

**Ministry of Industry and Handicraft
Department of Geology and Mines**

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DEVELOPMENT PLAN OF GEOLOGY – MINES SECTOR DURING 2001 – 2010 AND TO 2020

I. Implementation of 1996 – 2000 Development Plan of Geology – Mines Sector

1. Geological Survey, Mineral Prospection, Exploration and Exploitation

Geological and mineral reconnaissance survey has been carried out in some areas of Lao PDR. Thus enabling to know about the structural geology of the country and discover over 500 mineral occurrences. Over 50 of these occurrences were selected for undertaking exploration and reserve estimation. However, information collected is not enough for evaluating the mineral potential of the country. Status of geological and mineral investigation is as following:

Up to date, geological survey and mineral reconnaissance survey at scale 1:1000000 have been conducted over the whole country. 1:200000 systematic mapping covers Samneua, Xiengkhouang, Vientiane, Bolikhamxay and Khammouan province totaling 51,972 square kilometers (equivalent to 21.95 % of the whole area of the country). Mineral prospection and exploration at scale of 1:50000 have been performed in some locations such as in Sepon, Sanakham, along river - banks of northern part.

Up to 2000, detailed exploration has been conducted for over 20 mineral types – over 50 mineral deposits (see Table 1). 10 of these deposits have been mined for use for instance coal, tin, gemstone, limestone for cement, clay for cement manufacture, barite, gypsum, zinc, phosphorites, peat, halite, construction materials, ornamental rocks, etc.

Investment in mineral prospection, exploration and mining: Up to 2000, local and foreign investors have been permitted to conduct mineral business. 27 of 110 projects have been cancelled, of which 3 Oil and Natural Gas Exploration Companies (Enterprise Oil, Hunt Oil and Monument Oil Company), 2 Gold Exploration Companies (Newmont Viengkham having license area in Sanakham – Paklay and MMC Company authorized to conduct gold exploration in Xiengkhouang – Samneua) and 1 Gemstone Company.

2. Local and External Market

Mineral products that have been exported are: lignite (200,000 tons per year), tin (650 tons per year), gypsum (200,000 tons per year), barite (5,500 tons per year), sapphire, ornamental rocks, etc.

Mineral products that have been sale in the country are: gypsum, limestone, clay, anthracite for cement manufacture, peat and phosphorites for fertilizer manufacture, ornamental rocks and halite.

3. Investment in the Geology – Mines Sector

3.1. Public Investment

Public investment in the geology – mines sector in the period 1996 – 2000 amounted to 4.19 billion kips and 1.06 million US Dollars, of which 1.06 million US Dollars was grant aid from the United Nations. This investment is mostly used in the geological and mineral survey, in the strengthening of the sector and in staff training.

3.2. Investment of State Enterprises and Private Companies

Investment value in the mineral prospection, exploration and exploitation in the past years (registered capital) amounted to 16.15 billion kips, 125 million bath and 74.35 million US Dollars. Mineral product value in 1996 – 2000 amounted to 168.54 billion kips.

4. Characteristics, Potential and Limitations of Development

4.1. Characteristics and Potential

Lao PDR is a landlocked country and mostly covers by mountains and dense forest. Infrastructure is little developed, therefore geological survey and mineral development is difficult and expensive. High investment, long period, appropriate survey equipments / vehicles and high technology are needed for geological survey and mineral development in Lao PDR.

Geology – Mines sector is a small sector that comprises a small quantity of staff and equipments. Besides a limited budget has been allocated to the sector.

Lao PDR is located in between many geological structures endowed with minerals. In reality, many mineral occurrences and deposits are found in each structure.

Geological survey and mineral exploration cover 21.95 % of the whole area of the country. Over 500 mineral occurrences and mines were discovered. Mineral prospection and exploration showed that some mineral deposits have quite large reserves. Those that can be classified as medium and large deposits are for instance: potash, halite, and gold deposit. Many mineral types present in Lao PDR are needed for consumption in neighboring countries.

