a 88.15 m depth and a 90.50 mm depth.

In the amphibole schist, between a 69.50 m depth and a 82.00 m depth, pyrite and chalcopyrite occur as impregnation or being accompanied by quartz veins. The copper content is 0.113% of Cu in the portion between a 69.50 m depth and a 75.00 m depth.

GSJ-10

The part between a 1.85 m depth and a 12.00 m depth consists of biotite schist, judging from slime collected therefrom.

The deeper part up to a depth of 39.95 m consists of weakly altered dolerite which is thought to have been considerably affected by weathering. The part between the 39.95 m depth and a 52.55 m depth consists of quartz schist, black schist, and graphite schist; the part between a 53.60 depth and a 70.05 m depth comprises principally graphite schist (?) which was collected in the form of dark-gray slime; the deeper part up to a 83.90 m depth is formed of green schist which is thought to originate from basic rock; the part between the 82.90 m depth and a 101.00 m depth consists of dolerite.

Aplite having intruded into various places, graphite schist that came in contact with them has occurred being accompanied by high-grade graphite, as observed between the 53.60 m depth and a 53.80 m depth. The assay for the high-grade graphite in the part between a 53.75 m depth and a 53.80 m depth is : 66.8% of fixed carbon, 7.3% of volatile matters, 24.8% of ash. 1.1% of moisture, and 5.86% of Fe_2O_3. However, this is the result of analyzing the highest-grade part of graphite; generally the quality of graphite in graphite schist is extremely small.

Summing up the above-mentioned, in Area III, the drill holes failed to catch the Bushman deposit-type copper ore, but existence of pyrite and chalcopyrite was confirmed in GSJ-9, and in GSJ-7 and 10 existence of graphite schist, though extremely small in the quantity of graphite, was confirmed. This area was found to have similar geological surroundings to that of Bushman copper deposit area.

Area IV-(1)

GSJ-11

The rock as found from GSJ-11 is formed of mica schist and mica quartz schist, except for amphibole schist in the portion between a 73.95 m depth and a 82.25 m depth.

In the amphibole schist, between a 79.35 m depth and a 81.20 m depth, small spots of native copper, about 2.0 mm in the maximum size, attached in a form of scattered spots along cracks, were recognized. According to the result of analysis, however, the copper content is as low as 0.022%.

GSJ-12

The rock consists of mica schist, mica quartz schist, quartzite, and green schist containing biotite and muscovite. Aplite and quartz veins too were found to have intruded.

No mineralization is found in this hole.

GSJ-13

The GSJ-13 is mainly formed of mica schist, mica quartz schist, and biotite amphibole schist. The schist between a 55.45 m depth and a 87.70 m depth contains a very small quantity of graphite (?). The mica schist between the 55.45 m depth and a 100.30 m depth is impregnated with a very small quantity of pyrite.

GSJ-14

The rock between a 1.50 depth and a 54.35 m depth is mica schist and mica quartz schist, and the deeper part up to a 100.00 m depth is formed of muscovite quartz schist, biotite schist, and quartzite.

In this part, pyrite is impregnated for the most part, while in some part it is widely scattered accompanied by quartz veinlets. According to the result of analysis, however, the maximum Cu content is 0.08% and copper scarcely occurs.

GSJ-15

The rock is formed of mica schist. In the rock of this hole an extremely fine (less than 1 mm in size) nonmagnetic, black mineral is extensively contained, though very little in quantity. But it could not be confirmed whether this is graphite or not. No mineralization is found in this hole.

Summing up the above-mentioned, holes of a favorable result from the drilling in this area were anticipated because there are mineralized floats, though not so close to the geophysical and geochemical anomalies, and also there are mineral indications in an area to the northwest of this area (X3.50, Y1.75). The result, however, was just to confirm a little native copper in GSJ-11 and fairly extensive impregnation of pyrite in GSJ-13 and 14. One of the reasons for it will be that since the network in the geochemical sampling in the 2nd year was a corse grid, 500 m by 500 m for one unit and 500 m x 250 m in a fine grid part, the mineralization areas were not narrowed down enough. However, the survey team was able to obtain the basic data of this area, which has the second highest potentiality after Area II.

Area IV-(2)

GSJ-16

The geology in the upper extent is formed of rock which has been intensely turned into calcrete from the surface and whose original rock is unknown, followed by a pegmatite part, and then fresh dolerite in the portion between a 8.40 m depth and a 41.75 m depth. This rock has well-developed vertical cracks which caused frequent jamming of the strings during the drilling work. The part between the 41.75 m depth and a 49.70 m depth is an aggregate of garnet, epidote, chlorite, talc, and carbonate minerals; it is greenish and feels greasy. In this extent, an about 1 m length of the top includes small quantities of muscovite, biotite and yellow-brown garnet, and as the depth becomes lower there are more talc and carbonate minerals. This rock is in direct contact with dolerite on its top side, and on its bottom side, at the 49.70 m depth, gradually changes into muscovite schist. Between the 49.70 m depth and a 70.50 m depth there is muscovite schist, out of which the 49.70 to 55.25 m part has more chlorite, epidote and hornblends than that of the 55.25 to 70.50 m. The part between the 70.50 m depth and a 92.20 m depth is talc carbonate rock, which feels greasy and is complexly tinged with mixtures of red, pink, white, brown, and others.

This rock, viewed broadly, comprises a part rich in carbonate minerals and another part rich in chlorite, epidote, amphibole, mica and talc. In both parts the minerals contained are almost the same, differing only in the ratio of their quantities. The part between the 92.20 m depth and a 100.20 m depth is formed of muscovite schist and talc carbonate rock with large quantities of carbonate minerals.

In the 41.75 to 49.70 m part, bornite, chalcocite, chalcopyrite, pyrite and malachite are recognized; the copper content is 0.564%, 0.162%, 0.103% and 0.172% respectively in the widths, from the upper to lower, of 0.65 m, 2.6 m, 2.5 m and 2.2 m. This copper is presumed to be originating from basalt.

GSJ-17

The rock of the part between a 1.60 m depth and a 23.10 m depth and the part between a 34.80 m depth and a 61.00 m depth is fresh dolerite, which has many vertical cracks that caused jamming of the strings during the drilling work. The portion lying between these two upper and lower layers of dolerite, that is, the portion between the 23.10 m dpeth and the 34.80 m depth has dolerite in the middle, the surroundings of which is altered rock rich in biotite and quartz (deriving from basalt), and the outsides of the latter are formed of aplite which has intensely replaced basalt. In the lower aplite part, particularly between a 32.40 m depth and a 33.40 m depth, garnet, epidote and diopside are formed.

In the part between a 30.50 m depth and the 34.80 m depth recognized are chalcocite, bornite, chalcopyrite and pyrite in the form of small spots, and malachite in the form of films along cracks; the copper content is 0.025%, 0.620% and 0.111% respectively in the widths, from the upper to lower, of 1.9 m, 1.0 m and 1.4 m.

The rock of the part between the 61.00 m depth and a 100.80 m depth is formed of biotite-talc-carbonate rock and biotite schist containing talc and carbonate minerals. Such rock too is considered, for a fairly large part, to have altered from basalt. In the part between a 64.0 m depth and a 66.0 m depth very small quantities of pyrite and chalcopyrite are recognized, with the copper content of 0.021%.

Now, summing up the above-mentioned result, the mineralization is considered as follows:

The part below the green copper which is observed in the rock containing garnet and diopside, as seen in the trench on the east side of GSJ-16, was unable to be confirmed because a dolerite dyke cuts the part, so that GSJ-17 was drilled.

Fig. 3 Isomag map around GSJ-16,17

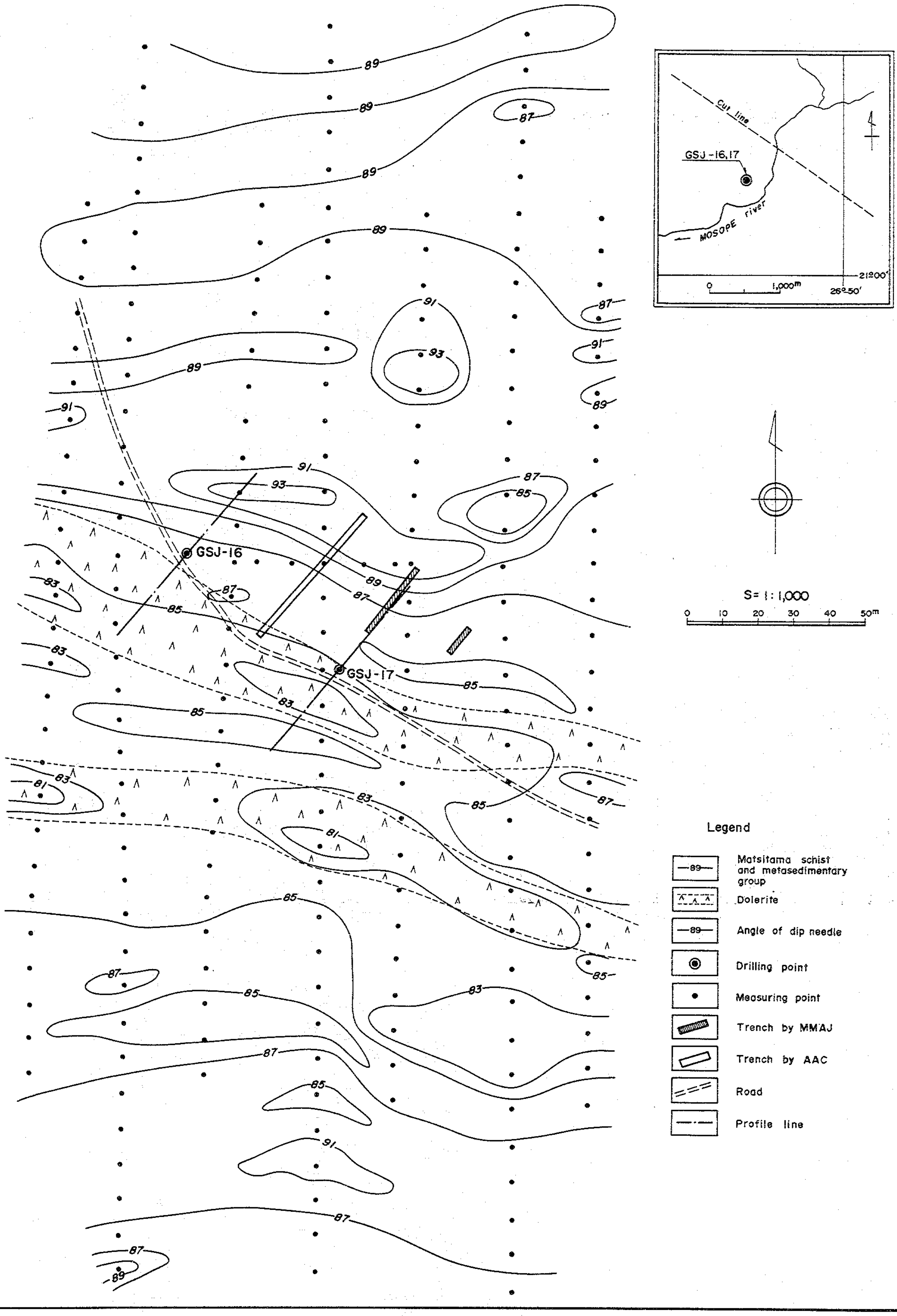


Fig. 4 Geological profile of drilling

(Copper area)

Fig. 4-1 (GSJ-4, GSJ-5)

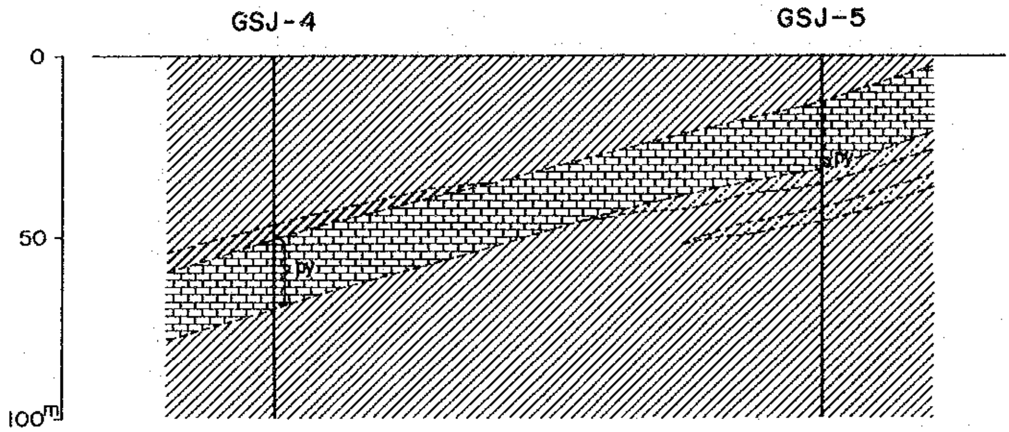
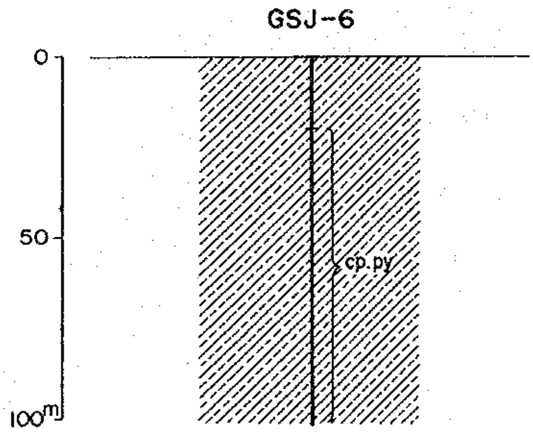


Fig. 4-2 (GSJ-6)



LEGEND

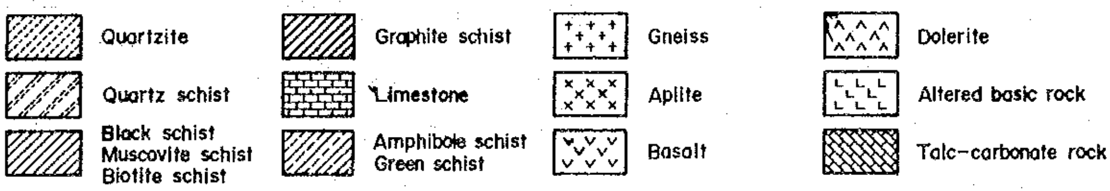


Fig. 4-3 (GSJ-7)

