MINISTRY OF ENERGY AND MINES
THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

THE GEOLOGICAL MAPPING AND MINERAL INFORMATION SERVICE PROJECT FOR PROMOTION OF MINING INDUSTRY IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

Volume I : Summary

October 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

MITSUBISHI MATERIALS TECHNO CORPORATION
KOKUSAI KOGYO CO., LTD.

PREFACE

In response to a request from the Lao Peoples Democratic Republic, the Government of Japan decided to conduct a study on "The Geological Mapping and Mineral Information Service Project for Promotion of Mining Industry in the Lao Peoples Democratic Republic" and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Yoshiaki Shibata of Mitsubishi Materials Techno Corporation and consists of experts from Mitsubishi Materials Techno Corporation and Kokusai Kogyo Co., Ltd. between March 2006 and October 2008.

The study team conducted field surveys in the study area and held discussions with the officials concerned of the Government of the Lao Peoples Democratic Republic. This final report was completed in October 2008.

I hope that this report will contribute to the promotion of mining development in the Lao Peoples Democratic Republic and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Lao Peoples Democratic Republic for their close cooperation extended to the study.

Mr. Seiich Nagatsuka
Vice President
Japan International Cooperation Agency

October 2008

October 2008

Mr. Seiich Nagatsuka
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith a final report of "The Geological Mapping and Mineral Information Service Project for Promotion of Mining Industry in the Lao Peoples Democratic Republic".

In Lao PDR, potentials of mineral resources such as gold, silver, copper, lead and zinc are expected to be very high. Mining development of these mineral resources can earn foreign currency income in future. However, mining investment has not been active for mineral potentials because information of domestic mineral resources and investment climate are not prepared well enough.

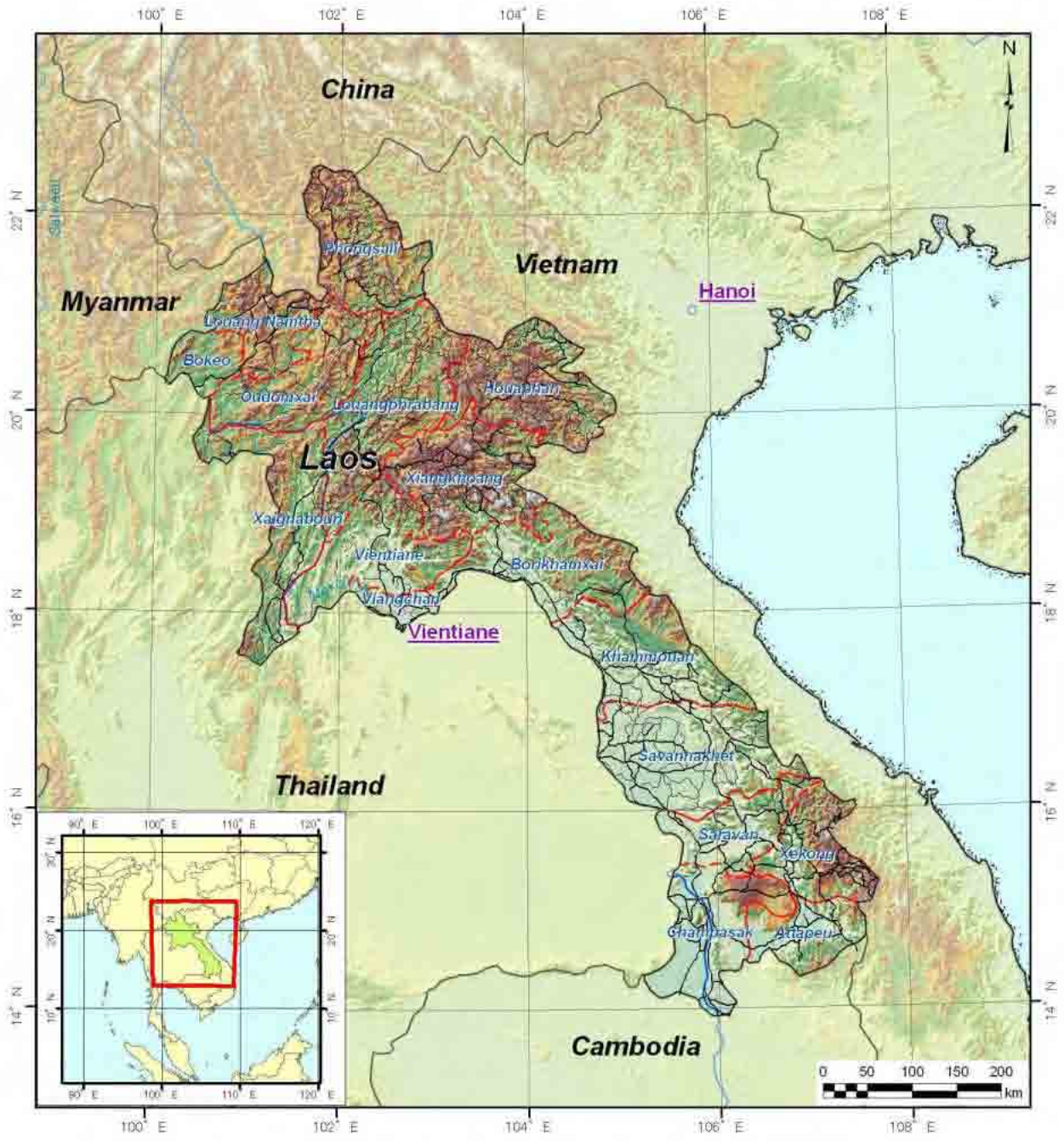
In order to accelerate investment in mining of Lao PDR, the study team and Laotian counterparts prepared information of geology and mineral resource of LAO PDR and disseminated the prepared information domestically and internationally during the project term from March 2006 to October 2008. Capacity development of Department of Mines and Department of Geology of the Ministry of Energy and Mines was also implemented at the same time during the project period. The team hopes the information prepared by the Project will be utilized for mineral exploration and development in future and engineers trained by the project will contribute further to enhancement of institutional capacity.

We would like to express our heartfelt appreciation to the people of Lao PDR for their active participation in the study, especially the Ministry of Energy and Mines, the Department of Mines and the Department of Geology. We also deeply indebted to the officials of JICA, the Ministry of Economy, Trade and Industry, the Ministry of Foreign Affairs, the Embassy of Japan in Lao PDR, and the JICA office in Lao PDR for their continuous support throughout the Project.

Finally, we hope that our outputs will contribute to development of mining sector of Lao PDR and to fostering a long-lasting partnership and friendship between Japan and Lao PDR.

Yours faithfully,

Yoshiaki Shibata
Leader of the JICA Study Team



Location map of the Lao People's Democratic Republic

THE GEOLOGICAL MAPPING AND
MINERAL INFORMATION SERVICE PROJECT
FOR PROMOTION OF MINING INDUSTRY
IN THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

SUMMARY

Table of Contents

List of Tables

List of Figures

List of Photos

CHAPTER 1 INTRODUCTION

1.1 Preface

This Report shows the result of the project of "The Geological Mapping and Mineral Information Service Project for Promotion of Mining Industry in the Lao People's Democratic Republic" conducted from 2006 to 2008.

The project is an international cooperation project implemented by Lao People's Democratic Republic (referred as Lao PDR) and Japan aiming at establishment of mineral information service in order to promote investment to mining sector of Lao PDR.

1.2 Background of the Project

Abundant mineral resources are expected in the Lao PDR such as gold, silver, copper, lead, zinc and iron. Mineral resources development is an industry which can serve as one of the future precious source of foreign currency earnings.

Mineral resources development is under the management of Ministry of Energy and Mines (MEM), Department of Geology (DGEO) and Department of Mines (DOM). Detailed information of domestic mineral resources is not fully prepared and legal systems are also inadequate. The organization of DGEO and DOM is not fully established for the mining development by private sector investment.

In order to promote investment by private capitals to the mining field in the Lao PDR, the DGEO and DOM are requested to play substantial role in establishing scheme for smooth acceptance of investment and in providing necessary information of related mineral resources. Moreover, management of mining development plan paying attention to environment-concerned manner will be much more enhanced in the future. Consequently, the Lao PDR government has requested to implement investigation which will improve service of information on mineral resources, in order to promote investment to the mining industry from domestic sectors and foreign countries.

1.3 Objectives of the Project

The main objectives of the Project is to develop the capability of Department of Geology (DGEO)and Department of Mines (DOM), Ministry of Energy and Mines (MEM) (former Ministry of Industry and Handicraft: MIH) and which is responsible for mineral resources development as well as to organize information of geology and mineral resources in accessible form from outside in order to promote mining industry in the Lao PDR. The major objectives are as follows:

1) To revise the 1:1.000.000 geological and mineral resources maps
2) To conduct geological field survey and prepare 1:200,000 geological and mineral resource maps
3) To construct and publish GIS-based mining information.
4) To enhance human resources necessary to accomplish above objectives.

1.4 Study Area

The target study area covers whole territory of the LAO PDR. An "Important geological survey area for construction of mineral information system" is selected in Attapeu, Sekong and Champasak Provinces, southern Lao with an area of 180km in east-west by 80 km north-south.

1.5 Organization of Implementation

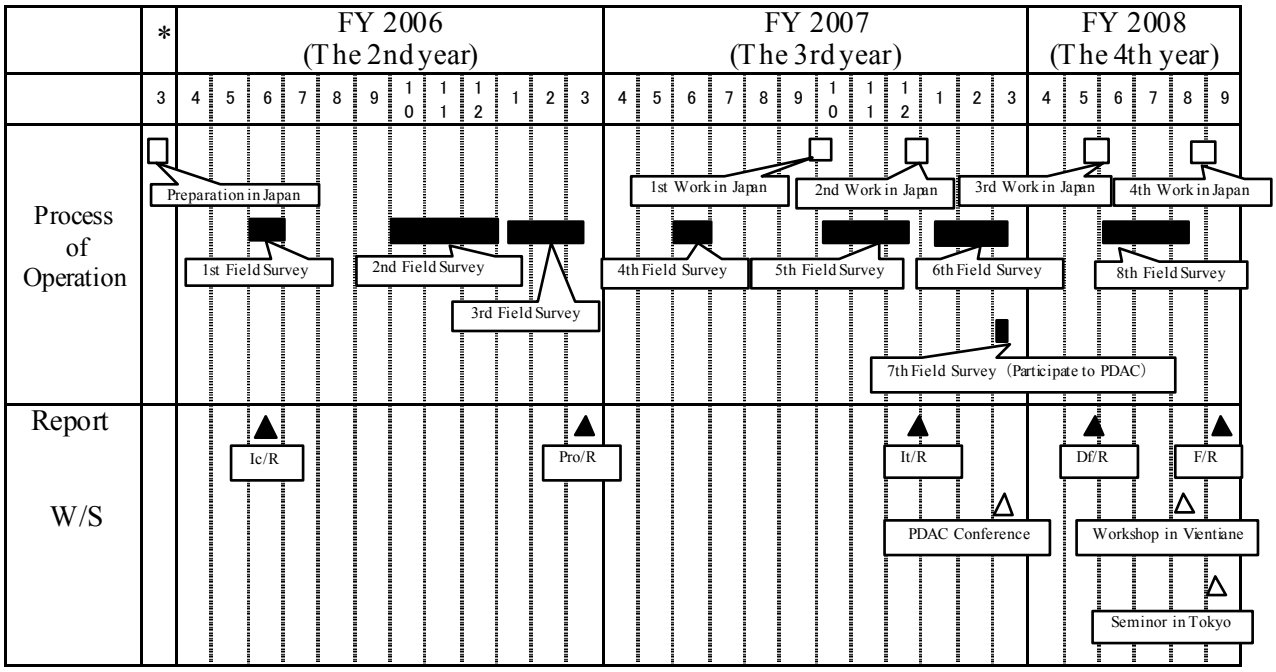
Members of the steering committee of the Project are as follows:

- Ministry of Energy and Mines: MEM
- Department of Geology: DGEO
- Department of Mines: DOM

1.6 Plan of the Project

General plan is shown in the Figure1.6.1. The survey consists of 4 years activities shown. Each activity is as follows:

- The first year : Preparation Work in Japan
- The second year : The 1st Field Survey in Lao PDR
  The 2nd Field Survey in Lao PDR
  The 3rd Field Survey in Lao PDR
- The third year : The 4th Field Survey in Lao PDR
  The 1st Study in Japan
  The 5th Field Survey in Lao PDR
  The 2nd Study in Japan
  The 6th Field Survey in Lao PDR
  The 7th Field Survey in Canada
- The fourth year : The 3rd Study in Japan
  The 8th Field Survey in Lao PDR
  The 4th Study in Japan



* : FY2005 (The 1st year)

Figure 1.6.1 The whole process of the Project

1.7 Member List of the Project

The member involved in the Project and the Steering Committee for the Project are listed in Table 1.7.1 and 1.7.2.

Table 1.7.1 Member list of the Project

Name	Assignment
<JICA>	
Mr. Satoshi Kobayashi	Staff / JICA Headquarter
Mr. Sota Sekine	Assistant Resident Representative
<GSJ, AIST>	
Dr. Yasushi Watanabe	Adviser to Study Team
<JICA Study Team>	
Mr. Yoshiaki Shibata	Team leader
Mr. Motomu Goto	Geological Mapping
Mr. Yoshimitsu Negishi	Evaluation of Mineral Resources
Ms. Yasuko Kamegai	Geochemical Analysis
Ms. Chiyo Kigasawa	GIS Database Preparation
Mr. Masayuki Shirai	Evaluation of Information for Mining Investment
Mr. Masami Sugita	Construction of GIS Database
Mr. Kazuyasu Tsuda	Coordinator
<C/P Staff>	
Mr. Khampha Phommakaysone	Team Leader
Mr. Sixomxeum Duangsurigna	Geological Mapping
Mr. Siphandone Vilayhack	Geological Mapping
Mr. Sisaad Phomkenthao	Geological Mapping
Mr. Amkha Voravong	Geological Mapping
Mr. Phonetalome Vilaysan	Geological Mapping
Mr. Thavone Khounchanthida	Geological Mapping
Mr. Boualay Saatsy	Geochemical Analysis
Ms. Phengsy Sirithongdy	Geochemical Analysis
Mr. Soubinh Siphandone	Geochemical Analysis
Mr. Phonephet Chounlamonty	Sample Preparation
Mr. Inpong Homsombath	GIS Database Preparation
Mr. Chantala Keohavong	GIS Database Preparation
Mr. Kuangnuvong Thepvongsa	GIS Database Preparation
Ms. Vannapha Phommachanh	GIS Database Preparation

Table 1.7.2 Member list of the Steering Committee

Name	Assignment
<Ministry of Energy and Mines>	
Dr. Bountheung Phengthavongsa	Deputy Director of the Cabinet of Ministry of E / M
<Department of Geology>	
Mr. Chansone Senebouttalath	Director General
Ms. Chansavath Boupha	Deputy Director General,
Mr. Oudom Phommachanh	Director of Geological Information Division,
<Department of Mines>	
Mr. Thongphath Inthavong	Director General
Dr. Simone Phichit	Deputy Director General

CHAPTER 2 PRESENT MINING ACTIVITIES IN LAO PDR

2.1 Introduction

Present situation of mining activities in Lao PDR is described in this chapter. Public income from mining sector is rapidly increasing in Lao PDR because of steep rise of metal prices in recent days and the interest in a mining sector is becoming increasingly. These data and information are largely cited from DGEO and DOM as well as the report of "Integrated Assessment of Mineral Resources in the Greater Mekong Subregion " prepared by United Nation in 1999, "Survey on Natural Resources Development Circumstance(in Japanese)" prepared by Japan Oil, Natural Gas and Mineral Resources Corporation in 2005 and "Sector Plan for Sustainable Development of the Mining Sector in the Lao PDR" prepared by World Bank in 2006.

2.2 Mining Policy

2.2.1 Principle of Mining Policy

In 1985, the Government introduced the "New Economic Mechanism (NEM)" which is aimed at changing the basis of the national economy from centralized planning to free-market principles and a new constitution was promulgated in 1991. The government's strategy for the mining sector based on the above policy is as follows;

(1) Promote the ecologically sustainable use of the country's mineral resources.

(2) Promote systematic exploration of the country by modern and integrated techniques.

(3) Promote the immediate development of small scale and artisanal mining ventures.

(4) Promote the medium-term development of large scale mining operations.

To implement this strategy, the Government has initiated a number of measures, which include the followings;

A) Establishment of appropriate national mining, environmental protection and investment laws so as to provide a well defined investment climate for both mineral exploration and subsequent development projects.
B) Encouraging the existing parallel market operators (usually small scale) to transfer to the formal market.
C) Providing administrative and support services to investors in mineral exploration and development. -
D) Undertaking geological survey programmes to help identify those areas with high prospectivity. Identified areas can be promoted as exploration targets to private sector companies.
E) Developing government organizations and services necessary to support the mining sector and efficiently manage new mining projects.

To achieve its goals, the Government plans to embark on a mineral resources investment promotion programme both within the region and internationally. The primary targets of the investment promotion programme will be foreign mining companies with an established reputation for environmental sensitivity and good environmental management. This programme will highlight the favourable investment climate (legal, financial, institutional) and the mineral prospectivity and development potential in the country. To support this programme, the Government will continue to expand geological information, laboratory and title management services within the DGM (currently DGEO and DOM). These services will provide investors with current information on which to base their exploration and investment decisions.

The Government decided to restructure the ministry in 2006 for the institutional strengthening, improvement of legal framework and sector management and development of human resources. The

mining sector is detached from the Ministry of Industry and Handicraft (MIH) and reorganized as the Ministry of Energy and Mines (MEM) by the consolidation. Furthermore, the Government also decided to divide the DGM into two departments, namely Department of Geology (DGEO) and Department of Mines (DOM) in 2007.

2.2.2 Legislation and Regulation in Mining

Foreign Investment Law, Mining Law, Environmental Protection Law, Tax Law and decree are applied to the mining activities in Lao PDR. Mining Law was promulgated in 31 May 1997.

1) Outline of New Foreign Investment Law for the Mining Sector

The new foreign Investment Law namely "Law on the Promotion of Foreign Investment" was adopted by the National Assembly on the 22 October 2004. Under the new investment law, three forms of business are open to potential investors from overseas who seek involvement in Laotian commercial ventures. These are:

(1) Business cooperation by contract

(2) Joint venture between foreign and domestic investors

(3) 100% foreign owned enterprise

Foreign investors who invest in a joint venture must contribute a minimum of 30 % of the total equity investment in that venture.

2) Mining Law

The purpose of the Mining Law is to provide a system of management for the conservation, exploration, mining and processing of minerals, for both local consumption and export, and for the use of mineral resources in industry and its processes and also to improve the quality of life for the people of the country.

Investment in mining activities (Article 21) shall take place under one of the following forms:

- Sole investment by the State
- Joint investment between the State and domestic and/or foreign parties
- Collective or private investment from domestic parties

Mining operations shall refer to all stages including prospecting, exploration, extraction, processing and trading of minerals. Prospecting, exploration and extraction shall be authorized only in areas where no mining activities for the same minerals are being conducted.

Persons or entities who seek to undertake mining activities shall apply for a prospecting license. When sufficient information has been gathered to justify further exploration, the person or entity shall apply for an exploration license.

After exploration, if a person or entity seeks to obtain a mining license, the following must be submitted to the Government: a study of the economic feasibility of the mine, an environmental assessment concerning the impacts of the mine on the environment, the ecology and society.

When a mining license is granted, the Government shall jointly invest in the mining operation. A person or entity who has been granted a mining license shall establish and register their enterprise in compliance with the laws of the Lao PDR.

Mineral prospecting refers to the procedure by which an evaluation of the geologic setting and the quality and distribution of mineral occurrences is determined by field observation. Mineral prospecting shall require the approval of the Government. The period of mineral prospecting shall not exceed 2 years but may be extended, with approval of Government, 2 times with each time for no more than 1 year.

Mineral exploration refers to geological and geophysical studies within a determined area for the acquisition of further detailed data on the geology and geological structures through testing, trenching, exploration drilling, analysis of the physical and chemical features of minerals in order to assess economic potential. Mineral exploration shall require the approval of the Government. The period of mineral exploration shall not exceed 3 years but may be extended, with the approval of Government, 2 times with each time for no more than 2 years.

After prospecting and exploration, licensees shall relinquish the undesired portion of the prospecting or exploration concession, in part or in full, and provide to the Government all data acquired from such prospecting and exploration. If it is discovered that a mineral occurrence extends beyond the licensed area, the licenses are entitled to apply for the addition of such area based on the acquired data.

An evaluation of the proposed mining project shall include an evaluation of the economics of the proposed mine and the foreseeable negative impacts of the proposed mine on the environment and the surrounding communities.

Mining, as referred to in this Law, refers to stripping, extraction, removal, processing, grinding, grading and storage of minerals. The period of the mining license shall not exceed 30 years from the date the concession is granted, but it may be extended twice, each time for no more than 10 years as approved by the Government who will consider the request for an extension upon a case by case basis and upon consideration of the scale of the mining operation.

Exploration and mining agreements (MEPA: Mineral Exploration and Production Agreement) which have been signed to date often contain basic provisions reiterating the ownership of mineral resources by the country and the development of these resources through agreements between the State, represented by the DIP (Department of Investment Promotion, Ministry of Planning and Investment) and relevant ministerial departments, and the investor.

With the Mining Act and implementing Decree enacted, there is a necessity for a capacity building programme in the fields of environmental impact assessment, social impact assessment, and public consultation within DOM. Expertise in these areas will be required to meet the needs of major new mining project(s) which are likely to reach the development stage over the next two or three years. Early training in proven environmental/social methodologies will enable Government to insure that the impacts of new projects are minimized.

3) Fiscal Regulation for the Mining Sector

In 1989, the taxation regime in Lao PDR was revised. Fiscal reforms included the introduction of new taxes, an extension of the tax withholding system, and the strengthening of the customs administration. In the past, the taxation on mining activity has generally been subject to the provisions of the general tax and investment law. Mining levies and charges are usually stipulated in governmental decrees.

The new Customs Law was promulgated in 1994. This Customs Law replaces the Decree No. 471CCM, dated 26/6/89, of the Council of Ministers on the state tax regime alone (Article 106).

For the fiscal obligations, under the Mining Law (Art. 42), the licensee shall have the obligation to properly and timely perform custom, tax and other fiscal obligations.

- Land rent is an annual payment to the government in kip or such other currency mutually agreed upon by the government and the mining company, to be measured by the number of hectares included in the contract area or mining area, respectively. Land rent for different types of mining activity, which are already in force, are enumerated under Article 16 of Decree No. 47 of 1989.
- Royalties, like land rents, are governed by Decree No. 47 of the State Tax System of 1989. Royalties for mineral production are computed and levied on the basis of the gross sales

value of the mineral in question, taking into account the purity of the mineral - and with the unit value determined in accordance with international norms and standards. For foreign companies doing mining business in Lao PDR under a contract of work/agreement, the rate of royalty is from 2.5-5 per cent for precious metals.

2.3 Investment Climate and Present Situation

Lao PDR is a land-locked country and a social infrastructure has been less prepared, which are negative factors for development. However, remarkable improvement of infrastructures of transportation, communication and electricity are expected recent years.

As Lao PDR is surrounded by Thailand, Vietnam, Cambodia, Myanmar and China and a economic size is relatively small, those neighbouring countries sometimes are economic threat to Lao PDR. On the other hand, there is another aspect that economic strategies of neighbouring countries involving Lao PDR are contributing economic development of Lao PDR itself. A concept of Greater Mekong Economic Zone will add significant strategic meaning to Lao PDR in the discussion of selecting destinations of foreign capital investments.

2.3.1 Transportation

For transportation, Indochina East-West Corridor which connects Thailand and Vietnam via No.9 National Road of Lao PDR was constructed. In December 2006 an international bridge crossing Mekong River at Savannaket of Lao PDR and Mukdahan of Thailand was completed by a soft loan provided by Japan. No.13 National Road is under renovation from South to North, crossing the East-West Corridor in Laos. Moreover, in northern Laos a main road is expected to connect Yunnan of China and Thailand through No.3 National Road of Lao PDR shortly. No. 18 National Road connecting Attapeu and Vietnam was constructed as a new major route in southern Laos. Asian Highway Project is also progressing.

