REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE VAN YEN AND WESTERN THANH HOA AREAS,
THE SOCIALIST REPUBLIC OF VIETNAM

CONSOLIDATED REPORT

MARCH 1996

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

In response to the request of the Government of the Socialist Republic of Vietnam, the Japanese Government decided to conduct a Mineral Exploration Project in the Van Yen and Western Thanh Hoa Areas and entrusted the survey to the Japan International Cooperation Agency (JICA) and the Metal Mining Agency of Japan (MMAJ).

The Government of the Socialist Republic of Vietnam appointed the Geological Survey of Vietnam to execute the survey as a counterpart to the Japanese team. The survey was carried out from 1993 jointly by experts from both governments.

The cooperative mineral exploration in the Van Yen and Western Thanh Hoa areas has continued for three years. It consisted of geological survey, geochemical exploration, geophysical survey and drilling survey.

We hope that this report will serve for the development of this project and contribute to the promotion of friendly relations between our two countries.

We wish to express our deep appreciation to the officials concerned of the Government of the Socialist Republic of Vietnam for the close cooperation extended to the team.

March, 1996.

Kimio FUJITA
President,
Japan International Cooperation Agency

Shozaburo KIYOTAKI
President,
Metal Mining Agency of Japan

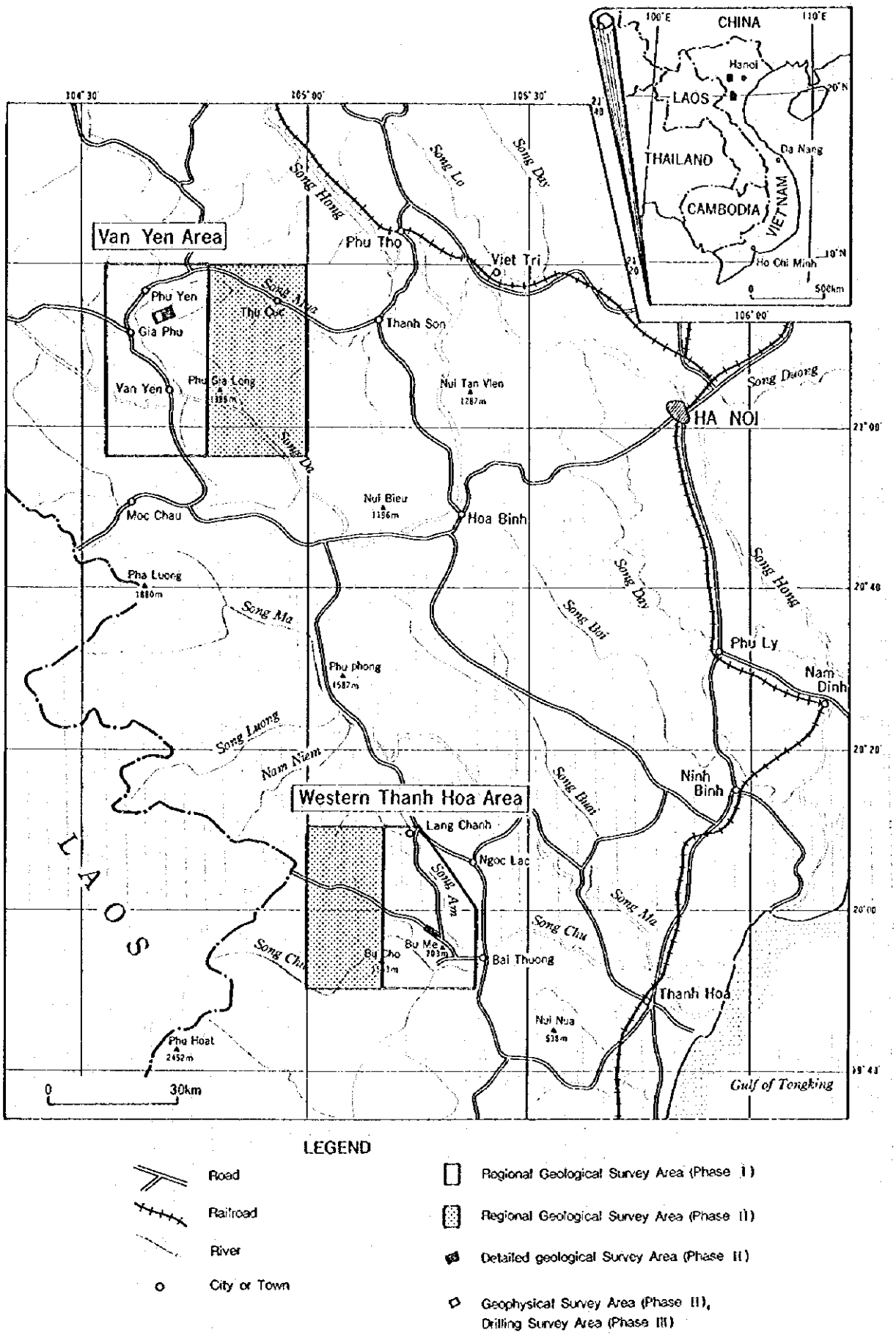

Fig. 1-1 Index Map of the Survey Area

SUMMARY

The results of works executed in this cooperative mineral exploration has continued for three years from 1993. The principal objective of the project is to evaluate the mineral potential of the areas through geoscientific investigation and to discover new mineral deposits.

In the first and second phases, regional geological survey and geochemical exploration were conducted in the Van Yen and Western Thanh Hoa areas, and detailed geological survey, geochemical exploration and geophysical survey were consequently continued on the promising zones for ore deposits.

The Suoi Boc zone of the Van Yen area was extracted to be hopeful for lead and zinc mineralization as a result of the above works.

The survey of the third phase consisted of drilling survey and trench survey in the Suoi Boc zone. Amount of the survey is four inclined drill holes totaling 742.30 m and three trenches with a total length of 600 m.

The followings are the conclusions obtained as the results of the above work and recommendations for the future exploration work.

Van Yen Area

This survey area belongs to the West Bacbo tectonic province. The basement of the area comprises the Proterozoic metamorphic rocks represented mainly by gneisses. Unconformably overlying the basement are metamorphic and sedimentary rocks of Cambrian to Permian age, pyroclastic and sedimentary rocks of Triassic age, Alkali volcanic and pyroclastic rocks and neritic sedimentary rocks of Cretaceous age, intrusive rocks and unconsolidated Quaternary sediments. Plutonic and hypabysal rocks of Permian to Cretaceous age are distributed. They are divided into ultramafic to mafic rocks, intermediate to felsic rocks. The intrusive bodies are commonly small.

The geology of this area is strongly controlled by the NW-SE trending main structure of the "West Bacbo", and the NW-SE direction is predominant in both major faults and foldings. The area is tectonically divided into three parts, namely northeastern to southeastern part, northwestern to central part and southwestern part. The northeastern to southeastern part of the area consists of Proterozoic to Ordovician and is controlled by NW-SE trending structure as principal structure of

"West Bacbo". The northwestern to central patt is underlain by Devonian to Cretaceous and is characterized by the structure of WNW-ESE to E-W direction. Lower Triassic to Cretaceous extends in NW-SE direction in the southwestern part.

The major mineralization in this survey area is those of gold, copper, lead - zinc, and platinum - copper - nickel. They are summarized below.

The major gold mineralization of this area is that associated by bedded cupriferous pyrite deposits. It is believed that the deposits have close genetic relation to the Early Triassic mafic to intermediate alkali volcanism. The ore bodies are narrow ranging in width from 0.2 to 0.5 m and the contents of gold and copper are relatively high (Au: 1 to 6 g/t, Cu: 1 to 7 %). There are a large number of ore bodies, but they are not extensive.

The relatively large quartz veins of about 2 m in width occur in the survey area, and are accompanied occasionally by copper minerals. However, the content of copper is not of significant commercial value.

The lead-zinc mineralization is represented by hydrothermal vein type, and is mostly hosted by the Middle Triassic limestone. It is believed that size of ore deposits is small, although grade of ore is locally high.

Platinum-copper-nickel mineralization occurs in and around ultramafic bodies which intruded during the Permian time. The bodies are generally small with several meters to 100 m width. The assay results for platinum are not high with the maximum being 40 ppb. The contents of copper and nickel are approximately 0.1 %. Thus, this type mineralization is very weak in this area.

As a result of stream sediment and pan concentrate geochemistry, there is no anomalous zone to indicate significant mineralization.

Suoi Boc Zone of the Van Yen Area

The geology of the Suoi Boc zone consists of Middle Triassic sedimentary rocks, Cretaceous dacite porphyry and aplite, and Quaternary sediments. The Middle Triassic is divided into clastic sedimentary rocks and limestone. The Triassic clastic sedimentary rocks tend to strike N-S to NNE-SSW direction and to dip mostly from 20° to 70°E.

The geological structure of the zone is characterized by the N-S to NNE-SSW direction that is expressed as the strikes of sedimentary rocks and faults, the distribution of igneous rocks and the extension of Quaternary sediments.

Geochemical anomalies in the zone indicate the vein-type mineralization. The potential for skarn ore deposits is low, because skarn minerals are absent in the Triassic rocks of these anomalous zones.

The high chargeability zones detected by IP survey, are interpreted to have been caused by graphite contained in the clastic sedimentary rocks. Therefore it has been proved that new Pb-Zn ore deposits are not expected to occur in the high chargeability zones.

The vein-type mineralization in this zone contains Pb-Zn, but it is supposed that size of ore deposit is small.

Western Thanh Hoa Area

The survey area belongs to the "Truongson" tectonic province which is the Late Paleozoic to Early Triassic mobile belt. This area is underlain mainly by the Cambrian metamorphic basement, the overlying Ordovician to Triassic marine and continental sedimentary rocks, and the Jurassic volcanic and pyroclastic rocks. The intrusive rocks of the survey area are classified into Triassic gabbro, Jurassic felsic rocks, and Late Cretaceous to Paleogene granitic rocks.

The geology of this area is controlled by the NW-SE trending main structure of the "Truongson". Two major N-S trending faults extend in the central part of the survey area.

Gold, copper, tin, and tungsten mineralization occur in the survey area.

Gold is associated by quartz veins, but is poor in content.

Copper mineralization occurs in the Hon Mo mineralized zone. The copper content is low at the outcrop.

The tin-tungsten Bu Me Prospect is believed to be a pneumatolytic to hydrothermal mineralization zone associated with porphyritic granitic intrusion. The ore minerals of this prospect are mainly cassiterite and wolframite, and the prospect occurs in the granitic body and the

surrounding hornfels zone. Areal extent of the major mineralization zone is estimated to be 1,200 m by 400 m. The average grade of Sn+W is 0.33 % along trenches with about 320 m in total length.

The present geochemical exploration revealed that the southwestern granite area is the most promising for tin-tungsten mineralization, excluding the Bu Me Prospect. However, any interesting area for future exploration is not extracted by the present geological survey.

Luong Son Zone of the Western Thanh Hoa Area

The zone is underlain mainly by the Middle Triassic sandstone, Jurassic dacitic crystal tuff, and Late Triassic intrusive gabbro. The sandstone occurs in a major part of the area and extends generally in the NNW-SSE direction. The strata are inferred to consist of a series of folds with about 2 km wavelength. The gabbroic bodies intruded into sandstone area and extend roughly in the N-S direction.

The gold-bearing hydrothermal quartz veins are concentrated in this zone. They are hosted by the Middle Triassic sandstone and mudstone as well as Late Triassic gabbroic bodies. Chemical analysis of the collected samples revealed that the highest content of gold was 0.24 g/t.

As a result of the soil geochemical exploration, four strong anomalous zones for Au sporadically scattered and have less than 200 ppb in content.

As the result of the works done in the both areas, no indication for new ore deposits was found. Therefore, no further exploration is needed in these areas.

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PART 1. INTRODUCTION

PART 1. INTRODUCTION

CHAPTER 1. OUTLINE OF THE SURVEY

1-1. Background and Objectives of the Survey

In response to the request by the Government of the Socialist Republic of Vietnam to conduct mineral exploration, the Japanese Government dispatched a preparatory survey team to discuss the details of the project. As a result of the consultations between the Geological Survey of Vietnam (GSV) of the Ministry of Heavy Industry and the Metal Mining Agency of Japan, an agreement was reached for the cooperative mineral exploration in the Van Yen and Western Thanh Hoa Areas. The Scope of Work was signed by the representatives of both governments in June 1993. The objective of this project is to assess the mineral potential of the areas through geological survey, geochemical exploration, geophysical survey, and drilling survey during the period of three years from 1993 to 1995.

The first phase survey of this project was carried out in fiscal 1993. The works conducted in the first phase were; compilation of available geological, geochemical and geophysical information, geological and geochemical field survey of the western part of the Van Yen area and the eastern part of the Western Thanh Hoa area, and geochemical exploration in the Bu Me zone of the Thanh Hoa area.

In fiscal 1994, geological and geochemical survey continued in the remained parts of the Van Yen and Western Thanh Hoa areas, after the compilation of available geological, geochemical and geophysical information was done. Geological survey was executed in the Suoi Boc - Suoi Cu zone and geochemical exploration and geophysical survey were done in the Suoi Boc zone of the Van Yen area, and geological and geochemical survey was conducted in the Luong Song zone of the Western Thanh Hoa area, since these were concluded to be promising for finding ore deposits by geological survey during the first year.

In fiscal 1995, drilling survey comprising four holes totaling 742.70m in length and trench survey with a length of 600 m continued on the Suoi Boc zone of the Van Yen area.

1-2. Coordinates of the Survey Area

The Survey area during the first phase is the Van Yen and Western Thanh Hoa areas. The coordinates of the area are as follows.

【Western Part of Van Yen area】 (1,000 km² in area)

1	21°20'N.	104°33'E	3	20°56'N	104°46'30"E
2	20°56'N	104°33'E	4	21°20'N	104°46'30"E

【Eastern Part of Western Thanh Hoa area】 (650 km² in area)

1	20°10'N	105°10'30"E	4	20°00'N	105°22'30"E
2	19°50'N	105°10'30"E	5	20°10'N	105°15'E
3	19°50'N	105°22'30"E			

【Bu Me zone of Western Thanh Hoa area】 (5 km² in area)

1	19°55'54"N	105°19'30"E	3	19°54'16"N	105°20'25"E
2	19°54'16"N	105°19'30"E	4	19°55'54"N	105°20'25"E

The Survey area during the second phase is the Van Yen and Western Thanh Hoa areas. The coordinates of the area are as follows.

【Eastern Part of Van Yen area】 (1,000 km² in area)

1	21°20'N	104°46'30"E	3	20°56'N	105°00'E
2	20°56'N	104°46'30"E	4	21°20'N	105°00'E

【Western Part of Western Thanh Hoa area】 (650 km² in area)

1	20°10'N	105°00'E	3	19°50'N	105°10'30"E
2	19°50'N	105°00'E	4	20°10'N	105°10'30"E

【Suoi Boc - Suoi Cu zone of Van Yen area】 (10 km² in area)

1	21°13'45"N	104°38'46"E	3	21°13'45"N	104°41'43"E
2	21°12'38"N	104°39'15"E	4	21°14'41"N	104°41'15"E

【Luong Son zone of Western Thanh Hoa area】 (4 km² in area)

1	北緯 19°57'58"	東経 105°15'14"	3	北緯 19°56'26"	東経 105°16'11"
2	北緯 19°57'16"	東経 105°14'46"	4	北緯 19°57'06"	東経 105°16'38"

The Survey area during the third phase is the Suoi Boc zone of the Van Yen area. The coordinates of the area are as follows.

【Suoi Boc zone of Van Yen area】 (4.5 km² in area)

1	21°13'45"N	104°38'46"E	3	21°13'45"N	104°41'43"E
2	21°12'38"N	104°39'15"E	4	21°14'41"N	104°41'15"E

1-3. Method of Exploration

Methods and amount of work in each phase are summarized in Table 1-1.

1-4. Members of the Survey

(1) Mission for Scope of work

Vietnamese Members	Japanese Members
Tran Dy (General Director, GSV)	Katsuo YOKOYAMA (Team leader, MMAJ)
Tran Van Tri (Deputy General Director, GSV)	Masayoshi SHIMODE (MMAJ, Bangkok)
Vu Ngoc Xuan (Director of Industrial Department State Planning Committee)	Kousuke TAKAMOTO (MMAJ)
Pham Xuan Hoang (Deputy Director, International Cooperation Department, Ministry of Heavy Industry)	Taro KAMIYA (MMAJ)
Doan Ky Thuy (Director, International Cooperation Division, GSV)	Koh NAITO (JICA)
Le Van De (Deputy Director, International Cooperation Division, GSV)	

(2) First Phase

Field inspection

Yoshiaki IGARASHI (MMAJ)

Field survey team

Vietnamese members	Japanese members (Nikko Exploration & Development Co., Ltd.)
Van Yen Area (Geological Mapping Division, GSV)	Yuya FURUKAWA (Team leader)
Nguyen Cong Luong (Team leader)	Masataka OCHI (Geologist)
Trinh Huu Nghi (Geologist)	Motomu GOTO (Geologist)
Dinh Van Tuy (Geologist)	Kazuyasu SUGAWARA (Geologist)
Nguyen Van Cu (Geologist)	Norihiro NAGANO (Geologist)
Le Van Dieu (Geologist)	
Western Thanh Hoa Area (Division No.4, GSV)	
Ho Nhiem (Team leader)	
Dau Ba Quang (Geologist)	
Tran Cong Bong (Geologist)	
Nguyen The Phuc (Geologist)	
Le Ich Nhi (Geologist)	

(3) Second Phase

Field inspection

Naoki SATO (MMAJ)

Vietnamese members	Japanese members (Nikko Exploration & Development Co. Ltd.)
Van Yen Area (Geological Mapping Division, GSV)	Masataka OCHI (Team leader)
Nguyen Dai Lu (Team leader)	Motomu GOTO (Geologist)
Pham Van Duong (Geologist)	Masami HIGASHIHARA (Geologist)
Nguyen The Cu (Geologist)	Takumi ONUMA (Geologist)
Nguyen Huy Than (Geologist)	Kazuyasu SUGAWARA (Geologist)
Tran Dang Hung (Geologist)	Tomoji SANGA (Geologist)
Dao Nguyen Viet (Geologist)	Takashi YAMAISHI (Geophysicist)
Nguyen Xuan Dong (Geophysicist)	Shinichi SUGIYAMA (Geophysicist)
Nguyen Duc Nhuong (Geophysicist)	Tadanori IWASAKI (Geophysicist)
Tran Thanh Dy (Geophysicist)	
Western Thanh Hoa Area (Division No.4 GSV)	
Ho Nhiem(Team leader)	
Dau Ba Quang (Geologist)	
Nguyen The Phuc (Geologist)	
Tran Cong Bong (Geologist)	
Nguyen Xuan Toan (Geologist)	
Nguyen Phi Tien (Geologist)	

(4) Third Phase

Vietnamese Side (Geological Division No.3, GSV)	Japanese Side (Nikko Exploration & Development Co., Ltd.)
Hoang Minh Hue (Coordinator)	Yoncharu MATANO (Team Leader)
	Saichi ISHII (Drilling Engineer)

