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REPORT ON THE [illegible] [illegible]

EXPLORATION OF [illegible]JAMMA AREA

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REPUBLIC OF ZIMBABWE

REPORT ON THE COOPERATIVE MINERAL EXPLORATION OF SHAMVA AREA

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FEBRUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

国際協力事業団	
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PREFACE

At the request of the Government of the Republic of Zimbabwe, the Japanese Government planned and carried out a geological survey concerning mineral exploration to examine the possibility of the existence of mineral resources in the Shamva district located in the northeastern part of Zimbabwe. The Japan International Cooperation Agency was entrusted with the execution of the general plan. The Japan International Cooperation Agency in turn entrusted the execution of this survey to the Metal Mining Agency of Japan since this survey was essentially a professional survey of geology and mineral resources.

The Metal Mining Agency of Japan organized a survey team of three members in 1983, the first year of the survey project, and dispatched the team to Zimbabwe during the period from July 7 to September 22, 1983.

The on-site survey was completed as scheduled with the cooperation of the Zimbabwe Government, particularly the Geological Survey Department of the Ministry of Mines.

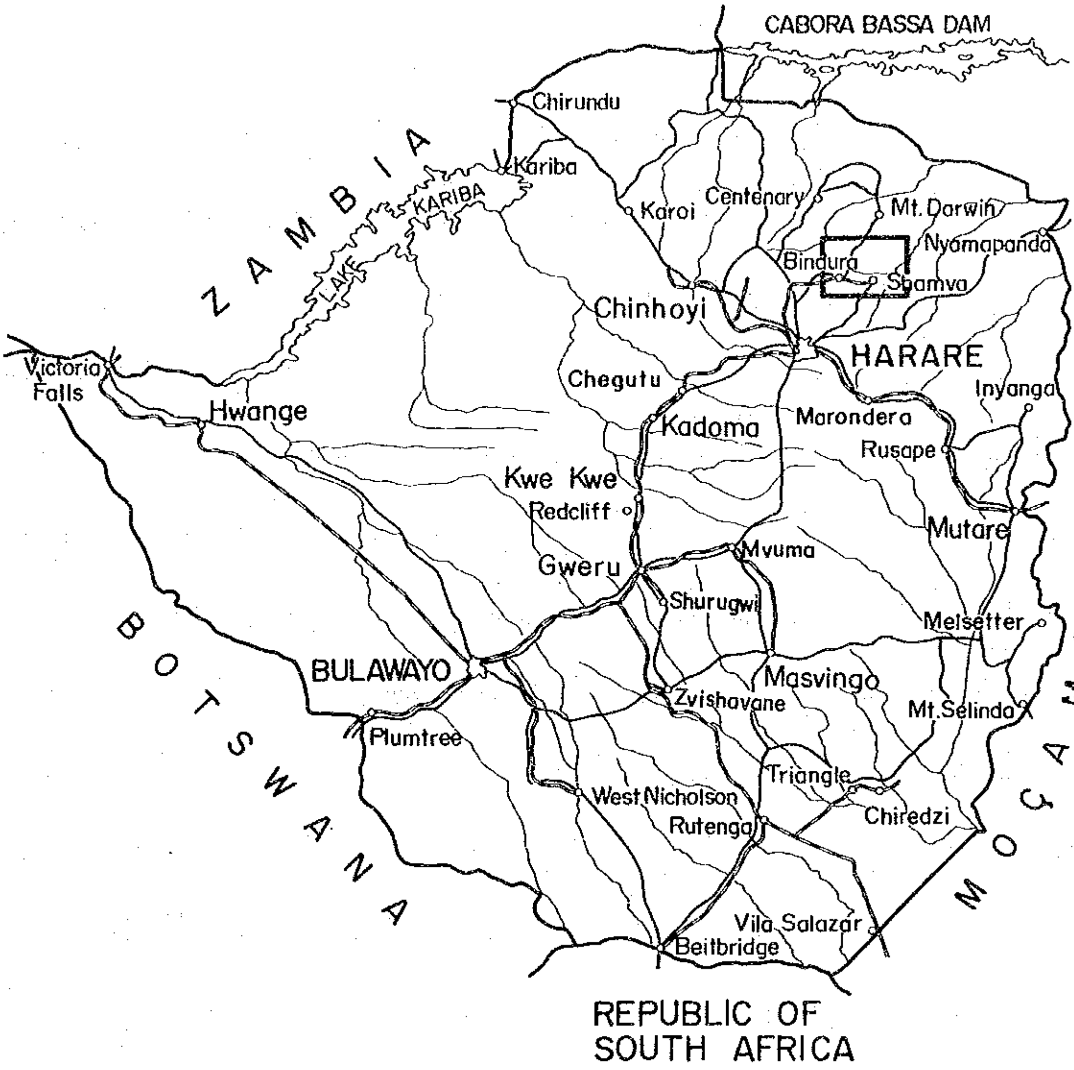
This report describes the survey results in the first year and will form a part of a final report.

Lastly, we would like to express our heartful gratitude to the members concerned of the Zimbabwean Government, the Ministry of Foreign Affairs of Japan, the Ministry of International Trade and Industry of Japan and the Japanese Embassy in Zimbabwe, and all of whom extended their kind cooperation to us in executing the above-mentioned survey.

January, 1984

Keisuke Arita
President,
Japan International Cooperation Agency

Masayuki Nishiie
President,
Metal Mining Agency of Japan



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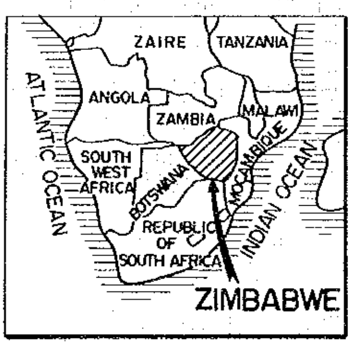

General Survey Area

Fig. 1 Location Map of Shamva Area, ZIMBABWE

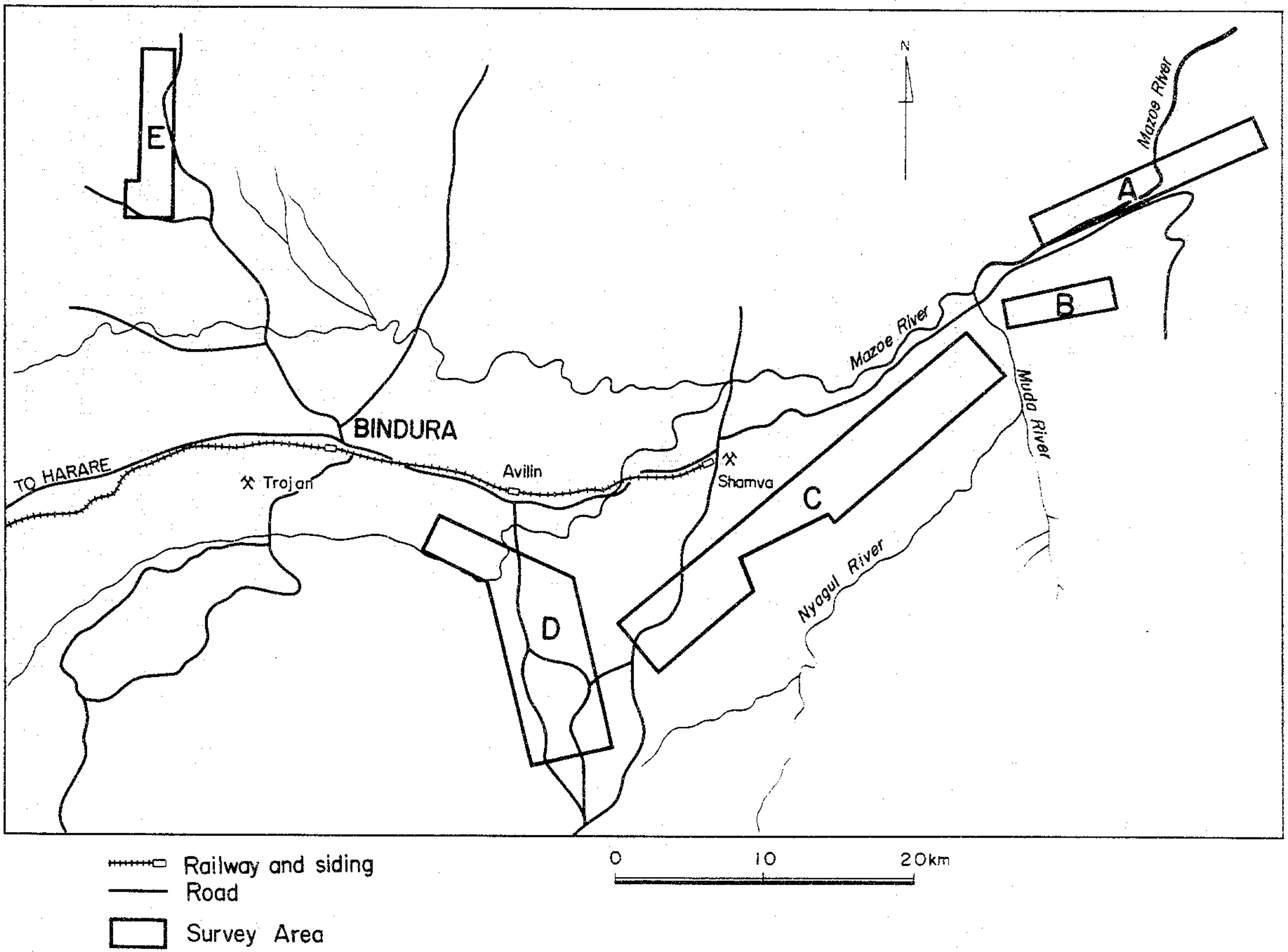

Fig. 2 Location Map of Survey Areas

ABSTRACT

ABSTRACT

In the first year of the survey in the Shamva district of the Republic of Zimbabwe, geological and geochemical surveys were carried out with the object of establishing the policy for future exploration and selecting promising areas by finding out the distribution of ultramafic rocks which may emblace nickel copper sulphide ore deposits and that of pegmatites which may contain tin, niobium and tantalum, and by clarifying the relationship between geological structure and mineralization.

The survey site consists of five areas having a total area of 242 km^2. In the geochemical survey, 4,501 soil samples were collected from the whole survey site and were analyzed for elements, Au, Cu, Zn, Cr, Ni and Nb, and 400 samples selected from 4,501 were further analyzed for elements, Co, Sn, As, Li, W, Pt, Be, Ce, S and Ta.

The survey in Zimbabwe was carried out over 68 working days, from July 14 to September 19, 1983.

The survey site occupies a part of the Rhodesia Craton and its geology is mainly of the greenstones of the Archaean Bulawayan group. In this group, it is known that nikel ore deposits (e.f. Trojan Deposit) associated with ultramafic rocks such as komatiite lava, pegmatite deposits which were once mined for Ta, Sn, W, etc., and gold-bearing quartz veins (Shamva deposit) exist.

The outline of survey results in areas A to E is as follows.

1. Area A

The geology of this area is mainly underlain by the Upper Greenstones of the Bulawayan group and intercalate in part lenticular serpentinites and komatiites. In the central northern part and at the eastern end of the area, granitic complexes are exposed with pegmatite

veins associated with them.

As a result of the geochemical survey, weak anomalies which seem to be associated with serpentinites were detected for four elements, Cu, Zn, Ni and Cr, in the area from the central to the western part of this area. As to Nb, anomalies caused by granites and pegmatites were detected.

2. Area B

Similar to area A, this area is also underlain by the Upper Greenstones of the Bulawayan group and intercalates in part lenticular serpentinites and komatiites. Pegmatites also intrude in several places.

As a result of the geochemical survey, anomalies mainly of Zn, Ni and Cr were detected in the central part, and small anomalies of Cu, Zn, Ni and Cr were detected at the eastern end. The former could be the anomalies caused by komatiites. As the latter has a distribution matching with that of serpentinites, they would be caused by those with serpentinites.

3. Area C

This area is underlain by the Upper Greenstones of the Bulawayan group and intercalates in part serpentinites and komatiites. The dykes or stocks of dolerite and gabbro have intruded these rocks here and there, and in part, pegmatites are distributed.

As a result of the geochemical survey, it was found that anomalies of Cu, Zn, Ni and Cr were extensively distributed overlapping each other in the southwestern part. As these anomalies have distribution almost agreeing with that of serpentinites, there is a possibility that they are related to the mineralization of nickel and copper and are regarded as promising anomalies. As to Au, widespread anomalies are distributed in the northeastern part, but since gold deposits exist in the vicinity, the anomalies are thought to be those related to the mineralization of gold in the site.

4. Area D

This area is mainly underlain by the Lower and Upper Greenstones of the Bulawayan group, but the Lower Greenstones exist only in a limited area of the northwestern part. The Upper Greenstones in the area host to the ore horizon of the nickel copper sulphide ore deposits of the Trojan Mine. Particularly, serpentinites are distributed extensively with of banded ironstones. Therefore the geological environment to embrace ore deposits is good.

As a result of the geochemical survey, it was found that anomalies of Cu, Zn, Ni and Cr were extensively distributed overlapping each other, matching with the distribution of serpentinites in the southeastern part as well as in the part a little to the west of the centre. These anomalies are not only high in Cr and Ni contents but accompany the anomalies of Cu and Zn. Therefore, they are regarded as promising areas which may host nickel ore deposits associated with serpentinites. No anomalies of Au were detected, but high anomalies of Nb were found at the southeastern and the southwestern ends. These anomalies are thought to be those associated with the intrusion of granites in the vicinity.

As to the mineralized zones of rare metals in the central part, analyses for ten elements including Co, Sn, As, etc. were carried out. As a result, several anomalies of Sn were found in pegmatites, and also Co, Li, Be and Co showed high values in accordance with the distribution of pegmatites. It would be advisable to investigate the possibility of extension of these pegmatites deep into the underground.

5. Area E

This area is underlain by the Lower and Upper Greenstones of the Bulawayan group, but the Lower Greenstones are distributed only locally to the east of the centre. Serpentinites are particularly extensively distributed.

As a result of the geochemical survey, anomalies of Ni and Cr, whose distributions almost agree with the distribution of serpentinites, were detected, but the anomalies of Cu and Zn were not found. These anomalies are thought to have been caused by serpentinites. Anomalies of higher Ni values are scattered in them. Anomalies of Au are found scattered all over the area. In particular, the anomalies at the southwestern end are thought to be related to the mineralization of gold because a small gold mine exist in the vicinity.

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GENERAL

CHAPTER 1 INTRODUCTION

1-1 Circumstances and Purpose of the Survey

The Republic of Zimbabwe is a land-locked country in the south of the Continent of Africa. After having experienced various historical changes, the young Republic of Zimbabwe was born on April 18, 1980.

Zimbabwe has maintained a comparatively stable economy next to that of the Republic of South Africa, attaining an annual economic growth rate of 4 to 5 percent. Zimbabwe's key industries are agriculture, mining and manufacturing and production rates of these industries in GDP in 1982 are 17.8%, 5.2% and 26.5% respectively. On the other hand, the foreign currency income generated by these industries in 1982 is 33%, 45% and 18.5% respectively, showing that this country is highly dependent upon primary industrial products.

Most of the land of Zimbabwe has geological conditions consisting of the so-called craton of the Precambrian era. The country is blessed with abundant mineral resources and produces more than 40 kinds of mineral products. Particularly, gold, chromium, asbestos, nickel, copper and coal are the six major mineral products of this country. In addition, lithium, beryllium, tungsten, corundum, platinum, silver, iron, graphite and phosphate rock are also important mineral products. The share of the mining section in total GDP was 5.2% in 1982, ranking third after manufacturing and agriculture. Most of the mineral products are expoted and produced 45% of the foreign currency in 1982. With the impotance of the technical cooperation from Japan for a survey and development of mineral resources in Zimbabwe, when prime minister Mugabe visited Japan in April, 1981, he requested positive technical cooperation to Japan.

The Metal Mining Agency of Japan dispatched a representative staff from Nairobi to Zimbabwe in July, 1981 to explain System of the Cooperative Mineral Exploration to the Zimbabwe Ministry of Mines. The ministry showed deep interest in the system and sent a request in April, 1982 to carry out cooperative mineral exploration project in five districts, Shamva, Harare, Chakari and Gatoma West, Bulawayo and Macdougall. When Vice-Minister of Mines of Zimbabwe, Mr. Usheokunze visited Japan in May, 1982, he again requested the need for this survey.

The Japanese Government received this request, and dispatched a project investigation mission. Based on the results of this survey, the Shamva district was selected, and in addition, five geologically promising areas in this district were selected. On April 29, 1983, a field survey agreement was concluded between the Japan International Cooperation Agency and Metal Mining Agency of Japan, and the Geological Survey Department of the Ministry of Mines of the Republic of Zimbabwe on implementing a cooperative mineral exploration.

The purpose of this survey is to grasp the state of ore deposits in the Shamva district of the Republic of Zimbabwe by making geological conditions clear in detail. This year, the survey seeks, as the first year's task, to select promising areas as well as to determine the direction of future exploration by making clear the state of distribution of ultramafic rocks which may embrace Nickel copper deposits and that of pegmatites which may embrace ores of gold, tin, niobium and tantalum and by clarifying the relationship between geological structure and mineralization.

1-2 Outline of Survey

The geological survey was planned to be carried out over an area of

250 km^2, but the area was reduced to 242 km^2 because of the existence of a dangerous shooting zone, the Police training ground. The geological survey was carried out on the same routes as those used for geochemical survey, and 1:25,000 scale route maps and geological maps were made.

During geochemical survey which was also carried out over the same 242 km^2 area, soil samples were collected in places at a line spacing of 300 m and a sampling interval of 200 m. However, in areas which seemed to be covered by ultramafic rocks or mineralized zones, soil samples were collected at a sampling interval of 50 m. Because of the nature of geochemical exploration, soil samples were not collected from Quaternary sediments or from farmland.

The number of soil samples analyzed was 4,501. The places where the samples were collected are shown on PL I-1-1 ~ 2.

The period of the survey from the time the party left Japan to the time it returned was 78 days. The number of working days required for the geological and geochemical surveys in Zimbabwe was 68 days, ranging from July 14 to September 19, 1983. In carrying out the surveys, various data obtained in the country, which had been prepared in the past, were fully utilized both for field works and the interpretation of the survey results.

During the surveys, the samples shown in the following table 1 were collected for laboratory works.

Table 1 List of Samples

	Elements	Number of Samples
Thin Section		100
Polished Section		20
X-ray Diffraction Analysis		10
Chemical Analysis of Rocks	SiO_2, CaO, Na_2O, Fe_2O_3, MnO, P_2O_5, LOI, Al_2O_3, MgO, K_2O, FeO, TiO_2, BaO	10
Chemical Analysis of Komatiite Rocks	SiO_2, CaO, Na_2O, Fe_2O_3, MnO, P_2O_5, LOI, Al_2O_3, MgO, K_2O, FeO, Tio_2, BaO Ni, Cu, S, Co, Cr	100
Chemical Analysis of Ore	Au, Cu, Zn, Ni	20
Chemical Analysis of Ore	Nb, Ta, Sn, W	20
Chemical Analysis of Ore	Cr, Fe	5

1-3 Organization of the Survey Team

The survey in the region was carried out under the cooperation of the Geological Survey Department of the Ministry of Mines of the Republic of Zimbabwe. For the field work, one counterpart member was dispatched from the Geological Survey Department to take part in the field work with Japanese members, and the survey was performed in a friendly atmosphere. The members of this survey were as follows.

(1) Prior Survey and Consultation for Agreement

Japanese Members

Makoto Ishida	Metal Mining Agency of Japan
Ken Nakayama	Metal Mining Agency of Japan
Tadaaki Ezawa	Japan International Cooperation Agency

Seiichi Mizusawa — Agency of Natural Resources and Energy, Ministry of International Trade and Industry

Zimbabwean Members

E.R. Morrison — Geological Survey Department, Ministry of Mines

D.E.H. Murangari — Geological Survey Department, Ministry of Mines

C.B. Anderson — Geological Survey Department, Ministry of Mines

(2) Field Survey

Japanese Survey Members

Ken Nakayama
Coordination — Metal Mining Agency of Japan

Takahisa Yamamoto
Coordination — Metal Mining Agency of Japan

Leader : Hiroji Kuronuma Dowa Koei Co., Ltd.
Geological and Geochemical Surveys

Members : Akiyoshi Komura Dowa Koei Co., Ltd.
Geological and Geochemical Surveys

Kazuyoshi Masubuchi Dowa Koei Co., Ltd.
Geological and Geochemical Surveys

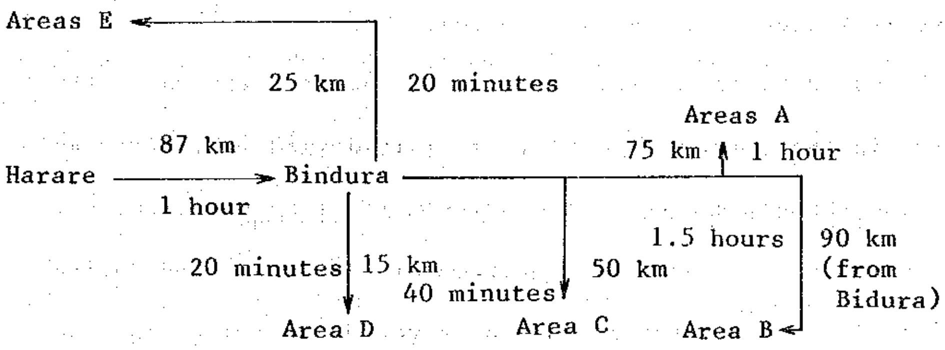
Zimbabwean Survey Member

Owen Nyamana — Geological Survey Department, Ministry of Mines

CHAPTER 2 GENERAL CHARACTERISTICS OF SURVEYED AREAS

2-1 Location and Transportation

The areas surveyed are located around Bindura about 70 km northeast of Harare and marked on 1:250,000 scale topographical maps MTOKO SE-36-6 and SALISBURY SE-36-5, published by the Zimbabwean Government. For transportation between Harare and the areas, automobiles were used. The road from Harare via Bindura to Shamva is paved facilitating travel by auto.



The distances and time by car to the center of the Areas A, B, C, D and E are shown above. Within these areas, there were rough places where we could not utilize automobiles and had to travel on foot. The Area B is farthest from Bindura. To reach it, we had to take the road, which leads to the Area A, farther to the north, and trun southward to the Area B.

2-2 Geographical Features and Climate

The surveyed areas are in the highland of Zimbabwe more than 800 m above sea level. The land in the areas generally reflects their geological structure. In the areas where basaltic, andesitic greenston, ultramafic rocks, or banded ironstone are distributed, there are narrow hilly districts which run parallel to the geologic terrains in relative heights of 200 to 300 m. Between these narrow hilly districts, quarternary formations have distributed and formed fertile farmlands. In these hilly districts, 5 to 6 m high shrubs have grown. In contrast with these features, granite terrains form rounded mountains quite different from the configuration of the areas where the basaltic, andesitic greenstone, or banded ironstone are distributed. In the Areas A, B and C, there are steep slopes more than 30 degrees. In the Areas D and E, serpentinite form low hilly districts running along the trend of strata. Their height is low compared with those hills in the A, B and C areas, and there are many flat areas, making surveying easy.

The surveyed areas are in the basin of the River Mazoe which flows northeastwards in the areas. The river is divided into many tributaries near Bindura and Shamva, but the tributaries unite into one river of nearly 100 m wide near the Area A. The time of the survey was during the dry season from July to September, but the river was flowing, and the people said that this river would not run dry there all through the year.

As the surveyed areas lie between south latitudes 17^{o} and 18^{o}, the climate of the areas would be tropical if the areas were lowlands, but because the altitude of the areas are higher than 1000 m, it was cool and comfortable in the morning and evening. The dry season from May to October and the wet season from November to March are clearly separated. the survey was carried out during the dry middle winter season, then the temperature was 25 to $30^{o}C$ in the daytime and 17^{o} to $18^{o}C$ at night and early morning. It was rather hot in the daytime, but cool at night. Since it was the dry season, there was no rain with the exception of one day, all through the survey period, aiding in the survey work. Although a annual rainfall in this district is 700 to 900 mm, it is concentrated in the rainy season, from the middle of November to April, and fine weather from May to October. In addition, there were no mosquitoes during the survey period. As we have seen, the climate in the area is very good compared with the low places of 17 degrees of the southern latitude.

2-3 Social Characteristics of the Surveyed Areas

The industries in the surveyed areas are agriculture and mining. Small scale farming in the Areas A and B which are remote from Bindura is carried out on the plains between the mountains by Africans employing primitive production methods. In Areas C, D and E, however, modern, large scale farming methods using agricultural machines have been adopted. The products are mainly maize, leaf tobacco, cotton, some coffee, citrus fruits, vegetables, etc. Stock-farming is also carried out in mountainous districts with comparatively gentle slopes, and because of the mild climate and abundant concentrated fodder, good quality cattle is said to be raised there.

Concerning mining, the Trojan Mine, a nickel and copper mine, is located about 5 km southwest of Bindura, the Shamva Mine which produces gold, is located about 20 km to the east, and many small gold mines are localed near Shamva. All these mines contribute to the economy in the areas.

In spite of the existence of the industries mentioned above, the standard of living in the areas is still low, and there are few job opportunities. When the survey team employed labourers, it was easy to obtain the required number. The level of the people's will to work, and their ability to perform their duties is very high judged by the African standard. It will become easy to find people with administrative capabilities and technical skill when the level of education is raised.