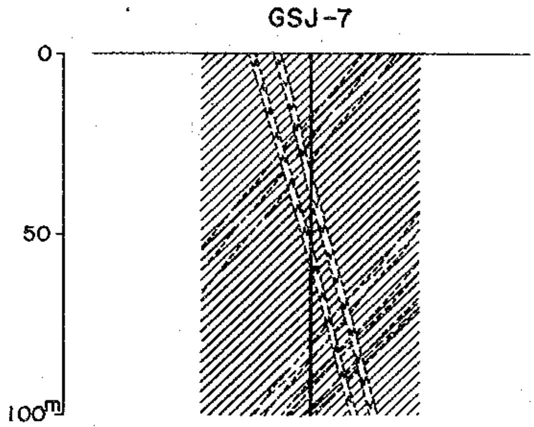


Fig. 4-4 (GSJ-8)

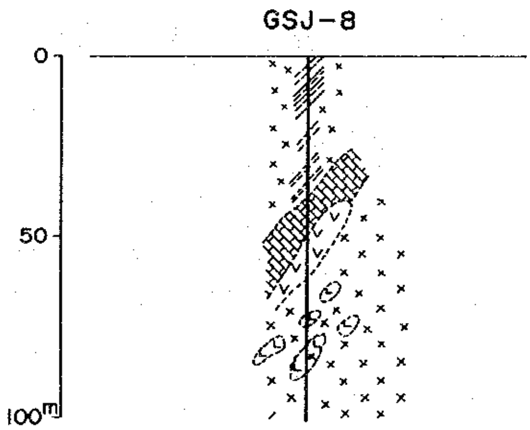


Fig. 4-5 (GSJ-9)

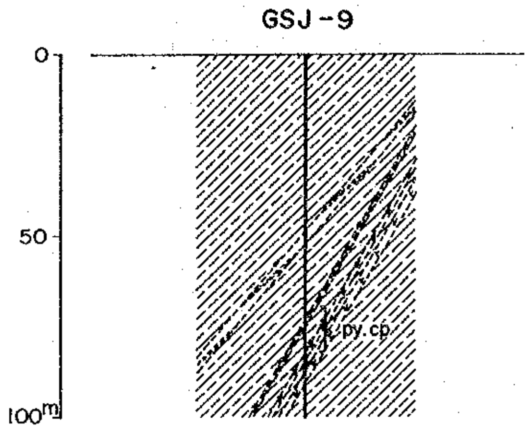


Fig. 4-6 (GSJ-10)

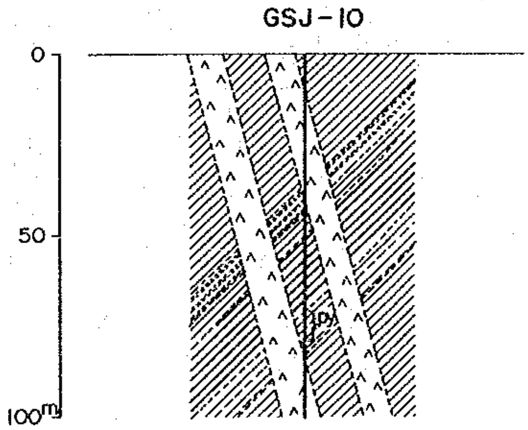


Fig. 4-7 (GSJ-11, GSJ-12)

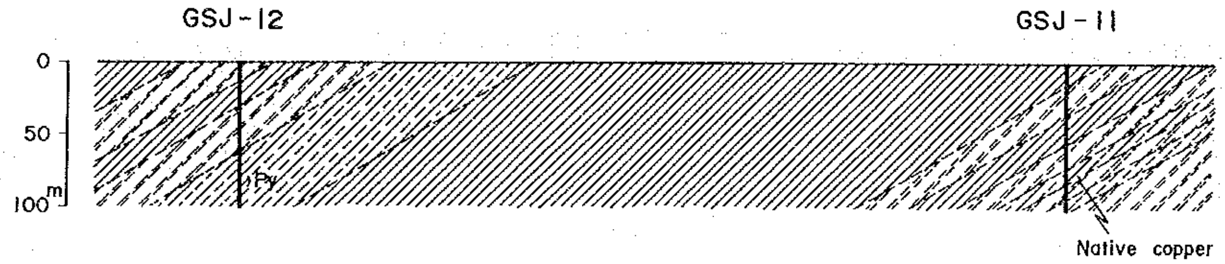


Fig. 4-8 (GSJ-13, GSJ-14)

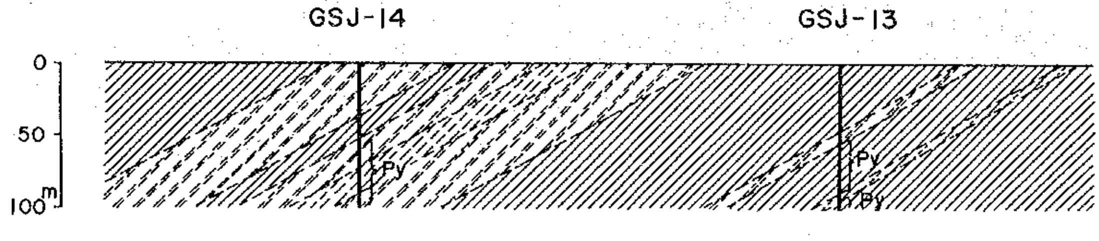


Fig. 4-9 (GSJ-15)

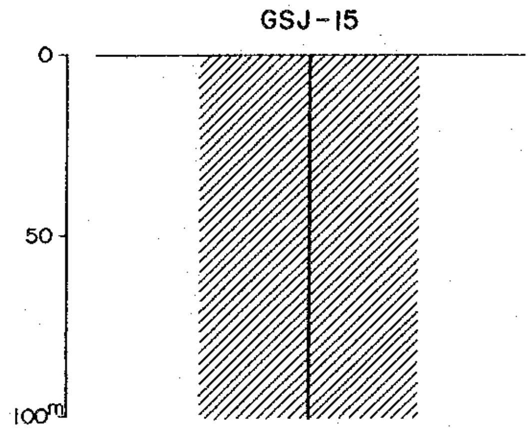


Fig. 4-10 (GSJ-16)

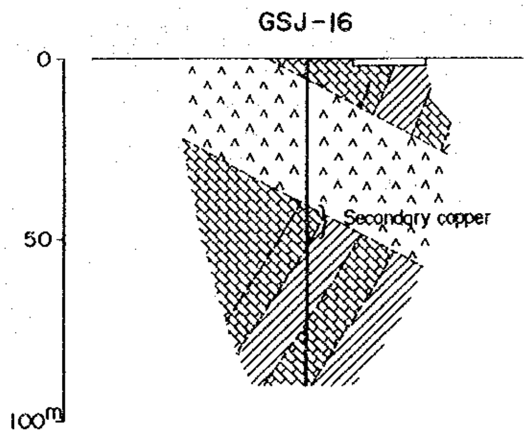
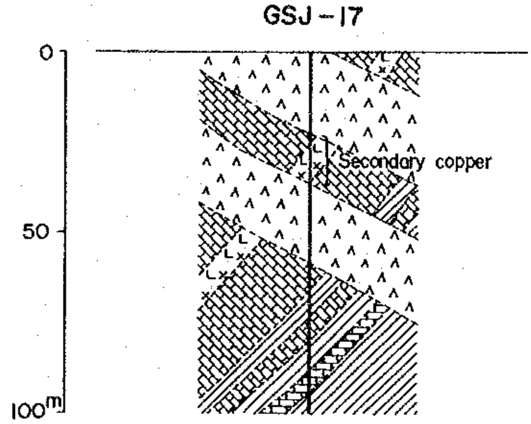


Fig. 4 - 11 (GSJ - 17)



Study of the result of the drilling of there two holes, however, leads one to the assumption that the copper minerals found by the two drill holes as well as the ones seen in the trench are the copper in basalt that has been extracted and redeposited. If this assumption should be right, this mineralization is judged to be of a small scale.

After the drilling of GSJ-16, a handy magnetic survey was made by the method described in II-3 to find the conditions of existence of the dolerite. The result is shown in Fig. 3. From this figure the dolerite is presumed to have intruded in a gentle, eastward inclination as shown in Fig. 4.

I-4 Geochemical Survey

I-4-1 Purpose of Survey

As the result of the soil geochemical survey in the 2nd year an anomaly area in the southwest of the survey area was found to be the most promising area, since it included class A anomalies with the maximum value of Cu 560 ppm and on the surface too floats containing copper minerals were discovered at several places.

Since this anomaly area was expected to extend further west, it was decided that following the geochemical survey in the 2nd year a soil geochemical survey should be made, in parallel with a geological survey, on an area of 2 by 6 km contiguous to the southwest side of the said prospecting area, to narrow down the extent of prospecting.

In addition to the above, since copper indications were found also in an area along Survey Line M-3, which was included in the 1980 survey, complementary soil sampling was made there.

The indicative elements were decided to be Cu, Pb and Zn, and the sampling, chemical analysis, the analysis of the data, and other work were made all following the methods in the 2nd year survey.

I-4-2 Sampling

Sampling was made along survey lines laid out on a grid pattern, in parallel with the geological survey.

Survey lines were set at 500 m intervals. At the survey lines handy surveying was made using a compass and a 100 m measuring tape, and while confirming the positions on the topographical map the soil sampling was carried out. The sampling was made at 250 m intervals as a rule.

In the sampling, soil was collected from horizon B, 30 cm below the surface in principle, and about 50 g of soil under a 80 mesh sieve was taken as a sample.

The number of samples was 183 in total, out of which 82 samples were collected from along survey line M-3.

I-4-3 Method of Analysis

The analysis was made by the method of atomic absorption spectroscopy. The outline of the analysis procedure is as follows:

After adding 40 ml of hydrochloric acid and 15 ml of nitric acid to 10 g of a sample, it is heated until attaining dryness and hardening through evaporation. It is let to cool and then 10 ml of hydrochloric acid is added; it is reheated and dissolved. This is diluted to a quantity of 100 ml with water. The filtrate is subjected to quantitative determination by atomic absorption spectroscopy. The wavelength lines of the analysis lines are: 3,247 Å for Cu, 2,170 Å for Pb and 2,139 Å for Zn.

I-4-4 Analysis of Data

In the 2nd year, the chemical analysis data were statistically processed with a computer, and monovariant analysis and multivariant analysis were made.

For the analysis for this year, since the number of samples is only about 1/13 of the one for the preceding year and also the sampling are is adjacent to the one in 1980, it is not conceivable that any remakably different tendency should be displayed.

Consequently, in processing the data for this year, it was decided that the new data should be only added to the ones of the preceding year and that the factors used for analysis in the same year should be employed as they were.

(1) Monovariant Analysis

In the 2nd year, a frequency histogram and a cumulative frequency distribution chart for each of the analyzed elements were prepared for the analytical values of Cu, Pb and Zn of the collected 1,363 samples, and a graphical analysis of the threshold values, background values and standard deviations of geochemical anomalies was made. The work for this year followed the classification of element density levels obtained as above-mentioned, which is shown below.

Table 3. Class Limits of Cu, Pb, Zn Content Distribution (ppm)

Class / Element	Back ground				Anomaly	
	F	E	D	C	B	A
Cu	10	18	32	60	108	
Pb		4	6	9	15	
Zn	18	24	32	43	58	

(2) Multivariant Analysis

As in the preceding year, the method of principal component analysis was used. What is sought in this numerical processing is numerical values called factor scores, which are considered the means to express collectively the results of analysis of the three components. As the first stage of the calculation procedure, correlative coefficients between the components are obtained, and from these a factor load matrix is calculated; from the load matrixes the factors of I and the rest are determined in the order of closer correlation. In the second stage, the factor score of each sample for each factor is calculated to produce the result of the principal component method. Becuase the number of the collected samples was small for this time, instead of newly calculating factor load matrixes in the first stage, the factor load matrixes for the preceding year were used as they were, and calculation for the second stage alone was made for Factor I, putting the results into a chart in the form of adding Factor I scores. In the classification of the levels of factor scores, as in the preceding case, the threshold value was set at 1.0, values in excess of it being taken as anomaly values and those below as background values. The anomaly values of 1.5 and over were classified as class A while those less than 1.5 as class B.

I-4-5 Interpretation of Result

A content distribution map for each element was prepared on the basis of the element density levels mentioned in the preceding section. (PL 7, 8, 9)

The geochemical anomalies for each element as picked up from these maps are described as follows:

As for copper anomalies, anomalies of class B extend in a belt shape from the 1980 survey area to the 1981 survey area on the west side of the former, and an anomaly of class A (Cu 423 ppm) was seen at the point of X: 2.01, Y: 3.25.

As for lead, the content is low on the whole and there were no distinct anomalies.

As for zinc, high content of it was observed generally, and anomalies of class A were recognized extensively in the southern half.

According to the Z_1 score distribution map (PL-10), the class B anomaly area including class A anomaly areas covers widely southern half of the geochemical survey area.

Class A anomaly areas are arranged in NW-SE trend and distributed comformably with Matsitama schist and metasedimentary group.

As green copper floats (S-1 – S-4) were found in M-3 anomaly area in Phase III geological survey, geochemical detailed sampling was conducted to that floated area to delineate the geochemical anomaly.

Some samples are high in copper content (max. 1,020 ppm), but they are isolated from others.

Part II. Geological Survey of Chromite Deposit Area (Detailed Survey)

II-1 Introduction

In the survey of a 5,300 km^2 area in the northeast of Botswana in the first year, three mineralization areas were found, and out of these an area of 800 km^2 of the Matsitama area was picked up for the survey area in the 2nd year. As the result of the geological survey, geophysical and geochemical prospecting in the 2nd year, areas promising for occurrence of copper and chromite deposits were selected. In the 3rd year survey, a geological survey and a drilling survey were made on them.

The beginning of doing a survey for chromite deposits in this are lies in discovery of a float of chromite in the first year. In the second year survey, a group of chromite indications, A, B, C and D, was confirmed as set forth later.