4.2. Limitations

Lao PDR has mineral potential however it could not be intensively exploited yet for mineral industry due to following limitations:

- Mineral industry is not yet classified, as priority in the development goal, in consequence there is only low investment in the mineral sector.
- Basic available geological data are not enough for attracting investment
- No good infrastructure (transportation, telecommunication, electricity and others) strains mineral investment
- Although mineral law is officially enacted, regulations on implementing of this law are not yet approved.
- There are some problems in custom policy on mining activities
- Market for mineral product sale is not large.

II. 2001 – 2010 to 2020 Mineral Industry Development Plan

1. Development Goal

- To know and evaluate principal mineral potential in the whole country, develop appropriate mineral deposits in each period.
- To strengthen monitoring institution for mineral investment and promote investment in prospection, exploration, mining and processing minerals that are economic for local use and for export.

2. Development Objectives

- Conduct geological survey and mineral exploration at scale 1:200000 in the northern, middle and southern part of the country. Areas to be necessarily surveyed amounted to 155,000 square kilometers. Get basic geological and mineral data for mineral industry development before 2010. In 2001 – 2005, complete geological investigation for 100,000 square kilometers and exploration of some minerals at scale of 1:50000.
- Explore and evaluate selected mineral deposits that are potential and have economic importance in each period, in particularly minerals needed for local production (metallurgy, cement plant, bio-fertilizer factory, construction materials, power plant, etc.) and for export. Increase mineral reserve estimation at 7 % in 2001 – 2005 and > 9 % in 2006 – 2010.
- Monitor mineral activities and promote production of minerals such as metals, fuel minerals, industrial rocks, etc. Mineral production should be quantitatively and qualitatively increased at about 15 % in 2001 – 2005 and > 15 % after 2005.

3. 2001 – 2005 Development Plan

- Attract local and foreign investment in the mineral sector in compliance with Lao law and guarantee the benefit of Lao PDR.
- The Government should invest in the geological survey and mineral exploration at 1:200000 scale valued at 10,850,000 US Dollars. 7,000,000 US Dollars have to be invested in this project in 2001 – 2005.
- The Government should invest 500 million kips per year in prospection and exploration of minerals that are easily to be mined such as phosphorites, peat, construction materials, ornamental rocks, etc.
- Increase investment in staff capacity building

3.1. 2001 – 2005 Mineral Mining Plan

- Coal mining (lignite and anthracite): in Louangnamtha, Sayabouly, Xiengkhouang, Vientiane and Saravan province for local use and export (3,750,000 tons)

- Tin mining: in Khammouan province for export (5,000 tons)
- Zinc mining: in Vientiane and Oudomxay province (34,250 tons)
- Gold mining: in Sepon, Savannakhet and Louangphrabang province (15.56 tons)
- Copper mining: in Sepon, Savannakhet province (120,750 tons)
- Gypsum mining: in Savannakhet and Khammouan province for local use and export (2,800,000 tons)
- Barite mining: in Vientiane for export (51,050 tons)
- Sapphire mining: in Bokeo province (7,350,000 carats)
- Mining of limestone for cement production: in Vientiane, Khammouan and Saravan province (> 2,000,000 tons)
- Mining of construction and ornamental rocks, sand: in southern, central and northern provinces
- Clay mining: for cement, pottery and brick production.
- Peat mining: 200,000 tons for fertilizer production in Attapeu, Champassack, Savannakhet, Khammouan province and Vientiane Prefecture
- Phosphorites Mining: > 52,000 tons in Savannakhet, Khammouan, Bolikhamxay and Vientiane province
- Potash Mining: about 30,000 tons in Vientiane Prefecture for local use and export
- Salt Mining (Halite): > 100,000 tons for consumption and use in food processing industry
- Rock quarrying: 3,250,000 cubic meters for construction
- Sand exploitation: 2,390,000 cubic meters for construction.