The Zimbabwean Government is concentrating its effort on education, and in such remote places as Areas A and B, there are schools where elementary education is enthusiastically offered.

The outline of the infrastructure of the surveyed areas at present in various aspects is as follows: Concerning transportation, the main roads are paved with asphalt as previously mentioned, and roads connecting villages have been developed. Therefore, the transportation is conparatively good. Concerning communications, there is post office in Bindura, and domestic and overseas mail service is readily available. Direct dial telephone communication in the city of Bindura is in use and calls to Harare are possible via an operator. Electric power is being supplied to Bindura, and to the large mines and farms in neighbouring areas. There are no problems in supplying electrical power to the homes in and around Bindura, so the electrical power supply can be regarded as better than in many other African countries. However, we will immediately be unable to obtain power of drilling in the surveyed areas.

Bindura is the center of both commerce and agriculture. It is easy to procure supplies and parts for agricultural machinery, as there are many shops dealing in them. There are also shops dealing in general commodities, foodstuff, clothing, etc., and there are no problems in procuring general articles. There is also a hotel and a bank. The survey team lodged at the hotel. The exchange of traveller's checks of US dollars to Zimbabwe dollars was provided by the local banks.

As mentioned before, general social conditions in the surveyed areas were good, and there were no particular problems in carrying out the survey.

CHAPTER 3 OUTLINE OF THE GEOLOGY AND ORE DEPOSITS

3-1 Geology

The Republic of Zimbabwe is geologically divided into two parts by a north-south line drawn from Plumtree (near the border of Botswana) to the area near the Zambezi River (to the north of Chinhoyi). The eastern half consists of two groups, one of which is composed of granite, gneiss, and hybrid rock, and one of which is composed of greenstone. These groups form the well-known Rhodesia Craton. It is a stable block of the Archaean era, being constituted of rock whose age ranges from 2,600 Ma to 3,600 Ma. This craton is separated from the Kaapvaal Craton at the south by the Limpopo Mobile belt. The Zambezi Mobile belt and the Mozambique Mobile belt extend to the north and to the east. The Karoo system (the Upper Carboniferous to the Lower Jurassic) and Cretacious system, cover the Rhodesia Craton in both south-eastern and northwestern Zimbabwe.

The greenstone groups in the Rhodesia Craton consist of the Sebakwian group at the bottom, followed by the Bulawayan group and the Shamvaian group, forming a broad scale synclinorium.

Sebakwian Group:

This group is rarely exposed, being distributed only around the southern central part of the craton. It was subjected to a metamorphism and is composed of ultramafic greenstones, amphibole schist, felsic schist, and gneiss whose age is unknown. It shows rock facies comparatively similar to those of the Upper Bulawayan Formation.

The age of a gneiss fragment which is a xenolith in the greenstone is indicated to be 3,500 Ma.

Bulawayan Group:

This group is distributed in the Rhodesia Craton here in place, especially appearing intermittently to Bulawayo, Kwe Kwe and the north of Harare, and near Shamva. Rocks are mainly composed of metamorphosed basalt and andesite lavas with metasedimentary rocks (quartzite, conglomerate) and ultramafic rocks in the lower part overlying the lower Sebakwian Group unconformably. Although the present distribution is limited as mentioned above, the group was once widely distributed, and the distribution became regulated owing to the intrusion of young granite. The thickness of this group is estimated to be 15,000 m. According to the age determination of basalt, it is said that the age of sedimentation of this group occurred about 2,700 Ma ago.

This group is divided into the Lower Formation and the Upper Formation. As for the Lower Bulawayan, the type locality appears near Belingue, and the thickness is several thousand meters. The lowest part consists of amphibolite folded with gneiss, and the other parts consist of quartzite, grits, conglomerate, banded ironstone, and phyllite. The upper part is composed of basalt which contains much magnesium. The basalt has partly pillow lava texture. The top layer is composed of pillow basalt, basalt with spinifex texture and ultramafic rock. There are thick conglomerates and siliceous agglomerates at the uppermost part of the layer. The formation around Shamva, being rich in pyroclastic rocks, is called the Iron Mask Formation.

Meanwhile, the Upper Bulawayan is composed of mafic lava, ultramafic lava, acidic lava, tuff, banded ironstone, limestone, and sedimentary rocks. The mafic lava and the ultramafic lavas are now altered into serpentinite and the like. Basalt having spinifex texture and pillow lava texture is also present in the Upper Bulawayan. The Upper Bulawayan

Formation is very important as regards mineral resources. Nickel and copper ore deposits are embedded in the ultramafic rock with spinifex texture.

Shamvaian Group:

This group overlies the Bulawayan group unconformably, being composed of meta arkose, meta graywacke, phyllite, and conglomerate, and in some places banded ironstone. The distribution of this group is narrower than that of the Bulawayan Group. It lies around the axis of the syncline and is surrounded by the Bulawayan Group. It is distributed near Shamva, Kwe Kwe, and Masvingo. It becomes sandy in proportion to the distance from Shamva of the type locality especially to the south. It was subjected to metamorphism by the intrusion of granite. As this group is deposited on the local shallow sedimentary basin, it is said that it has been distributed in a narrower region than the Bulawayan group.

The group of granite which occupies most of the Rhodesia Craton is composed of Older Gneiss Complex and granite which is younger than the former. The Older Gneiss is the base for the sedimentation of the greenstone, and the age is presumed to be 3,500 Ma. The granite, the youngest one of which is said to be 2,650 Ma, is reactiviated intrusion formed by the reactivation and intrusion of the basement at various times during and after the sedimentation of the greenstone group.

In the western part of the region (which is in the central part of the country), where old gneiss and granite are distributed, there is a characterisic intrusive rock, called the Great Dyke because of its shape. Being composed of ultramafic rock, the intrusive rock is a stratiform differentiation intrusion whose distribution length is the greatest in the world. It continues as long as 540 km, running from the

NNE to the SSW, and its width ranges from about 3 to 11 km. This construction is not a dyke essentially, but is constituted of four long extending lopolithtic complexes. The intrusion is said to have been occurred about 2,500 Ma ago, and it intruded in the greenstone, granite and gneiss groups.

Karoo System:

Sedimentary rocks and the basalt lavas of Permian and Jurassic overlie these basement rocks. Most of them are distributed to the west of the line from Plumtree to Chinhoyi.

3-2 The Mobile Belt

There are three mobile belts in Zimbabwe: the Limpopo, Mozambique, and Zambezi, all of which were formed during the Precambrian Age.

The Limpopo Mobile Belt:

This belt developed around the southeast border between Zimbabwe and the South Africa. The width is about 300 km, and the length about 600 km. The Mozambique belt traverses it in the east, and it disappears westward into Botswana. It is inferred that the belt probably extends under the Kalahari Desert. The rocks of the belt are mainly composed of highly metamorphosed rocks such as gneiss (2,700 ± 200 Ma) as well as greenstone and baserock. Owing to the stretching rock of the craton, there is no fundamentally structural and stratigraphical gap between the craton and mobile belt. The branch of the Great Dyke cut this mobile belt, and the orogenic movement ceased 2,600 Ma ago.

Mozambique and Zambezi Mobile Belts:

Both the Mozambique and Zambezi belts are a part of the Pan-African mobile belt and the Zambezi belt is a branch of the Mozanbique belt. The both mobile belts are composed of highly metamorphosed rocks (600 ± 200

Ma). The Mozambique mobile belt in Zimbabwe runs from south to north along the border of Mozambique in the east. According to the age determination of the belt over the whole of Africa, the movement, which was multicyclic, was concentrated in three periods respectively 835 Ma, 650 Ma, and 480 Ma ago.

The Zambezi mobile belt can be seen along the Zambezi River from the northwest to the northeast end in this country. It runs from Wankie to Nyamapanda through Kariba, and is 900 km in length.

3-3 Metallic Ore Deposits

The main metallic ore deposits in Zimbabwe, are gold, nickel, copper, chrome, tin, tantalum, and iron. Gold ore deposits occurred as a hydrothermal vein type ore deposits mainly in greenstone and granite in cratons. Nickel and copper ore deposits are associated with the ultramafic rocks, and are embedded in serpentinite or gabbro as host rock. The nickel ore deposits are not always formed in a definite geological structure. Most of them are embedded in the upper and lower parts of the Upper Bulawayan Formation. Ore bodies, being massive, are composed of pyrrhotite and pentlandite followed by an infinitesimal amount of chalcopyrite. The nickel-copper ratio is about 15:1. Meanwhile, there exist ore deposits such as Madziwa which consist of sulphide in gabbroic differentiated rock in the Older Granite-Gneiss. Copper is in cases produced together with hydrothermal gold ore deposits. Tungsten is produced from sheelite in gold bearing quartz veins in the basement. Tin and tantalum are mainly embedded in pegmatite. The main iron ore deposits always exist in a greenstone belt of the Archaean. It is produced as a hematite deposit concentrated in a banded ironstone or an iron bearing chert and limonite occurs as a minor.

The ore deposits of chromium, which occupy an important position in various metallic minerals in Zimbabwe, are classified into podiform (small mass and lenticular type) and stratiform deposits. The former is embedded in greenstone, whereas the latter is found in the Great Dyke. The podiform deposit is of gold whose age of occurrence is older than the time of intrusion of the Great Dyke, and destributes in the Seluke region. Chromium layers in the ore bodies in the Great Dyke are generally of the order of 10 cm thick. At any rate, Zimbabwe is known in the world as the country having the largest reserves of high grade chromium ores.

Asbestos is produced from ultramafic rocks in the Sebakwian and the Bulawayan Groups, excepting the Ethel Mine in fault zone in the Great Dyke to the north of Harare, and is an important mineral product of this country.

PARTICULARS

PART I GEOLOGICAL SURVEY

CHAPTER 1 INTRODUCTION

The general area covers the eastern part of the Mazoe-Shamva Greenstone Belt of Archean age. Most of the area is underlain by volcanic rocks ranging in composition from rhyodacite through andesite and basalt to komatiitic basalt and komatiite, mafic rocks being dominant. The volcanic rocks are interbeded with pyroclastic rocks and sedimentary beds, chiefly banded ironstone and limestone. The whole pile has been intruded by vein quartz, pegmatite, gabbro, and dolerite.

The Chindamora Granite Batholith, a part of which is exposed along the southwestern border of the general area, has previously been defined as a late stage granite in the batholith and intrudes the volcanic pile. In the northeastern and northwestern parts of the general area, margins of other granitic masses are exposed, and geological relations to the volcanic pile are just the same that of the Chindamora Granite. These have produced a contact metamorphic aureole overprinted on regional lower green schist to amphibolite facies of metamorphism.

The general trend of the Greenstone Belt varies from northeast-southwest in the eastern part to northwest-southeast in the western part. The Belt was tightly folded along an east-west trending synclinal axis along the central part of the Belt. The volcanic pile is cut by a number of faults radiating from the granites.

CHAPTER 2 STRATIGRAPHY

The Mazoe-Shamva Greenstone Belt is an east-west trending arcuate zone of tightly folded and regionally metamorphosed up to amphibolite facies, and consists of volcanic and sedimentary rocks of the Archean Bulawayan and Shamvaian Groups.

In the south it is bounded by the granite and gneiss complex of the Chindamora Batholith, and in the north by other granodiorite and gneiss complex.

The greenstone belt is subdivided into the following units.

Groups	Formations	Rocks
Shamvaian		pelitic to conglomeratic sedimentary rocks, pyroclastic rocks
Bulawayan	Upper Bulawayan (Upper Greenstones)	mafic volcanic rocks serpentinite, pyroclastic rocks, banded ironstone, limestone
	Lower Bulawayan (Lower Greenstones)	Mafic to felsic pyroclastic rocks, banded ironstone, limestone

The Lower Greenstones, forming the base of the greenstone belt in the general area, are exposed on the southwestern corner of the area. They consist mainly of felsic to mafic pyroclastic rocks, mafic lavas, limestone, and banded ironstone (dark grey chert with interbeded oxide iron, and tuffaceous layers). The thickness of the formation in this area is less than 1,000 meters.

The Upper Greenstones are the most extensively distributed rocks in the area, and overlie the Lower Greenstones uncomformably. The main lithological constituents are andesitic, basaltic, and komatiitic volcanic rocks, pyroclastic rocks, banded ironstone and limestone. Regiomal metamorphism is of lower greenschist to amphibolite facies, and contact metamorphism of the mafic rocks by intrusive granites has produced a recrystallized hornblende hornfels which is often schistosed. Ultramafic intercalations, outcropping as sheard serpentinite and actinolite-tremolite schist, are distributed throughout the area. The formation in this district is up to 5,000 meters thick.

The Shamvaian Group is distributed in the central part of the district, trending east-west, and in its middle parts occupying a regional synclinal axis. Rocks represented are greywacke, pebbly greywacke, conglomerate, felsic to mafic pyroclastic rocks, and agglomerate. The group in this district is up to 7,000 meters thick.

A schematic geological columnar section of the Shamba area is shown in Fig. I-2-1.

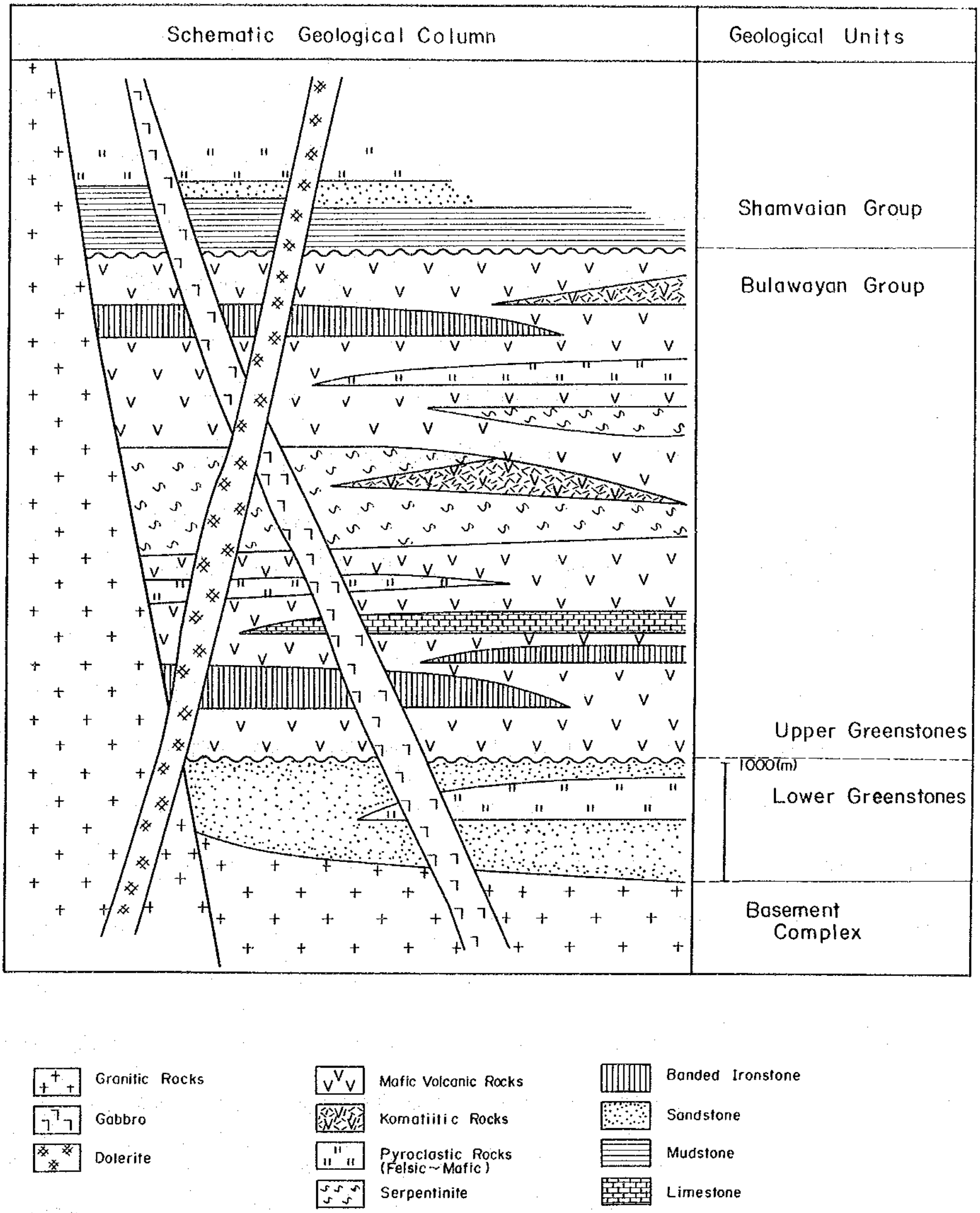


Fig.I-2-1 Schematic Geological Columnar Section of Shamva Area

CHAPTER 3 IGNEOUS ROCKS

Following are the descriptions of ultramafic rocks and other volcanic rocks in the greenstone belt, intrusive gabbro and dolerite, and granitic rocks surrounding the greenstone belt.

3-1 Ultramafic Rocks

Included in this group are the massive serpentinites, talc-carbonates, the talc-tremolite chlorite rocks, and komatiitic rocks.

The serpentinites fall into two groups: medium grained greyish green rocks with chlorite veinlets and carbonate patches, and fine grained dark bluish massive variety. Under the microscope, the fine grained type is observed to consist of partly to wholly serpentinized olivine crystals. Antigorite is the main alteration product of olivine, but talc is also present.

The talc-tremolite chlorite rocks are mostly greyish green schistose rocks where actinolite is present and the rock presents greyish brown in colour. The talc-tremolite chlorite rocks have chemical affinities (Mg-rich, Ca-poor) with the associated serpentinites. Under the microscope, it is recognized that the original rocks of these are mainly wehrlite, lherzolite, and dunite. But from the mode of field occurrences of the rocks it can be said that at least a part of the bodies was originally komatiitic lava flows, the name applied to mafic rocks with exceptional Mg contents.

These serpentinite group rocks have been extensively subjected to regional metamorphism which affected all over the greenstone belt. It is supposed that the metamorphosed temperature was between 400°C and 650°C, because no brucite is present and tremolite and talc are commonly present.

(from Winker's diagram 1973) There is no evidence of olivine being recrystalized. Actinolite is not observed under the microscope.

Typical komatiite units, which have beautiful spinifex texture consisting of olivine blades with some magnetite, tremolite, and chlorite, have been observed in several parts of the greenstone belt. Under the microscope, small crystals of amphibole, tremolite, chlorite, and plagioclase are observed with biotite, epidote, sphene, and iron minerals as accesory minerals. In some cases, blast-spinifex texture can be seen.

On hundred samples of ultramafic rocks, which were recognized as komatiitic rocks and serpentinites presumably altered from komatiitic rocks, were sampled for whole rock chemical analysis. The locations of the rock samples and the results of the chemical analysis are shown in an attached map and appendix 7.

Based on the results, the correlation coefficients between each constituent were calculated. The results are shown in the table I-3-2. In this table, specially followings are very significant.

	Positive Correlation	Negative Correlation
MgO	Fe_2O_3, Cr, Ni, LOI	SiO_2, Al_2O_3, Na_2O, CaO, TiO_2, FeO
TiO_2	Al_2O_3, FeO	(MgO), LOI
CaO	Al_2O_3, FeO	Fe_2O_3, (MgO), Ni, LOI
Cr	(MgO), LOI	SiO_2, Al_2O_3
Ni	Fe_2O_3, (MgO), LOI	SiO_2, Al_2O_3, FeO, (CaO), Na_2O

( ) : duplicatedly shown

Table I-3-1 Results of Whole Rock Analysis (10 samples)

	No.	1	2	3	4	5	6	7	8	9	10
	Sample No.	BM-37	CM-45	BM-27	AM-9	CM-49	AK-23	CM-41	AM-19	CM-55	HK-38
Elements wt (%)	SiO_2	46.09	45.47	67.59	70.65	38.06	52.68	50.03	52.73	53.34	52.32
	TiO_2	0.65	0.56	0.35	0.35	0.14	1.15	1.64	0.87	0.94	0.85
	Al_2O_3	17.13	10.24	16.12	15.27	3.29	14.98	14.35	15.81	14.13	13.93
	Fe_2O_3	2.30	2.48	2.47	1.16	9.42	2.40	2.13	1.28	1.10	0.95
	FeO	7.36	9.00	0.99	1.24	1.74	8.65	8.43	6.78	8.51	9.03
	MnO	0.16	0.17	0.03	0.03	0.10	0.12	0.25	0.16	0.14	0.23
	MgO	10.89	17.78	1.26	0.90	35.53	5.26	5.58	6.54	8.21	8.44
	CaO	10.64	5.34	2.50	2.14	0.30	8.84	13.83	11.42	9.58	9.87
	Na_2O	1.46	1.18	5.00	3.68	0.19	3.00	1.61	3.13	2.39	2.15
	K_2O	0.17	4.55	2.42	4.05	0.05	0.68	0.14	0.07	0.05	0.14
	LOI	1.80	2.64	1.28	0.53	11.18	1.95	1.79	1.36	1.41	2.17
	P_2O_5	0.10	0.11	0.18	0.17	0.08	0.20	0.24	0.11	0.13	0.09
	BaO	0.02	Tr	0.06	0.07	Tr	Tr	Tr	Tr	0.04	0.04
	Total	99.62	99.52	100.25	100.24	100.08	99.91	100.02	100.26	99.97	100.17
Norm wt (%)	Q	0.00	0.00	22.61	27.85	0.00	4.64	5.40	1.54	4.86	3.49
	C	0.00	0.00	1.06	1.22	2.89	0.00	0.00	0.00	0.00	0.00
	OR	1.03	27.74	14.44	23.99	0.33	4.10	0.84	0.42	0.30	0.84
	AB	12.62	0.04	42.72	31.21	1.81	25.89	13.85	26.77	20.51	18.55
	AN	40.55	9.49	11.64	9.87	1.09	25.91	32.05	29.19	28.07	28.49
	NE	0.00	5.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	DI	7.65	10.75	0.00	0.00	0.00	7.96	17.27	14.39	10.10	10.66
	HD	2.67	2.93	0.00	0.00	0.00	6.48	12.43	7.89	5.78	6.55
	EN	15.74	0.00	3.17	2.25	37.07	9.67	6.13	9.79	16.05	16.49
	FS	6.29	0.00	0.00	0.80	0.00	9.02	5.06	6.16	10.54	11.62
	FO	5.91	28.53	0.00	0.00	43.75	0.00	0.00	0.00	0.00	0.00
	FA	2.60	9.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	MT	3.41	3.71	2.29	1.69	6.21	3.55	3.14	1.88	1.62	1.40
	HM	0.00	0.00	0.91	0.00	6.31	0.00	0.00	0.00	0.00	0.00
	IL	1.26	1.10	0.67	0.67	0.30	2.23	3.17	1.67	1.81	1.65
	AP	0.28	0.31	0.49	0.46	0.24	0.55	0.66	0.30	0.36	0.25
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[Rock Name] 1 : Gabbro 2 : Mafic Pyroclastic Rock 3 : Dacite 4 : Granite
5 : Serpentinite 6 : Gabbro 7, 8 : Basalt
9, 10 : Basaltic Komatiite

[Norm] Q: SiO_2 C: Al_2O_3 OR: $K_2O \cdot Al_2O_3 \cdot 6SiO_2$
AB: $Na_2O \cdot Al_2O_3 \cdot 6SiO_2$ AN: $CaO \cdot Al_2O_3 \cdot 2SiO_2$
NE: $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$ DI: $CaO \cdot MgO \cdot 2SiO_2$
HD: $CaO \cdot FeO \cdot 2SiO_2$ EN: $MgO \cdot SiO_2$ FS: $FeO \cdot SiO_2$
FO: $2MgO \cdot SiO_2$ FA: $2FeO \cdot SiO_2$ MT: $FeO \cdot Fe_2O_3$ HM: Fe_2O_3
IL: $FeO \cdot TiO_2$ AP: $3(3CaO \cdot P_2O_5) \cdot CaF_2$

Table I-3-2 Correlation Coefficient Matrix of 100 Komatiitic Rocks

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O
SiO_2	1.0000								
TiO_2	** 0.6657	1.0000							
Al_2O_3	** 0.8404	** 0.7297	1.0000						
Fe_2O_3	**-0.8352	**-0.5666	**-0.8130	1.0000					
FeO	** 0.6761	** 0.8176	** 0.7845	**-0.7671	1.0000				
MnO	** 0.3252	** 0.4182	** 0.4447	**-0.2837	** 0.4651	1.0000			
MgO	**-0.9153	**-0.8028	**-0.9644	** 0.8257	**-0.8424	**-0.4648	1.0000		
CaO	** 0.7454	** 0.6523	** 0.9251	**-0.8063	** 0.8244	** 0.5209	**-0.9107	1.0000	
Na_2O	** 0.7940	** 0.7280	** 0.7574	**-0.6750	** 0.6505	** 0.2812	**-0.8125	** 0.6615	1.0000
K_2O	** 0.3638	0.1500	0.1489	-0.1325	0.0156	-0.0845	*-0.2164	-0.0434	0.0685
P_2O_5	0.1258	0.1642	0.1758	-0.1076	0.1087	** 0.3461	-0.1598	0.1173	0.0468
LOI	**-0.8945	**-0.7509	**-0.9493	** 0.8437	**-0.8638	**-0.4658	** 0.9782	**-0.9321	**-0.7796
S	0.1649	0.1735	0.1947	-0.1553	0.1326	** 0.3289	-0.1865	0.1486	0.0890
Cu	** 0.4897	** 0.5310	** 0.5632	**-0.4193	** 0.5530	* 0.2439	**-0.5984	** 0.5495	** 0.5151
Cr	**-0.7141	**-0.6508	**-0.7492	** 0.6722	**-0.6768	**-0.3081	** 0.7617	**-0.6926	**-0.6422
Ni	**-0.8088	**-0.6791	**-0.8364	** 0.7988	**-0.7545	**-0.3294	** 0.8634	**-0.8006	**-0.7157
BaO	** 0.4810	* 0.2405	* 0.1999	-0.1858	0.0272	-0.0884	**-0.2896	-0.0167	0.1400
Co	**-0.5614	**-0.3746	**-0.5274	** 0.5206	**-0.3575	-0.0324	** 0.5279	**-0.4576	**-0.4815

	K_2O	P_2O_5	LOI	S	Cu	Cr	Ni	BaO	Co
K_2O	1.0000								
P_2O_5	0.0516	1.0000							
LOI	-0.1569	-0.1139	1.0000						
S	0.0084	** 0.9526	-0.1470	1.0000					
Cu	0.0185	0.1590	**-0.5858	* 0.2139	1.0000				
Cr	-0.1524	-0.1133	** 0.7457	-0.1433	**-0.4846	1.0000			
Ni	-0.1505	-0.1083	** 0.3576	-0.1392	**-0.5337	** 0.6064	1.0000		
BaO	** 0.8207	0.0815	*-0.2203	0.0505	0.1024	*-0.2031	*-0.2082	1.0000	
Co	-0.1584	-0.0611	** 0.5211	-0.1051	**-0.3026	** 0.3991	** 0.6108	-0.1925	1.0000

Degree of Free
N = 98

Significance test
** : lR (0.01)l ≥ 0.2565
* : lR (0.05)l ≥ 0.1965

Furthermore, the relationships among important constituents, such as $CaO-MgO-Al_2O_3$, $Al_2O_3-(FeO+Fe_2O_3+TiO_2)-MgO$, MgO-Cr, MgO-Ni, MgO-CaO, and MgO-Co are shown in the following diagrams, Fig. I-3-1, Fig. I-3-2, Fig. I-3-3, and Fig. I-3-4.

