REPORT
ON
THE COOPERATIVE MINERAL EXPLORATION
IN
THE BO CU AREA
THE SOCIALIST REPUBLIC OF VIETNAM

PHASE I

FEBRUARY 1997

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

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PREFACE

The Government of Japan, in response to a request of the Government of the Socialist Republic of Vietnam, decided to conduct a mineral exploration in the Bo Cu area, northern Vietnam, 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, the Ministry of Industry to make the survey as a counterpart to the Japanese team. The survey was carried out from 1996 jointly by experts from both governments.

The First Phase of the Cooperative Mineral Exploration consists of geological survey, geochemical survey and geophysical survey for precious- and base-metal resources in the Bo Cu area.

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

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

February 1997

Kimio FUJITA
President
Japan International
Cooperation Agency

Shozaburo KIYOTAKI
President
Metal Mining Agency of
Japan

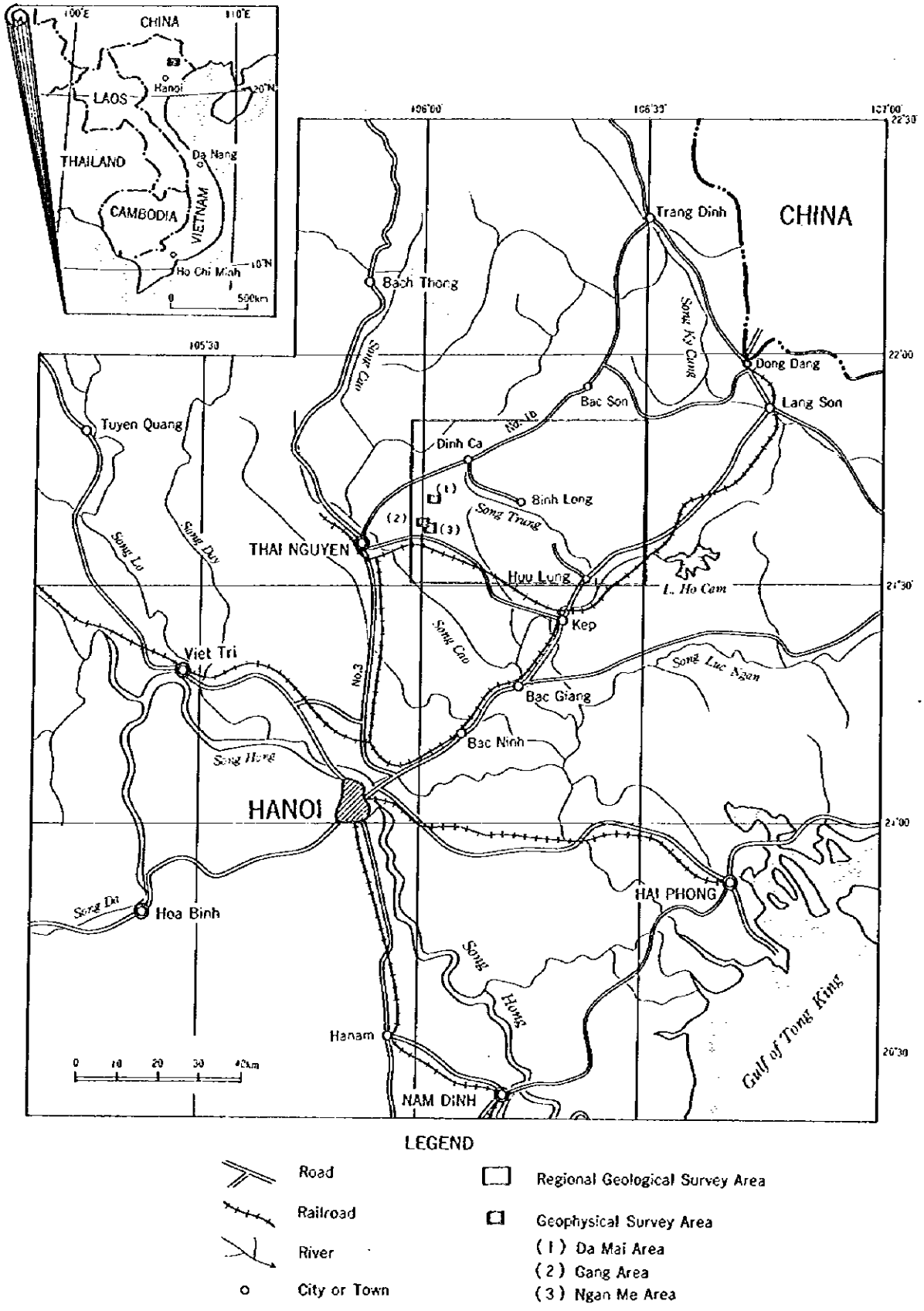

Fig. 1-1 Index Map of the Survey Area

SUMMARY

The survey this year corresponds to the first phase of the Cooperative Mineral Exploration in the Bo Cu area. The principal objective of this project is to find a new mineral deposit in the Bo Cu area through the exploration and examination of geology and mineralization. The works this phase were composed of regional geological survey, stream sediment geochemical survey, panning survey, detailed geological survey and geophysical survey (Array CSAMT). The regional geological survey and geochemical exploration were carried out over an area of 2,000 km^2. The detailed survey was conducted in three areas: Da Mai, Gang, and Ngan Me, which were thought to have a potential for the gold-bearing quartz vein deposit. A survey length of 530 km was traversed, and more than 1,910 stream sediment and panning samples and 100 ore samples were collected this phase. The Allay CSAMT survey was carried out in the detailed survey area, and the resistivity anomalies were analyzed.

The distribution of six major stratigraphic units from the Cambrian to the Quaternary systems was surveyed and the geologic map of 1:50,000 scale was prepared in the Bo Cu area by the regional geological survey this phase. Geostructurally, the survey area is characterized by a series of anticlines and synclines called Bac Son anticlinorium whose axes orientate from NE, ENE to WNW. Three major fault systems were distinguished in the survey area: NW, N-S, and NE systems. Small stocks of granite which were regarded to have some relationship with the gold mineralization were found at the northern part of the survey area. The nature of this granite is discussed based on the whole rock analysis. It is concluded that this granite belongs to the granitoids of the magnetite series and of the S-type.

Regarding metallic mineral deposits in the Bo Cu area, two sorts of significant mineralization, gold-bearing quartz veins and galena veins, were recognized.

Gold-bearing quartz veins occur extensively in the western part of the Bo Cu area. Although the width of each vein is not magnificent, they sometimes occur together forming a vein zone of 100-300 m wide stretching nearly E-W for 500-1,000 m. The system of quartz veins and the nature of gold mineralization were investigated by the detailed geological survey. Two vein systems were distinguished by means of the stereo net analysis. One is N80E with steeply dipping S, and another is E-W with gently dipping S. The veins occur on the wing of the Bo Cu anticline, and it is interpreted that the formation of veins is controlled structurally by the regional folding activity occurred probably from the Triassic period. On the basis of the results of studies such as geologic environment, ore and gangue mineralogy, alteration, chemical analysis and fluid inclusion, it is concluded that the type of mineralization is mesothermal gold vein hosted by sedimentary and metamorphic rocks of the Cambrian Mo Dong and Than Sa Formations.

The galena veins occur mostly in the Carboniferous-Permian limestone. Several galena showings were found in the course of the regional geological survey and geochemical exploration. Some of them contain a significant amount of silver and lead (up to 99.6 g/t Ag, 9.33 % Pb at 120 cm in width). The similarity of geology and mineralization is discussed with the galena deposit in the Cho Dien area which is a famous Pb-Zn district in the northern Vietnam. The potential of galena resources in the Bo Cu area is estimated to be small from the survey results.

On geophysical survey, the Array CSAMT method was carried out in order to investigate the relationships between resistivity and geologic structure and extract resistivity anomalies related to the mineralization in the Da Mai, Gang and Ngan Me areas. The survey results showed that the resistivity of the survey areas is high as a whole and the resistivity structure matches with the geologic structure. Especially, the Da Mai area has higher resistivity than the other areas, and high resistivity areas suggesting the distribution of granite were detected broadly below about 300 m from the surface. With reference to the mineralized zone, the high resistivity zones resulting from a group of quartz veins more than 100 m in width were extracted. The results of the laboratory test gave an obvious contrast between the quartz vein containing pyrite and the other rocks in the survey areas. The IP method is available for the high resistivity zones extracted by this survey in order to delineate prospective parts, because these zones seem to contain few amounts of graphite.

On the basis of the results of the detailed geological survey together with the results of geochemical exploration, three areas for gold-bearing quartz veins have been examined, and potential for each area is preliminary evaluated. Among three areas and their extensions, Da Mai-Khe Dui and Ba Khe are believed to be promising prospects for gold resources.

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PART I OVERVIEW

PART I OVERVIEW

Chapter 1 Introduction

1-1 Background and Objective

The Vietnam-Japan Cooperative Mineral Exploration has been carried out in one area of the Socialist Republic of Vietnam: "Van Yen and Thanh Hoa (1993-1995)". As a result of these works, a significant amount of information regarding metallic mineral resources was obtained. The exploration also contributed to the technical progress of the Geological Survey of Vietnam, as well as to the acquisition and accumulation of knowledge regarding geology and mineral deposits of the country.

The Ministry of Industry of Vietnam planned to conduct mineral exploration in the Bo Cu area, northern Vietnam, and requested the cooperation of the Japanese Government. In August 1996, the Japanese Government, responding to the request, sent a mission for discussing the Scope of Work and to make a program of the first phase survey. As a result of consultations with the Geological Survey of Vietnam, the counterpart of the Japan International Cooperation Agency and the Metal Mining Agency of Japan, an agreement was reached for cooperative mineral exploration in the Bo Cu area on August 8, 1996.

The survey this year was the first phase of the Cooperative Mineral Exploration in the Bo Cu area, the Socialist Republic of Vietnam.

The principal objective of this project is to find a new mineral deposit in the Bo Cu area through the exploration and examination of geology and mineralization. It is also important to pursue technology transfer to the Vietnamese counterpart organization in the course of the project.

The program this year was composed of geological survey, geochemical exploration and geophysical survey in the Bo Cu area.

1-2 Outline of the First Phase Survey

1-2-1 Survey Area

The survey area in the first phase is approximately 2,000 km^2 surrounded by the coordinates listed below. It is located approximately 70 km north of Hanoi. It lies over three provinces: Bac Thai, Lang Son and Ha Bac. The location map of the survey area is shown in Fig. 1-1.

No.	Latitude	Longitude
1	21°50'N	105°58'E
2	21°50'N	106°30'E
3	21°30'N	106°30'E
4	21°30'N	105°58'E

1-2-2 Exploration Theme

The field survey this year corresponded to the first phase in the Bo Cu area. It was composed of (1) regional survey comprising geological survey and geochemical exploration covering 2,000 km^2 in area, and (2) detailed survey comprising geological survey, geochemical exploration and geophysical survey in the Da Mai, Gang and Ngan Me areas.

On the basis of the existing information mainly provided by GSV, mesothermal gold deposit was the prior target mineralization in the Bo Cu area.

The followings are the major themes emphasized in the first phase program:

(1) The regional survey comprising geological survey and geochemical exploration was carried out over the area shown in Fig. 1-1, in order to prepare geologic map at a scale of 1: 50,000. It also aimed at investigating the mineral potential -- firstly that of mesothermal gold -- of the Bo Cu area.

(2) The detailed survey consisting of geological survey, geochemical exploration and geophysical survey was carried out in the Da Mai, Gang and Ngan Me areas. The purpose is to survey mineral showings in the area, to catch geochemical anomalies and to define target mineralization for the next phase exploration. Geophysical exploration using the Alley CSAMT method was carried out in the detailed survey areas for the purpose of investigating the relationship between resistivity and geologic structure.

1-2-3 Exploration Work

Regional Survey

The regional survey in the first phase was composed of geological survey, stream sediment survey and panning survey over an area of 2,000 km².

Detailed Survey

The field work in the detailed survey areas was composed of geological survey and CSAMT geophysical survey. The survey area was amounted to 16 km² in total.

The amount of works done this phase is summarized as follows:

Survey	Area and Amount of Samples
Regional Survey	
Geological Survey	2,000 km²
Survey Length	530 km
Samples (Stream Sediments and Pan Concentrates)	1,919 pcs
Detailed Survey	
CSAMT Survey	16 km²
Survey Length	30 km
Survey Points	330 pts

The amount of samples for chemical analyses and laboratory works is listed in the following table:

Chemical Analysis & Lab Work	Amount of Samples
Geological Survey & Geochemical Exploration	
Thin Sections	31 pcs
Polished Sections of Ore	31 pcs
X-Ray Diffraction Analysis	40 pcs
Fluid Inclusion Study	11 pcs
Heavy Mineral Identification	405 pcs
Chemical Analysis	
a) Whole Rocks (13 Major Components)	20 pcs
b) Stream Sediments (Au, Ag, Cu, Pb, Zn, As, Sb, Hg)	1,514 pcs
c) Ores (Au, Ag, Cu, Pb, Zn, As, Hg)	103 pcs
Geophysical Survey (CSAMT)	
Resistivity & Chargeability	20 pcs

1-2-4 Survey Team

The Japanese Preliminary Survey Team of the Japan International Cooperation Agency and the Metal Mining Agency of Japan headed by Mr. Toyo Miyauchi visited Vietnam during the period of August 5 to 10, 1996, and made a field survey in the Bo Cu area. The Scope of Work was agreed and signed on August 8, 1986. The S/W meeting was held by the attendants listed below:

[Members of Japanese Side]

Toyo MIYAUCHI	Leader of the Team, Director, Overseas Activities Department, Metal Mining Agency of Japan
Toru NAWATA	Energy and Mining Development Study Division, Mining and Industrial Development Study Department, JICA
Yuichi SASAKI	Technical Cooporation Division, Metal Mining Agency of Japan
Katsutaka NAKAMURA	Representative of Bangkok Office, Metal Mining Agency of Japan

[Members of Vietnamese Side]

Tran Dy	Director General, GSV
Do Huu Hao	Deputy Director General, International Cooperation Department, Ministry of Industry
Nguyen Van De	Senior Geologist, Technology and Product Quality Management Department, Ministry of Industry
Doan Ky Thuy	Director, International Cooperation Division, GSV
Ta Viet Dung	Director, Technical and Planning Division, GSV
Le Van De (Dr)	Deputy Director, International Cooperation Division, GSV
Phan Doan Thanh	Director, GSV-I
Nguyen Van Quy	Senior Geologist, GSV
Dan Ngoc Tran	Senior Hydrogeologist, GSV

The geological and geochemical surveys of the first phase were carried out during the period from September 30 to December 21, 1996. Geophysical survey was made within the period from October 14 to December 21. Laboratory works and reporting followed the field works. The organization of the survey team consisted of the following members:

[Metal Mining Agency of Japan]

Eishi ENDO	Coordinator
Susumu NAGAE	Coordinator and Geologist

[Members of Vietnamese Team]

Le Van De (Dr)	(GSV) Coordinator and Geologist
Phan Doan Thanh	(GSV-I) Coordinator and Geologist
Dang Tran Quan	(GSV-I) Team Leader and Geologist
Nguyen Trang Tuyet	(GSV-I) Geologist
Dao Thai Bac	(GSV-I) Geologist
Phan Van San	(GSV-I) Geologist
Vu Duc Tuy	(GSV-I) Geophysicist
Ngo Duc Tan	(GSV-I) Geophysicist
Le Van Du	(GSV-I) Geophysicist

[Members of Japanese Team]

Kohei IIDA	(NED) Team Leader and Chief Geologist
Hideya KIKUCHI	(NED) Geologist
Kazuyasu SUGAWARA	(NED) Geologist
Masahiro SUZUKI	(NED) Geologist
Takashi YAMAISHI	(NED) Geophysicist

Shin'ichi SUGIYAMA	(NED)	Geophysicist
Saburo TACHIKAWA	(NED)	Geophysicist

*Note: JICA; Japan International Cooperation Agency
GSV; Geological Survey of Vietnam
GSV-I; Geological Division No. 1, GSV
NED; Nikko Exploration and Development Co., Ltd.

