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

PHASE I

FEBRUARY 1994

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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PREFACE

In response of 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).

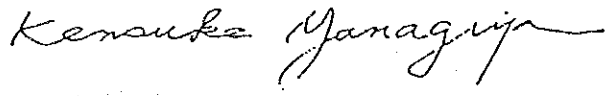
This is the first phase survey. The JICA and MMAJ sent a survey team headed by Mr. Yuya Furukawa to the Socialist Republic of Vietnam from 24 October to 31 December, 1993.

The team exchanged views with the officials concerned of the Government of the Socialist Republic of Vietnam and conducted a field survey in the Van Yen and Western Thanh Hoa areas. After the team returned to Japan, further studies were made and the present report is the result.

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.

February, 1994



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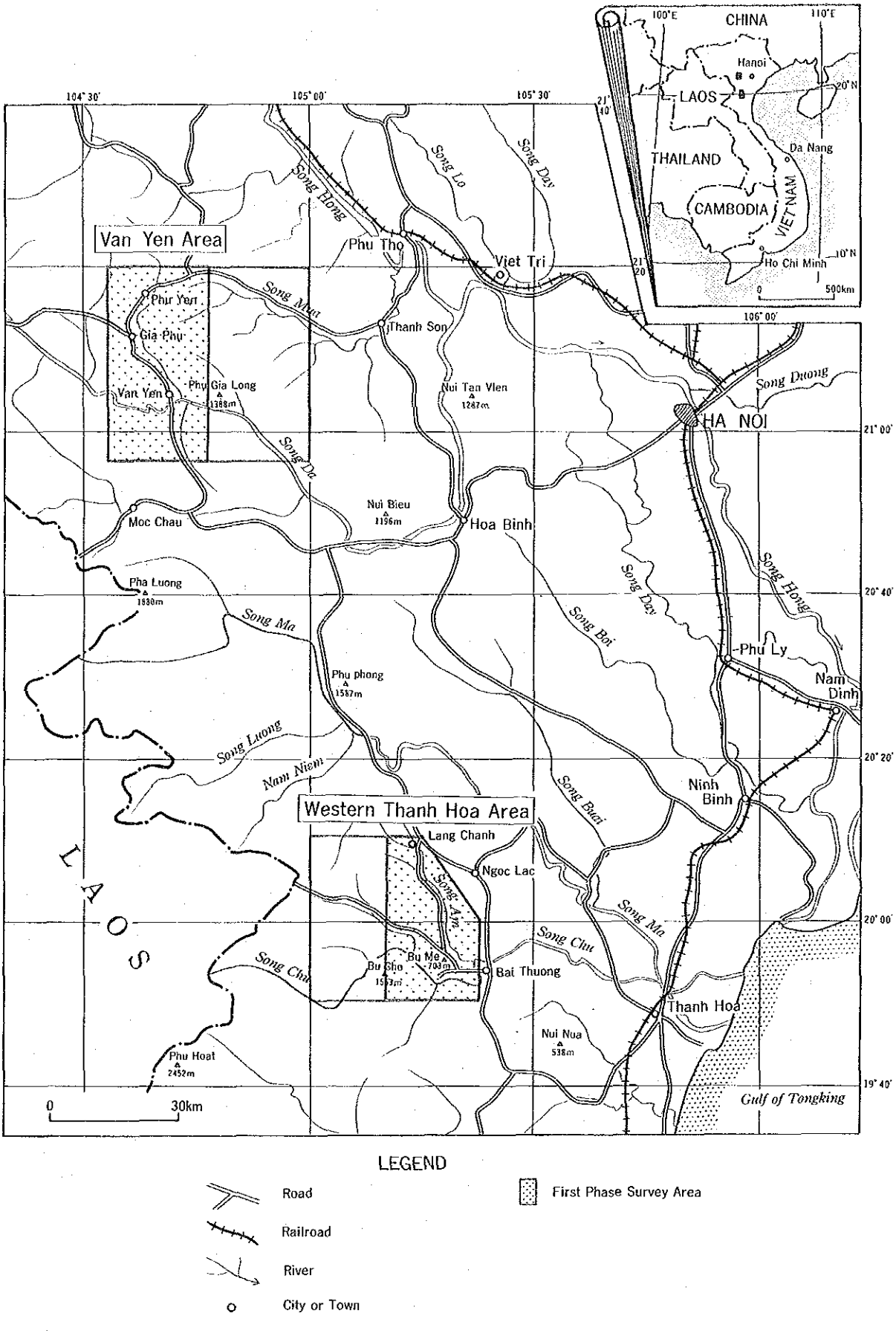

Fig.1 Location Map of the Survey Areas

SUMMARY

The survey of this year is the first phase of the Cooperative Mineral Exploration in the Van Yen and Western Thanh Hoa Areas of the Socialist Republic of Vietnam. The project is based on the "Scope of Work" concluded between the Geological Survey of Vietnam (GSV) and the Japan International Cooperation Agency (JICA) as well as the Metal Mining Agency of Japan (MMAJ) on 23 June 1993.

The objective of this project is to evaluate the mineral potential of the areas through geoscientific investigation and to discover new mineral deposits.

The duration of the work of this phase was from 24 October 1993 to 28 February 1994, total of 128 days. The field survey and subsequent analysis in Vietnam were carried out during 69 days from 24 October to 31 December 1993. The laboratory studies and preparation of report were carried out during the period from 1 January to 28 February 1994.

The following summarizes the results of the first phase survey.

A. Van Yen Area

1. Results of the Survey

(1) The field work was carried out in this area during the period from 24 November to 20 December, 1993. The scope of the work during this phase is as follows.

- Geological survey : 1,000 km^2
- Geochemical exploration (collected samples):

  Stream sediments 899 samples

  Panned concentrates 193 samples

(2) The major geoscientific work carried out in this area are geological survey and soil and panned concentrate geochemical exploration. Maps showing their results have been prepared at a scale of 1:200,000. Geologic mapping at a scale of 1:50,000 by GSV is presently underway.

(3) The previous geoscientific work revealed that the survey area has mineral potential for gold, copper, lead, and zinc. It was shown by the work that Lower Triassic area is important for mineralization of the first two. Mineralization of the rest, on the other hand, occurs in the area of the Middle to Upper Triassic carbonate rocks.

(4) The survey area belongs to the "West Bacbo" tectonic province. This area is underlain chiefly by the Devonian to Permian shallow-marine sedimentary basement which is overlain by; the Triassic and Cretaceous alkali volcanic and pyroclastic rocks, shallow-marine sedimentary rocks, and unconsolidated Quaternary sediments. Small bodies of gabbroic rocks, quartz-bearing trachyte, and syenite intruded mainly the Lower Triassic rocks in the central part of the survey area.

(5) The geology of this area is strongly controlled by the NW-SE trending major structure of the "West Bacbo", and the NW-SE direction is predominant in both major faults and axes of folds. This structure also controls the direction of igneous intrusion and the principal gold-copper deposits in this area.

(6) The major mineralization in this survey area are those of gold, copper, lead, and zinc. They are summarized below.

a) The major gold mineralization of this area is that associated with bedded cupriferous pyrite deposits. It is believed that the deposits are of metamorphic origin and 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 many ore bodies, but they are not large. Therefore, possibility exists for finding deposits of this type with gold content sufficient for mining. The most promising area is in the vicinity of the Suoi Tiat mine, where many mineral showings and Au-Cu geochemical anomalies are concentrated.

b) The relatively large quartz veins of about 2 m in width occur mainly in the

central part of the survey area, and are accompanied occasionally by copper minerals. However, the content of copper is low. Also copper content does not improve in other veins of different levels and in veins along the extension of the same level. Therefore, high mineral potential is not expected laterally and vertically for quartz veins of this type. The width of the veins varies considerably, resulting in unstable contents of minerals.

c) Some metasomatic lead and zinc mineralization and mineral showings occur in the central part of the survey area, and the ores are hosted mainly by the Middle Triassic carbonate rocks. The details of the dimensions and other characteristics of mineralization are not known because of thick soil cover. However, further exploration is needed for these prospects because the contents of lead and zinc are very high (Pb: 12 to 26 %, Zn: 29 to 39 %). The above assay results are from chip samples of floats. The most promising area is the Suoi Boc mineralization zone and followed by the Suoi Cu and Ban Suoi Ton mineral showings.

2. Recommendations for Phase II Survey

From the conclusions reached during the Phase I survey, the following work is recommended for Phase II survey to be carried out in Fiscal 1994.

(1) Detailed geological survey in the vicinity of the Suoi Tiat mine for an areal extent of 6 km x 3 km
(2) Detailed geological survey and geophysical prospecting (IP method) for the Suoi Boc mineralization zone
(3) Detailed geological survey for the Suoi Cu mineral showing
(4) Detailed geological survey for the Ban Suoi Ton mineral showing

B. Western Thanh Hoa Area

1. Results of the Survey

(1) The field work was carried out in this area during the period from 29 October to 20 November, 1993. The scope of work during this phase is as follows.

- Geological survey : 650 km^2

- Geochemical exploration (collected samples):

Stream sediments	532 samples
Panned concentrates	147 samples
Soils	241 samples

(2) The major geoscientific work carried out in this area are geological survey and soil and panned concentrate geochemical exploration. Maps showing their results have been prepared at a scale of 1:200,000, and in some parts 1:10,000. In addition to those surveys, the detailed geological survey was conducted in the Bu Me Prospect together with the geochemical exploration, the electric (IP method) and magnetic surveys, trenching as well as shallow pit survey. Their results were compiled on maps at a scale of 1:2,000.

(3) The geoscientific studies of the previous work revealed that the survey area has mineral potential for gold, copper, tin, and tungsten. Special attention for exploration is paid to the tin-tungsten Bu Me Prospect.

(4) 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.

(5) 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 eastern and western parts of the survey area. These faults were formed during Tertiary time and the granitic rocks are cut by the faults. These faults are post-mineralization.

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

a) Gold is associated with quartz veins. Quartz veins are relatively concentrated in the Luong Son mineralization zone, where the existence of gold

was confirmed through chemical analysis of vein samples and geochemical samples. Further point of interest is the existence of a wide acidic alteration zone around the mineralization zone. Quartz veins are concentrated also in the Coc Thuong mineralization zone where the presence of gold was confirmed at some places. Gold and Cu anomalies are found to occur concentrated over this mineralization zone. Thus, this zone is considered to be promising for future exploration for gold.

b) Regarding copper mineralization, the Hon Mo mineralization zone is promising. The ores of this zone is hosted by gabbroic body and have massive and dissemination type of occurrence. The copper content is low at the outcrop, however, there is a possibility for this zone to be an orthomagmatic deposit associated with mafic intrusive rocks. The mineralization contains also gold. From the above, this zone is concluded to be one of the priority areas for future exploration.

c) Tin-tungsten mineralization is represented by the Bu Me Prospect in this area. This 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. The prospect is divided into several mineralization zones. Areal extent of the major mineralization zone is estimated to be 1,200 m x 400 m. The average grade of Sn+W is 0.33 % along trenches with about 320 m in total length. Although all kinds of exploration was not completed up to present time, it is believed that time is not mature to proceed to the detailed geological survey and drilling exploration due to the following three factors.

- Relatively low content of tin and tungsten
- Low level of tin market
- Worldwide prevalence of exploitation from placer deposits with low price

The present geochemical exploration revealed that the southwestern granite area is highly promising for tin-tungsten mineralization, following the Bu Me Prospect. However, access to the area is not favorable, and

transportation costs will be a negative factor for development. The survey for calculating reserves can be carried out in the area, but the priority of mineral exploration is low considering the commercial value.

2. Recommendations for Phase II Survey

The following work is recommended for Phase II survey on the basis of the above conclusions.