CHAPTER 2. GEOGRAPHY

2-1. Location and Access

(1) Van Yen Area

The regional survey area is located about 110 km west of Hanoi and belongs to three provinces of the Son La, Vin Phu, and Ha Son Binh as administrative district. The largest village called Phu

Table 1-1 Summary of Exploration Work in the Van Yen and Western Thanh Hoa Areas

Phase	Survey	Area	Amount of Work
First	Study of Available Relevant Data	Van Yen Area Western Thanh Hoa Area	
	Regional Geological Survey and Geochemical Exploration	Van Yen Area	Area : 1,000 km² Stream Sediments 899 pcs Pan Concentrates 193 pcs
		Western Thanh Hoa Area	Area : 650 km² Stream Sediments 532 pcs Pan Concentrates 147 pcs
	Semi-detailed Geochemical Exploration	Bu Me Zone, Western Thanh Hoa Area	Area : 5 km² Soils 241 pcs
	Laboratory Works		Thin Sections 62 pcs Polished Sections of Ore 41 pcs X-ray Diffraction Analysis 24 pcs Chemical Analysis Whole Rocks 39 pcs Ore 124 pcs Stream Sediments 1,431 pcs Soils 241 pcs
Second	Study of Available Relevant Data	Van Yen Area Western Thanh Hoa Area	
	Regional Geological Survey and Geochemical Exploration	Van Yen Area	Area : 1,000 km² Stream Sediments 915 pcs Pan Concentrates 240 pcs
		Western Thanh Hoa Area	Area : 650 km² Stream Sediments 469 pcs Pan Concentrates 120 pcs
	Detailed Geological Survey and Geochemical Exploration	Suoi Boc - Suoi Cu Zone, Van Yen Area	Area : 10 km² Soils 100 pcs
		Luong Son Zone, Western Thanh Hoa Area	Area : 4 km² Soils 207 pcs Pan Concentrates 15 pcs
	Geophysical Survey	Suoi Boc Zone, Van Yen Area	Area : 3 km² IP 15.8 km
	Laboratory Works		Thin Sections 79 pcs Polished Sections of Ore 37 pcs X-ray Diffraction Analysis 17 pcs Chemical Analysis Whole Rocks 42 pcs Ore 93 pcs Stream Sediments 1,384 pcs Soils 307 pcs
Third	Drilling Exploration Trench Survey	Suoi Boc Zone, Van Yen Area	Area : 4.5 km² Drilling (4 holes) 742.70 m Trench (4 lines) 600.00 m
	Laboratory Works		Thin Sections 19 pcs Polished Sections of Ore 7 pcs X-ray Diffraction Analysis 12 pcs Chemical Analysis Rock 141 pcs Ore 36 pcs

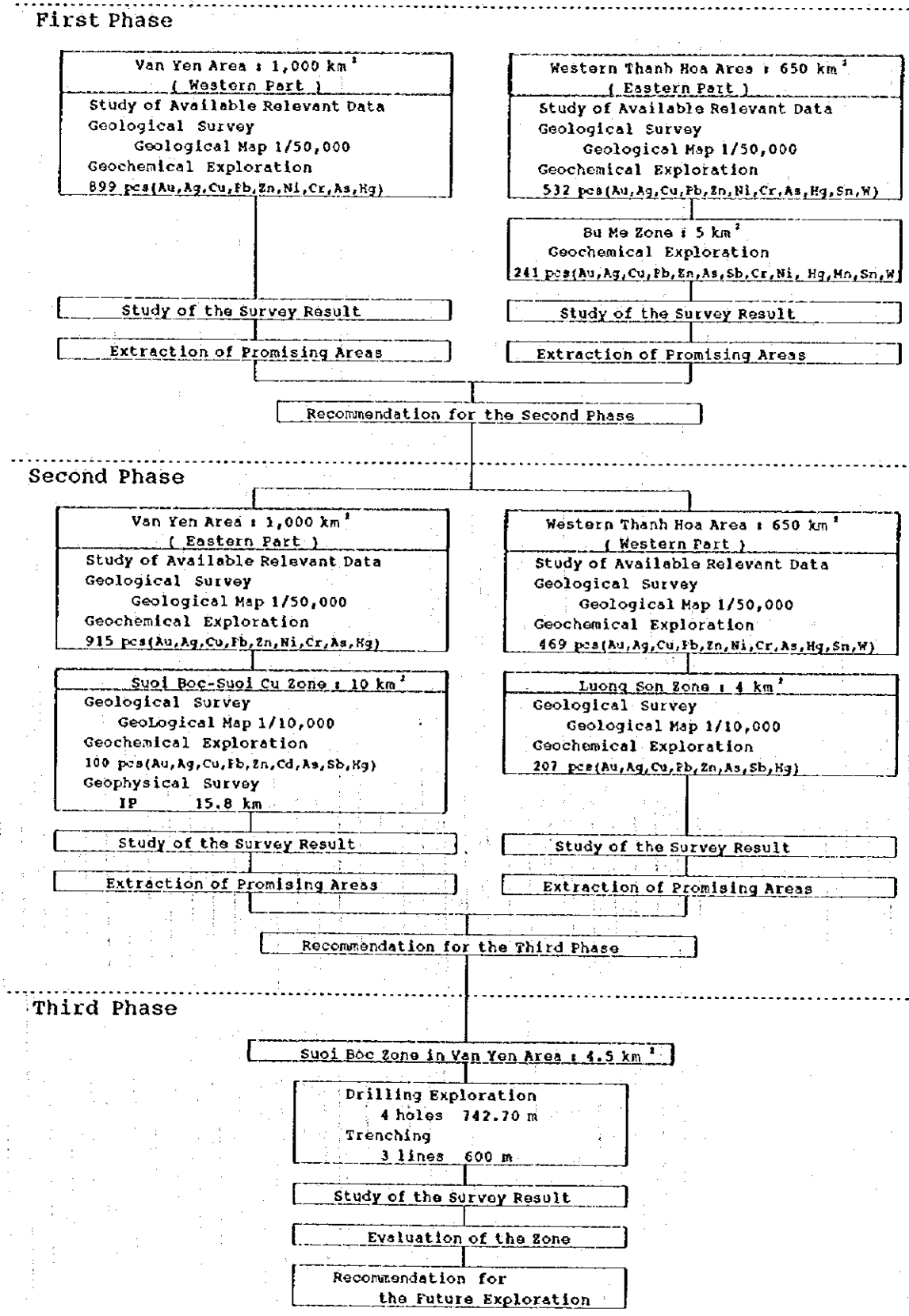


Fig. 1-2 Flowsheet of Survey in the Van Yen and Western Thanh Hoa Areas

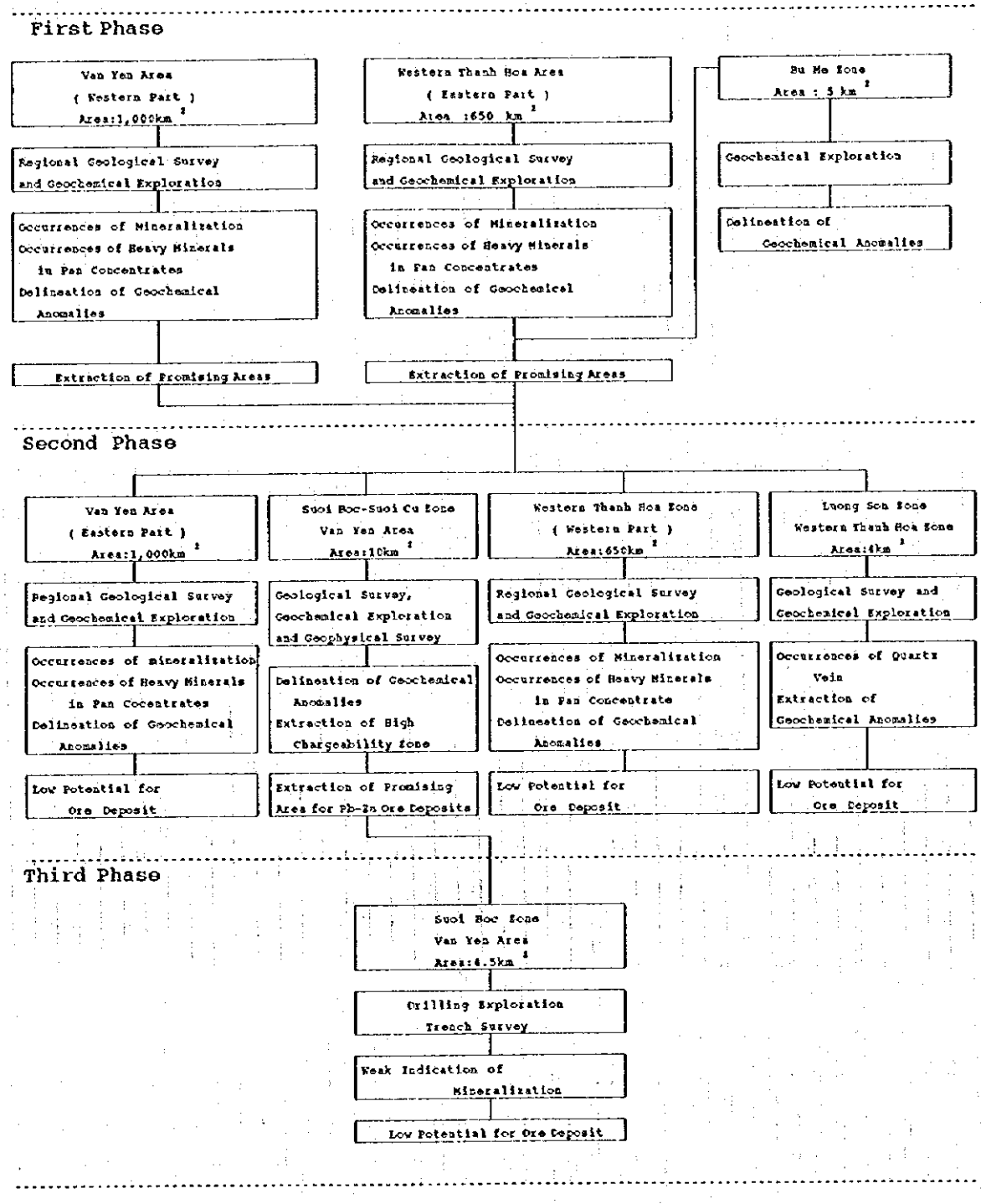


Fig. 1-3 Flowsheet Illustrating the Exploration Step in the Van Yen and Western Thanh Hoa Areas

Yen has a population of 3,000. Small villages of highland tribe are scattered in the intra-montane basins and uppermost reaches of many tributaries. There are two routes to reach Phu Yen from Hanoi, the northern and southern routes. The northern one leads to Phu Yen via Son Tay along the Hong River. The distance along the road is approximately 170 km and it is about seven hours drive by jeep. In this route it is necessary to cross the Da River by ferry at the point to the west of Ba Vi. The road is flat and paved from Hanoi to Ba Vi, while from the Da River westward the road is unpaved and leads to Phu Yen via Thanh Son.

The southern route leads to Phu Yen via Hoa Binh and Thanh Son through the national roads No.6 and No.24. The distance along the roads is approximately 210 km and it takes roughly eight hours by jeep from Hanoi. The road No.6 is flat and paved from Hanoi to Hoa Binh, but the road No.24 is unpaved and narrow with one track on one side from the dam constructed near Hoa Binh up to Phu Yen.

The car-road network is very sparse in this survey area. There are six roads for vehicle transport through the northern part of this area. Four of them are the north-south direction and the rest east-west. The footpaths are developed with relatively high density along the major tributaries and on the ridges. Various sizes of motor boats are available in the villages along the dammed up Da River of 800 m wide to cross any parts of the River. Thereby the boats are useful for the survey along the River.

The Suoi Boc zone is located in the northwestern part of the area, and is about 4 km south-southeast of Phu Yen. There is one road for vehicle transport to the survey area from Phu Yen.

(2) Western Thanh Hoa Area

The area lies about 140 km to the southeast of the Van Yen Area. The central part of the area is about 130 km SSW as the crow flies from Hanoi. The area belongs to the Thanh Hoa and Nghe An provinces as administrative district. The route passing through Thanh Hoa is useful to approach the area. The distance is roughly 150 km from Hanoi to Thanh Hoa along the national road No.1 and it takes about four hours by car.

About two hours and half drive are needed to reach Bai Thuong, southeastern edge of the survey area, with the distance of about 45 km. The road No.1 is paved from Hanoi to Thanh Hoa, but most parts of the road are unpaved from Thanh Hoa to the survey area.

There are two roads for vehicle transport through the northern half of this area. They

are of the east-west direction. One is located in the northern part and the other in the central part of the area. However, those roads are made of red-soil and are narrow. Thus, travel is difficult with even light rain. The car-road network is not present within the southern half of the survey area. The footpath-network is also very sparse in the whole survey area. There is especially no footpath even along the principal rivers from the west-central to southwestern part of this area. It is necessary to use bamboo rafts to cross the Chu River in the south.

The Luong Son zone is located in the southeastern part of the area, and is about 10 km northwest of Thuong Xuan

2-2. Topography and Drainage Systems

(1) Van Yen Area

The area is situated within the steep mountains whose altitude ranges from 200 m to 1,400 m. The ridges generally run in parallel with the major geologic structures. Namely the ridges extend in the NW-SE, N-S, and WNW-ESE to E-W directions, respectively in the northeastern to southeastern, the southern, and the other parts of the area. Limestone beds occur in the central, northern, and southern parts of the area and the parts are characterized by the karst landforms. Nui Voi (altitude: 1,386 m) in the central part and Phu Gia Long (altitude: 1,349 m) in the southwest are the representative high peaks in the area.

The major drainage systems also flow in the NW-SE, N-S, and WNW-ESE to E-W directions parallel to the major faults. The tributaries flow into the main rivers from the north, south, northwest, and southwest. The largest river in this area is named the Da River whose origin is in China and it flows southeastward in the southern part of the area. A large dam for electric power generation has been constructed at Hoa Binh on this river. Thus, the river is about 1 km wide in the survey area, and many old small villages are now submerged. Other large rivers are the Toc, Be, and Bua Rivers.

(2) Western Thanh Hoa Area

There is a large topographic difference between two parts divided by an N-S trending major fault in the eastern part of the area. The western part has high relief with steep and high peaks ranging in the N-S direction. Representative peaks are Mt. Ginh (B) (altitude: 1,180 m), Mt. Cho (1,563 m), and Mt. Ta Leo (1,400 m). The eastern part, on the other hand, shows hilly landforms

that range in altitude from 100 m to 400 m. The karst topography is developed within the limestone area in the eastern edge of the area.

The NW-SE trending main rivers are controlled by the principal structure of the area and flow from northwest southeastward. They are the Ma, Chu, and Cao Rivers. The first two are several hundreds meters wide and the water flow is very large even in the dry season.

2-3. Climate and Vegetation

The whole of Vietnam belongs to the Asian monsoon climatic zone. Climate is similar for the Van Yen and Western Thanh Hoa Areas, since both areas are located in the humid, semi-tropical climatic region. The areas have two seasons, rainy (May to October) and dry (November to April). The precipitation is low during the dry season in these areas. There were three to four rainy days periodically within seven to ten days from November to December. Rainy days are frequent until the middle of October, but almost every day is fine from the beginning of November.

Hot days continue until the end of November with the temperature approaching 30°C. The temperature from December fluctuates from 20°C in the day time to below 10°C at night.

The climatic data have not been obtained for the survey areas concerned. The monthly data in Hanoi is listed in Table 1-4 for reference. The temperature and precipitation are respectively lower and higher in the mountainous survey areas than the data below.

Table 1-2 Monthly Meteorological Data in Hanoi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. Temperature (°C)	20.4	204	23.1	27.3	31.7	32.8	32.7	32.0	30.9	28.8	25.6	22.0
Min. Temperature (°C)	13.8	14.7	17.5	20.8	23.9	25.5	25.7	25.4	24.3	21.6	18.2	15.0
Ave. Temperature (°C)	16.6	17.1	19.9	23.5	27.1	28.7	28.8	28.3	27.2	24.6	21.2	17.9
Ave. Humidity (%)	80	84	88	87	83	83	83	85	85	85	81	81
Precipitation (mm)	18	26	48	81	194	236	302	323	262	123	47	20

(Japan External Trade Organization, 1990)

The areas of low altitude are covered by subtropical rain forest in both regional survey areas. Most of the mountainous parts, on the other hand, belong to the tropical high forest zone, and

generally are covered by the dense evergreen broad leaf and coniferous trees. Most of the lowlands have been cultivated for paddy rice because of much river water supply, and many places have also been cultivated for upland rice by the slash-and burn agriculture even on the steep mountain sides.

CHAPTER 3. GENERAL GEOLOGY AND MINERALIZATION

Comprehensive review of geology and mineral resources of Vietnam was carried out by Dang Trung Ngan et al.,(1981), GSV (1990), UNESCAP (1990), and GSV (1991).

These are excellent reference material for understanding the geologic conditions of the country. UNESCAP (1990) is based principally on a book titled "Geology and Mineral Resources of Viet Nam", issued by the General Department of Mines and Geology (GDMG) of Viet Nam in December 1988.

Although stratigraphy of each geologic province has been reported using representative stratigraphic names in GSV (1991), these names are not accepted in this report due to difficulty in specifying their type localities, but the symbols of the geologic units in the above report are adopted as a rule.

3-1. General Geology

The geology of the northern part of Vietnam is divided into four tectonic provinces bounded. They are the "Littoral Bacbo" and "Vietbac" provinces in the northeast and the "West Bacbo" and "Truongson" provinces in the southwest (GSV, 1991) as shown in the Figure 1-4. The Van Yen Area is located in southern end of the "West Bacbo" and the Western Thanh Hoa Area is situated in northern end of the "Truongson" province.

The "West Bacbo" tectonic province is in fault contact with the "Truongson" province. This is the Ma River fault trending in the NW-SE direction along the Ma River. The Paleozoic, Mesozoic, and Cenozoic strata are accumulated successively over the Proterozoic units in both provinces, but there are some geological differences (see Figures 1-5 and 1-6).