2.3.2 Telecommunication

The penetration rate of telephone service has been dramatically increased in recent years. As of the year 2006, the number of subscribers of fixed line telephone service was reported as 91,235 (e.g. about 2% of coverage rate) and the number of mobile phone was 901,637 (e.g. about 16% of coverage rate) by the Ministry of Public Works. As mobile phones are provided mainly by pre-paid system, actual penetration is thought to be far greater than that of announced number.

Optical fiber main network connecting major points of whole territory has been established and international connection with neighboring countries have also completed. However, constructions of branch lines and further lines up-to end-users are in primitive stage and eservice is limited to the urban areas like Vientiane and major cities. Comparing urban areas with rural districts, more than 60% of villages have been left out of telecommunication reach and there are no remarkable change of the gap existing between urban areas and rural villages.

2.3.3 Electric Power

The Lao PDR is highly endowed with water resources and hydropower generation is far exceeding the other power source. At the end of 2007, national total electric generation was 672.2 MW and 99.83 % are generated by 10 hydropower plants. In the midst of industrialization, present domestic demand for electric power is still modest comparing to the actual electric power production, surplus of electric power has been exported earning considerable amount of foreign income.

On the contrary, construction of domestic main power line networks is still lagging in behind. Especially a north-south major line which connects the north of power production to the south is not completed yet. Construction and improvement of major power line networks are on the way by the support of international aids and loans.

2.3.4 Present Situation of Investment for Mining Sector

In the mining sector, Lao PDR became gold-copper producing country in 2003 when Sepon Mine started mining operation by Lane Xang Minerals Co., a local company of Australian Oxiana Limited. At present, besides Oxiana, Pan Australian Resources, an Australian company, started the operation of Phu Kham Copper-Gold Mine and more than 50 domestic and foreign companies are active in exploration for copper, zinc, iron and etc.

GDP growth of 2005 was 7.3% resulting great increase comparing with 6.4% of 2004. Mining development of copper, gold, gypsum, limestone and tin and rapid expansion of export of hydraulic generated electric energy are of great contributers. While 2.4% of GDP attributed to mining in 2004, contribution of more than 10% is estimated by mining sector in 2006. Corresponding to these developments, investment of foreign capital to the mining sector of Lao is also increasing (Table 2.3.1).

Table 2.3.1 Approved foreign investment in Lao PDR by sector 2000- September 2006

No	Sectors	Projects	Value of Investment (US$)
1	Electricity Generation	36	3,293,252,200
2	Agriculture	114	582,884,768
3	Mining	117	500,683,198
4	Industry & Handicraft	161	313,712,020
5	Trading	83	257,713,089
6	Construction	23	159,336,874
7	Services	131	127,251,907
8	Hotel & Restaurant	45	102,263,695
9	Telecom	3	39,940,000
10	Wood Industry	32	24,564,290
11	Others	52	34,569,032
	Grand Total	797	5,490,268,785

As of July 2008, there were 181 mining concessions (55 prospecting phase, 74 exploration phase, 3 F/S phase and 52 exploitation phase), held by 46 domestic companies and 72 foreign companies. Foreign concessions holders include 39 Chinese, 16 Vietnamese, 6 Thai, 4 Australian, 2 Korean, 2 Russian companies and 1 company each from North Korea, Poland and England (Fig.2.3.4).

Major mines and mineral occurrences in Lao PDR are shown in Fig. 2.3.5

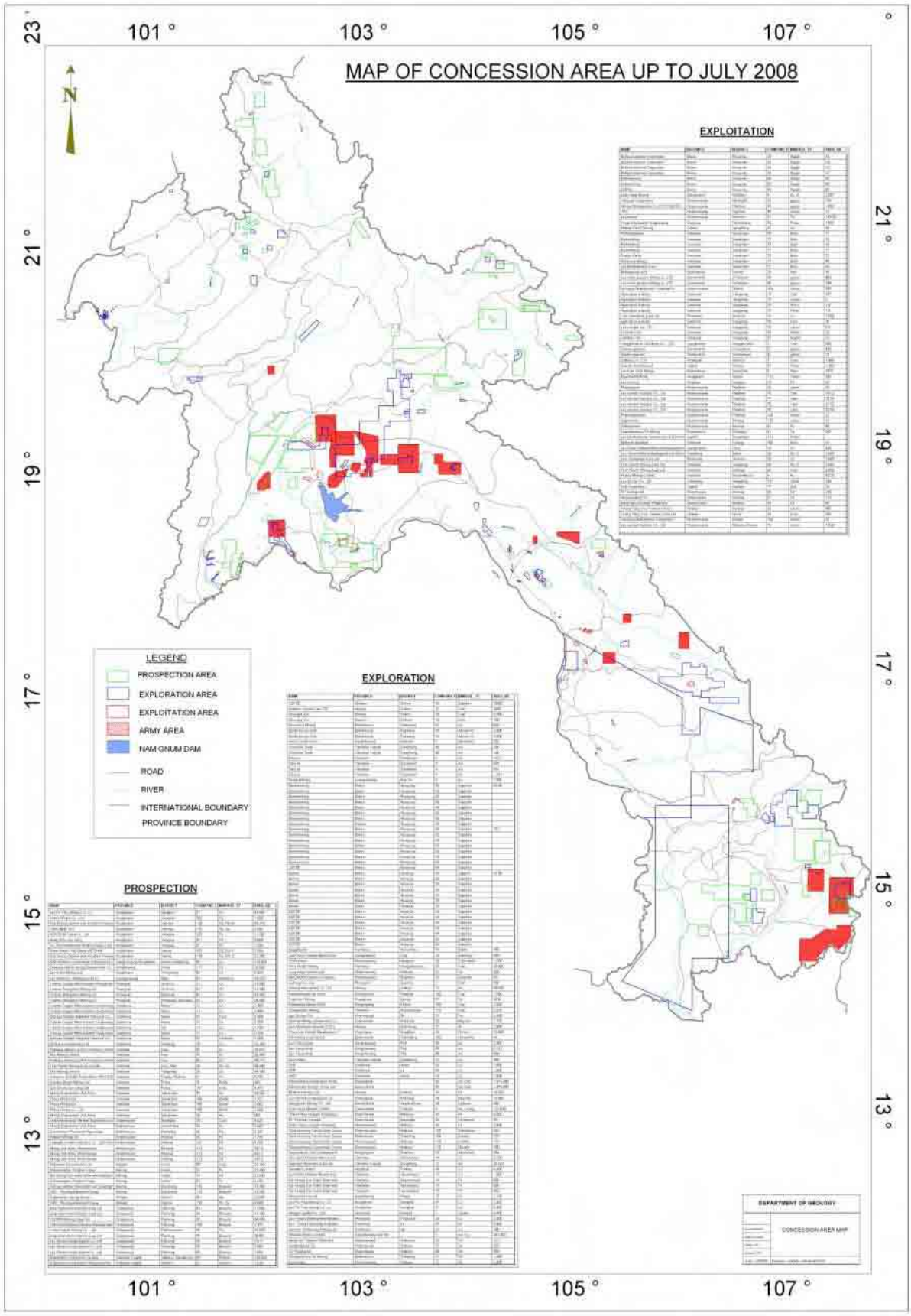


Figure 2.3.4 Map of concession areas up to July 2008

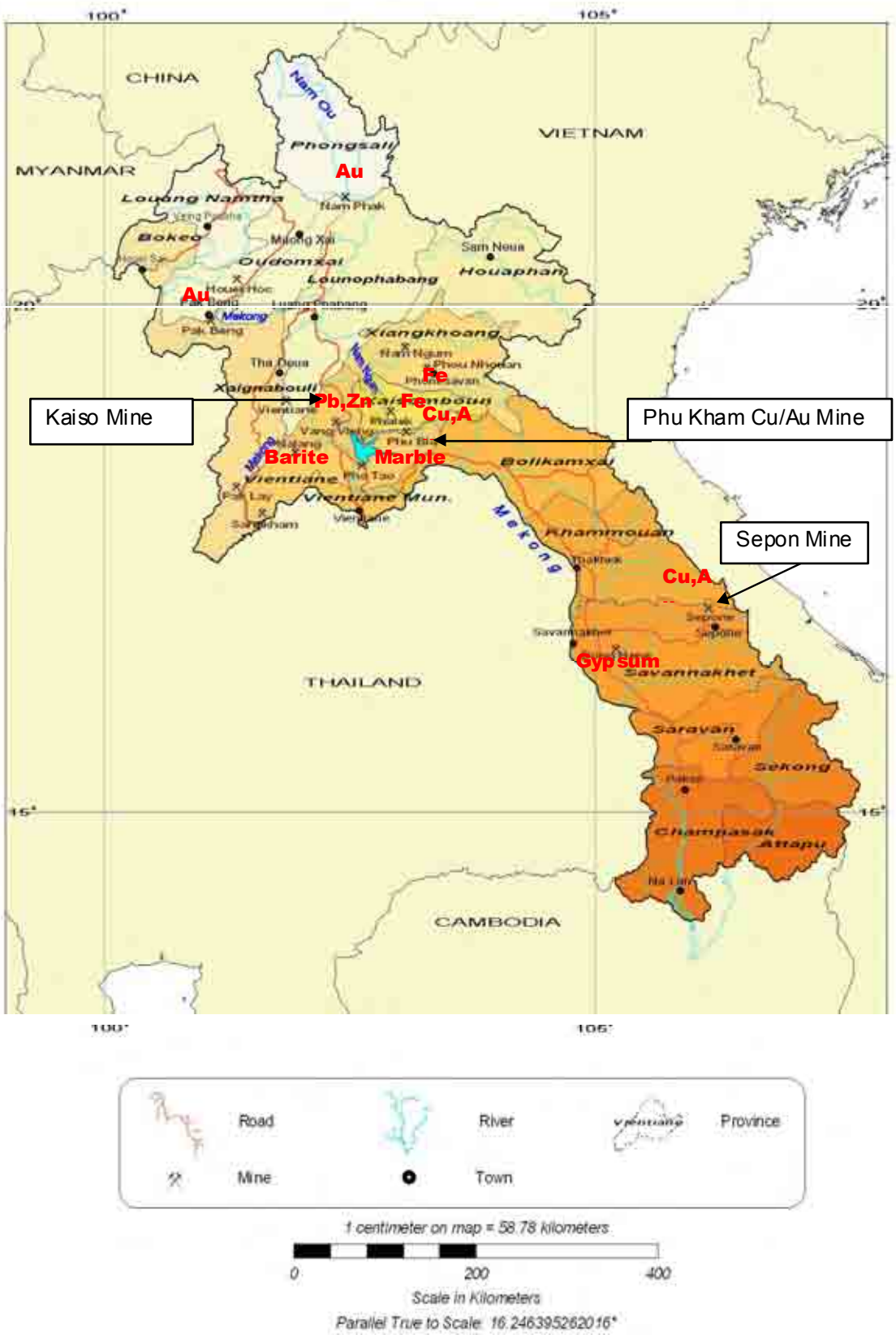


Figure 2.3.5 Location map of major mines and mineral occurrences in Lao PDR

2.4 Mineral Production

Ore deposits, such as tin, tungsten, rare metal, gold, iron ore, coal, gypsum, barite, limestone, potassium, and gem were confirmed by the investigations in the past. Mineral production value is increasing from 69,005,313 US$ in 2004 to 213,391,712 US$ in 2005.

Production of each major minerals was described below based on "Lao PDR Mineral Year Book 2006" prepared by DGEO and DOM.

2.4.1 Gold and Silver

The production of gold and silver began in 2003 with the start of the Gold / Copper Sepon project in Savannakhet province. The project is invested by Oxiana Ltd. The gold-bearing orebodies at Sepon contains 14 millions tons of ore with 1.5 millions oz of gold and 2.6 millions oz of silver.

An additional Phu Kham heap leach operation at Phu Kham Cpper-gold mine located in Saysomboun special zone is started to operation by Pan Australian Resource Limited in 2005. It has a reserve of 31.1 tons (1 million oz) of gold. Besides small scale mining of gold is currently undertaken by Lao-China Mining Industry in Khamkeut district, Bolikhamxay province and Phialat Gold Mining Company in Vientiane province. Gold prospecting and exploration were carried out by other 10 companies.

2.4.2 Copper

Copper was started to produce in 2005 at Sepon mine and the cathode is produced 30,514 tons in the first year. The production of 2006 reached 60,000 tons according to plan. Phu Kham copper/gold mine started copper operation by Pan Australian Resources Limited in May 2008 and initially produce over 200,000 dry metric tons of concentrate annually, containing on average 52,000 tons copper, 47,000 ounces gold and 400,000 ounces silver.

2.4.3 Zinc

The Kaiso zinc mine which is situated in Vangvieng district, Vientiane province, has been developed by Phadeang Industry Public (Lao) Company Limited since 2001. The ore deposit is a secondary type as well as Phadeang ore deposit in Thailand. The produced zinc ore is exported to Thailand.

First Pacific Mining Lao, Padaeng Industry companies are undertaking zinc prospecting and exploration in Vientiane province.

2.4.4 Gypsum

There are four mining companies conducted gypsum exploration and exploitation in 2005. Three companies undertook exploration activities in Khammouan and Savannakhet Provinces. Gypsum Mining Co. Ltd. produced gypsum from the mine located in Champhone district, Savannakhet province.

The total production in 2006 was more than the previous year's production at 199,019 tons. The total product was exported to Vietnam.

It is reported that another mine located in Khammouan province will be operational by next year.

2.4.5 Coal

Coal is an important energy commodity for industrial development. Many coal deposits and prospects occur from north to south of Lao PDR. There are two types of coal: anthracite of Paleozoic to Mesozoic age and lignite of Tertiary age. There are 2 companies undertaking coal prospecting, 3 companies of coal exploration and 3 companies of coal mining.

Anthracite has been mined by a local company for local consumption, as a raw material for supplying to cement plant in Vangvieng, Vientiane province. In 2006, the production amounted to 63,500 tons.

Lignite has been mined by a Thai company in Louangnamtha province and exported to Thailand. The amount of lignite mined in 2006 was 432,421 tons.

One large lignite deposit with reserves of over 505 millions tons located in Sayabouly province is planned to be mined for supplying to a power plant.

2.5 Mineral Prospecting

Mineral prospecting has been carried out for many years under the cooperation of Vietnam government. At present there are other projects such as the Project by JICA and reconnaissance and detailed surveys by private companies over concession areas. A regional survey is also active as explained in the Chapter 3.

2.6 Mine Development and Mineral Exploration

2.6.1 Sepon Mine

Oxiana Limited owns the Sepon gold and copper operation. Sepon mine is an open pit mine producing gold and copper locating in the eastern part of Savannaket province in central Lao PDR.

Exploration by CRA/Rio Tinto between 1993 and 1999 resulted in the discovery of around 3 million oz of gold and an estimated 0.9 million tons of contained copper in six separated deposits. In 2000, Oxiana acquired the rights from Rio Tinto and started to the mine development.

Gold and copper deposits discovered in the Sepon district now contain an estimated 3.8 million oz of gold and 1.7 million tons of contained copper and the exploration by Oxiana Limited continues to increase these resources.

1) Development of Gold Deposit

Production started in December 2003. Annual capacity is 2,500,000 tons of ore and gold is recovered by Carbon-in-leach process. In 2006, 6,121kg of gold and 29,003kg of silver were produced and accumulated production figure is 19,413kg of gold and 54,751kg of silver. In 2006, 2,845,540t of ore with the grade of 2.15g/t and 10.19g/t were treated.

The currently defined gold deposits are Discovery, Discovery West-Colluvial, Nalou, Namkok West, Namkok East, Vangg Nang and Luang. Gold mineralization occurs as fine dissemination in highly altered calcareous sedimentary rocks with many affinities to the Carlin style gold deposits of Navada, USA.

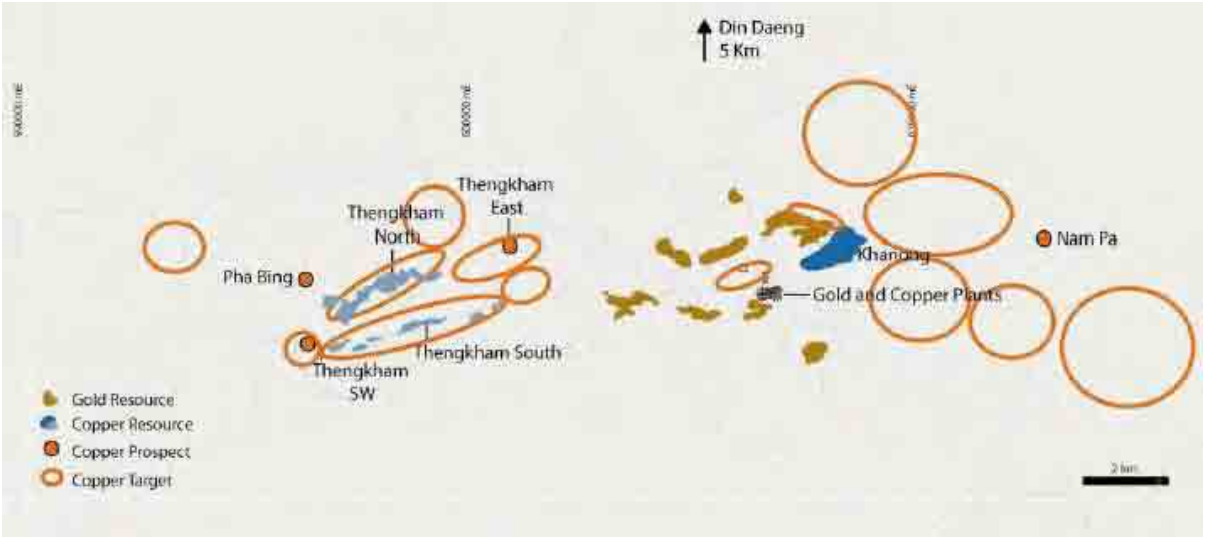
2) Development of Copper Deposit

The Khanong copper deposit was developed by open pit and copper is recovered at the 60,000t/year capacity SX-EW plant. The complex was completed February 2005 and the first produced copper cathode of Lao PDR exported to Thailand in March of the same year. In 2005, 455,000t of ore was treated and 30,514t of cathode was produced. In 2006, corresponding figures were1,216,000t and 60,758t.

The Khanong copper deposit is a near surface, high grade, supergene chalcocite and oxide copper body derived from the weathering of a replacement type massive sulphide deposit developed in shallow dipping, highly sheared carbonate rocks.

3) Exploration

Exploration has seen further copper resources discovered at the Thengkham North and Thengkham South deposits, approximately 7 km west of the plant (Fig. 2.6.1). Many target areas remain to be tested and resent drilling results, including those from the newly discovered Pha Bing deposit, indicate the further high grade copper mineralization like that at Khanong and Thengkham is likely to be discovered elsewhere in the project area.



(Oxiana Limited, 2007)

Figure 2.6.1 Location map of copper deposits and target areas in Sepon

2.6.2 Phu Kham Copper-Gold Mine

Phu Kham copper-gold Mine is located approximately 120km north of Vientiane. Pan Australian Resources started exploration in this area in 2002 and entered gold production by heap leaching method in November 2005. The Phu Kham copper-gold deposit consists of an oxide gold cap and primary copper-gold zone.

1) Development of Gold Deposit

Production of gold was 481.3kg in 2005 and 1,391.5kg in 2006. The operation is currently conducting for Phu Kham Gold Cap which overlays the Phu Kham copper-gold deposit. Additional gold resources are found in the Ban Houayxai deposit. Total reserve is reported as 8,600,000t with the grade of gold 1.1g/t.

The mine is seasonal and produces gold during the dry months, from October to May. During the four-month wet season, the heap leach pads are protected from rainfall by a plastic cover.

2) Development of Copper-Gold Deposit

Pan Australian Resources started copper operation in May 2008. The mine initially produce over 200,000 dry metric tons of concentrate annually, containing on average 52,000 tons copper, 47,000 ounces gold and 400,000 ounces silver. Ore reserve is estimated as 192,000,000t with the grade of copper 0.62%/t and gold 0.24g/t allowing more than 12 years of mine life.

Primary copper-gold mineralization is associated with quartz-sulphide stockwork, disseminated sulphide and massive sulphide zones. The mineralization is hosted by a sequence of volcanic rocks (tuffs), limestone and carbonaceous siltstone. The deposit is interpreted to be related to a porphyry intrusion.

3) Exploration

Pan Australian Resources has many prospective exploration targets within 2,637 km2 contract area. In Ban Houayxai gold-silver deposit, located some 25km west of the Phu Kham deposit, drilling has identified oxide and primary mineralization from surface to a depth of over 300m.

(Pan Australian Resources Limited,2007)

Figure 2.6.3 Location map of deposits and target areas in Phu Bia area

2.6.3 Other Exploration Projects

About 180 km north of Vientiane, Canadian junior Rox Resources Ltd. is in a joint venture with local partner First Pacific Mining Lao Co. Ltd. to explore the Pha Luang zinc-lead-silver deposits. Deeper drilling is underway in Pha luang and Nam Yen deposits.

Australian junior Argonaut Resources NL is exploring 50 km northwest of Vientiane in the Century area, and, in southeast Laos, in Sekong area. At Century, the Ang Noi area, where gold is hosted in mesothermal quarts veins, is the priority for future resource drilling.

In southern Lao PDR, Australian junior Ord River Resources Ltd. is a joint venture with China Nonferrous Metals International Mining to explore the Bolaven Plateau bauxite deposits.

CHAPTER 3 DATA REVIEW OF GEOLOGY AND MINERAL RESOURCES

3.1 Introduction

The revising of 1:1,000,000 geological and mineral resources map published in 1991 is carried out in this project. Many geological survey and mineral exploration were conducted since 1991 and abundant data were accumulated. Furthermore, the geological mapping projects of 1:200,000 in scale are in progress in many areas including this project. By 2008, approximately 65% of Lao PDR will be covered by 1:200,000 geological maps. The revising will be carried out based on the above geological information.

3.2 Existing 1: 1,000,000 Geological and Mineral Resources Map

The 1:1,000,000 geological and mineral resources map published in 1991 is prepared by British Geological Survey and British Mineral Consultants Ltd., commissioned by the Asian Development Bank. Although a simplification on geologic division has been made, all known mineral occurrences are added on the map. Main source of information for this map is as follows;

1) Geological map at 1:500,000 over whole Indochina prepared by Service Geologique de l'Indochine, based in Hanoi, Vietnam, in 1930.
2) Geological map of Xam Neua(northeast Lao PDR), Khang Khay(north of Xiengkhouang) and Vientiane area at 1:200,000 prepared by DGMV, in 1975 – 1990.
3) Geological map of whole Indochina at 1:1,000,000 prepared by DGMV, in 1988. Second edition was published in 1991.
4) Summary geological map of Lao PDR at 1:1,500,000 prepared by ESCAP, in 1990.

3.3 Mapping Program for 1:200,000 Geological and Mineral Resources Map

Geological maps at 1:200,000 produced by 2006 are 12 sheets in total covering central and northeastern parts of Lao PDR, which covered one-third of the whole country. As shown in Figure 3.3.1, however, mapping projects in northern and southern parts will be completed by 2008 and the coverage will reach approximately 65%.

3.3.1 Northern Part

4 sheets of geological map in north-eastern part and 1 sheet in Vientiane Province were already prepared by DGMV before 1988. The mapping project in northern area covering 12 sheets by DGMV was completed in 2007. However, the mapping in north-western area covering 5 sheets by DMR is suspended for a while.

3.3.2 Central Part

9 sheets of geological and mineral resources map in this part were already prepared by DGMV before 1999 and are available in digital form.

3.3.3 Southern Part

This part includes 2 sheets of map over Attapeu area in this project. DGMV is conducting geological mapping around Attapeu area and will complete it in 2008.