(1) Detailed geological survey and geophysical prospecting covering the area from the Luong Son to Hon Mo mineralization zone.

- It is convenient to conduct the detailed geological survey for an area covering the above two zones because they are closely located.
- Geophysical prospecting (IP method) for selected areas

(2) Detailed geological survey for the Coc Thuong mineralization zone and the surrounding area.

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PART I OVERVIEW

PART I OVERVIEW

CHAPTER 1. INTRODUCTION

1.1. Background and Objectives

In response of 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 cooperative exploration of the Van Yen and Western Thanh Hoa Areas. The "Scope of Work" (SW) 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 exploration, and drilling during the period of three years from 1993 to 1995.

1.2. Objectives and Outline of Operations of Phase I Survey

1.2.1. Survey areas

The survey of this project was carried out in two areas, the Van Yen and Western Thanh Hoa Areas. These areas are located in the northern part of the Socialist Republic of Vietnam as shown in Figure 1. The two areas are enclosed by the following coordinates.

Van Yen Area

Northern Limit: 21°20′N
Southern Limit: 20°56′N
Eastern Limit : 105°00′E
Western Limit : 104°33′E

Western Thanh Hoa Area

Northern Limit: 20°10′N
Southern Limit: 19°50′N
Eastern Limit : 105°22′30″E
Western Limit : 105°00′E

During the Phase I survey carried out in fiscal 1993, the survey was conducted in the western and eastern halves of the Van Yen and Western Thanh Hoa Areas, respectively. These areas are enclosed by the following coordinates.

Van Yen Area

Northern Limit: 21°20′N
Southern Limit: 20°56′N
Eastern Limit : 104°46′30″E
Western Limit : 104°33′E

Western Thanh Hoa Area

Northern Limit: 20°10′N
Southern Limit: 19°50′N
Eastern Limit : 105°22′30″E
Western Limit : 105°10′20″E

- Areal extent of the Phase I survey
  Van Yen Area: 1,000 km²
  Western Thanh Hoa Area: 650 km²

1.2.2. Objectives of Phase I survey

The phase I survey was carried out with the following major objectives.

1) Collection and analysis of available relevant data

This work was done in order to formulate detailed exploration program through the study of the previous surveys on geology, geologic structure, and mineralization with respect to the areas concerned.

2) Selection of promising areas

These areas were selected through the elucidation of relationship between geology, geologic structure and mineralization on the basis of the effective field survey supported by the analysis of the available relevant data.

1.2.3. Work of the Phase I survey

The Phase I survey consisted of the following activities.

1) Analysis of available relevant data

2) Geological survey

3) Geochemical exploration

Scope of the work

The scope of the work during this phase is as follows.

Table I-1 Survey Contents and Laboratory Studies

Survey and Laboratory Works	Areas and Amount of Works		
Geological Survey and Geochemical Exploration	Van Yen Area	Western Thanh Hoa Area	Total
1) Areal extent	1,000 km²	650 km²	1,650 km²
2) Geochemical exploration			
Stream sediments	899 samples	532 samples	1,431 samples
Soils		241 samples	241 samples
Panned concentrates	193 samples	147 samples	340 samples
3) Laboratory works			
Thin section study	34 samples	28 samples	62 samples
Polished section study	26 samples	15 samples	41 samples
X-ray diffraction	8 samples	16 samples	24 samples
4) Chemical analysis			
Rock	23 samples	16 samples	39 samples
Ore	78 samples	46 samples	124 samples

Duration of the work

The duration of the work of this phase is listed in Table I-2.

1.3. Organization of the Survey Team

The preparatory survey team visited Vietnam for the preliminary survey and conclusion of scope of work during the period from 13 to 29 July, 1993.

Table I -2 Schedule of the Work

ITEMS OF THE WORK	'93/Oct.	Nov.	Dec.	'94/Jan.	Feb.	REMARKS
Travel to Vietnam	24–25					
Preparation	26–28	21–23				
Analysis of Available Relevant Data	29–31					
Field Survey Van Yen Area Western Thanh Hoa Area		24–30 1–20				47 days
Analysis in Vietnam			21–30			10 days for compilation, analysis, and interim reporting of the field survey
Return Trip to Japan			31			two days
Analysis in Japan				1–27		
Presentation of Report					28	

1.3.1. Preparatory survey team

Vietnamese members

Tran Dy	(General Director, GSV)
Tran Van Tri	(Deputy General Director, GSV)
Vu Ngoc Xuan	(Director of Industrial Department State Planning Committee)
Pham Xuan Hoang	(Deputy Director, International Cooperation Department, Ministry of Heavy Industry)
Doan Ky Thuy	(Director, Chief of International Cooperation Division, GSV)
Le Van De	(Deputy Director, International Cooperation Division, GSV)

Japanese members

Katsuo YOKOYAMA	(Team leader; Metal Mining Agency of Japan)
Masayoshi SHIMODE	(Metal Mining Agency of Japan; Bangkok)
Kousuke TAKAMOTO	(Metal Mining Agency of Japan)
Taro KAMIYA	(Metal Mining Agency of Japan)
Koh NAITO	(Japan International Cooperation Agency)

1.3.2. Field inspection

Yoshiaki IGARASHI	(Metal Mining Agency of Japan)

1.3.3. Field survey team

Vietnamese members

【Van Yen Area】

Nguyen Cong Luong	(Team leader; Geological Mapping Division, GSV)
Trinh Huu Nghi	(Geological Mapping Division, GSV)
Dinh Van Tuy	(Geological Mapping Division, GSV)
Nguyen Van Cu	(Geological Mapping Division, GSV)
Le Van Dieu	(Geological Mapping Division, GSV)

【Western Thanh Hoa Area】

Ho Nhiem	(Team leader; Division No.4, GSV)
Dau Ba Quang	(Division No.4, GSV)
Tran Cong Bong	(Division No.4, GSV)

Nguyen The Phuc (Division No.4, GSV)

Le Ich Nhi (Division No.4, GSV)

Japanese members

Yuya FURUKAWA (Team leader; Nikko Exploration & Development Co., Ltd.)

Masataka OCHI (Nikko Exploration & Development Co., Ltd.)

Motomu GOTO (Nikko Exploration & Development Co., Ltd.)

Kazuyasu SUGAWARA (Nikko Exploration & Development Co., Ltd.)

Norihiro NAGANO (Nikko Exploration & Development Co., Ltd.)

CHAPTER 2. GEOGRAPHY

2.1. Location and Access

Van Yen Area

This area is located about 150 km west of Hanoi and belongs to the Son La province in terms of administrative district. The largest village called Phu Yen lies in the north-central part of the area. Its population is about 3,000, and has one state-operated and two private hotels. 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 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 is about six hours drive by jeep. 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 from the dam constructed near Hoa Binh up to Phu Yen.

The southern route leads to Phu Yen via Moc Chau and Van Yen through the national roads No.6 and No.155. The distance along the roads is about 270 km and it takes roughly eight hours by jeep from Hanoi. In this route it is necessary to cross the Da River by ferry at Van Yen and more than 30 minute wait may be necessary. The road No.155 from Moc Chau is unpaved toward Phu Yen, but is wider than the northern road No.24.

The car-road network is very sparse in this survey area. There are two roads for vehicle transport through this area, one is the north-south direction and the other east-west. The footpaths are developed with relatively high density along the major tributaries and on the ridges. Not only the above ferry but also various sizes of motor boats are available to cross any parts of the Da River of 1 km wide. The boats are useful for the survey along the River.

Western Thanh Hoa Area

This area lies about 140 km to the southwest of the above Van Yen Area. The central part of the area is about 130 km south-southwest as the crow flies

from Hanoi. The area belongs to the Thanh Hoa province in terms of administrative district. The survey area is easy of access through Thanh Hoa city. 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 are needed to reach Thuong Xuan in the southeastern edge of the survey area by vehicle on the provincial road from Thanh Hoa with the distance of 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 Thuong Xuan.

Density of the car-road network is higher than that of the Van Yen Area as shown Figure 1. However, those roads are made of red-soil and are narrow. Thus, travel is difficult with even little rain. The bamboo rafts are available along the major rivers, but only two motor boats exist in the area.

2.2. Topography and Drainage Systems

Van Yen Area

This area is situated in the steep mountainous belt that ranges in altitude from 100 m to 1,400 m. The altitudes of the ridges roughly decrease from north southward and the ridges run in the NW-SE direction, namely parallel to the major geologic structures. Limestone beds occur in the central, eastern, and southern parts of the area and the parts are characterized by the karst landforms. Mt. To (altitude: 1,425 m) in the northwest and Mt. To (altitude: 1,269 m) in the southeast are the representative high peaks in the area.

The major drainage system also flow in the NW-SE direction parallel to the major faults. The tributaries flow into the main rivers from the north 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 has been constructed at Hoa Binh on this river. Thus, the river is 1 km wide in the survey area, and many old small village including Van Yen are now submerged. Other large rivers are the Toc, Be, and Bua Rivers.

Western Thanh Hoa Area

There is a large topographic difference between the western and eastern parts of this area. The boundary of the above two parts is an N-S trending major fault in the central part. 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 belong 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 September) and dry (October to April). The precipitation is very low during the dry season in these areas. There were one to two rainy days periodically within seven to ten days during this field survey from November to December. Rainy days are frequent until the middle of September, but almost everyday is fine from the beginning of October.

Hot days continue until the end of November with the temperature approaching 30°C, while from December, the temperature 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 below for reference. The temperature and precipitation are respectively lower and higher in the mountainous survey areas than the data below.

Table I-3 Monthly Meteorological Data in Hanoi

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Temperature(°C)												
Maximum	20.4	20.4	23.1	27.3	31.7	32.8	32.7	32.0	30.9	28.8	25.6	22.0
Minimum	13.8	14.7	17.5	20.8	23.9	25.5	25.7	25.4	24.3	21.6	18.2	15.0
Average	16.6	17.1	19.9	23.5	27.1	28.7	28.8	28.3	27.2	24.6	21.2	17.9
Average 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 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 broadleaf and coniferous trees. However, many places have been cultivated for upland rice by the slash-and burn agriculture, not only in the lowlands but on the steep mountain sides.

CHAPTER 3. REGIONAL 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.

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 north-east and the "West Bacbo" and "Truongson" provinces in the south-west (GSV, 1991) as shown in the Figure I-3-1. 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, however, there are some geological differences (see Figure I-3-2 and I-3-3).