3.2. Projects to be implemented in 2001 – 2005

To meet governmental goals and objectives, work should be divided into following activity group:

- a. Group of geological and mineral survey activity
- b. Group of promotion activities of geological and mineral sector
- c. Group of mining concession management activity

Projects to be implemented are:

1/ Project of geological and mineral mapping of North Laos at scale 1:200000:

Mapping area of the project covers about 100,000 square kilometers. Expected budget allocated to this project amounts to 56,000,000, 000 kips equivalent to 7,000,000 US Dollars (1USD = 8,000 kips)

2/ Project on mineral exploration:

This project is responsible for exploring minerals that are needed in short and long term. 15 mineral occurrences should be explored. Expected budget allocated to the project is 4,200,000,000 kips equivalent to 525,000 USD.

3/ Project on mining concession management:

This project has duties to control and promote mining activities and establish regulations on running mining activities. Needed budget for 2001 – 2005 amounts to 1,300,000,000 kips equivalent to 160,000 USD.

4/ Project on promotion of geological and mineral activities:

Major duties of the project are to promote the DGM - archive library, the geological and mineral museum, the mineral laboratory and the remote sensing unit. Besides, this project is expected to receive assistance on staff training by UNDP (150,000 USD).

5. Project on promotion of mining activities:

This project will be focused on staff capacity building and may be invested by private companies.

4. 2006 – 2010 Development Plan

4.1. Work on geological prospection and survey and mineral exploration

- Continue to implement the project on geological mapping of North Laos at scale of 1:200000.
- Continue to carry out mineral reconnaissance survey for attracting investment in the mineral sector. Minerals to be prospected include gold, lead, zinc, tin, antimony, manganese, copper, etc.

4.2. Mineral Mining

Principal mining are as following:

- Coal mining: > 1,000,000 tons per year
- Gold mining: 3.5 tons per year

- Copper mining: 40,000 tons per year
- Potash mining: 1,000,000 tons per year

5. 2010 – 2020 Vision

- Increase mineral industry at 18 – 19 % per year, compared to 2001- 2010

III. Major duties to be implemented

- Establish regulations on implementing the Mineral Law
- Increase capacity on consideration of investment permit, control and monitor mining activities, in particularly consideration in accordance to staff recommendations.
- Agreement between investor and Government should be signed. It should be mentioned in the Agreement about the monitoring central and local agencies.
- Define duties and functions of central and local monitoring agencies.
- Increase public investment in basic geological survey through foreign loan or grant aid.
- Establish facilities for local and foreign institutions in mineral development participation.
- Focus on improvement of infrastructure in particularly human resources development.
- Increase the cooperation with international agencies for getting financial, technical and technological assistance in development.

Vientiane, 28 April 2001

Director General

Department of Geology and Mines

Table: Mineral Deposits and Reserves investigated up to 2000

No.	Commodity	Unit	Deposit Quantity	Reserves
1	Iron	Tons	3	57,666,420
2	Tin	Tons	3	29,600,000
3	Zinc	Tons	1	71,000
4	Copper	Tons	1	1,000,000
5	Manganese	Tons	1	300,000
6	Sapphire	Carats	1	32,300,000
7	Gold	Tons	2	100
8	Pyrite / Marcasite	Tons	1	701,065
9	Gypsum	Tons	2	34,700,000
10	Limestone for cement	Tons	5	2,205,800,000
11	Clay for bricks	Cubic meters		70,621,000
12	Ornamental rocks	Cubic meters	3	5,000,000
13	Barite	Tons	4	401,815
14	Glass sand	Tons	1	7,989,000
15	Salt (Halite)	Tons	8	20,000,000,000
16	Potash salt	Tons	1	51,000,000,000
17	Phosphorites	Tons	3	550,000
18	Peat	Tons	3	1,500,000
19	Lignite and Anthracite	Tons	7	655,000,000
20	Magnesium salt	Tons	1	10,700,000,000

GEOLOGY AND MINERALS OF LAO PDR

By: Chansone SENBOUTALATH, Bounthin SOUVANNOUDOM

I. INTRODUCTION

The aim of this paper is to explain about the structural setting, the tectono - stratigraphic evolution and the related metallogeny of Lao PDR.

Tectonic map and geological structure were summarized from information collected by many geologists and in accordance to comparison of field survey.