Chapter 2 Geography of the Survey Area

2-1 Location and Access

The survey area is located in the northern part of Vietnam, and is called the Bo Cu area. It is under the jurisdiction of three provinces: Bac Thai, Lang Son, and Ha Bac.

The access to the Bo Cu area is obtained via Thai Nguyen, whose population is about 180,000 and which is the nearest town to the survey area within the province. The national road No. 3 connecting Thai Nguyen to Hanoi is roughly sealed (tarred), and it takes about 2 hours by car. From Thai Nguyen to the survey area, there is a couple of roads. They are partly tarred, mostly unsealed. There is locally no bridge for cars where crossed rivers, and they sometimes become muddy when rain continues. In such season, only four-wheel-drive vehicles are possible to go to the survey area. Several tracks are running in the survey area. Most of them are rugged, interrupted by rivers.

2-2 Topography and Drainage System

The survey area is situated in a hilly land. The altitude ranges from 50 to 500m. The geology consists of Paleozoic and Mesozoic, mostly limestone. It often forms Karst topography. Drainage systems are sometimes discontinuous; rivers flow in such steep land, suddenly disappear in underground. The major drainage systems in the survey area are Song (river) Rong and Song Trung, both are branches of Song Cau. They flow to the southeast in the southern part of the survey area.

2-3 Climate and Vegetation

The area belongs to the subtropical Asian monsoon climate zone. It is composed of four seasons. Spring comes in April, when red flowers of frangboiyan tree start to blossom everywhere in the town and countryside. Summer comes rather earlier, in May when the average temperature goes over 27 degrees C. In addition to the temperature, the humidity also goes up in June and July. Typhoon occasionally visits to this area in July or August. From October to December, it is the best and comfortable autumn season for the people. From the end of December, cold and rainy winter starts, and continues until March at most.

The following is the climatological data in Hanoi and its surrounding area:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ave Temp °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/month	18	26	48	81	194	235	302	323	262	123	47	20

Paddy rice fields cover along the alluvial plains in the survey area.

The subtropical rain forest grows in a lowland in the survey area. Some of the hilly areas are developed as a tea plantation.

Chapter 3 Geology of the Survey Area

3-1 Geological Setting of the Bo Cu Area

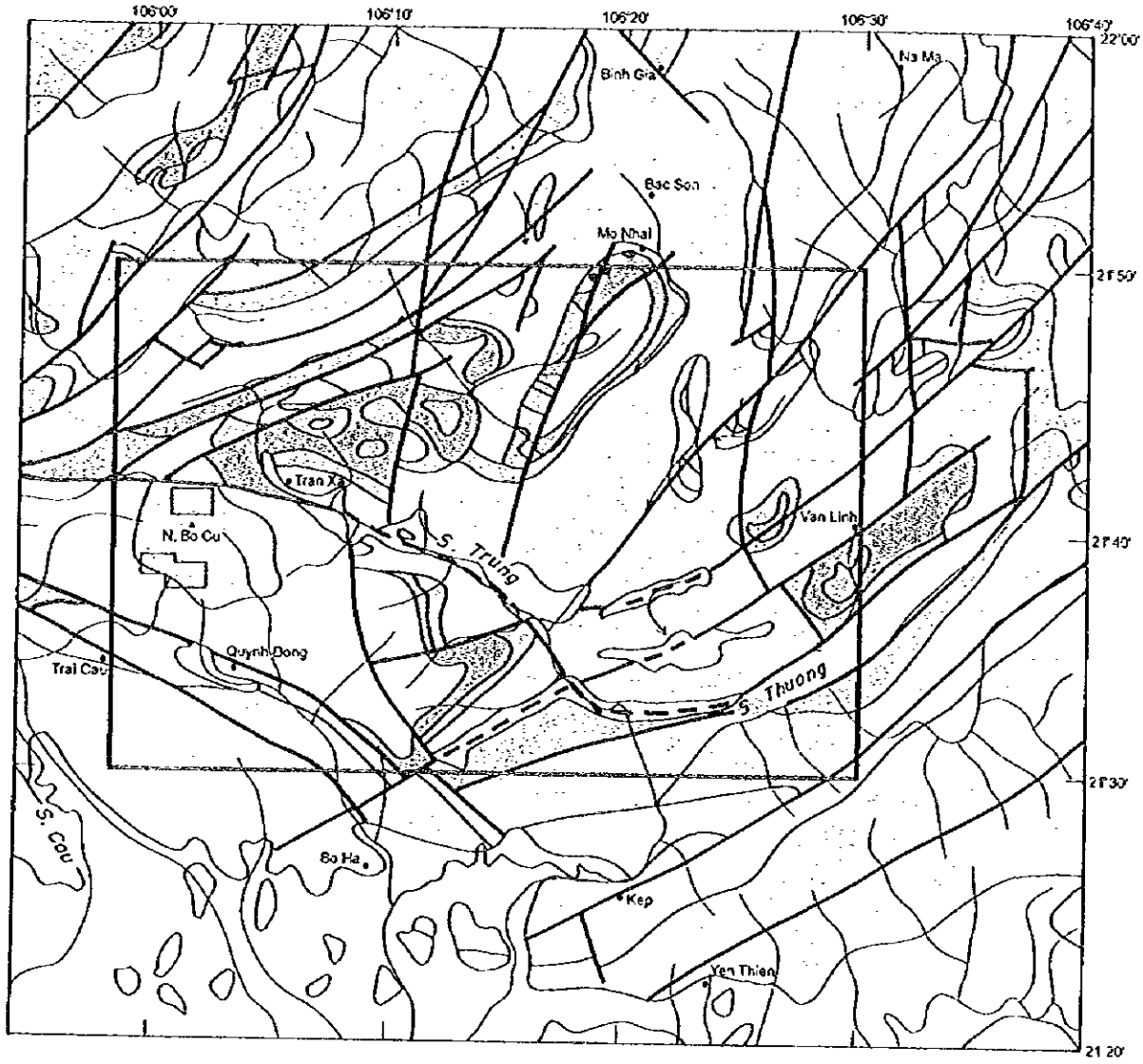
The survey area is located in the eastern part of the Vietbac district on the geological classification of the northern Vietnam. The Vietbac and Littoral Bacbo districts are separated with the West Bacbo district on the southwestern side by a structural zone of NW-SE direction which passes near Song Hong. This zone forms a part of the boundary between the South China plate on the northeastern side and the Indochina plate on the southwestern side. That is, this area is situated in the southernmost of the South China plate, and structurally corresponds to the southern extension of the Chinese continent. Geology of this area is composed of schist and sedimentary rocks of the Cambrian to Ordovician systems as the basement, and various sedimentary rocks from the lower Devonian to the middle Jurassic systems overlain the basement. Major parts of these geologic units show the structural direction of NE-SW which is comprehensively a characteristic feature in the eastern part of the Vietbac district. They form a complex folding zone. Moreover, they are cut into several blocks by faults of the same direction. The southwestern part of this area (southwestern part of the regional geological survey area and in ranges of the mineralization belt), however, tends to show directions of NW-SE or WNW-ESE. These structural directions extend to the west. The Precambrian rocks along Song Hong exhibit the NW-SE direction distinctly.

No big-scale igneous body is known in this area. Only small stocks are found; the late Triassic biotite granite occurs 50 km northwest from the western boundary of the survey area; the Cretaceous granite also occurs to the southwest of the survey area.

3-2 Geology and Geologic Structure of the Bo Cu Area

Geology of this area is composed of sedimentary and metamorphic rocks of Cambrian, Ordovician, and Devonian to Jurassic systems. The geology is classified into the following six major stratigraphic units: 1) Cambrian sedimentary rocks and schist with some limestone (Mo Dong Formation and Than Sa Formation), 2) Ordovician sedimentary rocks and schist (Na Mo Formation), 3) Devonian sedimentary rocks and schist with some limestone (Bac Bun Formation, Mia Le Formation and Na Quan Formation), 4) Carboniferous to Permian limestone with some clastic rocks (Bac Son Formation and Dong Dang Formation), 5) Triassic sedimentary rocks with interbedded acidic volcanic rocks (Lang Son Formation, Song Hiem Formation, Na Khuat Formation, Mau Son Formation and Van Lang Formation), and 6) Quaternary sediments.

In the central to the eastern part of the survey area, a series of Carboniferous to Permian limestone crops out widely, and forms the typical Karst topography. The rocks except the recent one in the western part of the survey area generally show strike directions of

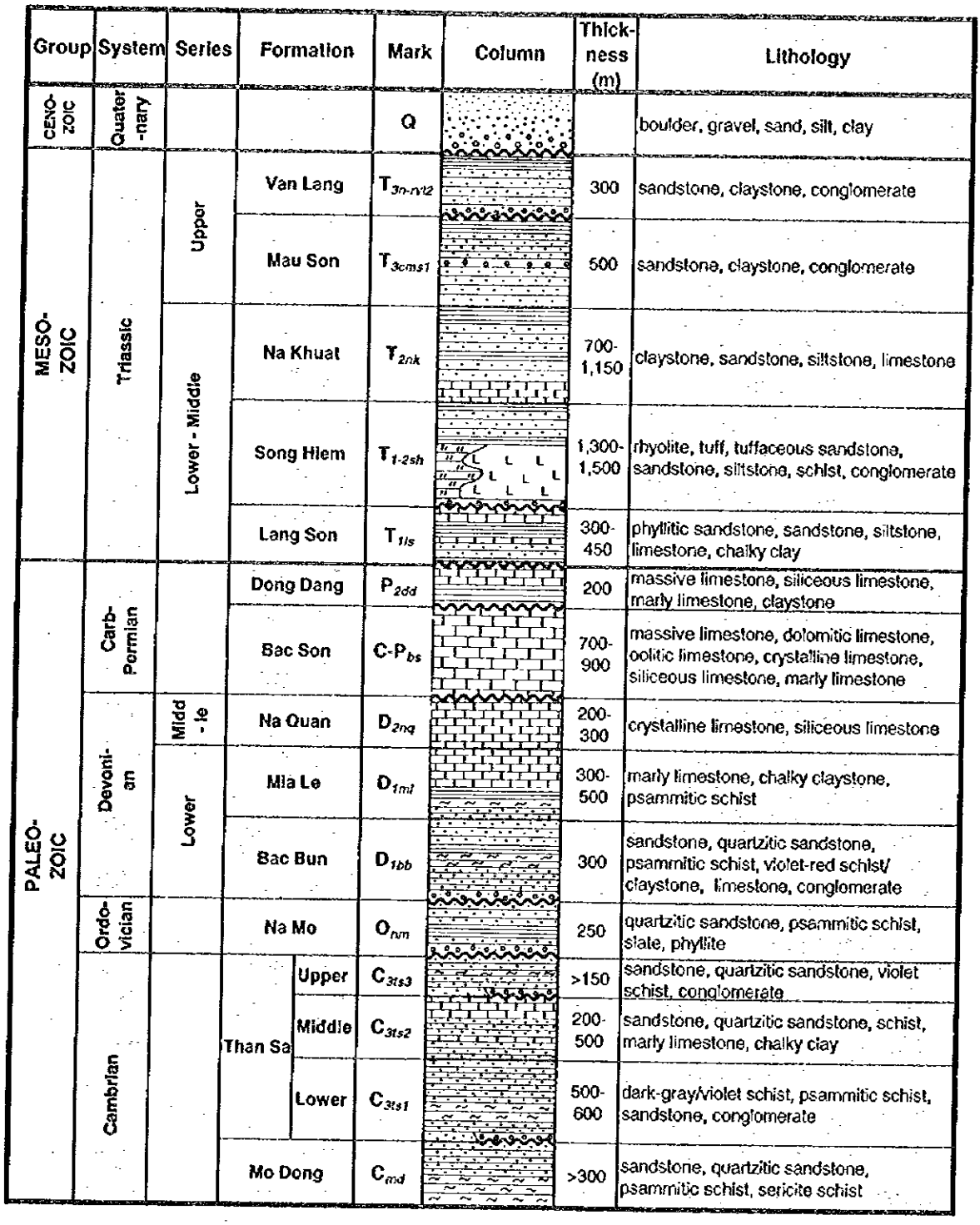


LEGEND

Quaternary	Alluvial deposits	Granitic rock
Jurassic	Ha Coi F.	Fault
Triassic	Van Lang F.	Survey Area
	Mau Son F.	Detailed Survey Area
	Na Khuat F.	
	Song Hiem F.	
	Lang Son F.	
Carb. -Permian	Dong Dang F.	
	Bac Son F.	
Devonian	Na Quan F.	
	Mia Le F.	
	Bac Bun F.	
Ordovician	Na Mo F.	
Cambrian	Than Sa F.	
	Mo Dong F.	

0 10 20km

Fig. 1-2 Geology of the Bo Cu Area and It's Surroundings



Group	System	Series	Formation	Mark	Thick-ness (m)	Lithology
CENO-ZOIC	Quater-nary			Q		boulder, gravel, sand, silt, clay
MESO-ZOIC	Triassic	Upper	Van Lang	$T_{3n-rvl2}$	300	sandstone, claystone, conglomerate
			Mau Son	T_{3cms1}	500	sandstone, claystone, conglomerate
		Lower - Middle	Na Khuat	T_{2nk}	700-1,150	claystone, sandstone, siltstone, limestone
			Song Hiem	T_{1-2sh}	1,300-1,500	rhyolite, tuff, tuffaceous sandstone, sandstone, siltstone, schist, conglomerate
			Lang Son	T_{1ls}	300-450	phyllitic sandstone, sandstone, siltstone, limestone, chalky clay
PALEO-ZOIC	Carb-Permian		Dong Dang	P_{2dd}	200	massive limestone, siliceous limestone, marly limestone, claystone
			Bac Son	$C\text{-}P_{bs}$	700-900	massive limestone, dolomitic limestone, oolitic limestone, crystalline limestone, siliceous limestone, marly limestone
	Devoni-an	Midd-le	Na Quan	D_{2nq}	200-300	crystalline limestone, siliceous limestone
		Lower	Mia Le	D_{1ml}	300-500	marly limestone, chalky claystone, psammitic schist
			Bac Bun	D_{1bb}	300	sandstone, quartzitic sandstone, psammitic schist, violet-red schist/ claystone, limestone, conglomerate
	Ordo-vician		Na Mo	O_{nm}	250	quartzitic sandstone, psammitic schist, slate, phyllite
	Cambrian		Than Sa — Upper	C_{3ts3}	>150	sandstone, quartzitic sandstone, violet schist, conglomerate
			Than Sa — Middle	C_{3ts2}	200-500	sandstone, quartzitic sandstone, schist, marly limestone, chalky clay
			Than Sa — Lower	C_{3ts1}	500-600	dark-gray/violet schist, psammitic schist, sandstone, conglomerate
			Mo Dong	C_{md}	>300	sandstone, quartzitic sandstone, psammitic schist, sericite schist

Fig. 1-3 Stratigraphic Column of the Bo Cu Area

ENE, E-W and WNW. Those in the central to the southern part of this area dip to the south to south-southwest at angles of 30 to 40 degrees. Therefore, the upper strata crop out to the south. On the other hand, the lower Cambrian system forms an anticlinorium of almost E-W axis in the northern part of this area. The lowest horizon in the survey area appears on the surface in this part. The distribution of gold-bearing quartz veins is believed to be controlled by the anticlinal structure.