In and around the survey areas, the Proterozoic to Cambrian, Cambrian to Lower Ordovician, Lower to Middle Devonian, and Upper Permian to Upper Triassic strata are widely developed, and the Ordovician to Silurian, Upper Silurian to Lower Devonian, Upper Jurassic to Upper Cretaceous

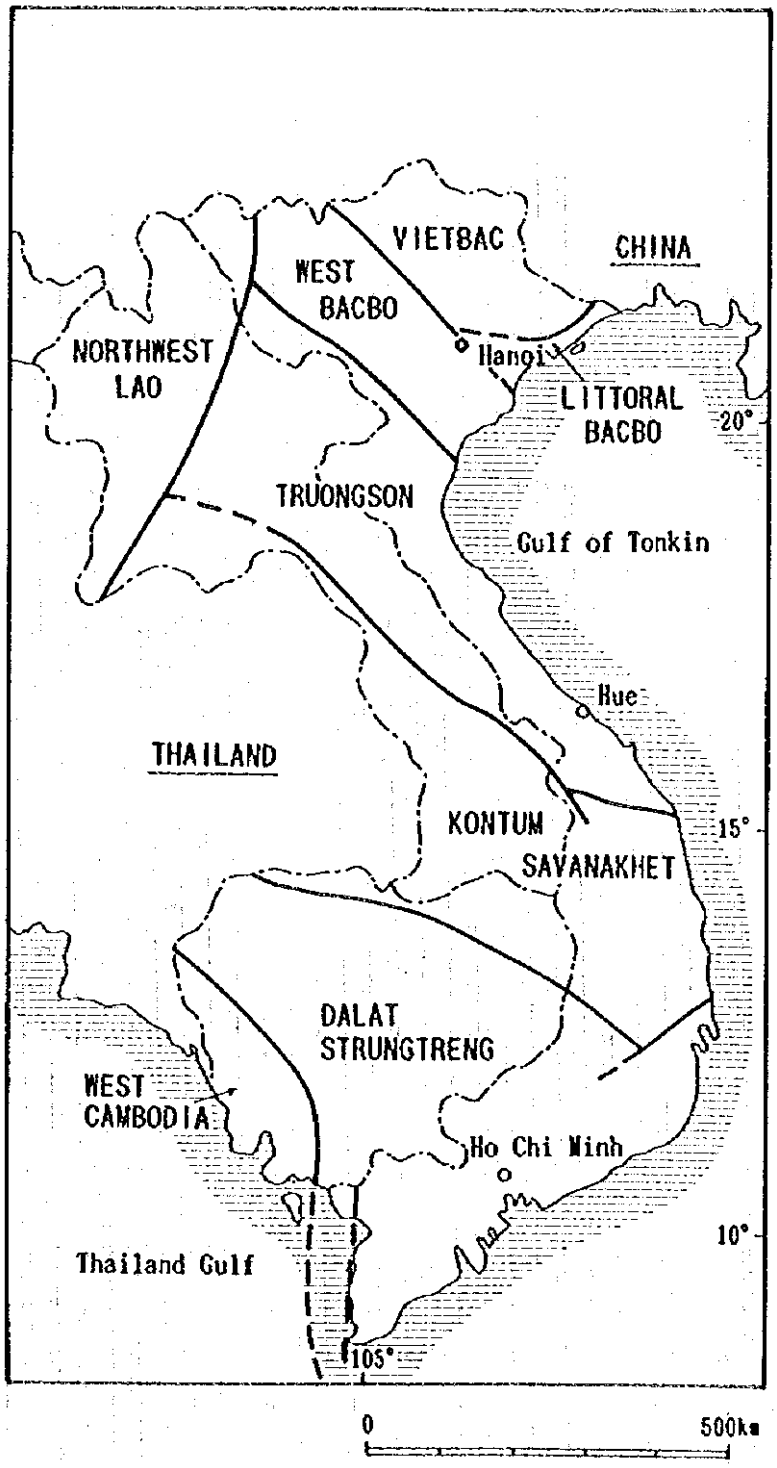
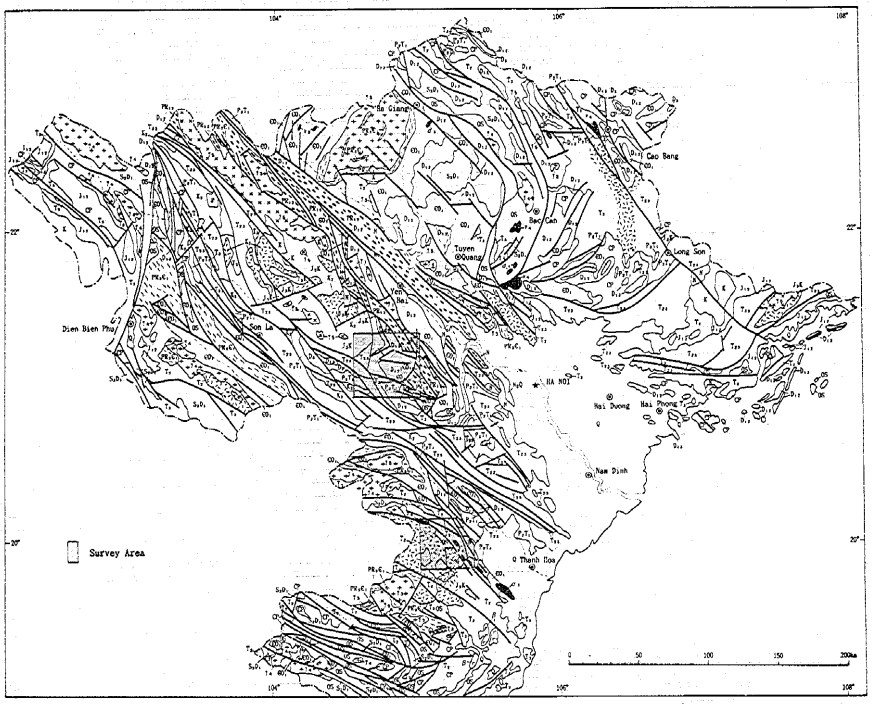


Fig. 1-4 Tectonic Provinces of Vietnam, Laos, and Cambodia



(Simplified from ESCAP, 1990)

LEGEND

STRATIFIED ROCKS

- Quaternary : Alluvium with marine deposits in coastal area, β : Basalt
- U. Neogene-Quaternary : Gravel, clay, pebble, laterite
- Neogene : Conglomerate, sandstone, claystone, lignite
- Paleogene : Trachyte, leucitophyre
- U. Cretaceous : Red continental deposits-conglomerate, sandstone, siltstone
- Cretaceous : Red continental deposits of conglomerate, sandstone, siltstone, rhyolite
- U. Jurassic-Cretaceous : Orthophyre, tuff, basalt, rhyolite
- L-M. Jurassic : Continental deposits of conglomerate, sandstone, siltstone
- U. Triassic : Conglomerate, sandstone, early shale, coal
- M-U. Triassic : Shale, limestone, conglomerate, sandstone, basalt, rhyolite
- M. Triassic : Conglomerate, sandstone, shale, limestone, rhyolite
- U. Permian-L. Triassic : Conglomerate, siltstone, siliceous limestone, shale, coal, basalt
- Carboniferous-Permian : Shale, coal, limestone, chert with andesite and basalt
- U. Devonian : Limestone, chert, shale
- L-M. Devonian : Conglomerate, sandstone, shale, limestone
- U. Silurian-L. Devonian : Sandstone, shale, limestone, rhyolite, chert
- Ordovician-Silurian : Conglomerate, sandstone, shale, chert, rhyolite, orthophyre
- Cambrian-L. Ordovician : Limestone, shale, quartzite, greenstone, chert
- U. Proterozoic-L. Cambrian : Schist, quartzite, dolomite
- L-M. Proterozoic : Gneiss, amphibolite, quartzite, marble

INTRUSIVE ROCKS

LATE MESOZOIC-EARLY CENOZOIC

- Granodiorite, granite, granosyenite, diorite

LATE PALEOZOIC-EARLY MESOZOIC

- Biotite granite, granophyre, granodiorite, diorite
- Gabbro
- Dunite, peridotite

EARLY-MIDDLE PALEOZOIC

- Biotite granite, plagiogranite, granodiorite, diorite
- Gabbro-diabase, gabbro
- Serpentinite, dunite

PROTEROZOIC

- Granodiorite, granite, migmatite
- Plagiogranite, granodiorite, granite, migmatite

Fault Felsic volcanics River

U: Upper M: Middle L: Lower

Fig. 1-5 Generalized Geologic Map in the Northern Part of Vietnam

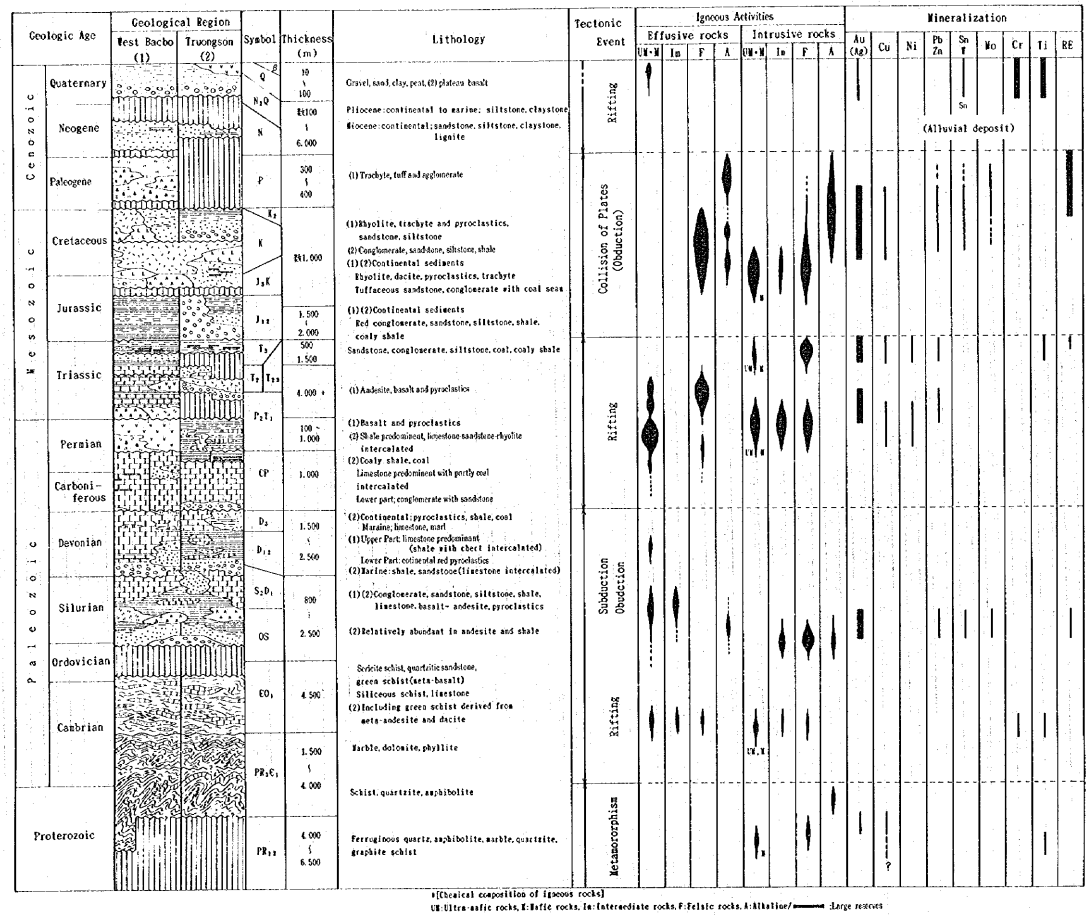


Fig. 1-6 Comprehensive Columnar Sections in the Northern Part of Vietnam

units are partly found. The Cenozoic formations with the exception of the Quaternary unit are restricted and sporadic.

The Proterozoic to Cambrian and Cambrian to Lower Ordovician units occur mainly on the right banks of the Da and Ma Rivers, and are composed of metamorphic rocks, namely crystalline schist, quartzite, and marble as well as limestone. The Lower to Middle Devonian are composed of terrestrial red clastic rocks and marine sedimentary rocks consisting mainly of shale and sandstone. They occur on the periphery of the Proterozoic to Cambrian and Cambrian to Lower Ordovician masses. The Upper Permian to Upper Triassic units occur most widely in the survey areas. They are composed mainly of sedimentary rocks, namely carbonate rocks, sandstone, and shale and occur partly with volcanic and pyroclastic rocks, such as andesite, basalt, and rhyolite. Felsic volcanic rocks judged to be the Jurassic to Cretaceous, also widely occur in the "Truongson" province in the south.

Intrusive magmatism in the northern part of Vietnam took place in four stages, namely, Proterozoic, Early to Middle Paleozoic, Late Paleozoic to Early Mesozoic, and Late Mesozoic to Early Cenozoic times (Figures 1-5 and 1-6).

In and around the survey areas, the Proterozoic intrusives intruded concordantly into the Proterozoic metamorphic rocks on the right bank of the Hong River. Besides, Early to Middle Paleozoic felsic rocks consisting of diorite and granite and Late Paleozoic to Early Mesozoic felsic rocks of the same nature as the above are located on the right bank of the Ma River ("Truongson" province) occurring as fairly large masses.

Ultramafic and mafic rocks are Early to Middle Paleozoic and Late Paleozoic to Early Mesozoic intrusive ones. They consist of dunite and gabbro and turn out generally in the shape of small lenticular bodies.

Although Late Mesozoic to Early Cenozoic intrusives are widely developed in the Tu Le region, the central part of the "West Bacbo" province, they are restricted in the southern part of the Western Thanh Hoa Area.

3-2. General Geologic Structure

Geologic structure of the northern part of Vietnam is complicated from repeated tectonic movements extending over long geological age. Every tectonic province, such as "West Bacbo", "Truongson" and others, is aligned in the NW-SE direction. Boundaries of tectonic provinces are the main tectonic lines that extend in the NW-SE direction along the Hong and Ma Rivers. Many

NW-SE faults parallel to the main tectonic lines exist in the tectonic provinces and control the occurrence of strata. Furthermore, intrusive rocks occur concordantly with the NW-SE structures.

The "West Bacbo" and "Truongson" provinces are situated at the contact of South China and Indochina plates. It is generally believed that the separation and joining of these two plates had been repeated during Paleozoic to Cenozoic times, but detailed tectonics is not verified yet. These plate movements were accompanied by the formation of rift zones, obduction zones, and subduction zones, as well as with sedimentation, NW-SE striking strata, and the formation of tectonic lines.

Structural control in the NW-SE direction is remarkable also in the survey areas. The wide spread Upper Permian to Upper Triassic units cover an area of 20 to 40 km wide elongated in the NW-SE direction. The Proterozoic to Cambrian and Lower Paleozoic units are also located in a horseshoe-shaped area elongated in the NW-SE direction. These strata used to contact with each other by NW-SE trending faults. Intrusives on the right bank of the Ma River are concordant with the NW-SE structures and small lenticular ultramafic to mafic intrusives also occur scattered along the NW-SE trending tectonic lines.

3-3. Mineralization

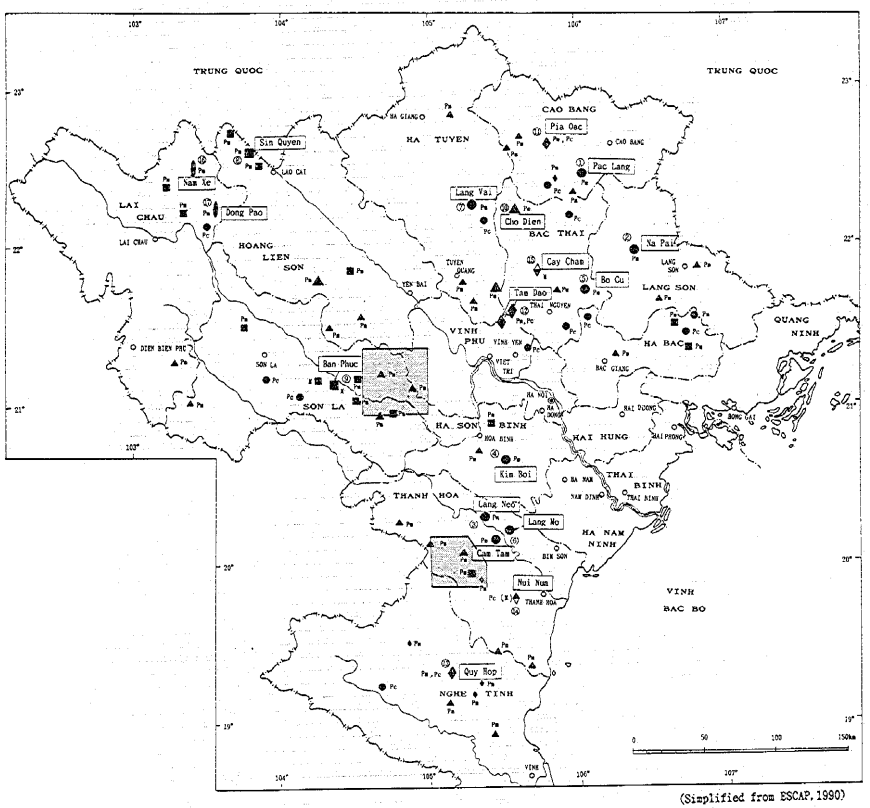
The long and eventful tectonic movements in Vietnam resulted in a variety in mineralization. Metallogenic epochs can be divided into the following five.

Precambrian epoch
Early to Middle Paleozoic epoch
Indosinian epoch (Late Carboniferous to Late Triassic)
Late Mesozoic to Early Cenozoic epoch (mainly Cretaceous to Paleogene)
Neogene to Quaternary epoch

Many useful mineral deposits and showings are located in the northern part of Vietnam as shown in Figure 1-5. Based on the UNESCAP (1990), several mineral deposits and showings of gold, copper-nickel, tin-tungsten, and placer chromite are revealed in and around the survey areas. Lead-zinc deposits and showings are also observed, but they seem to be small.

Known mineral deposits in and around the survey areas are summarized below.

As gold deposits, the Kim Boi deposit in the central part of the Ha Son Binh Province, and the Lang Neo, the Lang Mo, and Cam Tam deposits in the northern part of the Thanh Hoa Province are



(Simplified from ESCAP, 1990)

Metallic Mineral*

- Au (-Ag)
- Cu,Ni-Cu
- Pb-Zn
- Sn-W
- Cr
- Ti
- Rare -Earth

Genetic Type

- M : Magmatic
- Pm : Post-magmatic
- Pc : Placer

Others

- Pac Lang ① Name of deposit or mine with its number
- Boundary of Province
- Survey Area

*Smaller size -symbols may show occurrences of the minerals concerned. They have not been described in the text of ESCAP REPORT, 1990.

Fig. 1-7 Distribution Map of the Major Ore Deposits in the Northern Part of Vietnam

known. These are vein deposits emplaced in the Cambrian limestone, Late Permian and Early Triassic mafic volcanics and Triassic sediments. The Suoi Tiat mine is now under operation in the western part of the Van Yen Area as gold bearing copper deposit. Placer gold deposits are found in most of the streams in the mountains. These are rather small and not known in detail.

As a representative nickel-copper deposit, the Ban Phuc deposit is known in Ta Khoa region, Son La Province. This largest nickel-copper sulfide deposit in Vietnam is of vein and dissemination type accompanying ultramafic bodies of Permian to Triassic age. This deposit is located on the right bank of the Da River in the Da River Mobile Belt.

As tin-tungsten deposit, the Quy Hop deposit composed mainly of placer is known in the Nghe An Province. Also cassiterite-sulfide veins are found in crystalline schist in the vicinity. Tin-tungsten pneumatolytic to hydrothermal mineralization zones are developed in the Bu Me Prospect in the Western Thanh Hoa Area. This is now being explored by GSV.

As placer chromium deposit, one in Nui Nua region in the eastern part of Thanh Hoa Province is known. This deposit is situated around an Early to Middle Paleozoic ultramafic body and has been mined for a long time in large scale.

As lead-zinc deposit, the Cho Dien deposit in the Bac Thai Province is well known. In the survey areas, however, lead-zinc deposits are sporadically located, and details on dimensions and location are not known.