In and around the survey area, the Proterozoic to Cambrian (PR_{12}, $PR_3 \in_1$), Cambrian to Lower Ordovician ($\in O_1$), Lower to Middle Devonian (D_{12}), and Upper Permian to Upper Triassic (P_2T_1, T_2, T_{23}, T_3) strata are widely developed, and the Ordovician to Silurian (SO), Upper Silurian to Lower Devonian (S_2D_1), Upper Jurassic to Upper Cretaceous (J_3K, K_2) units are partly found. The Cenozoic formations with the exception of the Quaternary unit is

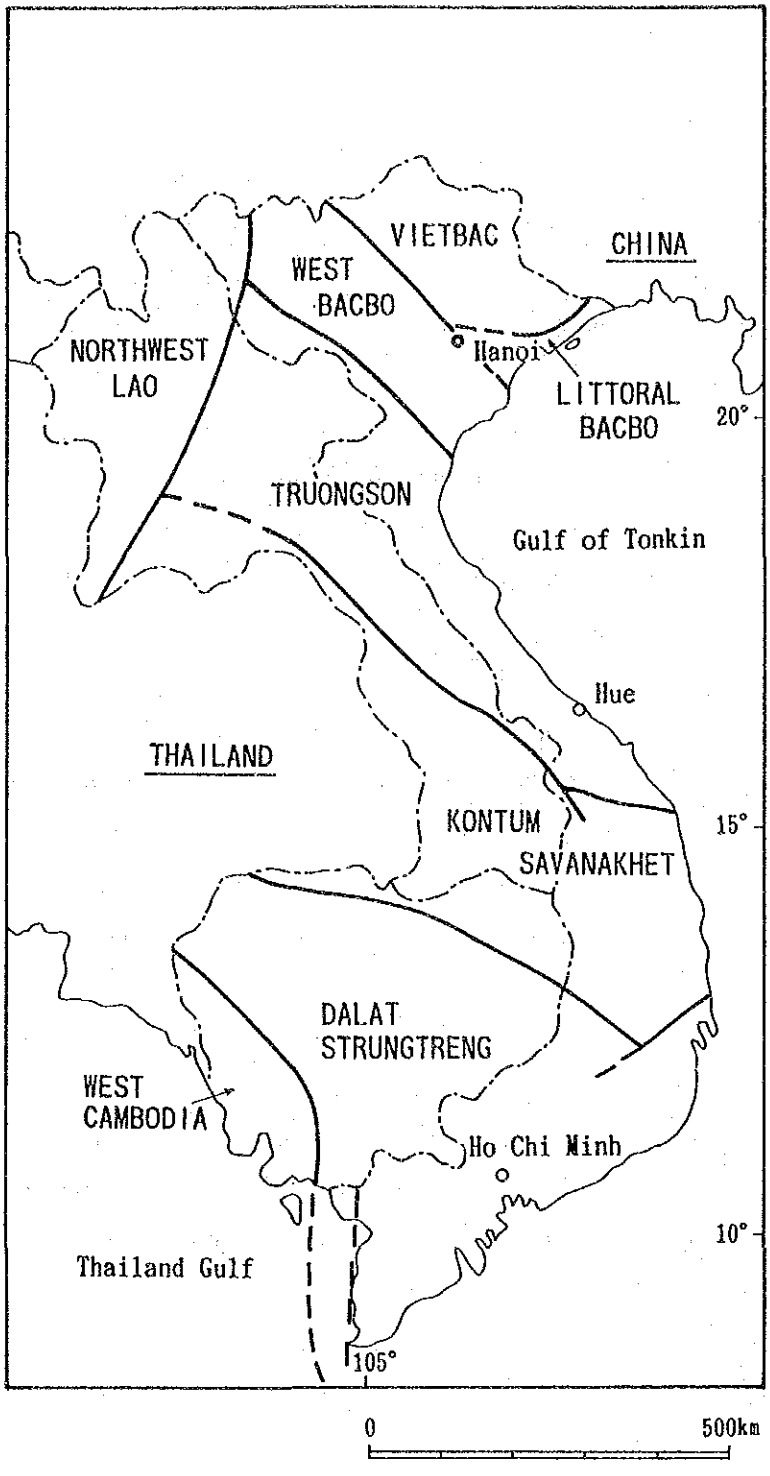
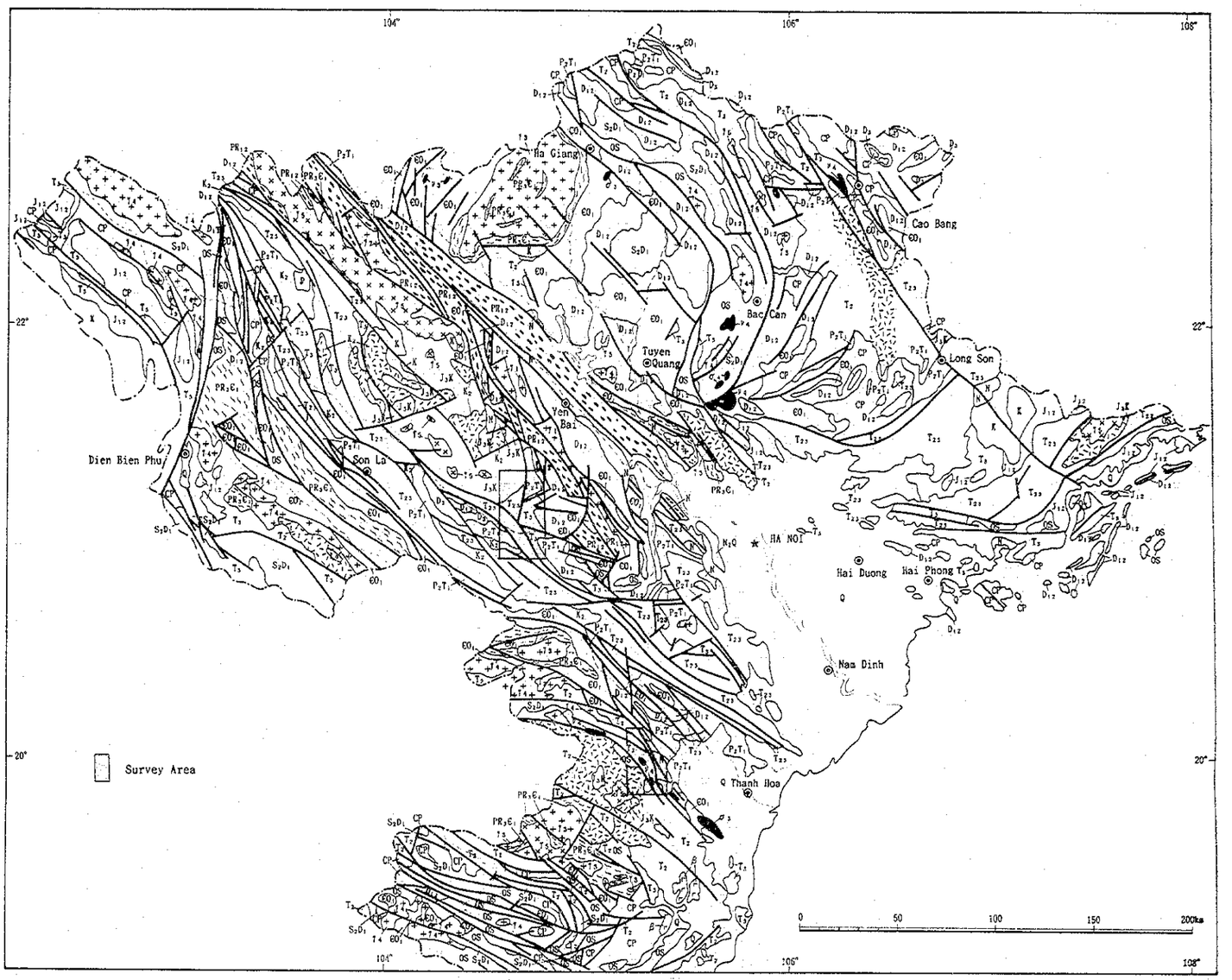


Fig. I -3-1 Tectonic Provinces of Vietnam, Laos, and Cambodia



(Simplified from ESCAP, 1990)

LEGEND

STRATIFIED ROCKS

- Q / β : Quaternary : Alluvium with marine deposits in coastal area, β : Basalt
- N_2Q : U. Neogene-Quaternary : Gravel, clay, pebble, laterite
- N : Neogene : Conglomerate, sandstone, claystone, lignite
- P : Paleogene : Trachyte, leucitophyre
- K_2 : U. Cretaceous : Red continental deposits-conglomerate, sandstone, siltstone
- K : Cretaceous : Red continental deposits of conglomerate, sandstone, siltstone, rhyolite
- J_3K : U. Jurassic-Cretaceous : Orthophyre, tuff, basalt, rhyolite
- J_{1-2} : L-M. Jurassic : Cotinental deposits of conglomerate, sandstone, siltstone
- T_3 : U. Triassic : Conglomerate, sandstone, marly shale, coal
- T_{2-3} : M-U. Triassic : Shale, limestone, conglomerate, sandstone, basalt, rhyolite
- T_2 : M. Triassic : Conglomerate, sandstone, shale, limestone, rhyolite
- P_2T_1 : U. Permian-L. Triassic : Conglomerate, siltstone, siliceous limestone, shale, coal, basalt
- CP : Carboniferous-Permian : Shale, coal, limestone, chert with andesite and basalt
- D_3 : U. Devonian : Limestone, chert, shale
- D_{1-2} : L-M. Devonian : Conglomerate, sandstone, shale, limestone
- S_2D_1 : U. Silurian-L. Devonian : Sandstone, shale, limestone, rhyolite, chert
- OS : Ordovician-Silurian : Conglomerate, sandstone, shale, chert, rhyolite, orthophyre
- $\in O_1$: Cambrian-L. Ordovician : Limestone, shale, quartzite, greenstone, chert
- $PR_3\in_1$: U. Proterozoic-L. Cambrian : Schist, quartzite, dolomite
- PR_{1-2} : L-M. Proterozoic : Gneiss, amphibolite, quartzite, marble

INTRUSIVE ROCKS

LATE MESOZOIC-EARLY CENOZOIC

- $\gamma\delta_5$: Granodiorite, granite, granosyenite, diorite

LATE PALEOZIC-EARLY MESOZOIC

- γ_4 : Biotite granite, granophyre, granodiorite, diorite
- ν_4 : Gabbro
- σ_4 : Dunite, peridotite

EARLY-MIDDLE PALEOZOIC

- γ_3 : Biotite granite, plagiogranite, granodiorite, diorite
- ν_3 : Gabbro-diabase, gabbro
- σ_3 : Serpentinite, dunite

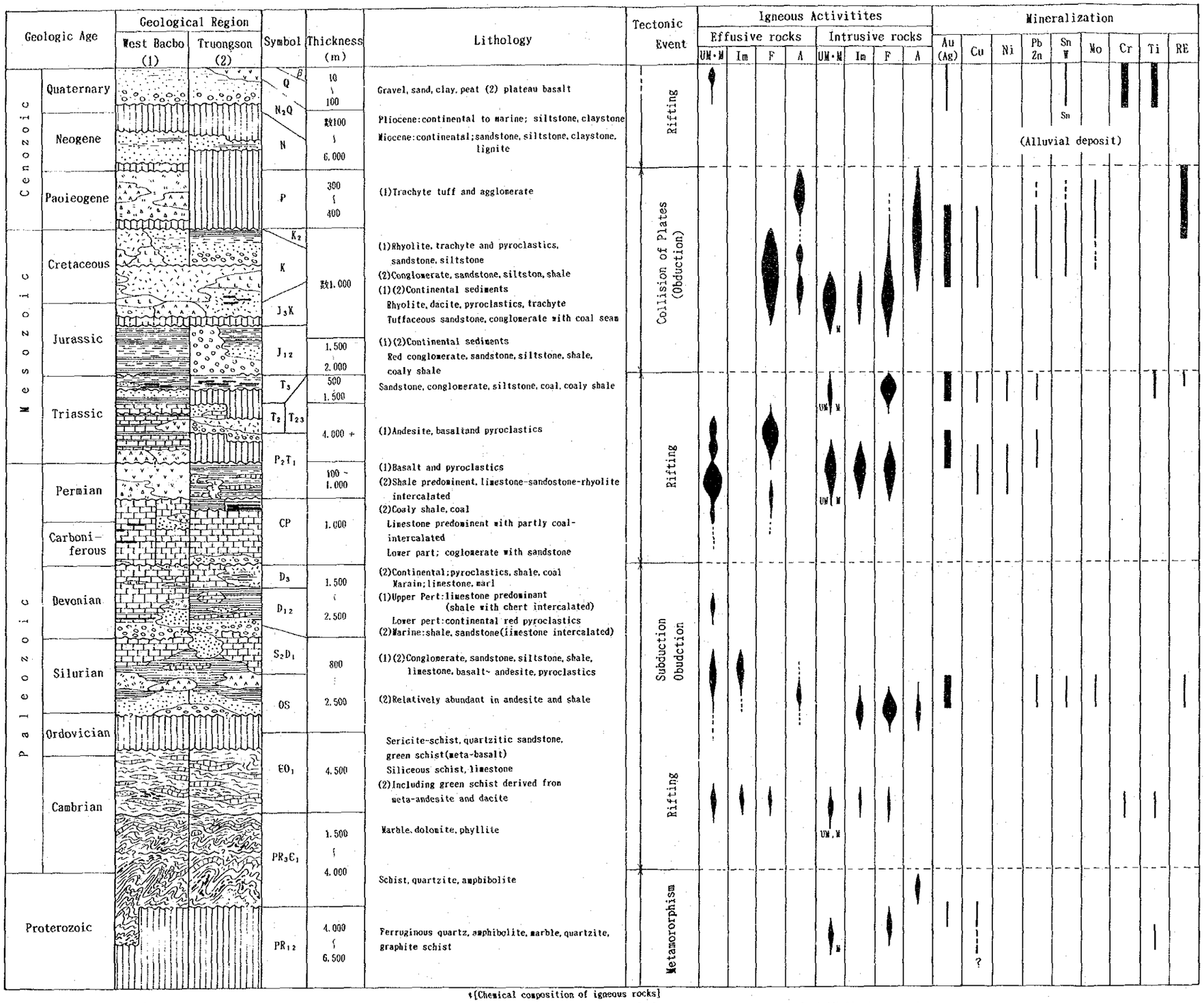
PROTEROZOIC

- γ_2 : Granodiorite, granite, migmatite
- γ_1 : Plagiogranite, granodiorite, granite, migmatite