Fields for various rocks indicated by Arndt (1977) are shown in the diagram (Fig. I-3-1). According to this, the mafic to ultramafic rocks in this area are distributed in the fields of peridotitic komatiite - pyroxinitic komatiitic - basaltic komatiite - tholeiitic basalt, specially dominantly in the field of basaltic komatiite.

Also fields for various rocks indicated by Jensen Plot are shown in the diagram (Fig. I-3-2). According to this, the mafic to ultramafic rocks in this area are distributed in the fields of ultramafic komatiite - komatiitic basalt - tholeiitic - calc-alkalic, specially dominantly in the two fields, ultramafic komatiite and tholeiite.

Among them 28 samples are plotted in the field of ultramafic komatiite. 16 samples out of 28 are from serpentinite, and the rest of samples are from ultramafic lavas in the greenstone belt. These ultramafic komatiite lavas are from Area C, D, and E, but we found komatiite lavas which showed beautiful spinifex texture in Area A and B.

It can be said that volcanism of the greenstone belt in these areas was of a mixed type with the coexistence of both komatiite and tholeiite series. The posibility of such phenomenon was indicated by L. Haynes (1982).

Two variation diagrams between MgO and TiO_2, and MgO and CaO, (Fig. I-3-3), show steep diagonal spots concentration of low MgO·high TiO_2 - high MgO·low TiO_2, and low MgO·high CaO - high MgO·low CaO. These relationships match the general tendency of whole komatiitic rocks in Zimbabwe as indicated by E.G. Nisbet et al. (1983).

On the other hand, comparing with the diagram (Fig. I-3-4) which shows the case of Lac Guyer volcanic rocks, the rocks in the Shamva area are distributed in the fields of peridotitic komatiite - pyroxenitic komatiite - basalt, and dominantly in the area of basalt. In addition to that, some of the rocks in the Shamva area show much higher MgO contents than the Lac Guyer rocks. This means that those rocks field of serpentinite.

Two components diagrams between MgO and Cr, and MgO and Ni show right side up positive correlation coefficient distribution. But the spots are concentrated in the low MgO area, and are scattered in the high MgO area. In the diagram between MgO and Co, spots are separated in two groups, low MgO and high MgO groups, and the correlation coefficient is very low.

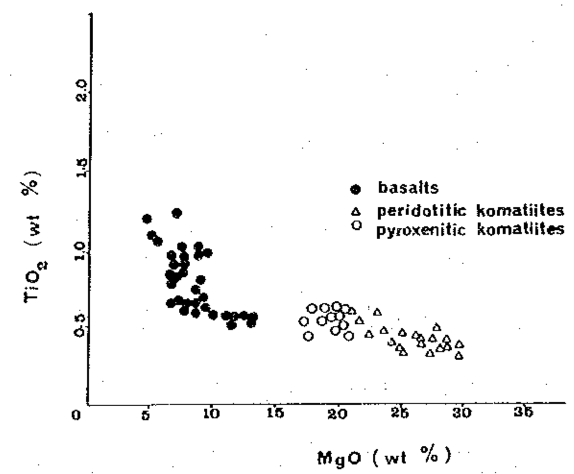
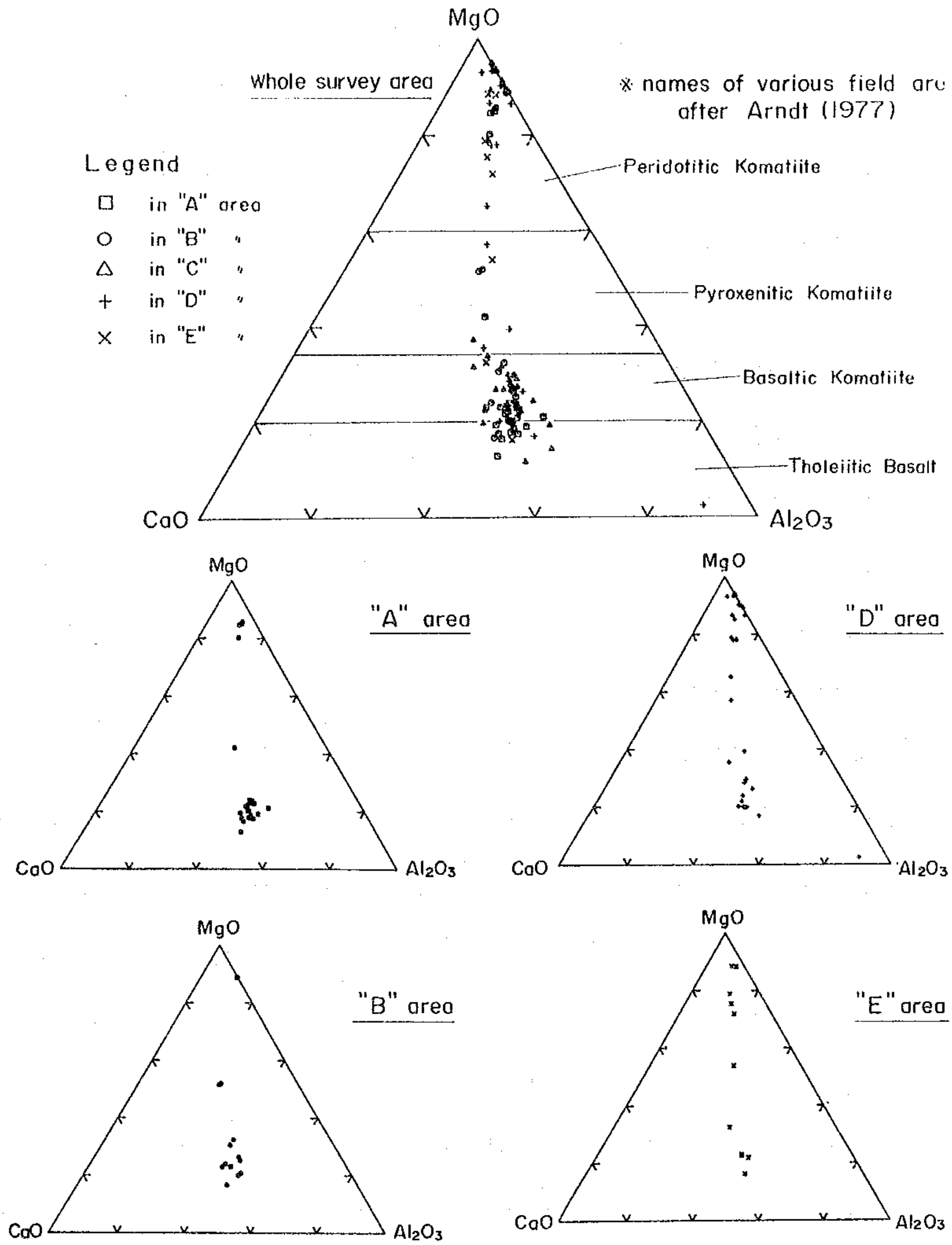


Fig I-3-4 MgO versus TiO (wt.%) diagram for the Lac Guyer mafic and ultramafic volcanic rocks. The komatiites are characterized by less than 1 wt.% TiO and form a continuous spectrum of liquid compositions ranging from 16 to 25 wt.% MgO. Those with more than 25 wt. % MgO represent samples enriched in olivine. The Lac Guyer volcanic rocks display a population minimum at 15 wt.% MgO separating komatiitic magmas from basalts

After K. Stamatelopoulou Seymore et al.(1983)



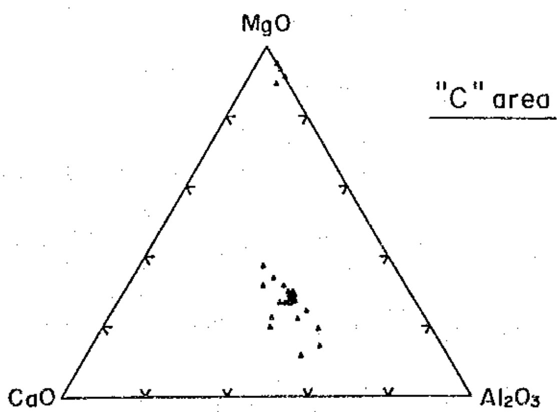
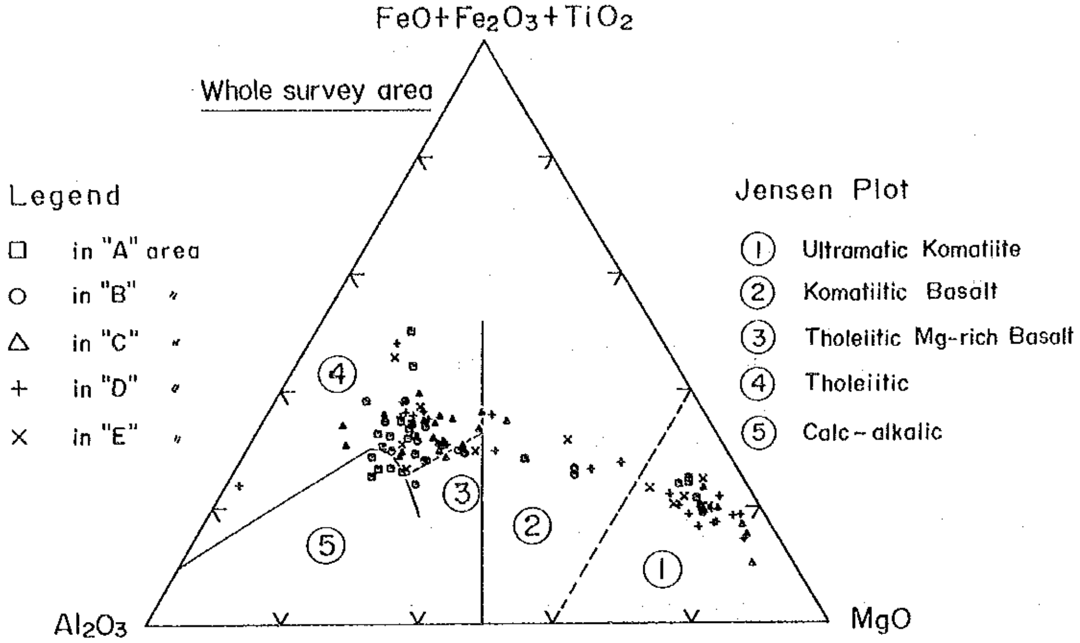
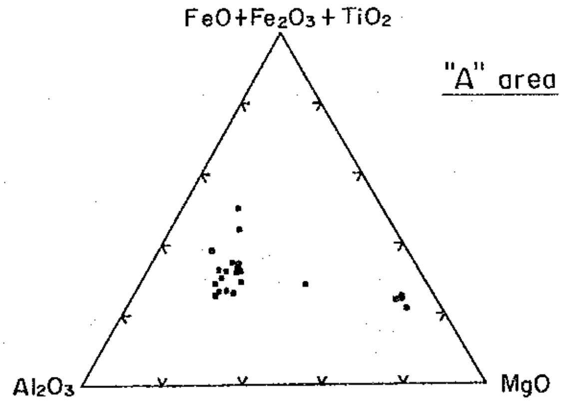
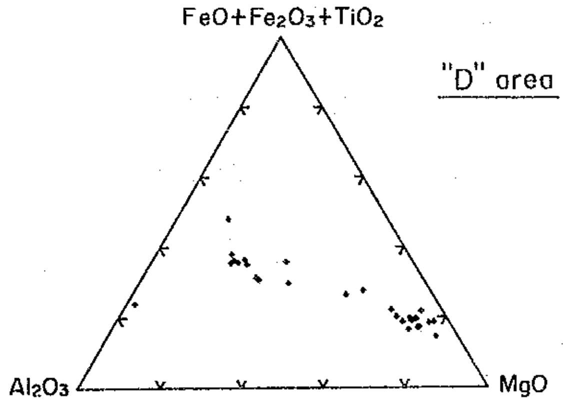
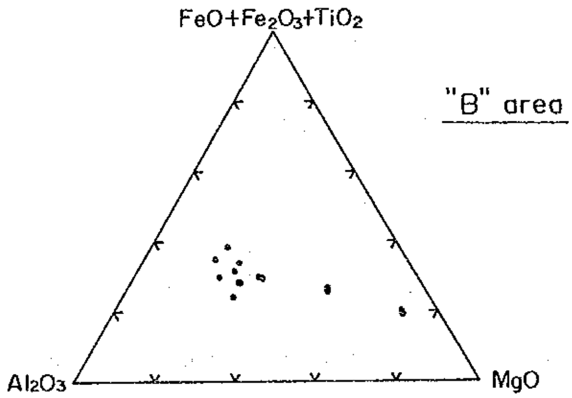


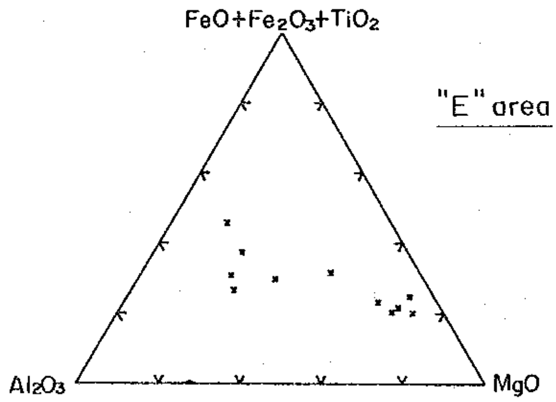
Fig. I-3-1 CaO–MgO–Al_2O_3 Diagram of Komatiitic Rocks in the Survey Areas











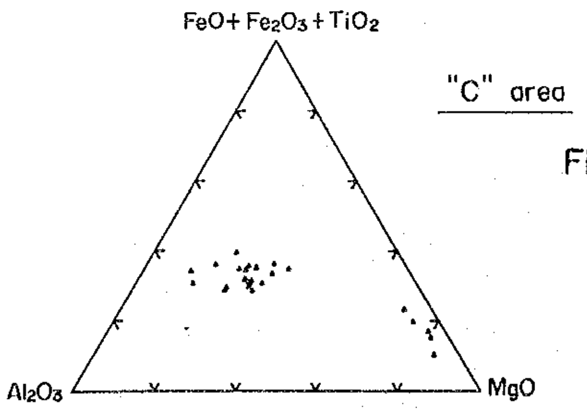


Fig. I-3-2 Al_2O_3-($FeO+Fe_2O_3+TiO_2$)-MgO Diagram of Komatiitic Rocks in the Survey Areas

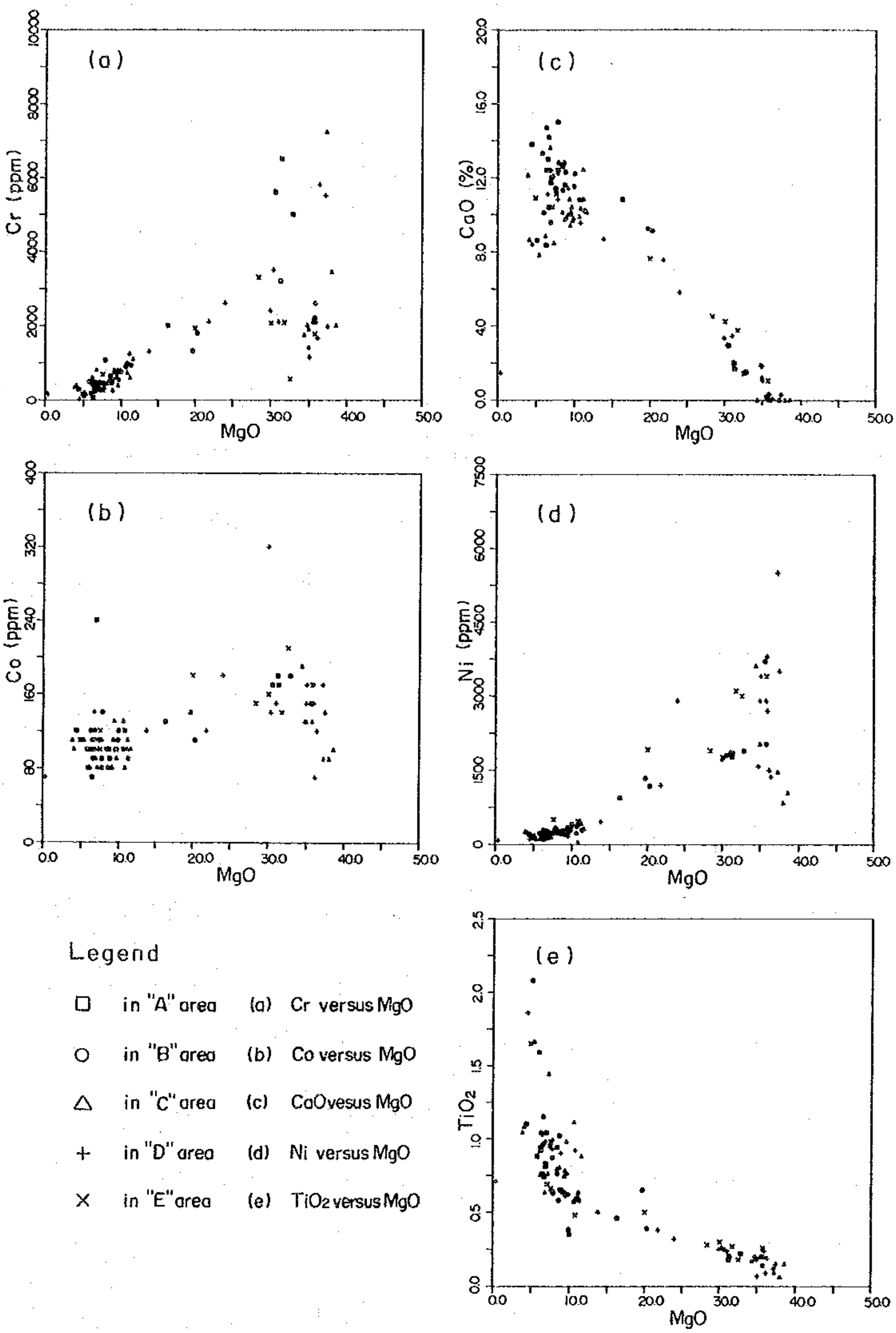


Fig. I-3-3 Variation Diagrams of Some Elements versus MgO

3-2 Lavas in the greenstone belt

The main constituent rock of the belt is mafic basaltic rock, but some thin lava flows of dacitic to andesitic rocks and thin layers of various pyroclastic rocks are intercaleted.

The basalt has been metamorphosed into amphibolite facies, and mainly consists of amphibole, plagioclase, epidote, and chlorite. Some parts of the basalt show andesitic components.

The dacite has been metamorphosed into quartz-feldspar schist.

3-3 Granite and Pegmatite

The granite and gneiss are most commonly exposed in south and north of the greenstone belt. Lithologically, the granites are extremely variable, incorporating all types from tonalite to adamellite. Grain size and mafic mineral content show considerable differences and the structure varies from massive to well-foliated.

The granites contain xenoliths consisting of felsic volcanic rocks, greenstones, ultramafic rocks, and ironstones. On the other hand, in the lower part of the Lower Greenstones, the volcanic breccia contains granite pebbles. Hence, it is possible to say that there were various igneous activity stages of the granites, from pre-greenstone to post-greenstone. But all the granites in contact with the greenstone belt in this area are intrusive, and nowhere was the pre-greenstone basement observed.

East-west striking bands of migmatite and injection gneiss are situated at the eastern end of the greenstone belt, and these are considered to be mixed zones of older granites, gneisses, greenstones, and younger reactivated granite intrusions.

Most of the pegmatites in this area are of the complex variety. The pegmatites mainly consist of large crystals of quartz, feldspar, muscovite, and lepidolite. Some of them have been mined for lithium, beryllium, tantalum, and tin.

3-4 Gabbro

A number of small size stocks and sill-like bodies of gabbro have intruded into the greenstones. Most of them show very coarse poikilitic texture or finer ophitic texture, but in some parts they show porphyroblastic texture. The rocks are usually slightly altered. It is thought that the gabbro intruded at the Upper Bulawayan age, but some of them are of the same activity as dolerite.

3-5 Dolerite

The dolerite is the youngest intrusive rock in the greenstone belt, and appears as a long dyke some of which are 100 km in length in this country. Three trends of the dykes are recognized; northeast-southwest, northwest-southeast, and north-south. Lithologically the dykes vary from quartz diorite to dolerite and gabbro, and some of them have been metamorposed into amphibolite facies.

CHAPTER 4 GEOLOGICAL STRUCTURE AND METAMORPHISM

4-1 Geological Structure

The general area covers the eastern part of the Mazoe-Shamva Greenstone Belt. The overall trend of rocks is east-west with a central synclinal axis in the central part of the belt, however, the southeasten boundary of the belt trends northeast to southwest, and the southwestern boundary trends northwest to southwest. The greenstone terrain is surrounded by large masses of granite-gneiss complex.

The greenstones are tightly folded along the synclinal axis, therefore the rock pile generally shows very steep dips. Folding was possibly accompanied by granite and ultramafic intrusions and some mineralization.

The horizon hosting the Trojan ore deposits could be very important for future exploration activities, because of the reason mentioned in Chapter 5 "Mineral Deposit and Occurrence". A postulated extention of the horizone in the area is shown in Fig. I-4-1.

4-2 Metamorphism

The whole greenstone belt has been subjected to a regional metamorphism. The Metamorphism is of a low pressure regional type, ranging green schist facies to amphibolite facies, judged from the existence of andalusite and cordierite as metamorphic minerals.

Ultramafic rocks have been commonly metamorphosed into sheared serpentinite and actinolite-tremolite schist.

It can be assumed that metamorphic temperature ranges between $400^{\circ}C$ and $650^{\circ}C$, judged from common existence of tremolite and talc. The assumed temperature is not against the regional metamorphism facies.

Intrusion of granite rocks into the greenstone belt made contact metamorphic effect to the country rocks, and in some places greenstones have been metamorphosed into recrystallized amphibolite hornfels with some schistosity.