3.4 Revising of 1:1,000,000 Geological and Mineral Resources Map

3.4.1 Revising of Geological Map

Revision work was applied to the 1:1,000,000 geological map sheet which was compiled by British Geological Survey (BGS) of 1991, referring to the 1:1,000,000 geological map of Indo-China Peninsular made by DGMV (Vietnam) in 1991 and also taking the result of 2 sheets of 1:200,000

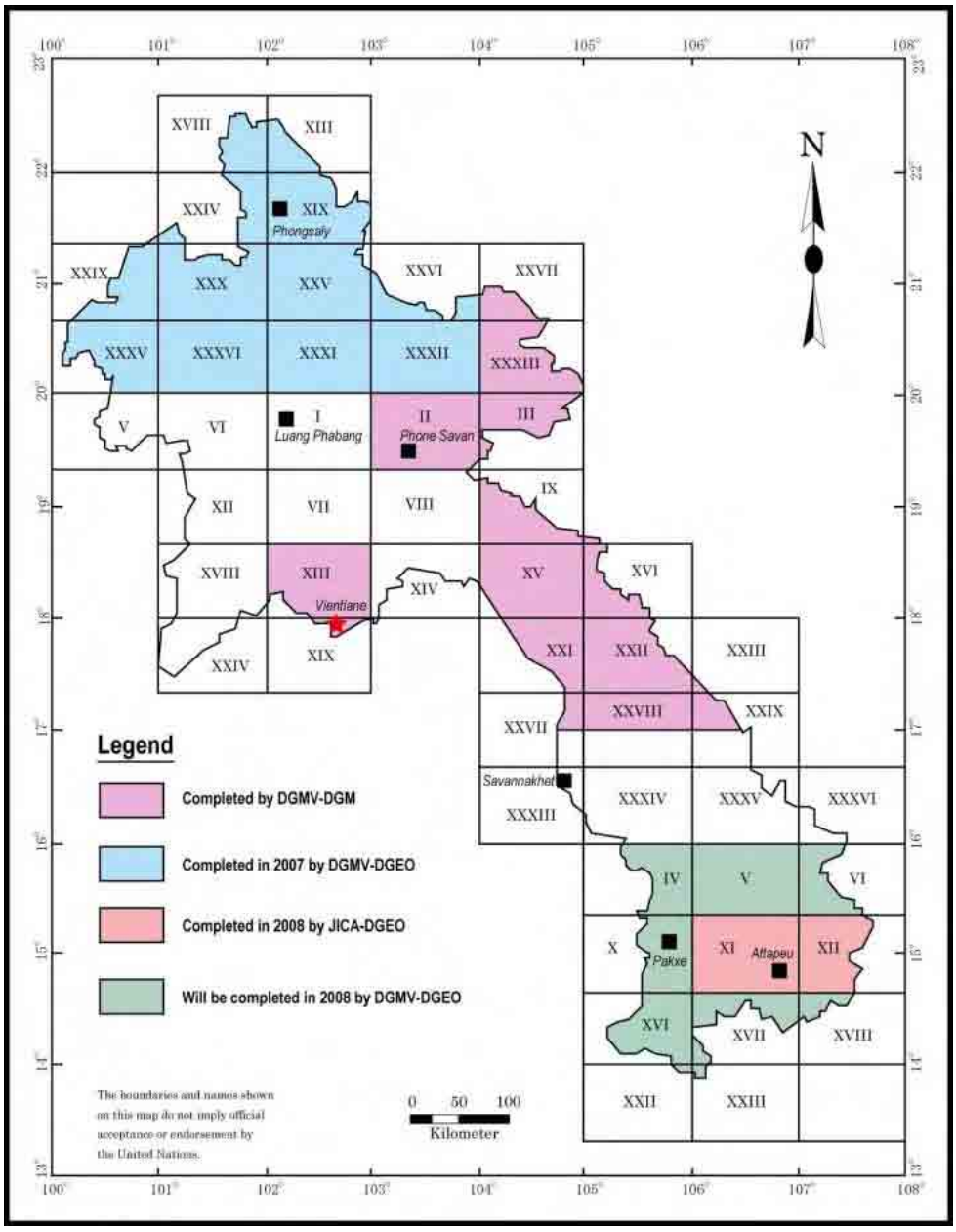


Figure 3.3.1 Index map of geological and mineral resources map at 1:200,000

regional geological map made by the Project as well as sheets over Lao PDR made by DGMV (Vietnam) after publication of the 1:1,000,000 geological map compiled by BGS.

Revised 1:1,000,000 geological map is shown in Figure 3.4.1 (in reduced size).

3.4.2 Revising of Mineral Resources Map

In a sheet of 1:1,000,000 Mineral Resources Map of 1991 compiled by BGS showing 479 locations of mineral occurrence. After BGS's compilation DGMV surveyed over central area and 151 localities were described as "Record Book of Mineral Deposits and Ore Occurrences" In Attapeau district a new copper occurrence was discovered by the Project and in the northern part newly discovered mineral occurrences have been reported by DGMV survey team. Although these information was added on the list following a format arranged by BGS, there were uncertainty with information of locality of new discovery and separate files were generated depend on projects.

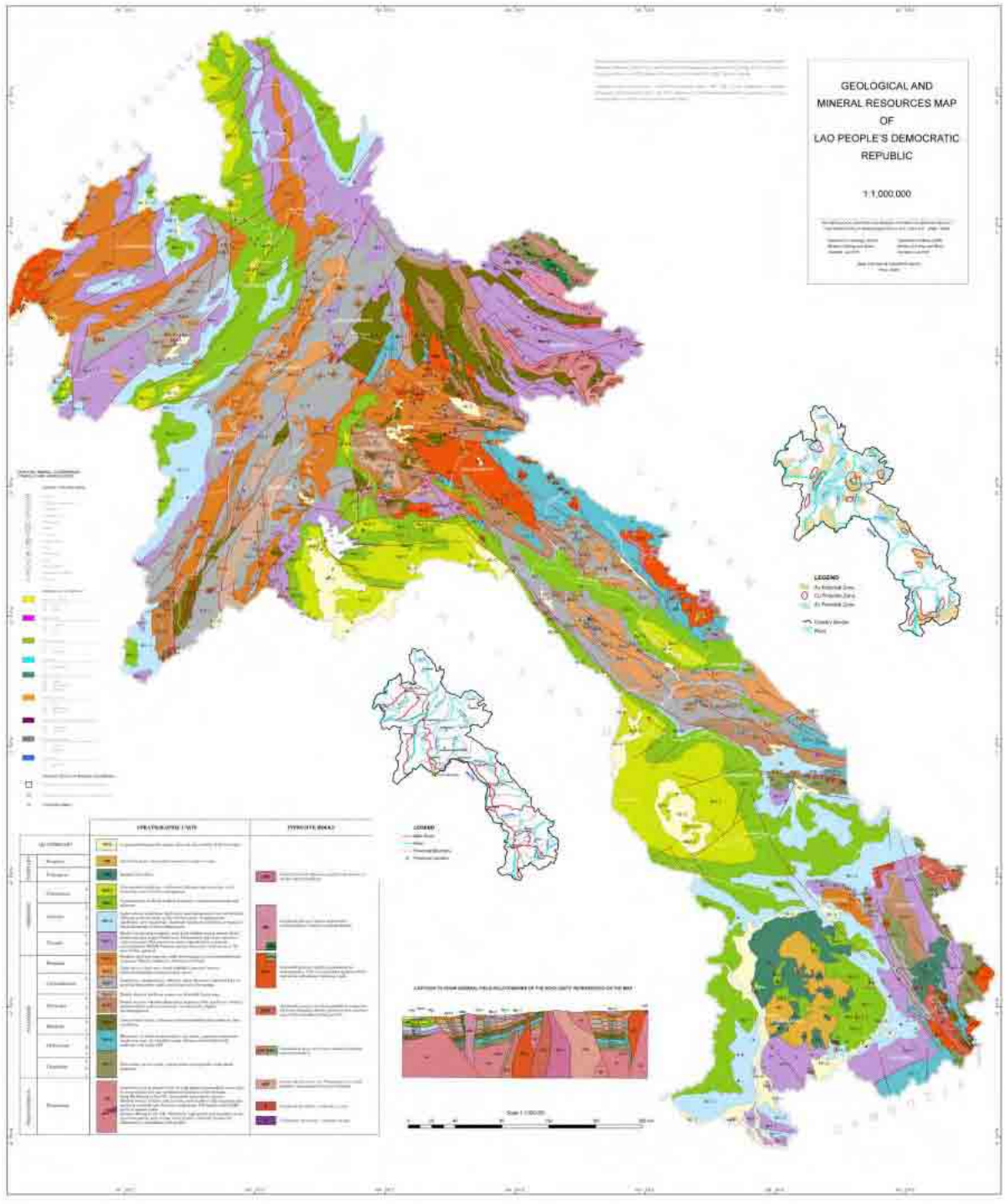


Figure 3.4.1 Revised 1:1,000,000 geological and mineral resources map

CHAPTER 4 GEOLOGICAL SURVEY IN THE ATTAPEU AREA

4.1 Introduction

The counterpart (DGM, MIH) proposed the Attapeu area as a target area for making 1:200,000 geological maps during the meeting on the Inception Report in June 2006. The area covers 180km (east-west) and 80km (south-north) and has not been studied in detail; however, it is known as a high potential area for mineral recourses such as gold and the area was selected for geological mapping in this study.

4.2 Current Status and Issues of the Geological Division, DGEO

4.2.1 Current Status

Geology Department of DGEO has ten staff members that are two(2) deputy director, three(3) chief geologists, and four(4) geologists headed by Mr. Siphandon Vilayhack, Director. Their age structure consists of five forties, one thirties, four twenties. As for education, they are two university graduates, five degree holders of post graduate level from Russian graduate school and three technological high-school graduates. Three out of the five twenties are technological high-school graduates.

Geological mapping has been completed in three regions of 4,800km^2, accounting for 20% of the whole country. In mid-2007, the geological map of the northern Lao PDR at scale of 1:200,000 will be completed under a technical cooperation project supported by Vietnam's DGMV. The other DGMV's projects are in progress, i.e., 1:200,000 geological mapping and mineral resources investigations for bauxite and other minerals in the southern Lao PDR, including the Attapeu area, and will be finished by the end of 2008. There is bauxite mineral showing in the basalt plateau and seven lenticular ore bodies have been found. Various evaluation reports on mineral resources development are kept in the mining sector and those of contract expiration are available for review or inspection in the library, in which other reports are also available, although the number of collections is limited. A geological structural map currently available shows only major geological structure, which is compiled from the Indochina geological map at scale 1:1,000,000 in 1988, based on site investigation and interpretation of satellite images and aerial photos.

Topographical maps available are those at scales 1:1,000,000, 1:500,000, 1:200,000, 1:100,000 and 1:50,000. As for the Attapeu area, each scale is available. National Geographic Department holds 1:50,000 aerial photos and they are available through DGEO.

The geochemical prospecting report on the Lao PDR is only available in the geological investigation report made under Vietnamese project.

4.2.2 Issues

From the age structure and academic background of DGEO staff members, training for young geologists should be addressed. Geologists working in the private sector are trained by the company; however, the DGEO's young geologists have few opportunities to be trained in the field. It is very important to provide them with such during the course of this type of project.

DGEO neither employs the Russian surveying method nor the Chinese. Since they have not their own manuals for geological survey, they use different methodologies in different projects. It is urgently necessary to establish unified standards for petrographic description, classification of rock types, etc. They do not have standards for evaluation on geological investigation and environmental protection yet.

As for survey tools, DGEO has hammers, Brunton compass, magnifying glasses (10 to 20 times), although two or three available for each tool. They are too few even for ten staff members. The field survey is being conducted by five chief geologists and eight young geologists for the project and a lack of tools is a problem.

4.3 Survey Methodology and Survey Routes

It is important to have team meetings for survey briefing, discussions, solving problems, selecting survey routes, etc. in the office and site in order to accomplish geological mapping at scale 1:200,000 and mineral resources assessments and to implement capacity development for the counterpart members. At the beginning, frequent meetings will be required for sharing purposes of technical aspects. Based on survey results, mineral deposit models for promising mineral deposits will be established.

In fieldwork, a camping survey with tents is required and appropriate equipment and logistics such as food provision by porters should be selected and prepared. There is possibility of flooding in the typhoon season, safety and security should be the main concern. Since the second survey was done during a rainy season, the survey was mainly conducted along the major road in the western area to avoid river flooding. A camping survey for a week or so was scheduled in December, however.

The numbers of samples collected in the 2nd to the 6th surveys are shown in Table 4.3.1.

Table 4.3.1 Samples collected in the Attapeu area and detail survey area

Analysis and Element Items	Sample Number	Phase and Number of Samples			
		Field survey			
		2nd	3rd	4th	5th
1) Thin section	100	25	25	25	25
2) Polished section	77	8	9	30	30
3) X-ray diffraction	70	13	27	15	15
4) Rock chemical analysis	40	10	10	10	10
SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, MnO,					
CaO, Na2O, K2O, P2O5, LOI: 12 elements					
Rb, Sr, Ba, Zr, V, Nb, Y, La, Ce, Pr, Nd, Sm,					
Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu: 21 elements					
5) Ore assay	168	19	29	60	60
Au, Sb, Ag, Cu, Fe, Mn, Ni, Pb, Zn, Ti, Sn, W: 12 elements					
6) Stream sediments analysis	800	250	229	321	
Au, Sb, Ag, Cu, Fe, Mn, Ni, Pb, Zn, Ti, Sn, W: 12 elements					
7) Magnetic susceptibility measurement	100	30	30	20	20
8) Fluid inclusion measurement	10			5	5
9) Dating	12			6	6
K-Ar method or Ar-Ar method					

4.4 Geology and Geological Structure in the Attapeu Area

The survey work includes site investigation, route mapping, outcrop description, data input, etc. Drawing geological columnar section and geological cross section based on observation data were carried out.

The geology of the Attapeu area based on the survey is given below. Figure 4.4.1 illustrates field survey routes during second to sixth field survey. The major tectonic elements of the area were compiled in the geological interpretation map of Figure 4.4.2.

The geological and mineral occurrences map of the Attapeu area, scale 1/200,000, was created to be reflected analytical work result during second to sixth field survey.

After drawing of first edition of the geological map, a discussion on geology of Attapeu area was carried out between JICA-DGEO Team and Intergeo Division, Department of Geology and Minerals of Vietnam. This meeting was held in the DEM of Attapeu Province on November 5 and 6, 2007.

Subjects of meeting are as follows:

a. Alignment of geological boundary between geological map of Attapeu area by JICA Team and geological map of peripheral Attapeu area by DGMV

b. Correlation of geological formation name and geological age

c. Stratigraphy and metallogeny of bauxite deposit in the Bolaven Plateau

Final edition of the geological map and mineral occurrence map were drawn after 6th field survey. It was described to be outlined of geology, geological structure and mineral resources in the Attapeu area as bellow.

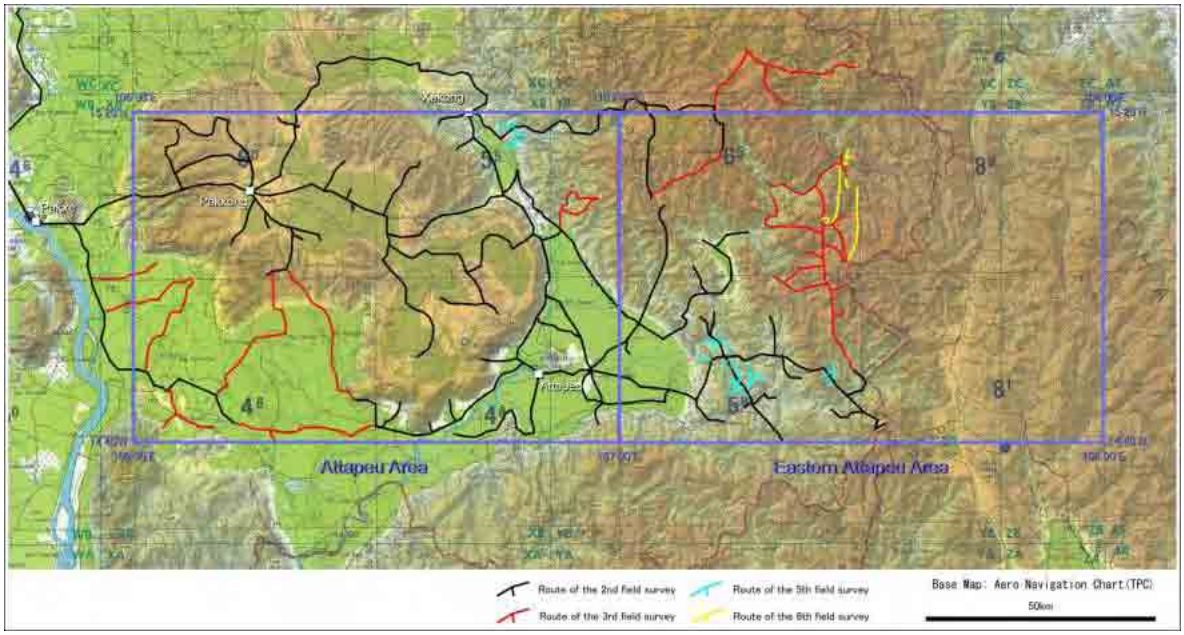


Figure 4.4.1 Field survey routes

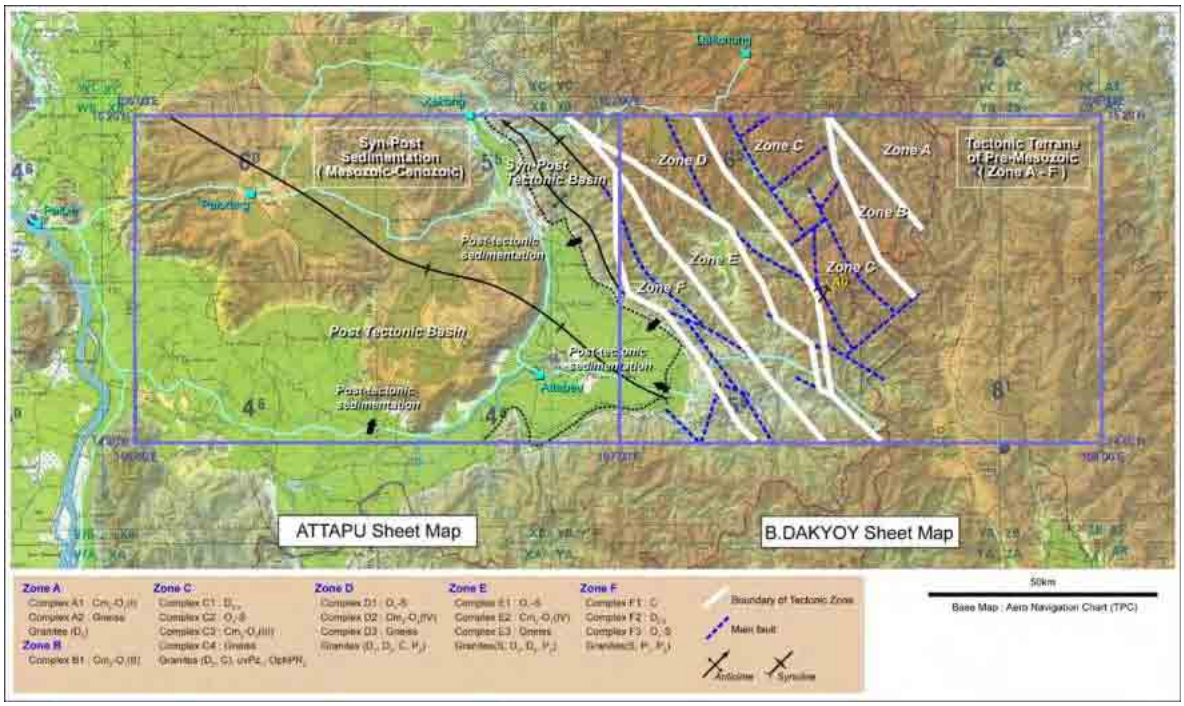


Figure 4.4.2 Comprehensive tectonic map of survey area

4.4.1 B.Dakyoy Area

1) Geology

The geology of the B.Dakyoy map sheet area consists of gneisses of possibly related to accretion of the continental crust, gabbro, granite, pelitic schist dominant metamorphic rocks, slate, metasandstone, conglomerate dominant low-grade metamorphic rocks, chert, limestone, marine to continental sedimentary rocks, rhyolitic to andesitic volcanic rocks, basalt lava, etc. Each group of lithological unit is distributed in a separate area, forming structural terrain. The geological map produced based on the second and third surveys is shown in Figure 4.4.3.

Gneiss and gabbro are observed in the eastern mountain fringe. Their occurrence extends in a northwest–southeast direction. Granite is interruptedly observed in the central mountain area and its occurrence is in a northwest-southeast direction as a whole. Their east to west width of granite bodies is about 30km long. It is not a single intrusive body but composite intrusive body consisting individual rock bodies of granites (biotite granite and two-mica granite), granodiorite (porphyritic granodiorite, schistose granodiorite and granodioritic mylonite), quartz diorite and diorite. The mylonitic texture and schistose texture characterized by preferred orientations of quartz and colored mineral or mica-fish are observed in some of granodiorite and diorite. Those textures are observed in the border zones to pelitic schist or other granitic rocks. A sandstone and mudstone mixture occurs at the contacts of granodiorite or two-mica granite with pelitic schist.

Slate, metasandstone and conglomerate dominant low-grade metamorphic rocks are broadly observed in the mountain area, together with muscovite schist and greenschist dominant schistose rocks or quartzite. Pelitic schist is often observed locally in the low-grade metamorphic rock, suggesting that it is sheared zone. Quartzite is closely related to conglomerate in the north of Nong Fa Lake in the eastern part and to gneiss along the Route 18B in the southeastern part. The schist and quartzite extend in NW-SE to S-N in their occurrence and these metamorphic rocks sandwich the basement rocks of gneiss, gabbros and granites between themselves. The chert and limestone occur between slate, metasandstone, conglomerate dominant low-grade metamorphic rock and pelitic schist in the northeast mountain fringe in the eastern mountain area. Their occurrences are limited, however. The limestone does not include muddy facies and is homogeneous to the naked eye. Along the Xe Kaman River, white limestone of probably coral reef origin is rarely observes.

The elongation of schists and quartzite is NW to SE direction or N to S direction. Furthermore, their rocks are engulfed by the basement rocks of gneiss, gabbro and granites.

Marine to continental sedimentary rock occurs in the central to western hill and flat areas, overlying or bordering on the above-mentioned geological bodies. They consist mainly of sandstone and alternating beds of sandstone and mudstone, locally intercalated by thin bed of muddy limestone. Rhyolitic to andesitic volcanic rocks intercalate the marine to continental sedimentary rocks or locally intrude into the low-grade metamorphic rocks in the western to southern hill, flat and mountain areas. They consist chiefly of rhyolitic to andesitic ignimbrite and partly they are altered to white color by leaching and enrichment. The intrusion consists mainly of rhyolite with alteration of sericite or kaolinite. Basalt lava occurs in the northern and northwestern parts, overlying the entire formations. Basaltic scoria is observed around the Nong Fa Lake in the northeastern part.

Felsic volcanic rocks occur in the northern fringe area. They show pale brown to brown and consist of fine to coarse dacitic tuff with abundant biotite and a small amount of hornblende and lapilli tuff. The geological age is considered to be Neogene.

Basic volcanic rocks occur in the northern fringe area. They consist of pyroxene basalt lava. They are considered to be erupted around the Neogene to Quaternary period.