In the third year, a geological survey on the surface, a handy magnetic prospecting as an auxiliary measure, a geological survey including trenching, and a drilling survey were conducted over a 4 km^2 area, 2 km in east-west direction by 2 km in north-south, centering on the above-mentioned group of indications. This area is located about 28 km to the north-northeast of Matsitama.

II-2 Geological Survey

II-2-1 Outline of Geology

This area is situated in the northeastern part on the Mosetse-Matsitama Area Geological Map (Bennett 1970). According to Bennett (1970), the geology around this area is formed of the Mosetse river gneiss group belonging to the Archean and the Matsitama schist and metasedimentary group lying above. The geology of the chromite deposits survey area is formed of the strata of the Mosetse river gneiss group, rock bodies that have intruded them, and the Recent sediment overlaying these.

Since outcrops are scarcely seen in this area, mapping and analysis were made on the basis of such little information as an extremely small number of little outcrops about 1 m in size, sparsely lying floats and the results of trenching and drilling, making full use of the results of geological analysis of aerial photos and the handy magnetic prospecting.

II-2-2 Stratigraphy

1) Mosetse River Gneiss Group

The geology of this group is formed primarily of gneiss and amphibole schist and in addition of thin layers or lenticular bodies of quartz schist quartzite and limestone.

The gneiss is rock distributed most widely; it is generally granitic paragneiss of medium to coarse grains. Locally some part contains porphyroblasts less than 7 mm in size.

The principal component minerals of the gneiss are quartz, plagioclase, potassium feldspar, muscovite, biotite and amphibole. However, since the quantities of the mafic minerals contained vary, the lithofacies change from leucocratic gneiss which hardly contain such minerals to gneiss with a great quantity of mafic minerals.

In gneiss with plenty of mafic minerals, the gneissic structure is obvious.

The quartz schist to quartzite is not entered in the geological map, being only found as floats; it is presumed to be distributed here and there in the form of thin layers. This rock is white or light-gray to dark-gray and generally fine-grained, compact and hard; it is principally composed of a large quantity of quartz and a small quantity of feldspar, containing an extremely small quantity of mica in addition. Also it is assumed that magnetite-hematite quartzite exist as thin layers or lenticular bodies, because such a float was found.

The amphibole schist is dark-green, foliated rock. On the geological map it is indicated as strata in a 100 m width, but that which can be actually confirmed on the surface is only floats sparsely lying intermittently together with calcrete and one small outcrop about 50 cm in size.

The amphibole schist has the main components of amphibole and feldspar, containing besides small quantities of epidote, chlorite and sphene. The quantity of amphibole accounts for 20 to 60% usually. It principally consists of amphibole, but is accompanied occasionally by actinolite and tremolite. It resembles amphibolite in its lithofacies of having coarse grains and poorly developed schistosity.

The limestone is white to gray, crystalline one. As it has been confirmed only as fist-size boulders, it presumably exists as little lenticular bodies or thin layers.

2) Quarternary

The Quarternary comprises pebbles, soil and calcrete. Near dykes of basalt, "black turf", characteristic black soil, often develops.

II-2-3 Igneous Rock

The igneous rock comprises ultrabasic rock, basalt and granite.

The ultrabasic rock consists of dark-green serpentinite, the rock is accompanied by chromite deposits.

As for the distribution of this rock on the surface, it is distributed in the form of several small outcrops and sparsely lying floats. The rock bodies themselves, however, are considered to be less than 30 m in width and not more than 200 m in their strike length, in view of the conditions of float distribution and the fact that as the result of the handy magnetic survey no magnetic anomalies were detected in almost all cases.

With regard to the direction of intrusion, since a NE direction has been recognized at the chromite deposits of A to F, intrusion in the NE direction has been inferred for the rock bodies other than the central part also. The central part ore body has floats distributed in an EW direction, which could be from an aggregate body in a NE direction.

The ultrabasic rock is, for the most part, strongly magnetic excluding that which has been intensely turned into talc and which has been epigenetically changed into actinolite or biotite, and in many cases magnetite is recognized on weathered surfaces in the form of scattered dots, or arrangement in some direction, or reticulately.

This rock, for the most part, has completely been altered into serpentine (serpentinite), but partly actinolite, biotite and epidote, which are epigenetic, are recognized. As the primary minerals, there are chromite and magnetite.

Basalt has no outcrops at all, but a map was prepared by making reference to only meager existence of small floats, the result of the handy magnetic survey, and the distribution of "black turf". Basalt is distributed in a NWW-SEE direction as sykes, with the maximum width of 100 m. But this dyke width has not been confirmed.

Basalts consist mainly of dolerite, subordinately of basalt and gabbro.

The basalt is strongly magnetic in the second place after the ultrabasic rock.

The rock-forming minerals are mainly pyroxene and feldspar, and in addition magnetite, chlorite and other minerals are contained.

In the kind of granite, there are pegmatite, aplite, granite and syenite. These are not found as outcrops, but are presumed to exist as small-scale dykes from sparsely distributed floats. The kind of granite is not entered in the geological map.

II-2-4 Geological Structure

Geological structure in this area is presumed as follows on the basis of the result of the survey in the 2nd year.

Geological structure in this area is presumed to be between a synclinorium to the north of the area and an anticlinorium to the south, dipping to the west as a whole.

II-2-5 Ore Deposit

Chromite accompanies strongly magnetic ultrabasic rock containing serpentinite and magnetite. This ultrabasic rock is distributed in the form of small rock bodies in strata of gneiss and other rocks.

Chromite in this area exists only as a small number of outcrops and floats sporadically observed, out of which the most sizable one is a mineral indication area to the north of the Lepashe river. Confirmed by the 2nd year survey, this is formed of a group of several outcrops scattered over an area of 100 m by 50 m, which has been divided into the four deposits of A, B, C and D, being named from the east side (MMAJ report in 1980).

Deposit A is observed as several small outcrops of chromite at the northern end of ultrabasic rocks, distributed in an extent of 10 m by 6 m.

Deposit B is formed of outcrops of massive chromite distributed over an lenticular shape, extending in a NE direction within an area of 20 m x 6 m. At the western end there is an outcrop of ultrabasic rock in an area of 7 m by 3 m. Also, about 7 m to the north of this mineral indication, ultrabasic rock is distributed on a scale of 12 m by 7 m.

Deposit C lies several meters apart from Deposit B on its NE side extension, being formed of outcrops and floats scattered in an area of 25 m by 15 m. The strike is assumed to be in a NE direction from the disposition of the outcrops.

Deposit D, situated about 40 m away in a NE direction from deposit C, is distributed in an oval shape extending north to south with the size of 15 m by 8 m. About 10 m apart from it, there is an outcrop of ultrabasic rock 2 m by 3 m in size.

Besides these outcrops, as the result of the survey in 1981, a comparatively sizable chromite outcrop was confirmed at the point of X 4.6, Y 23.3 in the southwest of the survey area. This is a small ore body of chromite in a lenticular shape, interposed between ultrabasic rock which is widely distributed over an area 100 m by 30 m; it has been divided into two deposits of E and F from the outcrop distribution.

Deposit E is a continual one, but is separated into a body 0.5 m in width and 3 m in length and another 0.5 m in width and 6 m in length; it has a strike of N60°E and a dip of 85°N.

Deposit F, lying about 3 m to the north of Indication E, is distributed in a size of 1 m in width and 10 m in length; it has a strike of N60°E and a dip of 50°N.

Both the deposits of E and F have intensely magnetic parts on their hanging wall side.

At a place about 50 m to the west of deposit F also, a small outcrop of intensely magnetic chromite is observed in a size of 30 cm and 3 m in length.

In addition, chromite indications are sporadically found as small floats, at several places in the survey area, but name of them is of a sizable one.

All of the chromite is black, hard, massive ore and its ore grade is: in deposit B 31.5 to 35.1% of Cr_2O_3 and 16.8 to 17.7% of T.Fe, in deposit C 35.3 to 36.1% of Cr_2O_3 and 18.0 to 19.2% of T.Fe, in deposit D 34.2 to 38.4% of Cr_2O_3 and 18.1 to 19.3% of T.Fe, and in deposit E and F 30.1 to 32.6% of Cr_2O_3 and 18.5 to 21.0% of T.Fe.

It is difficult to know the size of ore bodies and their relations with the geological structure only from the conditions of chromite distribution over the surface, but these mineral indications are inferred as follows by consideration into which the results of trenching and drilling stated hereinafter are also taken.

From the result of the trenching, it has been found that the part from the surface to a 1 to 1.5 m depth is a top layer part, formed of gravels, soil and so forth. Since chromite is spread as floats on the tops of one bodies, what seemed a chromite outcrop has often turned out to be gravel in the top layer, so that the real scales of ore bodies are very small as compared with the distribution of floats over the surface.

The size of the ore bodies is inferred to be in the range of 0.5 to 1 m in thickness and 5 to 10 m in length. An ore body which is seen in trenches T-3 and T-4 in deposit B presents a relatively distinct strike and dip, and the drill hole of GSJ-2, which was aimed at its downward extension, found four layers of ore body. However, the four are considered to be separate ore bodies in view of their depth. These chromite ore bodies have no definite orientation. They have been controlled by the minor structure of the country rock, ultrabasic rocks, to be oriented in various directions, and also their shapes are inferred to be lenticular or pod-like. This means that the survey has allowed the team to grasp only part of the total ore bodies, and occurrence of other similar ore bodies is anticipated.

On the other hand, as for the country rock, ultrabasic rocks, its small bodies are interposed between gneiss or schist, but there are only few outcrops of them and their shape, structure and other matters are unclear. Out of such outcrops, it is in deposit A and D and also E and F that some sizable ones can be seen, and only little of small outcrops and floats are found in other parts. As for the extent of their distribution area, they are scattered in a NE-SW direction on the whole, and the individual outcrops are also distributed in the same direction in many cases.

Also, below GSJ-1 and 2 there is gneiss. As for the surroundings of these drilling points, from the distribution of gneiss on the surface, its boundaries with ultrabasic rock are presumed to dip east (Fig. 7). Accordingly, from a broad point of view, it is presumed that ultrabasic rocks are interposed between gneiss in a NE-SW trend and that chromite ore bodies also are concordant with the trend.

II-2-6 Trenching

Since, although the extent of chromite ore bodies is roughly estimated from the outcrops and floats of chromite scattered in a small extent, it is difficult to know clearly the strike, dip and scale of them, confirmation of the ore bodies was made by trenching in parallel with drilling.

Two to four trenches, 5 to 10 m in length, 0.7 to 0.8 m in width and 1.0 to 1.8 m in depth for one ore body, were excavated at about 5 m intervals across the ore body which was inferred from the distribution of the outcrop.

The excavation of a trench was carried out with picks and shovels by one team, composed of two workers.

The following is the findings from individual trenches.

Deposit B

T-1: The mineral indication was as wide as 3 to 4 m on the surface, and massive ore 30 to 40 cm in size was seen here and there, so it appeared as if it was part of an outcrop. However, the ultrabasic rock appeared at a 0.7 m depth, so such massive ore of chromite proved to be floats of the upper part.

T-2: At a 1.5 m depth, the thickness was 0.7 m, and the ore body should a strike of N80°E and a dip of 50°S. On the hanging wall side, another ore body without any outcrop practically disclosed itself, showing a strike of N45°E and a dip of 45°S, but at the side wall on the south side the ore is in the form of breccia. All of these are of black, massive chromite. The ore grade of the former is: 35.1% in Cr_3O_3, 17.7% in T.Fe, 12.1% in Al_2O_3, 13.6% in MgO and 9.4% in SiO_2.

T-3: At a 1.5 m depth, the thickness was 0.7 m, and the ore body showed a strike of N50°E and a dip of 50°N. This is a different ore body from the one in T-2. The ore grade here is: 33.9% in Cr_2O_3, 16.9% in T.Fe, 12.2% in Al_2O_3, 15.3% in MgO, and 9.9% in SiO_2.

T-4: As a 1.5 m depth the thickness was 0.7 m; at a 1.7 m depth, the thickness was 0.3 m. The ore body showed a strike of N55°E and a dip of 30°N, being the east side extension of the ore body in T-3. The ore grade is: 31.5% in Cr_2O_3, 16.8% in T.Fe, 10.9% in Al_2O_3, 15.1% in MgO and 11.1% in SiO_2.

Deposit C

T-5: At a 1.6 m depth, the thickness was 0.5 m. The ore body showed a strike of N27°E and a dip of 85°N.

T-6: At a 1 m depth at the side wall on the west side and at a 1.6 m depth at the side wall on the east side, the bed of ultrabasic rock appeared. This is possibly the end of a pod-shaped ore body dipping from west to east. The extension of the ore body in T-5 was unable to be confirmed. The ore grade here is: 35.3% in Cr_2O_3, 19.2% in T.Fe, 13.1% in Al_2O_3, 11.3% in MgO and 7.8% in SiO_2.

T-7: At a 1.7 m depth the ultrabasic rock appeared. It is chromite in the form of breccia.

T-8: At a 1.7 m depth the thickness was 0.7 m, the ore body showing a strike of N55°E and a dip of 50°N. The ore grade is: 36.1% in Cr_2O_3, 18.0% in T.Fe, 13.1% in Al_2O_3, 12.0% in MgO, and 7.5% in SiO_2.

T-9: At a 1.6 m depth the thickness was 0.2 m, the ore body showing a strike of N50°E and a dip of 60°N. This is presumed to be a different ore body from the one in T-8.

Deposit D

T-10: At a 1.4 m depth at the side wall on the south side and at a 1.8 m depth at the side wall on the north side wall, the ultrabasic rock of the foot wall and weathered gneiss appeared. These are possibly the end of a pod-shaped ore body dipping from south to north. The ore grade is: 38.4% in Cr_2O_3, 18.1% in T.Fe, 13.0% in Al_2O_3, 12.2% in MgO and 6.5% in SiO_2.

T-11: At a 1.7 m depth the thickness was 1.6 m, the ore body showing a strike of N10°W and a dip of 50°E. The ore grade is: 35.8% in Cr_2O_3, 19.3% in T.Fe, 11.7% in Al_2O_3, 12.5% in MgO and 7.9% in SiO_2.