Fault — Felsic volcanics — River

U: Upper M: Middle L: Lower

Fig. I -3-2 Generalized Geologic Map in the Northern Part of Vietnam



*[Chemical composition of igneous rocks]

UM:Ultra-mafic rocks, M:Mafic rocks, Im:Intermediate rocks, F:Felsic rocks, A:Alkaline/▬▬:Lage reserves

Fig. I -3-3

Comprehensive Columnar Sections in the Northern Part of Vietnam

restricted and sporadic.

The Proterozoic to Cambrian (PR_{12}, $PR_3\in_1$) and Cambrian to Lower Ordovician ($\in O_1$) units are developed mainly on the right bank of the Ma River and the right bank of the Da River, and are composed of metamorphic rocks, namely crystalline schist, quartzite, and marble as well as limestone. The Lower to Middle Devonian (D_{12}) are composed of terrestrial red clastic rocks and marine sedimentary rocks consisting mainly of shale and sandstone, and occur on the periphery of the Proterozoic to Cambrian and Cambrian to Lower Ordovician masses. The Upper Permian to Upper Triassic (P_2T_1, T_2, T_{2s}, T_3) 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 (Figure I-3-1 and I-3-2).

In and around the survey areas, the Proterozoic intrusives (γ_1, γ_2) intruded concordantly into the Proterozoic metamorphic rocks on the right bank of the Hong River. Besides, Early to Middle Paleozoic felsic rocks (γ_3) consisting of diorite and granite and Late Paleozoic to Early Mesozoic felsic rocks (γ_4) of same nature as the above are located on the right bank of the Ma River ("Truongson" province) occurring as fairly large masses. Regarding ultramafic and mafic rocks, Early to Middle Paleozoic rocks (σ_3, ν_3) and Late Paleozoic to Early Mesozoic rocks (σ_4, ν_4) are found. They consist of dunite and gabbro and turn out generally in the shape of small lenticular bodies. Although Late Mesozoic to Early Cenozoic intrusives (γ_5) 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 Van Yen 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 basically in the NW-SE direction. Boundaries of tectonic provinces are the main tectonic lines which extend in the NW-SE direction along the Hong River and the Ma River. 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 are not verified yet. These plate movements were accompanied with 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 are remarkable also in the survey areas. The wide spread Upper Permian to Upper Triassic (P_2T_1, T_2, T_{23}, T_3) units covers an area of 20 to 40 km wide elongated in the NW-SE direction. The Proterozoic to Cambrian (PR_{12}, $PR_3\in_1$) and Lower Paleozoic ($\in O_1$, SO, D_{12}) units are also located in a horseshoe-shaped area elongated in the NW-SE direction. These strata use 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 I-3-4. 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 Ha Son Binh Province and the Lang Mo and Cam Tam deposits in the northern part of Thanh Hoa Province are 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.

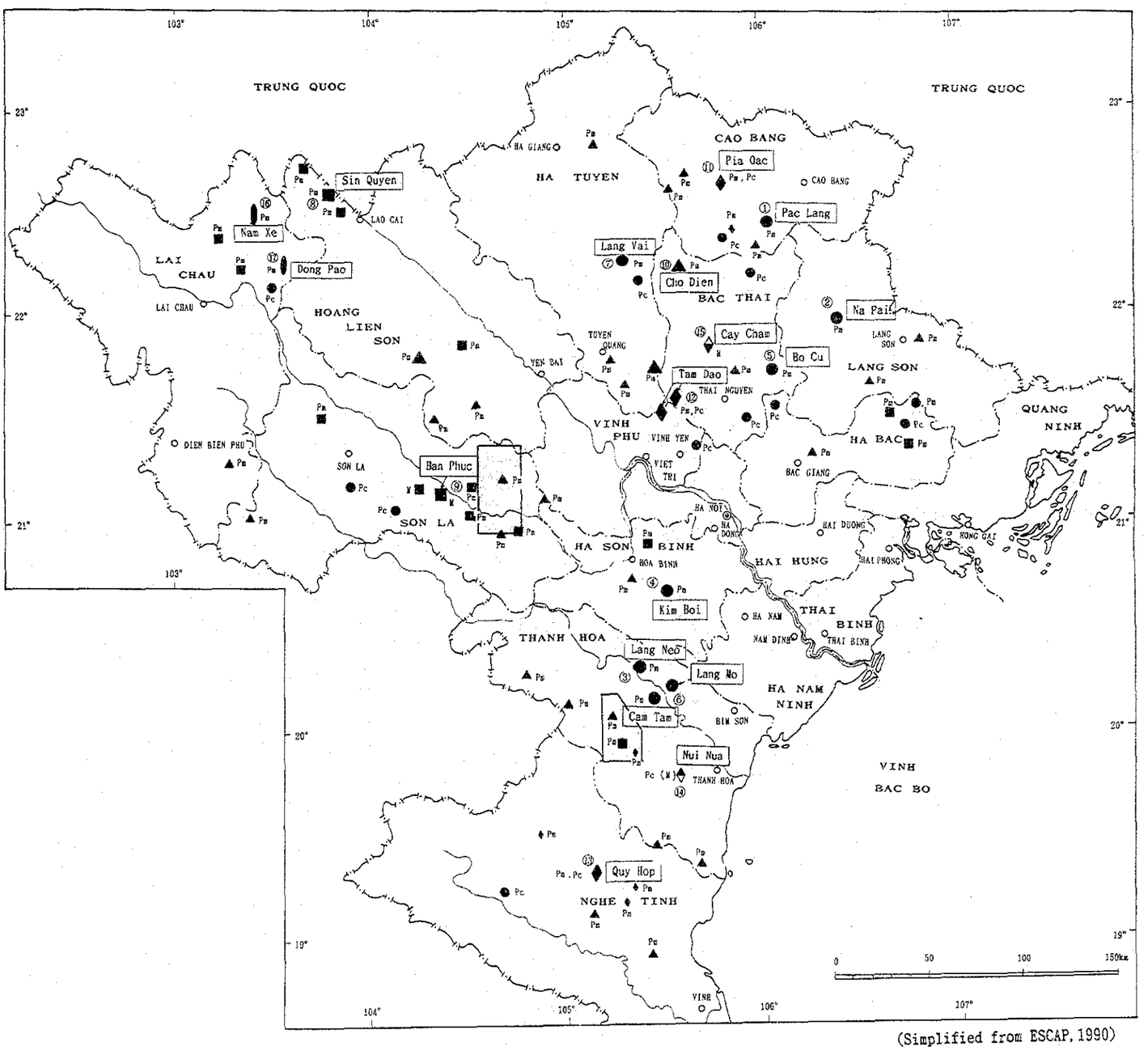
As a representative nickel-copper deposit, the Ban Phuc deposit is known in Ta Khoa region, Son La Province. This largest nickel-copper sulfide deposit in Vietnam is of vein and dissemination type accompanying ultramafic bodies of Permian to Triassic age. This deposit is located on the right bank of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

As tin-tungsten deposit, the Quy Hop deposit composed mainly of placer is known in Nghe Tinh 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 Bac Thai Province is well known. In the survey areas, however, lead-zinc deposits are sporadically located, and details on scale and location are not known.



(Simplified from ESCAP, 1990)

Metallic Mineral*	Genetic Type	Others
● AU (-Ag)	M : Magmatic	Pac Lang ① Name of deposit or mine with its number
■ Cu, Ni-Cu	Pm : Post-magmatic	Boundary of Province
▲ Pb-Zn	Pc : Placer	Survey Area
♦ Sn-W		
◈ Cr		
◈ Ti		
▮ Rare -Earth		

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

Fig. I -3-4 Distribution Map of the Major Ore Deposits in the Northern Part of Vietnam

PART II ANALYSIS OF AVAILABLE RELEVANT DATA

PART II ANALYSIS OF AVAILABLE RELEVANT DATA

CHAPTER 1. PREVIOUS SURVEYS

1.1. Van Yen Area

The geological surveys and geochemical exploration have been carried out covering the whole survey area. Some geologic maps have already been published at scales of 1:1,500,000, 200,000, and 50,000, but the 1:50,000 maps have not been completed.

Soil and panned concentrate geochemical exploration was done in the past with considerably high density. The collected samples amounted to about 6,000. The panned-concentrate sampling is particularly popular in Vietnam. Thus, the panning skill is high. The compilation results of the above data are shown in Plate 1. Also magnetic survey was conducted in the eastern part of the survey area, but the data were not available.

The available relevant data in both areas are laid out in TableII-1-1. Additionally, a list of the known mineral showings in this area is given in TableII-1-2.

1.2. Western Thanh Hoa Area

The geological survey was carried out covering the whole survey area in the past. Two kinds of geologic map have already been published at scales of 1:1,500,000 and 200,000. In addition to those surveys, the detailed geological survey was conducted in the Bu Me and Lang Mun areas and 1:10,000 scale geologic maps have been prepared. Soil and panned concentrate geochemical exploration was done in the Bu Me area. Moreover, the electric (IP method) and magnetic surveys, trenching as well as shallow pit survey were carried out in tin-tungsten mineralization zone (the Bu Me Prospect) in the eastern part of the Bu Me area. The tin-tungsten zones are being exploited by local inhabitants in small scale.