The tectonostratigraphic evolution was gained from interpretation of geological structure and tectonic system, dating analysis of different rocks and investigation results from many geologists like Fontaine, Saurin, Fromaget, Hoffet, Metcalfe, Bonapus, Hatchitson, Gatinsky, Garwin, Bakulin, Burke, Workman, B. Vongdara, Cooper, Stockes, etc. Mineral map is summarized from data reported by Lao and foreign geologists (Vietnamese, French, Soviet) and by public projects as well as companies investing in Lao PDR.

Although all information in this paper are general, they may help in defining strategy of mineral industry development in accordance with mineral deposits of which each province has different potential.

In the future, if more budget, staff and conditions are available to systematically undertake more geological prospect ion and exploration, it is estimated that some minerals deposits with economic importance would be found in Lao PDR. Those deposits will then be exploited for using in the country development and for generating more national revenue.

2. GEOLOGICAL STRUCTURE

Lao PDR is a country lying in the geological structure subjected to complex evolution and important tectonic movement. Most part of the country has geological fold belts covering the eastern and northern site. Only the central and southern part along the Lao – Thai and Lao – Kampuchea border are plains.

Most part of the country is lying in Indochina plate that is in contact with South China by Nam Ma suture in the north east and with Thailand by Nan – Louangnamtha suture in the north - west.

Geological structure is composed of 4 fold belts and one intermediate massif separated from each other by deep crustal structure and suture as following:

Fold Belts

Chongsong Fold Belt:

It is elongated along the eastern part of the country covering Houaphan, Xiengkhouang, Special zone, Bolikhamxay, Khammouan and Savannakhet province and considered as Hercinian fold belt having NW direction. This fold belt comprises anticlines and ... separated from each other by deep crustal structure. Large anticlines are present in Sepon, Hinboune, Phoukham, Nape, Phonsavanh, Phou Loei, Nam Kiene – Nam Mouan, Samtay and Samneua. Large fractures parallel to the fold belt are: Chongsong, Namtheun, Phonsavanh – Nam Mo and Nam Khao – Nam Neun fracture.

Paklay – Louangnamtha Fold Belt:

It is scattered in the northern and north – western part of the country covering Vientiane, Sayaboury, Louangphrabang, Oudomxay and Phongsaly province, and considered as Indosinian fold belt having N-NE direction. This fold belt is composed of large Triassic anticlines such as Centery, Paklay, Nadokmai, Natoung, Louangphrabang, Nam Nga, Nam Bak, Muong Khoua, Phongsaly and large fractures are those of Paklay, Nam Ou, Nam Med and Century.

Louangnamtha Fold Belt:

It is present in the north - west of the country and considered as Indosinian fold belt covering Bokeo and Louangnamtha province. Geological anticlines found along this fold belt are: Pakbeng, Louangnamtha and Tonpheung anticline. Large fractures are those of Nam Tha, Bokeo and Tonpheung.

Xiengriap – Attapeu Fold Belt:

This fold belt is lying in the far southern part of the country and considered as Indosinian having NW-N direction and covering Attapeu and Xekong province. It comprises Attapeu anticline and large fracture having NS direction.

Indochina Plate

It is a plate covering southwestern part of Mid-region and southern part of South-region of Lao PDR. This plate is composed of 4 Mesozoic basins: Vientiane Basin, Nam Theun Basin, Savannakhet Basin and Champassack Basin.

3. TECTONOSTRATIGRAPHIC EVOLUTION

In accordance to different information, it is known that Lao PDR region was subjected to tectonic evolution and sedimentation from Middle Paleozoic time, where rifting between South China Plate and Indochina plate occurred. The rifting between Indochina plate and Sanxay plate might occur in Upper Paleozoic period.

Due to vertical and horizontal movement of tectonic system, earth surface was subjected to changes, subduction, etc. in Permian – Lower Triassic time. After that, the 3 plates moved towards each other and collided in Triassic period originating fold belts and fractures at different scale.

After collision, rifting occurred and leads to Upper to Middle Triassic fractures. In consequence, anticline changed to horst and syncline to graben. Magmatic rocks originated in this period are rocks having high content in basic minerals. In Upper Jurassic period, incipient rifting occurred along the border of Indochina plate originating volcanic rocks along border fractures.