T-12: At a 1.8 m depth the thickness was 1.7 m, the ore body showing a strike of N50°W and a dip of 50°S. Since it is quite differently oriented from the ore body in T-11, it is considered to be a different ore body. It is not clearly known what shape these ore bodies take. The ore grade is: 34.2% in Cr_2O_3, 18.6% in T.Fe, 12.2% in Al_2O_3, 13.5% in MgO and 8.9% in SiO_2.

Fig. 5-1 Occurrence of chromite deposits (A,B,C,D)

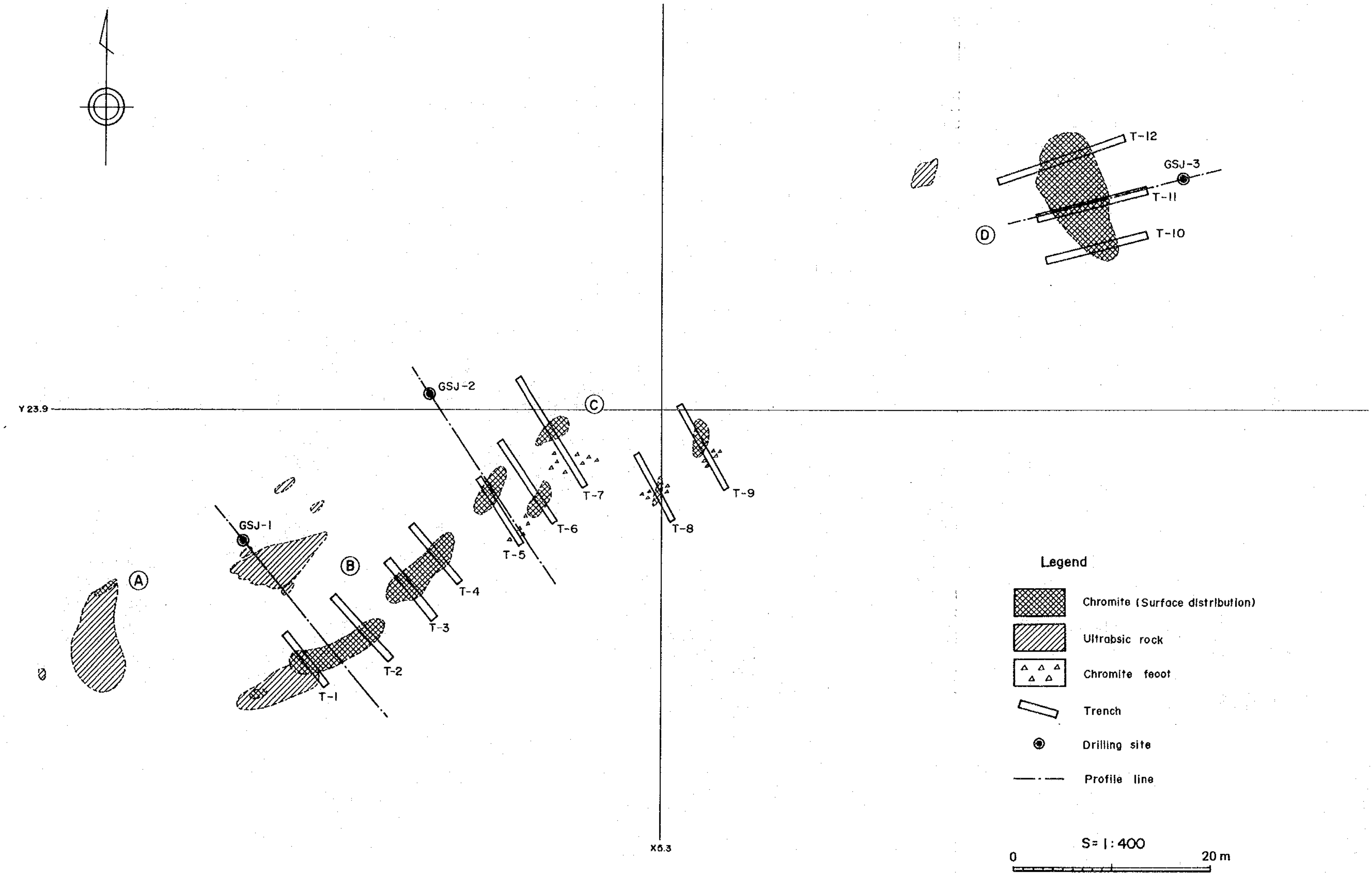


Fig. 5-2 Occurrence of chromite deposits (E, F)

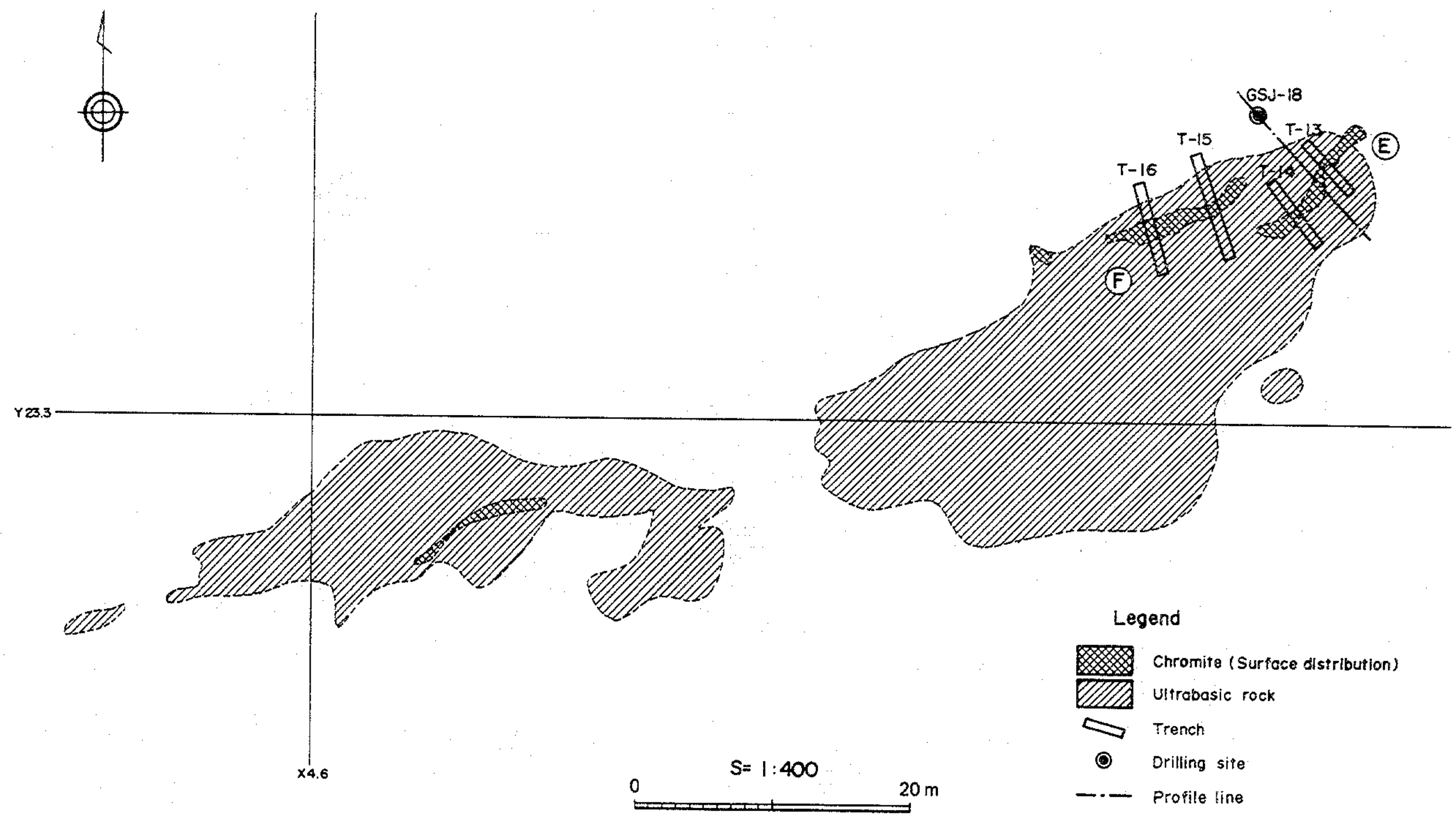


Fig.6 Geological sketch of trench

Fig.6-1 T-1

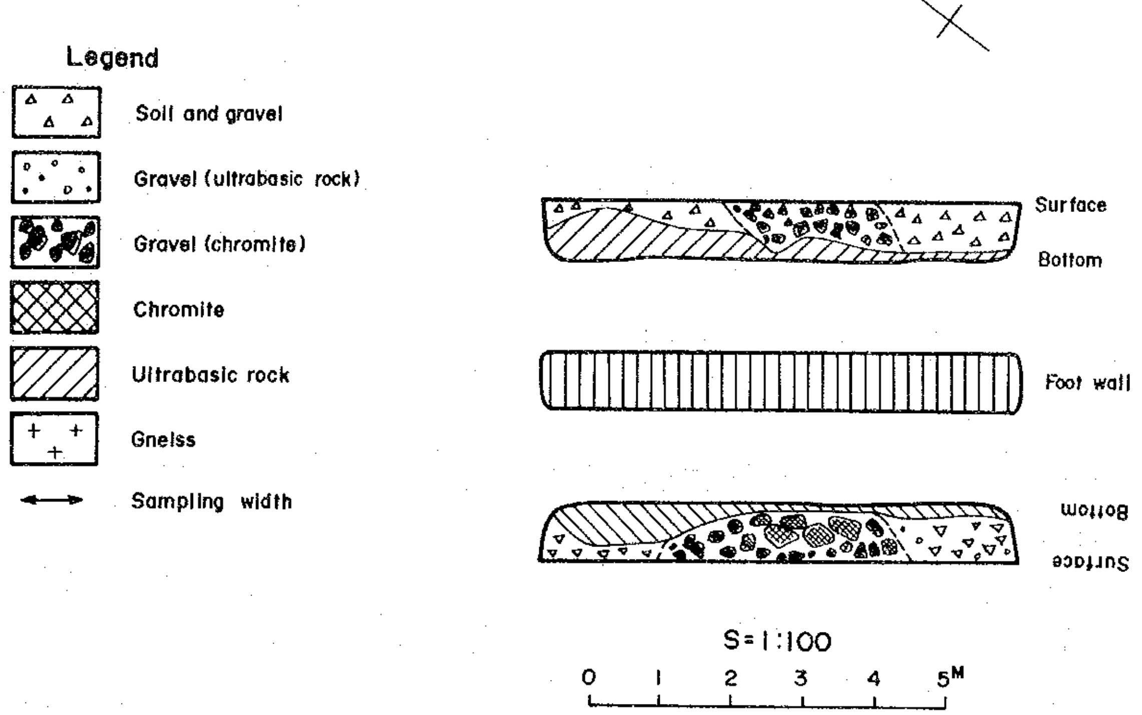
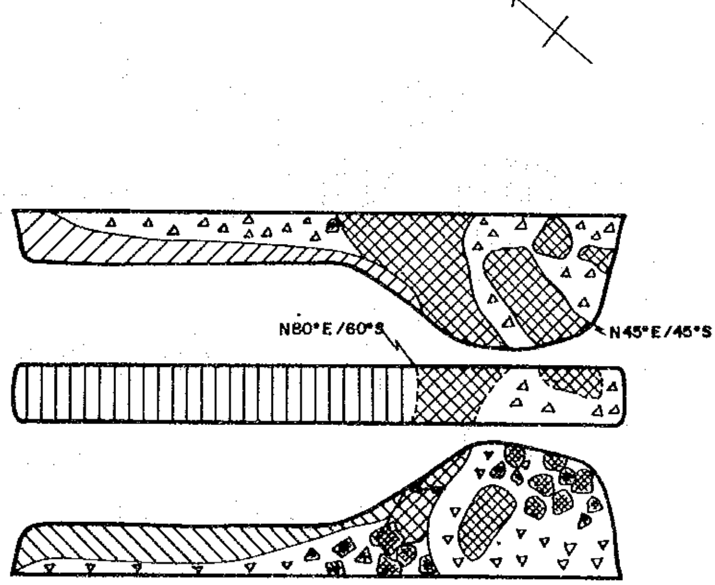


Fig.6-2 T-2

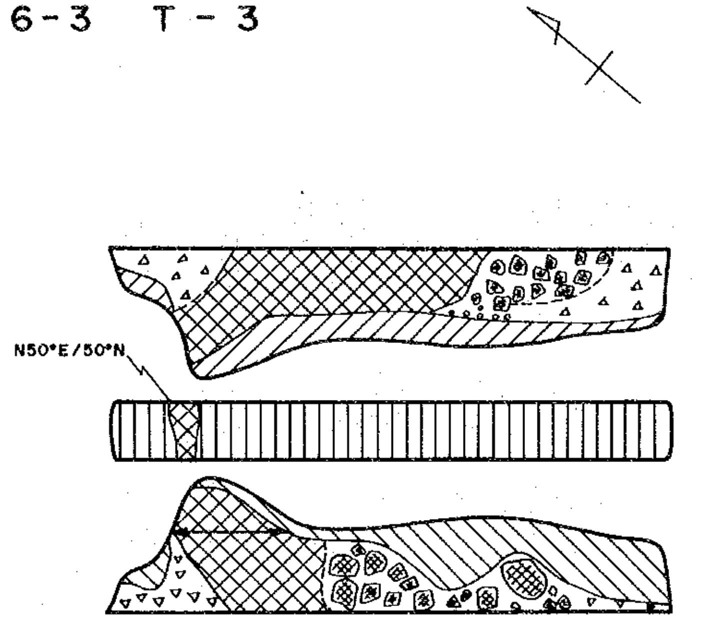


Sample No.	width	Cr_2O_3	T.Fe	Al_2O_3	Mgo	SiO_2
S-37	0.60M	35.1%	17.7%	12.1%	13.6%	9.4%