Table II-1-1 List of the Available Relevant Data (1)

1.Both Areas

Name of data	Quantity	Scale	Author
1)Geological map of Viet Nam (1986)	1	1:1,500,000	ESCAP
2)Geological map of the Socialist Republic of Viet Nam	1	1:200,000	GSV
3)Mineral resouces map of Viet Nam(1986)	1	1:1,500,000	ESCAP
4)The photogeological Interpretation of Satellite Images in The Northern part of The Socialist Republic of Vietnam(1993)(in Japanese)	1		JICA and MMAJ

2.Van Yen Area

Name of data	Quantity	Scale	Author
1)Geochemical map of the Van Yen Area	1	1:50,000	GSV
2)Geochemical map of the Van Yen Area	6	1:200,000	GSV
3)Map of heavy mineral concentrate of the Van Yen Area	1	1:200,000	GSV
4)Maps of minerals in the Van Yen Area	1	1:200,000	GSV
5)Summary of report on geological situation in the Van Yen Area	1		GSV

Table Ⅱ-1-1 List of the Available Relevant Data (2)

3.Western Thanh Hoa Area

Name of data	Quantity	Scale	Author
1)Geochemical map of the Thanh Hoa Area	2	1:200,000	GSV
2)Geochemical anomalous map of cassiterite, wolframite and gold by pan concentrate in the Thanh Hoa Area	1	1:10,000	GSV
3)Geochemical anomalous map of cassiterite, wolframite and gold by pan concentrate Thuong Xuan,Thanh Hoa Area	1	1:10,000	GSV
4)Geological columnar Section of the Thanh Hoa Area	1		
5)Geological map of the Bu Me Area	1	1:10,000	GSV
6)Geological map of the Western Thanh Hoa Area	1	1:200,000	GSV
7)Geological map with mineral distribution of the Thanh Hoa Area	1	1:200,000	GSV
8)Geological map of Lang Mun area, Thuong Xuan, Thanh Hoa Area	1	1:10,000	GSV
9)Geophysical Cross Section, Bu Me, Thanh Hoa Area	1	1:2,000	GSV
10)Map of heavy mineral concentrate of the Thanh Hoa Area	1	1:200,000	GSV
11)Map of resistivity, inductivity and magnetism, Bu Me, Thanh Hoa Area	2	1:2,000	GSV

Table II-1-1 List of the Available Relevant Data (3)

Name of data	Quantity	Scale	Author
12)Map of the mineral distribution the Thanh Hoa Area	2	1:200,000	GSV
13)Map of the results of the exploration for Tin-tungsten ore deposits	1	1:2,000	GSV
14)Mineral distribution map of the Thanh Hoa area	1	1:200,000	GSV
15)Summary of report on geological situation in the Western Thanh Hoa	1	1:200,000	GSV

Table II-1-2 Characteristics of the Known Mineral Showings Based on the Available Relevant Data

Mine	Location	Type	Ore mineral	Gangue mineral	Dimension	Ore grade	Country rock	Exploration/Production
Bon Vam Ban	Suoi Dame	Diss.	Au	Actinolite	1.2km× 10m	Au:0.3 g/t	Trachyte	
Suoi Tiat	Tiat river	Vein	Au,Cp,Py	Qz,Chl	1~2km× 500m	Au:1~ 51.83 g/t	Basaltic and.	in production
Ban Pun	Ban Buu Trong	vein	Au	Qz	1km× 100-300m	Au:6.2 g/t	Basaltic tuff	
Van Ban Pun	Tuong Phu	Vein	Cp,Cc	Cal,Ep		Au:0.6-0.8 g/t Cu:1.32 %	Basaltic tuff	
Suoi Let	Ban Tam Peo	Vein	Cp,Cv,Py	Qz,Chl	500m× 20-30m	Cu:2.05 %	Basalt	Trench
Suoi Bao	Bao river	Vein	Cp,Oxcp	Qz	500-1000m× 30m	Cu:16.55 %	Trachyte	Drift
Ban Ban	Ban Buu Trong	Vein			100-150m× 20m	Cu:4.13 %	Basalt	
Ban Nhoy	Suoi Niot	Vein			40-60m× 5-10m	Au:0.4 g/t	Basalt	
Phae Lang 1	Som Buc	Vein			30m× 5-10m	Au:0.3 g/t Cu:2.25 %	Basaltic tuff	
Phai Lang 2	Tan Si Tai	Vein			30m× 5-10m	Au:<0.3 g/t Cu:<0.5 %		Basaltic tuff
Bancho	Suoi Kan	Floats				Pb:28.76-36.72 % Zn:9.04 %		
Suoi Cu	Suoi Cu	Floats			200m× 2-2.5m	Pb:6.8-8.86 %		
Suoi Den	Suoi Den	Vein			20-30m× 5-7m	Zn:16.09-25.07 % Au:0.3 g/t	Limestone	Trench
Ban Coc	Suoi Coc	Vein			50m× 3-7m	Cu:4.2 %	Diabase	
Cinnaber	Ban Na Dane	Vein			2000m× 3-10m	Hg:0.0032 %		Basalt

Abbreviation:Au;gold,Cp;chalcopyrite,Py;pyrite,Cc;chalcocite,Cv;covelline,Oxcp;oxidized copper minerals
Qz;quartz,Chl;chlorite,Ep;epidote,Cal;calcite,diss;dissemination,and;andesite

CHAPTER 2. ANALYSIS OF AVAILABLE RELEVANT DATA

2.1. Mineralization

2.1.1. Van Yen Area

The following characteristics regarding mineralization have been recognized in the data acquired by the past exploratory work. Gold, copper, lead and zinc mineralization is known in this area. The gold and copper mineralization is concentrated in an NW-SE trending belt bounded by the "Toc River Fault Zone" and the Da River. This belt is characterized by the prevalence of mafic to intermediate volcanic activities during the Early Triassic time, and is underlain by thick sequences of trachybasalt (to trachyandesite) lavas and its pyroclastic rocks. These rocks have been affected by the low-grade regional metamorphism and exhibit schistosities. Although not yet clarified, there probably is some kinds of genetic relationship between the gold and copper mineralization and the above volcanic activities in view of the concentration of the gold and copper mineralization zones. Additionally, the gold and copper mineralization seems to be related to pyritization because the pyritization was reported in the vicinity of the above mineralization zones.

The lead and zinc mineralization is concentrated in the areas of Middle Triassic carbonate rocks. Only some floats of the ore were found until present time and no intrusive body occurs in the areas. Nevertheless some subsurface contact metasomatic deposits are inferred to have possibly been emplaced in the wide areas of carbonate rocks (see Plate 1).

2.1.2. Western Thanh Hoa Area

Gold, copper, tin, and tungsten deposits and mineral showings have been described in this area (see Plate 2). Many mineral showings of gold occur in the northeastern part of the area, but most of them are of placer type. Other showings of gold in the south are of vein type associated with quartz veins. Some copper showings lie in the central part of the area. It is inferred that the copper mineralization is genetically related to gabbroic plutonism because of the wide occurrence of gabbroic rocks in that part.

The tin-tungsten mineralization is observed in the Bu Me Prospect which is now under exploration (see Plate 3). This prospect is located at the eastern foot of Mt. Me (Bu Me, altitude: 703 m) in the southeastern part of this area. The mineralization zones are developed in the center and peripheries of the Cretaceous granites and the mineralization has close genetic relation to the rocks. Some showings of tin-tungsten were found also in granites of the southwestern part (see Plate 3). Granitic bodies of the similar lithofacies intruded into other geologic units in the central to western and northern parts of this area, but no tin-tungsten mineralization was recognized in those bodies.

2.2. Previous Geochemical Exploration

2.2.1. Van Yen Area

As previously mentioned, soil and panned concentrate geochemical exploration was carried out in this area. The pathfinder elements were Au, Cu, Pb, Zn, Ni, Cr, Co, and Hg. Heavy minerals were observed under microscope in the panned concentrate samples. During the present survey, Plate 1 showing the geochemical anomalous zones was compiled from the existing data. The results of the previous exploration can be summarized as follows.

Au:

Localities where gold grains were confirmed microscopically are plotted on the map. The map shows that these localities are most densely distributed in the the Lower Triassic Series belt bounded by the "Toc River Fault Zone" and the Da River, but the concentration of the gold localities is very restricted.

Cu:

The map shows the zones of soil anomalies of soil geochemistry (Cu$\geqq$0.003 %). Most of these zones occur also in the Lower Triassic areas. This is similar to the gold occurrence. These zones are wide.

Pb:

The anomalous zones (Pb$\geqq$2.4 g/m^3) of panned concentrates are delineated in the map. Distribution of the zones is restricted to the northwest and southeast of Phu Yen. Zinc anomalies do not occur in this area.

Ni:

The anomalous zones (Ni≧0.001 %) were detected through soil geochemistry. These zones roughly overlap those of Cu.

Cr:

Two kinds of anomalous zones (Cr≧0.005 % and CrO≧12 g/m^3) were obtained through the soil and panned concentrate geochemistry. All of these zones almost coincide with those of Cu and Ni.

Co:

Only one zone (Co≧0.005 %) of soil anomalies is shown on the map. It is located on the left bank of the Da River in the western part of the area and overlaps a Cr zone.

In addition to the above zones, some localities of cinnabar occurrences confirmed by microscopic study are plotted on the map, but they are restricted in a small part. Furthermore, occurrence of non-metallic minerals such as apatite, barite, and others were also examined together with the above metallic minerals.

2.2.2. Western Thanh Hoa Area

The geochemical exploration was conducted for the soil and panned concentrate samples over an area to the west of the above Bu Me mineralization zone with an areal extent of 9 km x 5 km. Total amount of collected samples is 3,018, and the pathfinder elements were Sn, W, and Au. No data are available in individual amounts between the samples of soil and panned concentrate. Plate 3 shows the Sn and W anomalous zones in and around the Bu Me mineralization zone. Gold anomalous zones were not delineated during this survey because they are not clear from the existing maps.

Tin panned concentrate anomalies were divided into the following four levels in the map by the previous survey.

(1) First level : $SnO_2 > 273$ g/m^3
(2) Second level: $SnO_2 = 273$ to 101 g/m^3
(3) Third level : $SnO_2 = 100$ to 51 g/m^3
(4) Fourth level: $SnO_2 < 50$ g/m^3

The anomalous zones of the first and fourth levels are not shown in Plate 3, because the zones of the first level are scattered and those of the fourth level occur in a large area without a clear indication of the mineralization.

Three zones of the second level have been detected in the part of the Bu Me mineralization zone, but they are very small. In addition to them, two small zones of this level have also been found in the western edge of granitic body and near the main stream of the Am River. The above body consists of Mt. Phamay (altitude; 463 m) that is located west of the Bu Me mineralization zone. Three zones of the third level have been found in the central part to the periphery of the granitic body on the eastern slope of Mt. Me. They are arranged in the N-S direction and the central one is the largest. These zones are distributed surrounding the two zones among the three of the second level that are located in the center and south of the alignment.

Some geochemical anomalous zones of Sn (Sn$>$0.02 %) by soil samples have been detected within the granitic body consisting of the Bu Me mineralization zone, but they are small.

With respect to the anomalous zones of W, both kinds of zones by panned concentrate ($WO_3 > 101$ g/m^3) and soil (W$>$0.02 %) samples are scattered with small dimensions in the Bu Me mineralization zone and in the vicinity of the Ho Kin reservoir.

2.3. Promising Areas Based on the Available Relevant Data

2.3.1. Van Yen Area

The principal mineralizations of this area is interpreted to be gold, copper, lead, and zinc from the results of previous work. As described earlier, there is a large possibility that gold and copper mineralization and pyritization are closely related one another. These are inferred to have close relationship with the Triassic intermediate to mafic volcanism. From the above, the following conditions are considered to be relevant factors for detecting gold and copper mineralized areas.

1) A belt of active volcanism

2) Presence of mineral showings of gold, copper, and pyrite

3) Superimposition of Au, Cu, and pyrite anomalies

The Suoi Tiat mine and the surrounding area (mentioned later) are in good agreement with the above conditions. Additionally, two areas can be promising with the conditions. Namely, one is the area to the west of middle to lower reaches of the Toc River and the other is the area of the north slope of the Bua River which is one of the main tributaries of the Toc River.

There are a few Cu, Cr, Ni, and Co geochemical anomalous zones on the slope of the left bank of the Da River. These zones occur superimposed. Furthermore, the Ban Phuc deposit is located 15 km west of the survey area. It is an orthomagmatic Ni-Cu deposit associated with ultramafic rock bodies. Therefore, these zones may have mineral potential similar to the Ban Phuc deposit.