In Jurassic and Cretaceous time, at low level of Indochina plate and..... between Indochina plate and Sanxay plate occurred shallow sea and sedimentation. In Upper Jurassic time occurred ...rifting and in Middle Cretaceous time incipient rifting occurred again. Outcrops of rhyolite and granite show the evidence.

In Neogene period, incipient rifting and sedimentation occurred leading to coal deposit.

4. Metallogenic Belt in Lao PDR

Metallogenic belt is mostly distributed along geological fold belt; however some copper minerals and natural gas are mostly found at basin bed of Indochina plate.

Gold-copper metallogenic belt is distributed along geological fold belt, around anticlines in nearly all provinces of the country. Lead and zinc are mostly distributed along calcareous mountains. Tin is scattered in Jurassic and Cretaceous granite in the middle and northern part of the country. Iron is mostly found at contact of Carboniferous granite and Devonian limestone (for example in Xiengkhouang province). Sapphire and ruby are distributed along area comprising Precambrian / Cambrian rocks and basic basalt. Anthracite is distributed in Carboniferous and Permian rocks. Limestone is found in the middle and northern part of the country, in Saravan and Attapeu province (North Laos) where there are only small outcrops of Mesozoic rocks. Lignite is distributed in intramountainous basins of northern provinces, Louangnamtha and Chongsong fold belts. Peat is found in....lakes.

5. DISCOVERED MINERALS AND TO BE DEVELOPED IN EACH COUNTRY

Phongsaly province:

Phongsaly province is lying in the area of Louangphrabang fold belt cut by NamOu fracture. Found minerals are copper, lead-zinc barite, salt and coal. Minerals that should be developed are copper, lead-zinc, barite, salt and coal.

Louangnamtha province:

Louangnamtha province is lying in the area of Louangnamtha fold belt cut by NamTha fracture. Found minerals are lignite, peat, antimony, salt, gold, copper, iron, thermal water and industrial minerals. Minerals that should be developed are coal, gold and salt.

Bokeo province:

Bokeo province is lying in the area of Louangnamtha fold belt cut by Bokeo and NamTha fracture. Found minerals are gold, sapphire, manganese and thermal water. Minerals that should be developed are sapphire, manganese and gold.

Oudomxay province:

Oudomxay province is lying in the area of Louangphrabang fold belt and having mineral potential. Found minerals are gold, copper, lignite, salt, tin, lead-zinc, iron, thermal water, industrial minerals and other minerals related to ophiolite outcropping along the suture such as cobalt, nickel, chromium, platinum and asbestos. Minerals that should be developed are copper, lead-zinc, coal, salt, gold, iron and industrial rocks. Reconnaissance survey should be undertaken for minerals related to ophiolite.

Louangphrabang Province:

Louangphrabang province is lying in the area of Louangphrabang fold belt cut by NamOu and NamMed fracture. Found minerals are gold, copper, coal, lead-zinc, tin and industrial minerals / rocks. Minerals that should be developed are gold, lead-zinc, copper, coal and industrial minerals / rocks.

Sayaboury Province:

Sayaboury province is lying in the area of Louangphrabang fold belt cut by NamOu fracture. Found minerals are lignite, gold, copper, manganese and salt. Minerals that should be developed are coal, gold, manganese and salt.

Vientiane Province:

Vientiane Province is lying in the area of Louangphrabang fold belt cut by NamOu, NamMed and Century fracture, and having quite high mineral potential. Found minerals are gold, copper, iron, lead-zinc, tin, manganese, anthracite, barite, phosphorites, salt, industrial minerals / rocks and natural gas. Minerals that should be developed are coal, salt, zinc, gold, barite, phosphorites, copper and industrial minerals / rocks.

Xiengkhouang Province:

Xiengkhouang province is lying in the area of Chongsong fold belt cut by Chongsong, NamXan and NamMo fracture, and having highest mineral potential in comparison to other northern provinces. Found minerals are gold, copper, iron, lead-zinc, tin, pyrite, mercury, lignite, thermal water, industrial minerals / rocks. Minerals that should be developed are iron, gold, copper, coal, lead-zinc, tin, pyrite, mercury, industrial minerals / rocks and thermal water.