The geological time of individual formations tends to be younger towards west; however, due to lacking the detailed study in the past, there are many unknowns. According to DGM (1991) and DGMV (1991), gneisses and gabbros belong to Pre-Cambrian; granitic rocks to Permian to Triassic, Ordovician to Carboniferous, and Silurian*; metamorphic rocks to Ordovician to Carboniferous; rhyolitic to andesitic volcanic rocks to Triassic; chert and limestone to Triassic; marine sedimentary

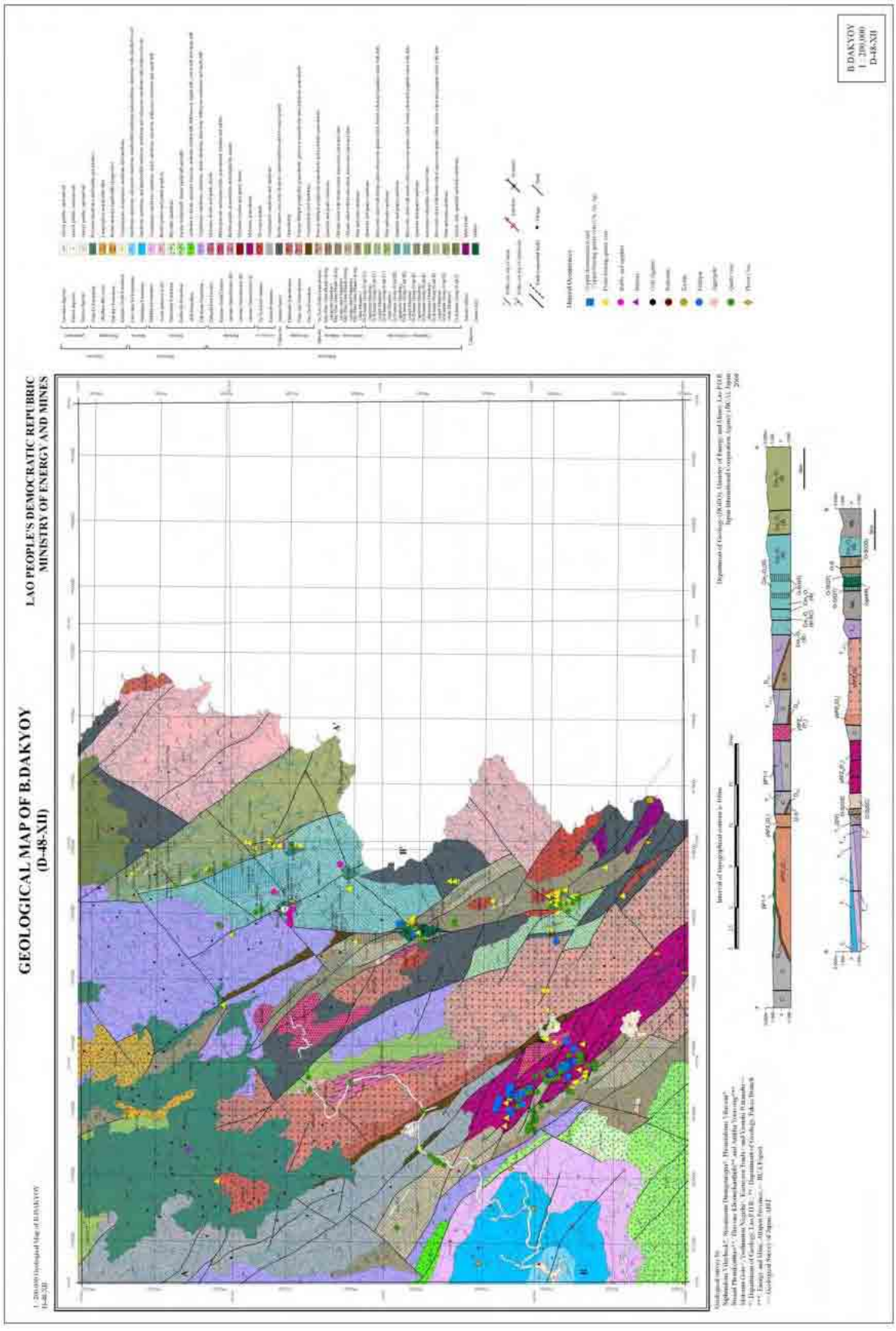


Figure 4.4.3 Geological and mineral occurrences map of B.Dakyoy map sheet

rocks to Carboniferous to Jurassic; continental sedimentary rocks to Jurassic to Cretaceous; basaltic volcanic rocks to Tertiary to Quaternary.

*Note: Ar-Ar dating reported by JMEC (2006)

2) Geological Structure

From geological situation of the B.Dakyoy map sheet area and structures observed in the formations and the rock bodies, five structures zones are identifiable in the pre-Carboniferous geological units that occur in the mountain area. The structural zones are classified as, in westward direction, gneiss and gabbro dominant zone, quartzite dominant zone in metamorphic rock, granite dominant zone in metamorphic rock, pelitic schist dominant zone and slate dominant zone. They extend in NW-SE to S-N. The schistosity developed in individual formations in the structural zones is steeply inclined at an angle of 70 to 80 degree and extends in NW-SE to S-N harmonious with the extended direction of the structural zones. Ductile to brittle shear zones to have formed probably in the deep to medium/shallow area are observed in the granite and schist on every border between the structural zones. Mylonite, schist, cataclasite, etc. occur in these shear zones. The general form of the structural zones is possible to be a west vergence judging from asymmetric folds observed in the pelitic schist dominant zone.

As for the shear sense in the individual structural zones by naked eye, the vertical sense is dominant in the mylonite of the central part and in the schist of the western part, the lateral sense is dominant in the schist of the eastern part.

The bedding structure in the marine to continental sedimentary rocks and the welded structure in the ignimbrite are inclined at an angle of around 10 degree to the west. Therefore, the formation of these rocks took place after the formation of above mentioned structural zones.

4.4.2 Attapeu Map Sheet Area

1) Geology

The geology of the Attapeu map sheet area tends, in general, to be younger toward the west. It consists of, in a westward direction, massive hard sandstone, intermediate to felsic volcanic rocks, three units of alternating beds of continental sandstone and mudstone, continental sandstone, basic to intermediate volcanic rocks and terrace sediments. Geological structures include, in a westward direction, an anticline, a monocline and a flat structure that forms the Bolaven Plateau. A gentle syncline in the southeast part and in its westward a monoclinic structure is observed. The geological map produced based on the results of the second and third surveys is shown Figure 4.4.4.

The massive hard sandstone occurs in the mid- to upper stream of the Houay Po River in the east of Sapeuan village in the north of Attapeu. This sandstone consists mainly of fine to coarse lithic sand and quartzose sand intercalated by thin layers such as conglomerate, rhyolitic tuff and tuffaceous sandstone, etc. They are considered to be formed in Carboniferous.

The intermediate to acidic volcanic rocks occur in the east, the northeast and the southeast of Sapeuan, in the northeast fringe of the survey area and in the east and west of the south part of survey area. They show pale gray to white and consist mainly of fine to coarse tuff, lapilli tuff, volcanic breccia, volcanic conglomerate and welded tuff. Most of rubbles in the volcanic breccia and volcanic conglomerate are rhyolitic tuff and welded tuff. Although the geological ages of these have been considered as Triassic, it possibly is Permian, judging from fossils observed in the upper formation.

The alternating beds of continental sandstone and mudstone broadly occur in the east of the Bolaven Plateau and extend southwards. They are grouped into three units, i.e., the upper, middle and lower. The lower unit consists of medium calcareous sandstone with fossils, conglomeratic sandstone, alternating beds of thin dark gray siltstone and mudstone, dark gray limestone and pale green siliceous mudstone or thin chert in an ascending order. The calcareous medium sandstone includes fossil shell and trace fossil and reddish brown mudstone includes silicified wood. The middle part consists of alternated thick pale gray to pale purple medium to fine quartzose sandstone and thick bluish gray to

purplish gray siltstone intercalated by reddish brown fine sandstone. They include a small amount of small rubbles of tuff. The uppermost part is intercalated by green tuffaceous coarse sandstone.

The continental sandstone forms the Bolaven Plateau and extends westwards. It consists of medium to coarse quartzose and lithic sand, including carbonized wood fragments. Laminas are formed in the sandstone and its one unit ranges from several tens cm to one m. Thin reddish to bluish gray siltstone to mudstone overlays conglomerate and at least three units are observed. Sandstone in the uppermost part shows white to pale gray and has a high permeability (Photo 4.5.14). Parallel lamina and cross-lamina of ten to several tens cm are observed and angular quartz rubbles in the massive part are included. Since kaolin clay occurs on the contact with the lower alternating beds of sand and mud, it is possible to be the unconformity.

The basic to intermediate volcanic rocks occur in the western Bolaven Plateau. They consist, in ascending order, of pyroxene basalt, andesite, olivine basalt and nepheline-olivine basalt. The latter two are porous. The olivine basalt includes the mantle nodule of lherzolite, pyroxenite, etc. The nepheline-olivine basalt has not suffered from erosion and the structure of pahoehoe ropy lava is observed. The geological ages of their eruption are believed to be Pliocene to Pleistocene for pyroxene basalt and andesite; Holocene for olivine basalt; and latest Quaternary for nepheline-olivine basalt.

The terrace sediments of Pliocene to Quaternary occur mainly along the Xe Kong and Xe Kaman Rivers.

2) Geological Structure

The Attapeu map sheet area can be divided into two areas according to geological structure; sedimentary rock with folding and volcanic zone of the western part. A N-NW to S-SE trending anticline axis runs from the eastern part to the western part in the area. In the westwards, there are a monocline gently inclined to the west and the Bolaven Plateau with an almost flat structure. In the southeast part, there are a gentle syncline and a monocline gently inclined to the north in the westwards. The volcanic zone is divided into two groups, i.e., pyroxene basalt and andesite formed by early igneous activities and olivine basalt and nepheline-olivine basalt formed by late igneous activities. The latter is alkali basalt generated from the mantle.

4.5 Mineral Resources in the Attapeu Area

The Attapeu area is known as an area that have various mineral showings such as gold, copper, lead, zinc as shown on the mineral resources map at 1:1,000,000 issued by DGM in 1991 (Figures 4.5.1 and 4.5.2). This chapter describes mineral occurrences observed during the second and third surveys.

4.5.1 Metallic Mineral Resources

1) Gold

A prospect of gold is observed around Ban Dakyoy village in the northeast part of the B.Dakyoy map sheet area. Currently, the Lao PDR's army is exploring gold ore in the area and the operation of mine is schedules to start in 2008. Artisanal gold mining activities by panning are vigorous by villagers (Photo 4.5.1).

Gold mineralization occurs in the ductile shear zone on the geological border between pelitic schist and metabasalt and gold is included in quartz veins of the sheared pelitic schist. Some of the pelitic schist and metabasalt are hydrothermally altered causing sericite in the pelitic schist and talc in the metabasalt. Pyrite dissemination is observed in the quartz veins. The occurrence of the gold mineralization suggests that this is a gold mineralization of orogenic type.

2) Copper

Copper mineral showings occur along the Xe Kong River in the northeast to east part of the Attapeu map sheet. Although France explored in 1950s and the U.S.A. in 1990s, they concluded that its potential scale was limited. No further exploration has been done since then.

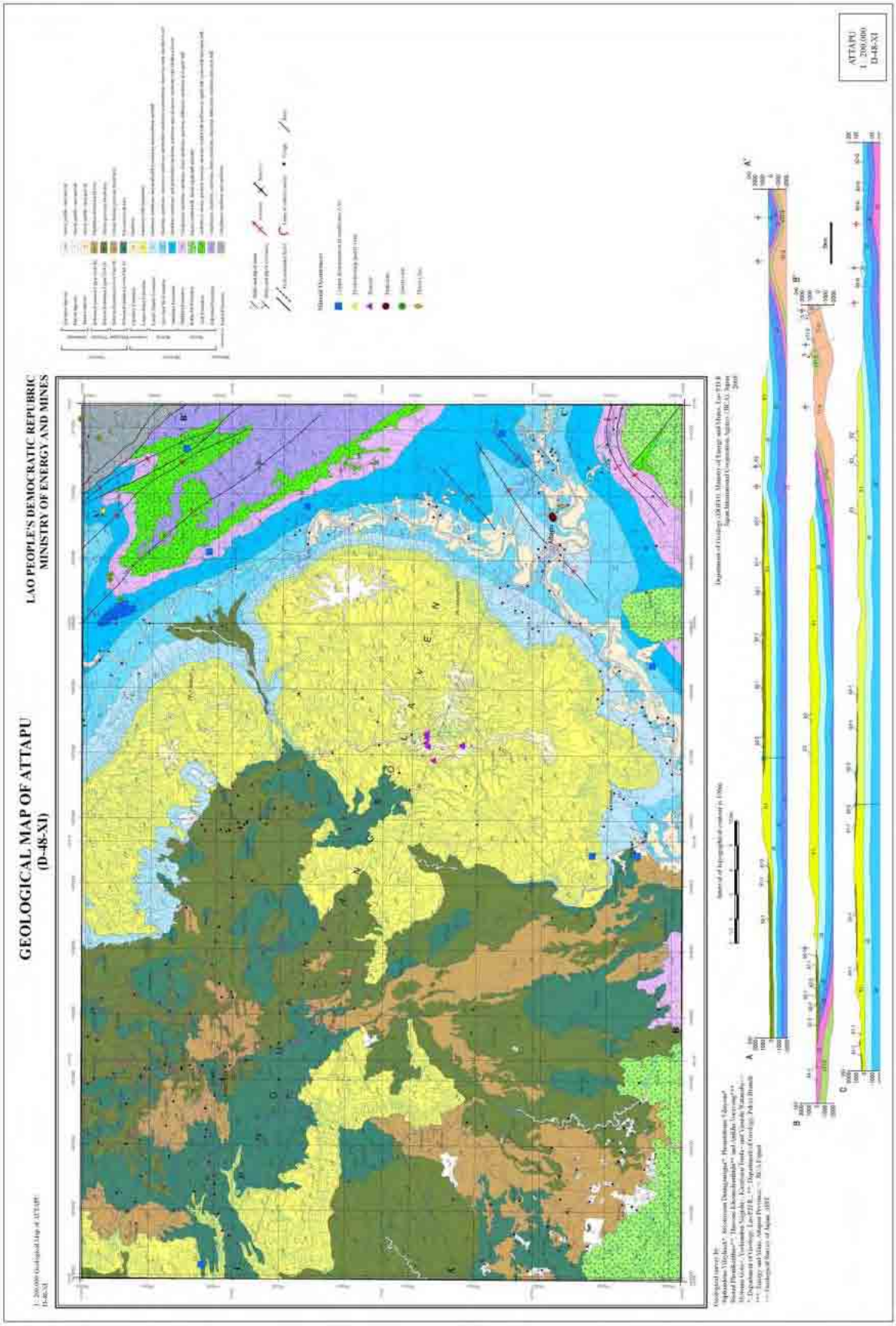


Figure 4.4.4 Geological and mineral occurrences map of Attapeu map sheet

Photo 4.5.1 Gold mine in the north of Ban Dakyoy village

Photo 4.5.2 Copper mineral indicative (azurite) and fossil shell

Mineralization occurs as dissemination along small-scaled fractures in the alternating beds of the Permian to Jurassic marine sandstone and mudstone. Copper minerals of malachite and azurite are observed. The country rock is not altered. It is highly possible to be a strata-bound deposit type; however, due to mineralization constrained in fractures, it is also possible to be related to hydrothermal fluids. The neighboring Triassic rhyolite is possible heat source for the hydrothermal fluids.

3) Bauxite

Lateritic soils extend in the Bolaven Plateau in the Attapeu map sheet and on the plateau in the eastern upper-stream area of the Xe Kong River in the northern part of the B.Dakyoy map sheet, in which bauxite occurs. Currently, a joint-venture company between the Lao PDR and China is exploring and mining on the Bolaven Plateau in the southern Pakxong city and on the eastern plateau of the Xe Kong River basin. On the east side of the Xe Kong River, a Vietnamese cooperation project is carrying out exploration together with Attapeu's DEM staff members.

They are weathered bauxite deposits in the lateritic soils on the Quaternary basalt lava plateau.

As a result of the detailed field survey carried out in the southeast area of Bolaven Plateau, it was identified that the stratigraphic horizon of bauxite mineral deposits occurs in the lowest part of upper Cretaceous sediments. The thickness of the deposits tends to be thin in eastern part of the area and thick in the central area. White clay layer is occurred in the bottom of the deposits, and the kaolinitization advances in the sandstone just below the clay layer. On the other hand, the top of the bauxite mineral deposit is rapidly changed to the above sandstone bed. The deposits consist of pisolitic bauxite pebbles, and the lateritization strongly progress in a part of the deposits area.

4) Rare Earth Elements

The lateritic soil of bauxite deposits in the Bolaven Plateau has high concentrations of rare earth elements. The concentrations are particularly high in the kaolinitic clay layer occurring between lateritic soil and host rock. The high concentrations of rare earth elements in the lateritic soil of the area have not been known before and no mining activity has been conducted in the area.

The area with high rare earth elements concentrations occurs overlapping the distribution of bauxite deposits on the Bolaven Plateau in the Attapeu geological map sheet. The same as bauxite deposit, the source of rare earth elements is alkali basalt.

Since distribution of lateritic soil on the Bolaven Plateau is widespread, mining of the lateritic soil seems to be not difficult. If a low cost extraction of rare earth elements from laterite can be applied, future development of the area as laterite mine seems to be highly possible.

5) Placer Gold

Attapeu placer gold has been known since a long time ago and had been mined along the major rivers in the Attapeu area such as Xe Kong, Xe Kaman, etc. It is now under the mining moratorium for reviewing the mining standards and the company is not allowed to mine. Only villagers continue panning in a small scale, especially in the dry season when they are not busy with the paddy work.

4.5.2 Non-Metallic Mineral Resources

1) Feldspar

Phenocrysts of alkali feldspar have a homogeneously large size of up to 3cm across in the granodiorite that broadly extends in the central mountain area of the B.Dakyoy map sheet. Some of granodiorite are weathered into soils and observed in various places. Weathered granodiorite turns brittle and feldspar phenocrysts are large; thus it will be easy to pick them by sieving or vibrating. They are good raw material for tile and ceramics.

2) Kaolinite

Intrusions of rhyolite occur in a small scale in the B.Dakyoy map sheet. They are, in many cases, altered into kaolinite and some of them have a high degree of purity, which occur near the border between the Lao PDR and Vietnam. In a case with high purity, run-of-mine can be used for cosmetics and/or cement additives as it is. Due to the closeness to Viet Num that has a large demand potential for such materials it may make an easy commercialization.

3) Bentonite

The outer layer in the central Attapeu flat area includes bentonite layers. Bricks are manufactured using mined bentonite in the suburb of Attapeu. They have a simple system, i.e., after a brick-forming machine powered through a farm tractor, dry under the sun and send the dried to the furnace for brick .

The bentonite layer would broadly extend in the flat area, including the suburbs of Attapeu.

4) Talc

Soap-like white mineral is observed in some of metabasalt that occurs in the gold mineralization area described above where the army of the Lao PDR is exploring. It is seemingly talc in the metabasalt, of which width exposed is over 10m. In a case with high purity, it would be promising resources.

5) Limestone

Limestone with a reasonable scale and high purity occurs along the Xe Kaman River in the east of the Nong Fa Lake. The extension is estimated at more than 1km x 2km, to which access is so difficult that it takes two days on food even in the dry season. Thus, it is not minable resources at present; however, once access has been established following hydropower development projects in the area, it would be promising.

6) Gemstone

Villagers mine gemstone by panning around Nong Fa Lake located in the mountain area in the eastern part of the B.Dakyoy map sheet (Photos 4.5.3 and 4.5.4). They are chiefly sapphire, ruby and spinel. Nong Fa Lake is seemingly formed by the late Quaternary volcanic activities with the basalt erupted from a substantial depth. Spinel observed there is melted; thus, gemstone would also come from the deep place with the eruption.

As it was clarified by this survey that the distribution of the basaltic volcanic rocks is very limited near the Lake Nong Fa, the deposits of gemstone seem to be very small-scale.

Photo 4.5.3 Picking gemstone with sieve around Nong Fa Lake

Photo 4.5.4 Ruby (left) and Sapphire (right)collected

4.6 Geochemical Survey of Stream Sediments

4.6.1 Purpose of Survey

Geochemical survey of stream sediments was conducted simultaneously with geological survey for understanding potentiality of the mineral resources in the area.

4.6.2 Survey Method

Sampling of stream sediments was conducted at locations near the main roads, along the main rivers and their tributaries. At each point, stream sediments of approximately 100g was collected using 80-mesh sieve. At each sampling point, in addition to sample number, UTM coordinates by GPS, name of the stream, description of outcrop, rolling stone, width and flow rate of stream and size of sediments were recorded in the sampling list. A total of 479 stream sediments samples were collected.

Chemical analysis of following 51 elements was conducted.

Au, Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg,
In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta,
Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr

4.6.3 Results of Geochemical Survey of Stream Sediments

The results of geochemical survey of the stream sediments are summarized as below.

1) The mineral resources expected in the Attapeu area are that of related to Au and Cu mineralization. The maximum value of Au in the stream sediments is very high (4,830ppb) and this samples was collected near the gold mine of army concession. Cu tends to be relatively high in the area of Au high samples occur.

2) The maximum value of Cu is 79.8ppm and Cu high samples are found in the area of mafic rocks such as basalt and gabbro. The occurrences of High Cu stream sediments near the border to Vietnam, east of Route 18B, seem to be related to the distribution of gabbro originated from the ophiolite sequence rocks. The areas of Cu high concentration without occurrence of mafic rocks are;

   a. Surrounding area of the gold mine of army concession.

   b. The area near cross point of Route 18B and Ho Chi Minh Trail

3) The area with occurrences of the stream sediments samples with Au concentrations more than threshold value of 200ppb are considered to have high potentiality of Au mineralization. These areas are;

a. Surrounding area of the gold mine of army concession in the south of the Nonga Fa Lake.
b. Surrounding area of the Nonga Fa Lake
c. Northeast of the Nong Fa Lake
d. Northwest of the Nong Fa Lake
e. Surrounding area of Ho Chi Minh Trail

4) Among the five factors extracted from the factor analysis, three factors shown below have relation to mineralization.

- Factor 3: As, Bi, Pb, Sb (Acidic hydrothermal mineralization)
- Factor 4: W, (Bi) (Acidic hydrothermal mineralization)
- Factor 5: Au, ((Bi)) (Gold mineralization)

In the mineralized area of the gold mine of army concession, Au, Ag, As, Bi, and S are high and, consequently, Factors 3 and 5 show high factor scores in the area. This geochemical anomaly was caused by Au mineralization by epi- to meso-thermal activities.

Other than above, the area of high Factor 5 scores of more than 1.0 was found in the area near the cross point of Route 18B and Ho Chi Minh Trail. In this area, samples with high Au concentration exceeding 2,000ppb were obtained. However, lack of high Factor 3 scores in the area, none of them exceeds 1.0, the type of mineralization seems to be different from the one occurs in the mineralized zone of the gold mine of army concession.