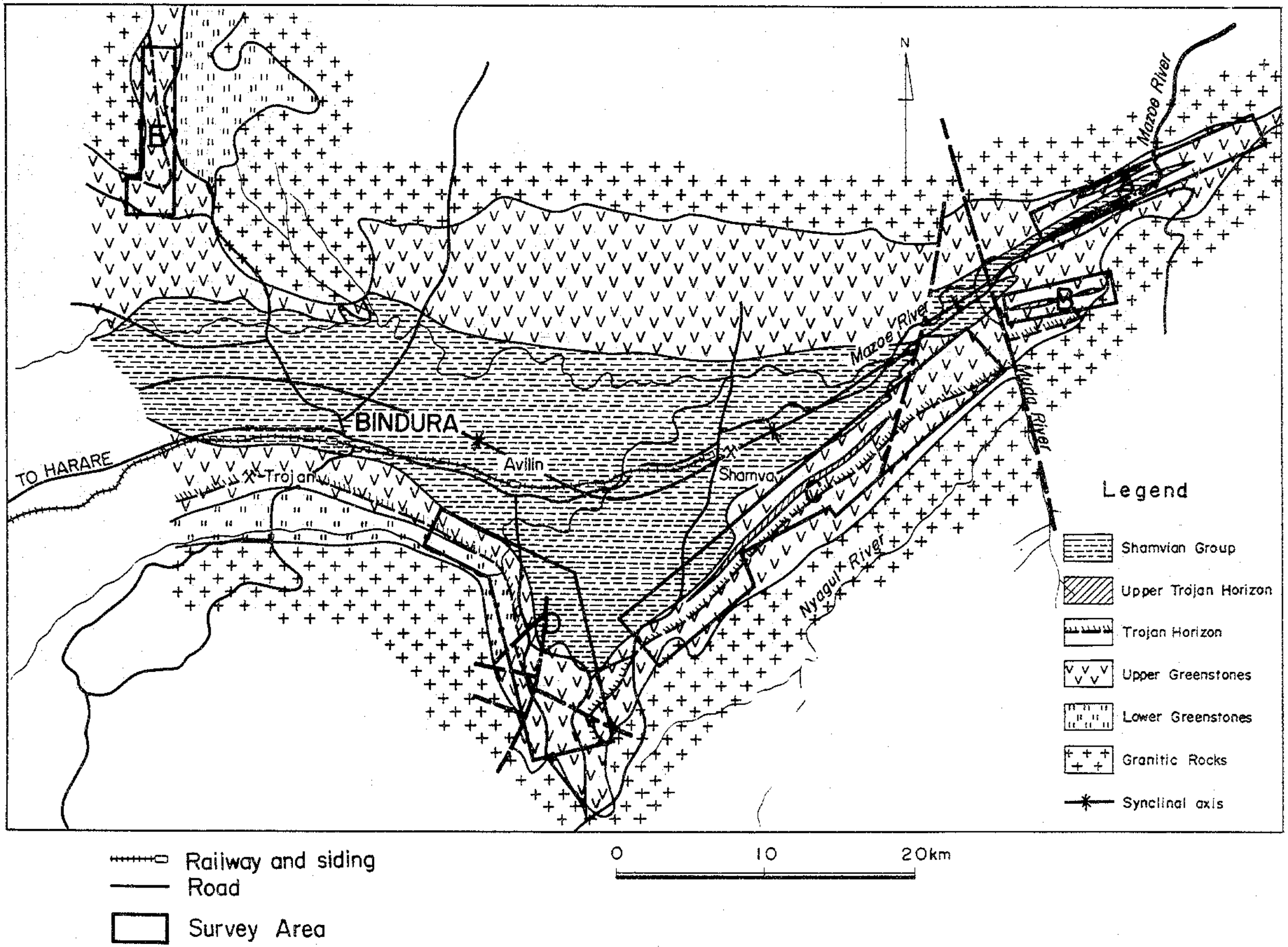


Fig.I-4-1 Outline of Geological Structure of the General Area

CHAPTER 5 MINERAL DEPOSIT AND OCCURRENCE

Three main types of mineralization occur in the general area; gold bearing quartz veins, nickel deposits associated with ultramafic rocks, and rare earth mineral-bearing pegmatites.

5-1 Gold Ore Deposits

- Shamva Mine (operated by Attica Mines Pvt. Ltd., Lonrho Group)

  Location : Central part, East of Shamva

  Geology : Metamorphosed pyritiferous tuffaceous sedimentary rocks of the Shamvaian

  Ore Deposit : Ore channels are almost indistinguishable from the country rock, but are aligned principally along north-east and east-north-east directions parallel to shear or fracture directions dipping steeply to the north. Total strike length of the mineralized channels is about 1,200 m

  Output : Started 1893. Total output to the end of 1965 was 46.447 kg of gold reflecting a recovery of 5.1 g/t. Presently annually producing about 45 kg Au.

- Gold mineralization zone around the Bindura Granite Stock (Kimberley Reef, R.A.N., Kingsley Hoard, Prince of Wales, Slam, Promoter, Hay: Some operating)

  Location : Central part. north of Bindura

  Geology : Bindura Granite and surrounding sandstone of the Shamvaian. Closely associated with the granite intrusion

  Ore Deposit : Three types of ores; quartz fissure veins, quartz veins with impregnation or replacement of wall rocks, impregnation deposits. Dominant strike of the reefs is east-west with a few trending north-south. Dips are get steep away from the granite

- Output : Not available

- Montdor Mine (operated by a private owner)

  Location : Central part, Eastern part of Area C

  Geology : Foliated greenstones of the Upper Bulawayan. Strike north-east, dip 50° - 70° north.

Ore Deposit : Gold occurs within laminated stringer zones and folded quartz veins, and is associated with much pyrite and pyrrhotite, coccurring as fine disseminations, stringers, and large blebs.

Output : Started 1909. Operated intermittently. Total output of the end of 1965 was 2,745 kg of gold at an average recovery grade of 22.6 g/t. Almost exhausted.

o Red Dragon Mine

Location : Central part. Middle of Area C

Geology : Basaltic greenstone of the Upper Bulawayan. Some plagioclase, porphyry and banded ironstone

Ore Deposit : Four quartz reefs. Strike E-W, dip 30° - 55°N width 15 - 45 cm

Output : Started 1908. Operated intermittently. Total output at the end of 1965 was 183.5 kg of gold, reflecting a recovery of 8.8 g/t

o Churchill Mine

Location : Northwestern part. Southwestern portion of Area E

Geology : Basaltic greenstone of the Upper Bulawayan and intrusive micro-diorite

Ore Deposit : Quartz vein on the contact between greenstone and micro-diorite

Output : Not available, ceased the operation in 1982

o Ivan Claim

Location : Central part. Near the east boundary of Area C

Geology : The Upper Bulawayan

Ore Deposit : Quartz vein

Output : Since 1937 a total of 1.46 kg of gold at an average recovery grade of 4.2 g/t

o Inyagui Mine

Location : Eastern part. In the south of Area B

Geology : Recrystallized limestone in the Upper Bulawayan. Strike NNE-SSW, dep 60° - 65°NW

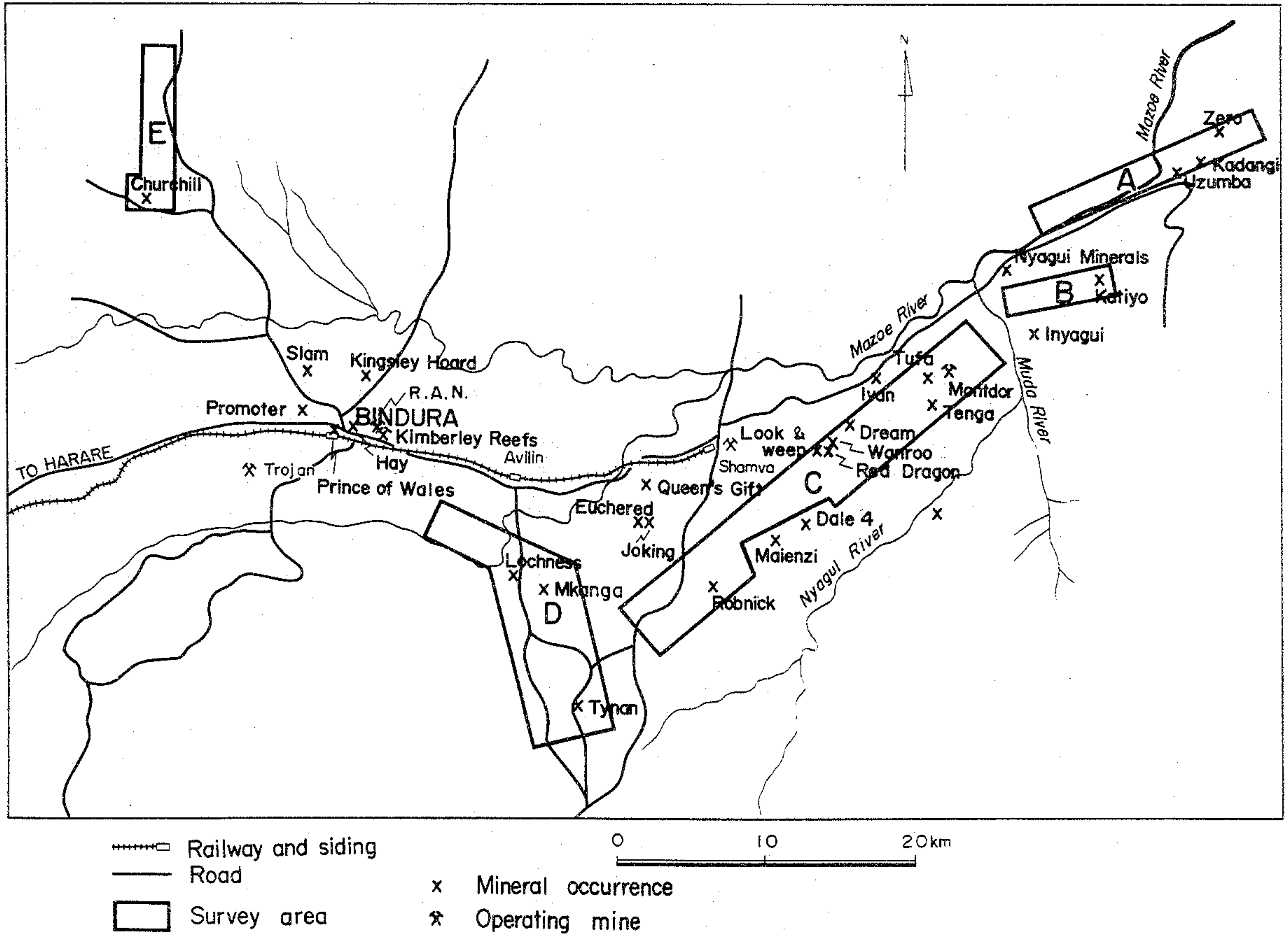


Fig.I-5-1 Mineral Occurrences in the General Area

Ore Deposit : Mineralized shear zone in of the crystalline limestone band

Output : Started 1910 operated intermittently. Total output at the end of 1936 was 5.88 kg of gold reflecting a recovery of 14.9 g/t

o Kadangi Mine

Location : Eastern part. In the east of Area A

Geology : The Upper Bulawayan

Ore Deposit : Quartz vein

Output : Since 1925 until 1939 a total of 22 kg of gold at an average recovery grade of 9.7 g/t

5-2 Nickel Ore Deposits

o Trojan Mine (operated by Bindura Nickel Co.)

Location : Western part

Geology : The Upper Bulawayan. From base of sequence ; andesitic lava, banded ironstone, and serpentinized ultramafic lava. Iron formation is interlayered with the ore bearing serpentinites and the whole assemblage is inclined nearly vertically to the north. The rocks have suffered amphibolite grade metamorphism.

Ore Deposit : The deposits occur in the serpentinite as massive, near massive, and disseminated ores. The main sulphide minerals are pyrrhotite, pentlandite, and chalcopyrite. Minor amounts of pyrite are present. The NI : Cu ratio of all three types of ore averages 15:1. Two main, as well as several minor, ore bodies occur at Trojan, and contain a total reserve of some 13 million tons of ore with an average tenor of 0.68% Ni.

Output : Started 1961. Total output at the end of 1982 was about 13 million ton of ore

o Katiyo Claims

Location : Eastern part. In the east of Area B

Geology : Serpentinite and banded ironstone of the Upper Bulawayan

Ore Deposit : Pyrite and pyrrhotite mineralization in serpentinite

Output : no production

5-3 Pegmatite Deposits

- o Uzumba Claims

  Location : Eastern part. Center of Area A

  Geology : Granite stock intruded into the Upper Bulawayan

  Ore Deposit : Pegmatite vein in the granite

  Output : Beryl 0.25 t

- o Zero Claims

  Location : Eastern part. In the east of Area A.

  Geology : Tremolite schist in the Upper Bulawayan.

  Ore Deposit : Pegmatite vein

  Output : Beryl 2.07 t

- o Wanroo Mine

  Location : Central part. Middle of Area C

  Geology : Greenstones of the Upper Bulawayan

  Ore Deposit : Lepidolite bearing pegmatite vein. 16 parallel veins within a belt of greenstone about 700 m wide. Strike SE-NW, dip 75° - 90° SW. Strike length up to 600 m. Width 0.3 - 5 m grade 1.15 kg/t microlite

  Output : 1959 - 1962. Microlite 4.62 t. Average concentrate grade 9.48% Sn, 68.60% Ta_2O_5 + Nb_2O_5

- o Look and Weep Claims

  Location : Central part. Middle of Area C

  Geology : Greenstones of the Upper Bulawayan

  Ore Deposit : Pegmatite vein

  Output : Until 1962 : tantalum concentrate, 0.52 t

- o Chenjera Claims

  Location : Southeastern part

  Geology : Younger granite

  Ore Deposit : Pegmatite vein

o Tafuna Hill area (Euchred, Joking, Queen's Gift, etc.)

Location : Central part

Geology : Greenstone of the Upper Bulawayan

Ore Deposit : A large number of lepidolite-bearing pegmatites. Strike N-S, dip 40° - 65°W. Strike length 30 - 400 m, width 20 - 150 cm

Output : Until 1962 Euchered clm. 0.95 t microlite
Jocking clm. 4.45 t microlite

o Robnik Claims

Location : South-central part. In the west of Area C

Geology : Greenstones of the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein

o Maienzi Claims

Location : South-central part. Middle of Area C

Geology : Greenstones of the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein. Strike E-W, dip 35° - 50°N, length 100 m, width 4 m, some visible cassiterite

o Dale 4 Claims

Location : South-central part. Middle of Area C

Geology : Greenstones of the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein. 3 reefs. Strike NW-SE. dip 30°E

o Nyagui Minerals Claims

Location : Eastern part. In the northeast of Area C

Geology : Greenstones of the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein

o Lochness Mine

Location : Central part. Middle of Area D

Geology : Serpentinite in the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein o Mkanga Mine

Location : Central part. Middle of Area D

Geology : Serpentinite in the Upper Bulawayan

Ore Deposit : Tin-bearing pegmatite vein

The precedings are the mineral deposits and occurrences which were recorded in some papers and maps, but there are many other mine trenches found in the area. Almost all spots underlain by ironstones or gossans have been previously prospected by trenching or other ways, as well as quartz veins or pegmatite rich areas.

In other words, it can be said that surface prospecting in the area has been satisfactorily done by now.

5-4 Geological setting of mineral occurrences

(1) Nickel sulphide deposits associated with ultramafic rocks.

Two types of nickel sulphide deposits are well known in the world; one is high copper-nickel ratio type associated with tholeiitic mafic rocks (Sudbury, Noril'sk, etc.), the second is low copper-nickel ratio type associated with komatiitic ultramafic rocks (Kambalada, Thompson, Trojan, etc.). the latter is restricted in the age of 2,700 Ma to 2,800 Ma, late Archean age.

A schematic geological diagram of the Trojan area, where is one of the typical nickel sulphide mineralized areas associated with komatiitic ultramafic rocks, is shown in Fig. I-5-2.

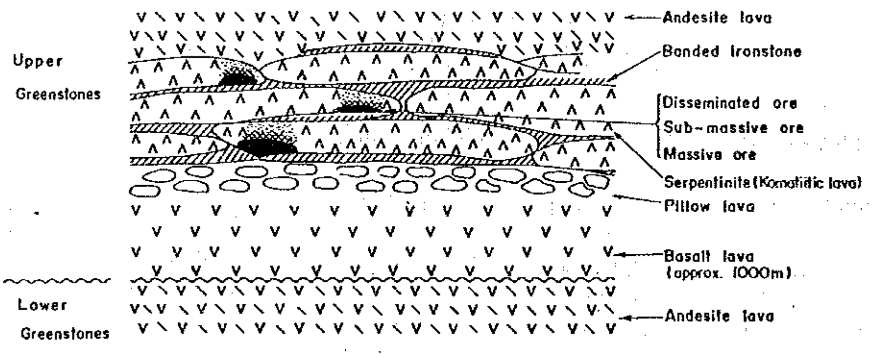


Fig.I-5-2 Schematic Geological Section of Trojan Mine Area

The basalt part of the Upper Greenstones, host rock horizon of the Trojan ore deposits, is very important horizon because of existence of ore hosted komatiitic ultramafic lava flows. It is said that nickel ore deposits in Zimbabwe would be restricted in this horizon. (L. Haynes 1982). According to him ore genesis is of contamination of banded ironstone into magma, sulphide-silicate immiscibility, and gravitic segregation.

The rocks of this horizon are extensively distributed in Area D, specially serpentinite and banded ironstone increase their thickness significantly. But from Area D to the east, to Areas C, B and A, the distribution of these rocks gets poor.

In addition to above mentioned geological settings, it is appraised that the vicinity of big ore deposits has high potential for hidden new deposits, and to trace same horizon in vicinity of known deposits is relatively easier than in remote areas. Therefore Area D would be given high marks geologically for hidden ore potential.

It is a well known fact that ores associated with komatiitic ultramafic rocks have high nickel-copper ratio (=15:1), and ores associated with tholeiitic rocks have low nickel-copper ratio (=3:1). Furthermore, the two magma types are generally regarded as being part of the same magmatic event and therefore they can also be intimately mixed. (L. Haynes 1983). In Zimbabwe, several ore deposits associated with tholeiitic rocks are known, (Empress, Preserverance, Madziwa etc.), and this type of ore deposit in the world frequently contain certain amount platinoid minerals.

From the above mentioned points, it is worth while to think of the potential of whole ultramafic to mafic rocks including both komatiite and tholeiite rock series.

(2) Gold and Pegmatite Deposits

All known gold and pegmatite deposits are associated with granitic activity, and situated in marginal areas of granitic bodies or surrounding greenstone areas. Geologic structural interpretation, specially of fissure pattern, is essential for the further exploration of such type of ore deposits.

(3) X-ray Refraction Analysis

Ten samples of gossan from Area A, disseminated sulphide in greenstone, gabbro contained some unidentical minerals, and pelitic schist disseminated by sulphide from Area C, and serpentinite and gossan from Area D were investigated by X-ray refraction analysis. The results are shown in Table I-5-1.

Geothite as well as quartz and hematite is commonly detected in the gossan samples, but no other important minerals were found. In the other rock samples nothing special has been detected.

Table I-5-1 Results of X-ray Diffraction Test

NO.	Sample NO.	Location	Minerals										Remarks
			goeth	Q	Ht	Ol	Amp	Chl	Tlc	Mc	Mont	Ser/Chl	
1	AK-18	A Area	◎	◎	△								Aosson
2	C-5	C Area				○	◎	◎	△				Mafic volcanic rock
3	C-8	〃	○	◎				△		○			Gossan
4	C-17	〃					◎	△			△		See thin section NO.43 Gabbro
5	C-22	〃		◎				○		◎		△	Pelitic schist
6	CM-2	〃		◎	○								See polished section NO.10 Gossan
7	HK-53	〃	○				◎						Gossan
8	D-7-17	D Area					◎	○	◎				Serpentinite
9	EX-10	〃	◎		◎								Gossan
10	BP-9	〃					◎		◎				Serpentinite

Legend

(Amount)
◎ abundant
○ medium
△ little

Condition

Target : Cu
Filter : Ni
Voltage : 35KV
Current : 25mA
Time constant : 5 sec
Scanning Speed : 1 °/min
Divergency : 1°
Receiving Slit : 0.3mm
Detector : S.C

Abbreviation

goeth : goethite
Q : Quartz
Ht : Hematite
Ol : Olivine
Chl : Chlorite
Tlc : Talc
Mc : Muscovite
Mont : Montmorillonite
Amp : Amphibole group
Ser/Chl : Sericite-Chlorite mixed-layer

CHAPTER 6 DESCRIPTION OF SURVEYED AREAS

6-1 Area A

The area is situated in the northeastern end of the Mazoe-Shamva Greenstone Belt, and is underlain by the Upper Bulawayan. The formation mainly consists of mafic lavas with interbedded lavas and beds of serpentinite, felsic pyroclastic rocks, and banded ironstone.

Parts of the mafic lava are komatiitic ultramafic rocks, which show spinifex texture in the field, but exact distribution of such komatiitic rocks is not clear. The serpentinite appears as small lenticular bodies concordantly with surrounding greenstones beds, therefore it is thought that the serpentinites are metamorphosed from ultramafic lavas.

The basal parts of the Shamvaian Group are locally exposed in the southern part of the area, and consist of arenaceous to lutaceous sediments.

The bedding of the rocks strikes eastnorth-east to west-south-west, and dips nearly vertically.

In the northwestern ridge and east end of the area, granite-gneiss complex bodies are exposed. Swarms of pegmatite dykes are intruded into those complex bodies, and parts of them have been mined for microlite. (Uzumba, Zero). Gold-bearing quartz veins are intruded in the eastern part of the area.

Small stocks of gabbroic intrusion are scattered in the area.

6-2 Area B

This area is underlain by the Upper Bulawayan. Most of the formation mainly consists of mafic lavas with interbedded thin layers of felsic-mafic pyroclastic rocks, serpentinite, and banded ironstone.

Parts of mafic lavas are komatiitic ultramafic rocks, which show spinifex texture in the field. But the exact distribution of such komatiitic rocks is not clear. The serpentinite appears as small lenticular bodies concordantly with surrounding greenstone beds, so it is thought that original rocks of the serpentinite were ultramafic lavas. Bedding of the rocks strikes east-north-east to west-south-west, and dips nearly vertically.

In the eastern part of the area, a mining company undertook some exploration program, consisting of trenching and shaft sinking, to test sulphide mineralized zone in the contact between the serpentinite body and the banded ironstone layer. At present no mineralized rock can be seen on the surface.

In this area, small size lenticular bodies of gabbro are intruded into the greenstone belt, as well as pegmatite dykes, but no economically profitable pegmatite deposits exist.

6-3 Area C

The area is underlain by the Upper Bulawayan. Most of the formation consists of mafic - ultramafic lavas with interbedded layers of felsic - mafic pyroclastic rocks, felsic lavas, limestone, banded ironstone, and serpentinite. In the center to west of the area, komatiitic lavas are abundant, and range in thickness up to 200 m. But exact distribution of the lavas is not clear. Small lenticular serpentinite bodies intermittently extend concordantly with surrounding mafic rocks.

Based on these occurrences, it can be said that the original rocks of the serpentinite are mainly ultramafic lavas. The limestone extend intermittently in the almost same horizon, so that can be marked as a key bed.

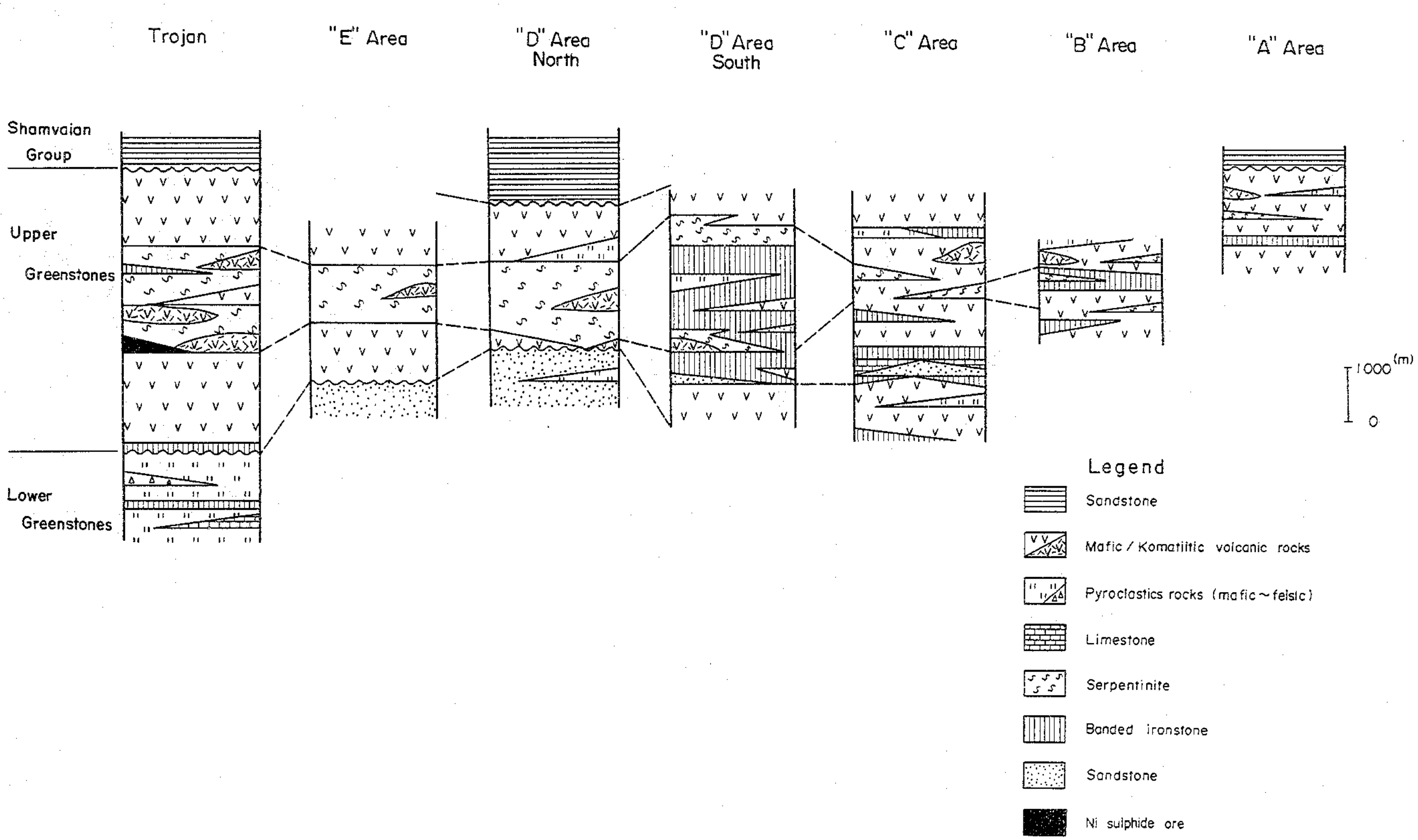


Fig.I-6-1 Correlation of Geological Columns of Each Area

The greenstone beds strike northeast-southwest, and dip almost vertically.