3-3 Mineralization

According to the existing geological reports, the occurrences of gold-bearing quartz veins are known in the following areas:

- Da Mai
- Gang
- Cay Thi
- Ngan Me
- Bai Vang

Gold mineralization in the Da Mai area is characterized by the gold-bearing quartz vein/veinlet mainly in sandstone and sericite schist of the Cambrian Mo Dong Formation. The vein is sometimes accompanied by pyrite. The width of the quartz vein is generally narrow, 10 to 100 cm. In some case it occurs along the schistosity of the host rock. However in another case, it cuts across the schistosity. The general strike of the quartz vein is E-W and it is almost the same as that of the host rock. Nine veins were found by the survey of GSV within the area, and they were named No. 1 to No. 9 Vein respectively. According to GSV data, the No. 1 Vein has the average width of 56 cm, and average grade of 12 g/t Au for example. The No. 8 Vein has the average width of 50 cm, and average grade of 31 g/t Au. The strike length of each vein is said to be several hundred meters intermittently. The extension to the dipping is uncertain.

The gold-bearing quartz vein shows a characteristic feature of the mesothermal vein. Ore minerals included in the vein are pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite and galena. Hydrothermal alteration mainly composed of weak silicification is recognized along the vein. Sericitization and chloritization are also reported in the host rock.

The ore deposit in the Gang area is gold-bearing quartz vein/veinlet hosted mainly by sandstone and sericite schist of the Cambrian Mo Dong Formation. Pyrite is commonly associated with the gold mineralization. The width of the quartz vein is generally narrow, several centimeters to 70 cm. The vein shows two modes of occurrence like in the Da Mai area; it occurs along the schistosity of the host rock in some case; and in another case, it cuts across the schistosity. General strike of the quartz vein is E-W to WNW-ESE with general

dips of 30 degrees to the south. This trend is almost concordant with that of the host rock. Two veins were found by the survey of GSV within the area, and they were named G-1 and G-2 Vein respectively. One is located at one branch creek of S. Hoan (southern side), and another is located at another branch creek (northern side). According to the existing data, the G-1 Vein has the average width of 60 cm, and average grade of 16 g/t Au. The G-2 Vein has the average width of 35 cm, and average grade of 2 g/t Au. The strike length of each ore body is estimated to be several hundred meters intermittently. The extension to the dip side is about 20 m.

In this area, alluvial gold is mined by local people everywhere along S. Hoan. Sand and gravel at the riverbed are mined down to 3 to 4 m deep, and ores are processed by a series of crashers and traditional blanket sluicing. The Cay Thi deposit makes up of gold-bearing quartz veins hosted in black shale of the Cambrian Than Sa Formation. Pyrite is associated with the vein. The quartz vein occurs along the bedding plane of the host sediments which dip gently. The width of vein is narrow, commonly 3 to 5 cm, and occasionally 10 to 30 cm. In this area, gold ore is mined by local people some 300 m along S. Hoan. Gold-bearing quartz veins near the river are mined, and ores are processed in a small scale.

Ore deposits in the Ngan Me and Bai Vang areas show similar features to those in the Gang area. Three or four orebodies are known in each area.

Chapter 4 Discussion on the Results of the Second Phase Survey

4-1 Geology, Geologic Structure and Mineralization

The geological features of the Bo Cu area consist of sedimentary and metamorphic rocks of the Cambrian, Ordovician, and Devonian to Jurassic systems. Acidic volcanics occur in the lower or middle Triassic system. The major part of these geologic units forms complex foldings with axes of NE to ENE direction which are characteristics to the eastern part of the Vietbac geological district. Moreover, the area is cut into many blocks by tectonic faults. No large-scale igneous complex was found in this area except small stocks of granite.

The Bo Cu area is structurally characterized by a series of anticlines and synclines named Bac Son anticlinorium comprising Bo Cu anticline, Bac Son anticline, Trang Xa-Nhat The syncline, etc. The major directions of these folding axes are NE to ENE in the northwestern to eastern part. In the southwestern part of the survey area where gold-bearing quartz veins occur extensively, there is a distinctive anticlinal structure whose axis trends WNW.

Three major fault systems -- NW, N-S and NE -- were distinguished in the Bo Cu area. The NW and N-S faults are interpreted to be formed nearly at the same time as the Bo Cu anticline. The NE faults cut both NW and N-S faults, and are regarded to be formed after the major folding activity. Along these faults, intense deformation and shearing were observed.

The main orogenic activity in the Bo Cu area is interpreted to be occurred in the Triassic or later period. The formation of the Bac Son anticlinorium, the formation of regional tectonic faults and acid volcanic activity in the Song Hiem Formation altogether indicate the importance of this period.

Outcrops of small granite bodies occur at the northern part of the survey area arranging in the ENE-WSW direction. The emplacement of this granite is estimated to be sometime between Triassic and Cretaceous. This granite belongs to the granitoids of the magnetite series and of the S-type in another category according to the whole rock analysis. Tectonically, it is considered that the emplacement occurred at the marginal zone of the South China plate.

Regarding metallic mineral deposits in the Bo Cu area, two significant mineralizations, gold-bearing quartz veins and galena veins, were observed.

The galena veins occur mostly in the Bac Son limestone, and partly in claystone. Some of them contain a significant amount of lead and silver. The similar Pb-Zn deposits are known widely in the Cho Dien area (west of Thai Nguyen). They are galena-sphalerite-pyrite veins/lenses hosted by carbonate rocks and schist of the Silurian to Devonian systems. They occur along faults which appear to be controlled by the folding structure. Some spatial relationship of mineralization with the distribution of igneous bodies is said to exist in these

areas. Resources of galena veins in the Cho Dien area are significant. Some of the veins have been mined for long time.

The gold-bearing quartz veins are understood to belong to the mesothermal type gold deposit. Three promising areas for gold-bearing quartz veins were extracted through the detailed geological survey this phase within the Bo Cu area. Those are: Da Mai, Gang, and Ngan Me areas. Moreover, several anomalous zones have been closed-up as interesting extensions of these promising areas by the regional geochemical exploration. They are: Northeast of N. Bo Cu and Khe Ma both located to the east of the Da Mai area, Khe Can located to the northeast of the Gang area, Bai Vang located to the east of the Ngan Me area, and Khe Cam located to the northeast of the Ngan Me area.

Tens of shafts, adits and outcrops of quartz veins are distributed from the flank up to the ridge of nearly 400 m above sea level in the Da Mai area. Three major groups of veins are known in the Da Mai Area. Among those, Khe Dui and Da Mai are interpreted to form a consecutive zone from having the same trend and distribution of ENE-WSW. This zone has a width of 200 to 300 m and extends more than 1 km to the strike direction. These veins have already mined out near the surface. However, the deeper part and the extensions of this zone are untouched. The detailed exploration of this zone is necessary. Three areas - Da Mai, NE of N. Bo Cu, and Khe Ma are interpreted to be a series of gold mineralization zones stretching from east to west continuously. Further work is required for the examination of this zone.

In the Gang area, there are three major zones of gold-bearing quartz veins: Khe Gang, Khe Hoac, and Cay Thi. They have a general E-W strike direction, and are characterized by gentle S-dips commonly. This trend is concordant with the general geologic structure of the Cambrian system in this part. The host rocks form an anticline, and the area is situated on the southern wing of the anticline. In Cay Thi, two gently dipping veins are observed. They occur 40 m apart, and run parallel each other. The details of the correlation among these groups of veins have not been surveyed this phase. The genesis of the fracture system of quartz veins, together with the correlation, should be an important matter for the next stage investigation.

In the Ngan Me area, three prospects were distinguished: Ba Khe, Left Ba Khe-Middle Ba Khe, and West Ba Khe. West Ba Khe is situated about 500 m west of the Ba Khe prospect, and lies in the western extension of the Ba Khe mineralized zone. Gold mineralization in the Ba Khe prospect is expected to continue to West Ba Khe. The gold anomalous zone at the upper reaches of S. Bai Vang is located about 2 km east of the Ba Khe prospect. It is likely that the gold mineralization continues to the east until the Bai Vang area. If so, this mineralized zone extends for about 3.5 km in the E-W direction. This is one of the interesting prospects for the next stage exploration.

The gold-bearing quartz veins in the detailed survey area are understood to belong to the mesothermal type gold deposit. This matter has been confirmed according to the following evidences obtained during the survey this phase:

(1) Geologic environment that the veins are hosted mainly by sedimentary and metamorphic rocks of the Cambrian system.

(2) Gangue minerals of veins (consisting almost only of quartz).

(3) Ore mineral assemblage (particularly, arsenopyrite, pyrite, chalcopyrite and galena are intimately accompanied).

(4) The occurrence of pyrrhotite and bornite which probably indicates comparatively high temperature type deposit.

(5) Alteration features (mainly composed of silicification, sericitization and chloritization) .

(6) Significantly low Ag/Au ratio (=1.5 averaging of 88 ore samples in the detailed survey area).

(7) Results of fluid inclusion studies indicating mesothermal conditions.

Gold-bearing quartz veins occur on the wing of the Bo Cu anticline. The formation of these veins was probably controlled by the folding activity. According to the results of the stereo net analysis, two vein systems - N80°E with steep S-dip, and E-W strike with gentle S-dip - were distinguished. The details of conditions such as the stress-strain field and tectonic environments are not clear at the moment. Further studies must be done. Generally saying, the mesothermal gold deposit is sometimes accompanied by granitic intrusions in the vicinity. Some article said that there was a granite intrusion at the south of Da Mai gold vein (General Department of Mines and Geology, 1988). If so, it is very important to understand the gold mineralization of the survey area. We have not confirmed this evidence this time.

Three areas show their own characteristic features in the vein trend, mineral assemblage and fluid inclusion property. Veins in the Da Mai area are mostly steeply dipping S, and relatively sulfide-rich. Fluid inclusions show relatively low homogenization temperature and fine size. Veins of the Gang area are gently dipping S in common. Two groups of homogenization temperature -- higher and lower -- coexist. In the Ngan Me area, two groups of vein trends -- steeply dipping and gently dipping -- occur together. The homogenization temperature is rather low in the Ngan Me area.

These varieties are understood to be originated from the difference of the conditions of their formation. The spatial relation with the heat source -- probably somehow related to the granitic intrusion -- is considered to be one of the main factor concerned.

The place of the mineralization in this area is presumed within a marginal part of the South China plate according to the results of the regional geological survey. It suggests that the gold mineralization in this area probably belongs to the category of the continental type gold deposit.

4-2 Geochemistry

Several significant anomalous zones were outlined through the stream sediment geochemical survey and panning survey this phase. The major anomalous zones thus defined are: upper reaches of S. Ca, Northeast of N. Bo Cu, middle reaches of S. Hoan, upper reaches of S. Ngan Me, upper reaches of S. Bai Vang, and Cuc Duong.

Upper Reaches of S. Ca: Numerous Au anomalies (up to 7,211 ppb) and several anomalies of As, Cu, Ag and Hg of stream sediments were found. Many gold grains accompanied by arsenopyrite (and chalcopyrite in some case) were obtained in almost all pan concentrates in this area. This panning anomalous zone nearly corresponds to the stream sediment anomalous zone, and is interpreted to be originated from gold-bearing quartz veins in the Da Mai area.

Northeast of N. Bo Cu: Strong Au anomalies (up to 12,295 ppb) and a few As anomalies were detected. Gold grains were caught in almost all pan concentrates in this area. Arsenopyrite was found in two samples. This panning anomalous zone nearly corresponds to the stream sediment anomalous zone, and is interpreted to be the eastern extension of gold mineralization in the Da Mai area.

Middle Reaches of S. Hoan: Extensive Au anomalies (up to 2,418 ppb) and several anomalies of Ag, As, Pb and Hg of stream sediments were detected. Gold grains and arsenopyrite were obtained in some pan concentrates. The distribution of the panning anomalies almost overlaps to the stream sediment anomalies. These anomalies are interpreted to come from the gold prospects of Khe Gang, Khe Hoac and Cay Thi.

Upper Reaches of S. Ngan Me: A series of stream sediment anomalies (up to 2,448 ppb Au, and As) was found continuously from the lower reaches to the upper reaches of S. Ngan Me. These anomalies are interpreted to be originated from the gold-bearing quartz veins in the Ngan Me area. Many panning anomalies composed of gold and arsenopyrite occur in the same area.

Upper Reaches of S. Bai Vang: An Au anomalous zone (up to 2,054 ppb) of stream sediments was discriminated along the upper reaches of S. Bai Vang. Gold grains and arsenopyrite were detected in ten and two pan concentrates respectively at the upper reaches of S. Bai Vang, where a group of stream sediment anomalies occurs. This anomalous zone is located to the east of the Ngan Me area, and the source of anomalies is assumed to be the eastern extension of gold mineralization in the Ngan Me area.

Cac Duong: Several strong Pb anomalies (up to 9,925 ppm) were discovered at Cac Duong. Au, Zn, As, Ag and Hg anomalies are accompanied. Gold grains were detected in three pan concentrates. Galena and arsenopyrite were found in one sample each. The geology of this zone is composed of the Bac Son limestone and Son Hiem shale, these are fault-contacted in the ENE-WSW direction. Wastes of lead smelting were found at the upper reaches of S. Cau Ran in this area. Based on these evidences, lead mineralization, probably that of galena vein type, may exist within this anomalous zone.

The other localities where significant gold anomalies were detected by panning survey in the first phase are: Khe Ma, upper reaches of Khe Can, and upper reaches of Khe Cam. Khe Ma is located to the east of the Northeast of N. Bo Cu anomalous zone, and the gold mineralization of the Da Mai area is expected to extend to this locality for nearly 5 km. Gold grains and arsenopyrite were detected along the upper reaches of Khe Can. It is situated to the east of the Gang area. Several gold anomalies in pan concentrates were also detected along Khe Cam, a branch of S. Bai Vang and located to the far east of the upper reaches of the Khe Can anomaly. Gold mineralization is expected to occur between the upper reaches of Khe Can and Khe Cam.

The correspondence of specific metallic elements in the stream sediment geochemistry is well each other as far as the gold mineralization is concerned. Generally, they occur in a concentrated form at some small areas. As showed the best association with Au. Ag, Hg and Cu (in some area) follow to As.

Gold was detected in 133 pan concentrates either by naked eye in the field or under the microscope in the laboratory. It is composed of coarse to very fine carat of gold up to 2.6 mm by 1.5 mm. Some heavy/sulfide minerals displayed a good association with gold in pan concentrates, and those associations can be explained by the mineral assemblage of gold-bearing quartz veins in the Da Mai, Gang or Ngan Me areas. Tourmaline and arsenopyrite showed a significant correspondence with gold. Chalcopyrite showed some intimate relationship with gold. Whereas, cinnabar showed a faint relationship with gold in this area.

Galena was found in 6 samples. Three of them were taken from pan concentrates near galena veins.

Among the anomalies obtained by the stream sediment geochemistry and/or panning survey, the major ones correspond to the mineralization zone of the existing gold-bearing quartz veins. In addition to this fact, it is clarified that there are several other gold anomalous areas where the occurrence of gold vein has not known yet. Some of them correspond to the extensions of the known mineralization zones. The detailed investigation is necessary for such anomalies in the next stage.

4-3 Geophysics

The laboratory test results confirmed that the quartz vein has remarkably high resistivity. It can be seen that when the group of quartz veins (many quartz veins concentrated) is large in width (more than 100 m) , a high resistivity zone is extracted. The relationships between the high resistivity zones (related to quartz veins) extracted by CSAMT and the known prospects are as follows.