The Middle Triassic limestone area is promising for lead-zinc mineralization, particularly in the area about 3 km southeast of Phu Yen. Some mineral showings of Pb-Zn have been found in this area as represented by the Suoi Boc showing. Occurrence of skarn type deposits is a possibility in the area in view of the above showings and the presence of geochemical anomalous zones of Pb-Ba.

2.3.2. Western Thanh Hoa Area

The principal mineralization is of gold, copper, tin, and tungsten in this survey area, based on the results of past work. It is supposed that the gold mineralization is associated with tin-tungsten mineralization and gold is expected to occur along the periphery of the granitic bodies. Thus special attention should be paid to the vicinity of the bodies. Similar to that, the mafic intrusive bodies can be the target for the copper exploration because of genetic relation inferred between the bodies and copper mineralization.

It is doubtless that the tin-tungsten mineralization has genetic relation to granitic intrusion from the available relevant data. Therefore, the most significant areas for the exploration are the greisenized granitic bodies and

the surrounding hornfels zones.

The following metallic mineral deposits are possibly found in three parts of the survey area shown below.

(1) Au, Cu, Sn, W: western half
(2) Au, Cu : central part
(3) Sn, W, Cu : area of Mt. Me of the southeastern part

PART III VAN YEN AREA

PART III VAN YEN AREA

CHAPTER 1. GEOLOGICAL SURVEY

1.1. Survey Methods

Conventional field methods including photogeological interpretation 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 supplementally conducted for mapping in some areas without field reconnaissance. 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.

1.2. Geologic Setting

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 compositions range from ultramafic to felsic.

This area is underlain chiefly by the Paleozoic and Mesozoic sedimentary, volcanic, and pyroclastic rocks. The Paleozoic strata occur in some of the eastern and western parts of the survey area, and consist of Devonian to Permian marine sediments represented mainly by limestone and mudstone. The Mesozoic is composed of Triassic and Cretaceous volcanic, pyroclastic, and sedimentary rocks. Although large intrusive masses have not been found in this area, small bodies of gabbroic and alkalic rocks of various types occur mainly in the Lower Triassic area in the central part of this survey area. They extend in the same direction as the structural trend of the Lower Triassic strata.

1.3. Stratigraphy

The basement of this area comprises the Devonian to Permian sedimentary rocks represented mainly by limestone and mudstone. Unconformably overlying the basement are volcanic, pyroclastic, and sedimentary rocks of Triassic (Early, Middle, and Late) and Cretaceous (Middle) Periods, and unconsolidated Quaternary sediments. Figure Ⅲ-1-1 shows the schematic columnar sections, and the geologic map and sections are given in Figures Ⅲ-1-2 and Ⅲ-1-3, respectively. Since the objective of the field work of this phase is not to pursue the detailed lithology of the geologic units, they are divided into "Systems" and "Series". Moreover the complicated symbols given to the units of the published geologic maps were simplified for the compilation of this phase as shown in Figure Ⅲ-1-2.

Numerous NW-SE striking faults are developed in the vicinity of two rivers named the Bua and Toc which flow southeastward in the central part of this area. These faults provide important control of 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 to the southwest and northeast of this fault zone. The schematic columnar sections are, therefore, separately prepared for the "Southwestern belt" and "Northeastern belt". The description of the intrusive rocks will be discussed in section 1.4.

(1) Lower Devonian Series (D_2)

This Series occur only in the northeastern edge of the survey area. It generally comprises dark grey limestone and extends outside the survey area to the north and southeast. The structural trend of the Series in the survey area is not clear. This Series is in fault contact with the Lower Triassic Series (T_1; mentioned later) to the southwest.

The apparent thickness calculated from the exposed rocks is estimated to exceed 1,000 m.

(2) Middle to Upper Devonian Series (D_{23})

This Series is found in the western edge of the survey area as two

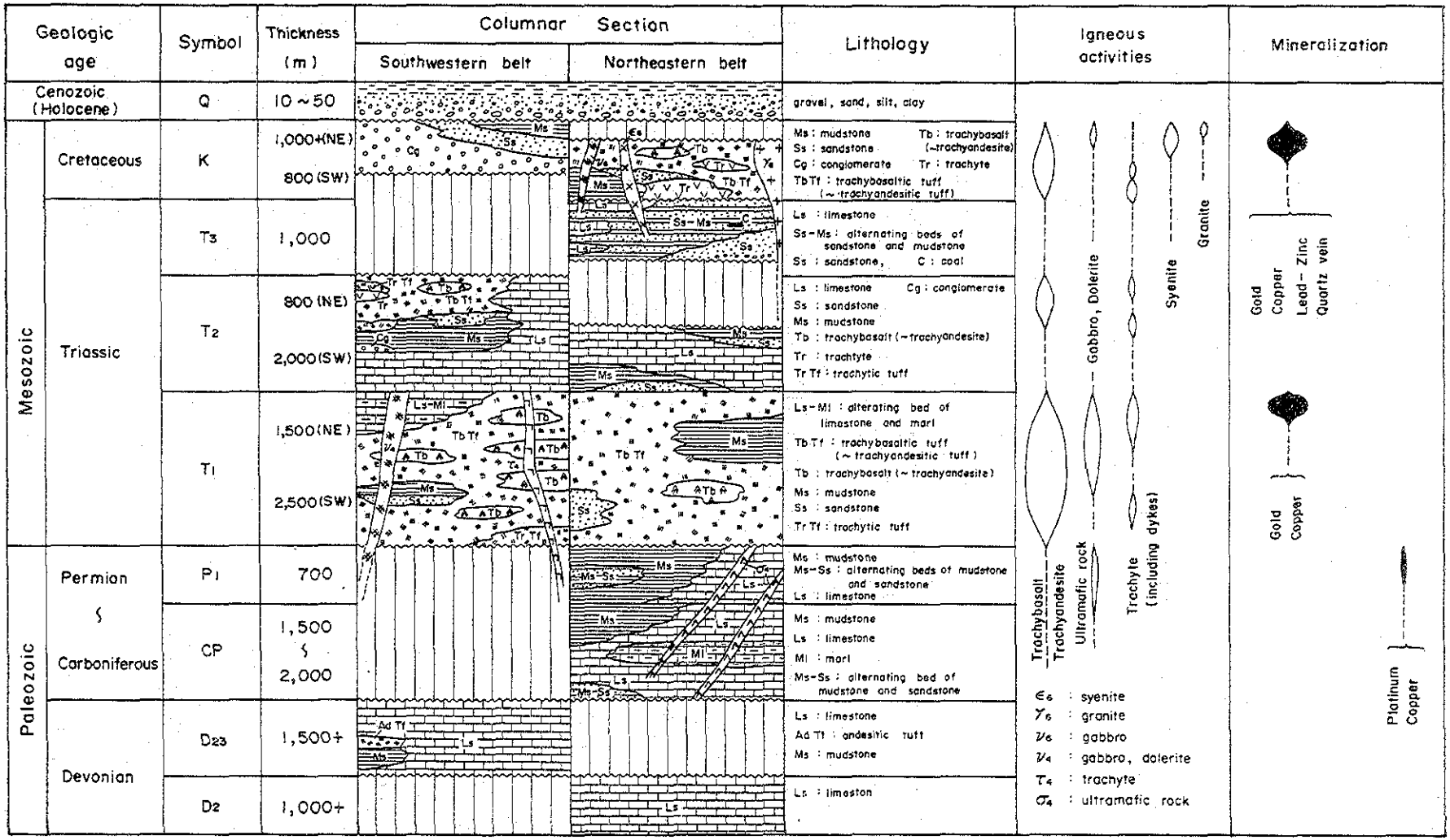


Fig.Ⅲ-1-1 Schematic Columnar Sections of the Van Yen Area

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 (T_2; mentioned later) 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 grey limestone. In the block on the left bank of the river, on the other hand, the beds of black mudstone and green andesitic tuff are intercalated with the above limestone. This Series is widely distributed to the west outside the survey area.

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

(3) Carboniferous to Permian System (CP)

This System occupies the eastern part of the survey area and forms two large folded mountain chains in the north and south ("North Chain" and "South Chain"). These chains have an E-W trend and the North Chain is about 5 km wide and the South Chain 7 km. Both distribution areas extend outside the survey area eastward. The relationship with the underlying D_2 and D_{2s} Series is not clear because these strata occur separate from this System.

The major part of the System in the North Chain is made up of dark grey seemingly massive limestone whose bedding is developed with intervals of about a meter. The thin upper part mainly consists of light grey to light greenish grey limestone to marly limestone which has well developed bedding planes 5 to 10 cm apart. Alternating beds of black mudstone and grey fine-grained sandstone as well as thin beds of black bedded chert are partly found near the basal part of this System.

In the South Chain, the major part also comprises limestone similar to that of the North Chain. Beds of somewhat brittle black marl are intercalated in the middle part of this System. The middle to upper part is dominated by hard and compact mudstone beds.

Some limestones in the major parts of both chains yield abundant fusulinids and corals.