4.6.4 The Area of High Potential for Mineralization Based on the Geochemical Survey of the Stream Sediments

As mentioned earlier, potentialities of Au and Cu mineralization are high in the Attapeu area. The areas with high Au and Cu potentialities extracted form the Au concentration and high factor scores of Factor 3 and 5 are;

1) Surrounding area of the gold mine of army concession in the south of Nong Fa Lake
2) Surrounding area of the Nong Fa Lake
3) Northeast of Nong Fa Lake
4) Northwest of the Nong Fa Lake
5) The area near the cross point of Route 18B and Ho Chi Minh Trail

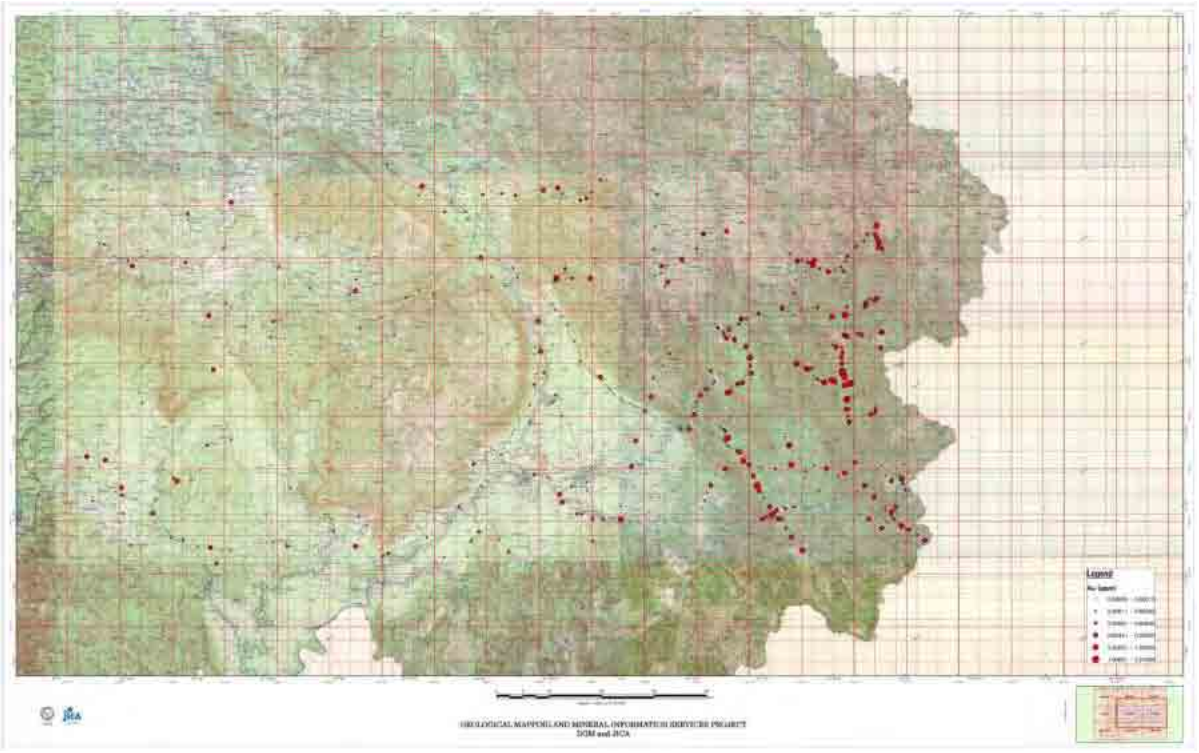


Figure 4.6.4 Distribution map of Au anomaly

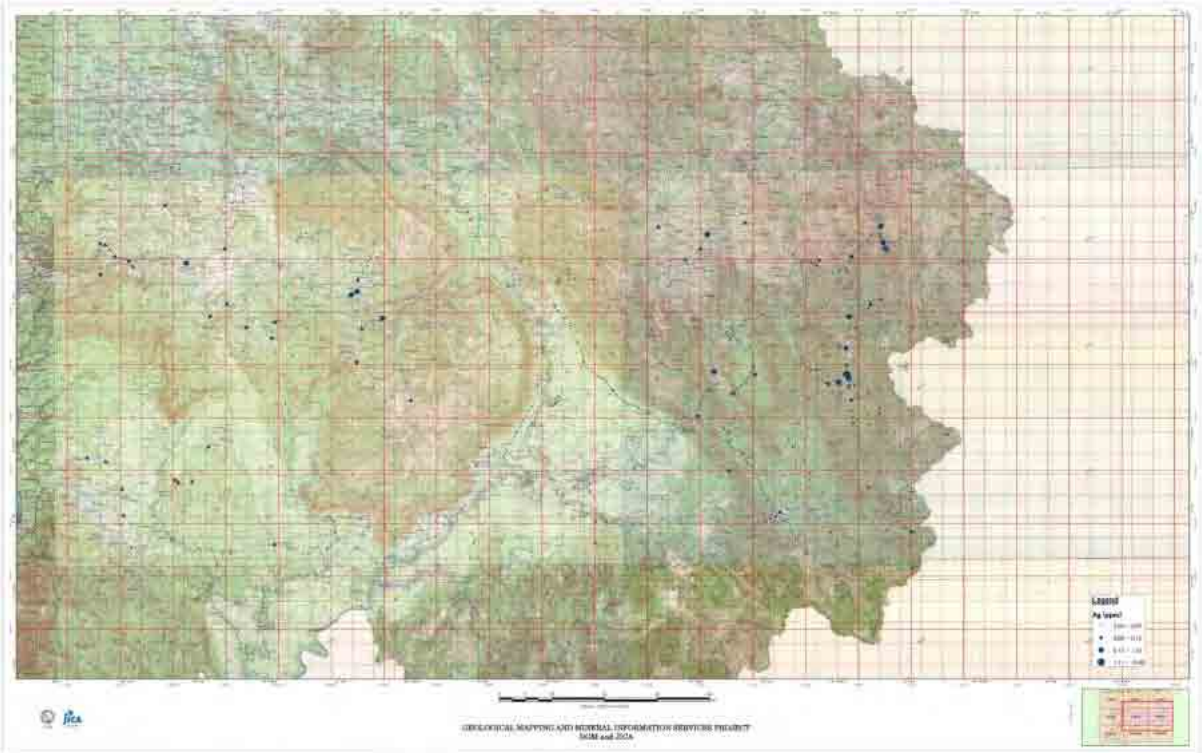


Figure 4.6.5 Distribution map of Cu anomaly

4.7 Geological Mapping of Detail Survey (1:10,000 scale)

The detail survey was conducted in the areas of high potentially for mineral resources selected on the bases of mineral showings and anomalies of stream sediments geochemical survey found by the geological mapping of 1:200,000 scale (Figure 4.7.1). Three areas from the Eastern Attapeu Area (Area A, Area B, Area D) (Figures 4.7.2) and one area from the Western Attapeu Area (Area C) (Figures 4.7.3), comprising total area of 84km^2, were selected for detail survey.

The geological mapping of the detail survey area was commenced during the fifth and sixth survey. Stream sediments geochemical survey is simultaneously conducted.

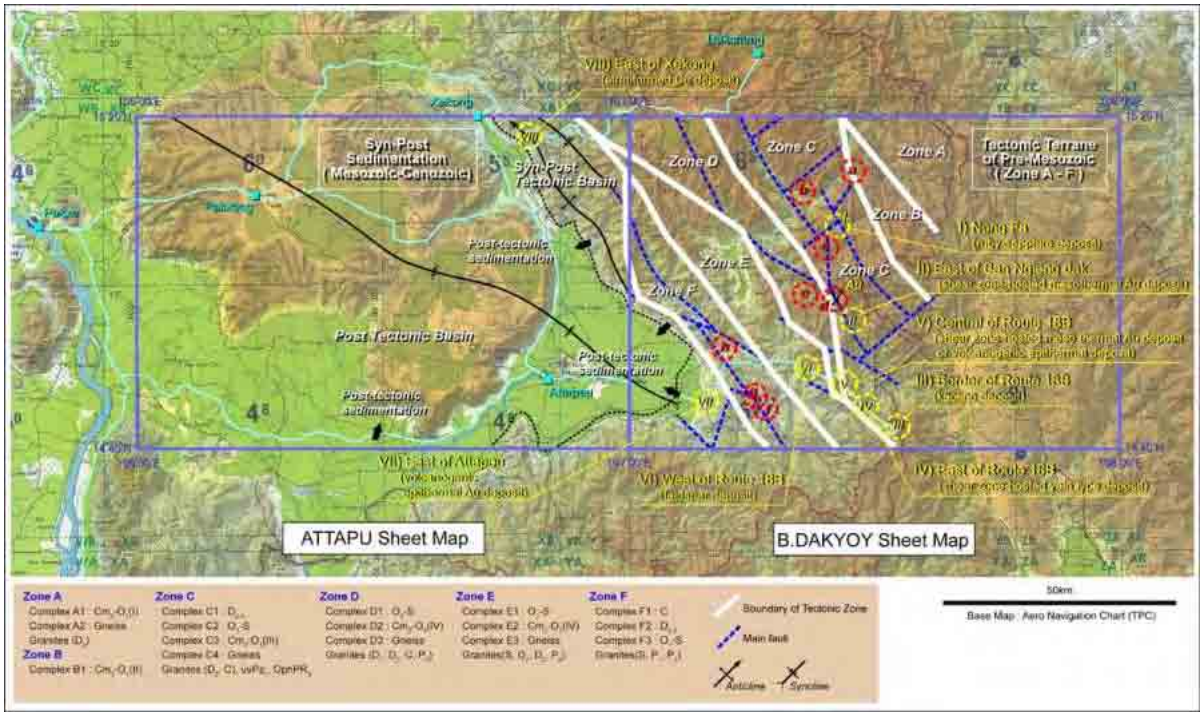


Figure 4.7.1 Location map of potential area for mineralization

The area A is located in the western part of the mountains existing in the eastern part of Attapeu City. The survey range is north-south 8km by east-west 8km. As the geochemical anomalies of gold by stream sediment are detected in this area, gold mineralization are expected in the area.

The area B is located at the sign 90km point on the National route 18B line in the mountains existing in the eastern part of Attapeu City. The survey range is north-south 4km by east-west 4km. As the quartz veins, pyrite dissemination, veinlet and sulphur leached are observed in the outcrop of the sign 90km point, the gold mineralization is expected.

The area C is located in the eastern part of Kong River flowing in northern end of the geological map sheet of the Attapeu area, and the area situates in the southeastern part of Xekong City. The survey range is north-south 4km by east-west 4km. As the copper minerals such as malachite and azurite are observed within the sandstone exposed on the road in the area, the copper mineralization is expected.

The area D is located in the western part of the mountains as well as the area A. The area D is adjoins the area A. The survey range is north-south 4km by east-west 4km. As the geochemical anomalies of gold by stream sediment are detected in this area, gold mineralization are expected in the area.

The objectives of detailed geological survey are to understand the characteristics of mineralization, to grasp the scale of the ore deposits, and to create the ore genesis model. During field survey, in

addition to the description of detail geology and mineralization, the densely sampling of stream sediment, the collection of ore samples in mineralized points, and their chemical analysis were carried out.

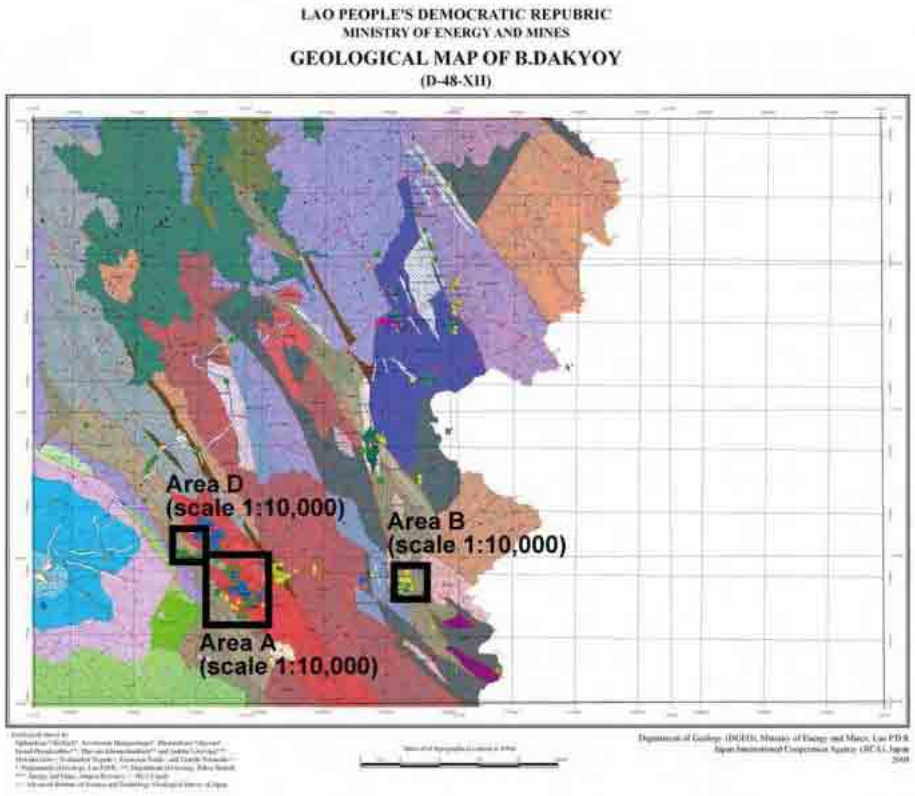


Figure 4.7.2 Location map of detail survey area of B.Dakyoy map sheet

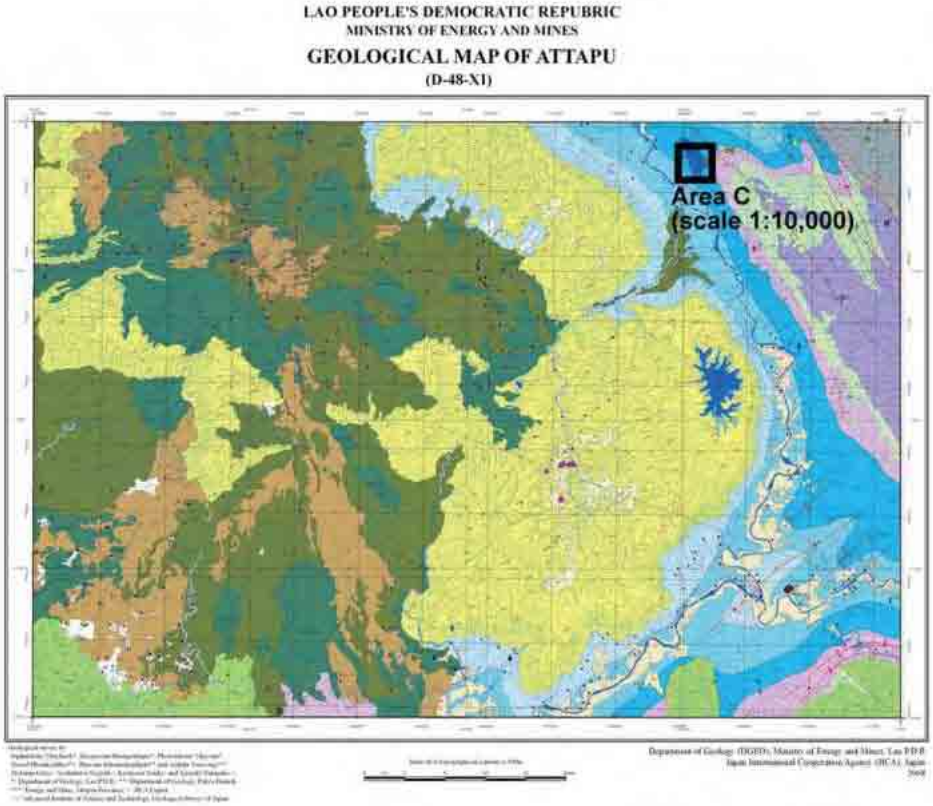


Figure 4.7.3 Location map of detail survey area of Attapeu map sheet

4.7.1 Area A

Granitic rocks of probably Palaeozoic to Mesozoic age are distributed in the most of Area A and metamorphosed pelitic rocks and slate occur in western part of the area.

The main occurrences of mineralization found in the area are dissemination of malachite in the mylonite zone of granodiorite and foliated granite, quartz vein with malachite-chalcopyrite-pyrite and quartz vein with pyrite. Although all of these are only small scale mineralization observed on outcrop, since the mineralization occur along ductile fracture and schistosity, an extension of mineralization along the fracture zone is expected. The ductile fracture and schistosity strike in NW-SE direction.

The mineralization similar the porphyry type copper deposits is observed in the central part of the area. Size of mineralization is 5m to 10m in width. In the outcrops of granodiorite, the mineralization has the copper oxide minerals of malachite and azurite and develops the dissemination of chalcopyrite and bornite. And it is followed by the quartz network with the sericite alteration and the quartz veins with the dissemination of pyrite and chalcopyrite.

The mineralization was probably formed after the emplacement of granodiorite body accompanying with the porphyry type copper mineralization in-situ, and it was formed under the wrench tectonics caused mylonitization and cataclasitization.

In the two sites indicating the copper mineralized zones accompanying with the sericite alteration and quartz stockwork, the trench survey was carried out in order to detect the extension of mineralization. Sketching in the trench survey, the ore samples for chemical analysis and the rock samples for the identification of alteration minerals were collected from two trenches.

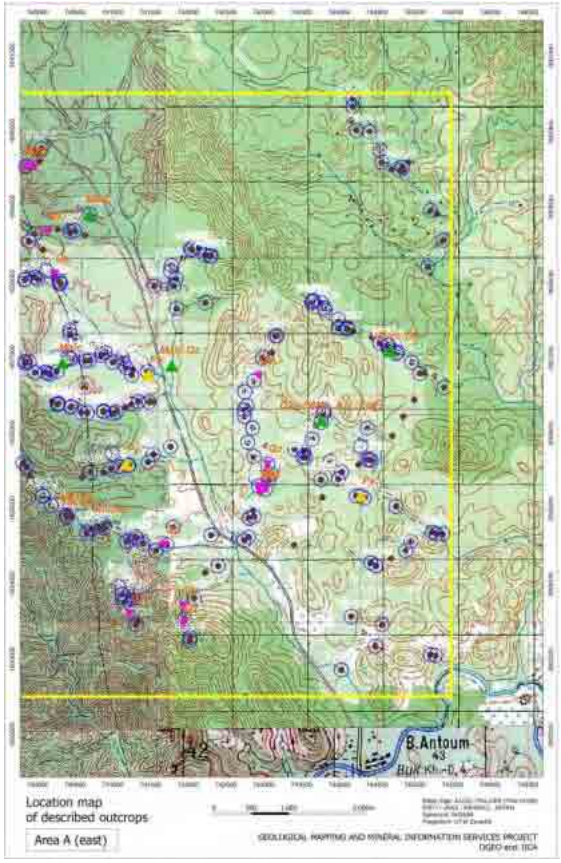


Figure 4.7.4 Topographic map of Area A (east)

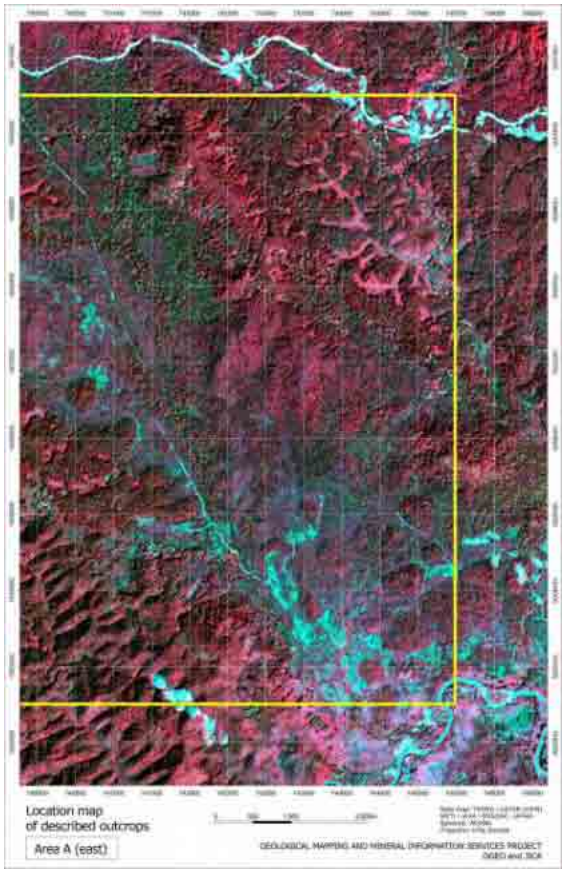


Figure 4.7.5 ASTER imagery map of Area A (east)

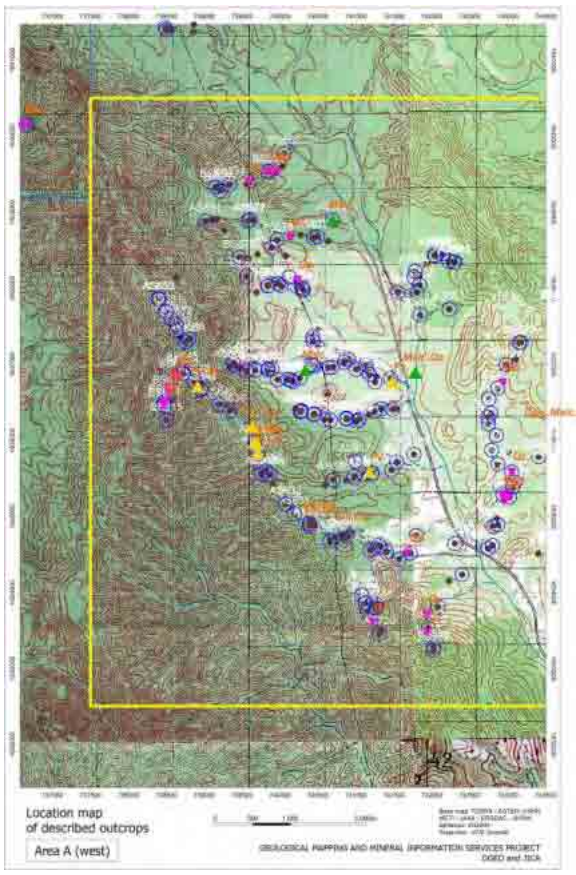


Figure 4.7.6 Topographic map of Area A (west)

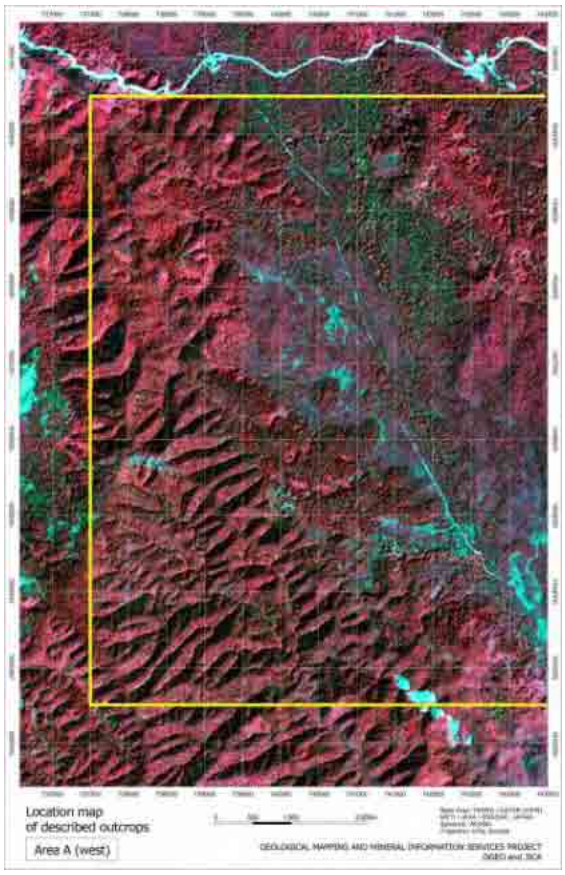


Figure 4.7.7 ASTER imagery map of Area A (west)

4.7.2 Area B

Most of the area is occupied by weakly metamorphosed rocks of the Paleozoic age, mainly consisting of slate, and pelitic schist, mainly consisting of muscovite schist, occur in the western part of the area.

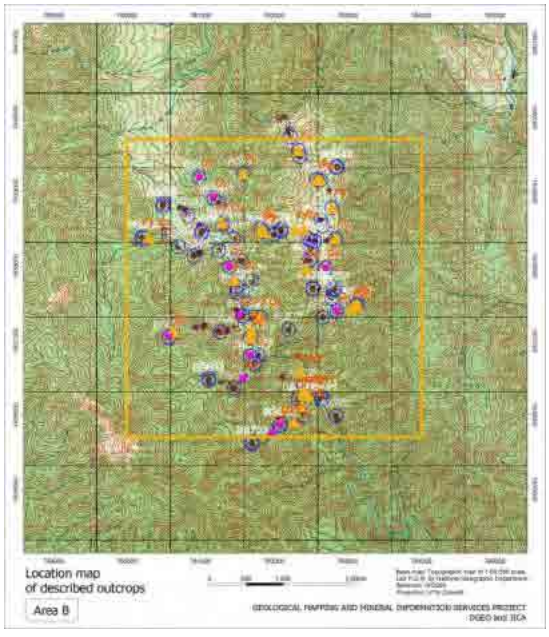


Figure 4.7.8 Topographic map of Area B

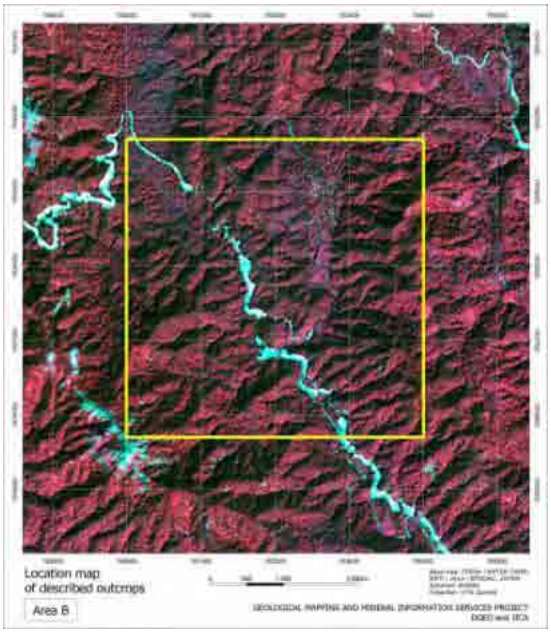


Figure 4.7.9 ASTER imagery map of Area B

Brittle fractures zones were found in the slate of the center apart. They trend in NW –SE to N-S direction and, in many places in fracture zones, strong pyrite dissemination and stockwork veins of quartz were found. The fracture zone with mineralization together with fracturing, found along Route 18B, is 100m wide.