Da Mai area: The high resistivity zones expected to result from the group of quartz veins were detected at the following locations.

•No.7 and 8 on lines D-3 to D-5

•Southern part of lines D-7 to D-9

The high resistivity zone at the No.7 and 8 on lines D-3 to D-5 results from the Da Mai prospect and that in the southern part of lines D-7 to D-9 results from the Goc San prospect. They are expected to be relatively steep and extend to the deep zone. A high resistivity zone related to the Khe Dui prospect was not extracted. It is supposed that the prospect was shielded by low resistivity zones in the surface.

Gang Area: The high resistivity zones expected to result from the group of quartz veins were detected at the following locations in the shallow zone.

•Southern part of lines G-5 to G-7

•Middle part of lines G-3 to G-4

•Northern part of lines G-4 to G-7

The high resistivity zones in the southern part of lines G-5 to G-7 and the middle part of lines G-3 to G-4 result from the Khe Gang prospect. In the vicinity of the northern part of line G-4 to G-7, the known prospect is not found. These high resistivity zones are restricted up to the depth of about 100 m from the surface and do not extend to the deeper zone. They will have gentle dip, since they are distributed rather broadly in the shallow zone.

Ngan Me area: The high resistivity zones expected to result from the group of quartz veins were detected at the following locations.

•Southern part of line N-5

•Middle part of line N-2

These high resistivity zones result from the Ba Khe prospect. Especially, the zone in the southern part of line N-5 extends to the deeper zone with steep dip and is expected to extend to the east. The extension of the high resistivity zone to the west (the West Ba Khe prospect) was not detected, since it was probably intercepted by the low resistivity zone attributed to fracture zone. High resistivity zones related to the Left Ba Khe - Middle Ba Khe prospects were not extracted. Because it is supposed that these prospects are small in size and the resistivity of this area is somewhat low on an average.

4-4 Potential of Mineral Resources

Potentials of gold and base-metals in the Bo Cu area have been investigated in the first phase survey.

Several showings and geochemical anomalies for galena veins were found within the survey area. The similarity to the Cho Dien galena mine and the type of the mineralization are examined. The potential of galena resources in the Bo Cu area is concluded to be small from the survey results.

As for the potential of gold, three mining areas and several geochemical anomalous zones have been defined in the western part of the survey area. The promising areas for gold-bearing quartz veins extracted through the detailed survey this phase are: Da Mai, Gang, and Ngan Me areas. The interesting extensions of these promising areas delineated by the geochemical survey are: Northeast of N. Bo Cu and Khe Ma both located to the east of the Da Mai area, Khe Can located to the northeast of the Gang area, Bai Vang located to the east of the Ngan Me area, and Khe Cam located to the northeast of the Ngan Me area.

Among three promising areas together with their extensions, the Da Mai-Khe Dui prospect is the prior target for the next stage exploration. Da Mai is a classic gold prospect in the Bo Cu area. The distribution of gold mineralization in the Da Mai-Khe Dui prospect is approximately 200-300 m wide and more than 1 km long. The mining activity by local people there is already at the waning stage. However it still has significant gold resources in the deeper part and the extensions. The gold mineralization is expected to extend to the east through Northeast of N. Bo Cu until Khe Ma gold anomalous zones for approximately 5 km. The Ba Khe prospect in the Ngan Me area is understood to be another target for the further exploration. Adits and inclined shafts are distributed for about 900 m along the creek in the E-W direction. The activities of local miners are limited above the ground water level. The gold mineralization is likely to extend both westwards to the West Ba Khe creek and eastwards to the Bai Vang gold anomalous zone for approximately 3.5 km in total. The Cay Thi prospect and its surrounding zone in the Gang area have another potential for gold resources.

It is concluded that the type of mineralization is mesothermal gold-bearing quartz veins hosted by the Cambrian Mo Dong and Than Sa Formations. The veins occur on the wing of the Bo Cu anticline. It is interpreted that the formation of veins was controlled structurally by the regional folding activity. The details are still not clear; it is one of the matters to be investigated in the next phase. The development of quartz veins is relatively intense. Anomalies occur densely. The size and magnitude of gold mineralization are estimated to be medium or small from the features of mineral showings and geochemical anomalies. The possibility for the development of mine may depend on the ore grade. The integrated interpretations of the survey results for the regional survey area and three detailed survey areas are shown in Figs. 1-4 to 1-7 respectively.

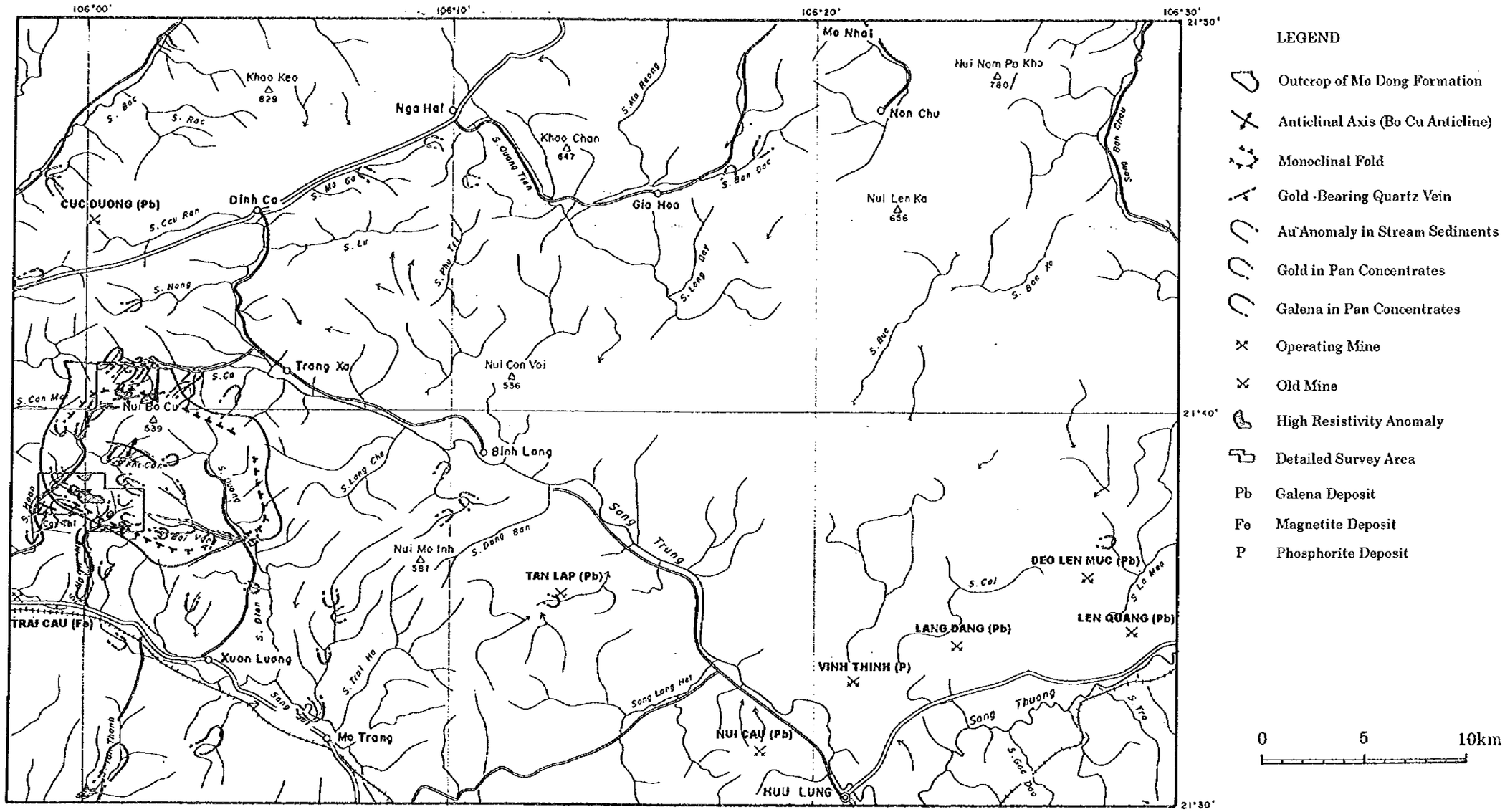


Fig. 1-4 Integrated Interpretation of the Survey Results in the Bo Cu Area

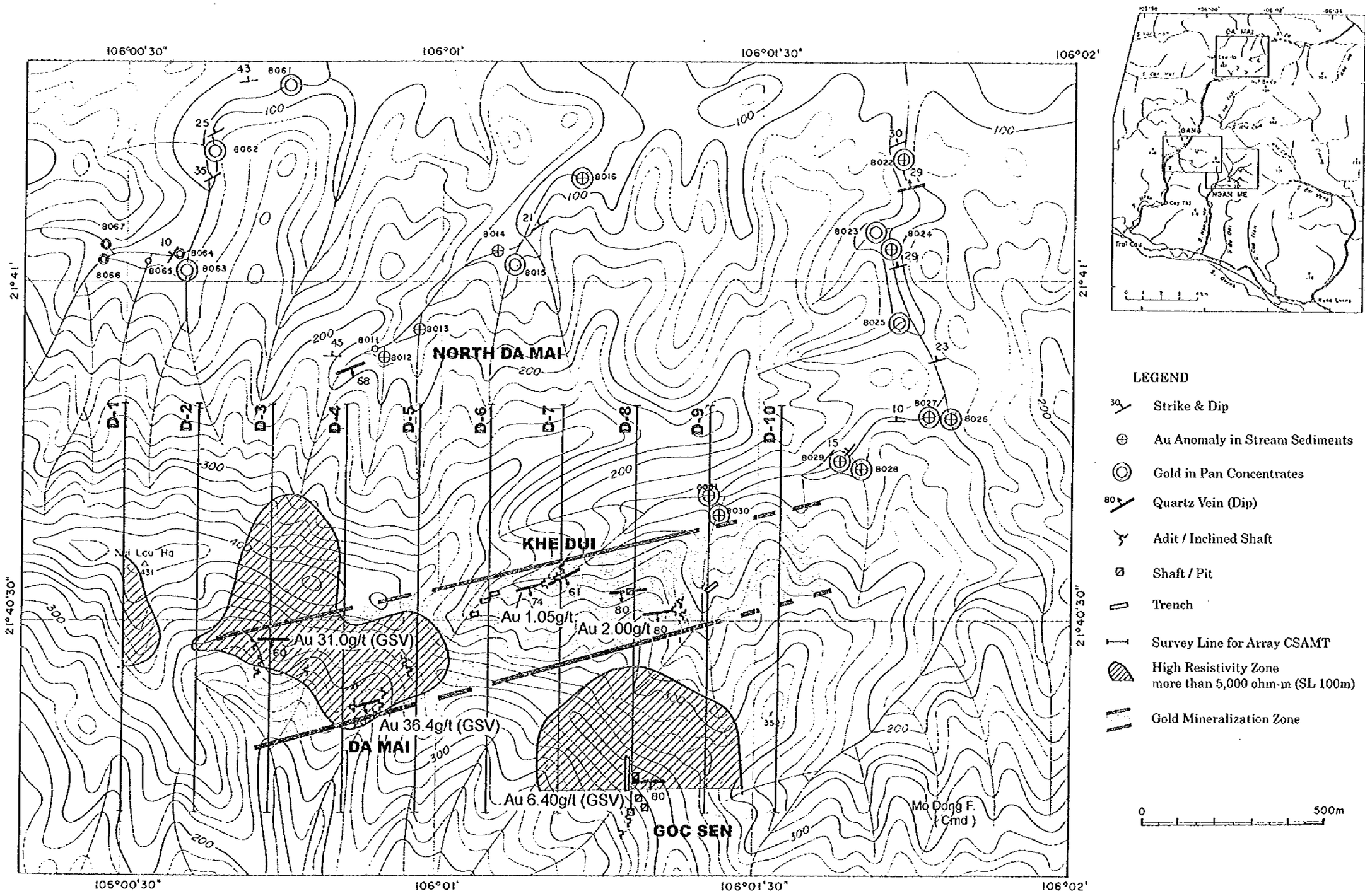
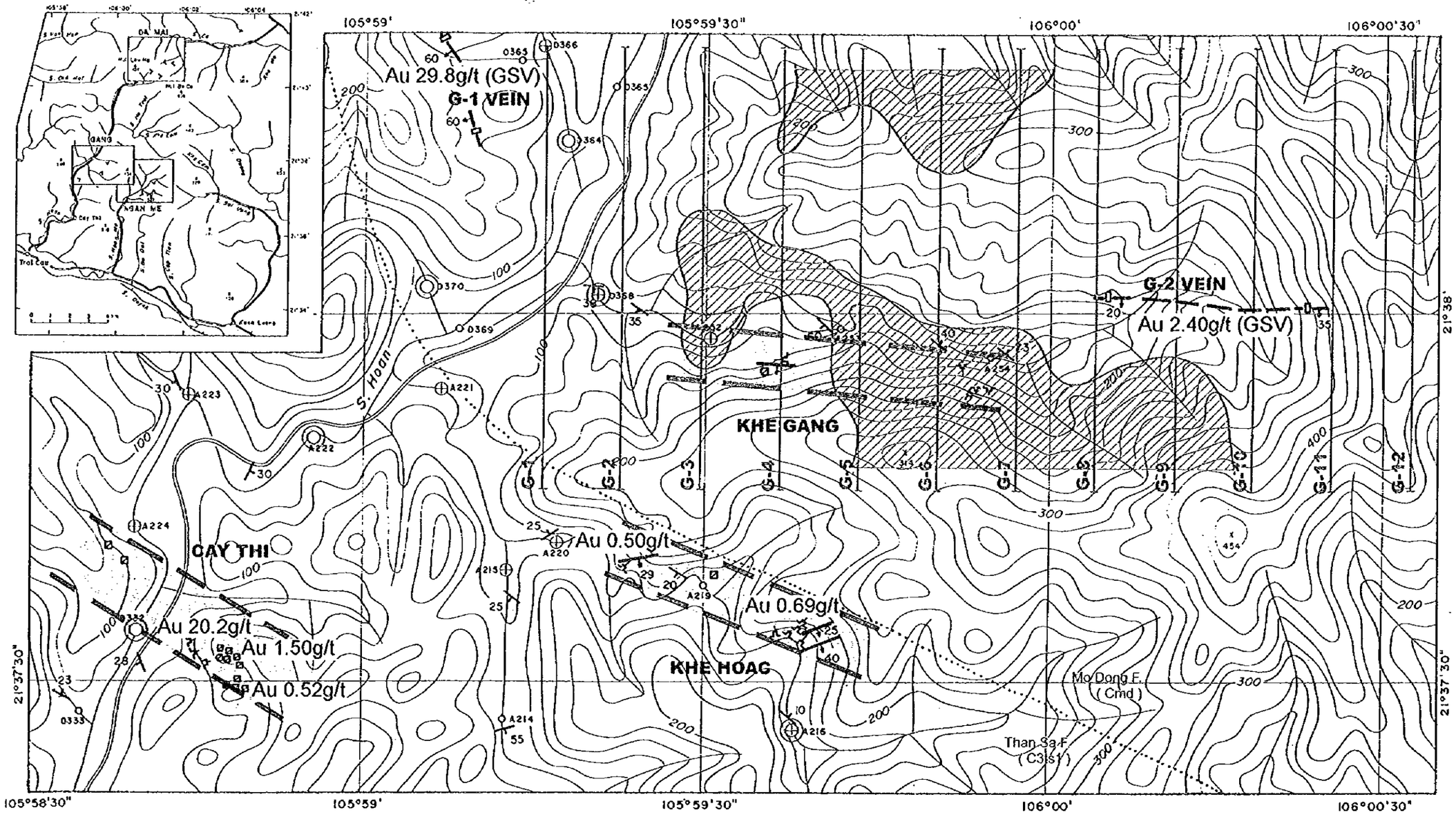