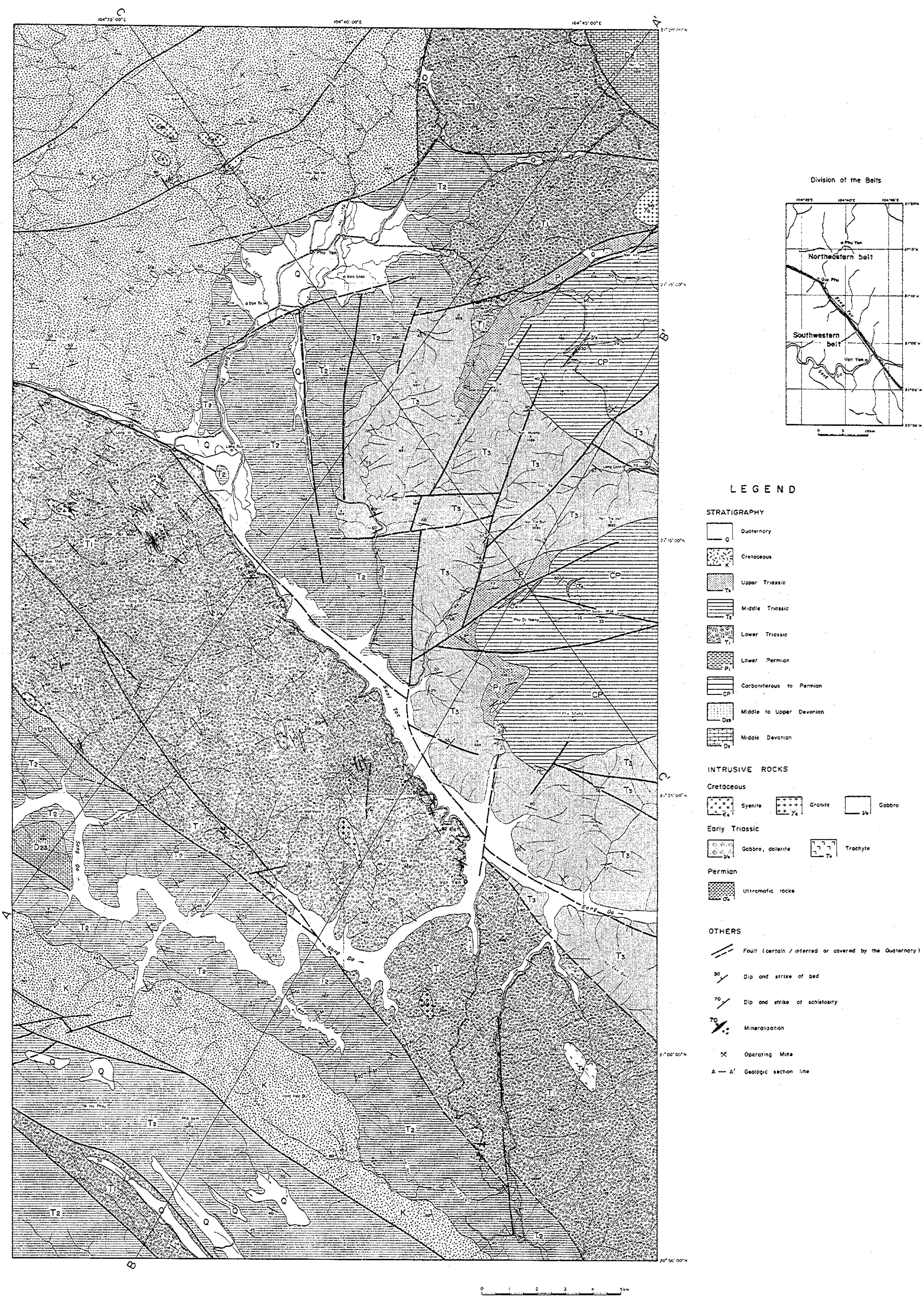
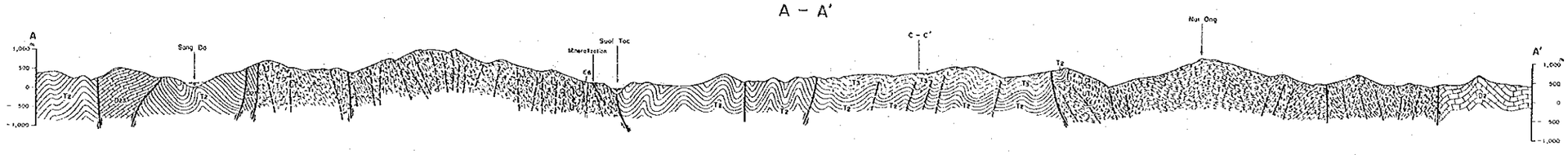
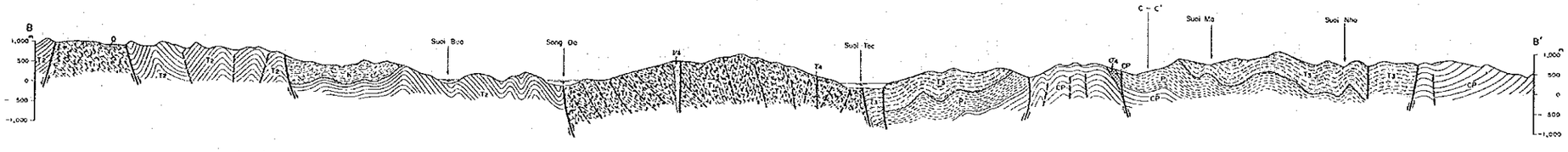


Fig.Ⅲ-1-2 Geologic Map of the Van Yen Area

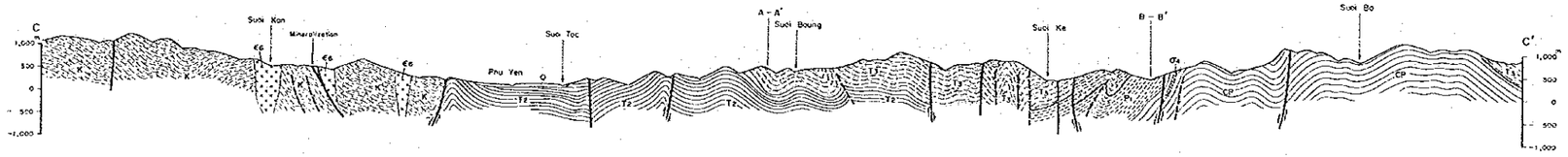
A – A′



B – B′



C – C′



LEGEND

STRATIGRAPHY

- Quaternary
- Cretaceous
- Upper Triassic
- Middle Triassic
- Lower Triassic
- Lower Permian
- Carboniferous to Permian
- Middle to Upper Devonian
- Middle Devonian

INTRUSIVE ROCKS

Cretaceous

- Syenite
- Granite
- Gabbro

Early Triassic

- Gabbro, dolerite
- Trachyte

Permian

- Ultramafic rocks

OTHERS

- Fault (certain / inferred or covered by the Quaternary)

Fig. Ⅲ-1-3

Geologic Sections of the Van Yen Area

The estimated thickness of the System in the area is 1,500 to 2,000 m.

(4) Lower Permian Series (P_1)

This Series is present along the northern and western margin of the two areas where the CP System (3) occurs. The Series has an unconformable relationship with the underlying the CP System, but some parts occur in fault contact with the System. In both mountain chains, the distribution of this Series is narrow with 1 km width.

The constituent rocks and their lithology in the North Chain differ from those of the South Chain. In the North Chain, the eastern part is dominated by massive limestone, but the western part is represented by black mudstone and occasional alternating thin beds of black mudstone and grey micaceous fine-grained sandstone. These stratified rocks are inferred to be in interfingering relationships. The South Chain, on the other hand, is generally characterized by complicated alternation consisting of well-bedded dark grey limestone, grey fine-grained sandstone, and black phyllitic mudstone. Among these rocks, the mudstone is prevalent and continuous outcrops can be observed on the path along the Ke Stream.

The thickness of this Series is 700 m in the survey area.

(5) Lower Triassic Series (T_1)

This Series occurs separately in the northeastern, central, 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.

【Northeastern part】

The T_1 Series occurs to the northeast and east of Phu Yen in the northeast. The strike of beds is variable, but the Series as a whole extends in the E-W direction and is 9 km wide. The Series conformably overlies the Middle Triassic Series (T_2) in many places, and occurs in fault contact with the Cretaceous System (K).

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 grey 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. The bedding of the above fine tuff is developed every a few cm.

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

【Central part】

The T_1 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.

The main central watershed is present in this part from the western edge to the Da River, and it is elongated in the NW-SE direction. As numerous tributaries flow into the Da or Toc River perpendicularly to the watershed, a typical trellis drainage pattern is developed.

This Series lies in fault contacts with all adjacent geologic units (D_{23}, T_2, T_3, and K). Most of the faults extend in the NW-SE direction parallel to the structural trends of the rocks.

The Series is also composed mostly of dark green to green trachybasaltic (to trachyandesitic) fine tuff similar to the lithofacies in the northeastern part. Effusive activity of lavas is also active, and the tuff is interbedded with trachybasalt (to trachyandesite) lavas as well as trachyte lavas in many places. Those lavas occur widely, particularly to the southeast of the Da River. 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.

As will be described later in section 1.5., this Series in this part 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 (T_2), extending in the NW-SE direction with 1 to 1.5 km width. This unit is bounded by units of the Series T_2 through NW-SE trending faults on both sides.

This Series is generally made up of alternating beds of dark grey 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 T_1 is calculated from the exposed rocks to exceed 1,000 m in this part.

(6) Middle Triassic Series (T_2)

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 (T_3) and Cretaceous System (K) unconformably covers this Series or they are in fault contact with it. This Series consists mostly of dark grey 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 T_1 area in the central part of the survey area that has been described in item (5). This Series is divided into three separate parallel zones by the Middle to Upper Devonian Series (D_{2-3}), the Lower Triassic Series (T_1), and Cretaceous System (K) in this belt. All of three zones of this Series extend continuously in the NW-SE direction. The relationship between the Cretaceous and this Series is unconformity or fault contact. With the Series D_{2-3} and T_1, 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. The widths of the three are 3 to 5 km, 4 km, and more than 3.5 km, respectively. The rocks of the Series D_{2-3} mentioned in item (2) are exposed in the northwestern edge of the A zone.

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 grey fine-grained sandstone are dominant in the lower part. Dark grey 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 grey 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 T_2, 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.

(7) Upper Triassic Series (T_3)

This Series occurs widely in the eastern part of the area. The Series has unconformable relationships or fault contacts with the underlying Series

$CP\text{-}P_1$ and T_2. The apparent occurrence of this Series covers a zone between the Series $CP\text{-}P_1$ and T_2, and is distributed around those underlying geologic units. Although strike of the beds is not constant in the T_3 area, they are roughly consistent with the macroscopic structural trend of the underlying units except in the vicinity of faults.

The Series comprises sandstone, mudstone, and limestone. No volcanic and pyroclastic rocks are contained. The major part consists of alternating beds of dark grey to grey, hard compact fine-grained sandstone and black phyllitic mudstone. Sandstone is occasionally red near Lang Canh in the eastern edge of the area. The beds of the middle part is interbedded with thin coal beds. The same hard sandstone as that of the major part is dominated in some horizons of the lower part. Moreover, the whole part of this Series is interbedded with frequent beds of dark grey to grey massive limestone that occurs several tens of meters thick. This occurrence is especially observable in both sides of the Da River (in the southeastern part of the area).

This Series is estimated to be 1,000 m thick.

(8) Cretaceous System (K)

This System is distributed widely in the northwestern part and is also present in the southwestern part of the survey area. The former part belongs to the "Northeastern belt" and the latter the "Southwestern belt" as shown in the schematic columnar sections. These two parts are located at a distance from each other. The geologic characteristics will be described below separately because there are differences in lithology and constituent rocks between the two.

【Northwestern part】

The System in this part occurs widely and continuously from the north of the Suoi Bua River to the north and northeast of Phu Yen. The structural trend is not constant, but this K area is located in the southernmost part of the Tu Le Basin outside the survey area and 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 Series T_1, and has

unconformable relationship or fault contacts with the Series T_2.

This System in this part is composed mainly of dark green well bedded trachybasaltic (to trachyandesitic) fine tuff and is partly accompanied with their lavas and trachyte lava. Black mudstone, grey 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 to the southwest of the Da River, forming a belt with NW-SE trend. The strata ranges in width from 1 to 3 km. This System lies in fault contact with the Series T_2 on the southwest and unconformably overlies the underlying Series T_2 on the northeast.

The major part of this System is made up of grey 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).