Main mineralization observed in the area is, above mentioned, pyrite bearing quartz stockwork veins in the fracture zone. Similar mineralization of 5m to 50m wide is found in several locations along the Route 18B and on river bed. Occurrences of this mineralization together with brittle fracture suggest that brittle fracture zone are genetically related to the mineralization.

4.7.3 Area C

The sandstones of Triassic to Jurassic, mainly consist of very fine sandstone and fine sandstone and alternation of calcareous sandstone and shale and muddy limestone are locally observed. Very fine sandstone is pale red to gray and fine sandstone is pale greenish gray to gray, and each bed of them few m thick forms alternation. They have NW–SE trend and dip 10 degree to west. The sandstone beds has a horizon including abundant shell fossils and this horizons can be traced for few kilometers.

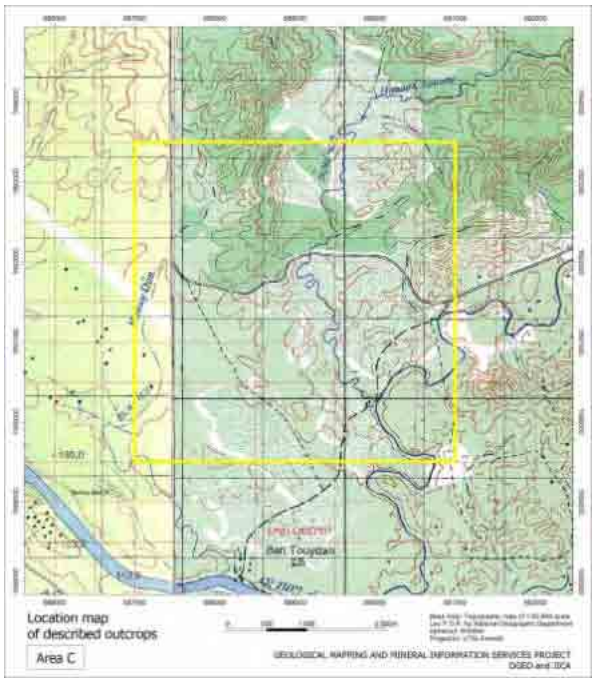


Figure 4.7.10 Topographic map of Area C

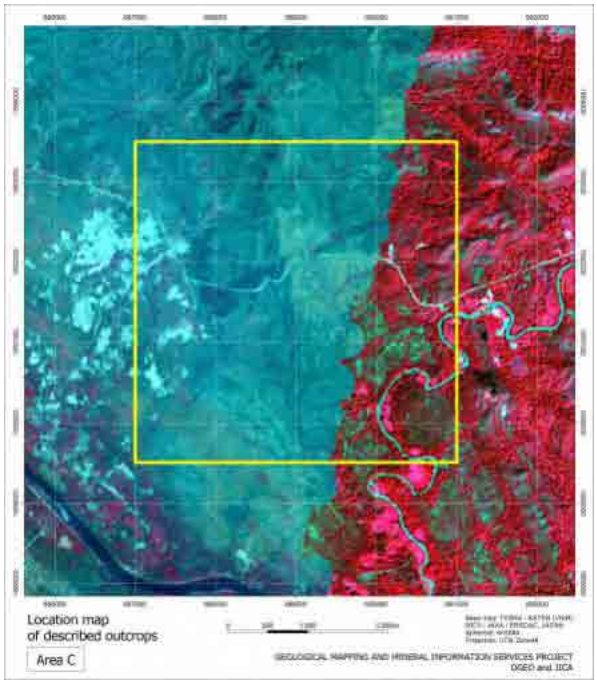


Figure 4.7.11 ASTER imagery map of Area C

The mineralization found in the area shows occurrences of azurite and malachite in the sandstones. Disseminations of these are found along irregular fractures of small scale in the sandstones. Absences of alteration in the country rock suggest the type of mineralization in the area to be either strata-bound or epithermal type.

The host rock of the strata-bound type copper mineralization observed in the area is the calcareous sandstone with fossils of mollusk. The sandstone bed continues more than 4km from south end to north end in the area. The thickness of the bed is 10cm in south part, about 2m in central part and 1.5m in north part, and the continuity of the bed is very good. The horizon includes copper oxide minerals mainly consisting of malachite and accompanies with azurite and chalcopyrite in northern part of the area. The copper minerals such as malachite and azurite are observed in the thin beds of pale grey mudstone with the red mudstone bed.

4.7.4 Area D

The granitic rocks of Paleozoic to Mesozoic ages occur in the northwestern part of the area and metamorphosed mudstone and sandstone and slate occur in the central to western parts of the area. The conglomerate and sandstone occur in the southwestern part of the area, uncomformably overlying the metamorphic rocks.

The mineralization in the area is azurite dissemination and malachite-azurite-calcopyrite-pyrite bearing quartz vein occurring in mylonite zone of granodiorite and schistose granite. The mineralization occurs in the fracture zones of country rock and locally dissemination of azurite occurs in the massive part of country rock.

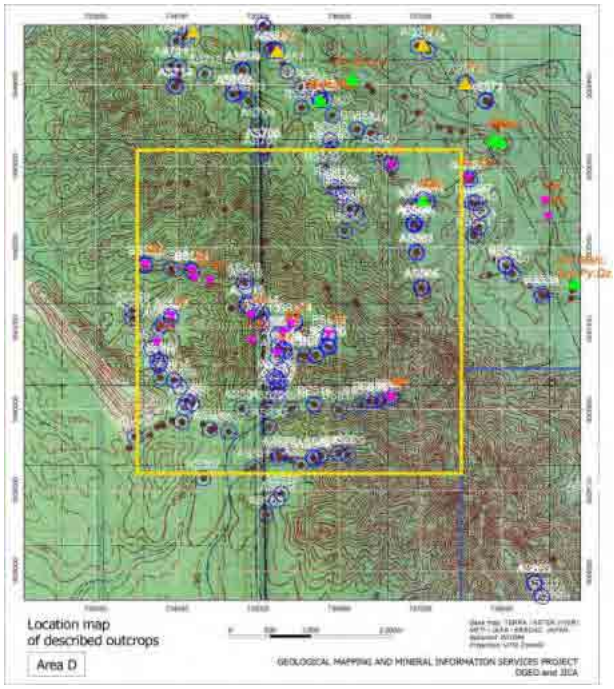


Figure 4.7.12 Topographic map of Area D

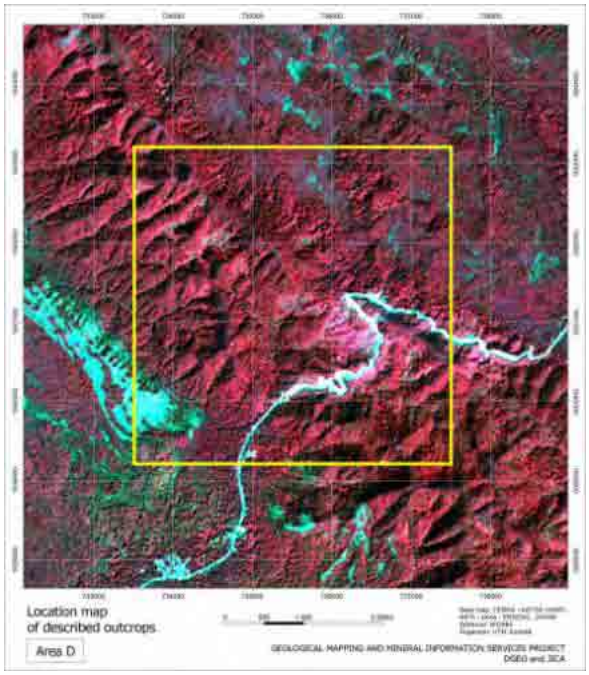


Figure 4.7.13 ASTER imagery of Area D

4.8 Comprehensive Considerations

As the results of geological survey in the Attapeu Area, two sheets of 1:200,000 scale geological map and four sheets of 1:10,000 scale geological map were produced. Before the survey work of this project, only sparse information of the geology and mineral occurrences of the Attapeu area were available. Among these, two maps with relatively comprehensive information of the Attapeu Area are "Geological and Mineral Occurrence Map of LAO P.D.R., Scale 1:1,000,000" by DGM (1990) and "Geological Map of Cambodia, Laos and Vietnam (1991), Scale 1:1,000,000" by Geological Survey of Vietnam (1991). But these are small scale maps and, consequently, not having been enough for consideration of Time-Space development of geology/ore genesis and evaluation of potentiality of mineral resources. In addition to these, there had been many uncertainties concerning the occurrences of geological units and mineralization, and the ages of only a small number of stratigraphic sequences had been confirmed by the marine and non-marine index fossils. None of the ages of the igneous activities and ages of mineralization had been confirmed and the ages of these had been only predicted by relations between intrusive rocks and host rocks and similarity of their appearances.

Under the above mentioned situation, the geological survey of the Attapeu Area was conducted and the Geological and Mineral Occurrences Map at the scales of 1:200,000 and 1:10,000 were completed. All through the geological mapping work, various geological aspects of the area, such as detail geology, geological structure and mineral resources (distribution, characteristics, potential and ages of mineralization) of the Attapeu Area were clarified.

Based on the geological work of the Attapeu Area, comprehensive aspects of the geology and mineralization are summarized below.

4.8.1 Geology of the Attapeu Area

As shown in Figure 4.8.1, the geological aspects of the Attapeu area were summarized in the schematic columnar section produced based on the information obtained by the project, such as stratigraphic sequence, intrusive rocks, occurrences of mineralization, age determination.

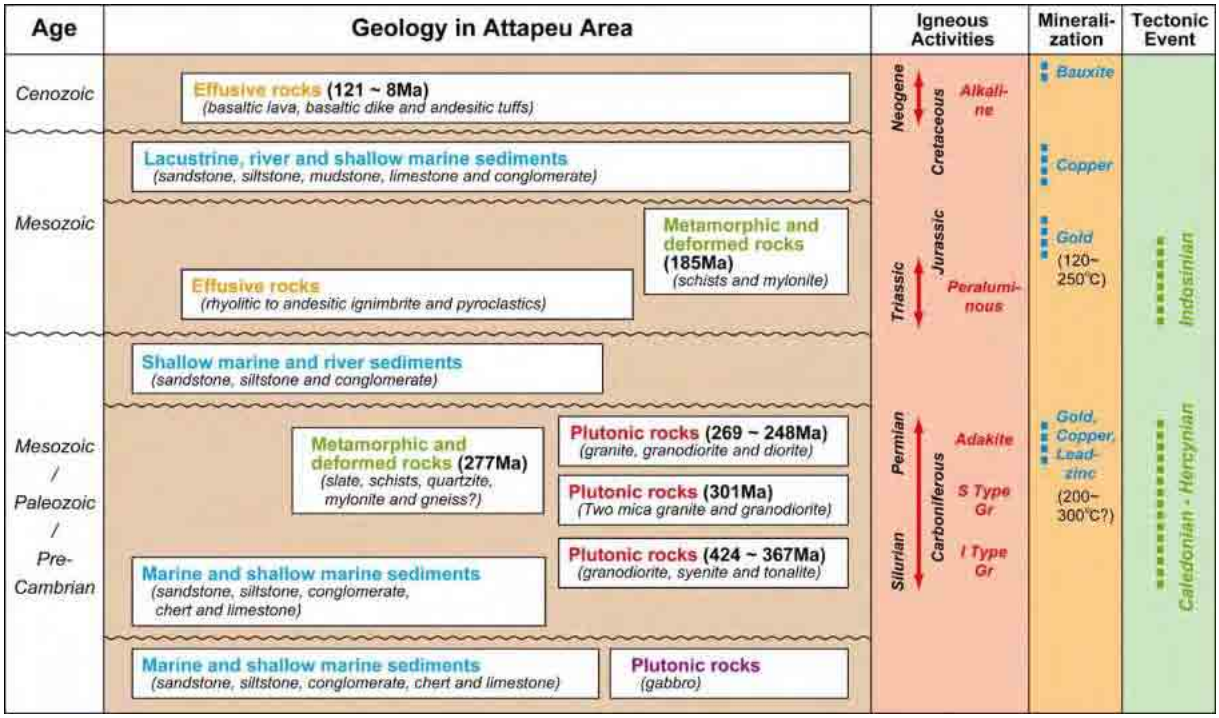


Figure 4.8.1 Schematic columnar section of Attapeu Area

As shown above, formation of sedimentary rocks started in Cambrian and continued to Cretaceous. The environments of sedimentations was oceanic to neritic at the beginning in Cambrian and after Permian it changed to neritic to non-marine and then after Cretaceous non-marine.

The igneous activities in the area started from formation of mafic rocks in Precambrian, and then followed by intrusion of granitic rock in Silurian to Permian. In Triassic, intrusion/effusion of intermediate to acidic rocks took place followed by intrusion and effusion of alkaline rocks in Cretaceous to Tertiary. Among these igneous activities, chemical nature of granitic magma related to the formation of granitic rocks change depending on the time of the activities as shown below.

i) Silurian: I-type granite (island arc)

ii) Devonian: I-type granite (island arc) to A-type granite (island arc to within plate)

iii) Carboniferous: S-type-adakitic granite (island arc)

iv) Permian: I-type-adakite granite (island arc)

The area encountered regional metamorphism in Silurian to Devonian. The mafic rocks of Precambrian and marine sediments of Cambrian to Silurian were metamorphosed to mainly pumpellyite-actonolite facies to green schist facies. After Devonian no clear evidence of formation of metamorphic minerals and metamorphic textures are observed. The metamorphic events in the area, therefore, are restricted in a period of after the formation of Silurian marine sediments and before formation of Devonian marine sediments.

The three periods of tectonic movements in the area, Silurian to Devonian, Devonian to Carboniferous and Permian to Triassic, were identified and each of which, respectively correspond to Caledonian, Variscan and Indosinian periods of tectonic movements. The characteristic features of each of the tectonic movement in the Attapeu Area are summarized below.

i) Silurian to Devonian (Caledonian): Occurrences of pumpellyite-actonolite facies to green schist facies metamorphic rocks.

ii) Devonian to Carboniferous (Variscan): Occurrences of pumpellyite-actonolite facies metamorphic rocks.

iii) Permian to Triassic (Indosinian): Occurrences of fractures zones characterized by mylonite and cataclasite.

4.8.2 Mineral Resources of Attapeu Area

As summarized below, variety of mineral resources including metallic, non-metallic and energy resources are found in the Attapeu area.

i) Metallic resources
- -gold (mesothermal, placer) : Vantat area.
- -copper (porphyry cupper, strata-bound sedimentary type): Attapeu East and eastern part of Xekong
- -bauxite and rare earth elements (residual deposits): Bolaven Plateau

ii) Non-metallic resources
- -industrial materials (ignimbrite): east of Attapeu.
- -feldspar (porphyritic granite): east of Attapeu.
- -Kaolinite (rhyolite): east of Attapeu.
- -benntonite (weathered soil): neighbors of Attapeu town
- -gem stones (ruby and sapphire): Nong Fa Lake area.

iii) Energy resources
- -coal (lignite): Dakchung area

The occurrences of these resources are shown in Figure 4.8.2.

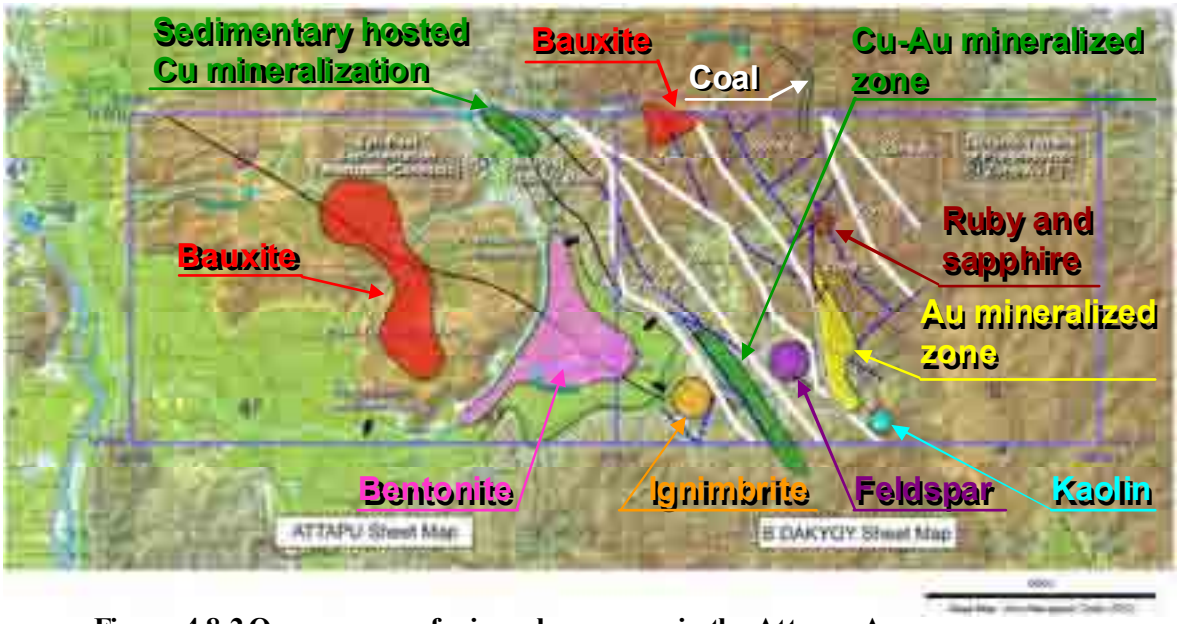


Figure 4.8.2 Occurrences of mineral resources in the Attapeu Area

Among the main mineral resources identified by the survey, these given below are considered to be economically important based on scale and extension.

a) Gold-Copper mineralization (Vantat area)
b) Copper-gold mineralization (Attapeu East Area)
c) Bauxite and rare earth elements (Bolaven Plateau)

Locations of the three main areas of mineralization are shown Figure 4.8.3.

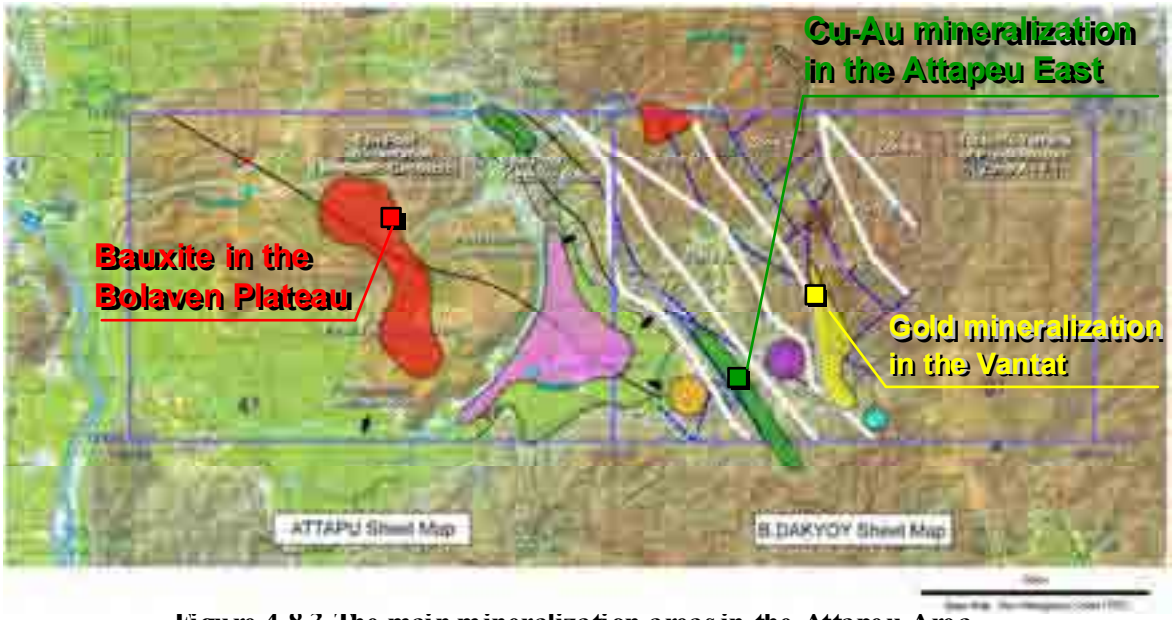


Figure 4.8.3 The main mineralization areas in the Attapeu Area

The characteristic features of these mineralization areas are given below.

1) Gold-Copper mineralization of the Vantat Area

The mineralization occurs in the protected area of the Laos national army and it was developed as a gold mine of the Laos National army. Production of gold was started in 2007. Geological and mineral resources map of the Vantat Area and its surrounding area, together with cross section of ore formation model are shown in Figure 4.8.4

The mineralization is characterized by dominant sericite-quartz alteration, nearly 200C degree of homogenization temperature of fluid inclusion of quartz veins, similar salinity of fluid inclusion to the veins of orogeny type gold mineralization and close association to fracture zones. These features of mineralization suggest the gold copper mineralization of the Vantat area to be low-sulfidation, mesothermal orogeny type. A summary of mineralization of Vandat area is given in Table 4.8.1.

Although a small scale mining operation is currently conducted in the Vandat area, since detail survey has not been done in the area, the scale of mineralization has not been known yet. Further, detail exploration work including surrounding area has not been done. For understanding the ore reserves of the mine and potentiality of the whole area, detail comprehensive survey including detail geological and mineralization surveys, geochemical survey (stream sediments, soil), geophysical survey (electric and magnetic) and drilling survey is necessary.

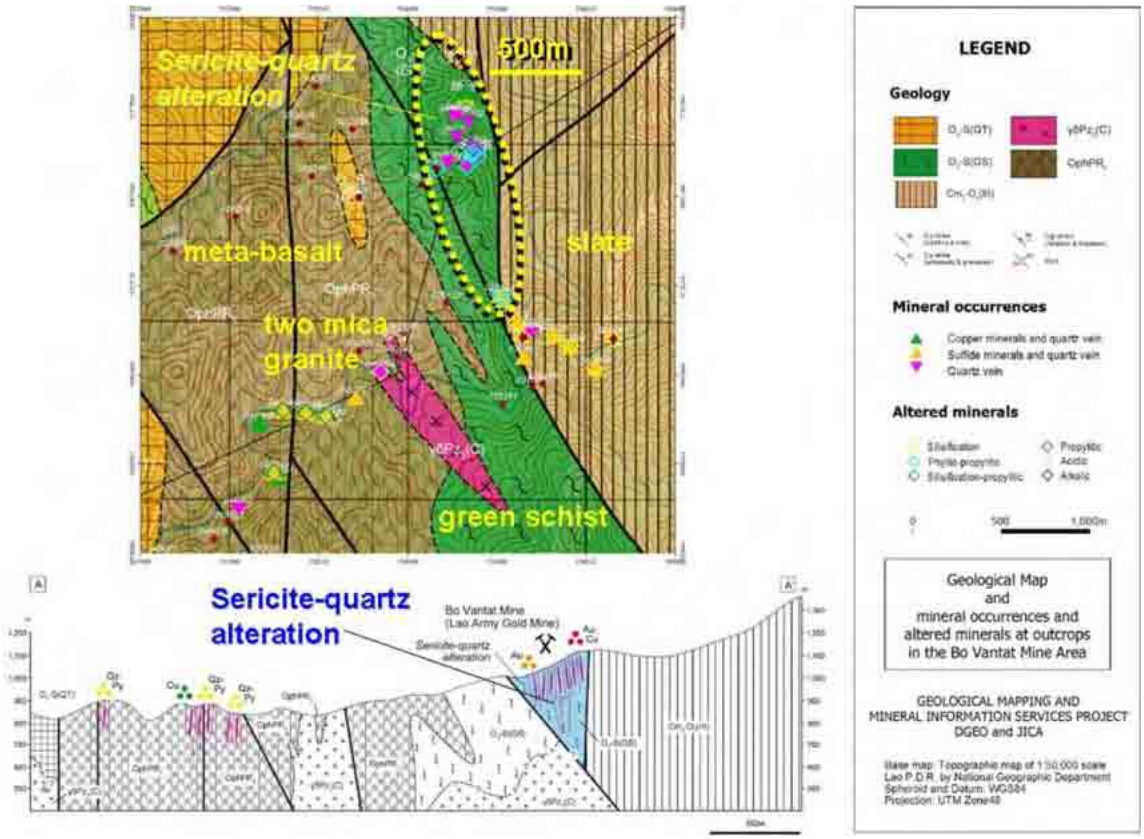


Figure 4.8.4 Geological and mineral resources map and cross section with ore formation model (Vantat Area)

Table 4.8.1 Gold-Copper mineralization of Vantat Area

		Vantat Area
Mineral	**Ore**	native gold and pyrite
	Gangue	quartz
Occurrences		vein, argillation and fracture filling
Alteration		sericite, chlorite and rutile
Host rock		chlorite schist, basalt and pelitic schist
Related rock		two-mica granite?
Ore grade		237ppm Au, 22.2ppm Ag, 1.64% Cu for an altered rock with quartz veinlets
Mineralization type		orogenic mesothermal

2) Copper-gold Mineralization of Attapeu East Area

A new copper-gold mineralization was found during the project in the east of Attapeu along the Rout 18B, south of currently under contraction dam , Xe Kaman 1, and it was named as Attapeu East Area. Geological and mineral resources map of the area together with cross section of ore formation model are shown in Figure 4.8.5.