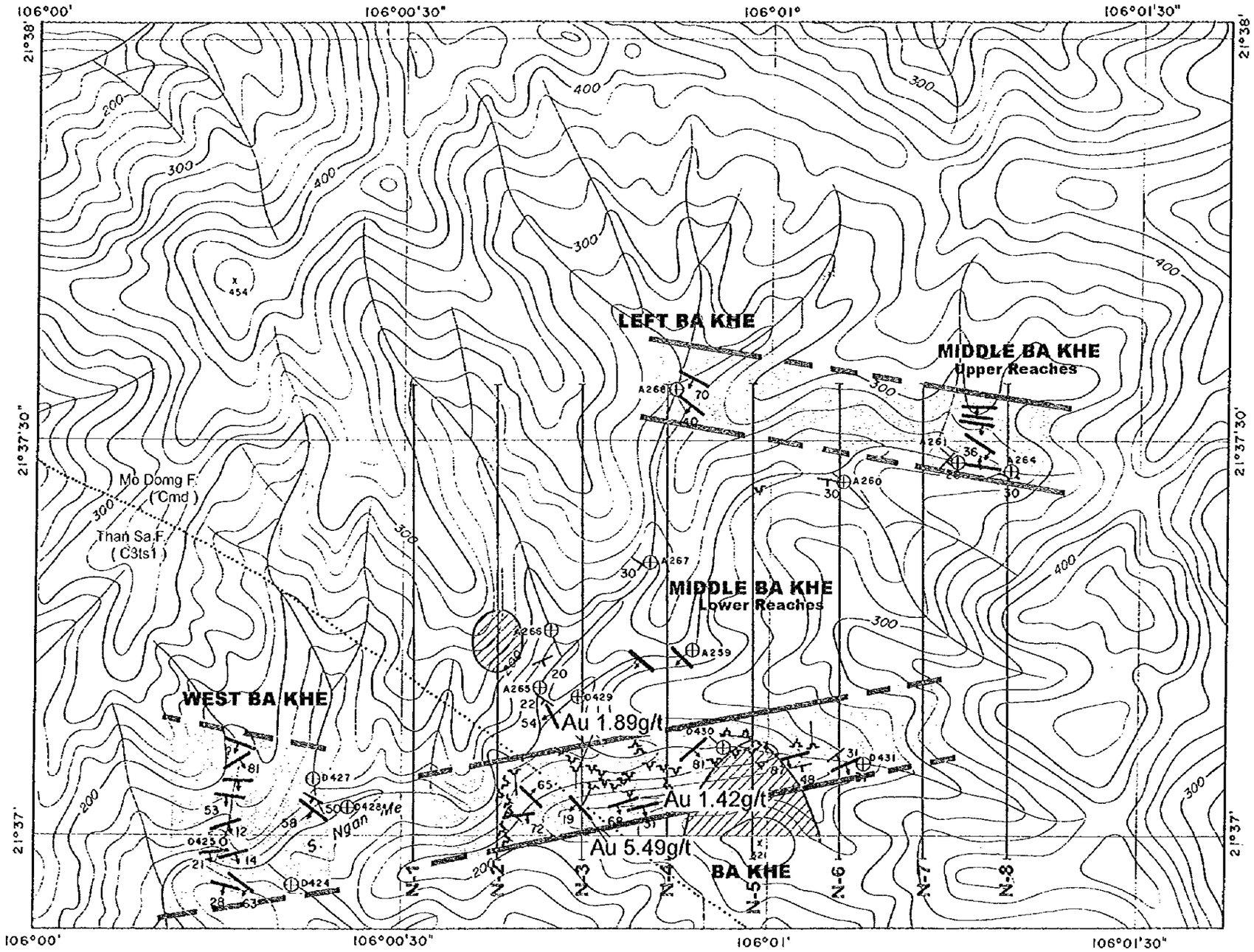
Fig. 1-5 Integrated Interpretation of the Survey Results in the Da Mai Area

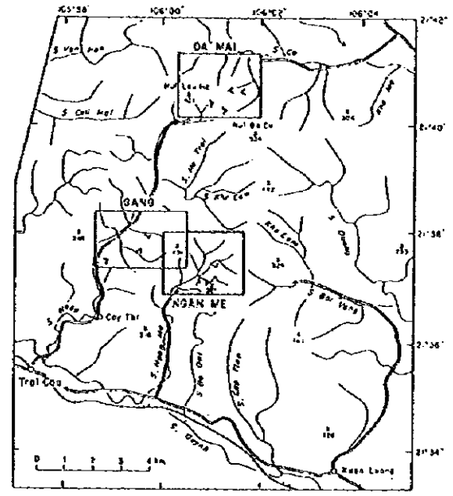


LEGEND

- Strike & Dip
- Boundary of Geological Unit
- Au Anomaly in Steam Sediments
- Gold in Pan Concentrates
- Quartz Vein (Dip)
- Adit / Inclined Shaft
- Shaft / Pit
- Trench
- Survey Line for Array CSAMT
- High Resistivity Zone more than 5,000 ohm-m (surface)
- Gold Mineralization Zone

Fig. 1-6 Integrated Interpretation of the Survey Results in the Gang Area





LEGEND

- Strike & Dip
- Boundary of Geological Unit
- Au Anomaly in Steam Sediments
- Gold in Pan Concentrates
- Quartz Vein (Dip)
- Adit / Inclined Shaft
- Shaft / Pit
- Trench
- Survey Line for Array CSAMT
- High Resistivity Zone more than 5,000 ohm-m (surface)
- Gold Mineralization Zone

0 500m

Fig. 1-7 Integrated Interpretation of the Survey Results in the Ngan Me Area

Chapter 5 Conclusions and Recommendations

5-1 Conclusions

On the basis of the results of the first phase works comprising regional geological survey, stream sediment geochemical survey, panning survey, detailed geological survey and CSAMT geophysical survey, the following conclusions are obtained.

(1) Regional Geology and Geologic Structure

The distribution of six major stratigraphic units from the Cambrian to the Quaternary systems consisting of 14 formations was surveyed and the geologic map of 1:50,000 scale was prepared in the Bo Cu area by the regional geological survey this phase. Geostructurally, the survey area is characterized by a series of anticlines and synclines called Bac Son anticlinorium whose axes orientates from NE, ENE to WNW. The Bo Cu anticline, whose axis trends WNW-ESE, is defined in the western part of the survey area where gold mineralization is extensively developed. Three major fault systems were distinguished in the survey area: NW, N-S, and NE systems. The main orogenic activity which resulted in the regional folding and tectonic faults in the Bo Cu area is interpreted to be occurred in the Triassic or later period. Small stocks of granite were found at the northern part of the survey area. The nature of this granite is discussed based on the whole rock analysis. It is concluded that this granite belongs to the granitoids of the magnetite series and of the S-type intruded at the marginal zone of the South China plate.

(2) Galena Mineralization

Regarding metallic mineral deposits in the Bo Cu area, two significant mineralizations, gold-bearing quartz veins and galena veins, were recognized. The galena veins occur mostly in the Carboniferous-Permian limestone. Several galena showings were found in the course of the regional geological survey and geochemical exploration. Some of them contain a significant amount of lead and silver. The similarity of geology and mineralization is discussed with the galena deposit in the Cho Dien area which is a famous Pb-Zn district in the northern Vietnam. The potential of galena resources in the Bo Cu area is estimated to be small from the survey results. As for the other mineral resources, a sedimentary phosphorite seam and a couple of magnetite lenses, both are considered to be small for that type of deposit, are known within the survey area.

(3) Gold Mineralization

Gold-bearing quartz veins occur extensively in the western part of the Bo Cu area. Although the width of each vein is not magnificent, they sometimes occur together forming a vein zone of 100-300 m wide and 500-1,000 m long. The system of quartz veins and the nature of gold mineralization were investigated by the detailed geological survey. On the basis

of the results of studies such as geologic environment, ore and gangue mineralogy, alteration, chemical analysis and fluid inclusion, it is interpreted that the type of mineralization is mesothermal gold vein hosted by sedimentary and metamorphic rocks of the Cambrian Mo Dong and Than Sa Formations. Two vein systems were distinguished by means of the stereo net analysis. One is N80°E with steeply dipping S, and another is E-W with gently dipping S. The veins occur on the wing of the Bo Cu anticline, and it is interpreted that the formation of veins is controlled structurally by the regional folding activity started probably from the Triassic period. According to the detailed geological survey together with the results of geochemical exploration, three areas for gold-bearing quartz veins have been examined, and potential for each area is preliminary evaluated. It is not likely to occur a big scale deposit in this area when seeing from the relative narrow and low grade quartz veins as well as the scale and intensity of geochemical anomalies. Among three areas and their extensions, Da Mai-Khe Dui and Ba Khe are promising prospects for gold resources.

(4) Geophysical Survey

The resistivity of the survey areas are high as a whole. The resistivity structure matches with the geologic structure. Especially, the Da Mai area has higher resistivity than the other areas and the high resistivity areas suggesting the distribution of granite were detected broadly below about 300m from the surface. With reference to the mineralized zone, the high resistivity zones resulting from the group of quartz veins more than 100m in width were extracted. The known prospects related to these zones and their features are as follows:

Da Mai area

- •No.7 and 8 on lines D-3 to D-5 (Da Mai, extension to deep zone, steep dip)
- •Southern part of lines D-7 to D-9 (Goc Sen, extension to deep zone, steep dip)

Gang Area

- •Southern part of lines G-5 to G-7 (Khe Gang, shallow zone, gentle dip)
- •Middle part of lines G-3 to G-4 (Khe Gang, shallow zone, gentle dip)
- •Northern part of lines G-4 to G-7 (no known prospects in the vicinity, shallow zone, gentle dip)

Ngan Me area

- •Southern part of line N-5 (Ba Khe, extension to deep zone and east, steep dip)
- •Middle part of lines N-2 (Ba Khe, shallow zone)

The laboratory test results gave the obvious contrast between the quartz vein containing pyrite and the other rocks in the survey areas. IP method is available for the high

resistivity zones extracted by this survey in order to delineate prospective parts, because these zones seem to contain few amounts of graphite.

(5) Da Mai-Khe Dui Prospect

The distribution of gold mineralization in the Da Mai-Khe Dui prospect is approximately 200-300 m wide and more than 1 km long. Gold-bearing quartz veins in the Da Mai-Khe Dui prospect are characterized by the vein trend of steeply dipping S. A significant amount of sulfide minerals is contained in the vein. Assay results by the GSV survey were significant this prospect. The mining activity by local people there is already at the waning stage. High grade ores near the surface were nearly mined out. However it still has significant gold resources in the deeper part and the extensions. The gold mineralization is expected to extend to the east through the Northeast of N. Bo Cu until Khe Ma gold anomalous zones for approximately 5 km. Remarkable Au anomalies of stream sediments and some gold anomalies of pan concentrates were found in the Northeast of N. Bo Cu and Khe Ma this phase.

(6) Ba Khe Prospect

The Ba Khe prospect in the Ngan Me area is understood to be another target for the further exploration. Adits and inclined shafts are distributed for about 900 m along the creek. Two systems of veins, E-W with steeply dipping S and E-W with gently dipping S, occur together in this prospect. The width of veins changes variously; some part shows a lens-like shape. Branching and joining of veins are frequently observed. Although assay results of ore samples were rather disappointing this time, the visible gold occasionally occurs in some part of quartz veins. The activities of local miners are limited above the ground water level. The gold mineralization is likely to extend both westwards to the West Ba Khe creek and eastwards to the Bai Vang gold anomalous zone for approximately 3.5 km. In Bai Vang, a couple of significant Au anomalies in stream sediments and tens of gold anomalies of pan concentrates were detected this phase.

(7) Other Prospects

The Cay Thi and its surrounding zone in the Gang area also have some potential for gold resources. Two zones of veins both are gently dipping S occur in this prospect. These two zones run parallel each other at 40 m apart vertically. Several significant assay results were obtained this phase. The other interesting gold prospects in the Gang area are Khe Gang and Khe Hoac. Gold-bearing quartz veins in these prospects show similar trend and nature as in the Cay Thi prospect.

5-2 Recommendations for the Second Phase Survey

Da Mai-Khe Dui Prospect

It is recommended that the detailed survey comprising IP survey and geological survey (including trenching and geochemical rock-chip survey) shall be made in this prospect and its eastern extension for the purpose of defining the drill target. After the detailed survey, a reconnaissance drilling for testing the IP anomalies shall be made.

Ba Khe Prospect

A detailed survey comprising IP survey and geological survey (including trenching and geochemical rock-chip survey) is recommended in the Ba Khe prospect and its extensions in the next phase. The purpose of this survey is to define the drill target for the further exploration.

PART II DETAILED DISCUSSIONS

PART II DETAILED DISCUSSIONS

Chapter 1 Regional Geological Survey

1-1 Outline of the Area

The Bo Cu area is located about 70 km north of Hanoi. It is situated in an inland area. The area lies along the upper to middle reaches of Song Rong and Song Trung, both are branches of Song Cau. The altitude of the area is not high; most of the area is situated between 50 and 500 m above sea level.

The area lies geologically among the distribution of Paleozoic to Mesozoic clastic rocks and limestone. The Tertiary rock does not occur in the Bo Cu area. Quaternary sediments occur along some drainage systems in the southern part of the survey area. These strata show complex foldings and cut by faults forming an anticlinorium with NE to ENE axes.

Based on the review of the existing geological information, together with the discussion held among Japanese and Vietnamese survey members at the beginning of the field survey, a preliminary geologic framework and stratigrapy were proposed, and regional geological survey was carried out over the survey area. The first phase survey covered over a rectangular area of 2,000 km^2. The field works for the regional survey area were composed of geological survey, stream sediment geochemical survey and panning survey. The major themes followed in the geological survey are: (1) to investigate the mineral potential -- mainly of gold --, and (2) to prepare geologic map of 1:50,000 of the Bo Cu area.

1-2 Survey Method

The first phase geological works in the Bo Cu area consisted of geological mapping and an investigating survey for the gold potential.

Prior to the field work, a series of topographic maps of 1:10,000 scale was prepared from the compilation of existing topographic maps (1:50,000 and 1:25,000) and satellite images. Several sets of GPS instruments were employed for locating major surveying points in the field.

During the field works, geology, gold mineralization and alteration were surveyed, and samples for petrography, ore mineralogy and other laboratory studies were collected together with samples for assaying at every major outcrop and mineral showing. Features of mineralization and alteration such as silicification, kaolinization and sulfide impregnation were carefully checked in the survey.

Several significant mineralized localities were found during the field survey. The route maps of 1:10,000 scale were produced by these surveys. The important outcrops, mineral

showings and old workings were studied in much detail (sketches of 1:50 to 1:200), and samples were taken for laboratory analysis.

A total length of more than 530 km was explored during the survey in the Bo Cu area, and the geological information was compiled into a geologic map of 1:50,000 scale. The geology and geologic profile of the Bo Cu area are shown in Fig. 2-1.

The numbers of samples collected in the survey are: 40 altered rock and clay samples for X-ray diffraction analysis, 31 rock samples for thin sections, 20 igneous rock samples for whole rock analysis, 11 quartz vein samples for fluid inclusion study and 103 ore samples for assaying (Au, Ag, Cu, Pb, Zn, As and Hg) and polished sections. The results of laboratory works and assaying are briefly summarized in Tables 2-1 to 2-10.