Several micro-diorite, gabbro, and dolerite bodies are intruded in the greenstone belt, particularly north-south and northwest-southeast trending long dolerite dykes are intruded in the eastern and central parts of the area.

Several gold ore deposits (Montdor, Red Dragon etc.) and pegmatite deposits (Wanroo, Look and Weep, Robnik, Maienzi, Dale 4 etc.) exist in the area, but only Montdor Mine is in operation.

6-4 Area D

The area is underlain by the Lower and Upper Bulawayan. The Lower Bulawayan occupies the northwestern part of the area, along with the edge of the granite batholith, extending northwest to southeast. The formation consists of felsic pyroclastic rocks and sandstone. The Upper Bulawayan occupies almost all of the remaining area, and consists of serpentinite, mafic lavas, banded ironstone, chert, felsic pyroclastic rocks, and sandstone. The serpentinite is mostly extensively distributed in the area reaching a thickness of 1,000 m in the central part, and 400 m - 600 m in the southern part. Specially in the southern part, more than one layers are distributed together with thick layers of banded ironstone. Under the microscope, it can be recognized that the original rocks of the main part of the serpentinite are wehrlite, lherzolite, harzburgite, and dunite. But from the occurrences, it may be said that at least some parts are ultramafic lavas.

A margin of a granitic batholith, which is extinsively distributed to the south, is exposed in the south end of the area. Small intrusive bodies of gabbro and pegmatite are intruded into the greenstone belt.

The area is situated in the southern expanded zone of the Mazoe-Shamva Greenstone Belt, therefore its geological structure is very complicated. The area is divided into three blocks by faults. The South Block is characterized by a west convex structure, and the sequence is from east to west, base to top. The central block shows north open concave structure, and the sequence is from outer rim to center (north). The north block shows simple northwest-southeast extending structure.

Some of pegmatite dykes in the central part (Lochness, Mranga) have been mined for rare earth metals and tin, but operations were very small scale. In the southern part of the area, several mining companies have conducted exploration programs in Tynan claims in the past several years and put several drill holes. Sulphide mineralized zones were intersected in several holes.

6-5 Area E

The area is underlain by the Lower and Upper Bulawayans. The Lower Bulawayan occupies very small area in the central east part of the area, and consists of quartzite and sandstone. The Upper Bulamayan occupies major part of the area, and consists of serpentinite and mafic lavas with interbedded thin layers of banded ironstone. The serpentinite is distributed in the central to northern part of the area, and is 200 m - 1,000 m in thickness. But serpentinization is generally weak. Under the microscope, original rocks of some serpentinites are identified as dunite, lherzolite, and wehrlite, but some others presumably seemed to be komatiitic ultramafic lava.

In the central west part of the area, an edge of a big granitic complex body is exposed. In the southern part of the area, small stocks of gabbro and microdiorite intrude in the greenstones.

The rock pile strikes north to south in the northern part of the area, but east to west in the southern part of the area. The shape of the geological structure is open to the north, and the dip of the rocks is generally very steep, almost vertical.

A small operation of gold was worked in the Churchill mine in the southern part of the area until several years ago when the gold price was high. But it has ceased operation now. The ore seems to be hosted in the contact zone between microdiorite stock and mafic rocks.

PARTICULARS

PART Ⅱ GEOCHEMICAL SURVEY

CHAPTER 1 SURVEY METHOD

1-1 Sampling and Treatment of Soil Samples

In the geochemical survey, 4,501 soil samples in total were collected and analyzed, and 400 of them out of 4,501 were further analyzed in detail for additional elements. The number of samples collected in each area and the elements for which the samples were analyzed are as shown in Table II-1-1.

Table II-1-1 Statistics of Soil Sampling

Area	Number of Samples	Analysed Element
A	690	Au, Cu, Zn, Ni, Cr, Nb
B	263	Au, Cu, Zn, Ni, Cr, Nb
C	1,562	Au, Cu, Zn, Ni, Cr, Nb
	of which (124)	Additional Elements Co, Sn, As, Li, W, Pt, Be, Ce, S, Ta
D	1,498	Au, Cu, Zn, Ni, Cr, Nb
	of which (276)	Additional Elements Co, Sn, As, Li, W, Pt, Be, Ce, S, Ta
E	488	Au, Cu, Zn, Ni, Cr, Nb
Total	4,501	

As shown in the above table, 4,501 samples were analyzed for six elements and 400 samples among them were analyzed for extra 10 elements.

The soil samples were collected generally at line spacing of 300 m and at sampling interval of 200 m, but in zones which seemed to composed of ultramafic rocks or mineralized zones, the sampling interval was reduced to 50 m to increase sampling density and obtain more precise data. Little soil has developed generally in the surveyed areas and there were very few places where all of the A, B and C horizons have developed. Soil samples were taken from the B horizon in principle, but the sampling depth was as small as 10 to 20 cm. By passing the sampled soil through a 20 mesh sieve on the site, a sample of 500 g to 800 g was taken. Then the sample was carried back to the base camp, and dried in the sun and sieved again with a 80 mesh sieve. From a 100 g of 80 mesh-under sample, 70 g were used as a sample for analyses and 30 g were kept as the duplicate of the sample. At each sampling site, the sampling depth, the colour of the soil and the name of the bedrock were recorded. The survey this time included the observation of the colour tones of soil in addition to chemical analyses. Since megascopic observation is always subject to inaccuracy based on personal differences, the colour tones of the -80 mesh fraction samples were determined by comparing them with those of the rock colour charts (published by the Geological Society of America).

1-2 Method of Analysis

As shown in Table II-1-1, all of the 4,501 samples were analyzed for six elements, Au, Cu, Zn, Ni, Cr and Nb, and specially selected 400 samples, which were collected in parts of Areas C and D where pegmatites are distributed or where other mineral occurrences are observed, were further analyzed for ten elements, Co, Sn, As, Li, W, Pt, Be, Ce, S and Ta.

Most of the samples were analyzed by the atomic absorption method, and the rest by fluorescent X-ray spectrometry and the induction coupled plasma method.

Anomalous zones were detected by applying statistical analyses and principal component analyses to the results using an ACOS-350 type computer made by the NEC Corporation. About the extracted anomalous zones, the analytical results were investigated with regard to the geology, geological structure and mineralization of the relevant areas to select prospecting areas and prospecting methods for the next survey stage.

CHAPTER 2 STATISTICAL PROCEDURES FOR TREATING ANALYTICAL RESULTS FOR Au, Cu, Zn, Cr, Ni AND Nb

2-1 Fundamental Statistics of Analytical Results

All the analytical results are shown in Appendix 1 and the fundamental statistics of statistical treatment results are shown in Table II-2-1. In most of the analytical results, Au and Nb were below the detection limits, therefore, mean values were not determined for them. For Cu, Zn, Ni and Cr, there were no cases where they were below the detection limits and their analytical values were obtained in all the cases. However, there were cases where values above the detection limits were obtained. To these results, statistical treatment for each element was done by substituting 1,000 ppm for the values of Zn and 5,000 ppm for the values of Ni.

The arithmetic means for the elements are, Cu: 112 ppm, Zn: 140 ppm, Cr: 618 ppm and Ni: 384 ppm. These values are all clearly higher than the average contents in ordinary soil given by Rose, Hawkes et al. in 1979 (Cu: 15 ppm, Zn: 36 ppm, Cr: 43 ppm and Ni: 17 ppm).

Table II-2-1 Foundamental Statistics of Analytical Results (6 Elements)

Element	Number of Samples	Minimum Value (ppm)	Maximum Value (ppm)	Arithmetic Mean (ppm)	Standard Deviation (ppm)	Geometric Mean (ppm)	Standard Deviation (log)
Au	4,501	<0.05	24	—	—	—	—
Cu	4,501	2	1,040	112	60	97	0.2696
Zn	4,501	8	>1,000	140	117	117	0.2384
Cr	4,501	3	3,970	618	631	361	0.4907
Ni	4,501	3	>5,000	384	511	212	0.4679
Nb	4,501	< 10	187	—	—	—	—

Fig. II-2-1 shows the mean values of element contents in ultramafic rock and mafic rock in Table II-2-2, and those of the soil samples of this time. The mean value line of the soil samples shows a tendency similar to that of the folded line of ultramafic rock. This similarity seems to show that ultramafic rock is exposed extensively in the surveyed areas and this geological condition is reflected in the soil compositions.

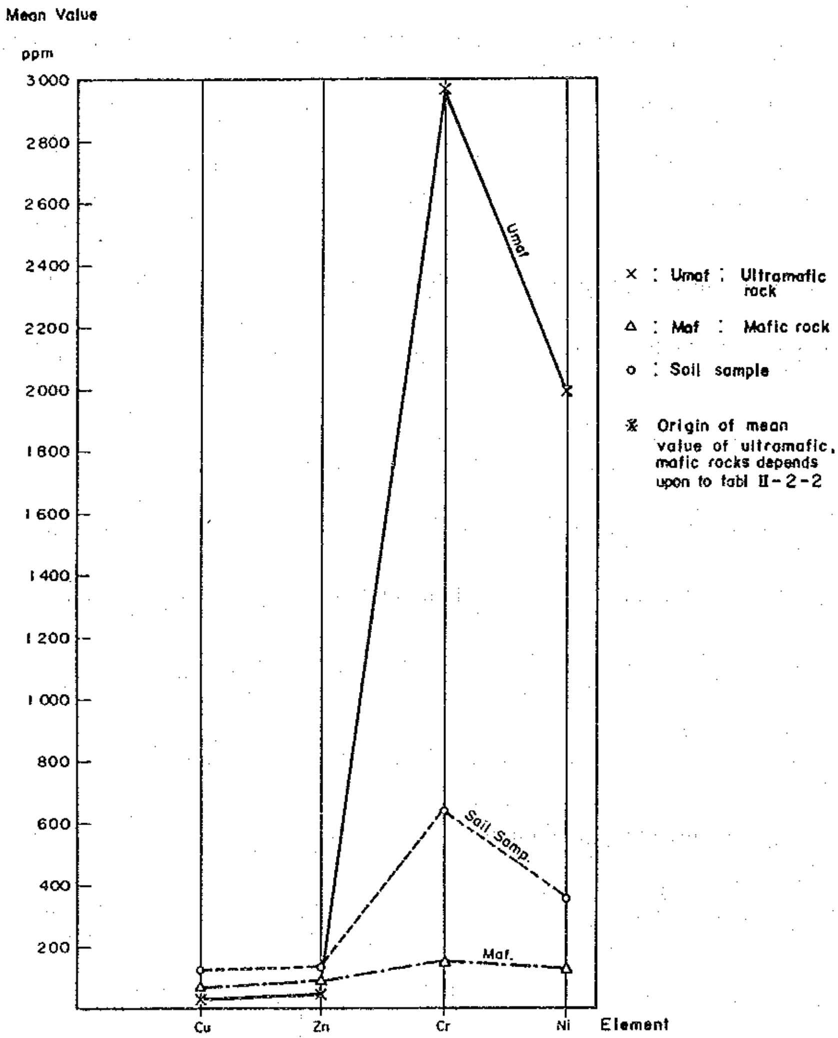


Fig. II-2-1 Mean Value of Ultramafic, Mafic Rock and Soil Sample for Cu, Zn, Ni and Cr

Table II-2-2 Content of Several Elements in Various Rocks and Soils

Elements	Igneous rocks			Sedimentary rocks			Soils
	Umaf	Maf	Gr	Ls	Ss	Sh	
Au	(med) 0.0032	(med) 0.0032	(med) 0.0023	(med) 0.005	(med) 0.005	(med) 0.004	(av) 0.002
Cu	(") 42	(") 72	(") 12	(") 5	(") 10	(") 42	(med) 15
Zn	(") 58	(") 94	(") 51	(") 21	(") 40	(") 100	(") 36
Cr	(av) 2,980	(av) 170	(av) 4.1	(av) 11	(av) 35	(av) 90	(") 43
Ni	(") 2,000	(") 130	(") 4.5	(") 20	(") 2	(") 68	(") 17
Nb	(") 1	(") 20	(") 20	-	-	(") 20	(av) 15
Co	(av) 110	(av) 48	(av) 1	(av) 0.1	(av) 0.33	(av) 19	(med) 10
Sn	(med) 0.5	(med) 1.5	(med) 3.0	(") 0.X	(") 0.6	(") 6	(av) 10
As	(") 1.0	(") 1.5	(") 2.1	(med) 1.1	(med) 1.2	(med) 12	(med) 7.5
Li	(av) 0.X	(av) 17	(av) 40	(av) 5	(av) 15	(av) 66	(") 22
W	(med) 0.1	(med) 1.0	(med) 1.5	(med) 0.5	(med) 1.6	(med) 1.8	(av) 1
Pt	(av) 0.032	(av) 0.030	(av) 0.0082	-	-	-	-
Be	(") 0.X	(") 1	(") 3	(av) 0.X	(av) 0.X	(av) 3	(range) 0.5 - 4
Ce	(") 9	(") 66	(") 57	(") 8	(") 15	(") 76	-
S	(av) 300	(") 300	(") 300	(") 1,200	(") 240	(") 2,400	(range) 100 - 2000
Ta	(") 0.018	(") 0.48	(") 3.5	-	-	(") 3.5	-

* after Geochemistry in Mineral Exploration,
Rose A.W., Hawkes H.E., Webb J.S.,
Academic Press, Second Edition

Abbrevaiton

Umaf: Ultramafic rock
Maf: Mafic rock
Gr: Granite
Ls: Limestone
Ss: Sandstone
Sh: Shale

med: median
av: average

2-2 Correlation of Elements

The correlation coefficients of the real numbers and results for pathfinders and of the common logarithms of the analytical results were determined, and the tests of significance were carried out for the correlation coefficients. The results are shown in Tables II-2-3 and II-2-4.

Table II-2-3 Correlation Coefficient and Significance Test

	Cu	Zn	Cr	Ni
Cu	1.00			
Zn	xx 0.56	1.00		
Cr	xx-0.08	xx 0.21	1.00	
Ni	xx-0.04	xx 0.22	xx 0.85	1.00

Degree of Freedom
n = 4,499
xx:|R(0.01)| ≧ 0.0384

Table II-2-4 Correlation Coefficient and Significance Test (in Logarithm)

	log Cu	log Zn	log Cr	log Ni
log Cu	1.00			
log Zn	xx 0.66	1.00		
log Cr	xx 0.22	xx 0.35	1.00	
log Ni	xx 0.21	xx 0.38	xx 0.93	1.00

Although there are positive and negative coefficients, correlation between elements can be recognized with a level of significance of 1%. In particular, the correlation coefficient between Ni and Cr is 0.85, showing that they are highly correlated with each other. The correlation coefficient between Cu and Zn is 0.56 which shows that there is a moderatelly positive correlation between them. Although the correlation coefficients between other elements show useful 1% levels of significance, the values are too small and it cannot necessarily be said that correlation exists between them. The high correlation between Ni and Cr also reflects the geological feature of the areas that they abound in ultramafic rock and mafic rock.

2-3 Frequency Distribution and Relative Cumulative Frequency Distribution of Analytical Results

The frequency distribution and relative cumulative frequency distribution of analytical results drawn and normal probability sheets are shown in Fig. II-2-2 to II-2-7. The histograms of 4.501 samples show almost normal distribution for Cu and Zn, but show a distribution form including a population of high content parts (anomalous population) and a population of backgrounds (background population) for Ni and Cr.

The histograms for the elements in Area A all show gentle curves in low content zones and steep curves in high content zones. This tendency represents that high content analytical values decrease rapidly.

The histograms in Area B show comparatively normal distribution for Cu and Zn, but show a form including plural normal distributions for Ni and also show in some degree similar tendency for Cr.

In Area C, the cumulative frequency curves for all the elements are almost linear, that is, the histograms show nearly a normal distribution form.

In Area D, the histograms for Cu and Zn show nearly normal distribution forms for Cu and Zn, but show, both for Ni and Cr, similar distribution forms having high mean values and being biased to higher content zones.

In Area E, the histograms for the elements are similar to these in Area D. They show forms similar to the normal distribution for Cu and Zn, but show distribution forms having high mean values and being biased to higher content zones for Ni and Cr. These results seem to show that ultramafic rock is distributed more in Areas D and E than in other areas.

2-4 Zoning of Analytical Results

When observed for all of the analytical results, each element shows a logarithmic normal distribution group as Cu and Zn, or plural logarithmic normal distribution groups as Ni and Cr. For the purpose of extracting the most promissing area from among the five areas, zoning for individual areas was not carried out, but zoning for all the analytical values was carried out.

The analytical values were grouped into eight zones, each zone covering a 1/2 σ range with the geometric mean as the center, as shown in Table II-2-5. As shown in PL II-2-1 ~ 5, contour maps of equal element contents based on these zones were drawn using the computer. As statistical treatment for Au and Nb was not carried out, only the analytical values for the elements were marked on the figures. On particularly anomalous areas, the results for Au and Nb will be investigated with the results of other elements later.

Based on the above zoning results, threshold values were selected to GM+σ, and the zones below GM+σ were grouped into C zone, zones from GM+σ to GM+2σ into B zone and the zone above GM+2σ into A zone. Consequentry the highest anormaly zone is A zone and next B zone. Such A, B zones are called anormaly zone and C zone is considered to present back ground value .

Table Ⅱ－2－5 Zoning of Analytical Values

(ppm)

Ele-ment	1	2	3	4	5	6	7	8
	≦GM−2σ	GM−2σ ~GM−$\frac{1}{2}$σ	GM−$\frac{1}{2}$σ ~GM	GM~ GM+$\frac{1}{2}$σ	GM+$\frac{1}{2}$σ ~GM+σ	GM+σ ~GM+$\frac{3}{2}$σ	GM+$\frac{3}{2}$σ ~GM+2σ	≧GM+2σ
Cu	≦ 52	53 ~ 70	71 ~ 96	97 ~131	132 ~179	180 ~244	245 ~333	≧ 334
Zn	≦ 68	69 ~ 90	89 ~116	117 ~153	154 ~202	203 ~266	267 ~350	≧ 351
Cr	≦117	118 ~204	205 ~360	361 ~635	636 ~1,117	1,118 ~1,967	1,968 ~3,461	≧3,462
Ni	≦ 72	73 ~123	124 ~211	212 ~363	364 ~628	624 ~1,068	1,069 ~1,831	≧1,832

※GM＝Geometric mean
※σ ＝Standard deviation

If the distribution of an element is a perfectly normal logarithmic distribution, the ratio of values from the threshold value (GM+σ) and higher will occupy 16% of the total number of samples, but because of the difference of the distribution from the perfectly normal logarithmic distribution, the results as shown in the above table were obtained.

Table Ⅱ－2－6 Thresholds and Zoning of Anomalies

Element	Number of Samples	Threshald		Zoning (ppm)		
		t (ppm)	≧t (%)	C	B	A
Cu	4,501	180	8.4	≦ 179	180 ~333	≧ 334
Zn	4,501	203	11.2	≦ 202	203 ~350	≧ 351
Cr	4,501	1,118	20.1	≦1,117	1,118 ~3,461	≧3,462
Ni	4,501	624	20.5	≦ 623	624 ~1,831	≧1,832

2-5 Relation between Rocks and Analytical Values

Histogram and cumulative frequency distribution curves of the analytical values for Cu, Zn, Ni and Cr in various rock terrains are shown in Fig. II-2-8 to II-2-11. Fundamental statistics for each rock are as shown in Table II-2-7.

The mean value of Cu content shows a comparatively low value for granitic rocks, but shows values ranging from 50 to 100 ppm for other rocks. Mafic rocks show comparatively high values, and in particular, dolerite and komatiite show higher values. Histograms for mafic rocks show forms near to the normal distribution, whereres those for felsic rocks and sedimentary rocks do not show normality.

The mean values of Zn content for nearly all the rocks are around 100 ppm. With the mean value of banded ironstone as the highest, the mean values of mafic rocks generally tend to be a little high. Banded ironstone, quarternary and dolerite show normal distribution, but other show usually irregular forms.

The mean value of Ni content is low for felsic rocks, but shows high values ranging from 150 to 200 ppm for mafic rocks. Especially the value for serpentinite is as high as 610 ppm, clearly reflecting the property of the rock. The histograms of Ni for various rocks rarely show normal distribution forms, but generally they are irregular forms.

On the mean values of Cr content, the bed rocks of soil have large influence as in the case of Ni. Especially in serpentinite, Cr content shows characteristically high values above 1,000 ppm. The histograms for Cr generally show irregular forms like those for Ni.

As described above it was made clear that the contents of Ni and Cr were closely related to ultramafic rocks.

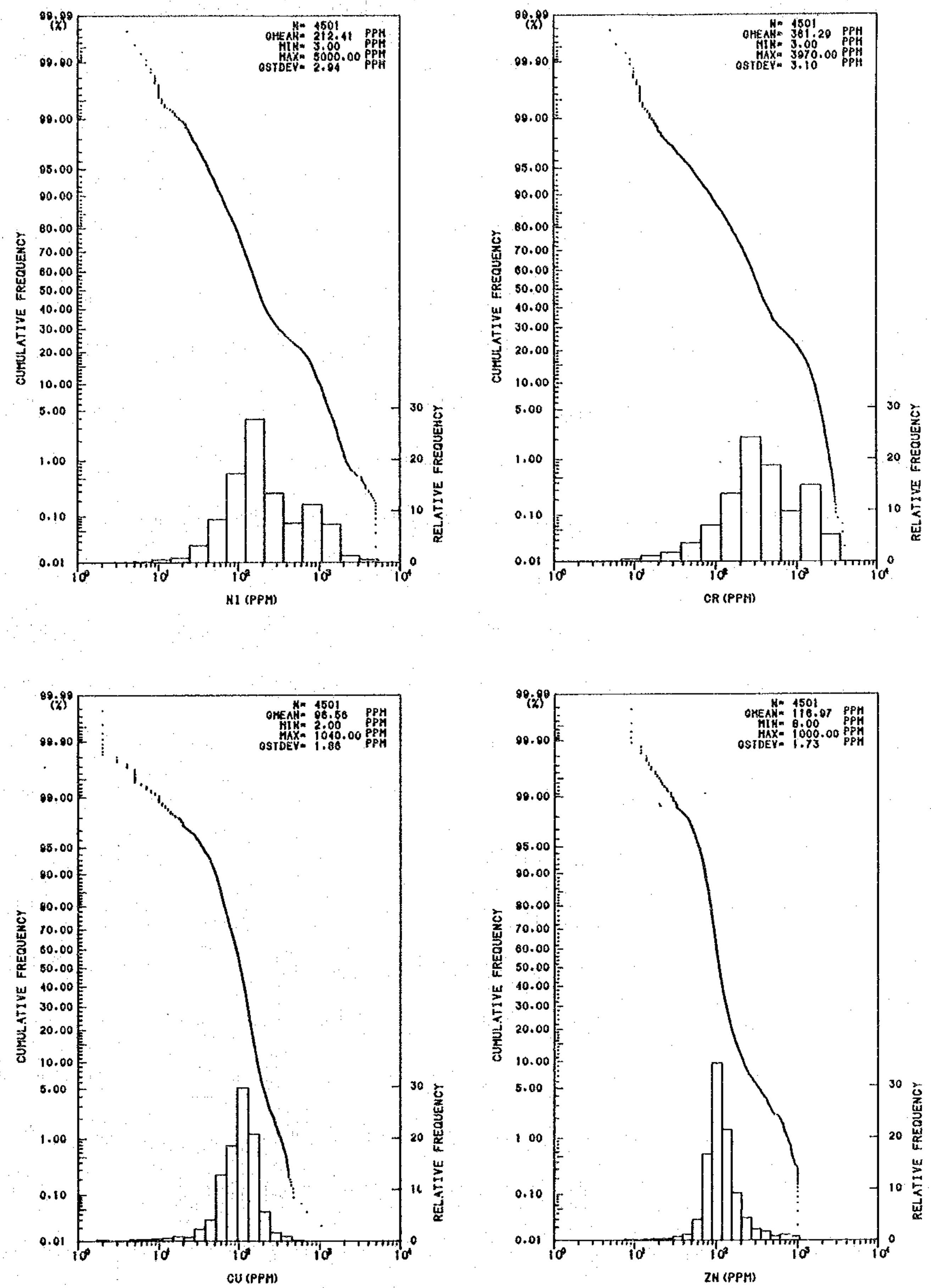


Fig. II-2-2 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in the Whole Survey Area