Houaphan Province:

Houaphan province is lying in the area of Chongsong fold belt cut by NamKhao fracture, and having quite high mineral potential. Found minerals are gold, copper, iron, lead-zinc, tin, manganese, lignite, gemstone, pyrite, mercury, wolfram, magnesite, talc, asbestos, thermal water, industrial minerals / rocks.

Saysomboun Special Zone:

Saysomboun Special Zone is lying in Vientiane Basin and in area of Chongsong fold belt cut by Chongsong and NamXan fracture. Found minerals are gold, copper, lead-zinc, tin, industrial minerals / rocks. Minerals that should be developed are gold, copper and zinc.

Vientiane Municipality:

Vientiane Municipality is lying in Vientiane Basin and in area of Louangphrabang fold belt cut by Hanuman fracture. Found minerals are gold, different types of salt, peat, industrial minerals / rocks and natural gas. Minerals that should be developed are salt, gold and peat.

Bolikhambay Province:

Bolikhambay province is lying in Vientiane Basin, MuongBo Basin and in area of MuongBo and Chongsong fold belt cut by Chongsong and NamXan fracture. Found minerals are gold, copper, tin, antimony, mercury, wolfram, bismuth, industrial minerals / rocks, thermal water, phosphorites, salt, peat and possible gemstone. Minerals that should be developed are gold, copper, salt, wolfram, antimony and tin. Reconnaissance survey for gemstone should be carried out.

Khammouan Province:

Khammouan province is lying in NamTheun and Sakonnakhorn Basin and in Chongsong fold belt cut by Chongsong and Namxan fracture. Found minerals are gold, copper, iron, tin, phosphorites, salt, industrial minerals / rocks (gypsum,) and coal. Minerals that should be developed are tin, phosphorites salt, gold and industrial minerals / rocks.

Savannakhet Basin:

Savannakhet province is lying in Savannakhet Basin and Chongsong fold belt cut by Chongsong fracture and having quite high mineral potential. Found minerals are gold,

copper, lead-zinc, barite, salt, industrial minerals / rocks and natural gas. Minerals that should be developed are gold, copper, salt, gypsum, zinc and natural gas.

Saravan Province:

Saravan province is lying in Champassack Basin and Attapeu fold belt cut by Attapeu fracture. Found minerals are gold, anthracite, industrial minerals / rocks and natural gas. Minerals that should be developed are coal, limestone and natural gas.

Sekong Province:

Sekong province is lying in Champassack Basin and Attapeu fold belt cut by Attapeu fracture. Found minerals are gold, copper, aluminum and industrial minerals / rocks. Minerals that should be developed are gold, copper and industrial minerals / rocks.

Champassack Province:

Champassack province is lying in Champassack Basin. Found minerals are copper, lead-zinc, tin, gold, peat industrial minerals / rocks, natural gas and bauxite. Minerals that should be developed are copper, coal, lead and industrial minerals / rocks.

Attapeu Province:

Attapeu province is lying at border of Champassack Basin and in Attapeu fold belt cut by Attapeu fracture. Found minerals are gold, lead-zinc, bauxite and gemstone. Minerals that should be developed are gold, gemstone, bauxite, copper and lead-zinc.

VI. CONCLUSION AND RECOMMENDATIONS

It can be summarized from studying of geological structure and mineral distribution in South-East Asia that Lao PDR good condition of geological structure for discovering quantitative and qualitative minerals. The structure is composed of rocks and fractures of appropriate Age for mineralisation. In comparison to Vietnam, Vietnam has older rocks; Thailand and South China comprise younger rocks (Mesozoic) and there is a low probability for mineralisation.

In southern part of the country, provinces that are rich in a variety of minerals are Xiengkhouang, Oudomxay, Houaphan, Louangphrabang and Bokeo. Those in central part are Vientiane, Savannakhet and Xaysomboun Special Zone; and that of southern part is Attapeu.

Mining industry development depends on the mineral richness and distribution according to geological structure.