1-3 Geology and Geologic Structure

1-3-1 Introduction

The geology of the Bo Cu area is composed of the following six major stratigraphic units:

- Cambrian sedimentary rocks and schist with some limestone (Mo Dong Formation and Than Sa Formation)
- Ordovician sedimentary rocks and schist (Na Mo Formation)
- Devonian sedimentary rocks and schist with some limestone (Bac Bun Formation, Mia Le Formation and Na Quan Formation)
- Carboniferous to Permian limestone with some clastic rocks (Bac Son Formation and Dong Dang Formation)
- Triassic sedimentary rocks with interbedded acidic volcanic rocks (Lang Son Formation, Song Hiem Formation, Na Khuat Formation, Mau Son Formation and Van Lang Formation)
- Quaternary sediments

The general trend of these formations is ENE, E-W and WNW with local disorders. They form a series of foldings with the axes of NE, ENE or WNW direction. These sedimentary-metamorphic formations are cut by numerous fault systems whose major trends are NW, N-S and NE. Small intrusive bodies of granite occur locally in these formations. Based upon the photogeological analysis on the JERS-1 OPS and SAR images, the geologic structure of the Bo Cu area is characterized by the development of lineaments trending NE to ENE direction.

1-3-2 Stratigraphy

Mo Dong Formation ($C_{mđ}$)

The Mo Dong Formation is composed of gray to greenish gray sandstone, quartzitic sandstone, psammitic schist and sericite schist of the Cambrian System. This is the oldest rock of this area. The Mo Dong Formation crops out widely in the western part of the survey area and forms the major host rocks of mesothermal gold deposits. The representative localities of this formation are: Khe Gang, Ngan Me, and Da Mai.

Tang Sa Formation (C_{3ts})

The Than Sa Formation overlies on the Mo Dong Formation with lens of conglomerate. It corresponds to the Cambrian System, and forms the host rocks of mesothermal gold deposits together with the Mo Dong Formation in the western part of the survey area. This formation is subdivided into three series: Than Sa duoi (lower), Than Sa giua (middle), and Than Sa tren (upper). These are composed of gray to dark gray sandstone, quartzitic sandstone, psammitic schist, and multi-color schist. Layers of marly limestone and/or chalky clay are intercalated in the sandstone. Schistosity is better developed in the lower series of this formation. The major localities are: Cay Thi, S. Ngan Me, and S. Dien in the southwestern area.

Na Mo Formation (O_{nm})

The Ordovician System is named the Na Mo Formation in the Bo Cu area. It is composed of gray quartzitic sandstone, psammitic schist, black slate and phyllite. The locality is: S. Nang in the northwestern area.

Bac Bun Formation (D_{1bb})

The lower Devonian System is called The Bac Bun Formation. It is mainly composed of a series of sandstone, which shows gray to light gray and various features: coarse sandstone, quartzitic sandstone or psammitic schist, with intercalations of violet red color schist to reddish brown claystone (sometimes weakly schistose). A conglomerate unit occurs at the bottom of this formation. A muddy part of the claystone sometimes contains shell fossils. The major localities are: S. Lu (a branch of Song Rong), Song Mo Ga (where it is fault contacted with limestone), and S. Y Tich (eastern area).

Mia Le Formation (D_{1ml})

A thick pile of limestone occurs from the lower Devonian up to the Permian System; some are continuous to the lower Triassic. The lower Devonian limestone is named the Mia Le Formation. It is composed mainly of marly limestone, partly of chalky claystone, and rarely of psammitic schist and schist. The major localities of the Mia Le Formation are: La Meo (limestone with several thin layers of black schist, eastern area), Gop Nien (a village in the northernmost area), and S. Lang Rong (northern area).

Na Quan Formation (D_{2nq})

The middle Devonian limestone is called the Na Quan Formation. It is composed mainly of dark gray crystalline limestone, partly siliceous (cherty). It occurs at: Nga Hai (northern area), and Na Dong (northern area).

Bac Son Formation ($C\text{-}P_{bs}$)

The thick limestone layer of the Carboniferous to Permian System is named the Bac Son Formation. It shows various limestone features: gray to light gray massive limestone, dolomitic limestone, oolitic limestone, crystalline limestone, marly limestone, siliceous (cherty) limestone, etc. It occurs widely over the central to the eastern part of the survey area. The major localities are: north of Dan Tien, S. Loi (branch of Song Thuong), and S. Buc (central area).

Dong Dang Formation (P_{2dd})

The Dong Dang Formation is a thin (about 200 m) Permian formation comprising mainly limestone and claystone. The limestone shows dark color, and is massive, marly. The claystone, occasionally silty, occurs locally at the bottom of this formation. Bauxite occurs in some part of claystone near the boundary to limestone after the enrichment of alumina component when weathered. It is a characteristic feature of the Dong Dang limestone. The Dong Dang Formation overlies unconformably on the Bac Son limestone in some area. The major localities are: Ban So (upstream of Ban Chau), and S. Mo Roong (northern area).

Lang Son Formation (T_{1ls})

The Triassic System is divided into five formations, and this is the lower Lower-Midle System of them. It is mainly composed of gray phyllitic sandstone. It accompanies some normal (not metamorphosed) sandstone and siltstone. In the upper part of this formation, limestone with thin bands of chalky clay occurs. The Lang Son sandstone occurs at the upper reaches of Ban Chau, upper reaches of Song Thuong, and S. Na Dong (northern area).

Song Hiem Formation (T_{1-2sh})

The Song Hiem Formation is the second Lower-Middle Triassic System in the Bo Cu area. It is mainly composed of rhyolite lava flows. The rhyolite shows green to greenish gray, massive, porphyritic features. It sometimes jointed. Phenocrysts of quartz and plagioclase of up to 3 mm in diameter are seen in the rock. Under the microscope, phenocrysts of plagioclase, quartz, potash-feldspar and biotite were observed in a matrix of microcrystalline plagioclase and mosaic quartz. These minerals show porphyritic texture. In the upper part of this formation, layers of rhyolitic tuff (tuff and tuff-breccia), sandstone, siltstone and conglomerate occur locally. The major localities of the Song Hiem Formation are: upper reaches of Ban Chau, S. Tra (a branch of Song Thuong, at which rhyolitic tuff-breccia occurs below rhyolite lava), Song Trung (at which sandstone is intercalated within rhyolite lava), and Binh Gia gold mine (northern outside the survey area).

Na Khuat Formation (T_{2nk})

The Na Khuat Formation is one of the third Lower-Middle Triassic System in the Bo Cu area. It is composed of lower limestone and upper clastic sediments. The lower part of the Na Khuat Formation consists of gray to dark gray limestone. Claystone (some part muddy), siltstone and sandstone are the main members of the upper part. The claystone shows various color: light gray, gray, whitish gray, dark gray, reddish brown, and yellowish brown. It is weakly metamorphosed and phyllitic in some part. An alternation of limestone and siltstone occurs intermediately between lower limestone member and upper clastic member. The Na Khuat Formation occurs mainly at: lower to middle reaches of Ban Chau (Van Gieng), S. Tan Thanh (southwestern area), and south of Trai Cau.

Mau Son Formation (T_{3cms_1})

The upper Triassic System is divided into two: lower Mau Song Formation and upper Van Lang Formation. The Mau Son Formation is composed of sandstone, claystone and conglomerate. This formation occurs locally at the southern part of the survey area such as: upper reaches of S. Tan Thanh, and S. Oc.

Van Lang Formation (T_{3n-vl_2})

The Van Lang Formation is composed of sandstone, claystone and conglomerate. This formation occurs locally at the southern part of the survey area (Dong Hun).

Quaternary Series (Q)

The Quaternary Series is composed of gravels, sands, silts and clays along the alluvial plains in the Bo Cu area. It occurs at the southern part of the survey area. The localities are limited; along Song Rong and Song Trong,

1-3-3 Intrusive Rocks

Small stocks of granite occur near Binh Gia in the northern part of the survey area. There is no other outcrop within the survey area.

Outside the survey area, the late Triassic biotite granite occurs 50 km northwest from the western boundary of the survey area; the Cretaceous granite also occurs to the southwest of the survey area.

Near the Da Mai, Khe Gang and Ngan Me areas, there were thought to be cryptobatholiths of granitic rocks, which were considered to be something related to the mesothermal gold mineralization in those areas. Some report showed the existence of a small granite body south of Da Mai in the map (General Department of Geology & Mineral Resources, 1988). No such evidence, however, has been indicated in the first phase field survey.

Granite ($T\text{-}C_3$)

Three small stocks of granite crop out near Binh Gia. The dimension ranges from a few hundred meters to 2 km in diameter on the surface. They occur within marly limestone

and calcareous sandstone of the Bac Bun Formation and Mia Le Formation. They show gray to light gray color, massive granular features, composed of phenocrysts of quartz, potash-feldspar, biotite and plagioclase. Under the microscope, phenocrysts of quartz, plagioclase, potash-feldspar and biotite were observed. These minerals show hypidiomorphic granular texture. Some handspacimen slightly show cataclastic texture which forms fissures filled by cryptocrystalline silica, flaky chlorite, sericite and fine-grain epidote. Small amount of tourmaline, zircon and opaque minerals are contained.

These three stocks, separated for 500 m to 5 km each other, are arranged in the ENE-WSW direction. They are interpreted to be connected below the surface. The time of emplacement of these stocks are considered to be sometime between Triassic and Cretaceous from the regional distribution.

Whole Rock Analysis

Twenty rock samples were provided for whole rock analysis. Thirteen major components including Cr_2O_3 and LOI were analyzed. Results of chemical analysis and CIPW norm calculation are shown in Table 2-1. Rock names of igneous and volcanic rocks identified from field observations and thin sections were checked and confirmed through the whole rock analysis.

Regarding eight granite samples, the results of the CIPW norm calculation were plotted on the Q (quartz)-A (potash-feldspar)-P (plagioclase) diagram. Most of the samples appear in the region of quartz-rich granitic rocks. The type and series of felsic magma of these granite samples were also examined by the whole rock analysis together with the petrographical studies. The results indicate that these samples belong to the magnetite series (Ishihara et al, 1977) and the S-type (Chappell & White, 1974) granitoids.

Table 2-1 Results of Whole Rock Analysis and Norm Calculation

Sample No.	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	Cr_2O_3 %	L.O.I. %	Total %	FeO*/MgO	Sol. Index %	Rock	Locality
A084W	71.66	0.81	10.34	2.90	4.98	0.05	0.91	1.84	1.63	2.97	0.10	<0.01	2.34	100.53	8.34	6.80	Rhyolite (T_{1-2sh})	Ban Cau
A085W	68.24	0.91	12.70	2.02	4.54	0.07	0.72	2.50	1.95	4.69	0.12	<0.01	1.91	100.37	8.83	5.17	Rhyolite (T_{1-2sh})	Ban Cau
A178W	75.02	0.78	11.57	1.52	2.24	0.03	0.54	0.08	3.08	3.49	0.04	<0.01	1.83	100.23	6.68	4.97	Rhyolite (T_{1-2sh})	Suoi Tra
A211W	69.08	1.06	12.70	2.41	4.88	0.07	0.89	0.35	3.00	2.58	0.15	<0.01	2.71	99.88	7.92	6.47	Rhyolite (T_{1-2sh})	Song Trung
C008W	72.26	0.91	12.50	2.91	2.24	0.03	0.73	0.16	4.61	0.90	0.10	<0.01	2.36	99.72	6.66	6.41	Rhyolite (T_{1-2sh})	Cue Duong
C009W	67.36	0.89	13.21	0.90	4.52	0.08	1.32	2.29	2.42	4.72	0.14	<0.01	2.40	100.26	4.04	9.51	Rhyolite (T_{1-2sh})	Cue Duong
C011W	67.42	0.91	13.80	1.48	3.67	0.05	1.23	1.71	2.50	4.86	0.13	<0.01	2.37	100.13	4.07	8.95	Rhyolite (T_{1-2sh})	Cue Duong
C019W	66.20	0.88	12.52	2.61	3.55	0.06	0.66	8.91	0.92	0.53	0.11	<0.01	3.40	100.36	8.94	7.98	Rhyolite (T_{1-2sh})	Luong Naung
C020W	70.12	0.73	11.90	1.14	4.50	0.05	0.71	2.11	3.29	2.80	0.11	<0.01	2.18	99.65	7.78	5.71	Rhyolite (T_{1-2sh})	Luong Naung
C021W	69.06	0.83	12.75	1.43	4.83	0.06	0.59	1.65	2.50	4.09	0.12	<0.01	1.89	99.81	10.37	4.39	Rhyolite (T_{1-2sh})	Huu Le
C022W	91.22	0.07	3.98	0.93	0.46	0.01	0.10	0.04	0.17	2.11	0.04	<0.01	0.47	99.61	12.97	2.65	Granite ($T\text{-}C_3$)	Mo Nhai
C023W	89.28	0.09	4.87	0.82	0.64	0.01	0.08	0.01	0.22	3.14	0.05	<0.01	0.43	99.65	17.23	1.63	Granite ($T\text{-}C_3$)	Mo Nhai
C024W	90.20	0.00	4.32	1.03	0.46	0.01	0.12	0.08	0.26	2.24	0.05	<0.01	0.53	99.30	11.56	2.92	Granite ($T\text{-}C_3$)	Mo Nhai
C025W	88.46	0.00	5.53	0.28	0.49	0.01	0.13	0.06	0.32	3.83	0.05	<0.01	0.54	99.70	5.71	2.57	Granite ($T\text{-}C_3$)	Mo Nhai
C026W	97.76	0.12	0.22	0.16	0.40	<0.01	0.02	0.19	0.07	<0.01	0.04	<0.01	0.25	99.23	27.20	3.08	Granite ($T\text{-}C_3$)	Mo Nhai
D125W	84.92	0.07	6.50	2.06	0.53	<0.01	0.03	0.03	0.41	4.78	0.06	<0.01	0.56	99.96	79.47	0.38	Granite ($T\text{-}C_3$)	Ho Tam Hoa
D126W	84.74	0.15	7.19	0.70	0.47	<0.01	0.24	0.05	0.21	4.22	0.05	<0.01	1.05	99.07	4.58	4.11	Granite ($T\text{-}C_3$)	Deo Keo Gan
D127W	89.76	<0.01	4.53	0.86	0.57	<0.01	0.12	0.03	0.24	2.45	0.05	<0.01	0.64	99.25	11.20	2.83	Granite ($T\text{-}C_3$)	Deo Keo Gan
D181W	67.84	0.91	13.10	1.13	4.51	0.06	1.39	2.45	2.20	4.35	0.16	<0.01	1.77	99.87	3.98	10.24	Rhyolite (T_{1-2sh})	Nga Hai
D183W	67.38	0.93	13.19	3.51	2.44	0.06	1.38	2.24	2.69	4.80	0.16	<0.01	1.55	100.34	4.06	9.31	Rhyolite (T_{1-2sh})	Ban It