S=1:100

0 1 2 3 4 5M

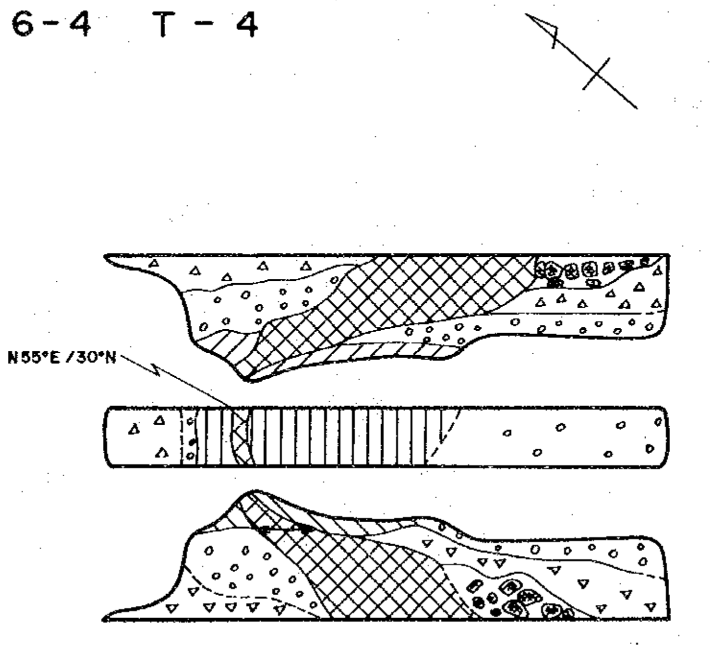
Fig 6-3 T - 3



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	MgO	SiO_2
S-38	1.50M	33.9%	16.9%	12.2%	15.3%	9.9%

S=1:100

Fig. 6-4 T - 4



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	MgO	SiO_2
S-39	0.80M	31.5%	16.8%	10.9%	15.1%	11.1%

S=1:100

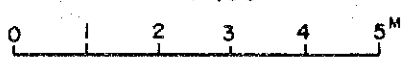


Fig.6-5 T-5

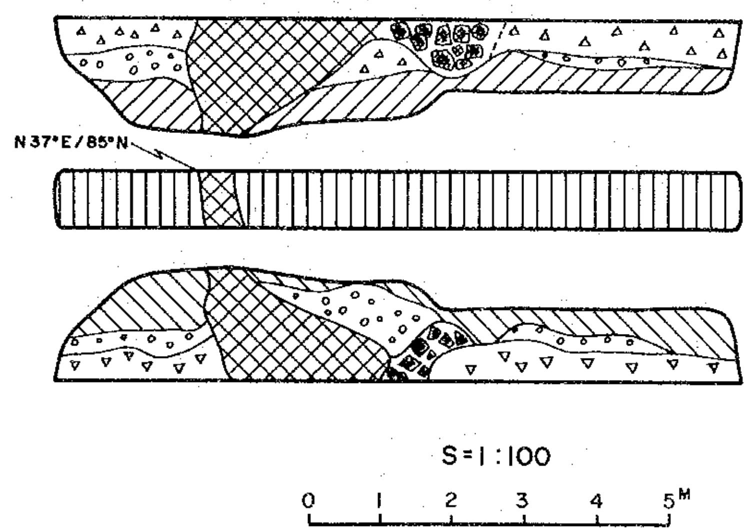
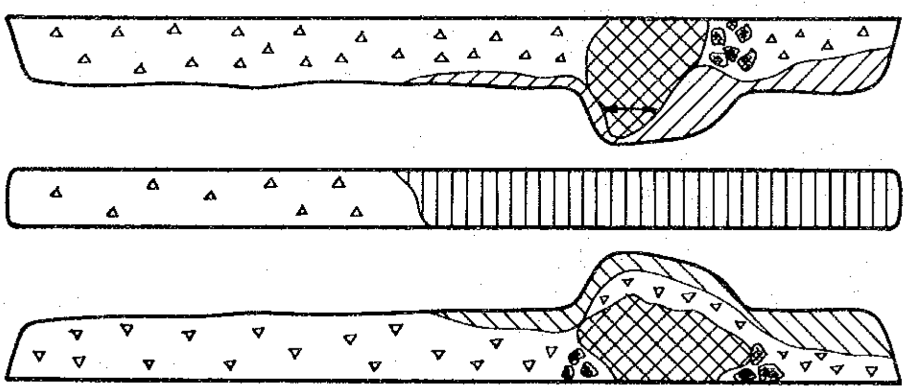


Fig.6-6 T-6



Sample No.	width	Cr_2O_3	T.Fe	Al_2O_3	MgO	SiO_2
S-40	0.80m	35.3%	19.2%	13.1%	11.3%	7.8%

S=1:100

0 1 2 3 4 5M

Fig. 6-7 T - 7

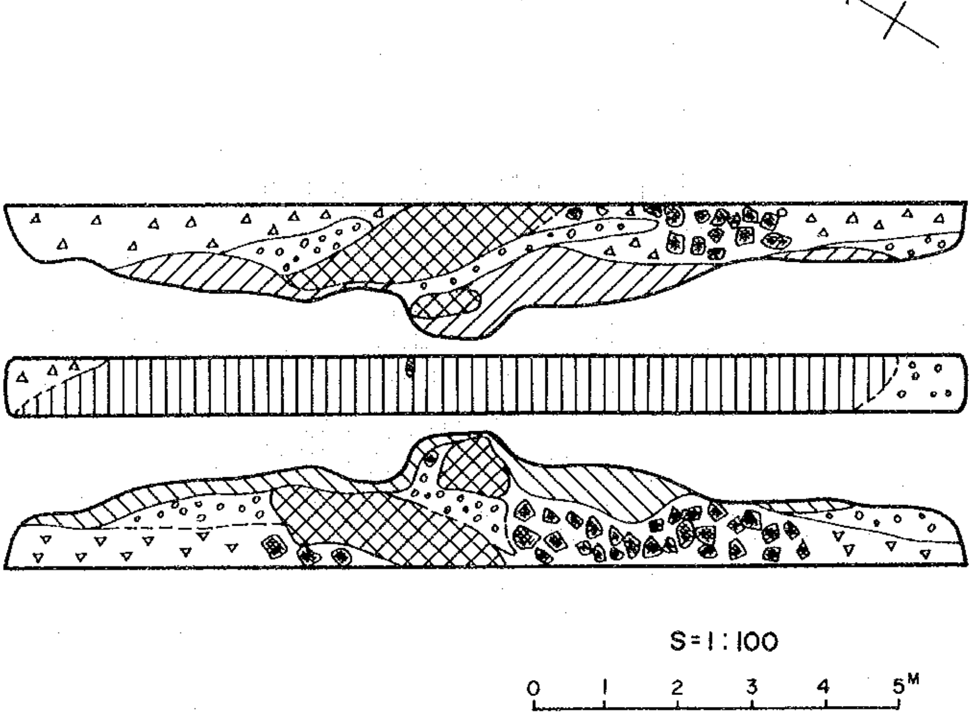
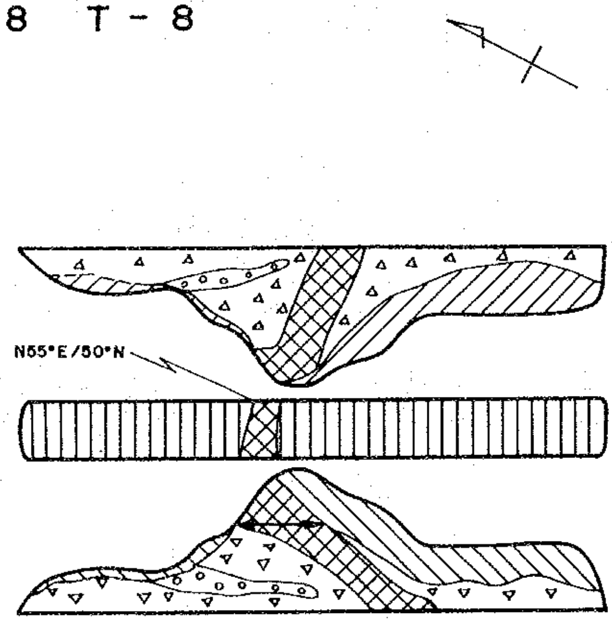


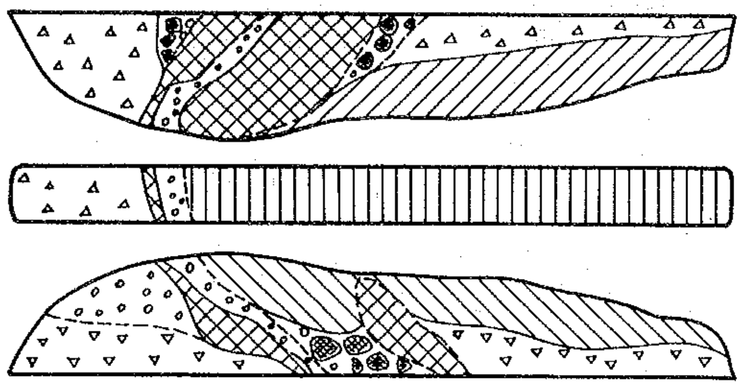
Fig. 6-8 T - 8



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	Mgo	Sio$_2$
S-41	1.00m	36.1%	18.0%	13.1%	12.0%	7.5%

S=1:100
0 1 2 3 4 5M

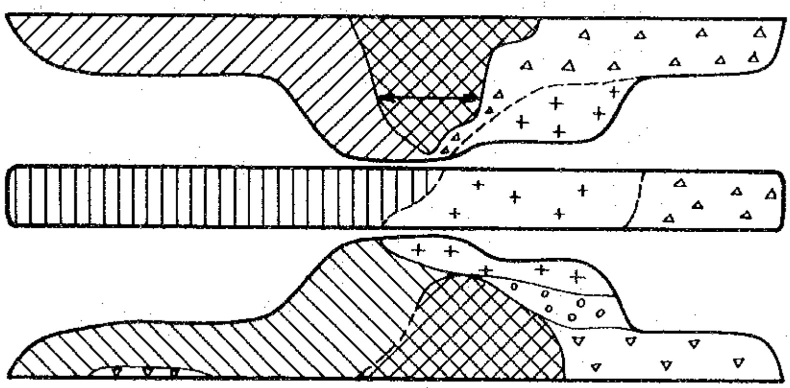
Fig.6-9 T-9



S=1:100

0 1 2 3 4 5 M

Fig.6-10 T-10

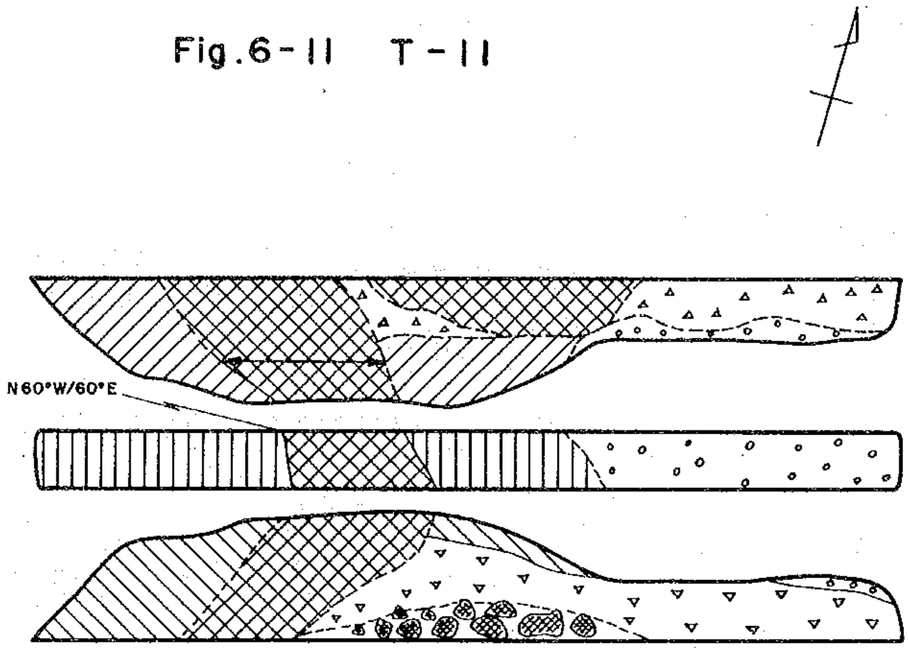


Sample No.	width	Cr_2O_3	T.Fe	Al_2O_3	Mgo	SiO_2
S-42	1.40 M	38.4 %	18.1 %	13.0 %	12.2 %	6.5 %

S=1:100

0 1 2 3 4 5 M

Fig. 6-11 T-11

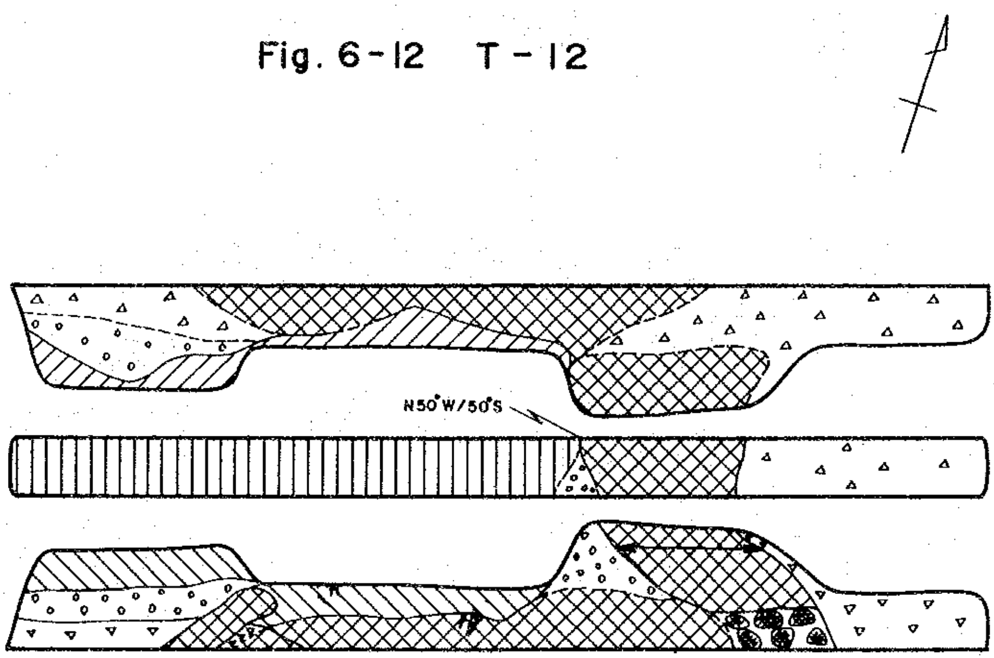


Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	Mgo	SiO_2
S-43	2.20m	35.8%	19.3%	11.7%	12.5%	7.9%