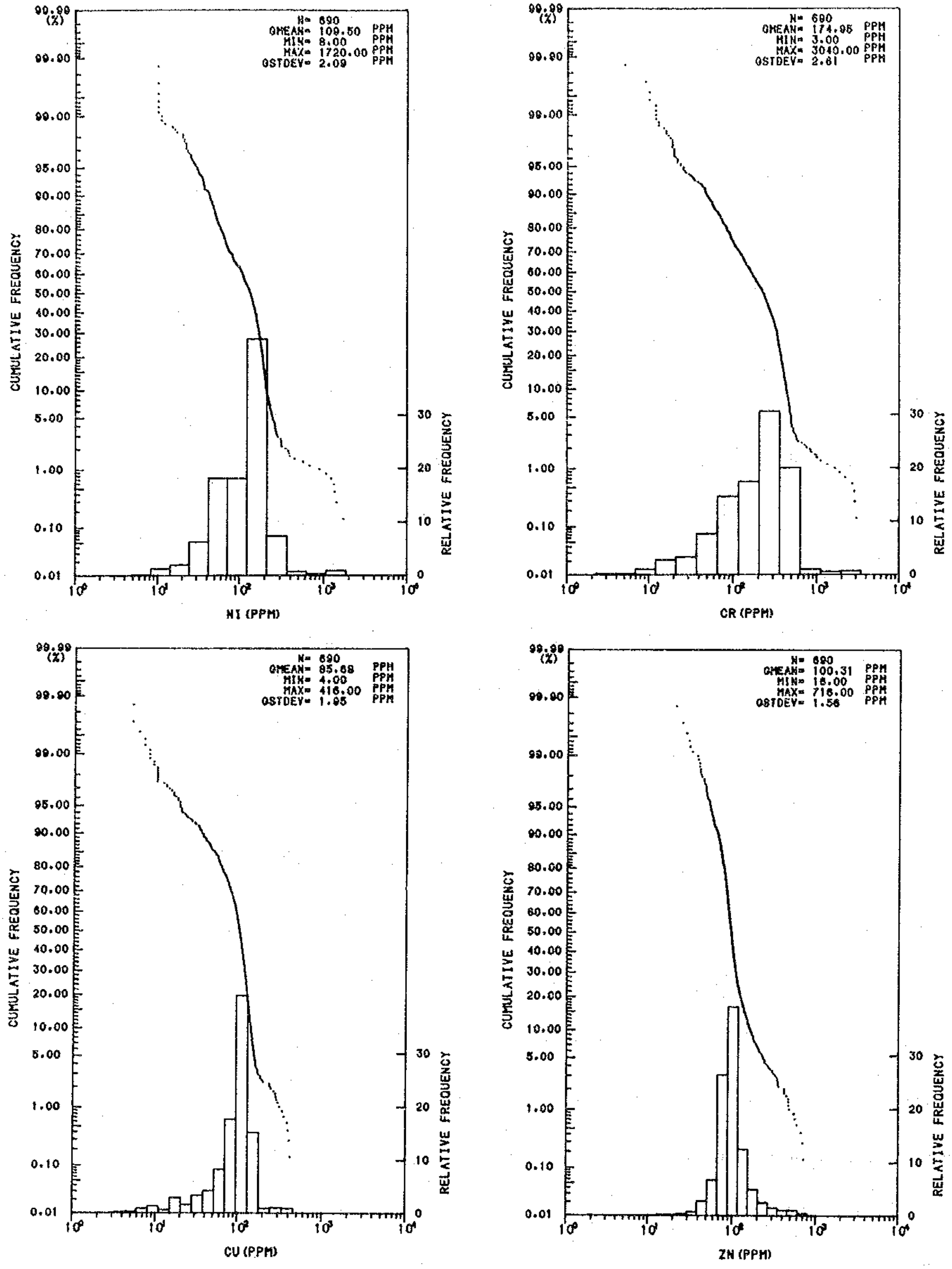


Fig. II-2-3 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in "A" Area

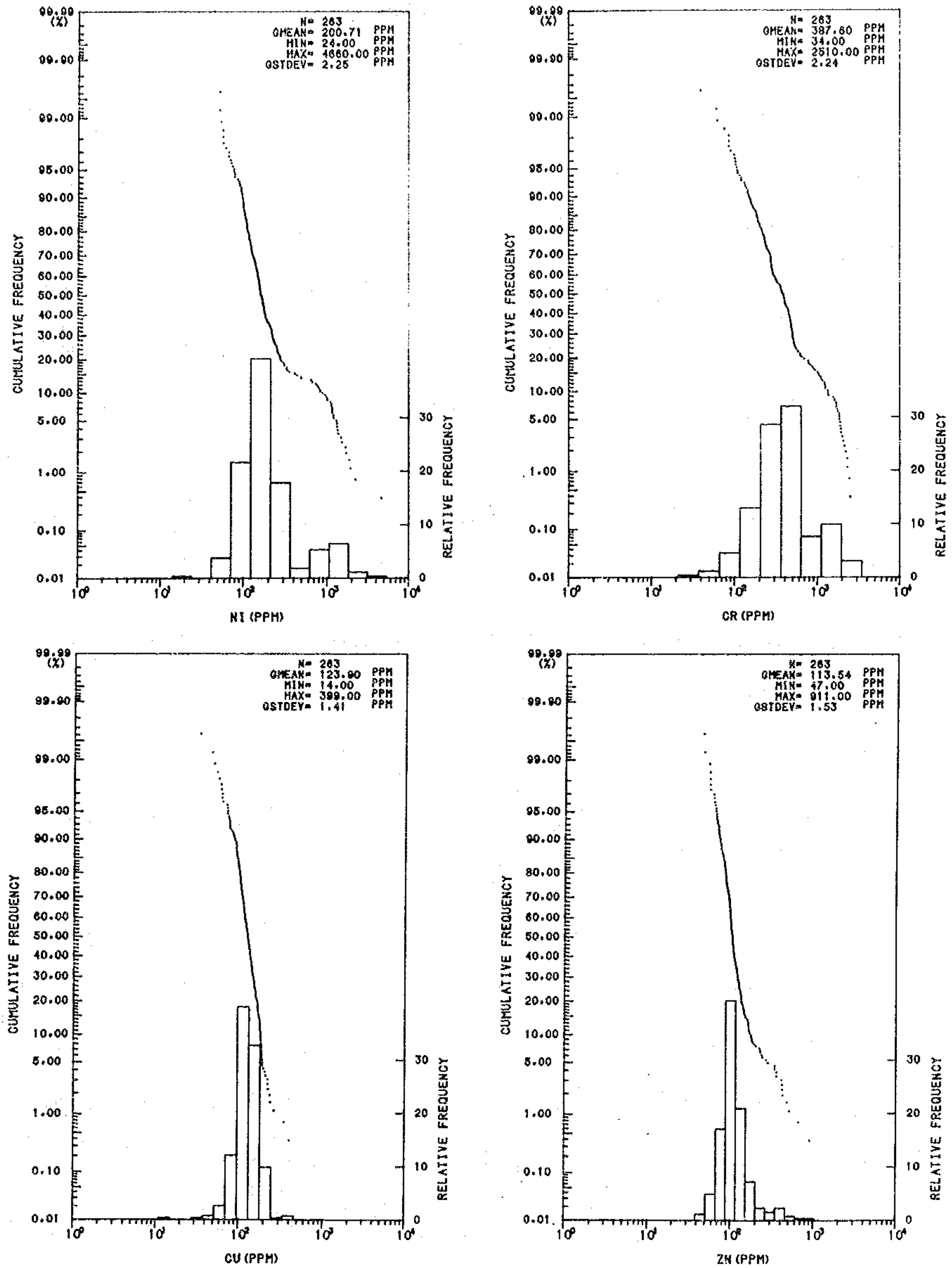


Fig. II-2-4 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in "B" Area

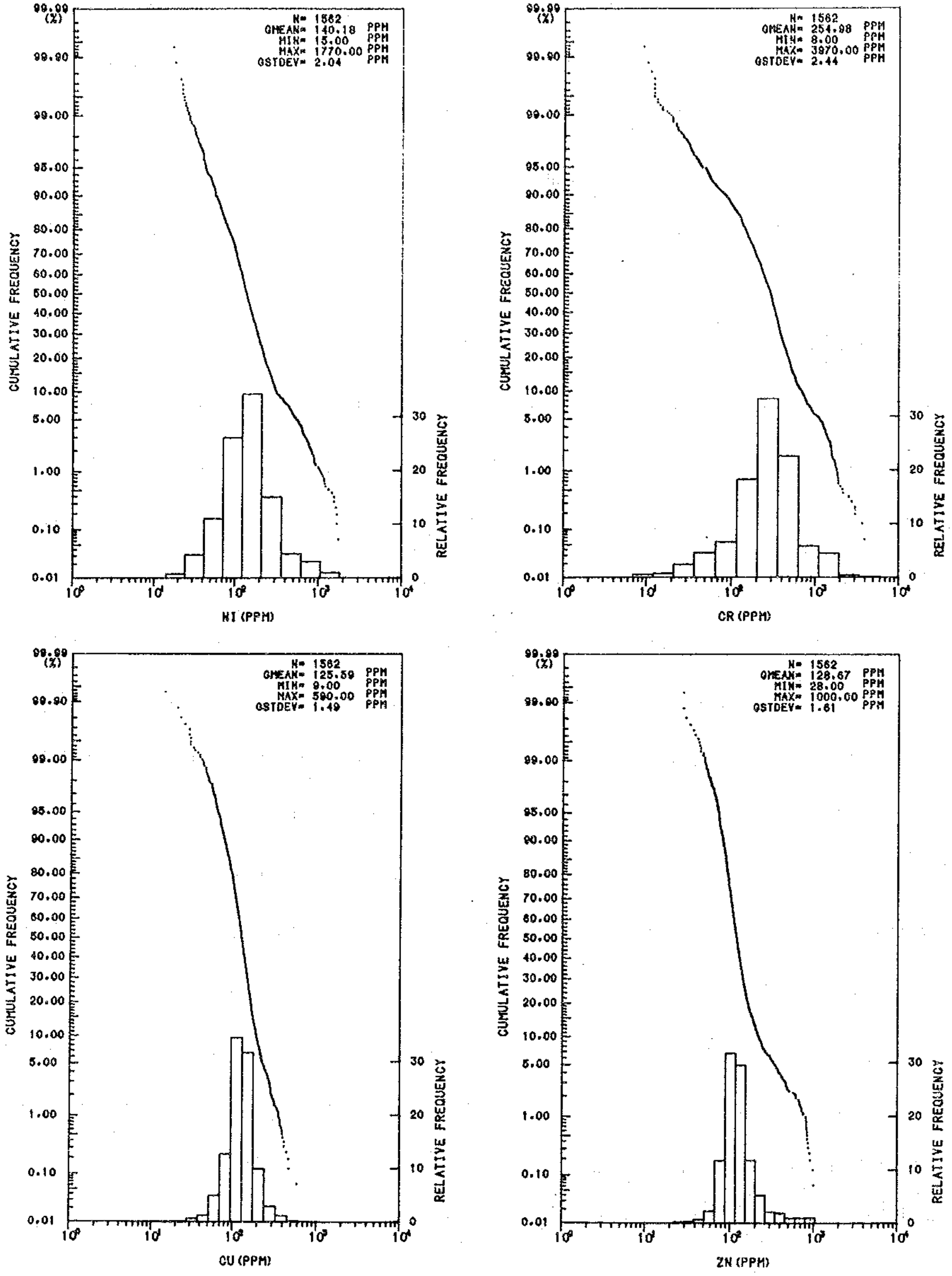


Fig. II-2-5 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in "C" Area

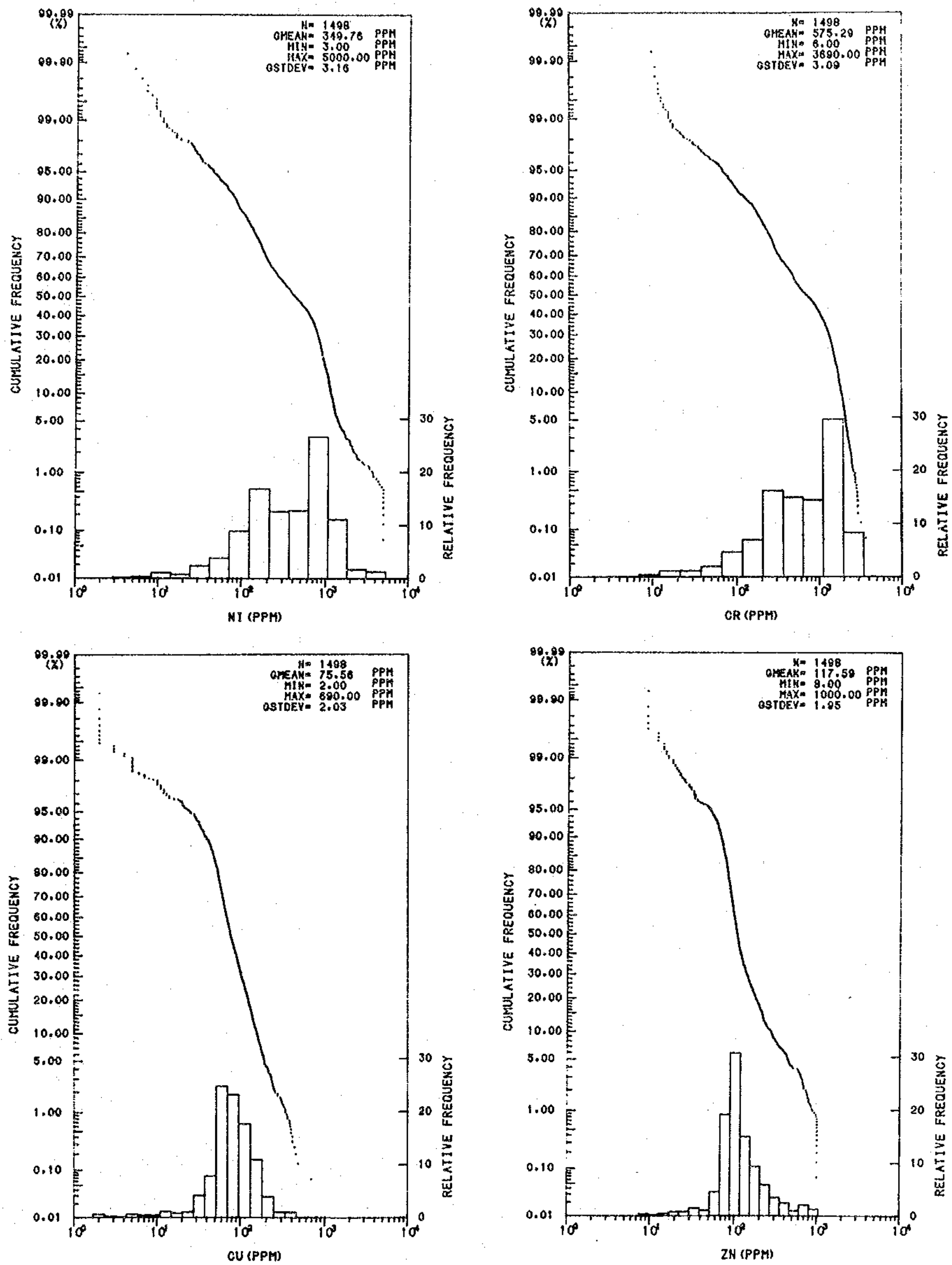


Fig. II-2-6 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in "D" Area

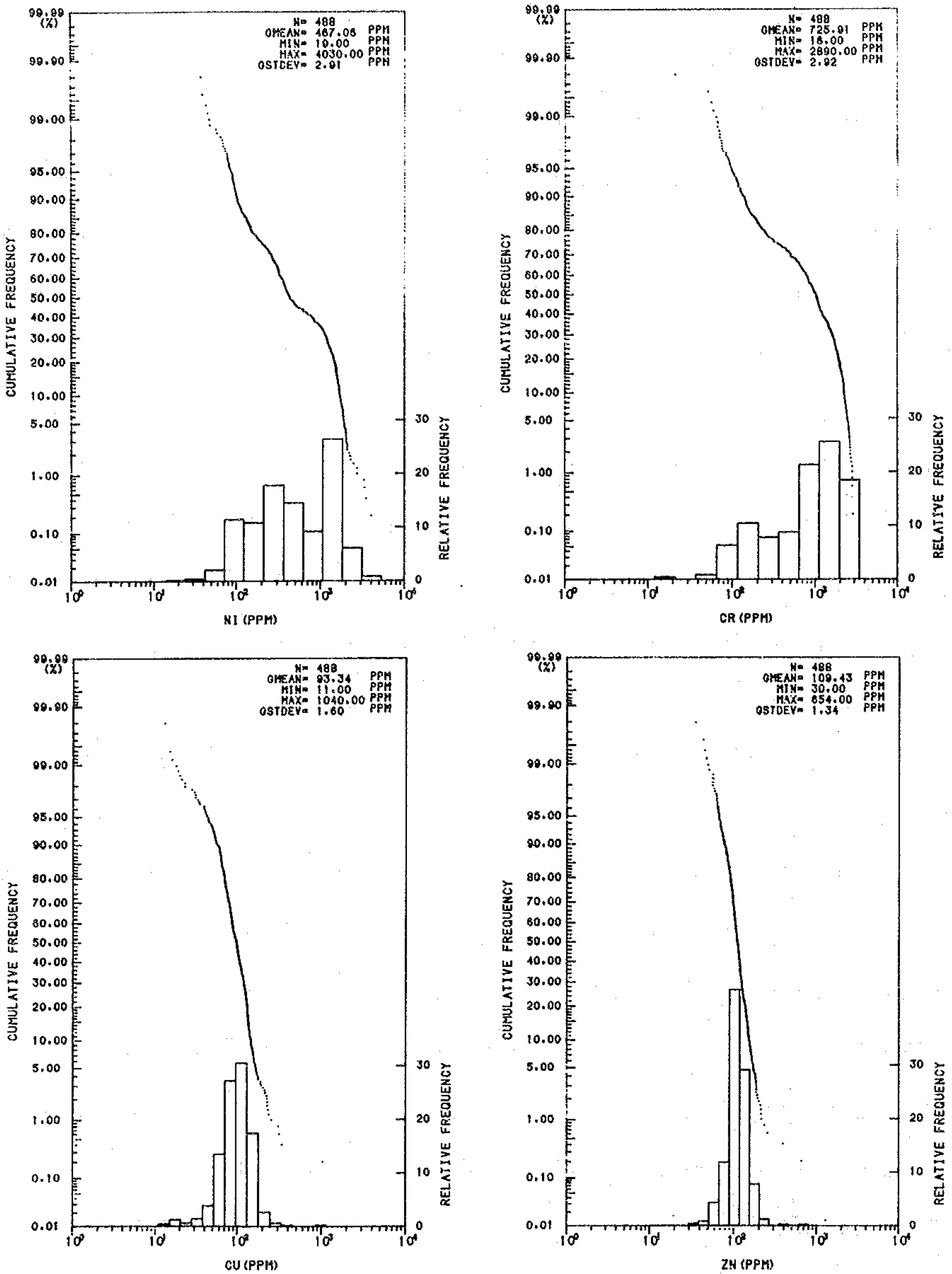


Fig. II-2-7 Histogram and Cumulative Frequency Distribution Curve for Cu, Zn, Ni and Cr in "E" Area

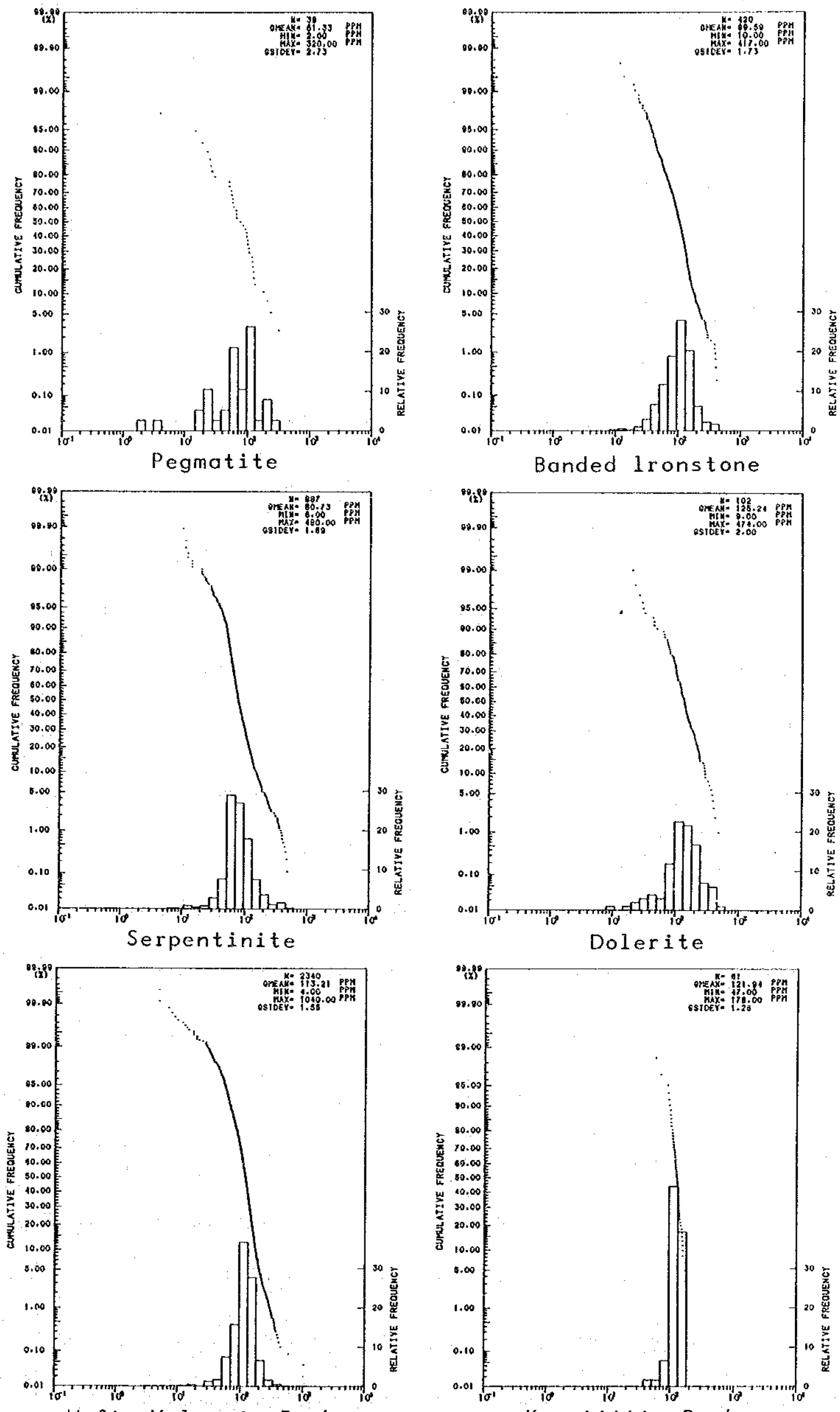
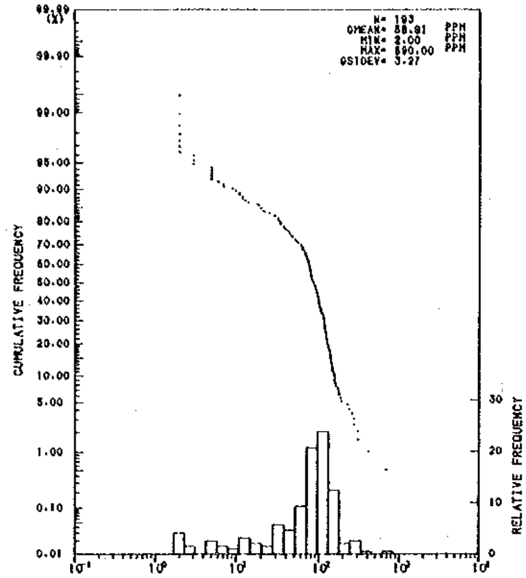
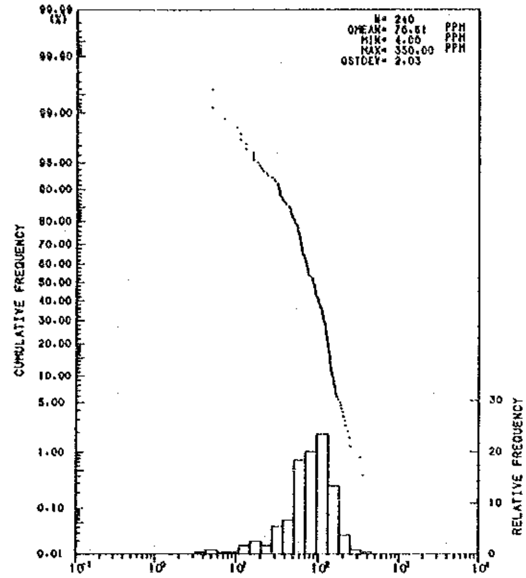


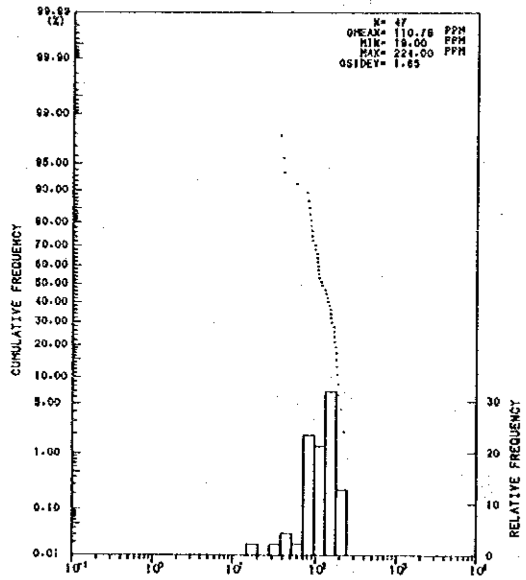
Fig. II-2-8-1 Histogram and Cumulative Frequency Distribution Curve for Geochemical Cu Analysis in Each Rock Type Terrain.