Sample No.	Q %	C %	or %	ab %	an %	wo %	di %	hy %	ol %	mt %	hm %	il %	ap %	Total %
A084W	43.29	1.34	17.55	13.79	8.48	0.00	0.00	7.77	0.00	4.20	0.00	1.54	0.23	98.19
A085W	30.44	0.16	27.72	16.50	11.62	0.00	0.00	7.09	0.00	2.93	0.00	1.73	0.28	98.46
A178W	42.15	2.68	20.62	26.06	0.14	0.00	0.00	2.97	0.00	2.20	0.00	1.48	0.09	98.39
A211W	37.67	4.69	15.25	25.39	0.76	0.00	0.00	7.57	0.00	3.49	0.00	2.01	0.35	97.17
C008W	40.73	3.89	5.32	39.01	0.14	0.00	0.00	2.08	0.00	4.22	0.00	1.73	0.23	97.35
C009W	25.90	0.29	27.89	20.48	10.45	0.00	0.00	9.52	0.00	1.30	0.00	1.69	0.32	97.85
C011W	27.28	1.63	28.72	21.15	7.64	0.00	0.00	7.17	0.00	2.15	0.00	1.73	0.30	97.76
C019W	40.92	0.00	3.13	7.78	28.47	1.71	9.22	0.00	0.00	3.78	0.00	1.67	0.25	96.95
C020W	32.24	0.00	16.55	27.84	9.43	0.00	0.27	7.83	0.00	1.65	0.00	1.39	0.25	97.46
C021W	31.86	1.50	24.17	21.15	7.40	0.00	0.00	7.89	0.00	2.07	0.00	1.58	0.28	97.91
C022W	82.02	1.42	12.47	1.41	0.00	0.00	0.00	0.25	0.00	1.30	0.03	0.13	0.09	99.12
C023W	75.72	1.11	18.56	1.81	0.00	0.00	0.00	0.56	0.00	1.19	0.00	0.17	0.06	99.18
C024W	79.90	1.44	13.24	2.20	0.07	0.00	0.00	0.31	0.00	1.49	0.00	0.00	0.12	98.77
C025W	71.44	0.86	22.63	2.69	0.00	0.00	0.00	1.01	0.00	0.41	0.00	0.00	0.12	99.16
C026W	96.93	0.00	0.00	0.59	0.29	0.00	0.35	0.27	0.00	0.23	0.00	0.23	0.09	98.98
D125W	64.25	0.65	28.25	3.35	0.00	0.00	0.00	0.07	0.00	1.50	1.03	0.13	0.14	99.37
D126W	67.01	2.28	24.94	1.74	0.00	0.00	0.00	0.63	0.00	1.01	0.00	0.28	0.12	98.02
D127W	78.69	1.48	14.48	1.95	0.00	0.00	0.00	0.64	0.00	1.25	0.00	0.00	0.12	98.60
D181W	28.81	0.70	25.71	18.62	11.11	0.00	0.00	9.42	0.00	1.64	0.00	1.73	0.37	98.10
D183W	26.96	0.00	28.37	22.76	9.74	0.00	0.26	3.47	0.00	5.09	0.00	1.77	0.37	98.78

Table 2-2 Results of Microscopic Observation of Thin Sections

Sample No.	Locality	Rock Name	Formation	Texture	Phenocryst/Crystal Fragment									Groundmas/Matrix						Alteration & Remarks
					Qz	Kf	Pl	Bi	Hb	Px	Ol	Ep	Op	Qz	Kf	Pl	Hb	Px	Gl	
A006T	S. Mo Ga	Arkose Sandstone	D1bb	Clas	●	·	△						·							
A084T	Ban Chau	Rhyolite	T1-2sh	Porp	△		○						·	△		△				Pl → Ch·Ep
A178T	S. Tra	Rhyolite	T1-2sh	Porp	·		△						·	△		○				Pl → Ch
A211T	S. Trung	Rhyolite	T1-2sh	Porp	△	·	○	·					·	△		○				Pl → Se, Bi → Ch
A212T	S. Trung	Tuff	T1-2sh	Pycl	△	·	·						·	●		△		·		Pl → Ch·Se
A252T	Ba Khe	Sandstone	Cmd	Clas	●		·						·							Subfeldspathic Arenite
B004T	Nui Bo Con	Sandstone	Cmd	Clas	●		△													Feldspathic Arenite
B011T	S. Khuyei	Sandstone	C3ts	Clas	●		·													Subfeldspathic Arenite
C008T	Cue Duong	Rhyolite	T1-2sh	Porp	△	·	○	·						△		○				Pl·Bi → Ch
C009T	Cue Duong	Rhyolite	T1-2sh	Porp	·	·	○							△		○				Pl → Ch·Se·Ep
C011T	Cue Duong	Rhyolite	T1-2sh	Porp	△	·	○	·						△		○				Pl·Bi → Ch
C019T	Luong Naung	Rhyolite	T1-2sh	Porp	△	·	△				·	·		△		○				Pl → Ch·Ep
C020T	Luong Naung	Rhyolite	T1-2sh	Porp	△	△	△	·			·	·		△		○				Pl·Kf → Ch·Ka, Bi → Ch
C021T	Huu Le	Rhyolite	T1-2sh	Porp	△	·	△				·	·		△		●				Pl → Se·Ep, Kf → Se
C023T	Mo Nhai	Granite	T-Cg	Hypd-gr	○	●	△	·												Weakly cataclastic
C025T	Mo Nhai	Granite	T-Cg	Hypd-gr	●	●	△	·					·							Weakly cataclastic
C026T	Mo Nhai	Quartz-rich Granite	T-Cg	Hypd-gr	●		△													Qz recrystalized
C028T	Mo Nhai	Barite	--	--																Barite crystal with Se·Qz
C056T	S. Dien	Shale	C3ts	Clas																Composed of Qz,clay,Se,Ch
D056T	S. Dao	Psammitic Schist	D1ml	Clas·Comp	●		·													Qz-vein intersected
D125T	Ho Tam Hoa	Granite	T-Cg	Hypd-gr	●	○	○	·												Pl → Se, Weakly cataclastic
D126T	Deo Keo Gan	Granite	T-Cg	Hypd-gr	●	○	○	·												Pl → Se, Weakly cataclastic
D127T	Deo Keo Gan	Granite	T-Cg	Hypd-gr	●	○	●	·												Pl → Se, Weakly cataclastic
D181T	Nga Hai	Rhyolite	T1-2sh	Porp	△	·	○	·					·	○		●				Pl → Se
D183T	Ban It	Rhyolite	T1-2sh	Porp	●	·	●	·						△		○				Pl → Se
D185T	Ban It	Sericite Schist	C-Pbs	Clas·Comp																Composed of Se,Ch,Ca,clay
D360T	S. Hoan	Altered Sandstone	Cmd	Clas	●															Altered into Se
D395T	Cay Tri	Claystone	C3ts	Clas	○															Mainly composed of clay,Se
D401T	Ngan Me	Psammitic Schist	Cmd	Clas·Comp	●		·	·												
D454T	Da Mai	Sericite Schist	Cmd	Clas·Comp																Mainly composed of Se,clay
D461T	Da Mai	Psammitic Schist	Cmd	Clas·Comp	●		●													

Abundance of Minerals: ● ;Abundant, ○ ;Common, △ ;Rare, · ;Trace

Formation Names : Cmd;Mo Dong, C3ts;Than Sa, Onm;Na Mo, D1bb;Bac Bun, D1ml;Mia Le, D2nq;Na Quan, C-Pbs;Bac Son, P2dd;Dong Dang, T1ls;Lang Son, T1-2sh;Song Hiem, T2nk;Na Khuat, T-Cg;Granite Intrusive

Textures : Pycl;Pyroclastic, Clas;Clastic, Porp;Porphyritic, Lepb;Lepidoblastic, Glom-gr;Glomerophyric granular, Hypd-gr;Hypidiomorphic granular, Ophi;Ophitic, Int-gr;Inter-granular, Hol-pp;Holocrystalline-porphyritic, Comp;Compressed

Minerals : Qz;Quartz, Kf;Potash Feldspar, Pl;Plagioclase, Bi;Biotite, Hb;Hornblende, Px;Pyroxene, Ol;Olivine, Ep;Epidote, Op;Opaque Minerals, Gl;Glass, Ch;Chlorite, Se;Sericite, Ca;Carbonates

1-3-4 Geologic Structure

Fold Structure

Geostructural scheme is established on the basis of geologic evolution and the age of fold movement. The Bo Cu area is structurally characterized by a series of anticlines and synclines called Bac Son anticlinorium. It is elongated from Bo Cu mountain following east to northeast to Bac Son, Dong Mo until Lang Son. It is well-proportioned; the southern side is cut by a fault running along the national road No. 1a and Quynh Dong-Bo Ha fault. The northern side is componented by Mesozoic formations. The axis of the anticlinorium orientates to ENE to NE. It passes through Bo Cu, Mo Nhai and Bac Son. It is composed of terrigenous, terrigene-carbonate, carbonate, and terrigene-volcanic sediments of the middle Cambrian to the middle Triassic in ages. The total thickness is about 10,000 m. The Bac Son anticlinorium consists mainly of Bo Cu anticline, Bac Son anticline and Trang Xa-Nhat The syncline. The time of these folding activities is thought to be Mesozoic according to the explanatory note of the 1:200,000 geologic map.

Fault

Three major faults systems are distinguished in the Bo Cu area: NW system, N-S system and NE system.

Faults of NW system are normal, compound ones, generated earlier than those of NE system. The most prominent NW fault occurs in the southern part of the survey area, running from Thai Nguyen through Trai Cau and Quynh Dong down to Yen Thien. Both NW and SE sides are cut through Mesozoic strata, and partly covered by Quaternary sediments. This fault system is interpreted to be formed nearly at the same time as the Bo Cu anticlinal activity.

Faults of N-S system occur in two areas: May Khoan-Khao Lien-Deo Giao, and Coc Vuong-Dong Khuong. These sublongitudinal faults are cut in many places by faults of NE system.

Faults of NE system occur pervasively over the survey area. They are subdivided into two groups: northwestern group and southeastern group. These faults cut both those of NW system and N-S system. Along these faults, intense deformation and shearing are observed.

According to the satellite image analysis, extensive development of lineaments was observed. The major systems recognized on the JERS-1 SAR image are: ENE, NE, NNE, E-W and NW. Among them, those of NE to ENE are dominating.

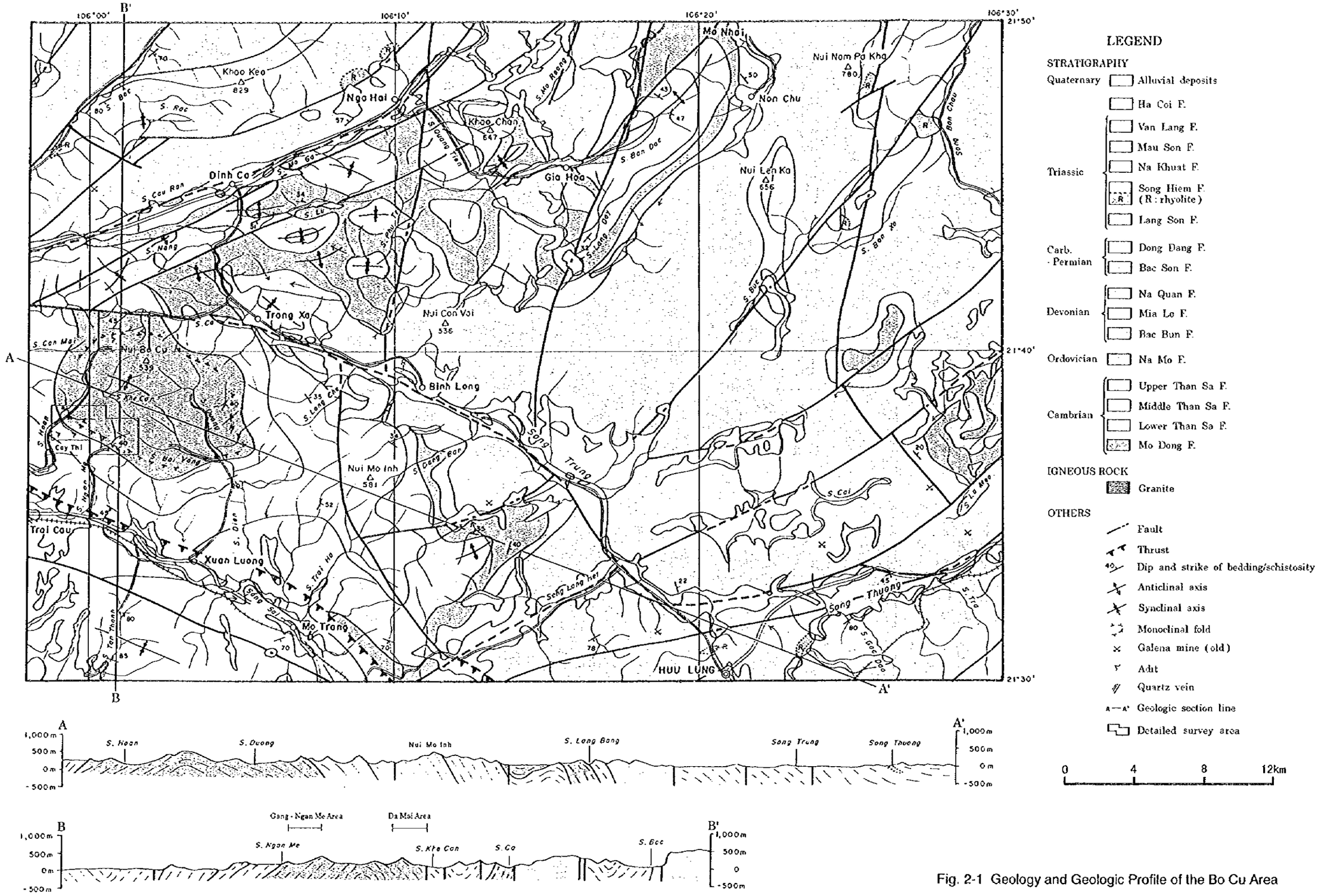


Fig. 2-1 Geology and Geologic Profile of the Bo Cu Area

1-4 Mineralization

Metallic and non-metallic mineral deposits whose occurrences were confirmed within the Bo Cu area during the field survey are as follows:

- •Gold-bearing quartz vein
- •Alluvial gold
- •Galena vein
- •Magnetite lens
- •Phosphorite
- •Limestone (for quarrying)

The list of the major known mineral deposits is shown in Table 2-3. The details of each deposit are described below.

Gold-Bearing Quartz Vein

Gold-bearing quartz veins are known in five areas: Da Mai, Gang, Ngan Me, Cay Thi, and Bai Vang. These are thought to be a mesothermal gold deposit. The details of the occurrences of gold deposits in each area is described in the chapter of the detailed survey.

Alluvial Gold

Alluvial gold is dug at many places around the hard-rock gold deposits. The major localities are: Trai Cau (lower reaches of S. Ngan Me), Trai Gai (middle reaches of Trai Cau), and Xuan Luang (upper and middle reaches of S. Bai Vang). Gold occurs mainly at the bottom of the Quaternary alluvial sediments in those localities. Alluvial gold also occurs at a few meters deep in the rice-field soil. Gold-bearing quartz veins several kilometers up the drainage systems are most likely the source of the alluvial gold.

Galena Vein

Galena veins were found in five places: Tan Lan (middle reaches of Song Trung in the central southern area), Nui Cau Re (lower reaches of Song Trung in the central southern area), Lang Dang (southeastern area), Deo Len Muc (southeastern area), and Len Quang (southeastern area). These galena veins are narrow (20 to 40 cm in width) and discontinuous (up to several ten meters). They are hosted mainly by limestone of Bac Son Formation. A small amount of sphalerite and pyrite also occur together with galena.

Magnetite Lens

Magnetite is concentrated in a particular horizon of siltstone and sandstone of the Jurassic Ha Coi Formation. It forms lenses of up to several meters. Magnetite lenses are outcropped near Trai Cau, and mined as iron ores. Magnetite mines are located a few km to the east and west of Trai Cau.

Phosphorite

Sedimentary phosphorite was found and mined at Vinh Thinh near Huu Lung in the southeastern area. Phosphorite occurs in limestone of the Bac Son Formation. Phosphorite ores at a grade of 25 to 30 % P_2O_5 were mined by the underground method intermittently between 1930's and 1992. It has been mined out, and now producing only limestone at this location.