S=1:100

0 1 2 3 4 5M

Fig. 6-12 T-12



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	Mgo	SiO_2
S-44	2.00m	34.2%	18.6%	12.2%	13.5%	8.9%

S=1:100

0 1 2 3 4 5M

Fig. 6 - 13 T - 13

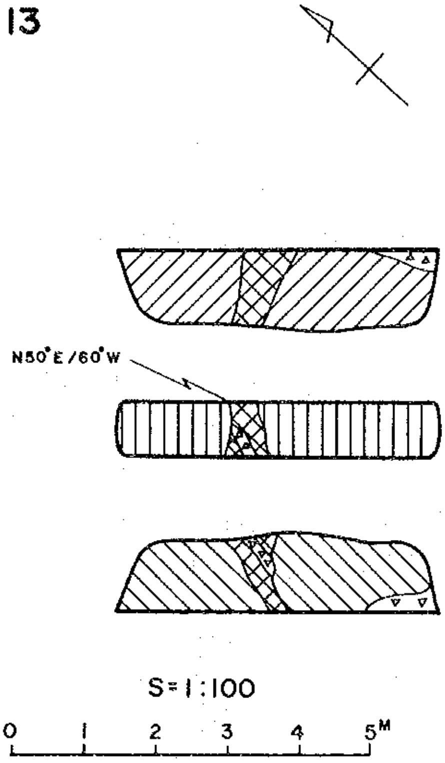
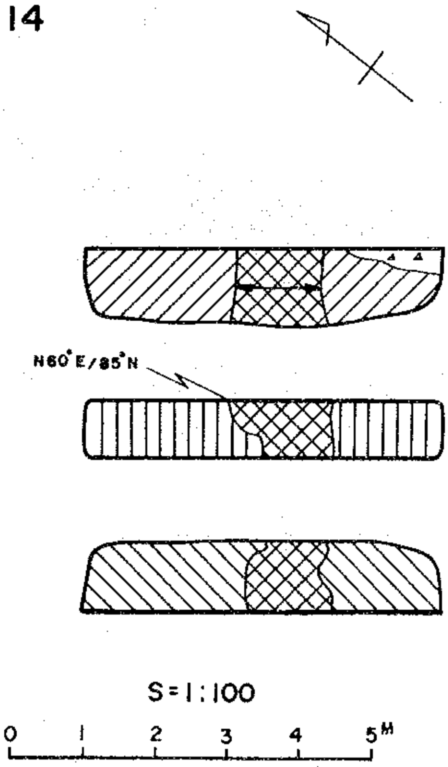
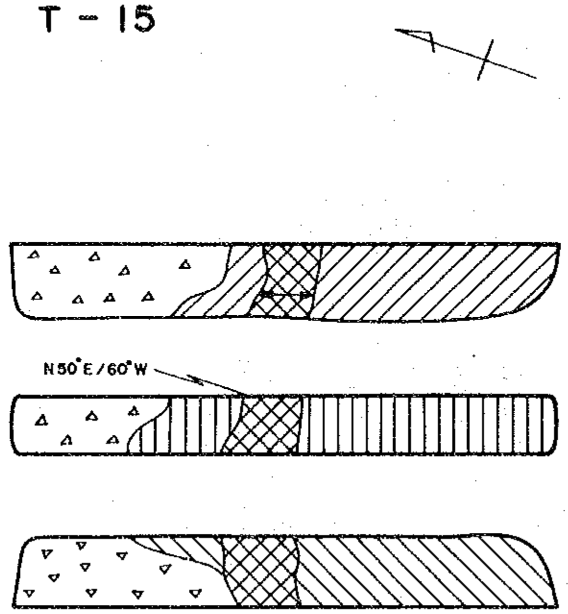


Fig. 6 - 14 T - 14



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	Mgo	SiO_2
S-45	1.20M	32.6%	18.5%	12.2%	13.9%	9.6%

Fig. 6-15 T - 15



Sample No.	width	Cr_2O_3	T. Fe	Al_2O_3	MgO	SiO_2
S-46	0.70m	30.1%	21.0%	10.8%	13.9%	10.6%

S=1:100

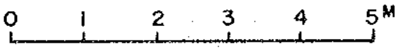
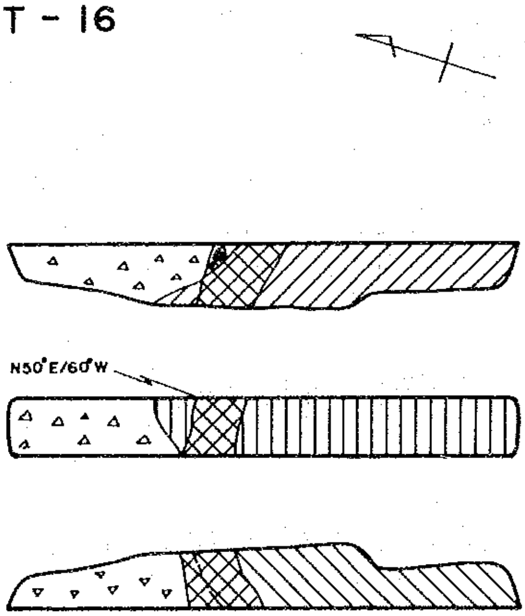
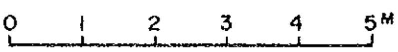


Fig. 6-16 T - 16



S=1:100



Deposit E and F

Here is hardly any top layer earth, and the outcrops show the shape of the ore bodies comparatively clearly. All the ore bodies have a part where strong magnetism is found on their hanging wall side.

T-13: The ore body has a 0.75 m thickness, showing a strike of N50°E and a dip of 60°W.

T-14: This is the extension of the ore body in T-13 on its outh side. It has a 1.2 m thickness, showing a strike of N60°E and a dip of 85°N. The ore grade is: 32.6% in Cr_2O_3, 18.5% in T.Fe, 12.2% in Al_2O_3, 13.9% in MgO and 9.6% in SiO_2.

T-15: This ore body has a 0.7 m thickness, showing a strike of N50°E and a dip of 60°W. The ore grade is: 30.1% in Cr_2O_3, 21.0% in T.Fe, 10.8% in Al_2O_3, 13.9% in MgO and 10.6% in SiO_2.

T-16: This is the extension of the ore body in T-15 on its west side. It has a 0.9 m thickness, showing astrike of N50°E and a dip of 60°W.

II-3 Handy Magnetic Prospecting

II-3-1 Purpose of Prospecting

Since in this area the surface provides hardly any geological information, a magnetic prospecting as the measures to obtain some geological information was carried out, to make use of it as an auxiliary step. The magnetic prospecting was made because it was considered that this would enable the survey team to follow up the intensely magnetic ultrabasic rock and basalt as they are distributed in this area. Among various kinds of measuring instruments for a magnetic prospecting, a dip needle instrument was adopted because a light and handy one was suitable as the purpose was auxiliary measures for the geological survey.

Consequently, it was not a regular magnetic prospecting, nor a high degree of precision was produced in the prospecting data, but some clue to the comprehension of the abovementioned distribution of rocks was acquired.

II-3-2 Method of Prospecting

The prospecting was carried out in parallel with the geological survey over an area of 4 km^2, 2 km east-west and 2 km north-south.

Using a handy compass and measuring tape, survey lines running in the north-south direction were laid out at 100 m intervals, and the survey points were set with the spacing of 100 m as a rule, and 50 m and 25 m as required. Also complementary survey points were set at necessity on the base lines in the east-west direction for the purpose of correction of positions.

The measuring instrument used was Sharp D-2, Dip Needle by Geophysical Instrument & Supply Co., and the magnetic measurement was made on 875 points in total.

In the execution of the prospecting a point (X6.4, Y12.0) laid in the camp site, was made the base point. At the base point the magnetic needle was set so that it might stand still when released at a point near the horizontal (89.5°). Every time before starting the survey and after finishing it, measurement was made five times, and the mean values were made the measured values before and after the survey at the base point on the day. As the result, the difference of the values between before and after the survey at the base point on the day remained within 2°.

At each survey point the value was read three times in repetition, and the mean value was taken as the measured value at the point. When, at 20 survey points out of points of 875, measurement was made at the same point on different days, the dispersion of the mean values at those times came up to 3.5° at maximum, which is larger than the difference between before and after the survey at the base point found every time. Consequently, correction of daily variance at each point was not made.

As mentioned in the above, as the measurement accuracy was low, the measured values were indicated with the angles from reading the magnetic needle at the points, and an isomag map was made by connecting points with equal angles. In this measuring instrument 1° is equivalent to 500 γ at maximum.

II-3-3 Result of Prospecting

The isomag map of this area is shown in PL 4. Out of the extracted anomalies most conspicuous are four anomalies oriented NWW-SEE which are presumed to be attributable to basalt dykes. Although no outcrops are observable, these anomalies are judged those owing to the dykes of basalts, mainly dolerite, from existence of scarce floats and "black turf" found there.

In addition to the above, there are an area of anomalies lying from the north of the major dyke (X5.30, Y23.90) to the central part of the survey area (X5.55, Y25.0), minor anomalies near the point of (X5.02, Y23.65), (X4.93, Y27.30) and (X5.02, Y23.65). These are judged to be attributable to ultrabasic rock from existence of floats or small outcrops.

Almost all intrusive rock bodies of ultrabasic rock, however, are not to be recognizable as anomalies in particular on the isomag map except for the above-mentioned minor anomalies. Therefore, each of the greater part of the intrusive rock bodies of ultrabasic rock is judged to be of a small scale.

Besides, weak magnetic anomalies in a NE direction were detected near the points of (X5.20, Y24.13), (X5.90, Y24.40), and (X5.90, Y24.12).

On the surface where these weak anomalies are distributed, however, neither outcrops nor floats, nor characteristic "black turf" are found. Such anomalies are presumed to be those owing to very thin dykes of basalt.

These dykes are not indicated in the geological map.

II-4 Drilling

II-4-1 Purpose of Drilling

On the basis of the results of the surveys, in the first to third years, four drill holes, each about 100 m in depth, were made aiming at chromite. The geological conditions as found by the four drill holes and the drilling result are set forth in Table 12, Figs. 7 and Apex. 1.

The exposure of this area is extremely poor, showing not single outcrop that allows measurement of the strike and dip of the strata. However, as a result of the trenching, the strike and dip of the chromite deposits were found to be N50°E and N50° respectively in deposits B, C, E and F and N60°W and N60° in deposit D, though quite indistinct.

Therefore, with the object of exploring the parts below the ore bodies, vertical drill holes of GSJ-1, 2, 3 and 18 were driven for deposits B, C, D, E and F, with all of their positions being made 10 to 20 m apart from the ore body on the side regarded as the hanging wall side.

II-4-2 Result of Drilling

As the result of drilling four holes, the rocks as observed in the cores are ultrabasic rock and gneiss. The ultrabasic rock has some relict of peridotite, but mostly consists of completely altered serpentinite. The principal components of the serpentinite are serpentine, talc and carbonate minerals, and in addition accompanied by small quantities of magnetite and chromite. In the serpentinite, parts where talc is concentrated, and actinolite, biotite and others that have been epigenetically formed, are often recognized. The gneiss is granitic paragneiss of medium to coarse grains and accompanied by biotite and amphibole as mafic minerals. It also contains, in some parts, porphyroblasts of feldspar. The chromite is black, massive and hard, and formed of fine grains (0.2 ~ 0.4 mm in size); some of it contains strongly magnetic portions.

In the following described are the findings from each hole.

GSJ-1: The rock in this hole is formed of serpentinite, gneiss and chromite. The chromite is found between a 12.97 m depth and a 13.39 m depth (length: 42 cm). It is black, massive and hard, and has fairly intense magnetism. The ore grade and Cr/Fe ratio are: 27.3% in Cr_2O_3, 22.9% in T.Fe and 0.8 of Cr/Fe ratio.

The serpentinite is found between a 50.6 m depth and a 85.9 m depth, and has the alteration of actinolite and biotite.

GSJ-2: The geology in this hole is formed of serpentinite, gneiss and chromite.

The chromite is found between a 20.45 m depth and a 21.75 m depth (length: 1.30 m), between a 23.38 m depth and a 24.10 m depth (length: 0.72 m), between a 38.10 m depth and a 38.45 m depth (length: 0.35 m), and between a 40.10 m depth and a 40.33 m depth (length: 0.23 m). It is all fine-grained, black, massive and hard, and fairly intense magnetism is recognized in the lower two layers. In them magnetism is intense at the rock boundaries and weak in the middle part. The ore grade and Cr/Fe ratio are: in the order of the upper to lower chromite layers, 31.7%, 30.2%, 26.7% and 17.0% in Cr_2O_3; 19.7%, 20.0%, 21.9% and 20.0% in T.Fe; 1.1, 1.0, 0.8 and 0.6 of Cr/Fe ratio respectively.

GSJ-3: The rock is formed of serpentinite and gneiss. Under microscope, peridotite relics are observed in serpentinite.

GSJ-18: The geology in this hole is formed of gneiss and serpentinite.

The profiles of the above-mentioned four drill holes are set forth in Fig. 7.

As mentioned in the above, drillings were made from a point 10 to 30 m away from each ore body aiming at the lower extension of the ore body on the hanging wall side, depending on the sole clue of the dip of the ore body (N50°E/50°N) as found in the trenches. The result was that such prevalent ore body conditions as seen in the trenches were run down at the lower parts. During the prospecting work, the reasons for the poor conditions at the lower parts were being surmised as follows:

1) Because of the pod-like shape of the ore bodies, the ore bodies cannot be grasped with a limited number of drill holes, 2) the ore bodies might have thinned out at the lower parts, or 3) the ore bodies might have been cut off by faults.