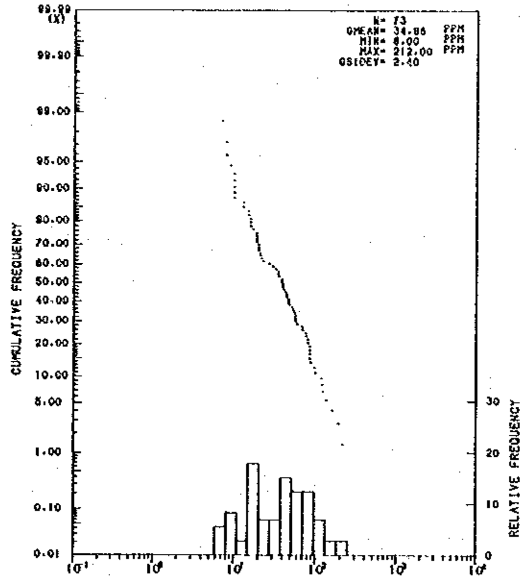
Sedimentary Rocks & Limestone



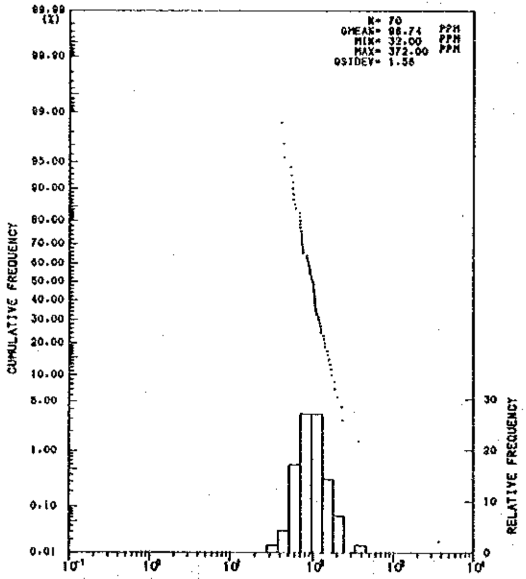
Quaternary



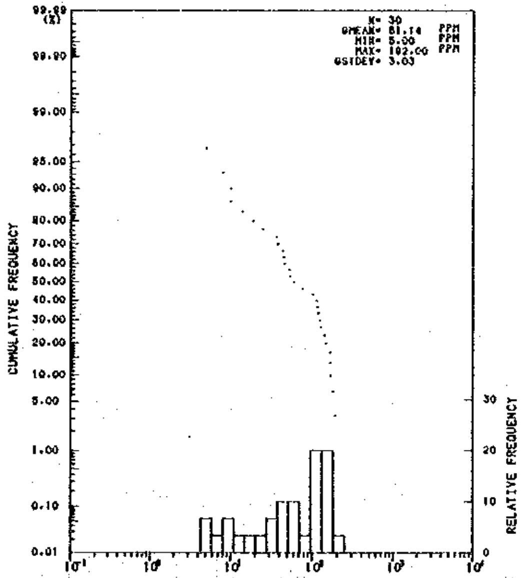
Gabbro



Granitic Rocks & Gneiss



Mafic Pyroclastic Rocks



Felsic Volcanic & Pyroclastic Rocks

Fig. II-2-8-2 Histogram and Cumulative Frequency Distribution Curve for Geochemical Cu Analysis in Each Rock Type Terrain.

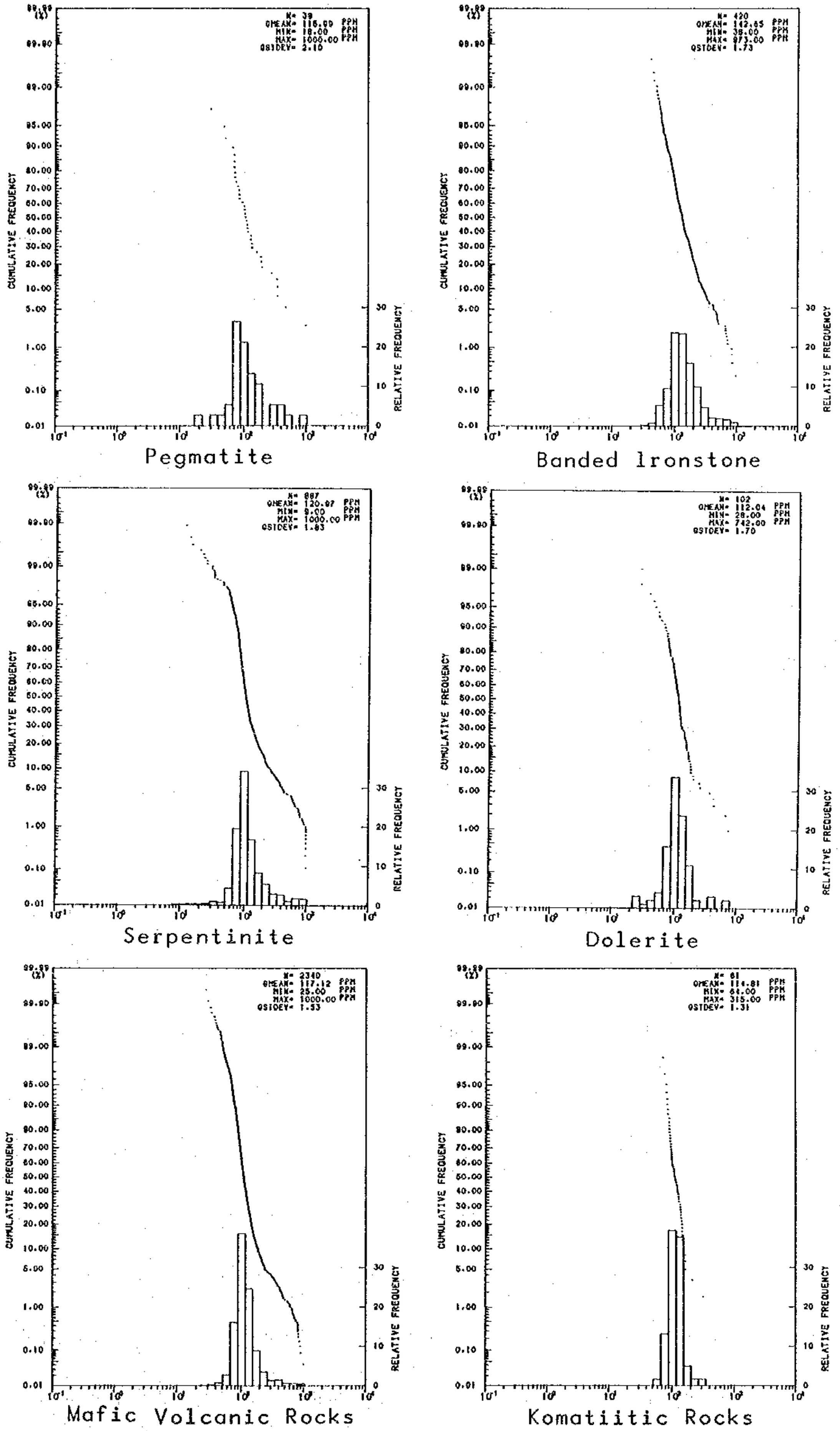


Fig. II-2-9-1 Histogram and Cumulative Frequency Distribution Curve for Geochemical Zn Analysis in Each Rock Type Terrain.

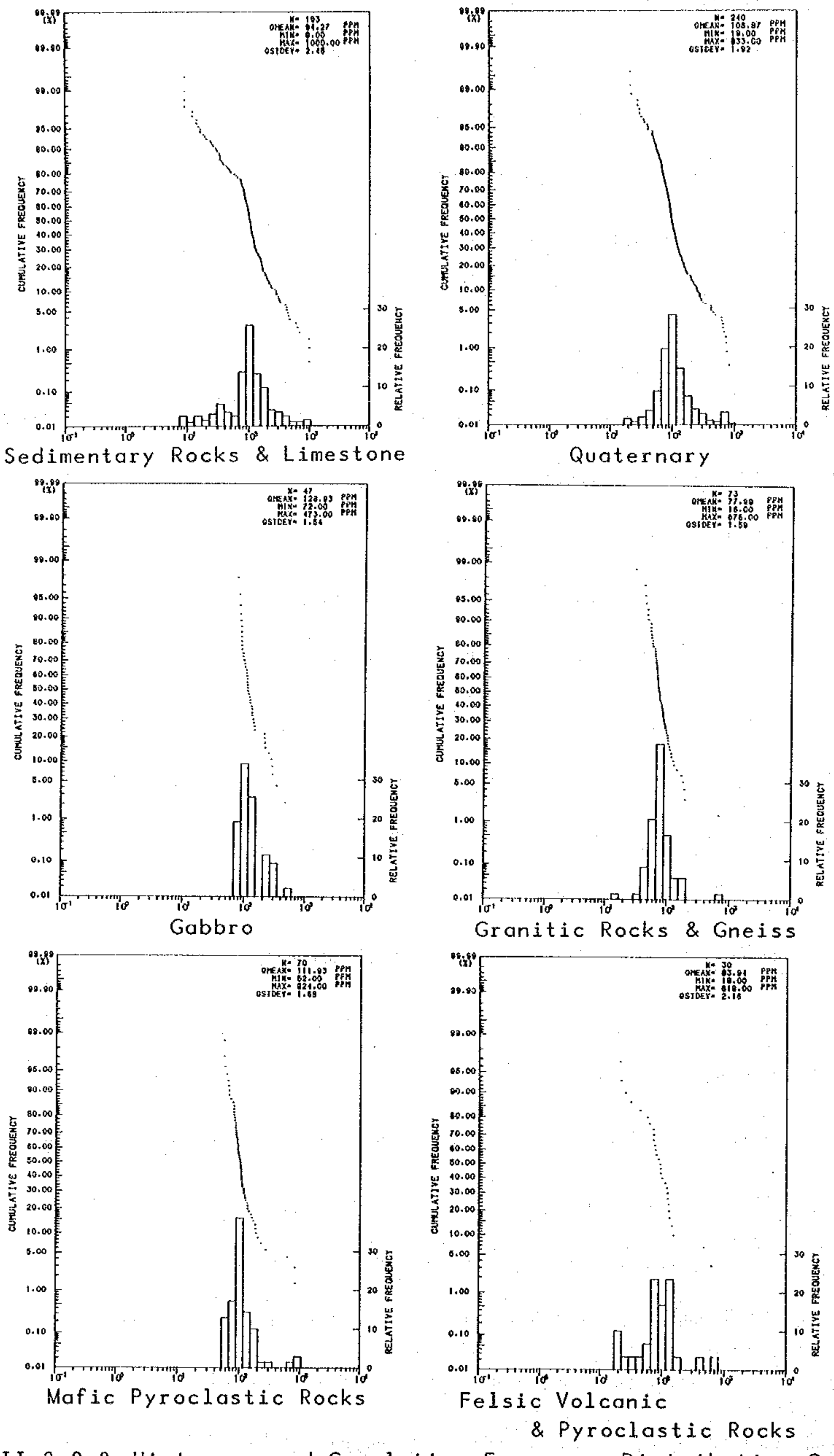


Fig. II-2-9-2 Histogram and Cumulative Frequency Distribution Curve for Geochemical Zn Analysis in Each Rock Type Terrain.

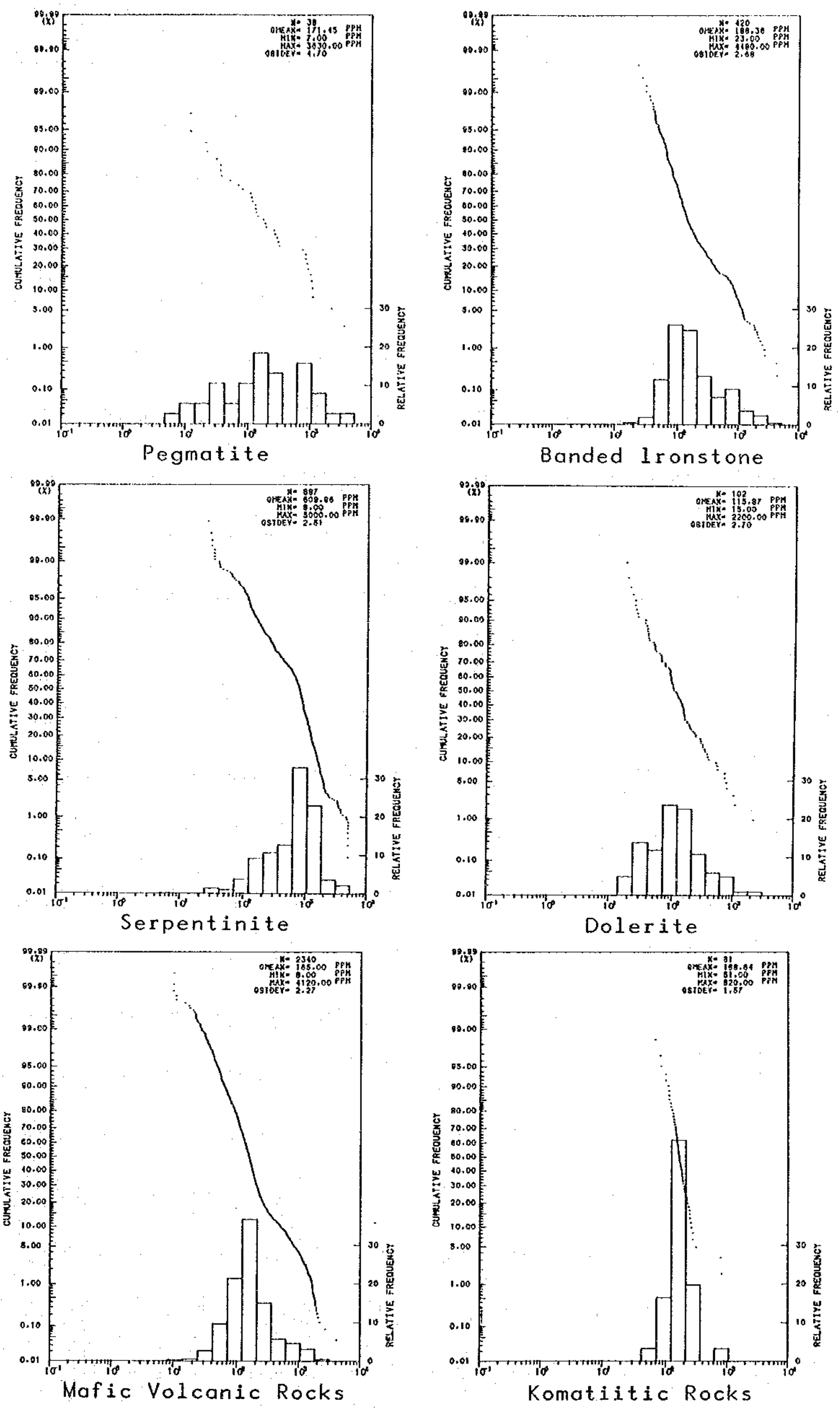


Fig. II-2-10-1 Histogram and Cumulative Frequency Distribution Curve for Geochemical Ni Analysis in Each Rock Type Terrain.

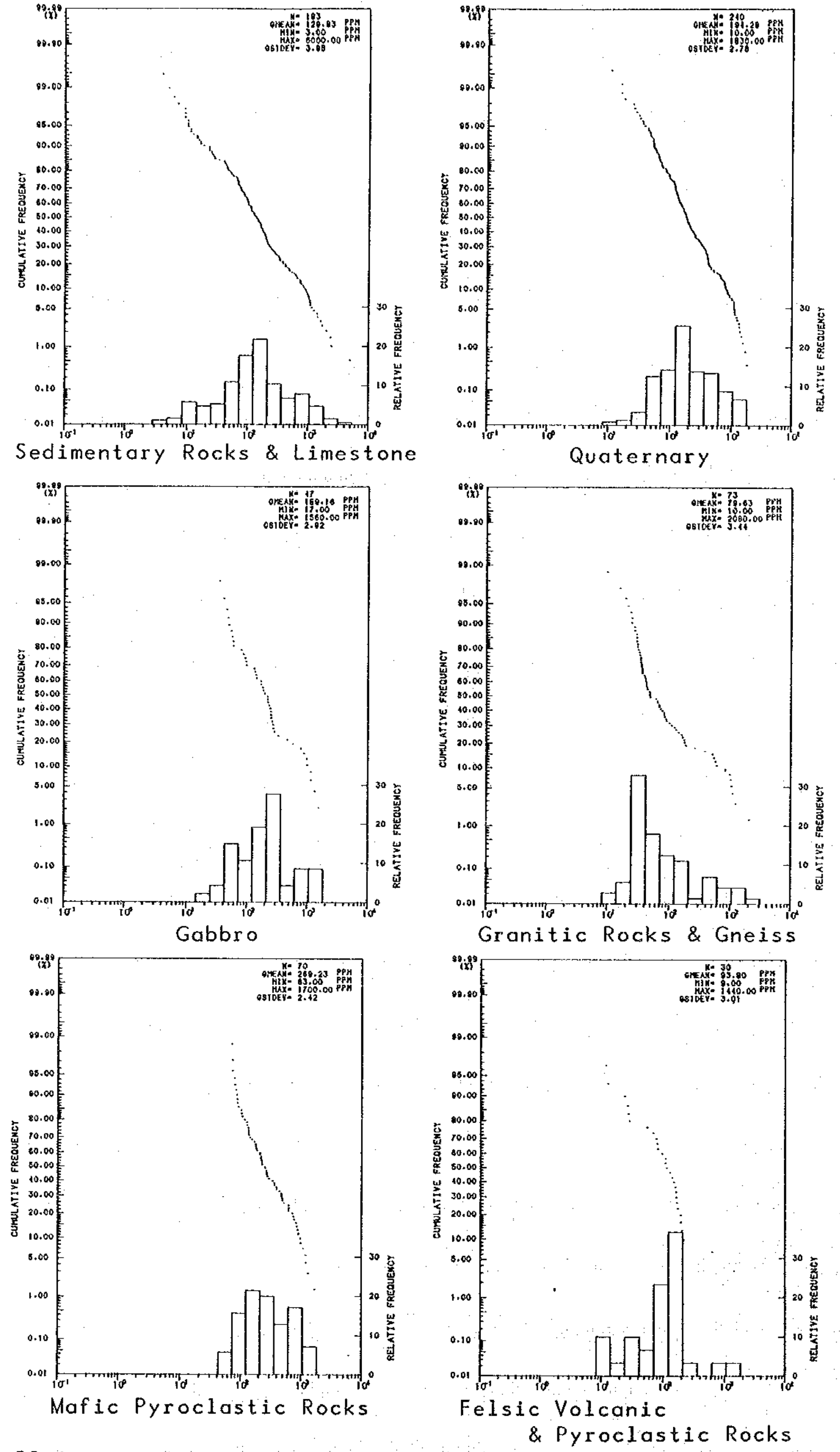


Fig. II-2-10-2 Histogram and Cumulative Frequency Distribution Curve for Geochemical Ni Analysis in Each Rock Type Terrain.

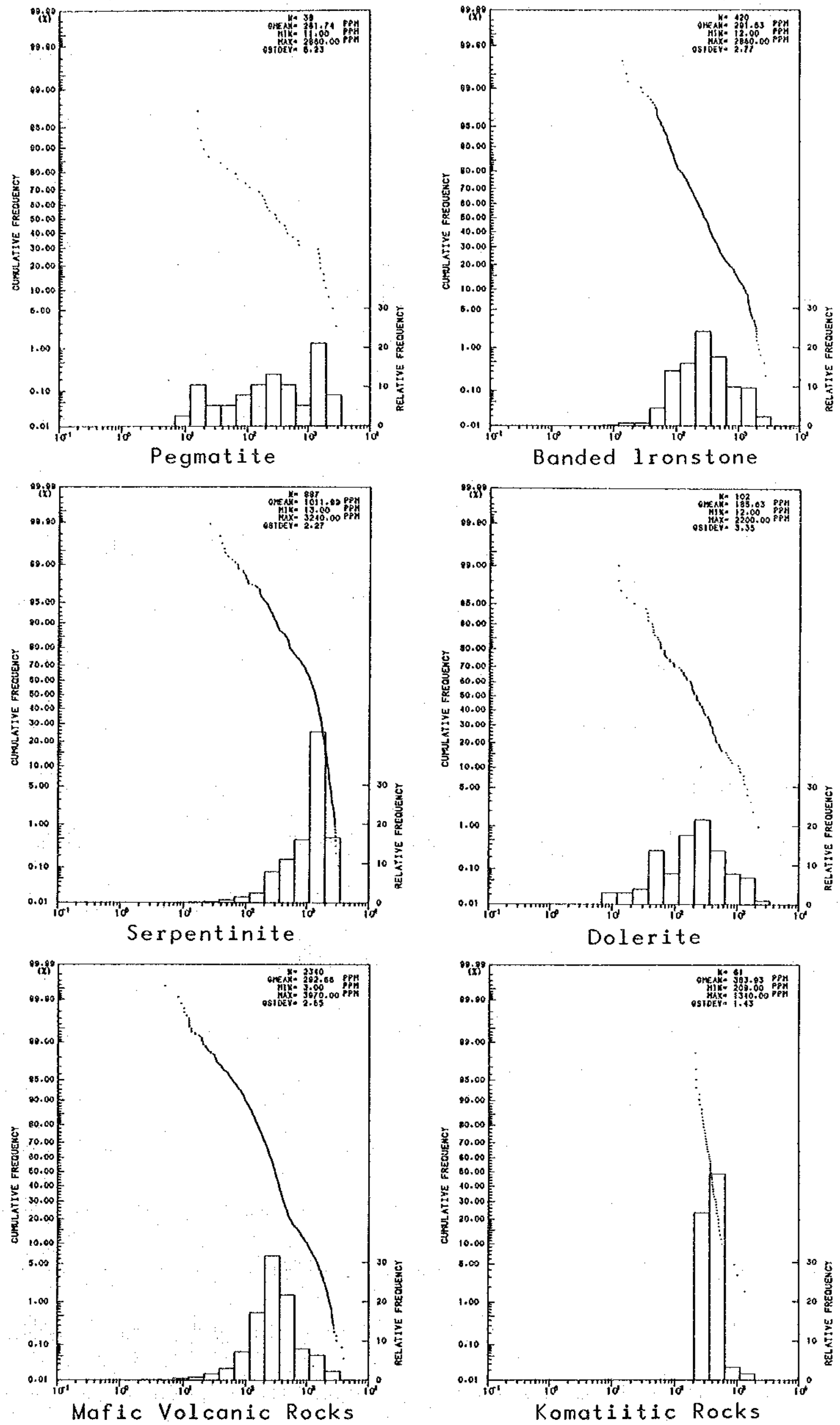
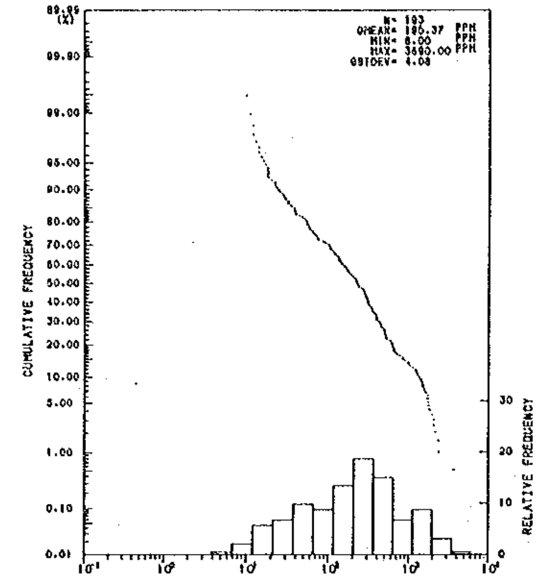
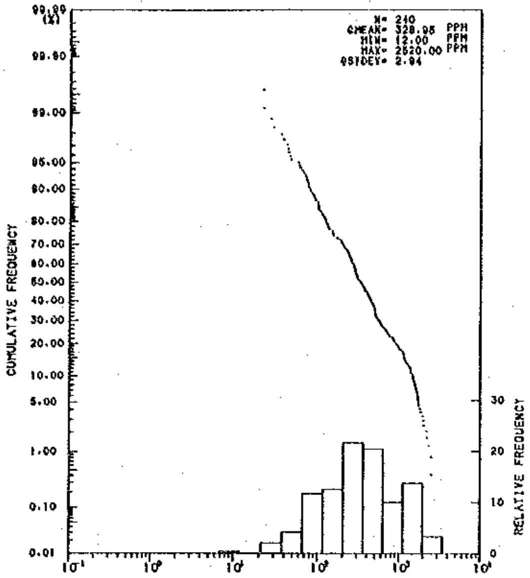


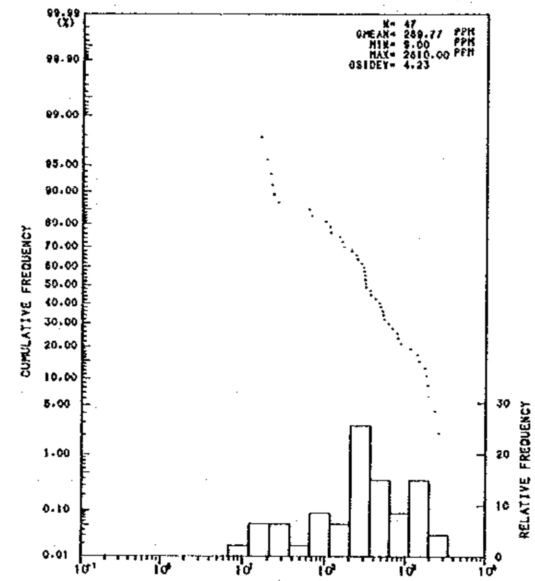
Fig. II-2-11-1 Histogram and Cumulative Frequency Distribution Curve for Geochemical Cr Analysis in Each Rock Type Terrain.