PART 2. VAN YEN AREA

PART 2. VAN YEN AREA

CHAPTER 1. REGIONAL GEOLOGICAL SURVEY

1-1. Introduction

The Van Yen area is located at 110 km west from Hanoi, and covers 2,000 km^2 in area. Regional geological and geochemical survey was conducted in this area from the first to second phase.

1-2. Geological Survey

1-2-1. Survey Method

Conventional field methods were used for geological survey. Topographic maps at a scale of 1:10,000 enlarged from the 1:50,000 published maps were used in the field and route mapping was carried out at this scale. Photogeological interpretation using aerial photographs was conducted for mapping in some areas without field reconnaissance as a supplement. Localities in the field were sometimes confirmed by means of GPS (global positioning system). Results of the geological survey were compiled on geological map at a scale of 1:50,000.

Schematic columnar section and geologic map are shown in Fig. 2-1 and 2-2, respectively.

1-2-2. Stratigraphy

This survey area belongs to the "West Bacbo" tectonic province. This province is a mobile belt lying between the South China Plate to the north and the Indochina Plate to the south, and is called the "Da River Mobile Belt". This belt is a submerged zone which was produced by the separation of the above two plates during the Indosinian stages (from the Late Carboniferous to Late Triassic). The igneous activities occurred along the submerged zone, and their chemical composition ranges from ultramafic to felsic.

This area is underlain chiefly by the Proterozoic metamorphic basement and the overlying Paleozoic and Mesozoic sedimentary (partly metamorphic) and pyroclastic rocks. The Proterozoic rocks consist mainly of gneisses and occur in the northeastern and southeastern parts of this area. The Paleozoic strata occur in the whole of the survey area, and consist of Cambrian to Permian marine sediments represented mainly by limestone, sandstone, and mudstone. The Mesozoic is composed of Triassic pyroclastic and sedimentary rocks.

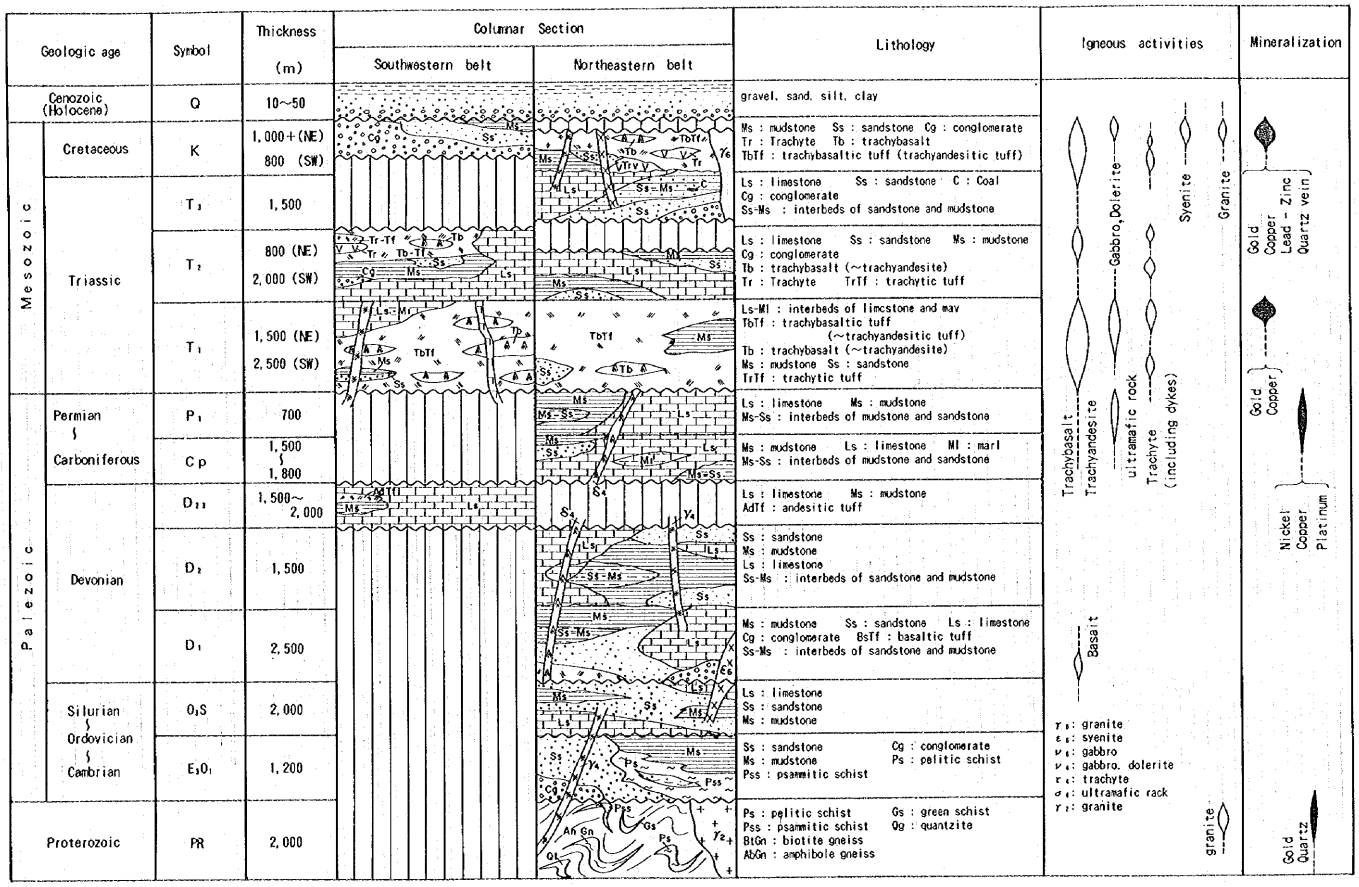


Fig. 2-1 Schematic Columnar Sections of the Van Yen Area

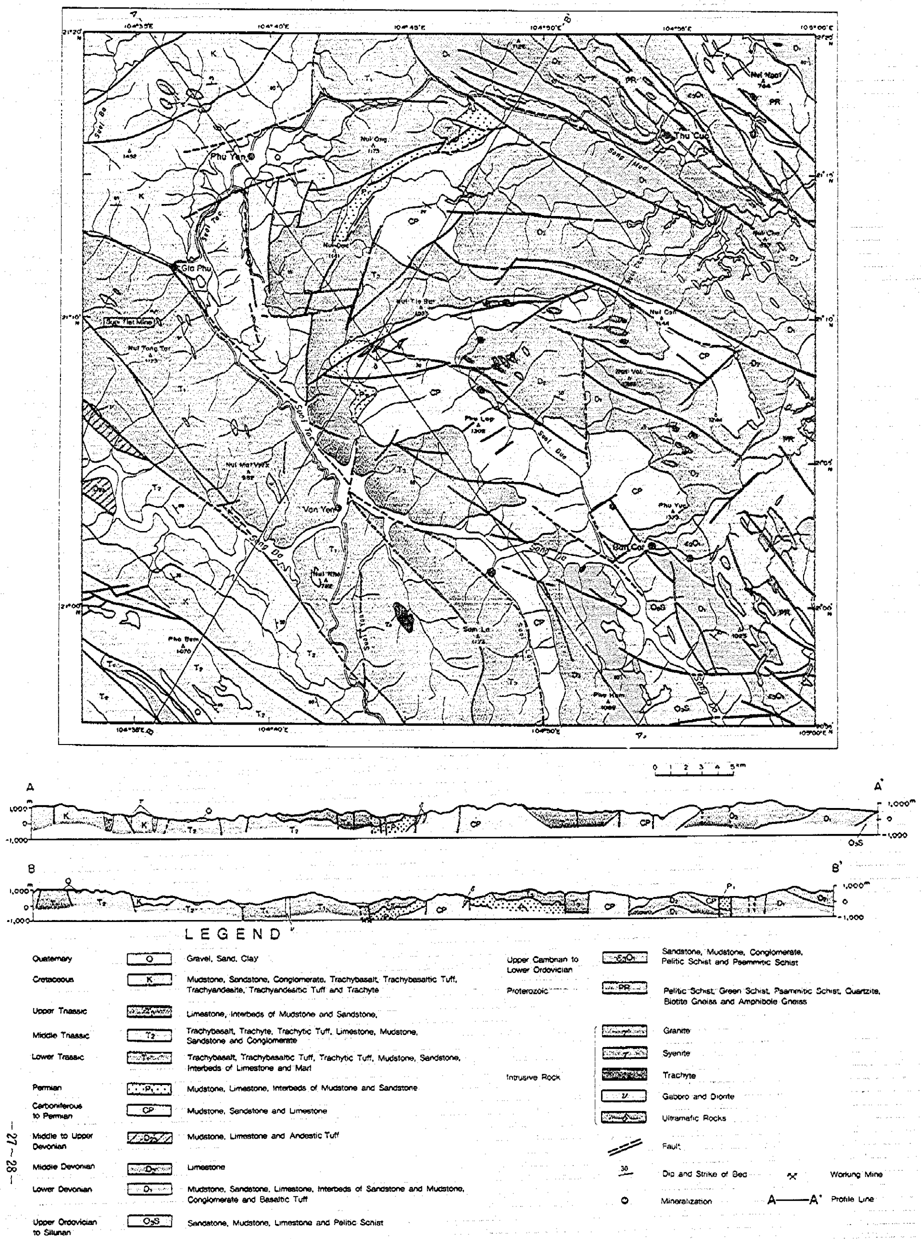


Fig. 2-2 Geologic Map and Cross Sections of the Van Yen Area

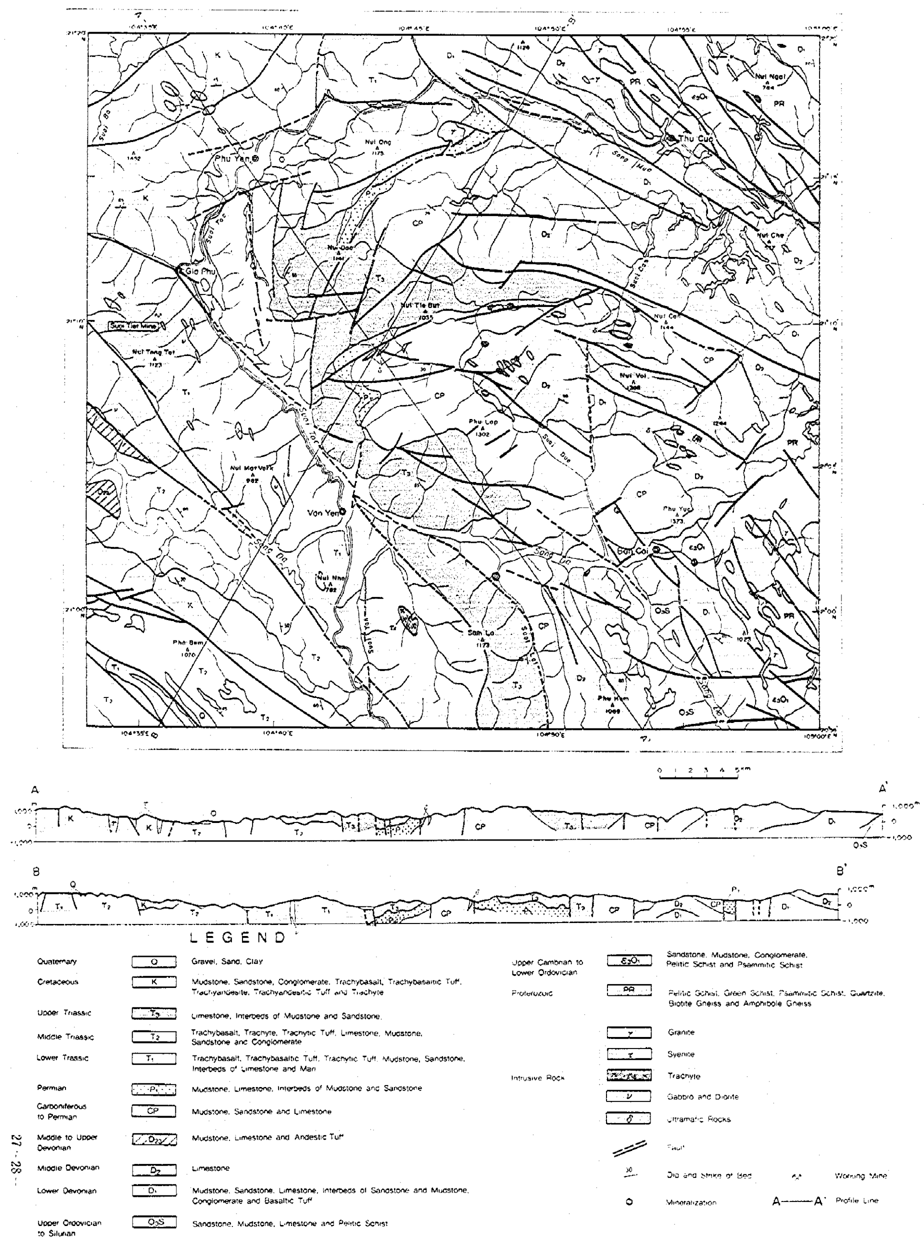


Fig. 2-2 Geologic Map and Cross Sections of the Van Yen Area

Large intrusive masses have not been found in this area, but granitic rocks and small bodies of gabbroic rocks occur mainly in the Proterozoic area. Numerous ultramafic bodies also intruded in the Middle Devonian of the eastern part of the survey area. Small gabbroic rocks and various alkaline rocks are found in the Lower Triassic.

The detailed lithology of geologic units are divided into "Group", "System" and "Series", since the objective of the regional geological survey is not to pursue the detailed lithology in this area.

Numerous NW-SE striking faults are developed in the vicinity of two rivers, namely the Bua and Toc Rivers which flow southeastward in the western part of this area. These faults provide important control for the geologic structure of this area. This fault zone is provisionally called the "Toc River Fault Zone". A large difference was recognized regarding the distribution pattern of intrusive rocks and geologic structure between the southwest and northeast of this fault zone. The schematic columnar sections are, therefore, separately prepared for the "Southwestern belt" and "Northeastern belt".

(1) Proterozoic Group

This Group occurs in the northeastern and southeastern ends of this area and comprises the basement of the area. The Group generally trends in the NW-SE direction with 2 km and 5 km width in the northeast end and more than 10 km in the southeast end.

The Group is mainly made up of gray coarse-grained biotite gneiss with partly intercalated amphibole gneiss, green schist, pelitic schist, psammitic schist, and quartzite. The gneisses show migmatic lithofacies in some parts and mylonitic facies are also found near faults.

The biotite gneiss represents conspicuous gneissic structure, and cataclastic texture is partly observed under microscope. The gneiss consists of abundant plagioclase and subordinate amounts of quartz and biotite as major constituent minerals.

The Group is estimated to be 2,000 m thick in this area.

(2) Upper Cambrian to Lower Ordovician Series

This Series occurs as three blocks separately in the northeastern part (one block) and the southeastern part (2 blocks) of the survey area. All blocks trend in the NW-SE direction with 2 to 4 km width. These blocks are present in the vicinity of the Proterozoic Group and unconformably overlie the Group in most parts.

The major part of the Series in the northeast is made up of dark gray phyllitic mudstone, and a few strata of the lower part are metamorphosed into pelitic schist. The northern block of the southeastern part consists mostly of light purple to dark purple coarse-grained sandstone locally with conglomerate of the same rock type. Abundant potash feldspars are found in the matrix of the sandstone, and pebbles in the conglomerate are quartzite and green rock with 1 to 4 cm in diameter. The southern block, on the other hand, comprises interbeds of pelitic schist, gray siliceous fine-grained sandstone, and gray psammitic schist.

The thickness of this Series is estimated to be 1,200 m in the survey area.

(3) Upper Ordovician Series to Silurian System

This geologic unit is present only in the southern part of the survey area (on both banks of the Da River). The unit roughly trends in the NW-SE direction with 4 to 7 km width. The major part of the unit is made up of gray hard compact siliceous sandstone, and its grain size varies from fine to coarse. Some horizons of the lower and upper parts are dominated by gray siliceous limestone beds, and black phyllitic mudstone is intercalated in the middle part.

This unit is estimated to be 2,000 m thick in the survey area.

(4) Lower Devonian Series

This Series occurs separately in the northern, central, and southern parts of the survey area. The Series extends in the WNW-ESE to E-W and NW-SE to NNW-SSE directions in the north and south, respectively. The extending direction in the central part is not clear. The widths are 4 to 5 km, 1 to 2 km, and 2 to 3 km (2 belts) in the northern, central, and southern parts, respectively.

The major parts of the northern and central parts are made up of gray to light gray fine- to medium-grained sandstone. The middle to upper part of these blocks becomes dominant in black to dark gray phyllitic mudstone and contains some interbeds of sandstone and mudstone. The southeastern block is dominated by gray limestone whose bedding is developed with intervals of about one meter. Moreover, brownish gray basalt and it's (partly andesitic) lapilli tuff and tuff breccia are intercalated in small areas of this Series located in the east-central and southern parts.

The estimated thickness of the Series in the area is 2,500 m.

(5) Middle Devonian Series

This Series occupies very wide parts of the survey area such as the northern, central, and southern (the mountains in the right bank of the Da River) parts, and unconformably overlies all

underlying geologic units except the Lower Devonian. This Series forms very steep folded mountains together with the Lower Devonian Series and Carboniferous to Permian System. The extending directions differ from part by part, and the Series has NW-SE, E-W, and N-S trends in the northern, central, and southern parts, respectively. The widths are 2 to 3 km, 2 to 5 km, and 2 to 3 km in the northern, central, and southern parts, respectively.

The major part of the Series consists of black to dark gray phyllitic mudstone. Gray massive limestone is found in the northern basal part and it overlies the Proterozoic Group. The lower and upper horizons of the central parts are dominated by gray to light gray fine-grained sandstone, and the middle horizon consists of interbeds of fine-grained sandstone and mudstone with intervals several centimeters apart. The Series in the southeastern part is composed of limestone and sandstone.

This Series is estimated to be 1,500 m thick in the survey area.

(6) Middle to Upper Devonian Series

This Series is found in the western edge of the survey area as two separate blocks on both banks of the Da River. These two blocks trend in the NW-SE direction with 1 to 2 km width. They occur within the wide Middle Triassic Series area and are in fault contact with the Middle Triassic rocks.

The block on the right bank of the river consists of almost massive dark gray limestone. On the other hand, the above limestone intercalates the beds of black mudstone and green andesitic tuff in the block on the left bank of the river.

The Series is estimated to be more than 1,500 m thick.

(7) Carboniferous to Permian System

This System occurs in northerly central, central, to southern parts of the area. The System unconformably overlies the Middle Devonian Series and occupies the zone around the Series. The major parts of the System extend generally in the E-W to WNW-ESE direction. On the contrary, it has the N-S trend in the right bank of the Da River in the south. Although the average width is 2 km, it attains 6 km in a wider part with a fault.

The System is composed generally of gray to dark gray massive fine-grained limestone and tower karsts are formed in many places.

The lowermost of this System in the northerly central part con sists of interbeds of black mudstone and gray fine-grained sandstone, and thin beds of black stratified chert.

Gray fine-grained sandstone and sandy mudstone are intercalated in this Series of the southern

part.