Mineralization of the area is characterized by chlorite alteration of the host rock of the Cu-Au mineralization, sericite-quartz alteration at the center of mineralization, occurrences of stockwork quartz veins in the zone of sericite-quartz alteration. The features of mineralization and alteration of the area suggest that the mineralization of the Attapeu East Area is porphyry copper type.

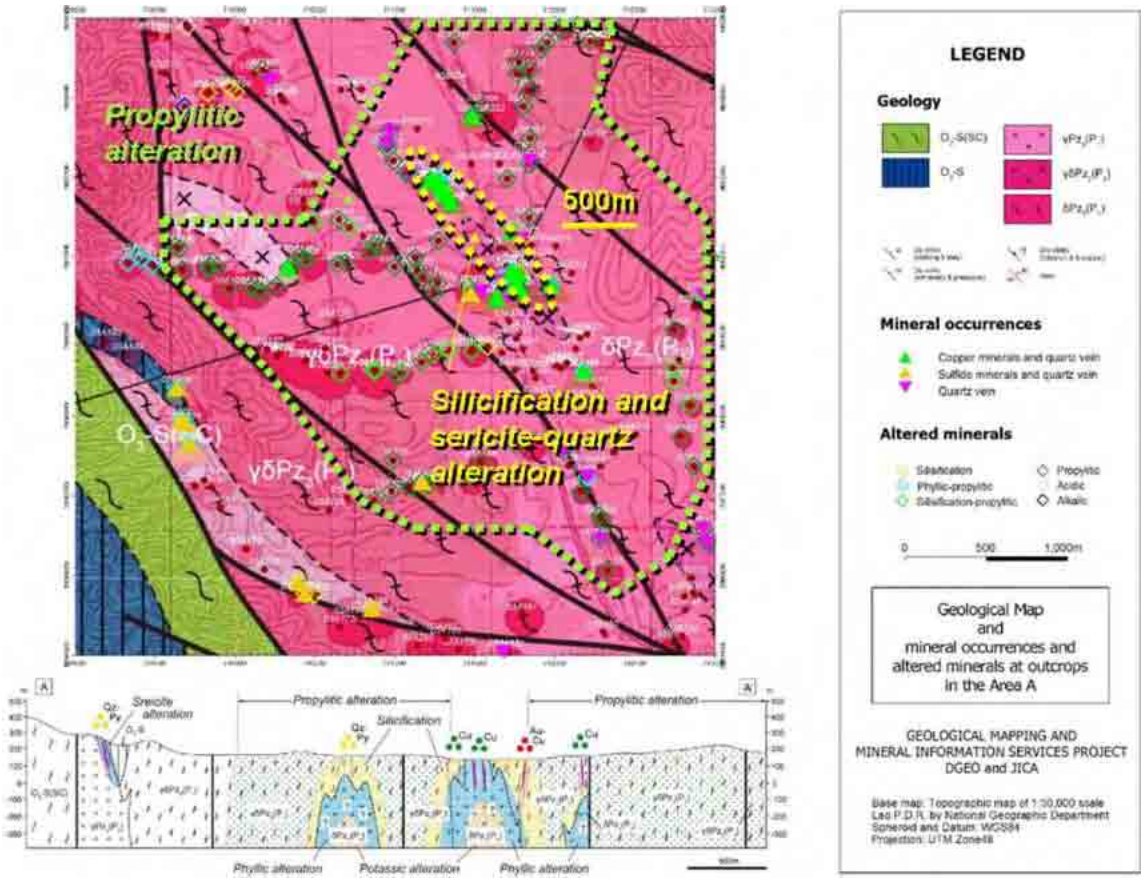


Figure 4.8.5 Geological and mineral resources map and cross section with ore formation model (Attapeu East Area)

A summary of mineralization of Attapeu East Area is given in Table 4.8.2

Table 4.8.2 Copper – Gold mineralization of Attapeu East Area

		Eastern part of Attapeu Area
Mineral	**Ore**	chalcopyrite, bornite, tenolite and pyrite
	Gangue	quartz
Occurrences		dissemination, vein and fracture filling
Alteration		sericite, chlorite, biotite and silicification
Host rock		granodiorite and tonalite
Related rock		mylonitic granodiorite and tonalite (adakite)
Ore grade		~ 6.55% Cu and ~ 6.9ppm Au for quartz veins, ~ 5.93% Cu for disseminated granodiorite
Mineralization type		porphyry Cu

The potentiality for economical mineral resources seems to be high in the area because of a wide distribution of Cu mineralization on the surface, high assay results of Cu and Au and possible type of mineralization being porphyry copper type. Further, Au and Cu anomalies extracted by stream sediments geochemical survey conducted during the project and findings of several bodies of granitic rocks possibly related to mineralization by analysis of satellite images suggest a fairly wide distribution of mineralized zone in the area.

Because of only surface information of mineralization is known, detail survey for confirming lateral and vertical extension of the mineralization is necessary in future for assessing potentiality of area. Detail geological survey (route mapping and trenching), geochemical survey (stream sediments and grid survey of soil), geophysical survey (IP and magnetic survey) and drilling survey are recommended for understanding the scale of mineralization and assessing potentiality of the area.

3) Bauxite with high rare earth elements of Bolaven Plateau

Bauxite deposit with high rare earth elements occurs on the plateaus of the Bolaven Plateau and east of Xe Kong. Recently, exploration projects by foreign investments are actively conducted in these areas.These are a residual type deposit formed near surface of alkali basalt and sandstone. The source of aluminum and rare earth elements are alkali basalt and the deposits were formed by enrichment of aluminum and rare earths elements through processes of weathering and erosion of alkali basalt.

Geological and mineral resources map of the area together with cross section of ore formation model and summary of mineralization are given in Figure 4.8.6 and Table 4.8.3, respectively.

The potentiality of the bauxite deposits with a wide spread distribution of lateritic soil in the area seems to be high. However, obtained grade of Al_2O_3 less than 40% in the area is rather low compared with general average grade of currently operating mine elsewhere, being more than Al_2O_3 40%. For assessing the potentiality of bauxite deposit of the area, it is necessary to extract sub-areas with more

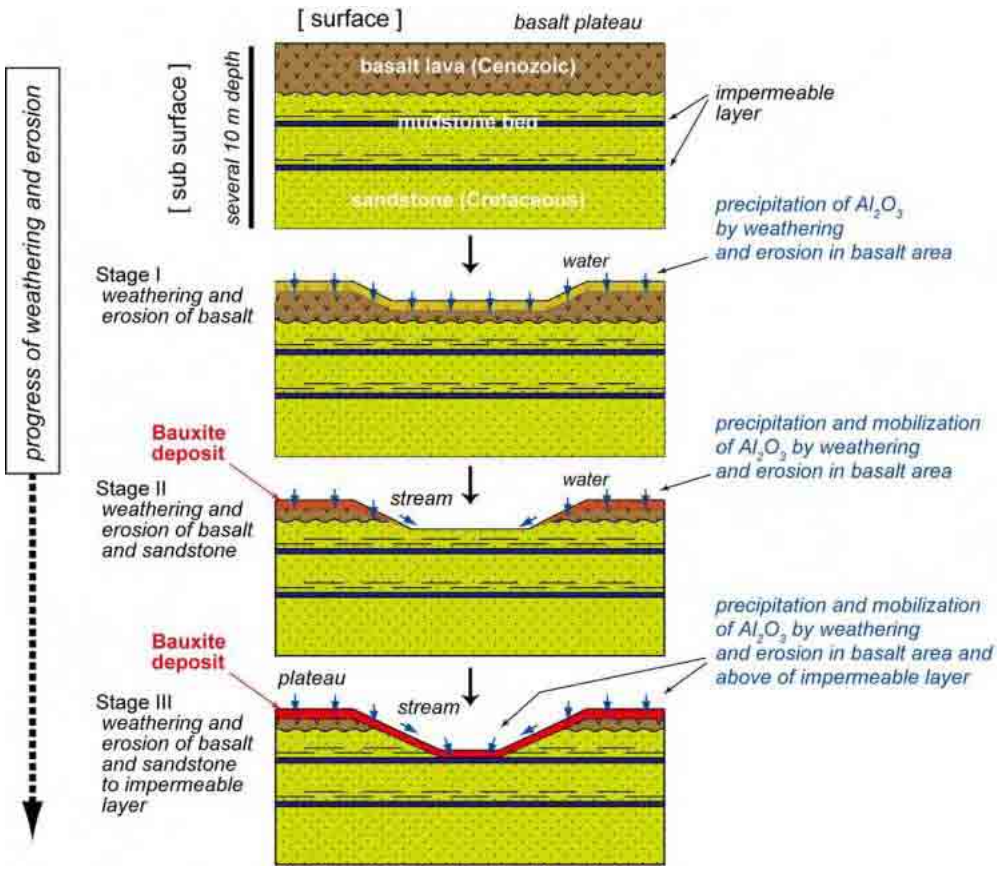


Figure 4.8.6 Cross section with ore formation model (Bolaven Area)

Table 4.8.3 Bauxite and REE mineralization of Bolaven Area

		Bolaven Area
Mineral	**Ore**	gibsite, goethite
	Gangue	opal
Occurrences		weathered soil near surface
Alteration		kaolin (weathering)
Host rock		basalt, sandstone
Related rock		alkali basalt
Ore grade		33.10% Al_2O_3, 37.90% Fe_2O_3, 939ppm REE for a bauxite.
Mineralization type		weathering residual near surface

high concentration of Al_2O_3. For this purpose, it is necessary to conduct detail survey for understanding distribution of Al_2O_3 concentration in the area.

The total REE in the lateritic soil of the area is rather high, reaching more or less 1,000ppm. Particularly, total REE concentration of the clay layer between lateritic soil and host rock is high exceeding 2,500ppm. Among the REE, LREE, such as Ce, Nd, La, is higher, warranting further detail survey in the area. Detail geological survey (route survey and trenching) and drilling survey are recommended for understanding ore reserves of the area. For considering possible mine operation in the area, an efficient extracting methods of the REE must be considered in addition to confirmation of enough ore reserves.

CHAPTER 5 TECHNICAL TRANSFER IN GEOLOGICAL SURVEY

5.1 Introduction

The important point in technical transfer on geological mapping for the geologists of DGEO is to enable them to acquire technological strength and knowledge required for ongoing geological mapping at scale 1:200,000 and mineral resources assessments and to carry out the same work by themselves.

Basic technological strength comes from geological classification. The field survey provides them with opportunities for their experiences to geologically classify every occurrence in the actual site selected for the mapping. On the other hand, mapping and mineral resources interpretation needs for knowledge about geology and ore genesis in the area.

We found that DGEO's geologists who have experience in overseas studying and/or training have acquired technology and knowledge enough for mapping and mineral resources interpretation during the preliminary field survey for the mapping area selected. On the other hand, the others have not even for mapping by their own, although they have high motivation for acquiring general knowledge on exploration and mining and technology for field survey.

Based on the above, we held workshop on basic knowledge necessary for mapping and mineral resources interpretation prior to the second survey. We intended to enable them to strengthen their knowledge on geology and mineral deposit so that we would smoothly carry out actual work in the site.

Photo 5.1.1 Drawing of geological map by C/P

Photo 5.1.2 Identification of rock samples

5.2 Progress of Technical Transfer and Present Skill Level

Through the geological surveys until the 6th field survey, basic understanding and practice on geological mapping and mineral survey of DGEO's geologists have been increased steadily by OJT. Counterparts' level of geological survey has been improved and they have come to recognize importance of field data acquisition on geology and mineralization at outcrops. Their motivation has increased during the geological survey in this project. We can evaluate that they have grown up so that they can draw geological maps by themselves under the supervisor or in a small area.

Most of DGEO's geologists, who have already got higher level capacity, are older than 40 years. They have experience of studying abroad with scholarship in foreign countries such as old Soviet Union, Eastern Europe, Vietnam etc. Academic career of younger geologists are limited to graduates from technical school. Most of the young geologists, who count for more than half of the total number of staff, are less experienced in geological survey, mineral exploration and interpretation work. Budget of DGEO for geological survey and the mineral exploration is limited. Apart from manpower, necessary materials and vehicles for field survey are not equipped in DGEO. Consequently, field activities of DGEO are concentrated and connected to occasion of joint surveys together with foreign countries or limited to supportive activities associated with such project.

Hereafter, geologists of DGEO will come to examine and evaluate survey reports submitted by concession holders and mining companies. While they need relevant knowledge of geology and metallogeny and ability of geological survey work to fullfil these tasks, it is important assignment to secure geologist and to encourage geologist.

As mentioned, the present technology can be summarized as follows;

1) The basic technique of geological survey work and mineral exploration is gradually improving.
2) They do not reach a level yet that they can carry out individually survey in a large area such as the area of 1/200,000 scale geological mapping.
3) They do not reach a level yet that they can individually do geological and metallogenyic interpretation.
4) Lack of necessary equipment for geological survey and mineral exploration and necessary materials for making thin sections and polished specimen is hindering smooth implementation of survey work.

5.3 Technical Assignment

The consciousness for geological survey and fundamental ability of the geologists in DGEO has been improved through technical transfer of geological survey until end of 6th field survey. However, it is important to increase the advanced knowledge related to drilling survey and geophysical survey, in order to conduct field survey and interpretation of survey results by DGEO individually.

It is expected that elder geologist with much experience will retire and number of younger geologist with less experience will increase in near future. Under such circumstances, it becomes important to acquire advanced knowledge of geology/metallogeny and high technology of survey/exploration for DGEO to conduct individually field survey/prospecting and make report of the survey. It is also very important to draw up an education system for settling these matters and to encourage talent in it.

Based on the items mentioned above, the assignment to the future is as follows;

1) Although the geologists of DGEO have reached a level that they can individually make geological mapping through OJT of geological mapping and mineral exploration, it is recommendable that geologists of DGEO individually carry out geological survey work in a standard area consisting of simple geology relatively easy to interpretation, for further CD of geological works.
2) If any mineral potential area is found, further mineral exploration work will follow. There are various geological works at advanced stages of exploration. As the geologists of DGEO do not have experience of geological works of latere stage of exploration, hereafter, it is necessary to expand understanding and experience of survey method adopted in each phase of mineral exploration process.
3) To improve geological survey method and mineral exploration technology, it is necessary to level up technical strength and to collect information of geology and metallogeny, through studying abroad, cooperating with foreign researchers and so on.
4) To ensure succession of technology, it is necessary to settle problem of understaffed and to train geologists and technical leader.

CHAPTER 6 GEOCHEMICAL ANALYSIS

6.1 Introduction

Geological sample analysis takes place at a division of DGEO called the Analytical Division (hereinafter referred to as the Lab). The Lab's daily activities include preparation of samples, thin section, polishing, chemical analysis, and mineral analysis. The main objective of the project is the capacity development of the Lab staff counterparts (C/P) through OJT (On the Job Training) analyzing samples that are collected in the field for the purpose of geochemical mapping.

6.2 Present Situation and Issues of the Lab

6.2.1 Human Resources

The Lab had eleven(11) staff members at the beginning of this project activity, and has recruited two more new members, and one member moved to a provincial office so that the total number of staff members is now twelve(12) (as of July 2008); the staff list is attached in Appendix 10. In the first period of the field survey, two of the Lab staff members took residence in the Sepon mine, and according to information obtained from one of the C/P, there are already one or two staff sent to Sepon mine from DGEO. The dispatched staff stays at the site for a few months in general, and they are separated from ordinary work at the Lab.

In the Lab, an Atomic Absorption Spectrophotometer (hereinafter mentioned as AAS) is mainly operated by two deputy directors to determine the metal element, and seven analysts (including two new members) are engaged in the preparation of samples, pre-treatment and wet analysis. A total of three geologists and mineralogists are on staff to cut samples, crush and make thin sections and conduct mineral analysis. Only a few of the staff are engaged solely in laboratory work since most are busy conducting fieldwork, participating in negotiations with mining companies and so on, so that few samples are analyzed compared with the number of staff.

6.2.2 Condition of Analytical Instruments and Consumables

The foremost problem is the difficulty to maintain and update instruments because of insufficient budget provisions.

The AAS is an indispensable analytical instrument for the analysis of any metal sample. During the first field survey, however, only one of the three AAS was barely operational. The Lab recognizes the importance of maintenance, but it is limited by its budget. There is no service engineer for AAS in Laos, so an engineer is usually called from a manufacturing agency in Thailand. When an instrument goes out of order, it tends to be left for long periods of time due to lack of budget. Many of the analytical instruments face the same problem and are vulnerable to break down at any time.

There are few suppliers in Laos, so generally they don't have stocks of laboratory consumables and equipment and must import these things from foreign countries when they have an order. The terms of delivery largely depends on what kind of equipment or consumable is ordered. Delivery of spare instruments takes more than a month, while common chemicals can be supplied in a week.

The scope of the Project does not include supply of equipment, however, the Project team considered it is necessary to keep the equipment working in order to conduct the minimum required analysis, and decided to request an agent to check the existing AAS. Meanwhile, the DGEO also considered the AAS problem is serious, and in October 2006 a new AAS (AA-6300) was installed in the Lab. On the other hand, the project team called a service engineer in June 2008 to perform maintenance on a furnace AAS which had been left inoperational since 2001. Now it is in working condition. Table 6.2.1 presents the condition of AAS at present.

Table 6.2.1 Present conditions of AAS

Name	Manufacturer	Condition
GBC 902	GBC	Flame-type AAS. Not working. Because model is too old, repair parts are no longer available.
GBC 902	GBC	Same model as above. In poor condition with insufficient sensitivity so that it is no longer used since installation of AA-6300.
GBC 932AA	GBC	Graphite furnace-type AAS, designed for high sensitivity analysis. Originally it was introduced for water analysis by UNDP project. The study teams examined the possibility of repair and finally fix it. Now it is in working condition.
AA-6300	Shimadzu	Flame type AAS. Installed in 2006. Only one instrument currently working for geochemical analysis

6.3 Actual Technical Transfer

6.3.1 Evaluation of Analytical Technique

The Lab has gained a certain technical level over its many years experience, but in terms of individual staff capacity, it seems to vary greatly and the quality of work is scattered. Because laboratory quality management is not sufficient, troubles were observed, such as problems identifying samples, misunderstanding dilution factor, and serious contamination caused by human error. Therefore, the strengthening of laboratory control is necessary, including quality control. The staff takes measures depending on the occasion, not to improve the overall system.

6.3.2 Items of Technical Transfer

Following the above discussion, the technical transfer was done through OJT in the Lab.

Item 1. Recovery test using SRM
Item 2. AAS analysis by high temperature burner
Item 3. Analysis of Ti, Sn and FeO
Item 4. Alkaline fusion for sample preparation
Item 5. Improvement of AAS analysis accuracy
Item 6. Determination of MDL and LOQ
Item 7. Direction of quality management

Photo 6.3.1 Analysis of FeO

Photo 6.3.2 Gold analysis by AAS-6300

Item 8. Direction of quality management

Item 9. Analysis manual

Item 10. Training of O&M for Furnace AAS

Item 11. Small seminar for laboratory members

Item 12. Documentation for management

They are gradually promoting their understanding about the importance of quality management and the actions needed for quality improvement. It is regrettable, however, that time is not allowed for these activities.

6.4 Future Task

6.4.1 Laboratory Equipment and Consumables

The Lab is always faced with tight finances and insufficient materials so that the new AAS installation was considered a special honor. However, there is still equipment in need of repair or update. The following equipments are urgently needed:

- Fume hood
- Sand bath
- Standard weight for analytical balance
- pH meter, Electric conductivity meter

A graphite furnace AAS has high sensitivity and it provides capability to measure very low concentrations, making it possible for the Lab to lower the detection limit and start the measurement of stream sediment. The project team considered the possibility that repair of the existing furnace AAS might contribute to increased Lab capacity once operations began. In the second period of the field survey, the study team identified the cause of the problem, and then, in the 8th period, the team fixed the furnace AAS so it was ready for analysis.

The most time consuming step in analysis of geological samples is digestion process, which, in the case of gold, requires more than 2 days. In the beginning, the poor capacity of digestion limited the number of samples that could be analyzed. For this reason, it was necessary to procure equipment for digestion to strengthen the analysis capacity. In 2007, a new sand bath was prepared by the project, which greatly increased the capacity of sample digestion. This fact proves that effective investments are necessary to strengthen capacity. The furnace AAS requires a relatively small sample size, such as a few ten μL for one measurement. In comparison, gold analysis by flame AAS requires 50mL. If geological sample analysis by furnace AAS was started, the Lab could reduce time needed for sample digestion, and in turn, the Lab can increase analysis capacity and also save costs.

6.4.2 Staff Capacity Development

There is no fixed training plan or evaluation system for the staff, making it difficult to know the capacity of each individual staff member. A training system should be established, which includes a gradual capacity development system with a stepwise achievement check. Still now, training for newly recruited staff members is not organized. The training is given by senior staff members as OJT through daily work. The C/P recognizes the necessity of well organized training, which can give the basic idea of the proper attitude for analysis. At present, the translation of the manuals from English to Laotian has come under consideration. If this is achieved, the manual would be an effective tool for the laboratory work.

6.4.3 Laboratory Management

It can be concluded from the above discussion that the overall management of the laboratory is lacking in stringency. For instance, the staff members display no habit of calibrating measuring tools like the mechanical pipette. Presently, they have come to understand that certain laboratory tools need to be calibrated before use. However, they tend to skip the process when a lot of work has piled up, which results in doubtful results. This very fundamental attitude is required for good practice and will require a dramatic change in the behavior of laboratory members. Therefore, the establishment of

complete management will likely require some time. Another problem is the faulty documentation measures apparent in the disorganized experimental back data and reported results, making it very difficult to find out past results. It will most likely take a long time to establish a proper document control system. In consideration of ideal laboratory conditions, there are many improvements to be made. However, the laboratory has a long established style of its own so one can expect that rapid change would be difficult. Firstly, the establishment of a common understanding of present laboratory conditions among the study team and DGEO is of pressing importance.

6.4.4 Laboratory Improvement Plan

Laboratory staff would like to start water analysis mainly targeted at mine effluent. It should first be understood that the water analysis laboratory must be separated from the rock analysis laboratory. Because, water analysis requires a very low concentration level of detection, whereas rock analysis is usually set at a far higher level of concentration, it would cause serious contamination. The water analysis laboratory is recommended to obtain new laboratory equipment such as glassware, and in addition, laboratory indoor conditions should be improved. The quality of pure water is applicable for rock analysis but not suitable for water analysis.

On the other hand, the current situation has been recognized by C/Ps through the project activities, that is, DGM cannot measure low concentration samples. To enable the analysis of lower concentration samples, it is necessary to start the operation of furnace AAS as well as instill greater accuracy management.

On the basis of the above considerations, it is recommended that DGEO should clarify the objective of laboratory operation and its function for the future. After that, the laboratory development plan will be established.

At a steering committee meeting in June 2008, it was proposed that the following issues be discussed specifically:

- What is the prospective function for the laboratory as a governmental laboratory? Is it a research laboratory for administrative direction, or a reference laboratory for quality control of mining activities, or alternatively, a study laboratory for investigation?
- What is the target material of the laboratory?

  Ore, rock, soil, sediment, discharge water from mines, environmental water, etc.
- Based on the above discussions, what is the required measurement range and analysis quality?

In response, DGEO expressed that they hoped the Lab would function as a reference laboratory and would start monitoring mine effluent. To crosscheck the quality of ore, the Lab should have the same level of ability as a private laboratory. To start water quality analysis, DGEO should start by setting the basic conditions of the laboratory room. The required level of achievement seems to be a great hurdle to clear, but DGEO hopes to make progress step-by-step. DGEO requested cost estimations for several cases with different achievement levels, so rough estimations of the cost for certain developing levels was submitted.