Synthetic analysis, however, has suggested, in addition to the above-mentioned reasons, the possibility that 4) the strike and dip of the chromite ore bodies as seen in the trenches indicated only a local dip of minor structure in serpentinite. So, if this point should be right, there is the possibility that, viewed broadly, the dip of the ore body is in the reverse direction.

In the drill hole profiles the underground is presumed on the assumption that the dip is in the reverse direction as mentioned in 4).

Fig.7 Geological profile of drilling
(Chrome area)

Fig. 7-1 (GSJ-1)

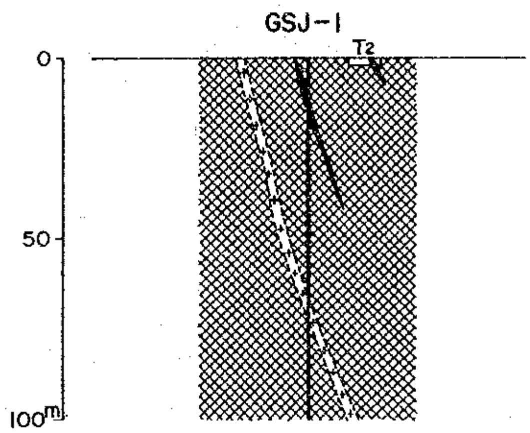


Fig. 7-2 (GSJ-2)

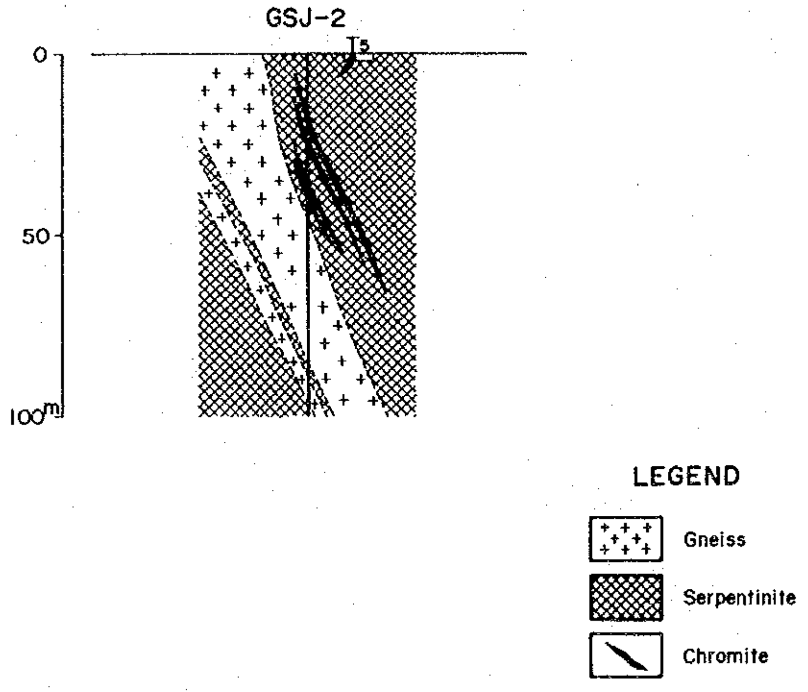


Fig. 7-3 (GSJ-3)

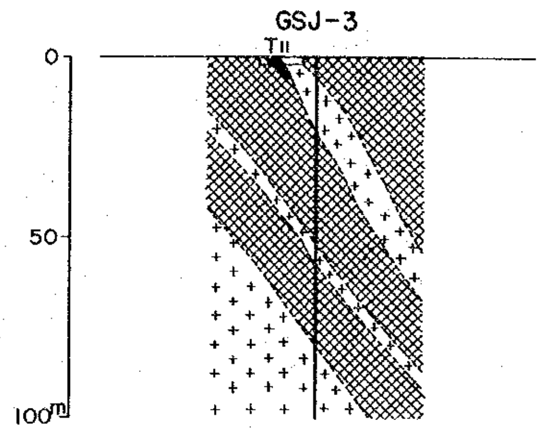
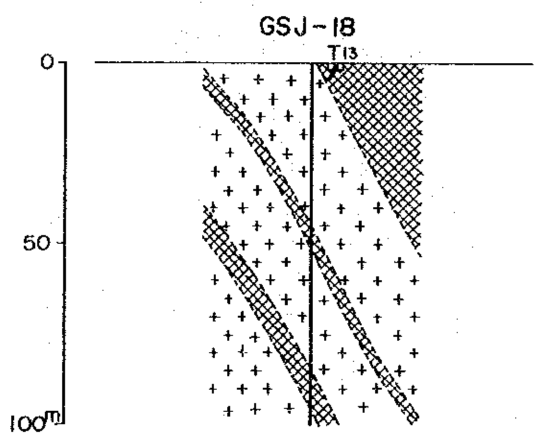


Fig. 7-4 (GSJ-18)



Part III. Drilling Work

III-1 Outline of Drilling Work

III-1-1 Purpose of Drilling

As a part of the third year survey in the northeastern region of the Republic of Botsuana, a drilling survey was carried out in the north area of Matsitama, on the basis of the results of the survey conducted in 1980, aiming at marked mineral indications where the results of the geophysical prospecting suggested existence of sulphides and with the object of confirming such indications. The drilling survey was conducted also for the purpose of looking into the conditions of minerals in the areas of chromite deposits which were revealed by the 1980 survey and in the areas of mineral indications detected by the geochemical survey.

III-1-2 General Description of Work

Two drilling machines, their fittings and materials were shipped from Japan to Botswana via Durban Port late in May 1981. Upon their arrival the leader of the survey team departed from Japan on 10th July and entered Botswana on 15th July via Johannesburg and Lusaka; he, receiving the shipped articles at the Geological Survey Department at Lobatse, discussed the drilling work plan with the officials in charge.

Six drilling engineers left Japan on 24th July and via Johannesburg arrived in Botswana on 26th July. They, until 28th July, inspected the machines and other things and checked their loading for transport to the site. The drilling party was divided into two groups; the first group arrived at the site on 29th July while the second one on 4th August.

On the site a camp was set up; the arrangement work was made from 5th August, and the drilling work was started on 8th August.

The drilling work was an all coring one using the ordinary method. The two drilling machines were operated in parallel. The drilling machines used here as follows:

Drilling machine	Number	Capacity
TDC-1G (Tone)	2★	150 m

★ Note: They are named No. 1 and No. 2 machine.

The work was carried out on a two shift system. For operation of one machine, two parties were formed, one consisting of the chief, the shift head and two workers while the other of the shift head and three workers. In addition, two 5 t trucks were stationed to transport water for the operation of the machines. A great distance to the water drawing points made the trucks run almost around the clock; to this operation four drivers and four assistant, were assigned. Also a jeep or a light truck was allocated to each of the drilling sites.

The drilling work was performed principally with the use of clear water, but when the hole conditions required mud water was used to protect the hole walls.

The amount of the work result is shown below in Table 4.

Table 4. Drilled length of each hole

Hole No.	Drilled length (m)	Core length (m)	Core recovery (%)
GSJ-1	100.20	99.80	99.6
GSJ-2	100.60	92.50	91.9
GSJ-3	100.50	89.55	89.1
GSJ-4	100.20	97.65	97.4
GSJ-5	100.40	95.15	94.8
GSJ-6	101.50	98.50	97.0
GSJ-7	100.20	91.75	91.6
GSJ-8	100.30	92.55	92.3
GSJ-9	100.20	94.20	94.0
GSJ-10	101.00	84.30	83.5
GSJ-11	100.05	76.90	76.9
GSJ-12	100.10	89.35	89.3
GSJ-13	100.30	95.65	95.4
GSJ-14	100.00	88.25	88.3
GSJ-15	100.20	92.05	91.9
GSJ-16	100.20	98.55	98.4
GSJ-17	100.80	97.55	96.8
GSJ-18	100.20	86.70	86.5
Total	1,806.95	1,660.95	91.9

No. 1 machine finished drilling work on 3rd November and No. 2 machine on 9th the same month. After the withdraw work at the sites was finished, the machines and other things, camping materials, core boxes and other matters were carried back to the Geological Survey Department in Lobatse and provisionally stowed in a warehouse in the grounds of the office, part of them being stored under sheets of waterproof canvas; thereafter the team members returned to Japan. The drilling members stayed about four months in Botswana from 26th July to 20th November.

III-1-3 Core Logging

The geologist examined all the cores from the drill holes for their lithologic characters, alteration and mineralization and made core log, 1 to 200 in scale.

III-2 Location of Drilling Site

The location of drilling site are scattered in an area 30 km in the north-south direction and 10 km in the east-west direction. The farthest point from the camp was about 13 km away, while the nearest one being about 4 km; the time for a jeep to reach them was 15 to 50 minutes.

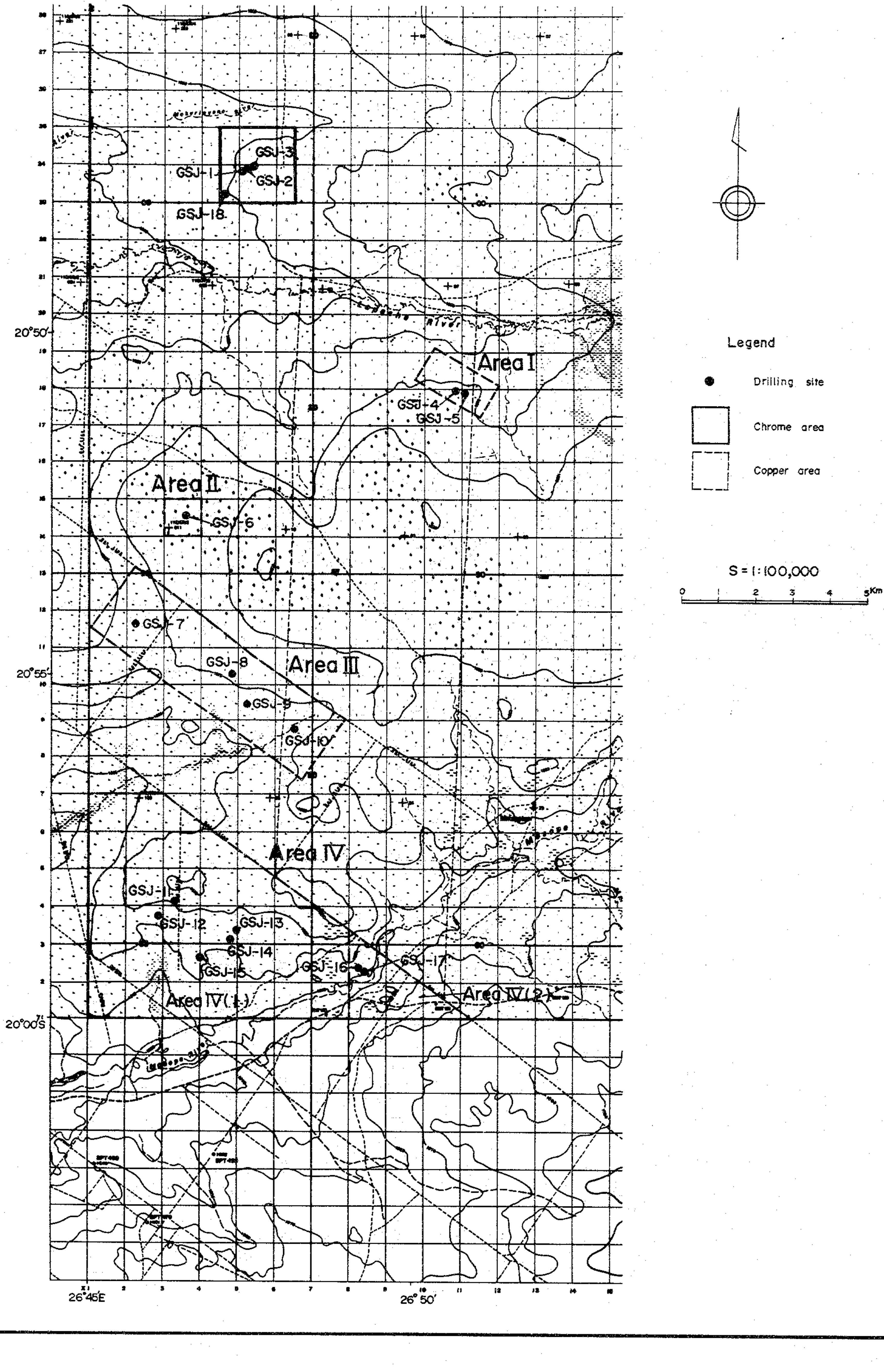
The positions of the drill holes in terms of longitudinal and latitudinal coordinates are set forth forth in Table 5.

This area is at an altitude of 1,000 to 1,100 m above sea level. Its topography is almost flat except for slight undulations, and it is in a savanna zone, being covered with thin woods of Mopani, Acacia.

Table 5. Long. & Lat. coordinates of drill hole

Hole No.	Latitude S	Longitude E
GSJ-1	20°47′32″	26°47′30″
GSJ-2	20°47′32″	26°47′30″
GSJ-3	20°47′32″	26°47′30″
GSJ-4	20°50′45″	26°50′48″
GSJ-5	20°50′50″	26°50′49″
GSJ-6	20°52′41″	26°46′28″
GSJ-7	20°54′15″	26°45′42″
GSJ-8	20°54′57″	26°47′13″
GSJ-9	20°55′25″	26°47′27″
GSJ-10	20°55′50″	26°48′11″
GSJ-11	20°58′19″	26°46′21″
GSJ-12	20°58′32″	26°46′06″
GSJ-13	20°58′46″	26°47′06″
GSJ-14	20°58′55″	26°47′12″
GSJ-15	20°59′06″	26°46′44″
GSJ-16	20°59′17″	26°49′13″
GSJ-17	20°59′19″	26°49′15″
GSJ-18	20°48′01″	26°47′03″

Fig. 8 Location map of drilling



III-3 Preparatory Works

III-3-1 Road Construction

Reconnaissance of the area planned for drilling was made from 29th July, and a routing plan for roads to transport machines and materials and a plan to transport them were made.

Prior to work at the drilling sites, clearance roads were prepared in due order. In the area, cut lines for vehicles run longitudinally and latitudinally. The cut lines were made by clearing trees and shrubs up to the nearest cut line, clearance for 1 to 4 km being made for each of the drilling site.