The estimated thickness of the Series in the area is 1,800 m.

(8) Lower Permian Series

This Series overlies as a small area in the northern edge and central part of the survey area in unconformity or fault contact with the Carboniferous to Permian System. The width of this Series ranges from 1 to 2 km width.

This Series in the northern edge is composed of interfingers with massive limestone and black mudstone.

The Series in the central part of the area consists as a whole of dark gray massive limestone, gray fine-grained sandstone and phyllitic mudstone.

The estimated thickness of the Series in the area is 700 m.

(9) Lower Triassic Series

This Series occurs separately in the northern, central to southern, and southwestern parts of the survey area. Since the distribution, structural trends, and lithology differ from one another in the above three parts, the geological characteristics of each part are described separately below.

Northern part

This Series extends in the E-W direction and is 9 km wide. The Series conformably overlies the Middle Triassic Series in many places, and occurs in fault contact with the Cretaceous System.

The Series consists mostly of dark green to dark bluish green trachybasaltic (to trachyandesitic) fine tuff in this part. The fine tuff is interbedded with gray medium- to fine-grained sandstone in the lower part, and with dark green trackybasaltic (to trachyandesitic) lavas as well as trachytic lavas in the middle part. Moreover, the fine tuff also contains some intercalated beds of black phyllitic mudstone.

This Series is estimated to be 1,500 m thick in this part.

Central to southern part

The Series is present on the west side of the "Toc River Fault Zone" and extends constantly in the NW-SE direction. The width ranges from 7 to 10 km and it continues from the northwestern edge to the southeastern edge of the survey area. Numerous tributaries flow into the Da or Toc

River perpendicularly to the watershed, and a typical trellis drainage pattern is developed. This Series lies in fault contacts with all adjacent geologic units.

The Series is composed mostly of dark green to green trachybasaltic (to trachyandesitic) fine tuff similar to the lithofacies in the northern part. The tuff is interbedded with trachybasalt (to trachyandesite) lavas as well as trachyte lavas in many places. The tuff contains trachytic tuff in the lowest part with intercalated beds of fine-grained sandstone and mudstone. However, the sandstone and mudstone are very subordinate in amount.

This Series was subjected to intense and extensive lateral compressional stress after its deposition. This stress resulted in fissile occurrence in most parts of the fine tuff, and the tuff seems to be green schist. The fissile plane is slightly oblique to the bedding of the original rock and is considered to be a kind of schistosity.

This Series is estimated to be 1,500 m thick in this part.

Southwestern part

This Series occurs isolated within the area of the Middle Triassic Series, extending in the NW-SE direction with 1 to 1.5 km width. This unit is bounded by units of the Middle Triassic through NW-SE trending faults on both sides.

This Series is generally made up of alternating beds of dark gray bedded limestone and black brittle marl, and is stratigraphically correlated with the upper part of the Lower Triassic (GSV, 1969). Kink and minor folds are observed in the limestone and they indicate that the rocks were subjected to intense deformation.

The apparent thickness of this Series is calculated from the exposed rocks to exceed 1,000 m in this part.

(10) Middle Triassic Series

This Series occurs separately in the "Northeastern belt" and the "Southwestern belt" as mentioned in the beginning of this chapter.

The Series in the "Northeastern belt" is distributed near Phu Yen and further to the south. It apparently occurs extended in the N-S direction. It ranges in width from 5 to 8 km. The overlying Upper Triassic Series and Cretaceous System unconformably cover this Series or they are in fault contact with it.

This Series consists mostly of dark gray massive limestone and is accompanied by very subordinate amounts of sandstone and mudstone in the lower and upper parts. The thickness of this

Series is 800 m in this belt.

The Series in the "Southwestern belt" covers most of the area southwest of the Lower Triassic area in the southwestern part of the survey area. This Series is divided into three separate parallel zones by the Middle to Upper Devonian Series, the Lower Triassic Series, and Cretaceous System in this belt. All of three zones of this Series extends continuously in the NW-SE direction. The relationship between the Cretaceous and this Series is unconformity or fault contact. With the Middle to Upper Devinian and Lower Triassic, this Series lies in fault contact. The above three zones are tentatively called the A, B, and C zones from the northeast southwestward for descriptive convenience.

There are differences in lithology and constituent rocks between the northwestern subzone (on both banks of the Da River) and southeastern subzone of the above A zone.

That is, in the former subzone black mudstone is dominant in the lower part. The upper part consists mainly of dark green trachybasaltic (to trachyandesitic) fine tuff with occasional thin beds of conglomerate, sandstone, trachyte and its tuff.

In the latter subzone, on the other hand, alternating beds of black mudstone and gray fine-grained sandstone are dominant in the lower part. Dark gray massive limestone is well developed in the upper part.

This Series of the A zone is estimated to be about 1,000 m thick.

The B and C zones of this Series are composed mostly of dark gray bedded limestone with very subordinate amounts of fine-grained sandstone and mudstone. The rocks of this Series in these two zones are stratigraphically correlated with the lower part of the Middle Triassic Series T2, together with the Series in the "Northeastern belt" mentioned above (GSV, 1969). The total thickness of this Series in these two zones is estimated to be about 1,000 m.

(11) Upper Triassic Series

This Series occurs separately in the central and southern parts of the area and is in unconformable or fault contact with the underlying Carboniferous to Permian System and Lower Triassic Series.

The Series consists of sandstone, mudstone and limestone. The main part of the Series is composed of interbeds of dark gray to gray fine-grained sandstone and black phyllitic mudstone.

Reddish sandstone occurs in the central part of the area with intercalation of coal seams.

Massive limestone predominates in the southern part.

The Series is estimated to be 1,500 m thick in the survey area.

(12) Cretaceous System

This System is distributed widely in the northwestern part and is also present in the southwestern part of the survey area.

Northwestern part

The System in this part extends largely in the NW-SE direction. From this viewpoint, the width of the strata is about 20 km in the survey area. The System lies in fault contact with the Lower Triassic Series, and has unconformable relationship or fault contacts with the Middle Triassic Series.

This System in this part is composed mainly of dark green well bedded trachybasaltic (to trachyandesitic) fine tuff and is partly accompanied by their lavas and trachyte lava. Black mudstone, gray fine-grained sandstone, and trachyte lava are developed in the lower part.

The thickness of this System is considered to exceed 1,000 m in this part.

Southwestern part

The System in this part is distributed in NW-SE trend. The distributional width ranges from 1 to 3 km. This System lies in fault contact with the Middle Triassic Series on the southwest and unconformably overlies the underlying Middle Triassic Series on the northeast.

The major part of this System is made up of gray to red, occasionally bedded conglomerate. The conglomerate has a red medium to coarse-grained sandy matrix, and contains pebble to cobble-sized (5 to 20 cm in diameter) limestone, sandstone, and mudstone. These fragments are rounded to subangular. Red fine-grained sandstone and black mudstone are occasionally recognized within the upper horizon. It is considered that the System of this part is stratigraphically situated higher than the System of the northwestern part (GSV, 1969).

(13) Quaternary System

The Quaternary System in this area is composed of fan sediments, recent fluviatile sediments and others which correspond to the Holocene alluvium. The sediments consist of gravel, sand, silt, and clay.

1-2-3. Intrusive Rocks

Abundant intrusive bodies formed by igneous activities during Proterozoic and Permian to Cretaceous times occur in this survey area. The lithology of these rocks is divided into several types such as granitic, ultramafic to mafic, alkali felsic rocks. Generally the rock bodies are of small dimensions. Their lithology will be described below in the order of intrusion (GSV,1991).

(1) Proterozoic granitic rocks

The granitic rocks intruded into the Proterozoic in the northeastern and southeastern parts of the area. The intrusive bodies range in width from 200 to 500 m with the maximum length of 4 km and more.

Generally the rocks are light pink to light pinkish gray medium-grained biotite granites and major trend of intrusion is NW-SE. Weak gneissic structures are partly observed and some rocks represent tonalitic lithofacies. Microscopic studies reveal that crystals of potash feldspar, plagioclase, quarts, and small amounts of biotite form holocrystalline equigranular texture.

(2) Permian ultramafic rocks

The ultramafic rocks intruded in the form of sheet and dike into mostly sedimentary rocks of the Middle Devonian Series and Carboniferous to Permian System in the central part of the area.

The bodies range in width from 20 to 200 m with the maximum length of 1.3 km.

Generally the rocks are black to dark green compact peridotites and major trend of intrusion is E-W to WNW-ESE. Microscopic studies reveal that crystals of olivine, clinopyroxene, and plagioclase form granoblastic texture and the olivine is often replaced by serpentine.

(3) Early Triassic gabbro and dolerite

Most of these intrusive rocks are sporadically scattered in the whole survey area except for the southwestern Paleozoic and Mesozoic areas. Generally the rock bodies are exposed in small dimensions and intrude as dikes. The trend of intrusion is NW-SE to WNW-ESE, and it coincides with the strike of intruded rocks. The rock bodies are several meters wide with a maximum of 300 m, and range in length from several hundreds meters to 1.0 km.

These rocks are divided lithologically into two types : dark green gabbro (to metagabbro) and dolerite (to metadolerite). In general the former is more abundant than the latter. Microscopic studies reveal that both types show ophitic texture and consist mainly of clinopyroxene and

plagioclase, with occasional accessory hornblende and actinolite.

(4) Early Triassic trachyte dikes

The dikes occur only in the Lower Triassic Series on the west of the "Toc River Fault Zone". All dikes extend in the NW-SE direction that coincides with the strikes of the Lower Triassic tuffs. Most of the dikes are several to 20 m wide and 500 to 1,000 m long. The density of distribution differs from part to part. It is higher in the vicinity of the Suoi Tiat mine located in northwestern part and along the Toc River Fault Zone near Van Yen than in other parts.

The dikes can be divided lithologically into gray to light gray trachyte and leucocratic quartz-bearing trachyte. These two are relatively concentrated near Van Yen and in the vicinity of the Suoi Tiat mine, respectively. Both types show trachytic texture with considerable amounts of potash feldspars in groundmass under microscope. When phenocrysts are present, they consist also of potash feldspars.

(5) Cretaceous granite

Only one granite body was recognized within the area of the Lower Triassic Series in the northeastern edge of this area. It seems that the body extends outside the survey area, thus the dimension is estimated to be 1 to 2 km in diameter.

The rock is white medium- to coarse-grained holocrystalline equigranular biotite granite.

(6) Cretaceous syenite

Syenite bodies intruded into the Cretaceous and the Lower Triassic in the northwestern part, the Lower Triassic in the western part, and the Upper Ordovician to Silurian and Lower Devonian in the southern part of this area.

This rock is generally pink and porphyritic. Microscopic studies reveal that the texture is holocrystalline porphyritic and both groundmass and phenocrysts consist of a large amount of potash feldspars.

(7) Cretaceous gabbro

Two gabbroic bodies have intruded into trachybasalt lava and mudstone of the Cretaceous in the northwestern part of the survey area. Both are 20 to 30 m wide small dikes. In the altered alkali gabbro body near the ENE-WSW trending fault, potash feldspars, clinopyroxene, alkali amphibole as well as the secondary biotite are recognized microscopically. The another body has also been

altered and the alteration minerals include a large quantity of epidote and actinolite.

1-2-4. Geologic Structure

(1) Folds

The formation of rifts during the Indosinian stages and subsequent collision of plates took place in and around this area. Thus, it is said that the area was subjected to intense and complex tectonic movements. As a result of the movements, the beds have enormously steep dip in the most parts of this area. Therefore, the overall and detailed features of foldings are very difficult to discern.

The available geologic map and sections were referred for the parts with poor field data, and the characteristics of folds in each geologic unit are summarized as follows (excluding the P1 and T1 Series).

1) Proterozoic Group

Gneisses and schists of this Group generally have a constant strike of NW-SE direction and steep dips of more than 60°. The metamorphic rocks show extremely complicated structure affected by several diastrophic disturbances. The Group consists of a series of NW-SE trending anticline and syncline with about 500 m wavelength, and those folds are believed to form large anticlinoriums both in the northeastern and southeastern parts of the area.

2) Upper Cambrian to Lower Ordovician Series

This Series consists of a series of NW-SE trending folds with 0.5 to 1 km wavelength, and those folds as a whole are considered to form anticlinoriums in both parts.

3) Upper Ordovician Series to Silurian System

The strata generally strike NW-SE to NNW-SSE and have steep dips. The northern part of this unit consists of a series of NNW-SSE trending folds with about 3 km wavelength, and those folds form a large anticlinorium. On the contrary, geologic structure is not clear in the southern part of this unit. Nevertheless the unit of this part is inferred to form a synclinorium by a series of folds with about 1 km wavelength.

4) Lower Devonian Series

This Series generally strikes WNW-ESE to E-W in the northern part, but the strike changes to NW-SE in the southeastern part of the area. Most of the strata steeply dip more than 50°. A large anticlinorium is formed by a series of WNW-ESE to E-W trending folds with about 1.5 km wavelength in the northern part, and it plunges to the west. In the southeastern part of the area the Series consists of NW-SE trending folds with about 2 km wavelength, but it is not clear whether those folds form an anticlinorium or a synclinorium because this Series is confined to small areas.

5) Middle Devonian Series

This Series generally strikes WNW-ESE in the northern edge, and E-W in the northern to central part of the survey area. The strata steeply dip more than 50°. The Series forms a syncline with about 3 km wavelength in the northern edge. On the contrary, in the northern to central part of the area the Series consists of a series of folds with 1.0 to 2.5 km wavelength, and those folds form two large anticlinoriums together with the underlying Lower Devonian Series. Both of them plunge to the west.

6) Carboniferous to Permian System, Lower Permian and Upper Triassic Series

These geologic units occur surrounding the Middle Devonian Series, and have folds similar to the Series in the northern to central part of the survey area. The wavelength of individual folds is estimated to be 3 to 4 km.

7) Lower Triassic Series

Northern belt of the area

This geologic unit generally strikes E-W, but the strike changes to N-S in the western zone of the unit. The central zone of the unit formes an E-W trending anticlinorium with about 2 km wavelength. The folds in both northern and southwestern parts of the unit ranges in wavelength from 700 to 1,000 m, forming a synclinorium and an anticlinorium, respectively. It is considered that fractures are developed along the axial planes of folds in both parts. The folds plunge to the west in the southwestern part of the unit.

Southwestern belt

The bedding planes or schistosities of this Series have a constant strike of NW-SE direction to the southwest of the "Toc River Fault Zone". Whereas the direction of dips varies irregularly to both NE and SW, and most of the beds dip steeply more than 60°. A large number of small parallel NW-SE striking faults are concentrated in the vicinity of Van Yen. Complicated medium-size folds also are observed in some outcrops. On the whole, most of the Upper Triassic strata on the northeastern side generally dip SW while those on the southwestern side dip NE. From the above, it is pointed out that the Upper Triassic of this part comprises a series of NW-SE trending anticline and syncline with 500 to 800 m wavelength, and the folds form a synclinorium. It is inferred that cleavages have been developed along most of the axial planes of the folds and the cleavages became fracture zones by the deformation caused by intense lateral compression.

This unit in the southwestern part, on the other hand, has a monotonous structure, striking generally NW-SE and dipping 30 to 60° NE.

8) Middle Triassic Series

Most of the limestone in the northwestern part largely strikes N-S. The exposed rocks form an N-S trending anticlinorium with about 1 km wavelength. The folds plunge both to the north and south.

This geologic unit in the "Southwestern belt" has a roughly constant strike of NW-SE direction. The direction of dip is usually NE, but SW dip is also present, varying in magnitude from 30 to 80°. Thus, the folds extend in NW-SE direction with varying wavelength from 500 up to 2,000 m.

9) Cretaceous System

This geologic unit generally strikes E-W to the northwest of Gia Phu. To the west and north of Phu Yen, most of the beds strike NW-SE. The strata as a whole steeply dip exceeding 60°. It is believed that the unit in this area comprises a repetition of NW-SE trending anticline and syncline with 800 or 1,500 m wavelength. It seems that these folds form a large synclinorium as a whole.

(2) Faults

There are four systems of faults in this area. They are NW-SE, WNW-ESE to E-W, N-S, and NE-SW systems. These faults occur in a complex pattern and the order of formation on those fault systems is not clear. With regard to the structural trend of the strata, there are two kinds of faults.

That is, one is concordant with the general trend of rocks of each geologic unit, and the other is oblique to the trend. Most of the faults in this survey area are in concordance with the general trend of rocks. The lengths of the faults vary considerably, ranging from 3 to more than 20 km. Relatively large vertical displacement has been calculated to be more than 2,000 m.

1-2-5. Mineralization

Gold, copper, lead, zinc and other deposits and mineral showings have been found in this survey area (Figure 2-3). These mineralized zones are grouped through their locations and host rocks as follows.

(1) Mineralized zones in the Cretaceous System at the northwest
(2) Mineralized zones in the Middle Triassic Series at the northwest
(3) Mineralized zones in the Lower Triassic Series at the west
(4) Mineralized zones in the Middle Triassic Series at the southwest
(5) Mineralized zones in the area of dolerite at the central part
(6) Mineralized zones in the Middle Devonian Series at the east

Quartz veins and pyrite dissemination are found in addition to above mineralized zones, but assay results show that ecomical metals don't occur.

Abundant small ultramafic bodies intruded into a wide area from the western to eastern part of this survey area. Mineralization of platinum, copper and nickel has been confirmed by GSV within 5 bodies located in the western and eastern parts of the area. The mineralization is characterized by the dissemination of very small metallic-mineral grains in ultramafic bodies. The maximum platinum content is 40 ppb, and this revealed that the platinum mineralization is weak as far as collected samples are concerned.

(1) Mineralized zones in the Cretaceous System at the northwest

These mineralized zones are composed of veins, bedded cupriferous pyrite deposits and floats of galena bearing ore in the Cretaceous sedimentary and pyroclastic rocks.

1-a) Ban Cho mineral showing

There are no outcrops but floats in this showing. One sample was collected from floats at the uppermost tributary of the upper reaches of the Kan Stream in the northwestern part of the survey area.