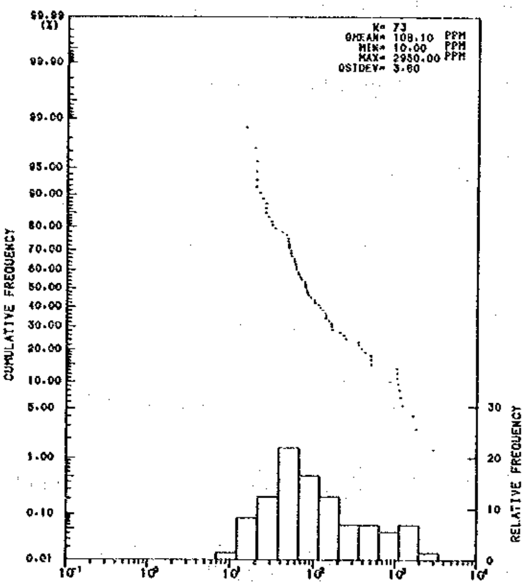
Sedimentary Rocks & Limestone



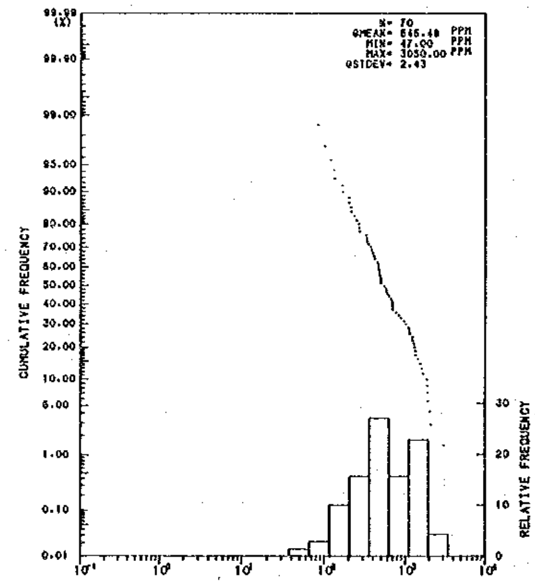
Quaternary



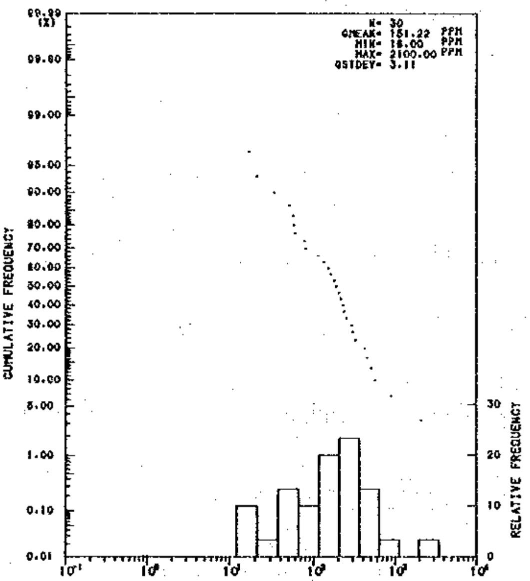
Gabbro



Granitic Rocks & Gneiss



Mafic Pyroclastic Rocks



Felsic Volcanic & Pyroclastic Rocks

Fig. II-2-11-2 Histogram and Cumulative Frequency Distribution Curve for Geochemical Cr Analysis in Each Rock Type Terrain.

Table II-2-7 Foundamental Statistics for Each Rock

	Rock Name	Number of samples	Minimum Value (ppm)				Maximum Value (ppm)				Geometric Mean(ppm)			
			Cu	Zn	Ni	Cr	Cu	Zn	Ni	Cr	Cu	Zn	Ni	Cr
1	Pegmatite	38	2	18	7	11	320	>1,000	3,630	2,860	61	116	171	262
2	Banded Ironstone	420	10	38	23	12	417	973	4,490	2,860	100	143	188	292
3	Sedimentary Rocks & Limestone	193	2	8	3	6	690	>1,000	>5,000	3,690	59	94	130	190
4	Quaternary	240	4	19	10	12	350	833	1,830	2,520	76	107	194	329
5	Serpentinite	887	6	9	8	13	480	>1,000	>5,000	3,240	81	121	610	1,012
6	Dolerite	102	9	28	15	12	474	742	2,200	2,200	125	112	116	186
7	Gabbro	47	19	72	17	9	224	473	1,560	2,610	111	129	189	270
8	Granitic Rocks & Gneiss	73	6	16	10	10	212	676	2,080	2,950	35	78	80	108
9	Mafic Pyroclastic Rocks	2,340	4	25	8	3	1,040	>1,000	4,120	3,970	113	117	165	293
10	Komatiitic Rocks	61	47	64	51	209	178	315	820	1,340	122	115	169	384
11	Mafic Volcanic Rocks	70	32	52	63	47	372	824	1,700	3,050	97	112	269	545
12	Felsic Volcanic & Pyroclastic Rocks	30	5	18	9	16	192	618	1,440	2,100	51	84	94	151

CHAPTER 3 PRINCIPAL COMPONENT ANALYSIS

3-1 Method of Principal Components Analysis

As there were many samples in which Au and Nb were below the detection limits, these two elements were not included in the objectives of this investigation.

As correlations were recognized among four elements, Cu, Zn, Ni and Cr, principal component analyses were carried out to grasp correlations among them. Main computation processes are as follows.

The linear combination function (principal component) of pathfinder is expressed as follows.

$$Zmn = \ell m_1 X_1 n + \ell m_2 X_2 n + \ldots + \ell mpXpn$$

where Z : principal component score

ℓ : eigen vector

X : analytical result or criterion score

m : number of principal component (m=1 ∿ M)

n : number of sample (n=1 - N)

p : number of element (p=1 - P)

and the coefficient (eigen vector) lmp of each pathfinder is determined so that the variance of Zmn may be made maximum and the respective principal components may be made non-correlative with each other under a condition $\sum_{p=1}^{P} \ell mp^2=1$

In order to find this mp, eigen values $\lambda_1 > \lambda_2 \ldots \lambda m \geq 0$ which satisfy the following equation are calculated,

$|R - \lambda mI| = 0$ (R: correlation matrix between elements,

I: unit matrix)

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{12} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ R_{1p} & \cdots & \cdots & r_{pp} \end{pmatrix}$$

$$I = \begin{pmatrix} 1 & \cdots & \cdots & 1 \\ \vdots & 1 & & \vdots \\ \vdots & & \ddots & \vdots \\ 0 & \cdots & \cdots & 1 \end{pmatrix}$$

and lmp which corresponds to each eigen value is calculated from the following simultaneous equations.

$$(R - \lambda mI)\,\dot{\ell}mp = 0$$

$$\dot{\ell}mp\ \dot{\ell}'mp = 1$$

$$\dot{\ell}mp = \begin{pmatrix} \dot{\ell}m1 \\ \dot{\ell}m2 \\ \vdots \\ \dot{\ell}mp \end{pmatrix}$$

$\dot{\ell}'mp$: transposed vector of mp

The principal component score Z is calculated from standardized score X, which was obtained by converting the analytical value into a common logarithm and standardizing it.

$$X' = \log X''$$

$$X = (X' - X')/\sigma X'$$

X'' : analytical value (ppm)

X' : geometric mean

σ : coefficient of deviation

X : criterion score

3-2 Results of Principal Component Analysis

The results of principal component analysis are shown in Table II-3-1. Principal component scores are zoned and shown respectively in PL II-3-1 ~ 4. The principal contribution ratio shown in Table II-3-1 means the ratio of variance between pathfinder which can be expressed by each principal component to the total variance between pathfinders, and an eigen vector represents a coefficient of weight. Each principal component is shown as follows.

$$Z_1 = 0.40X_{Cu} + 0.47X_{Zn} + 0.55X_{Cr} + 0.56X_{Ni}$$

$$Z_2 = 0.63X_{Cu} + 0.48X_{Zn} - 0.43X_{Cr} - 0.43X_{Ni}$$

The factor loading matrix represents the coefficients of correlation between principal component score obtained each principal component and pathfinder.

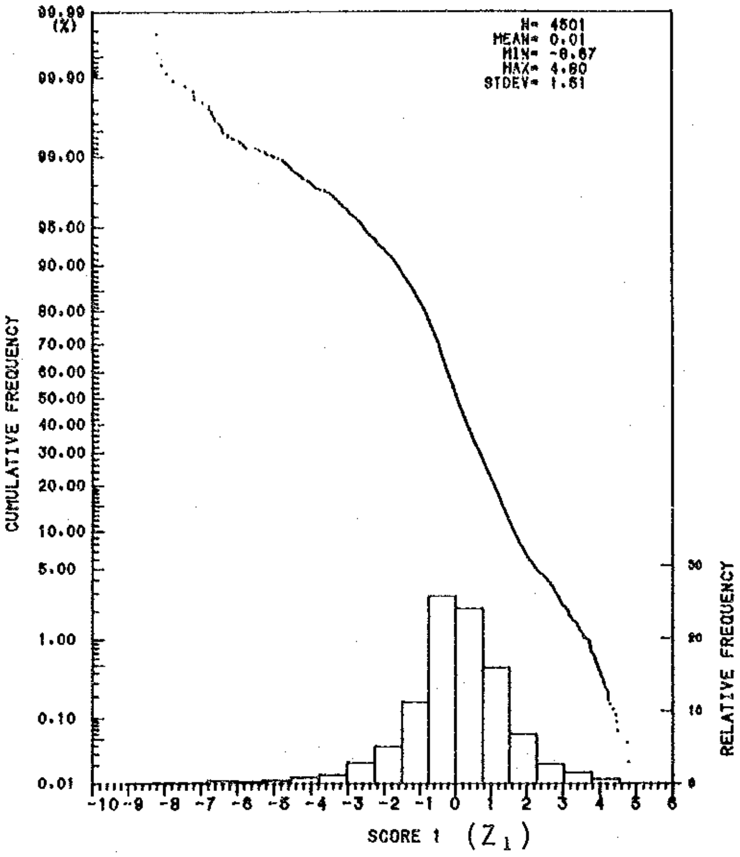
Table II - 3 - 1 Results of Principal Component Analysis of Analytical Values

Principal Component	Eigen-Values	Principal Contribution Ratio	Cumulative Contribution Ratio	Eigenvector				Factor Loanding Matrix			
				ℓm_1	ℓm_2	ℓm_3	ℓm_4	X_{Cu}	X_{Zn}	X_{Cr}	X_{Ni}
1st Comp Z_1	2.40	0.60	0.60	0.40	0.47	0.55	0.56	0.61	0.74	0.86	0.86
2nd Comp Z_2	1.20	0.30	0.90	0.63	0.48	-0.43	-0.43	0.69	0.53	-0.48	-0.47

As these principal components Z_1 (first principal component) and Z_2 (second principal component), which are composite variables, represent 90% of total variance, they will be interpreted substantially. By substituting with the standardized values (standardized scores) of analytical results, scores for Z can be obtained. Since the coefficients of all the terms of Z_1 are positive, Z_1 for a sample having higher analytical value becomes larger. If the values of Z_1 are arranged sequentially from the largest to the smallest, the order becomes the descending order of the sum of element contents. If these element contents are supposed to have resulted from mineralization, this order becomes that of the intensity of mineralization. In the principal components which have this tendency, the values of Cu, Zn, Ni and Cr are evaluated to be positive as a whole. This component represents a factor of increase in contents and represents about 60% of total variance. The second principal component Z_2, being different from the first principal component, represents a variance in which Cu and Zn show a behavior contrary to that of Ni and Cr, and represents about 30% of the total variance.

3-3 Zoning of Principal Component Scores

For the first principal component Z_1 which evaluates Cu, Zn, Ni and Cr collectively and the second principal component Z_2 which evaluates Cu, Zn and Cr, Ni separately, the histograms and relative cumulative frequency distribution curves of their principal component scores are shown in Fig. III-3-1. As shown in PL-II-6-1 ~ 2, the interval between the maximum score and the minimum score was divided into ten zones of score standard deviation steps with the mean value as the center and equal value lines were drawn.



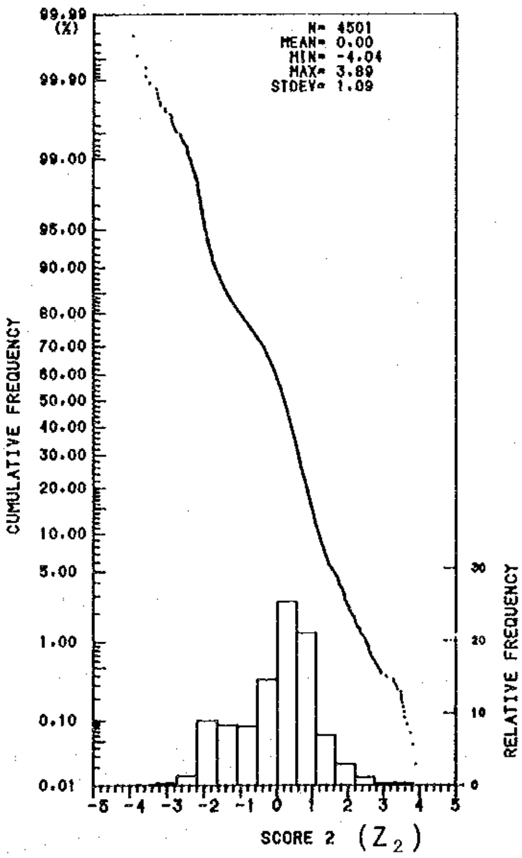


Fig. II-3-1 Histogram and Cumulative Frequency Distribution Curve of Scores for Z_1 and Z_2 of Principal Component Analysis in the Whole Survey Area

Table Ⅱ − 3 − 2 Zoning of Principal Component Scores

Prin. Comp.	1	2	3	4	5	6	7	8	9	10
	$\leqq M-2\sigma$	$M-2\sigma \sim M-\frac{3}{2}\sigma$	$M-\frac{3}{2}\sigma \sim M-\sigma$	$M-\sigma \sim M-\frac{1}{2}\sigma$	$M-\frac{1}{2}\sigma \sim M$	$M \sim M+\frac{1}{2}\sigma$	$M+\frac{1}{2}\sigma \sim M+\sigma$	$M+\sigma \sim M+\frac{3}{2}\sigma$	$M+\frac{3}{2}\sigma \sim M+2\sigma$	$\geqq M+2\sigma$
Z_1	≦−3.0	−3.0 ~−2.24	−2.25 ~−1.4	−1.5 ~−0.74	−0.75 ~−0.01	0.00 ~ 0.74	0.75 ~ 1.4	1.5 ~ 2.25	2.26 ~ 3.0	≧3.1
Z_2	≦−2.16	−2.16 ~−1.61	−1.62 ~−1.07	−1.08 ~−0.53	−0.54 ~−0.01	0.00 ~ 0.53	0.54 ~ 1.07	1.08 ~ 1.61	1.62 ~ 2.15	≧2.16

※ M = Mean
※ σ = Standard deviation

In the above table, the mean value was taken as 0 and the standard deviation as 1 by standardizing treatment, but because of the difference of the actual histograms from the perfect normal distribution form, little errors occurred and these values remained only approximate to 0 and 1.

From the above zones, the threshold value for the Z_1 was taken as $M+\sigma$, and the zones were regrouped as shown in Table II-3-3, zones up to $M+\sigma$ into zone I, zones from $M+\sigma$ to $M+2\sigma$ into zone II and zones above $M+2\sigma$ into zone III, and were shown in the figure.

For Z_2, the threshold values were taken as $M+\frac{3}{2}\sigma$ and $M-\frac{3}{2}\sigma$, and the zones were also regrouped and shown like the first principal component in the figure.

Table Ⅱ − 3 − 3 Thresholds and Zonig of Principal Component Scores

Principal Component	Threshold		Zoning		
	t	≧t(%)	Ⅰ	Ⅱ	Ⅲ
1st Prin Comp. Z_1	1.5	11.71	≦1.5	1.6~3.0	≧3.1
2nd Prin. Comp. Z_2	1.62	5.2	≦ −1.62	−1.61 ~1.61	≧1.62
	−1.62	7.1			

CHAPTER 4 SOIL COLOURS

As described in section 1-1, the colour tones of geochemical soil samples were determined by comparing with those of rock colour charts. However, as there were as many as 22 kinds of colours, the colour tones were simplified into seven series, reddish brown, dusky brown, grayish red, grayish brown, light brown, light yellowish brown and pale reddish brown, in showing them on maps. These maps were prepared by digitizing the colour tones of the series using a computer. The results are shown in PL II-4-1 ~ 2. The purpose of preparing the colour tone maps was to clarify the distribution of ultramafic rocks or mafic rocks which are thought to form dusky brown soil, and the distribution of acidic rocks, granitic rocks, sandstone, quartzite, etc., which form pale reddish brown soil.

As a result, it was clarified that the colour series which occupied the widest area was reddish brown, and in most of the areas where this colour tone was distributed, mafic igneous rocks or similar rocks were distributed. The reddish brown colour is the most popular one in the surveyed area, and this colour can be regarded as the representative colour of the surveyed area. The distribution of colours and rocks in each area is described as follows.

Area A : In this area, in parts where granite is distributed, light brown and pale reddish brown colours are distributed somewhat characteristically. No other relations between colours and distribution of rocks were recognized.

Area B : In this area, gabbro is distributed along line 21 and dusky brown is distributed along the same line. The colour tones of rock and soil match with each other. However, in the rest of this area, no colour changes related with particular rock were recognized, and reddish brown soil were distributed overwhelmingly.

Area C : Also in this area, the reddish brown colour is distributed in most of the parts, with dusky brown, pale reddish brown, grayish red and grayish brown colours distributed scatteredly. However, no particular relations between the colours and geology were recognized, and distribution was irregular. Moreover, in the area where mafic rocks were distributed, there were places where light colour soil was distributed.

Area D : The geology of this area comprises ultramafic rock, mafic rock, sedimentary rock, banded ironstone layers, etc., and abounds in changes more than in other areas. Therefore, some influence on the colour tones of soil was expected. The distribution of dusky brown soil comparatively matches with that of the ultramafic rock such as serpentinite, and comparatively light colour, or the light brown colour, soil has developed near sedimentary rocks which are distributed in the northwestern part of Area D. On the other hand, in the part of Area D where serpentinite has exposed, dusky brown and grayish brown soil has developed, showing interesting contrast.

Area E : In this area, ultramafic rock has exposed along a north to south trend, and the colour matching this rock was not necessarily found. Dusky brown and dark gray colour tones were distributed comparatively characteristically and they seem to have some significance.

The relation between colour tones and facies was investigated above, but it seemed deviod of any definite relation.

Next, the relation between colour tones and geochemical survey results in each area is described as follows.

Area A : No particular relation between the distribution of colour tones and the geochemical survey results was found in this area.

Area B : The condition in this area was similar to that in A area.

Area C : In this area, dusky brown soil has developed in the center of lines 77 - 86. The anomalous zones of Zn, Ni, Cr, etc., exist near here. In addition, serpentinite is exposed near here, and this rock has perhaps contributed to the formation of dusky brown soil.

Area D : It was pointed out before that dusky brown soil, which has a link with the facies, developed in this area. It is interesting that the distribution of the anomalous zones of Zn, Ni, Cr, etc., matches with that of dusky brown soil.

Area E : In this area, parts of dusky brown soil were found in the anomalous zones of Ni, Cr, etc., but the distribution of the soil does not necessarily match with that of the anomalous zones. The soil and the anomalous zones are distributed independently and locally, and the correlation between them is not clear.

CHAPTER 5 COMPREHENSIVE JUDGMENT ON Au, Cu, Zn, Ni, Cr AND Nb

5-1 Area A

In this area, no noticeably high content values of Cu were found. For Zn, B zone is distributed over the area from line 27 to line 44, and A zone is also distributed in a part of this area. B zone is distributed also over the area from line 45 to line 52, and A zone is also distributed slightly in this area. Since high correlativity exists between Ni and Cr, their B zones are distributed in the same places, and their distribution is supposed to be related with that of ultramafic rocks. According to the results of principal component analysis, high score zones of Z_1 are scattered over the area from line 25 to line 31, but they exist only locally. Although several anomalous zones are found as mentioned above, the anomaly of this area can be regarded weak when judged comprehensively.

5-2 Area B

In this area, B zone of Cu is distributed scatteredly, and A zone is dotted extremely locally. For Zn, A and B zones appear near line 5 and in the area from line 14 to line 20. Also for Ni the anomaly of A and B zones appears almost in the same places. For Cr, A zone does not appear, but B zone is distributed almost in the same places as Ni, showing that correlation exists between Ni and Cr. The anomaly, which appeared near line 5, is distributed together with serpentinite. The Z_1 and the Z_2 are both positive with high scores near this anomaly, showing that the analytical values of Cu and Zn are large. The MgO content (Sample No. B-6) of serpentinite near here is as high as 35%. By judging from the analytical values, principal component scores and rocks, the anomaly seems to be worthy of attention.

The principal component of the anomaly found between line 14 and line 20 has three high score points on lines 16, 17 and 19. These points show a tendency of high Cu and Zn contents, and the high scores are supposed to be resulting particularly from the high analytical values of Zn. Although komatiites are distributed in the vicinity their position is slightly different from that of the anomaly. The importance of this anomaly is thought to be inferior to that of the anomaly near line 5.

5-3 Area C

In the southwestern part of this area, the anomalies of B zones of Cu, Zn, Ni and Cr exist, overlapping in the area from line 79 to line 90. These anomalous zones are distributed in accordance with the distribution of ultramafic rocks, forming interesting anomalous zones. These ultramafic rocks show the MgO contents of 35% (Sample No. HK-74), 34.4% (Sample No. CM-47) and 38% (Sample No. HK-68). Also in principal component analyses, the zones II and III of the Z_1 exist and analytical values are high as a whole. These anomalous zones are thought to be connected with mineralized zones, so that this area can be regarded prospective.

Concerning Zn, A and B zones are distributed only scatteredly in the northwestern part of this area, but in the central part, a long-stretched strong anomaly ranges from the neighborhood of line 42 to that of line 78. Concerning Cu, the anomaly of B zone is dotted on the latter anomaly of Zn. However, Ni and Cr do not show behavior matching with that of Zn near here. The distribution of the high Zn anomaly from line 42 to the neighborhood of line 54 almost matches with that of banded ironstones, therefore, some relation seems to exist between the anomaly and banded ironstones, but it is not yet clarified. The high Zn anomaly spreading from line 54 to line 78 in the southwestern part of this area appears mainly on ultramafic igneous rocks. The relation between these continuous high Zn anomalies and rocks is not clear. It is necessary to investigate in future whether or not these anomalies were caused by mineralized zones.

Concerning Ni and Cr, anomalies belonging to B zone were detected on lines 65 and 54 in addition to that ranging from line 79 to line 90, but the scale of the former is smaller than that of the latter.

In the northeastern part of this area, dolerite is exposed crossing this area obliquely. Along this dolerite, B zone of Cu ranging from line 10 to line 30, and small spots of A zone are distributed here and there in the B zone. However, no anomalies of other elements are found, and the above zones are interpreted to be the anomalies detected in relation to the dolerite. In addition, komatiite has also intercalated concordant with strata mainly near the northern longer side of this area, but no anomalies were found directly on the komatiite.

5-4 Area D

In this area, the anomalies belonging to B zone of Cu are distributed here and there, but particularly high anomalies exist between line 29 and line 35 and on line 50. The strong anomalies of Zn exist in similar positions to those of Cu, showing correlativity between Cu and Zn, and in addition to them, A and B zones are distributed extensively in the southeast part on line 1 to line 12. Also between line 29 and line 42, the widest A zone is distributed.

The strong anomaly of Ni appears over the area from line 8 to line 10, and most part of this area is covered with B zone. Although the anomaly of the B zone of Cr, which shows similar distribution to that of Ni, exists, but no anomalies belonging to A zone are found. The distribution of these anomalies is closely related with that of serpentinites. However, on the serpentinites at the southwestern end of lines 1 to 10, no anomalies of elements other than Ni and Cr appear. To find out the reason for this fact, the chemical compositions of these rocks were compared with those of rocks in other areas, but no particularly noticeable difference was found. (Sample Nos. D-10-2, EX-9, DM-4, D-6-106, D-6-111 and D-6-17)

Since Ni-Cu ore deposits in this area are closely related with the existence of ultramafic rocks, these anomalies are regarded important in prospecting. According to the results of principal component analysis, zones II and III of high scores of Z_1 are distributed between lines 28 and 31, and lines 35 and 41, and these zones are regarded to be prospective. In addition, the high score sections of Z_1 exist also on lines 5 through 12 and zones II and III are distributed also on line 50, making these areas also interesting. For Z_2, zone I is distributed over the area from line 48 to line 66, indicating that the contents of Ni and Cr are higher than those of Cu and Zn. These zones are regarded as the anomalies appearing along the slender ultramafic rock which is distributed in this area.

After all, this area is regarded as the area worthy of future exploration judging from the distribution of anomalies determined from analytical values, geological conditions and principal component analyses.