III-3-2 Transportation of Machines and Materials

The machines and materials were brought from the Geological Survey Department at Lobatse to the camp site by three 5 t trucks, being divided in two trips on 29th July and 4th August.

Petrol, gas oil and grease were purchased when necessary at Francistown and brought in on a light truck.

III-3-3 Preparation at Drilling Site

At drilling sites, each 10 m in length and 15 m in width, trees and shrubs were cut and cleared, and the ground was prepared doing some leveling.

III-3-4 Drilling Water

Since it was the dry season there during the work, no water was found in the drilling area. So that drilling water was drawn at wells in Matsitama lying about 30 km to the south of the camp site and in Mosetse about 50 km to the west. It was transported by two 5 t trucks in drums, taking five to six hours for a trip.

III-4 Drilling Work

The upper part containing weathered rock and ranging from 2 to 13.5 m in depth was drilled with a 75 mm diam. metal crown, and the hole was protected with a 73 mm diam. casing pipe. Thereafter a 66 mm diam. diamond bit crown was used; paying attention to the conditions of the hole, a 63 mm diam. casing pipe was put in, and then the crown was replaced with a 56 mm diam. diamond bit one, thus drilling the planned length, more than 100 m in each drill hole.

All the holes were drilled using clear water as a rule, but there were often parts from where the water escaped at a depth between 16 and 50 m on the whole. Every time water escaped, every effort was made to prevent caving of holes by cementation and feeding mud water, but in some cases the drilling members were obliged to draw out the 63 mm diam. casing pipe and enlarge the hole.

A long distance from the source of drilling water, which required many hours of transport, caused not a few occasions in which the members had to wait for water during work.

The average drilling record for all the holes is shown in Table 6:

Table 6. Summary of operational data of drill holes

No. of drill holes (A)	18 hole	Total length (B)	1,806.95 m	Total core length	1,660.95 m	Core recovery 91.9 %

No. of working days (C)	190 days	No. of working shifts (D)	320 shifts	Total working hours (E)	3,578 hours
C/A	10.56 days/hole	D/A	17.78 shifts/day	E/A	178.8 hours/hole
B/C	9.51 m/day	B/D	5.65 m/shift	B/E	0.51 m/hour
No. of drilling days (F)	132 days	No. of drilling shifts (G)	261 shifts	Drilling hours (H)	1,379.5 hours
F/A	7.33 days/hole	G/A	14.5 shifts/hole	H/A	76.64 hours/hole
B/F	13.69 m/day	B/G	6.92 m/shift	B/H	1.31 m/hours

The progress of work at the drill holes is described in the following:

GSJ-1

0 to 2.00 m: Drilling was first made with a 75 mm diam. metal crown. At a depth of 2.00 m the drill reached hard rock, and a 73 mm diam. casing pipe was put in to the 2.00 m depth and set.

2.00 to 23.00 m: Drilling was made with a 66 mm diam. diamond bit crown. As the the rock has become stable, a 63 mm diam. casing pipe was put in to a 23.00 m depth and set.

23.00 to 100.20 m: Drilling was made with a 56 mm diam. diamond bit crown. The progress was comparatively smooth, but somewhat hard rock caused the use of three 66 mm diam. crowns and nine 56 mm diam. crowns, the length drilled per crown resulting in 8.18 m. The drilling was finished at a depth of 100.20 m.

GSJ-2

0 to 6.00 m: Drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 6.00 m depth and set.

6.00 to 30.00 m: Drilling was made with a 66 mm diam. diamond bit crown. The drill frequently lost circulation, each time of which mud water was pressured in to prevent loss of circulation.

30.00 to 100.60 m: A 56 mm diam. diamond bit crown was used. Although there was lost circulation to some extent up to a depth of 50.00 m, the rock has become stable after that depth letting the work progress smoothly. But because of the hardness of rock two 66 mm diam. crowns and nine 56 mm diam. ones were used, the length drilled per crown resulting in 8.60 m. The work was finished at a depth of 100.60 m.

Hole GSJ-3

0 to 7.50 m: Drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 7.50 m depth.

7.50 to 39.00 m: A 66 mm diam. diamond bit crown was used, and a 63 mm diam. casing pipe was put in to a depth of 32.00 m. After that the drill repeatedly hit lost circulation, and every time cementation and feeding water were conducted, but failed to prevent lost circulation, so that they drew out the 63 mm casing pipe, enlarged the hole up to a depth of 39.00 m, and put in a 63 mm diam. casing pipe again.

39.00 to 100.50 m: The drilling was first made with a 56 mm diam. diamond bit crown. Cracks between the depths of 57.65 m and 57.85 m caused lost circulation, but it was controlled with mud water; thereafter the rock was stable allowing smooth drilling. The work was brought to an end at a depth of 100.50 m.

GSJ-4:

0 to 2.50 m: The drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 2.50 m depth and set.

2.50 to 40.00 m: The drilling was made with a 66 mm diam. diamond bit crown. But the diameter of the hole grew too large and the casing pipe sank of itself to a depth of 9.00 m, so a casing pipe was added to it, setting the extended case at a depth of 9.00 m. Then a 63 mm diam. casising pipe was put in to a depth of 40.00 m and set.

40.00 to 100.20 m: A 56 mm diam. diamond bit crown was used. As there was caving of the hole and lost circulation, the drilling was conducted by cementation and feeding mud water. Extreme hardness of the rock made the use of crowns amount to four of 66 mm diam. ones and twelve of 56 mm diam. ones, resulting in 6.10 m of the length drilled per crown.

GSJ-5:

0 to 2.30 m: The drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 2.30 m depth and set.

2.30 to 27.50 mm: A 66 mm diam. diamond bit crown was used. The drill frequently hit lost circulation, and each time mud water for cementation was pressured in to control it. A 63 mm diam. casing pipe was put in to a depth of 27.50 m and set.

27.50 to 100.40 m: The drilling was made with a 56 mm diam. diamond bit crown. Big consumption of crowns was caused by the extremely hard rock, the numbers of used crowns amounting to three of 66 mm diam. ones and twenty of 56 mm diam. ones. The length drilled per crown was only 4.25 m, the lowest among all the holes.

GSJ-6:

0 to 3.00 m: The drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 3.00 m depth and set.

3.00 to 30.00 m: A 66 mm diam. diamond bit crown was used; the drilling work often suffered from lost circulation. A 63 mm diam. casing pipe was put in to a depth of 30.00 m and set.

30.00 to 101.50 m: A 56 mm diam. diamond bit crown was used. After a 30.00 m depth, the quality of rock being stable, the drilling progressed comparatively smoothly to the finish.

GSJ-7:

0 to 7.00 m: The drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was put in to a 7.00 m depth and set.

7.00 to 46.80 m: A 66 mm diam. diamond bit crown was used. A 63 mm diam. casing pipe was put in to a depth of 46.80 m and set. As there occured lost circulations many times, cementation and feeding mud water were repeated.

46.80 to 100.20 m: The drilling was made with a 56 mm diam. diamond bit crown. The comparatively soft rock allowed smooth progress of the work. The numbers of used crowns were rather small, two of 66 mm diam. ones and five of 56 mm diam. ones, resulting in 13.1 m of the length drilled per crown.

GSJ-8:

0 to 2.00 m: The drilling was first made a 75 mm diam. metal crown. Because at a depth of 2.00 m the drill hit a layer of quartz gravel and was unable to advance, a 73 mm diam. casing pipe was put in to that depth and set.

2.00 to 40.00 m: A 66 mm diam. diamond bit crown was used. At a depth of 30.00 m a 63 mm diam. casing pipe was put in, but after that a lost circulation was encountered. So the hole was enlarged with a 66 mm diam. diamond bit crown to a depth of 40.00 m, nad a 63 mm diam. casing pipe was put in again to the 40.00 m depth and set.

4.00 to 100.30 m: The drilling was made with a 56 mm diam. diamond bit crown. Numberous cracks caused heavy jamming, but the comparatively soft rock allowed smooth progress. The numbers of the used crowns were small, two of 66 mm diam. ones and four of 56 mm diam. ones, resulting in 16.38 m of the length drilled per crown.

GSJ-9:

0 to 6.00 m: The drilling was first made with a 75 mm diam. metal crown, and 73 mm diam. casing pipe was put in to a 6.00 m depth and set.

6.00 to 36.00 m: A 66 mm diam. diamond bit crown was used. Lost circulation was treated by cementation and feeding mud water. A 63 mm diam. casing pipe was put in and set at a depth of 36.00 m.

36.00 to 100.20 m: A 56 mm diam. diamond bit crown was used. The quality of rock was unstable, causing frequent jamming of the core, up to a depth of 45.00 m, but thereafter the drilling progressed smoothly, and the work came to an end.

GSJ-10:

0 to 13.50 m: The drilling was first made with a 75 mm diam. metal crown. Since the rock was weathered deeply and soft, a 73 mm diam. casing pipe was inserted to a depth of 13.50 m and set.

13.50 to 46.00 m: A 66 mm diam. diamond bit crown was used. The rock was soft and there were many cavings, causing the use of a large amount of cement and mud water. A 63 mm diam. casing pipe was put in to a depth of 46.00 m and set.

46.00 to 101.00 m: The drilling was made with a 56 mm diam. diamond bit crown. Because the quality of rock was unstable, part of the core was washed away.

GSJ-11:

0 to 9.00 m: The drill was first made with a 75 mm diam. metal crown. Caving of the hole occured at several parts, but a 73 mm diam. Casing pipe was inserted to a 9.00 m depth and set.

9.00 to 30.00 m: A 66 mm diam. diamond bit crown was used. There being few hard rock portions, the work advanced smoothly; a 63 mm diam. casing pipe was put in to a depth of 30.00 m and set.

30.00 to 100.05 m: The drilling was made with a 56 mm diam. diamond bit crown. The work progressed rather smoothly and came to an end.

GSJ-12:

0 to 9.00 m: The drilling was first made with a 75 mm diam. metal crown. A 73 mm diam. casing pipe was inserted to a 9.00 m depth

and set.

9.00 to 27.00 m: A 66 mm diam. diamond bit crown was used. A great number of cracks in the rock caused frequent jamming. A 63 mm diam. casing pipe was inserted to a depth of 9.00 m and set.

27.00 to 100.10 m: A 56 mm diam. diamond bit crown was used. Numerous cracks often caused heavy jamming, but the work made smooth progress owing to the uniform quality of the rock. The number of actual working days at this hole was five, the shortest record in this drilling survey work.

GSJ-13:

0 to 5.50 m: The drilling was first made with a 75 mm diam. metal crown. As the discharge of slime was poor, mud water was used. A 73 mm diam. casing pipe was put in to a 5.50 m depth and set.

5.50 to 44.00 m: A 66 mm diam. diamond bit crown was used. The rock had many cracks and occasioned heavy jamming.

44.00 to 100.30 m: The drilling was made with a 56 mm diam. diamond bit crown. The stable quality of rock allowed smooth drilling; the numbers of used crowns were two of 66 mm diam. ones and four of 56 mm diam. ones, the length drilled per crown being 15.80 m.

GSJ-14:

0 to 3.50 m: The drilling was first made with a 75 mm diam. metal crown. Mud water was used because of a poor discharge of slime, A 73 mm diam. casing pipe was put in to a 3.50 m depth and set.

3.50 to 30.00 m:	A 66 mm diam. diamond bit crown was used. The strings were heavily jammed because the rock was unstable. A 63 mm diam. casing pipe was put in to a depth of 30.00 m and set.
30.00 to 100.00 m:	A 56 mm diam. diamond bit crown was used. The work made comparatively smooth progress, though the drill hit hard rock at some part.

GSJ-15:

0 to 5.00 m:	The drilling was first made with a 75 mm diam. metal crown, and a 73 mm diam. casing pipe was inserted to a 5.00 m depth and set.
5.00 to 45.50 m:	A 66 mm diam. diamond bit crown was used. The rock was unstable up to a depth of about 10.00 m and part of the core was washed away, but apart from it the drilling made smooth progress. A 63 mm diam. casing pipe was inserted to a depth of 45.50 m and set.
45.50 to 100.20 m:	A 56 mm diam. diamond bit crown was used. The quality of rock was uniform and the drilling made smooth progress.

GSJ-16:

0 to 8.50 m:	The drilling was first made with a 75 mm diam. metal crown. A 73 mm diam. casing pipe was put in to a depth of 3.00 m; but it sank of itself to a 8.50 m depth, so that a casing pipe was again inserted and set.
8.50 to 42.50 m:	A 66 mm diam. diamond bit crown was used. Many cracks in the core made heavy jamming. A 63 mm diam. casing pipe was put in to a depth of 42.50 m and set.
42.50 to 100.20 m:	The rock was stable, but because of its hardness the drilled length in proportion to the numbers of used crowns was small, the numbers being three of 66 mm diam. ones and seven of

56 mm diam. ones, resulting in 9.7 m of the length drilled per crown.

GSJ-17:

0 to 5.50 m:	The drilling was first made with a 75 mm diam. metal crown. A 73 mm diam. casing pipe was inserted to a 5.50 m depth and set.
5.50 to 32.00 m:	A 66 mm diam. diamond bit crown was used. The strings were heavily jammed. A 63 mm diam. casing pipe was inserted to a depth of 32.00 m and set.
32.00 to 100.80 m:	A 56 mm diam. diamond bit crown was used. As the drill went deeper, the rock became harder, and the drilled length in proportion to the number of used crowns became smaller.

GSJ-18:

0 to 2.00 m:	The drilling was first made with a 75 mm diam. metal crown. A 73 mm diam. casing pipe was inserted to a 2.00 m depth and set.
2.00 to 31.00 m:	A 66 mm diam. diamond bit crown was used. A 63 mm diam. casing pipe was inserted to a depth of 31.00 m and set.
31.00 to 100.20 m:	A 56 mm diam. diamond bit crown was used. The rock was gneiss and hard. The work frequently ecountered cracks and cavings of the hole, making slow progress.

III-5 Removing of Drilling Machine

5 t trucks and light trucks were used to move a drilling machine and fittings. Prior to the move, a cut line allowing entry of 5 t truck was made, and the work was able to make relatively smooth progress.