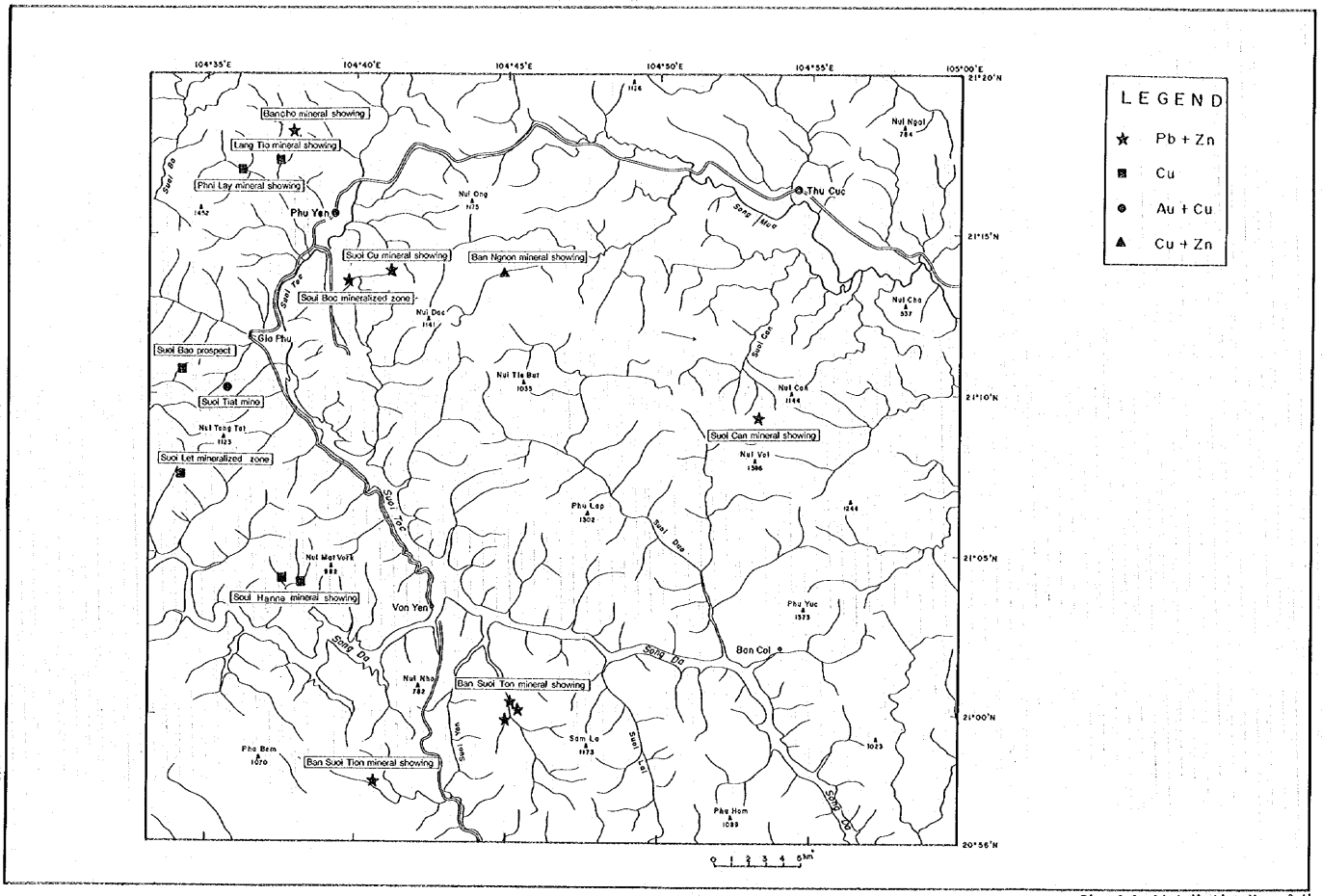


Fig. 2-3 Distribution Map of the Mineralized Zones in the Van Yen Area

There are a few floats of cobble size. The floats contain veins of galena, sphalerite, and quartz. The host rock appears to be Cretaceous muddy tuff from the floats.

The assay result of a sample shows 34.5% Pb.

1-b) Lang Tio mineral showing

This showing is located in the middle reaches of the Kan Stream in the northwestern part of the survey area. One quartz vein occurs in this locality. The vein strikes N40°E and dips 50°NE with 1.50 m width. The quartz vein contains small amounts of chalcopyrite and specularite. The host rock is the Cretaceous sandstone.

The highest assay result of the samples collected is 1.65% Cu.

1-c) Phai Lay mineral showing

This showing is located on the right bank of the middle reaches of the Lang River in the northwestern part of the survey area. Several lenticular ore bodies are developed in this showing. All bodies occur parallel to the schistosities of the Cretaceous trachybasaltic tuff, but host rocks are separated into several blocks near the surface.

Each ore body is 0.1 to 0.3 m wide and 1 to over 3 m long. Ore minerals are pyrite and chalcopyrite, and gangue mineral is translucent massive quartz.

The assay results of the ore samples range from 0.04 to 0.88% Cu.

(2) Mineralized zones in the Middle Triassic Series at the northwest

These mineralized zones comprise bedded cupriferous pyrite deposits and veins.

2-a) Suoi Tiat mine

The mine is located at the upper reaches of the Tiat Stream, a tributary of the Bua River in the western part of the survey area. Local inhabitants work for in the small-scale production. The monthly production is said to be about 100 g Au.

The ore body is concordant with the well-developed schistosities of the trachybasaltic tuff.

The ore body consists of the parallel assembly of banded ores with 1 to 5 cm width, and these ores are interbedded with chloritized host rocks.

The unit ore body is 10 m long with 0.05 to 0.50 m width, and several similar bodies occur in parallel pattern.

Several ore bodies of 0.05 to 0.50 m width are developed in parallel arrangement within a zone of 200 m with a maximum width. No data is available for number, extensions along the strike and dip.

The principal ore minerals are pyrite and chalcopyrite, and they are accompanied by a small amount of malachite as well as a trace amount of native gold, galena, covelline, bithmuthinite, and monazite. Gold grains of 25 micron in diameter occur in cavities of euhedral crystals of pyrite. The main gangue minerals are translucent to colorless massive quartz and chlorite with a trace amount of barite. Gangue minerals are less abundant than ore minerals.

Chloritization is the only host rock alteration recognized in this deposit. Calcite, dolomite, and muscovite were detected by X-ray diffraction in a host rock sample from the ore body.

Contents of gold and copper are 0.2 to 6 g/t and 1 to 6 %, respectively.

2-b) Suoi Bao Prospect

This prospect is located about 2.5 km west of the Suoi Tiat mine. The prospect consists predominantly of a wide quartz vein. Two drifts were driven with about 10 m level difference, but the details such as extensions are unknown because both drifts are flooded at present. It is inferred that both drifts are several meters long from the amounts of waste on the dumps. These two veins are more than 2.4 m and 1 m wide in the lower and upper drifts, respectively. The two drifts most probably were prepared for one vein in view of the strike. No other vein occurs in the vicinity of the vein.

The quartz vein contains a very small amount of chalcopyrite, pyrite, and specularite in a scattered occurrence, and malachite is observed along the fractures of the vein. The quartz is translucent and massive. The quartz vein occurs along the schistosities of host rock, trachybasaltic tuff.

The analytical results of the samples collected show very low grades of metallic elements.

2-c) Suoi Let mineralized zone

This zone is located about 5.5 km southwest of Suoi Tiat mine. The zone is hosted by the Lower Triassic trachytic basaltic tuff and consists of banded ores of chalcopyrite and pyrite developed in the parallel arrangement along the schistosities of the host rocks. The ores are accompanied by subordinate amounts of malachite, covelline, specularite, and quartz.

The ore bodies strike N15°W and dip 67°E with 0.27 m width. A drift was opened, but it is flooded at present. Additionally a trench perpendicular to the strike of the ore body has been made about 45 m south of the drift. However, no mineralization is observed in the trench. Dimensions

of the trench are 0.7 m wide, 1.5 to 4.0 m deep, and 50 m long. The host rocks dip steeply and exhibit intense minor foldings forming an anticline.

Many remnants of placer gold panning are scattered on the upper and lower reaches of the stream which flow through this mineralized zone.

2-d) Suoi Hanne mineral showing

This showing is located in the upper reaches of the Hanne Stream, that is a tributary of the Da River. Copper mineralization is found along the schistosities of the Lower Triassic trachybasaltic tuff.

The showing consists mainly of stockwork of quartz with a small amount of pyrite and chalcopyrite. In addition to those minerals, covelline, limonite, and ilmenite are observed under microscope. The width of quartz veins varies considerably, ranging from 0.3 to 2 m.

Local inhabitants were collecting panning gold at one site down stream.

(3) Mineralized zones in the Lower Triassic Series at the west

These zones consist of Pb-Zn mineralized zones.

3-a) Suoi Cu mineral showing

This showing is located about 2.5 km southeast of Phu Yen. Ore floats are scattered along a small dry stream which is a tributary on the upper reaches of the Cu Stream. Trenching was done in two sites by the Mapping Division of GSV during April to May 1993. Dimensions of trenches are 4 to 5 m long, 0.7 to 1.0 m wide, and 1.5 to 3.0 m deep. They are located parallel to the N55°W direction.

One 130 cm by 70 cm massive ore occurs in breccias of limestone at the western wall of the eastern trench, where the matrix consists of soil. The eastern wall of this trench is composed only of breccias of limestone. Thus, the massive ore does not extend eastward.

The massive ore contains mainly smithsonite and cerussite with subordinate amounts of sphalerite and anglesite. The limestone is grayish white, fine-grained crystalline, and is recrystallized to marble.

Some similar brecciated ores are scattered from the trench to 30 m south. One sample of a float of massive ore collected 30 m south of the trench consists of galena, sphalerite, and calcite. The float has a size of 50 cm and 50 cm. Only the breccias of grayish white, fine-grained crystalline limestone were confirmed at the western trench. Ore similar to those of the eastern trench was not found.

This showing lies in the Middle Triassic area. The above floats are believed to be almost autochthonous because the ore and limestone are angular in shape.

The assay results of the representative samples of this showing are below 75 ppm Ag, from 1.0 to 25.8% Pb and from 28.9 to 37.8% Zn.

3-b) Suoi Boc mineralized zone

This zone is located about 4 km south of Phu Yen, where the area is underlain by the Middle Triassic limestone. There are no outcrops but floats of ore brought from some pits.

Although it is said that the tunnel exploration (crosscut gallery) was carried out by Chinese engineers in this zone about 1982 to 1983, the tunnel could not be confirmed during this survey. In addition to the above, the Mapping Division of GSV dug five trenches around the tunnel, but they have collapsed and the details are not clear. According to GSV, the pits were 8 to 10 m deep and mineralized zone of galena and sphalerite was found with 0.1 to 1.0 m width at one pit whose wall consists of brecciated limestone.

Microscopically one ore sample collected from the stock pile near a pit consists mainly of cerussite and sphalerite with a small amount of pyrite, galena, and anglesite.

An assay result of the sample is 431 g/t Ag, 11.9% Pb and 39.4% Zn.

(4) Mineralized zones in the Middle Triassic Series at the southwest

There are two mineral showings of Pb-Zn in this zones

4-a) Ban Suoi Ton mineral showing

This showing is located on the middle reaches of the Han Stream in the southeastern part of the survey area. There are no outcrops but two floats were found. Both of them are quartz veins accompanied by a small amount of galena and anglesite. One sample contains also a trace amount of covelline.

4-b) Ban Suoi Tion mineral showing

This showing is located in the upper reaches of To Lai Stream in the western part of the area.

The mineral showing is exposed in the Middle Triassic limestone area. The ore consists mainly of galena with a small amount of anglesite and barite. The details are not clear regarding the occurrence of the mineralization zone because of poor exposure.

The host rock limestone is white, fine-grained, crystalline, and is recrystallized to marble. No

granitic bodies are found near this showing.

The assay result of one representative sample shows 17.2% Pb.

(5) Mineralized zones in the area of dolerite at the central part

The mineral showing in this part is tentatively called the Ban Ngnon mineral showing.

This showing is located about 3.3 km west of Ban Ngnon in the northeastern part of the survey area. A dolerite dike has dissemination of chalcopyrite and sphalerite and contains a relatively large amount of ilmenite and a small amount of limonite. The dike is 2.2 m wide. It strikes N39°E and dips 61°SE. The dike intruded into the Upper Carboniferous to Permian limestone.

(6) Mineralized zones in the Middle Devonian Series at the east

The Suoi Can mineral showing is located on the north-facing slope of the uppermost reaches of the Can Stream, a tributary of the Khac Stream in the eastern part of the area.

A trench trending in the N30°E has been made by the Geological Mapping Division of GSV. The trench is 2 to 3 m wide, 1.5 m deep, and 8 m long. The ore body is hosted by Middle Devonian gray massive limestone, and consists of vein-type ore along a fracture that has a N30°W strike and a vertical dip.

The vein-type ore zone comprises the mixture of crushed white limestone powder and aggregate of brecciated ore. Only galena is observed not only in the field but under microscope, and no other metallic minerals are recognized. Gangue minerals are calcite, dolomite, and quartz.

The vein-type ore body is exposed with 30 cm width and 70 cm length. The ore body does not continue southeastward and pinches out there. The host rock limestone has been crushed into powder with 1 to 2 cm width on both sides along the ore body.

The assay result of samples collected from the ore body is 8.9% Pb.

1-3. Regional Geochemical Exploration

1-3-1. Stream Sediment Geochemical Exploration

(1) Objectives

Stream sediment geochemistry was carried out aiming to extract promising areas for mineral deposit based on geochemical characteristics of the regional survey area.

(2) Sampling and chemical analysis

About 100 g of stream sediments with under 80 mesh size were collected for stream sediment geochemistry sample. A number of samples is 1,814 in total. Samples were analyzed for nine elements of Au, Ag, Cu, Pb, Zn, Ni, Cr, As, and Hg. Detection limits are shown below.

Elements	Au	Ag	Cu	Pb	Zn	Ni	Cr	As	Hg
Detection Limit	1 ppb	0.02ppm	0.2 ppm	0.5 ppm	1 ppm	1 ppm	1 ppm	0.2 ppm	10 ppb

(3) Statistics

1) Basic statistics

Basic statistic parameters calculated with common logarithm for analytical values are shown in Table 2-1. On the occasion of values below the detection limit, one half of detection limit values were substituted. Correlation coefficients of elements are shown in Table 2-2.

Table 2-1 Basic Statistics of Analytical Results of Stream Sediments in the Van Yen Area

	Au	Ag	Cu	Pb	Zn	Ni	Cr	As	Hg
Max. Value	2,460	3.2	17,393	714.1	1,969	2,368	18,984	138	803
Min. Value	<1	<0.02	0.7	<0.5	5	2	1	<0.2	<10
Geometric Mean	<1	0.10	21.6	15.8	65	34	128	1.9	27
M+2xSD*1	3	2.2	198.5	55.0	227	258	3902	58.6	237
PDL*2	87%	26%	-	-	-	-	-	20%	14%

M+2xSD*1 : Added double standard deviations to geometric means

PDL*2 : Frequency of samples that have analytical values below detection limits

Table 2-2 Correlation Coefficients of Analytical Results of Stream Sediments in the Van Yen Area

	Au	Ag	Cu	Pb	Zn	Ni	Cr	As	Hg
Au									
Ag	0.08								
Cu	0.39	0.26							
Pb	0.06	0.16	0.38						
Zn	0.16	0.23	0.67	0.53					
Ni	0.15	0.12	0.63	0.19	0.72				
Cr	0.10	0.09	0.48	0.10	0.70	0.89			
As	0.04	0.22	0.15	0.31	0.13	0.08	-0.01		
Hg	0.03	-0.02	0.08	0.13	0.13	0.16	0.11	0.07	

The highest correlative combination of elements is Ni-Cr. The combinations of Cu-Zn-Ni, Pb-Zn and Zn-Ni-Cr are relatively correlative.

2) Determination of threshold value

In order to determine threshold values, Lepelitier's method (1969) with cumulative frequency distribution diagrams drawn by logarithm of analytical values was adopted.

The threshold values for each element are follows.

Au: Cumulative frequency distribution diagram show L-shaped pattern, but a turning point is in the higher range. This point(10 ppb) is the threshold value.

Ag: No turning point on the distribution diagram is found. Two percent value of probability density is set for threshold(1 ppm).

Cu: A turning point in the higher range of cumulative frequency distribution diagram is found. This value is threshold(200 ppm).

Pb: A turning point in the higher range of cumulative frequency distribution diagram is found. This value is threshold(80 ppm).

Zn: This distribution diagram is approximately straight line. The sum of geometric mean and double value of standard deviation is threshold(227 ppm).

Ni: This distribution diagram is a straight line as a whole. The sum of geometric mean and double value of standard deviation is threshold(258 ppm).

Cr: This diagram is an S-type curve. It is consequently supposed that the distribution includes two populations. The population in the higher range has values over 1,000 ppm. The sum of geometric mean and double value of standard deviation in the higher population is threshold(3,012 ppm).

As: A weak turning point on the distribution diagram is threshold(30 ppm).

Hg: This distribution diagram is approximately straight line. The sum of geometric mean and double value of standard deviation is threshold(237 ppb).

(4) Geochemical anomalous zones

Anomalous points of each element extracted on the basis of the above threshold values are plotted in Figure 2-4.

Areas with concentration of anomalous points are listed for each element below. In principle, concentration means cases with nearby (about 1 km) two points or with 3 or more points closely (3 to 4 km) distributed. Anomalous points for Ni-Cr are restricted to be anomalous in both elements, because the correlation of both elements is higher.

The geochemical anomalous zones are as follows.

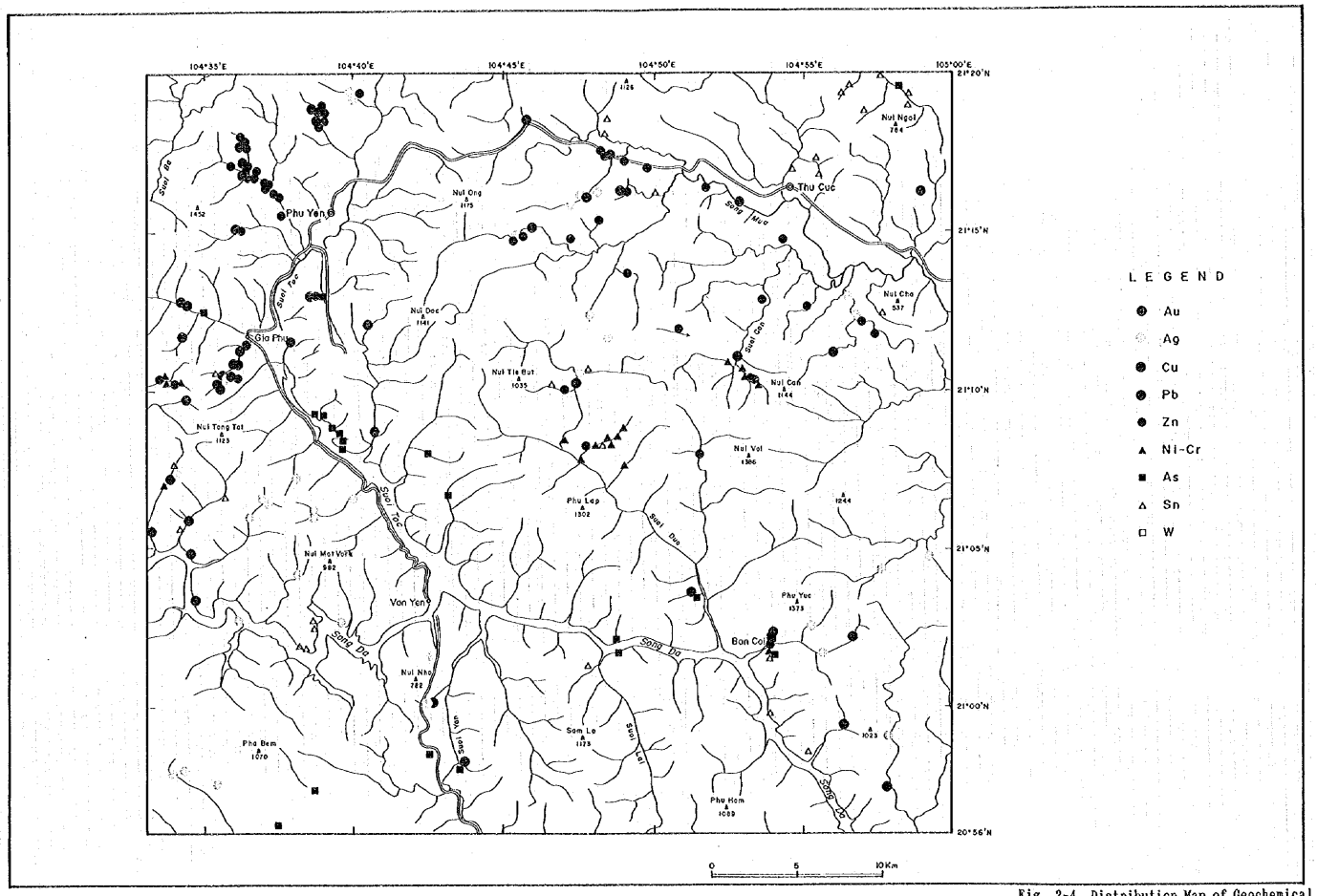


Fig. 2-4 Distribution Map of Geochemical Anomalies of Stream Sediment in the Van Yen Area

a) Around the Suoi Tiat Mine (Au, Cu)

b) The mountain area between Nui Tong tat and Nui Mat Vork (Ag)

c) The south of No Phay (Ag)

d) 10 km west of Thu Cuc (Ag)

e) 1.5 km north of Ban Suoi Hang

f) The area of 10 by 4 km revolving the 4 km northwest of Phu Yen (Ag)

g) Around the 10 km west-northwest of Thu Cuc (Zn(-Pb))

h) Around the 5 km southeast of Lang Phat (Zn(-Ag))

i) Around the 4 km west of the Suoi Tiay Mine (Ni-Cr(-Zn))

j) Around the 5 km south of Ban Suoi Hang (Ni-Cr)

k) Around the 6 km southwest of Lang Phat (Ni-Cr)

l) East bank of the middle reaches of Toc River

m) Around the 2 km north of Nui Ngai, at the northeastern edge of the area.