(9) Quaternary System (Q)

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. These sediments are distributed widely in the intra-montane basins where Phu Yen and Gia Phu are located and many streams flow in from the surrounding mountains with steep gradients. The sediments occur in the intra-montane basins also in the southwestern part of this area, where they form narrow belts along the adjacent mountain ranges. Some sediments in this part are decomposed into residual soil by weathering, because the part is largely underlain by

Sample No.	Sample No.	Sample No.	Sample No.
VFR 1	VFT16	VGR15	VGT15
VFR 2	VFR17	VGR25	VGT25
VFR 3	VFT22	VMR 1	VMT 1
VFR 4	VFT38	VMR 8	VMT 8
VFR 5	VFT47	VMR10	VMT10
VGR 5	VGT 5	TFR 2	TFT13
VGR10	VGT10	TNR 8	TNT 8
VGR11	VGT11		

(Correlation betweem sample numbers for whole rock analysis and thin section R:whole rock, T:thin section)

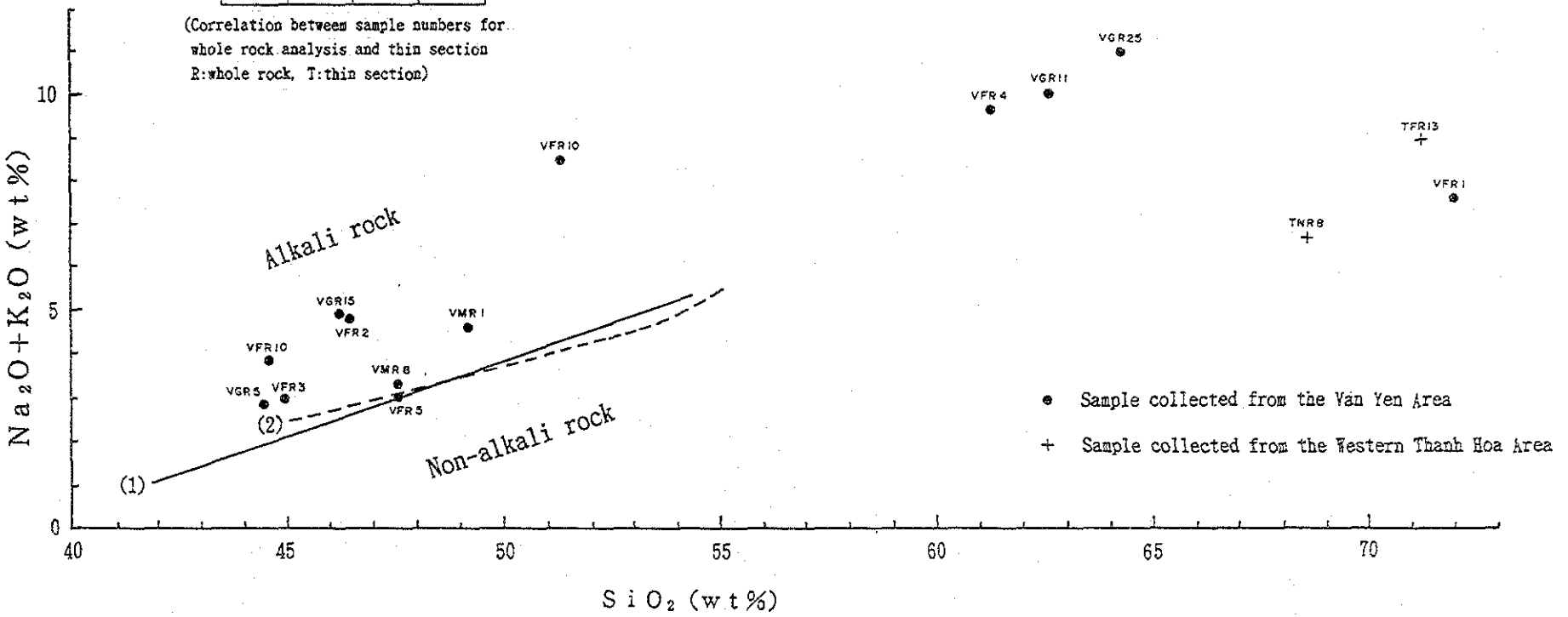


Fig.Ⅲ-1-4 Division of Alkali and Non-Alkali Rocks ($Na_2O+K_2O-SiO_2$ Diagram)

limestone and marl and the discharge of the streams is very small. In other parts, for instance, along the tributaries of the Da, Toc, and Suoi Bua Rivers, the sediments hardly occur due to extremely intense downward erosion since those tributaries are all rapids with short extension.

The $Na_2O+K_2O-SiO_2$ diagram is shown in Figure Ⅲ-1-4 which demonstrates division of alkali and non-alkali rocks in the volcanic-rock series. From this figure, it is distinct that the volcanic rocks of this survey area have alkali chemical composition. Two data of the Western Thanh Hoa Area (PartⅣ) were also plotted on the figure. These two, on the contrary, are in the domain of the non-alkali rocks.

1.4. Intrusive Rocks

Abundant intrusive bodies formed by igneous activities during Permian to Cretaceous time occur in this survey area. The lithology of these rocks is divided into several types such as ultramafic to mafic, alkali intermediate to felsic rocks. Generally the rock bodies are of small dimensions. No intrusive rock was found in the D_{23}, T_1, T_2, and K areas in the "Southwestern belt" and D_2, T_2, and T_3 areas in the "Northeastern belt", where all geologic units are sedimentary rocks. Their lithology will be described below in the order of intrusion (GSV,1990).

(1) Permian ultramafic rocks (σ_4)

The ultramafic rocks intruded into limestone and mudstone of the Series CP (South Chain) in the eastern part of the area. Three outcrops as one sheet and two dikes are observed. Also more rock bodies are believed to be exposed, because floats of these rocks were frequently recognized in the streams that flow into the Maru River. The bodies range in width from 2 to 20 m with the maximum observed length of 1.5 km. Generally the rocks are black to dark green compact peridotites and major trend of intrusion is NE-SW. Microscopic studies reveal that crystals of olivine, clinopyroxene, and plagioclase form granoblastic texture and the olivine is partly replaced by serpentine.

The list below shows the results of whole rock analysis of the representative rock samples.

Sample No.	SiO_2	TiO_2	$A\ell_2O_3$	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
VMR 1	43.47	0.85	7.25	3.40	8.70	0.19	21.39	8.04	0.74	0.16	0.06	2.92
VMR 7	43.64	0.65	5.91	3.26	8.58	0.18	22.96	7.03	0.51	0.21	0.05	4.27

Unit: percent

(2) Early Triassic gabbro and dolerite (ν_4)

These rocks were recognized at 21 localities in this area. Most of them except for two outcrops have intruded the Series T_1 on the west of the "Toc River Fault Zone". With regard to the two exceptions, one is located in the Series CP (North Chain) and the other crops out in the Series P_1 (South Chain). Generally the rock bodies are exposed in small dimensions and intrude as dikes. The trend of intrusion is NW-SE without exception, and it coincides with the strike of tuffs. The rock bodies are several meters wide with a maximum of 300 to 500 m, and range in length from several hundreds meters to 1.5 km. The density of distribution is higher in the northwestern part of the Series T_1 area than in other parts, and the rocks hardly occur in the southeastern part.

These rocks are divided lithologically into two types: dark green gabbro (to metagabbro) and dolerite (to metadolerite). In general the latter is more abundant than the former. Microscopic studies reveal that both types show ophitic texture and consist mainly of clinopyroxene and plagioclase, with occasional accessory hornblende. Two rock bodies in the eastern part are dolerites.

The whole rock analysis of a metagabbroic rock sample has revealed the following chemical composition.

Sample No.	SiO_2	TiO_2	$A\ell_2O_3$	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
VGR 13	47.39	2.32	14.61	3.45	8.32	0.20	6.71	10.52	2.50	1.11	0.32	1.88

Unit: percent

(3) Early Triassic trachyte dikes (τ_6)

The dikes were recognized at 20 localities in this area. Similar to the gabbro and dolerite (ν_4), the dikes occur only in the Series T_1 on the west

of the "Toc River Fault Zone". All dikes extend in the NW-SE direction that coincides with the strikes of tuffs in the same way as the rocks $\nu 4$. 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 grey to light grey 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.

(4) Cretaceous syenite (ε_6)

Nine syenite bodies are found in a scattered pattern in the northern half of this area. Localities of intrusion are as follows.

- "Southwestern belt": three bodies in the Series T_1
- "Northeastern belt": one body in the Series T_1
  five bodies in the System K

Five bodies within the System K are relatively large. They are 200 to 300 m wide and 400 to 1,200 m long, and occur in relatively restricted parts. No specific trend can be recognized. The dimension of the other four bodies with the Series T_1 is smaller than that of the above five bodies. The four bodies are 20 to 50 m wide and 300 to 1,000 m long, trending parallel to the strike of the surrounding tuffs.

These rocks are generally grey to dark grey and porphyritic. Microscopic studies reveal that the texture is holocrystalline porphyritic and both groundmass and phenocrysts consist of a large amount of potash feldspars. Two bodies which occur in the "Southwestern belt" can be called syenite porphyry because of the large phenocrysts of potash feldspars.

The list below shows the results of whole rock analysis of the

representative rock samples. The sample of VMR 11 was collected from the body in the Series T_1 of the "Southwestern belt", and the VFR 6 from the body in the System K of the "Northeastern belt".

Sample No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI
VMR 11	57.40	0.97	16.19	2.19	4.41	0.14	1.20	3.07	5.54	3.91	0.26	4.14
VFR 6	61.25	0.60	16.98	6.86	0.50	0.0	0.02	0.29	5.36	7.10	0.13	0.51

Unit: percent

(5) Cretaceous granite (γ_6)

Only one granite body was recognized within the area of the Series T_1 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 gabbro (ν_6)

Two gabbroic bodies have intruded into trachybasalt lava and mudstone of the System K 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.

1.5. Geologic Structure

(1) Folds

There is a large change of the structural trends of rocks between the "Northeastern belt" and "Southwestern belt" with the boundary at the "Toc River Fault Zone", as stated at the opening paragraphs of this chapter. The "Northeastern belt" has structural trends of E-W, N-S, NW-SE and so on, which differ from the geologic unit to unit as shown in Figure Ⅲ-1-2. The structural trend of the "Southwestern belt", on the other hand, is constant NW-SE.

Regionally traceable key beds do not exist in the sedimentary units of the survey area. For instance, a specific tuff bed usually can be a key bed within the alternating beds of sandstone and mudstone. In addition to this, where pyroclastic rocks are interbedded with a well continuous bed of mudstone, this can also be a good key bed. A part from this, 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. Nevertheless, bedding planes are well developed in most sandstone and mudstone, and fine tuff is usually well stratified showing bedding planes or schistosities. On the basis of the above structural elements including minor folds observed in the field, the macroscopic folds can be interpreted as shown in Figure Ⅲ-1-3. The available geologic map and sections were referred for the parts with poor field data.

The characteristics of folds in each geologic unit are summarized as follows (excluding the Series D_2 and D_{2s}).

【Northeastern belt】

1) Carboniferous to Permian System and Lower Permian Series ($CP-P_1$)

These geologic units generally strike N-S in the North Chain, but the strike in the South Chain vary considerably, namely E-W, NE-SW, and NW-SE. The beds of both chains usually dip 30 to 60°. The North Chain corresponds to the plunging part of an anticline with the axis in the E-W direction. The South Chain consists of a series of E-W trending anticline and syncline with 1 to 1.5 km wavelength. The folds form two anticlinoriums that plunge to the west.

2) Lower Triassic Series (T_1)

This geologic unit generally strikes E-W, but the strike changes to N-S in the western part of the unit. The central part 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.

3) Middle Triassic Series (T_2)

Most of the limestone 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.

4) Upper Triassic Series (T_3)

T_3 occurs surrounding the units CP-P_1, and has folds similar to those units. That is, the major part of the T_3 generally strikes E-W, but in the vicinity where the units CP-P_1 plunge to the west, the folds of T_3 change their strike to N-S and plunge also to the west. As a whole an E-W trending synclinorium has been formed in T_3 with about 1 km wavelength.

5) Cretaceous System (K)

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.

【Southwestern belt】

1) Lower Triassic Series (T_1)

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 T_3 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 T_3 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.

2) Middle Triassic Series (T_2)

This geologic unit in the "Southwestern belt" has a roughly constant strike of NW-SE direction in all zones (A to C) described in section 1.3. 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 The B zone is dominated by steep beds, and axial planes of folds are considered to have become fractures.

3) Cretaceous System (K)

This System consists of NW-SE trending folds with about 1 km wavelength.

(2) Faults

There is a large difference in the fault systems of the survey area between the two belts, namely the Northeastern and Southwestern belts, with the boundary at the "Toc River Fault Zone".

【Northeastern belt】

There are two systems of faults in this belt. They are N-S to NNE-SSW and E-W to ENE-WSW systems. These faults occur in a complex pattern and the structure before the faulting is not clear. The lengths of the faults vary considerably, ranging from 3 to more than 15 km. Relatively large vertical displacement has been calculated to be 500 to 1,000 m.

【Southwestern belt】

All geologic units are in fault contact with one another except between the Cretaceous System (K) to the south of the Da River and the Middle Triassic