Limestone

Limestone is wide spread from the eastern to the central parts of the Bo Cu area. It occurs mainly from the Mia Le Formation to the Dong Dang Formation. Limestone is quarried in many places. Most of them are small scale; sometimes mined by local people using hand-pick and dynamite. The limestone is sent mainly to the cement factories. Some of them are utilized for the other purposes such as road construction and building materials.

Table 2-3 List of the Known Mineral Deposits

	Da Mai (Gold Vein)	Gang (Gold Vein)	Ngan Me (Gold Vein)	Bai Vang (Gold Vein)	Binh Gia (Gold Vein)	Trai Cau (Alluvial Gold)	Xuan Luang (Alluvial Gold)	Tan Lap (Galena Vein)	Nui Cau Re (Galena Vein)	Deo Len Muc (Galena Vein)	Len Quang (Galena Vein)	Trai Cau (Magnetite Lens)	Vinh Thinh (Phosphorite)
Location	Upper reaches of Suoi Ca (NW of N. Bo Cu)	Middle reaches of Suoi Hoan (SW of N. Bo Cu)	Upper reaches of Suoi Ngan Me (S of N. Bo Cu)	Upper reaches of Suoi Bai Vang (S of N. Bo Cu)	Near Binh Gia (NE outside)	Lower reaches of Suoi Ngan Me	Upper & middle reaches of Suoi Bai Vang	Middle reaces of Song Trung	Lower reaches of Song Trung	Upper reaches of Suoi La Meo	Upper reaches of Suoi La Meo	E & W of Trai Cau	N of Huu Lung
(I) Host Rocks (1) Kind of Host Rocks	Cmd (Mo Dong) Qzite, SS, Psam, Ser-Sch	Cmd (Mo Dong) Qzite, SS, Psam, Ser-Sch	Cmd (Mo Dong) Qzite, SS, Psam, Ser-Sch	Cmd (Mo Dong) Qzite, SS, Psam, Ser-Sch	T1-2sh (Song Hiem) Rhy	C3ts2 (Than Sa giua) SS, Qzite, Sch, Cal-Sch	C3ts1 (Than Sa duoi) Sch, Psam, Cgl	C-Pbs (Bac Son) LS	C-Pbs (Bac Son) LS	C-Pbs (Bac Son) LS	C-Pbs (Bac Son) LS	Ha Coi Silt, SS	C-Pbs (Bac Son) LS
(2) Folding & Faults													
(II) Igneous Rock	(not known)	(not known)	(not known)	(not known)	(not known)			(not known)	(not known)	(not known)	(not known)		
(III) Alteration					Kaolinization								
(IV) Ore Deposit (1) Vein System & Structure	E-W, ENE, WNW, N-S, mostly steeply dipping S	NW, 60SW (G1) E-W, 20-35S (G2)	ENE, E-W, 40-85S	ENE, E-W, 40-85S	N-S, 75E								
(2) Ore Minerals								Galena, sphalerite, pyrite	Galena	Galena	Galena	Magnetite	Apatite
(3) Gangue Minerals													
(4) Major Assay Results	36.38g/t Au @90cm, 31.00g/t @50cm	29.77g/t Au @50cm	140.95g/t @70cm		Ave 10g/t Au @20cm			100g/t Ag, 9.33% Pb @120cm					
(V) Geochemical Features		Stream sediment anomaly (Au)				Stream sediment anomaly (Au)	Stream sediment anomaly (Au)						
(VI) Mining & Prospecting Activity	Mining by local people Pitting (GSV, 1992)	Mining by local people Pitting (GSV, 1992)	Mining by local people Pitting (GSV, 1992)	Mining by local people	Prod 30 kg Au/year Drilling 8 holes x 200m	Alluvial mining Pitting (GSV, 1988)	Alluvial mining Pitting (GSV, 1988)	Mining by local people	Mining by local people	Mining by local people	Mining by local people	Open pit mining	Underground mining (1930's-1992)
(VII) Remarks	Gossan				Discovered in 1986 Operated by Pha Lay Gold & Rare Minerals	Gossan							

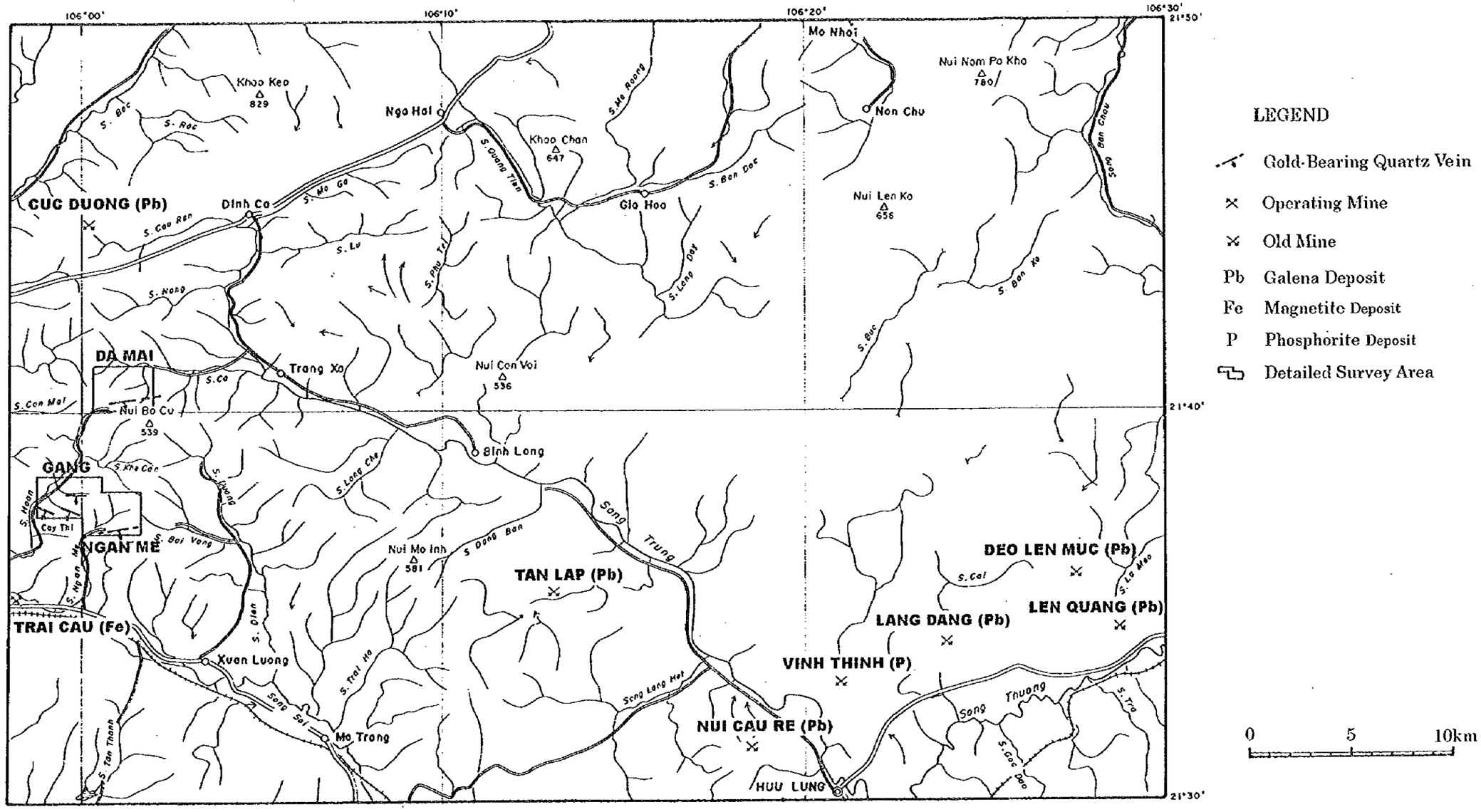
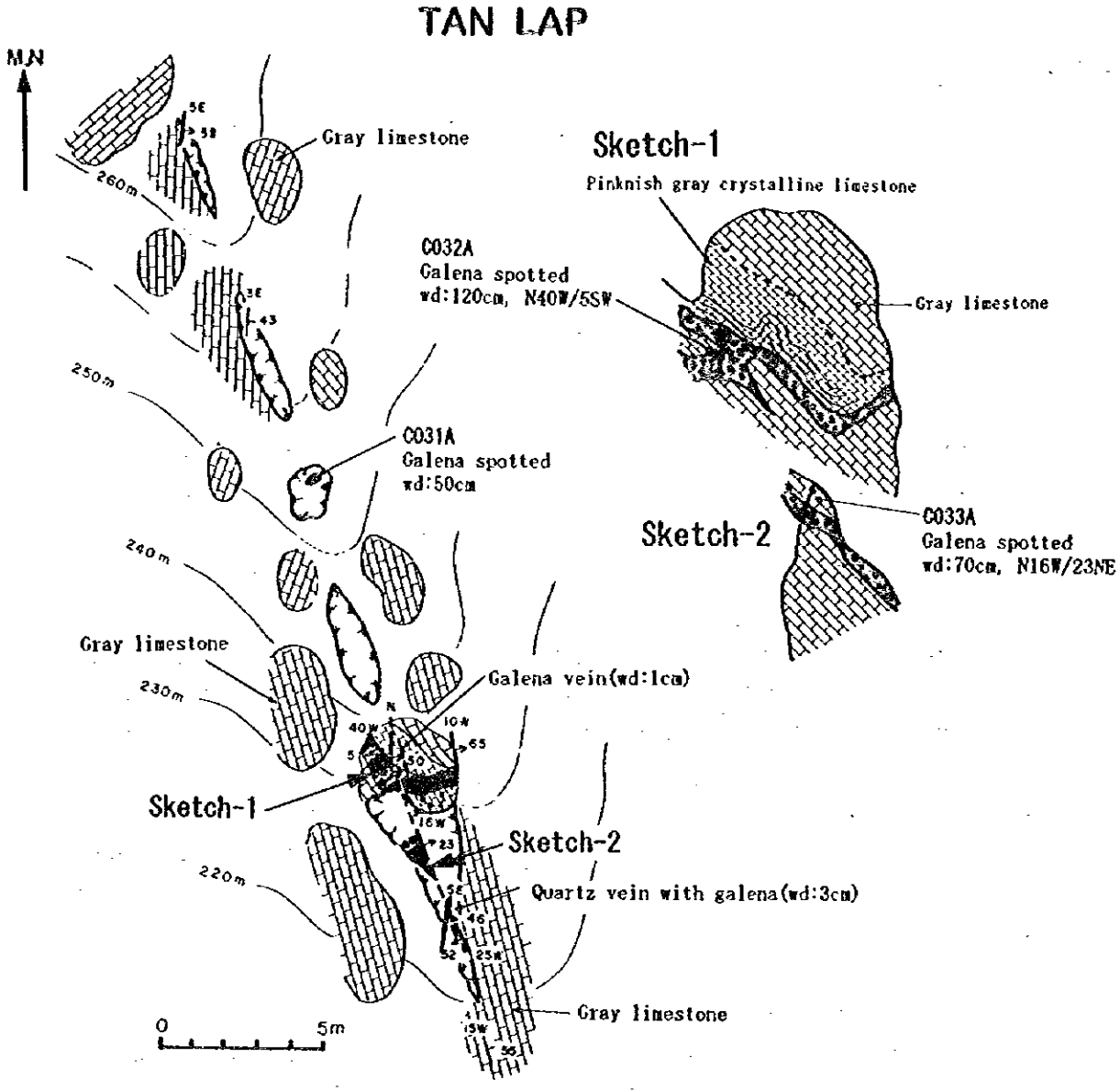


Fig. 2-2 Distribution Map of the Known Mineral Deposits in the Bo Cu Area



Sample No.	Width(m)	Au(g/t)	Ag(g/t)	Cu(%)	Pb(%)	Zn(%)
C031A	50cm	0.01	73.1	0.01	8.85	0.06
C032A	120cm	0.01	99.6	0.01	9.33	0.39
C033A	70cm	<0.01	162.9	0.01	5.83	0.07
B018A, M, X	grab	0.01	282.3	0.07	10.36	1.09
B019A, M, X	grab	0.01	178.3	0.10	9.84	6.88

※ A: Assay sample, M: Ore microscopy
X: X-ray diffraction analysis

Fig. 2-3 Sketch of Galena Veins in Tan Lap

1-5 Discussion

The geological features of the survey area consist of sedimentary and metamorphic rocks of Cambrian, Ordovician, and Devonian to Jurassic systems. Acidic volcanics occur in the lower-middle Triassic system. The major part of these geologic units exhibits the NE to ENE direction which represents the characteristics of the regional geologic structure (eastern part of the Vietbac geological district), and forms a complex folding structure (anticlinorium). Moreover, the area is cut into many blocks by tectonic faults. Intrusive of a large-scale igneous complex was not found in this area; only small stocks of granite occur within and in the vicinity of the Bo Cu area..

The Bo Cu area is structurally characterized by a series of anticlines and synclines named Bac Son anticlinorium comprising Bo Cu anticline, Bac Son anticline and Trang Xa-Nhat The syncline. The major directions of these folding axes are NE to ENE in the northwestern to the eastern part. Whereas in the southwestern part of the survey area, there is a distinctive anticlinal structure whose axis trends WNW. Most of gold-bearing quartz veins occur at the top and on the flank of this anticline.

Three major faults systems -- NW, N-S and NE -- were distinguished in the Bo Cu area. The NW faults are cut through Mesozoic strata, and was interpreted to be formed nearly at the same time as the Bo Cu anticline. The N-S faults were formed at the same time as the NW faults. The NE faults cut both NW and N-S faults, and was thought to be formed after the major folding activity. Along these faults, intense deformation and shearing were observed.

The main orogenic activity in the Bo Cu area was interpreted to be occurred in the Triassic or later period. The formation of the Bo Cu anticline, the formation of regional tectonic faults and acid volcanic activity in the Song Hiem Formation unanimously indicate the importance of this period.

Outcrops of small granite bodies occur at the northern part of the survey area arranging in the ENE-WSW direction. The time of emplacement of this granite was thought to be Triassic to Cretaceous. This granite belongs to the granitoids of the magnetite series and the S-type according to the whole rock analysis. No other igneous body was found in this area. Outside the survey area, similar bodies are known; the late Triassic biotite granite occurs 50 km northwest from the western boundary of the survey area; the Cretaceous granite also occurs to the southwest of the survey area. Tectonic loci of these granitic emplacements are considered to be at the marginal zone of the South China plate. However, the details such as the relationship to the mesothermal gold mineralization are not clear at the moment.

Two significant mineralizations, gold-bearing quartz veins and galena veins, were observed within the Bo Cu area.

The gold-bearing quartz veins belong to the mesothermal type gold deposit. The occurrence of gold veins is characterized structurally by the spatial closeness to the Bo Cu

anticline. The details of the mineralization and alteration are discussed in the chapter of the detailed geological survey.

The galena veins occur mostly in the Bac Son limestone, and partly in claystone Some of them contain significant amount of lead and silver. The similar Pb-Zn deposits are known widely in the Thai Nguyen and Cho Dien areas (west of the Bo Cu area). They are galena-sphalerite-pyrite veins/lenses hosted by carbonate rocks and schist of the Silurian to Devonian systems. They occur along faults which were thought to be controlled by the folding structure. Some spatial relationship of mineralization with the distribution of igneous bodies were said to exist in these areas. Although resources of the galena vein in the Cho Dien area is significant, the potential in the Bo Cu area may be small from the results of the field survey this phase.