(5) Relationship between geochemical anomalous zones and geology - geologic structure

a) Around the Suoi Tiat Mine (Au, Cu)

This anomalous zone is situated in the Lower Triassic area, and the Suoi Tiat Mine is in the zone. The Suoi Tiat deposit is bedded cupriferous pyrite deposit containing gold and chalcopyrite. The geochemical anomaly for Au and Cu is in harmony with above facts. New ore deposits are promising, because the anomalous points are distributed not only in the lower reaches but also upper reaches.

b) The mountain area between Nui Tong tat and Nui Mat Vork (Ag)

The geochemical anomalous zone is underlain by the Lower Triassic, gabbro and dolerite. There is the Suoi Haune mineral showing, a copper bearing quartz vein, near the anomalous zone, but the origin of the Ag anomaly is not clear.

c) The south of No Phay (Ag)

The geochemical anomalous zone occupies a part of the Lower Triassic that extends narrowly in NW-SE direction. The origin of the Ag anomaly is not clear.

f) 10 km west of Thu Cuc (Ag)

The geochemical anomalous zone is underlain by the Carboniferous to Permian and Lower Permian. There is the Cretaceous granite at the northwest of the zone, but the origin of the Ag anomaly is not clear.

e) 1.5 km north of Ban Suoi Hang

The geochemical anomalous zone is located at the Middle Devonian, Carboniferous to Permian and Upper Triassic area. There is no mineral showing around the zone, and the origin of the Ag anomaly is not clear.

d) The area of 10 by 4 km revolving the 4 km northwest of Phu Yen (Ag)

The geochemical anomalous zone is situated in the area comprising the Cretaceous and numerous syenite intrusions. There is the Ban Cho mineral showing with floats of galena, sphalerite and quartz. The Pb-Zn mineralization is expected to occur in this zone.

g) Around the 10 km west-northwest of Thu Cuc (Zn(-Pb))

The geochemical anomalous zone is underlain by the Lower Devonian. There is no intrusive rock near the anomalous zone, but the origin of the Zn-Pb anomaly is not clear.

h) Around the 5 km southeast of Lang Phat (Zn(-Ag))

The geochemical anomalous zone is underlain by the Lower Devonian. There are dolerite intrusions near the anomalous zone, but the origin of the Zn-Ag anomaly is not clear.

i) Around the 4 km west of the Suoi Tiat Mine (Ni-Cr(-Zn))

The geochemical anomalous zone is underlain by the Lower Triassic intruded by gabbro. The origin of the Ni-Cr-Zn anomaly is not clear.

j) Around the 5 km south of Ban Suoi Hang (Ni-Cr)

The geochemical anomalous zone corresponds to the area of numerous ultramafic intrusions in

the Middle Devonian.

k) Around the 6 km southwest of Lang Phat (Ni-Cr)

The geochemical anomalous zone corresponds to the area of numerous ultramafic intrusions in the Middle Devonian.

l) East bank of the middle reaches of Toc River

The geochemical anomalous zone is situated in the Lower Triassic area.
The origin of the As anomaly is not clear.

m) Around the 2 km north of Nui Ngai, at the northeastern edge of the area.

The geochemical anomalous zone corresponds to the area of gabbroic intrusions in the Proterozoic. The origin of the Hg anomaly is not clear.

1-3-2. Panned Concentrate Geochemical Exploration

(1) Objectives

The gold, lead-zinc, and platinum-copper-nickel mineralization confirmed by the previous geologic and metallogenic data in this regional survey area. This exploration was carried out in the survey area in order to evaluate the characteristics of heavy minerals in the mineralization zones and to discover new potential areas.

(2) Collection, treatment, and identification of panned concentrates

The sampling of panned concentrates was carried out along the main streams and their tributaries, and at the streams around the known mineralization zones during the course of the regional geological survey. The total number of panned concentrates is 433 samples in this area. Each sample was collected by five-times panning (approximately 25 liters). The samples were dried up and weighed.

(3) Results of the mineral identification

The identified minerals are magnetite, ilmenite, limonite, hematite, garnet, staurolite, epidote, siderite, tourmaline, chromite, pyroxene, serpentine, zircon, rutile, cinnabar, pyrite, and native gold.

(4) Distribution of heavy minerals

The heavy minerals related to mineralization in this area are considered to be native gold and copper minerals. Chromite is also found in many sample points. The location detected three heavy minerals is shown in Figure 2-5.

Areas with concentration of heavy minerals are listed for each element below. In principle, concentration means cases with nearby (about 1 km) two points or with 3 or more points closely (3 to 4 km) distributed. In the case of copper, detection means samples contained weighable amounts of copper minerals.

The geochemical anomalous zones are as follows.

Native gold

About 3 km west of Gia Phu
Let Stream in the western part of the area
Tributaries of Boung Stream in the western part of the area
Can Stream of the central-northeastern part of the area

Copper minerals

Tiat Stream in the western part

(5) Discussion

The following relationship was recognized between the localities of heavy minerals and the geology.

a) Anomalous zones of native gold

a-1) About 3 km west of Gia Phu

The anomalous zone is underlain by the lower Triassic system. The zone is situated at the northwest of Suoi Tiat Mine, an operating mine. A number of gold grains detected in the anomalous zone was less than that of gold grains obtained at the down stream of the mine.

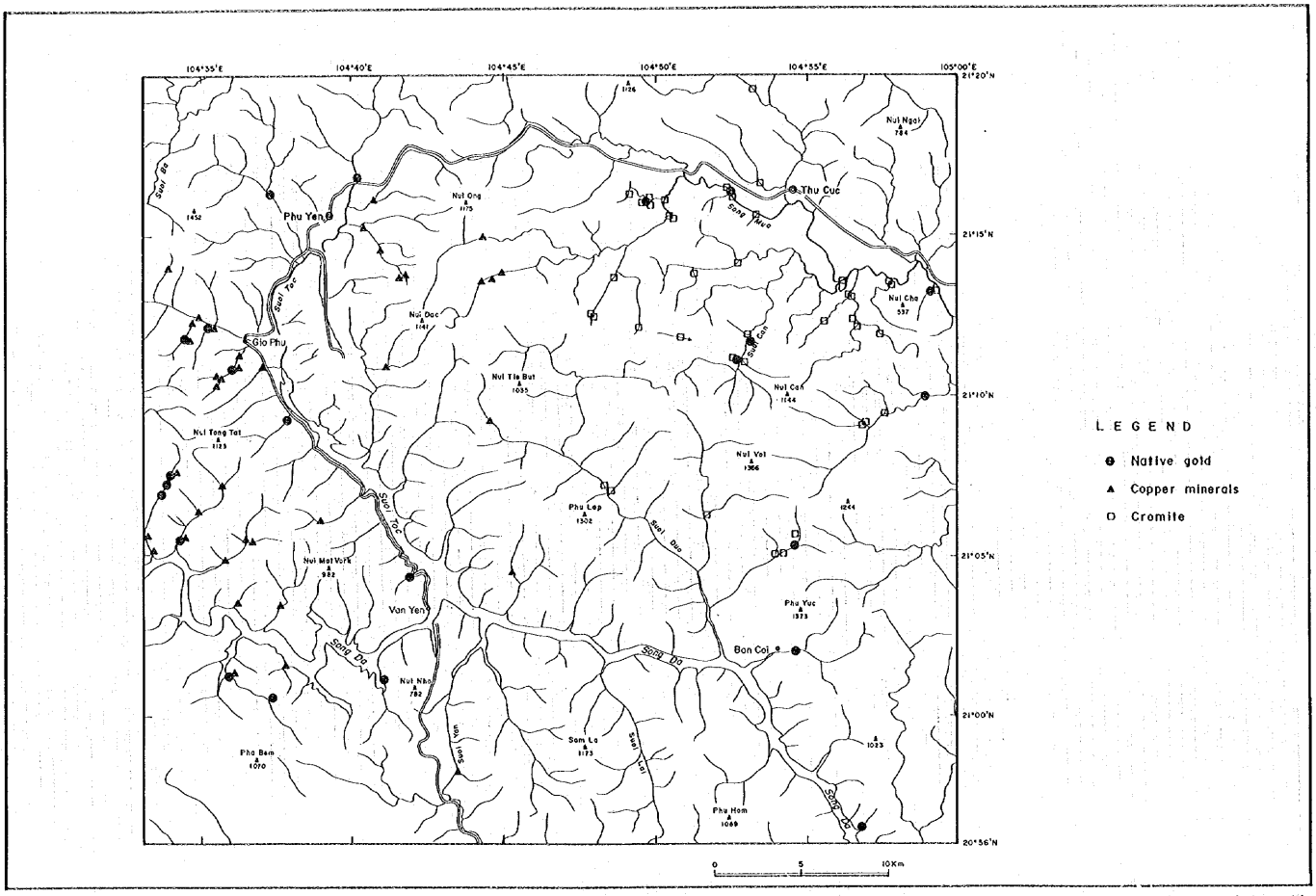


Fig. 2-5 Location Map of Heavy Minerals in the Van Yen Area

a-2) Let Stream in the western part of the area

The anomalous zone at Let Stream overlies the lower Triassic system. Mineralized zone of Suoi Let is situated in this anomalous zone, and similar to that of Suoi Tiat mine.

a-3) Tributaries of Boung Stream in the western part of the area

The anomalous zone is underlain by the Middle Triassic. There is no mineralized zone around this anomalous zone. This anomalous zone is not able to be interpreted geologically.

a-4) Can Stream of the central-northeastern part of the area

This anomalous zone is situated in the Middle Devonian area. The Suoi Can mineral showing is located at the upper reaches of this stream, but there are barren points between the mineral showing and the anomalous zone. Geological meanings are not clear.

b) Anomalous zone of copper minerals

b-1) Tiat Stream in the west

The anomalous zone at Tiat Stream in the west is situated around Suoi Tiat mine. Anomalies are considered to be originated in debris of the mine which contains copper minerals.

Native gold grains are sparsely confirmed in the whole survey area and their localities seem not to be related to the specified geologic units. Nevertheless, stockwork of quartz or floats of vein quartz were found in the upper reaches of the streams of those localities. Thus, it seems possible that the gold grains derive from the stockwork or floats.

Most of chromite grains were confirmed in the lower reaches of the streams where ultramafic bodies are exposed. Thus, the origin of those minerals is considered to be controlled by the ultramafic intrusion. In other localities the ultramafic bodies were not recognized through the field survey. However, it is inferred that the bodies will occur in the upper reaches of the streams of the localities and they are the origin of the minerals.

CHAPTER 2. SUOI BOC ZONE

2-1. Outline of the Zone

This zone is situated in the northwestern part of the Van Yen area. Pb-Zn mineralized zone occurs in this zone. Detailed geological survey, geochemical exploration, geophysical survey and drilling survey were conducted for the purpose of clarifying the geology and mineralization of this zone.

Two mineralized zones are in the geological survey area. This area is wider than the area studied by geochemical, geophysical and drilling exploration, and is called the Suoi Boc - Suoi Cu zone.

2-2. Detailed Geological Survey

2-2-1. Survey Method

Field geological survey was carried out using an 1:5,000 topographic map enlarged from a 1:50,000 map, and the survey results were compiled into a 1:10,000 geologic map. The mapped area is 10 km^2.

The geologic map of the Suoi Boc - Suoi Cu zone is shown in Figure 2-6.

2-2-2. Geology

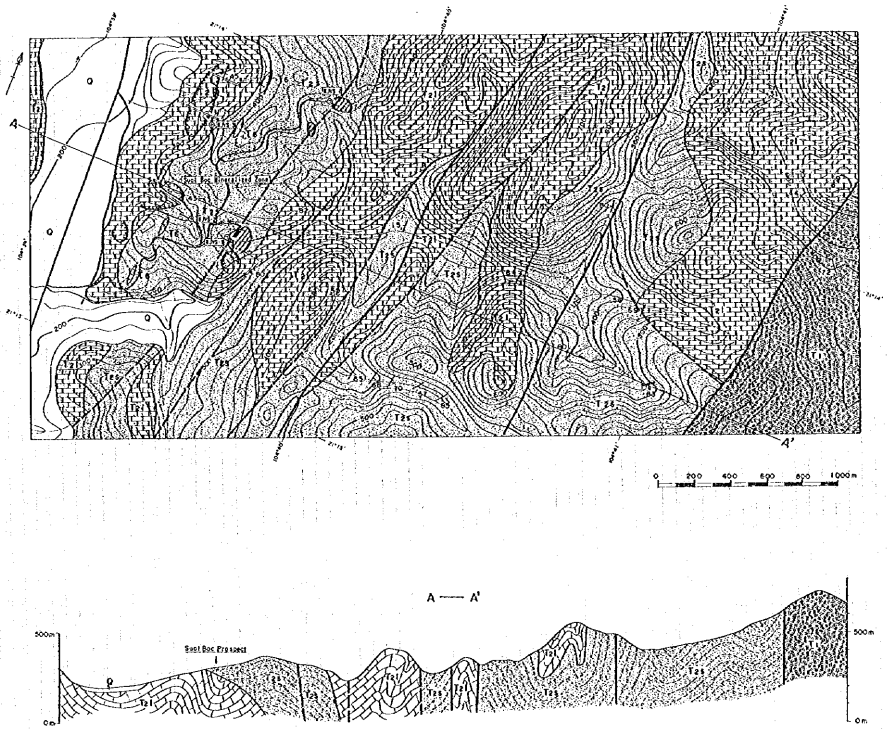
The geology of the survey area consists of Early Triassic volcanic-pyroclastic rocks and limestone, Middle Triassic sedimentary rocks, and unconsolidated Quaternary sediments in ascending order. Dacite porphyry and aplite dikes occur in the area. The dikes are considered to have intruded during Cretaceous time.

The Lower Triassic occurs in the eastern part of the survey area and consists of trachybasalt, trachybasaltic tuff, and light gray limestone.

The Middle Triassic occupies the major part of the area and is divided into the following two rock facies. One comprises clastic rocks that consist chiefly of black mudstone with subordinate amounts of gray to reddish gray fine- to coarse-grained sandstone, gray siltstone, and conglomerate. The sandstone of this rock facies is generally prevalent in the western part of the area, surrounding the Suoi Boc Prospect. The another rock facies is composed of light gray to dark gray limestone that forms vertical cliffs of 50 m to 100 m high in many places.

The Quaternary occurs as a belt in the western lowland extending in the N-S direction.

Small dacite porphyritic bodies and aplite dikes are recognized in the clastic sedimentary rocks



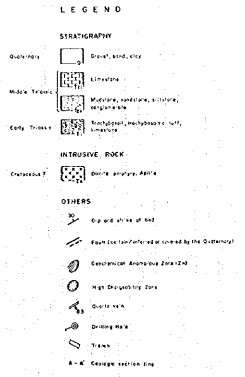


Fig. 2-6 Geologic Map and Cross Sections of the Suoi Boc - Suoi Cu Zone

near the boundary between limestone and clastic sedimentary rocks at the western ridge.

2-2-3. Geologic Structure

The bedding planes are partly developed in most mudstone, siltstone, and limestone in the survey area. The beds have generally N-S strikes and steep dips exceeding 50°. Particularly, in the Middle Triassic clastic areas of the south-central and eastern parts, there are steep sequences of nearly vertical beds. It is supposed that the complicated folds have been formed in this area because the area belongs to the "Da River Mobile Belt". From the data obtained through the detailed field survey, it is believed that the major part composed of alternant clastic rocks and limestone has been folded in a series of N-S trending anticline and syncline with about 500 m wavelength.

Faults of the N-S to NNE-SSW direction were recognized in the survey area, and NW-SE trending faults were inferred to occur. The Lower Triassic is in an N-S trending fault contact with the Middle Triassic. These N-S trending faults are interpreted to be settled near the axial planes of folds with steep flanks formed by the intense lateral compressional stresses. The vertical displacement by the faults developed within the Middle Triassic area is not known because the stratigraphic relationship between clastic rocks and limestone is not clear.

2-2-4. Mineralization

The Suoi Boc mineralized zone and Suoi Cu mineral showing are the lead-zinc mineralized zones confirmed by the field survey of the first phase.

(1) Suoi Boc mineralized zone

There are no outcrops but lumps of ore dug out from some pits in this zone. Although the tunnel exploration (crosscut gallery) was carried out by Chinese engineers in this Prospect during 1982 to 1983, the tunnel could not be confirmed at present. In addition to the above, the Mapping Division of GSV dug five pits around the tunnel, but they have collapsed and the details are not clear. According to GSV, the pits were 8 to 10 m deep and mineralization zone of galena and sphalerite was found with 0.1 to 1.0 m width at one pit. One ore sample collected consists mainly of cerussite and sphalerite with a small amount of pyrite, galena, and anglesite.

(2) Suoi Cu mineral showing

Trenching was done in two sites by the Mapping Division of GSV in this showing. Dimensions of trenching are 4 to 5 m long, 0.7 to 1.0 m wide, and 1.5 to 3.0 m deep. They are located parallel to the N55°W direction.