The management of DGEO gradually came to understand that laboratory operation requires the appropriation of a certain amount of spending, and to achieve higher quality analysis requires more investment and more manpower. Because a laboratory is a particular kind of body, it is necessary to acquire the advice of an expert to make a laboratory development plan.

Wherein, the project has proposed plans for short-term and middle- to long-term laboratory development as shown in Table 6.4.1.

Table 6.4.1 Requisite activities for development

Category	Items	Activities	
		Short-term	**Middle to long-term**
Working condition	Gas exhaust facility	Discharge capacity is improved.	Fume hood with scrubber is installed.
	Wastewater treatment	Equipment of neutralization is set.	Waste water treatment system is improved.
	Safety control	Safety tools are procured. Staff is trained about laboratory safety.	→Continue
Quality management	Budget implementation	Cost for QA/QC sample analysis is accounted.	→Continue
	Training and education	Intensive training of middle level staff members is conducted.	Institutional staff training is established.
	Standardization of procedure	SOP is prepared.	Translation of SOP to Lao language is progressed.
	Determination of detection limit	Detection limit of new parameter is determined.	Detection limit is reviewed.
	Determination of quality control standard and implementations	Tolerable limit of QA/QC sample measurement is determined and implemented.	Monitoring of Quality management activities is started.
Analysis instrument	Budget for O&M	Budget for consumables is allocated.	→Continue
		Possibility of making service contract is considered.	Instruments maintenance and updating plan is prepared and implemented.
Analysis capacity	Increase of analysis parameters	Lab can analyze platinum and palladium.	Lab can analyzes rare earth elements and others.
	Lowering detection limit	Geological sample is analyzed by furnace AAS.	Analysis procedure is reviewed and improved.
	Analysis of water quality	Water quality analysis by furnace AAS is tested.	Equipment for water quality analysis is procured.
		Designing water quality analysis room.	Consumables and standards are appropriated.
			Training of basic parameter analysis is provided to analyst.
Administrative capability	Check of Ore quality	Accuracy is improved with quality management.	→Continue
	Monitoring of mine effluent	Monitoring plan is prepared.	Staff is trained about sampling procedure.
	Administrative directive	Evaluation procedure of monitoring result is determined.	Monitoring plan is authorized and implemented.
			Monitoring report is prepared.
Human resource development	Appropriate staff assignment	Staff assignment plan is prepared.	New staff is recruited in line with the plan.
	Training and education	Training plan is prepared with assessment.	Institutional staff training is established.

CHAPTER 7 CONSTRUCTION OF GIS-BASED GEOLOGICAL AND MINERAL RESOURCES INFORMATION SYSTEM

7.1 Introduction

The regular work of Geological Information Division (GID) at DGEO is to produce GIS database (1:1,000,000 geological map, 1:200,000 geological map, Concession area map and so on.) and manage the library and the rock/mineral resource museum. In this Project, it is aimed that capacity of the C/P is further developed through technical transfer trainings focusing on understanding GIS basic theory and actual operation by using the existing data of various sources.

7.2 Present Situation and Issues at DGEO

Questionnaire and interview surveys were conducted during the first field survey regarding the following topics, in order to clarify the present situation of DGEO. The results are summarized in each section.

7.2.1 Equipment

The present condition of the hardware which the Geological Information Division (GID) possesses was confirmed focusing on the following equipment:

1) Computers

The GID currently possesses four PCs. While the memory of two of the computers is not sufficient, the CPU, hard disk and the OS satisfy the minimum requirements for running GIS software. Meanwhile, the remaining two machines have sufficient memory for creating reports and spreadsheets but they are not sufficient for running the software required for images with large volumes of data and database operation. At present, the purpose of these PCs is to use GIS software (MapInfo) to create data, output maps and create reports and ledger sheets.

Boosting the memory of the machines is an issue for utilization of the equipment that the GID currently possesses. Meanwhile, it is essential to introduce new high-end PCs for the application of advanced GIS software.

2) Plotter

A plotter which was purchased ten years ago is still being used to output A0 size sale maps. There are frequent malfunctions with parts but as they are old, it is difficult to obtain spare parts. The revenue from the sale of mining concession maps, and geological and mineral resource maps (1:1,000,000) output using this plotter, is an essential source of income for the maintenance of GIS equipment and for purchasing office supplies. In this project, securement of a new plotter is a future issue as the need for a plotter for the output of updated 1:1,000,000 geological and mineral resource maps and newly compiled 1:200,000 and 1:10,000 geological and mineral resources maps, will increase from the latter half of the second year. In this result, new plotter (HP DESIGN JET 800) was leased for the project during the 4th field survey.

7.2.2 Software

1) CAD Software

AutoCAD is the type of CAD software used, and it is applied for creation of mid to large-scale geological maps. It is not the latest version of the software and version upgrades are not conducted.

2) GIS Software

It is understood from the questionnaires that various types of GIS software are being used for various purposes. The main software used in practice is MapInfo and it is used for compiling the various mining, geological and mineralogical maps which GID sells. GID prints out maps and sells them in response to user requests, while constructing various GIS databases, creating the print layout

and updating appropriate information. MapInfo is good for data entry and conversion, and is a typical model of GIS software. At DGEO, there are also staff members who are adept at running MapInfo and a series of procedures such as, data creation, update and printing are culminated. In a discussion about the type of GIS software which should be adopted, there was a request for MapInfo not to be increased and for the introduction of GIS software instead which is adept at constructing databases and analysis. Also, the request came from the need of better data compatibility for utilizing GIS data provided by the Laos National Geographic Department (NGD) and other governmental organizations which adopt ESRI`s ArcGIS as a GIS system. The JICA study team agreed with this and DGEO consented a proposal from the study team to adopt ESRI`s ArcGIS (ArcView).

3) Database Management System

At GID there are no technicians who specialize in database management and there are only a few employees who can operate Microsoft Access. DGEO participates as a representative for Lao PDR in the Southeast Asian Network for a Geoscience Information System (SANGIS: http://203.148.160.165:8080/sdx/sangis/index.html) initiative sponsored by CIFEG（International Center for Training and Exchanges in the Geosciences）. Compilation of a bibliographic information database is required as part of the activities and Microsoft Access is primarily used for this objective.

7.3 Integrating of the Existing Data and Constructing of GIS Database

When constructing the GIS database, the existing DGEO database, which was confirmed in the first year of the survey, was taken as a base, data duplication was avoided and a standard frame was adopted to increase interoperation. Proposals are given in the World Bank's 「Sector Plan for Sustainable Development of the Mining Sector in the Lao PDR」, for evaluating and collecting existing geological and mineral resource information and for the future framework of GIS databases. An abundance of mining related information, including infrastructure information, has already been collected in this project and we have been provided with data collected by the WB in order to avoid duplicate collection. Furthermore, the Geo-science Database specifications in the World Bank project were proposed and DGEO accepted them as the specifications for their database. The results offered to DGEO were accepted and on the basis of these, the JICA study team made detailed additions and revisions in accordance with DGEO. The World Bank's output reached DGEO in late December and the JICA study team member responsible for GIS database construction/homepage release followed it up accordingly. The database specifications were formulated by the JICA study team. The points that were given attention to are finding and filling the missing items of the WB data specification, reflecting changes in the data O&M system due to DGM (Department of Geology and Mines)'s organizational changes, and formulating specifications for the data (metadata) summarizing the items related to the nature of the data, such as data source, the creating organization, creation period, depository, and the responsible party. Based on this, consultation and formulation with DGEO was performed at the fourth stage of the field survey.

Construction of a new GIS database will be carried out upon completion of the various geological and mineral resource maps output from this project. For those data, the database specifications will be in accordance with the database specifications (draft) from the consultation and formulation with DGEO.

7.4 DGEO and DOM Website

During the first and second field surveys, the MIH was reorganized as the Ministry of Energy and Mines and it was decided at the end of October 2006 that the affiliated DGM would also be divided into the Department of Geology (DGEO) overseeing geological and mining industry potential and analysis, and the Department of Mines (DOM) overseeing monitoring of mining concession, mines, and the mining environment. In fact, both departments were divided in May 2007. Following discussion with DGEO's chief staff regarding the current website, it was decided that the following plans would be advanced.

- As an interim measure, the former DGM website will be updated, and individual website will be established for DGEO and DOM, while the updated contents of the same will be utilized. As the current technician responsible for updating of web contents would be concentrated in the DGEO, there would be no technicians for website in DOM and website update and management will be overseen by DGEO.
- The IT environment within both organizations will be developed, the staff related to GIS, IT and the website will be enhanced and when the opportunity for each website to operate has increased, the website will be split to give each of them jurisdiction over the contents.
- At that time, the convenience for website users will be taken into consideration and links to the other sites will be created with easier interface.

The website will be divided from the DGM website, where information on Lao PDR geology, mineral resources and mining industry legal system and mining lots was collected in the one location, into one part only dealing with geological and mineral resource information and the other dealing with the mineral legislation, concession information and mine monitoring. In particular, from the perspective of foreign mining related investors, it is inconvenient as they will be compelled to access DGEO site for geological information and access GOM site separately for concession information. Consequently it could give an impression that the mining related organizations in Lao PDR being underdeveloped and could lead to underestimation of the mining industry potential. In the future, it is essential for both agencies to fully consider harmonized operation of a website with individual contents for each website.

7.5 Technology Transfer

Training was carried out twice during the Project corresponding to construction of GIS database. The first training in November 2006 was carried out focusing on the concept of GIS, basic operation, and handling existing data. In the second training in February 2008, the purpose was to ensure that C/P might effectively operate a GIS database which had been on the way of establishment.

Photo 7.5.1 GIS training (1/2)

Photo 7.5.2 GIS training (2/2)

7.6 Future Task

7.6.1 Application of GIS Database

Main work of the staff in charge of database at GID is data processing and output requested by DGEO, DOM and other related organizations. At present, 2 to 3 staffs are engaging these work and they are fully occupied to response those requests. The processing work is done mainly using MapInfo. As already existing data have been made by MapInfo and the engineers are much familiar with MapInfo than ArcGIS in processing and editing work, it is expected that there will be much dependence on MapInfo in future resulting in less occasion of operating ArcGIS. Although MapInfo is well-developed software, MapInfo is equipped efficient function which MapInfo cannot afford.

From now on, database should be operated by ArcGIS and by doing so various effective applications could be developed. At the first GIS technology transfer training, a detailed manual of ArcGIS operation is prepared. Consultation with this manual is sure to be great help when any question on data processing and operation on ArcGIS.

7.6.2 Training GIS Specialists

Training was carried out twice during the Project corresponding to construction of GIS database. As a result, one of the staffs was coming out as a new GIS engineer. Including the new engineer the total number of engineers who are in charge of database is limited to only three (3). As processing work of data related to geology and mines should be done within GID and diversification of daily work is expected, volume of work at GID is sure to expand. Besides, manpower is also required to update website. To cope with increasing work volume, the numbers of engineers should be increased

7.6.3 Facility to Support GIS

Mining operation and exploration project have a duty to submit reports of working results at regular intervals. These reports contain unique and valuable information for further explorations and geological works. To control accumulating reports in order and utilize effectively information contained in report at most extent, a database system is indispensable. Generation of electric data from submitted reports and upload to a database require additional manpower and enhanced GIS facility such as software, computer, data storage and input/output unit (scanner/printer).

CHAPTER 8 CO-OPERATION PROJECT BY OTHER DONORS

8.1 Introduction

Lao PDR has received a considerable amount of assistance in geology and mining field from the donor community. This has largely been related to:

- Assistance for strengthening the DGM (currently DGEO and DOM).
- Capacity development of DGM (currently DGEO and DOM) staff
- Assistance for geological mapping and mineral exploration
- Environmental management.

8.2 Geological and Mining Projects of Donors

Table 8.2.1 provides a list of major donor-funded projects undertaken in the geology and mining field since 1975, including the JICA project.

Table 8.2.1 List of projects funded by donors since 1975

Period	Donor	Project Title
Completed in 1980	Vietnam Govemment	1/200,000 Geological Mapping Project in Samnua-Khangkhay
Completed In 1981	Vietnam Govemment	Salt Prospecting at Savannakhet Sub Basin, Savannakhet Province
Completed in 1982	Vietnam Govemment	Iron Prospecting at Phou Nhuon, Xiangkhoang Province
1977-1982	VietnamG.	Gypsum Exploration at Dong Hen, Savannakhet Province
Completed in 1985	Vietnam Govemment	Coal Prospecting at Chakeui-Kaleum, Saravan Province
Completed in 1986	Vietnam Govemment	Coarse Sand Prospecting at Ylay, Vientiane Capital
1982-1986	VietnamG.	Potash Prospecting at Tha Ngon Area, Vientiane Capital
Completed in 1987	Vietnam Govemment	1/200,000 Geological Mapping Project in Vientiane-Ban Keun
Completed in 1991	Vietnam Govemment	1/1,000,000 Geological Mapping Project over Indochina
1989-1992	UNDP	LAO/88/023, Strengthening the Department of Geology and Mines.
1993-1997	UNDP	LAO/93/005, Mineral Sector Development.
1994-1999	VietnamG.	1/2 00,000 Geological Mapping Project in MiddlePart of Lao
1997-2000	UNDP	LAO/97/019, Environmental Management of Mineral Resources.
2002-2005	VietnamG.	Nong Lom Potash Procpecting in Khammouane Province
2002-2007	VietnamG.	1/2 00,000 Geological Mapping Project in Northern Part of Lao
2004- on-going	Thailand G.	Collaborate Project between DGM and DMR
2005- on-going	VietnamG.	1/2 00,000 Geological Mapping Project in Southern Part of Lao
2006	WB	Sector Plan for Sustainable Development of the Mining Sector in the Lao PDR
2006-2008	JICA	The Geological Mapping and Mineral Information Service Project for Promotion of Mining Industry in the Lao PDR

8.3 The Need for Co-operation Project

While enhancement of mining sector and preparation of basic data of geology and mineral resources had been supported by various international assistance donors, present situation is still far from satisfaction due to the limitation of both financial and human resources at DGEO and DOM. Especially, Capacity Development is one of the key issues and the government of Lao PDR has been requesting continued support to these issues.

CHAPTER 9 SEMINAR AND WORKSHOP

9.1 Presentation at International Seminar (PDAC)

During the 7th Survey, a presentation was made to introduce mineral potential and Project activity at the occasion of PDAC held in Toronto, Canada, from 2 to 5 of March, 2008. Materials such as pamphlet and poster used for the presentation were prepared jointly with C/Ps during the 6th Survey.

The PDAC seminar is held every year on regular base in the first week of March in Toronto. PDAC consist of two main activities, namely, Trade Show and Investor Show. Trade show is an exhibition attended by organizations of mineral exploration, exploration consultant companies, survey instrument companies and analysis service companies and etc,. Investor show is attended by mining companies and exploration companies. The Project attended Investor Show and set a booth to introduce mining climate and mineral resources potential of Lao PDR to promote investment from overseas to Lao PDR.

The total number of attendant of the PDAC was announced to be more than 20,000 much more than the last year. A lot of attendant visited the presentation at the booth of Lao PDR and made a series of question on mineral potential, mining law, status of database of geology and how to access to information.The back grounds of the visitors to Lao PDR booth are Chinese (almost half), then, Australians and Canadians of exploration companies.

Attending international seminar like PDAC was very fruitful as mineral potential of Lao PDR was appealed widely, C/P studied situations of mining and exploration of various countries, and had a chance to exchange information with mining people. Other organizations attended the PDAC were demonstrating voluminous basic date far well organized than Lao PDR impressing that Lao PDR should make hurry in preparation of basic data.

9.2 Workshop

A workshop was held jointly with C/P in Vientiane on August 6, 2008 during the eighth Survey. At the workshop presentations were made on the achievement of preparation of information which is one of the main purposes of the Project, C/D activity during the process of preparation of information and recommendations of institutional enhancement of DGEO and DOM exchanging opinions among the attendant.

Photo 9.1.1 Lao PDR booth at PDAC

Photo9.1.2 Workshop in Vientiane

CHAPTER 10 CONCLUSION AND RECOMMENDATION

10.1 Conclusion

The results of the survey are summarized as shown below;

(1) **Field geological survey:** Field geological survey was carried out in cooperation with Laotian counterpart in Attapeu area of southern Laos. So far there was no organized regional survey. Geological setting such as geological formation, characters of rocks, age, structure, mineralisation and etc., have been clarified by the survey. A mineralization of gold and copper was detected by geochemical survey of stream sediment sampling took place at the same time.

(2) **Detailed survey:** A detailed joint survey was carried out over promising area detected by geochemical survey said above. Several promising gold and copper indications were newly discovered by the detailed field survey. Some of these indications suggest porphyry copper type mineralization revealing distinct mineral resources potential in the area.

(3) **Mineral Information service:** Two sheets of geological and mineral resources map of 1:200,000 scale were generated and one sheet of geological and mineral resources map of 1:1,000,000 scale was revised as a part of preparation of information of geology and mineral resource data to promote investment from foreign companies to Laotian mining sector. To provide information to potential investors GIS database was enhanced and website was reconstructed with newly obtained data through the Project.

(4) **Mineral Information service:** By the request of counterparts, the Project adopted ArcGIS for construction of database to allow flexibility to utilize data prepared by other organizations and analysis capability although the Geological Information Division had been developing a database depend on MapInfo. Existing MapInfo data has been converted into ArcGIS data.

(5) **Mineral Information service:** During the term of the Project, the Department of Geology and Mines was reorganized to be consisting of two departments, namely Department of Geology and Department of Mines. According to this change the website was revised and contents were reviewed and substituted by newly obtained data to provide information targeting to potential investors.

(6) **Technical Transfer of geological survey skill:** In the course of mapping of 1:200,000 scale, the survey team and counterparts cooperated in the area of Attapeu during geological and geochemical field survey. A series of technical guidance and technical transfer are also took place during the field work aiming to enhance capacity of the counterpart staff. As a result, level of awareness as well as capability concerning geological survey had been improved among geologists of DGEO.

(7) **Technical Transfer of GIS:** So that counterparts may master operation of ArcGIS, training was provided twice during the Project. Although understanding of basic part was attained thanks to this training, further study by self-training is needed for advanced processing and analytical function

(8) **Technical Transfer of chemical analysis:** During the Project, analysis of ore samples by Atomic Absorption Spectrometer was conducted and thin section for rock observation and polish specimen for ore samples are produced at the Laboratory of DGEO.

(9) **Issues of chemical analysis:** Input of equipment, materials and technical staffs (increase number of staffs and training or new recruitment) is necessary to improve quality, accuracy and efficiency of chemical analysis. To secure necessary budget, a policy of management of lab and middle to long term plan should be established.

(10) **Overall achievement and future issues:** Enhancement of information and capacity development are expected two main purpose of the Project. Here the survey team and Laotian counterpart proudly share the opinion that each purpose has been realized more than expectations held at the beginning of the Project. Basic policy that every item should be done following joint work basis has been maintained through out the Project. This basic policy cultivated mutual understanding between the survey team and Laotian counterparts and led to the great success of the Project. However, enhancement of information transmission and capacity development can be accomplished only by further day-to-day effort of counterparts as well as long run support to them.

10.2 Recommendation

The Department of Geology and the Department of Mines are requested to fulfil function as a center of mining of Lao PDR further improving conditions necessary for promotion of mining investment and mining sector can be a driving force of national economic development of Lao PDR. Expecting to contribute super goal of the Project, recommendation are given below;

(1) After reorganization of the Department of Geology and Mines, two Departments were established with enhanced function to provide service for Mines and Geology separately. From now on each Department should make effort to improve internally. ⇒ **Institutional Enhancement**

(2) Neither present manpower nor present facilities of the departments are enough to provide essential service which is expected to be given by governmental organization of mining/geology. Improvement of those insufficiencies is the most urgent matter. ⇒ **Organizational/Functional Enhancement**

(3) Two offices, namely, Vientiane main office and Pakse local office are established. But these two offices cannot afford to control mining and exploration activities over whole territory of Lao PDR. Additional two local offices should be newly established to cover northern and central areas. These new local offices should be a branch of both departments of Geology and Mines. It is also important to build up a closer connection with Department of Energy and Mines of local goverments.

⇒ **Organizational/Functional Enhancement**

(4) To guarantee a policy that mining concession should be issued to proper applicant such as experienced mining companies and exploration companies, it is necessary to provide them proper, sufficient and high quality information of geology and mineral resources. It is also important to prepare and publish useful information attained by the survey carried out by the Department itself. To realize this function, enhance a section of geological survey/mineral exploration and set up field survey team as well as securing budget necessary for survey project.

⇒ **Survey as DGEO's own project**

(5) Implementation of internal survey/exploration project is essential for propagation/succession of technology, training of specialists and interaction with foreign organizations.

⇒ **Training of engineers through survey activities of DGEO's own project**

(6) As work reports (defined in mining law as an obligation of concession holder) is very useful information for future exploration, get reports secured and keep these information in database. Enhance manpower and facility of Geology Information Division so that all of the results of geological survey and exploration may be accumulated in GIS database.

⇒ **Enhance Mineral information service**

(7) Analytical Division, present and in near future, should work as a reference lab for rock/mineral analysis and also providing analysis service of mine waste water for environmental monitoring. To carry out these functions, additional improvement of working condition, new investment for facility, enhance quality control by capacity development of staffs and maintenance of analytical equipment are needed. ⇒ **Enhance facility of Chemical Analysis Center**

(8) Although technical levels have been upgraded over various fields comparing to the beginning savage of the Project, capacity development should be continued by inviting specialists from outside for training and sending staffs to overseas training and studying. ⇒ **Training of staffs**

(9) To accelerate capacity development, innovation of facility and preparation of information of geology/mineral resources, pursue occasions of joint project with foreign organizations same as this Project. ⇒ **By involvement of joint projects with foreign organizations**

Recommendations above are summarized in Table 10.2.1.

Table 10.2.1 Recommendation for Reinforcement of DGEO and DOM

Major items		Countermeasure, Plan			Expected result
		2009～2010	2010～2015	2016～2020	
Expansion of manpower (professional staffs)	DGEO	7 person (Geologist :4, GIS:1, Analysis: 2)	10 person (Geologist: 7, GIS: 2, Analysis: 1)	10 person (Geologist: 7, GIS: 1, Analysis: 2)	Institutional Enhancement
	DOM	4 person (Mining: 2, Geologist: 1, Environment: 1)	6 person (Mining: 3, Geologist: 2, Environment: 1)	6 person (Mining: 3, Geologist: 1, Environment: 2)	
Enforcement of facilities	Tools and instruments for field survey	Tools and instruments for field geological works, exploration of mineral resources and ground measurement		Tools and instruments for field geological works, exploration of mineral resources and ground measurement	Reinforcement of facility and function
	Software and hardware of IT	Additional GIS software license (3 licensees), introduction of LAN in Department and additional introduction of PC and peripheral items.		Additional GIS software license (2 licensees), and additional introduction of PC with peripheral items.	
	Chemical analysis instruments	Improvement of the laboratory, secure of maintenance of instruments, complete maintenance of instruments, exhaustiveness of spare parts and consumables, keep peripheral instruments for mine drag water analysis.		Establish an exclusive lab and introduce exclusive materials for water quality analysis	
Training of staffs	Junior figures	By involvement of joint projects with foreign organizations and training given by invited specialists from foreign countries			Organizational/Functional Enhancement
	Core figures	Addition to the above, by training or studying abroad, especially for core figures of the Departments.			
Branch office	Monitoring of mining activity Monitoring of environment	Establish a branch office in then northern area (for example at Luang Phabang)		Establish a branch office in the Central area (for example at Savannakhet)	Enhanced organizational function of inspection of mines and information of mining activity
Mineral information service/training of engineers	1/200,00 Geological Map 1/50,000 Geological Map	Complete 1/200,00 Geological Map sheets of whole territory (By joint projects with foreign countries)		Carry out 1/50,000 Geological Map sheets project (By joint projects with foreign countries)	Mineral information service for investment promotion in mining
Mineral information service/training of engineers	Preliminary exploration work over promising area	Exploration work over (By joint projects with foreign countries) areas by the initiative of DGEO (By joint projects with foreign countries)		Establish national scheme of basic survey over promising areas by DGEO's own project	Mineral information service for investment promotion in mining