One 130 cm by 70 cm massive ore occurs in breccias of limestone at the western wall of the eastern trench, where the matrix consists of soil. The eastern wall of this trench is composed only of breccias of limestone. Thus, the massive ore does not extend eastward. The massive ore contains mainly smithonite and cerussite with subordinate amounts of sphalerite and anglesite. The limestone is grayish white, fine-grained crystalline, and is recrystallized to marble.

Only the breccias of grayish white, fine-grained crystalline limestone were confirmed at the western trench. Ore similar to those of the eastern trench was not found.

This mineral showing is interpreted to be of vein type with the NW-SE direction through the electrical survey conducted by GSV.

2-3. Soil Geochemical Exploration

2-3-1. Objectives

This exploration was carried out aiming to extract new potential areas for ore body similar to the known Suoi Boc mineralized zone. The exploration area covers 4 km^2.

2-3-2. Sampling and chemical analysis

Soil samples were collected from the residual soil (B-layer) 30 to 40 cm deep from the surface. The sampling points are arranged along the geophysical survey lines with intervals of every 100 m apart (every 50 m near the Suoi Boc Prospect; see Plate 10). One hundred samples of about 100 g each were collected.

The samples were analyzed for 9 elements of Au, Ag, Cu, Pb, Zn, Cd, As, Sb, and Hg. Analytical methods used and detection limits of 7 elements except for Cd and Sb are the same as those of stream sediment geochemistry in the Van Yen Area. Two elements of Cd and Sb were analyzed by the method of ICP and their detection limits are 0.1 ppm and 0.2 ppm, respectively.

2-3-3. Statistical data-processing

Basic statistic parameters were calculated by common logarithm for analytical values. On the occasion of values below the detection limit, one half of detection limit values were substituted.

Elements except Au and As are correlative in the area. Especially, elements Pb, Zn, Cd, and Sb show strong normal correlation. Furthermore, Ag, Cu, Hg, and said four elements show relatively good correlation. It thus appears that these seven elements behaved together in a group.

2-3-4. Geochemical anomalies and anomalous zones

(1) Determination of threshold value

It is difficult to institute threshold values by the cumulative frequency distribution diagrams in the case of insufficient quantity of about 100 samples. In consequence, elements Pb and Zn which show the clear breaking points on the cumulative frequency distribution diagrams were remarked here. High content zones more than 1,000 ppm of Pb and Zn are delineated by means of iso-content contours.

(2) Anomalous zones

Since there are strong correlation among seven elements out of nine analyzed elements, those high content zones are delineated on the almost same parts of the anomaly maps. Therefore, four high content zones of Pb and Zn are representatively mentioned below. Background values of Pb and Zn are estimated to be respectively 40 to 60 ppm and 100 to 200 ppm through their histograms.
The geochemical anomalous zones are shown in Figure 2-13.

In the case of Zn anomaly map, two clear high content zones are also detected in the similar parts to those of the Pb anomaly map (in the central-western and southeastern parts). Values at the center of these zones indicate hundreds times or higher than background values. High content points are not separated but concentrated, and values become smaller abruptly into background values on the outskirts of the zones.

The other two high content zones, which are present also in the similar parts to those of the Pb anomaly map (in the northwestern part and in the southwestern end), have anomalous points with values ranging from 1,700 to 2,000 ppm.

2-4. Geophysical Survey

2-4-1. Objectives

The objectives of the geophysical survey are to detect IP anomalies related to mineralization and thus delineate the promising parts for ore deposits.

2-4-2. Survey Method

Electric method (time domain IP method) was employed with gradient array. The survey area covers 3 km^2. Total length of lines and measuring points are 15.8 km and 306 points, respectively.

(1) Time domain IP method

The IP method is the exploration method to observe electric polarization effect (IP effect) in the earth. The IP effect is caused by the following phenomenon.

When direct current flows through the rocks containing metallic minerals, electric potential difference is generated between the surface of metallic minerals and pore water around them, electric charge is stored, and therefore electric polarization is resulted in. This electric charge is discharged gradually after current is terminated. It forms the residual voltage decaying with the passage of time. However, the IP effect occurred not only in the rocks containing metallic minerals, but also in some sedimentary rocks containing clay or graphite.

In the time domain IP method, on and off alternating current in the shape of rectangular wave is generally used as transmitter current. Received voltage is composed of the primary voltage observed in on and the decay voltage observed while current is off. Chargeability is calculated with received voltage as index to express quantity of IP effect.

The chargeability is the proportion of time integral of secondary voltage to primary voltage. Its unit is millisecond.

(2) Measurement method

The specification of measurement is as follows.

Electrode configuration : Gradient array

Potential electrode spacing : 50 m

Period of transmitter current : 8 seconds

Measurement quantity : Electric potential difference and chargeability

The gradient array is applied to fast mapping of electric quantity in large survey area. Current electrodes whose spacing is very large, are fixed in location. The rectangular survey area is laid in the central part of electrodes. The potential electrodes whose direction is parallel to the direction of current electrodes and whose spacing is small, are moved for measurement.

(3) Location of current electrode and measuring points

Two sets of current electrodes (No. 1 and No. 2), whose directions are NNW-SSE, were laid out as shown Figure 2-7. The current electrode No. 1 (about 2,810 m in spacing) was applied to the measurement of the northern part of the survey area. The current electrode No. 2 (about 2,720 m in spacing) was applied to the measurement of the southern part of the survey area.

The survey area is covered by 306 measuring points almost uniformly. However, measuring points around the Suoi Boc mineralized zone are laid out densely.

(4) Laboratory test

Resistivity and chargeability of rock and ore samples in the survey area were measured in laboratory. The same method in the field measurement was applied. Forty-one samples (twenty-four from the surface and seventeen from drilled cores) were measured in laboratory.

(5) Equipment

The equipment used in this survey is as follows.

2-4-3. Results of Survey

(1) Apparent resistivity

The contour map of apparent resistivity is shown in Figure 2-8. The mean value of apparent resistivity of the survey area is 208 ohm-m (calculated with logarithmic value). The minimum and maximum values are 1,083 and 36 ohm-m, respectively.

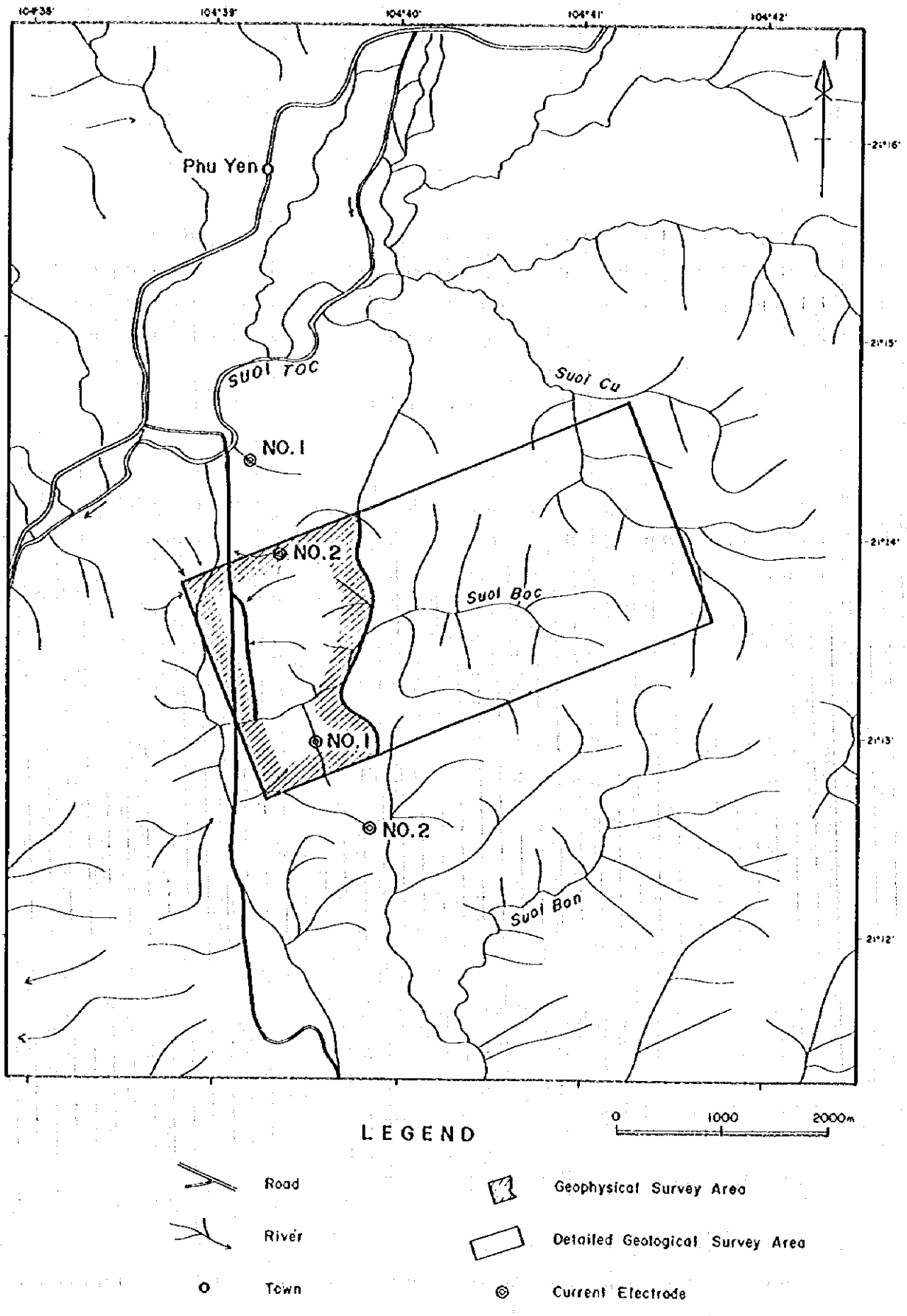


Fig. 2-7 Location Map of the Current Electrode

ITEM	NAME	SPECIFICATION
Transmitter	Zonge GGT-5 Transmitter	Outout Voltage : 250, 500, 750, 1000V Output Current : 0.2~25A Wave Form : Rectangular Wave Frequency Range : 1/8~2048Hz Weight : 57kg
Transmitter Controller	Zonge XMT-1 Transmitter Controller	Frequency Range : DC~2048Hz Power : 12V Battery Weight : 5.8kg
Engine Generator	Zonge ZMG-5 Engine Generator	Output Power : 5kw Frequency : 400Hz Output Voltage : 115V Engine : 5Hp, 4 Cycle
Receiver	Zonge GDP-12/2GB Data Processor	Frequency Range : 1/8~2048Hz Sensitivity : 0.2 μ V Power : 12V Battery Weight : 15kg
Electrode	Current Potential	Stainless Rod Non Polarization $CuSO_4$ Porous Pot

The low resistivity zones less than 50 ohm-m are detected in the northeastern edge and central parts of the survey area. The low resistivity zone less than 100 ohm-m are scattered in the areas connected the low resistivity zones less than 50 ohm-m. It is somewhat difficult to see the other distinctive feature about apparent resistivity in Figure 2-8.

The relief energy of the topography in this area is very high because of a typical karst landform. Therefore, it is considered that the apparent resistivity suffers from strong topographical effect. That causes the difficulty in interpreting the map of apparent resistivity.

(2) Chargeability

The contour map of chargeability is shown in Figure 2-9.

The mean value of chargeability in this area is a little high value of 33 ms. The maximum and minimum values are 120 and 7 ms, respectively.

Two IP anomalies (high chargeability anomalies) more than 60 ms were detected in the northeastern edge and middle east edge of the survey area. The anomaly in the northeastern edge is the strong one containing a measuring point more than 100 ms.

On the Suoi Boc mineralized zone, chargeability is only several ms higher than the mean value and thus no anomaly was detected.

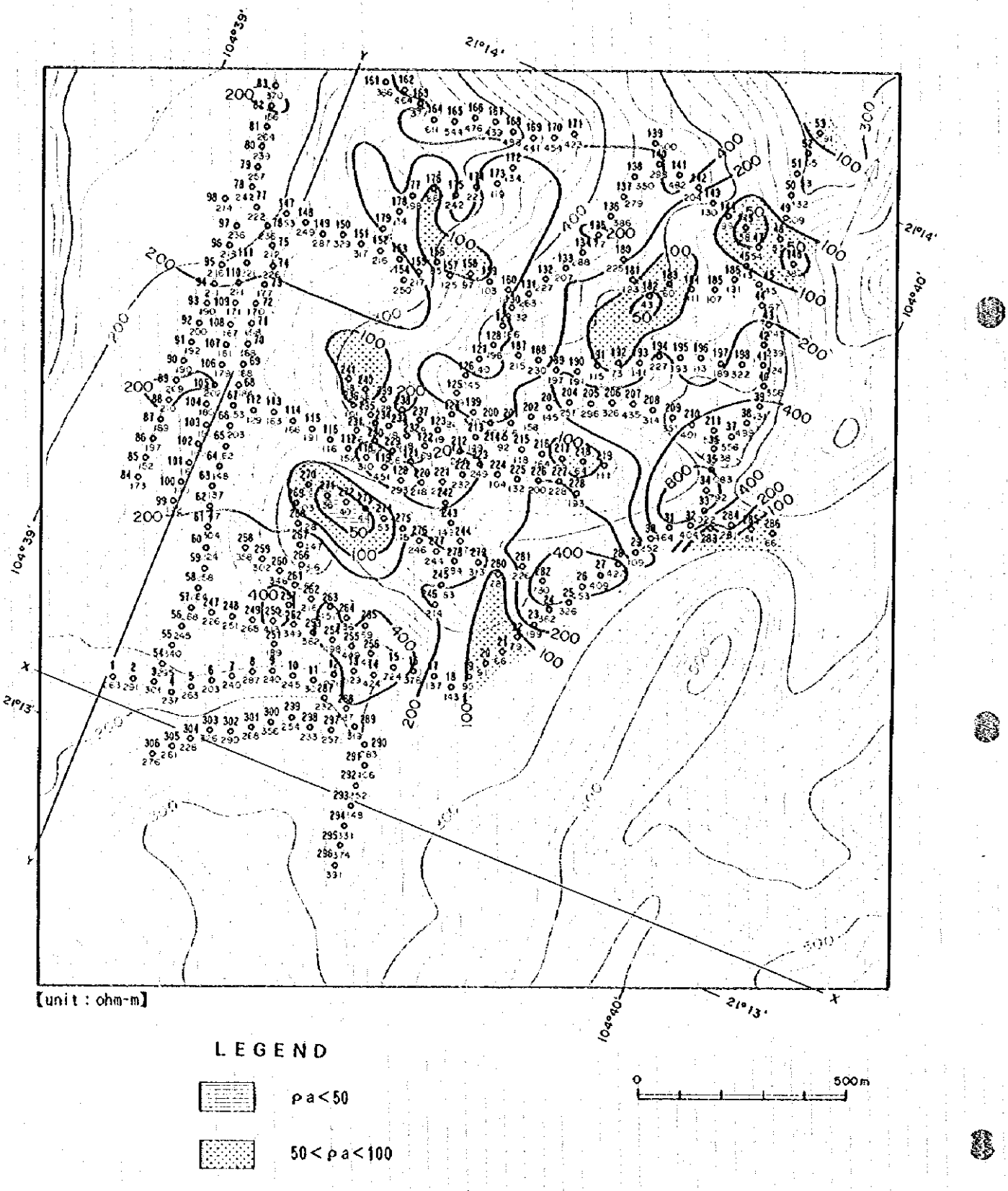


Fig. 2-8 Contour Map of Apparent Resistivity

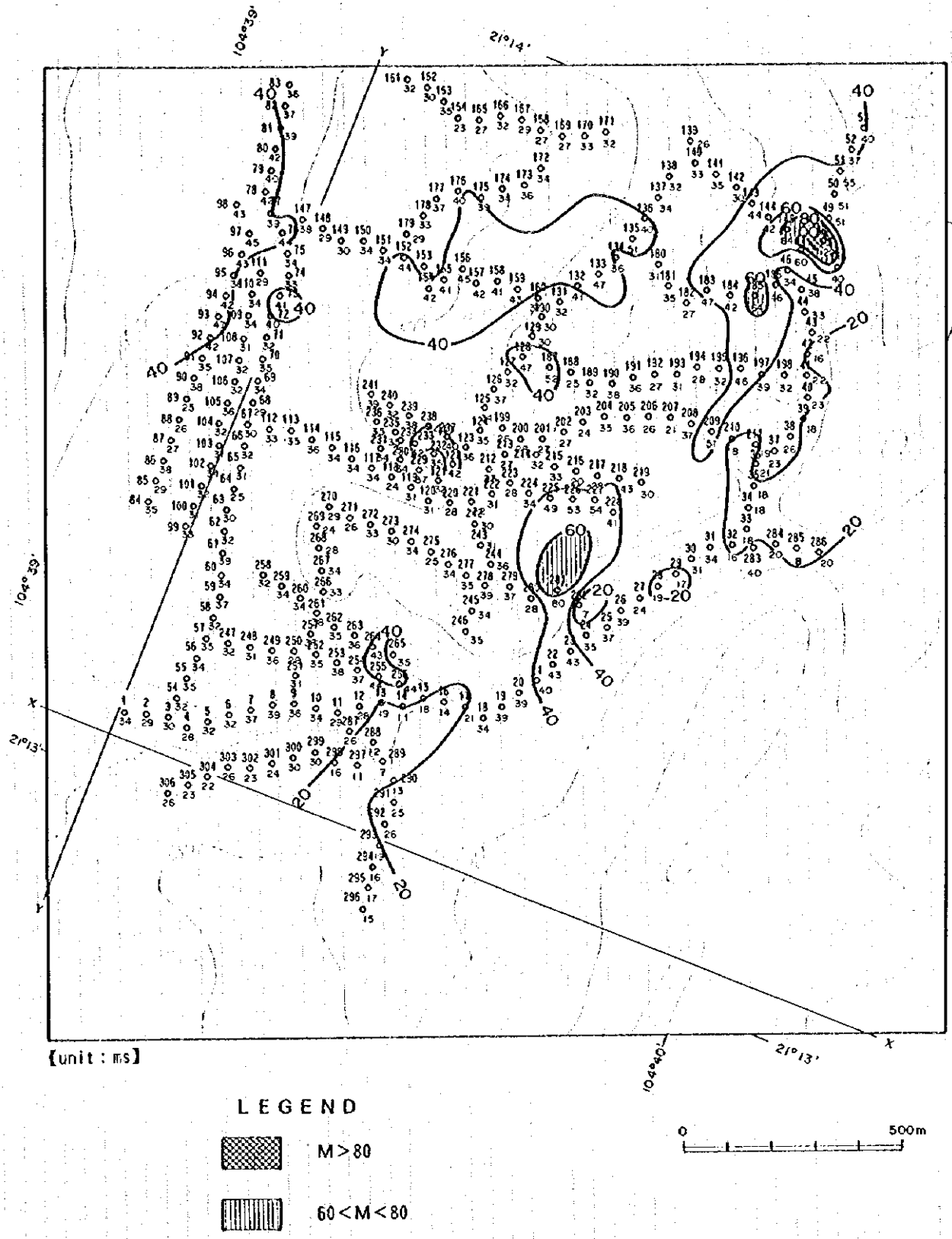


Fig. 2-9 Contour Map of Chargeability