Investigation for metals and gems should be further carried out in Attapeu, Xekong, Savannakhet, Bolikhamxay, Special Zone Saysomboun, and Houaphan province that are lying in Chongsong fold belt.

Vientiane, Sayaboury, Louangphrabang, Oudomxay and Phongsaly that are lying in Louangphrabang fold belt are rich in metals (gold, copper, lead-zinc, tin and iron) and salt. Therefore, investigation and search for methods to mine these minerals for use should be undertaken.

Bokeo and Louangnamtha province which are lying in Louangnamtha fold belt of Sanxay plate comprising Precambrian rocks are rich in gemstone, lignite and some metals.

It is recommended that mineral development should be focussed on non-metals like salt, natural gas and on metals like copper and industrial minerals / rocks for Vientiane province, Vientiane municipality, Bolikhamxay, Khammouan, Savannakhet, Saravan and Champassack province.

In conclusion, although information collected from many sources are not in detail, they may help to delineate strategy of mineral industry development according to mineral deposit conditions of which each province has different potential.

In the future, if further prospection and exploration is undertaken, it is expected that mineral deposits of economic importance will be found and exploited for using in the development and generating increasing national revenue.

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COAL IN LAO PDR

By: Khampha Phommakaysone, Khoun Phetsengsy, Vongkham Chaleunsouk

I. INTRODUCTION

Coal is considered as an important fuel mineral for industrial development as it can produce electricity, is used in the metallurgy and in industrial sector.

Coal is divided into three types according to its originated period, physical characteristics (calorific value, etc.) as following:

1. Coal with high calorific value originated in Paleozoic – Mesozoic Era and is of anthracite type. Coal bands have complex structure, are discontinuous and cut by fractures and faults therefore it is difficult for investigation. Their strike is steep - very steeped. Host rocks comprise of Paleozoic – Mesozoic sandstone with different characteristics due to sedimentation conditions. In Lao PDR, anthracite was found in three major areas like Phongsaly, Vientiane and Saravane.

1. Coal with medium calorific value originated in Tertiary Era and is of lignite type. Tertiary basins containing lignite are found in the northern part of the country such as Hongsa basin, Viengphoukha basin and Muong Phane basin. In comparison with structure mentioned above, lignite bands have no complex structure and continuous and in consequence there are better conditions to exploit.

Coal with low calorific value originated in quaternary period and is mostly of peat type. It dated 5 – 10 thousand years. Therefore leave imprints can be observed. Peat is not used as fuel, however it is used as principal raw material for manufacturing fertilizer.

II. GEOLOGY AND COAL DEPOSITS

Coal classified as sedimentary mineral is assumed to originate from plants subjecting to geological process. Chemical composition of coal is C. Coal has black color, grayish black color. In accordance to previous data, coal in Lao PDR into 3 major types originated from 3 periods:

1. Paleozoic – Mesozoic coal: This coal is present in Vientiane Basin, Saravane and Phongsaly and is classified as anthracite. According to Vietnamese data, anthracite in Bochan area and in Saravane originated in Carboniferous period. French and Vietnamese geologists indicate that Phongsaly anthracite date Upper Triassic (T₃). Coal bands are discontinuous due to tectonic movements, have very complex structure and deep strike therefore giving difficult conditions for survey and exploitation. Anthracite in Lao PDR has generally a calorific value from 5,500 to 8,500 Kcal/Kg. Anthracite reserves in Lao PDR are shown in Table 1.

Table 1: Anthracite Reserves in Lao PDR

Anthracite Deposit	C1 (Tons)	C2 (Tons)	P (Tons)	Total (Tons)
1. Ban Vangkhi Anthracite Deposit, Vientiane Province	-	-	400,000	400,000
2. Bochan Anthracite Deposit, Vientiane Province	2,010,000	2,144,000	4,000,000	8,154,000
3. Ban Namthom Anthracite Deposit, Vientiane Province	-	-	400,000	400,000
4. Ban Vangmiang Anthracite Deposit, Vientiane Province	830,000	1,310,000	-	2,140,000
5. Chakeui Anthracite Deposit, Saravane Province	-	92,000	27,890,000	27,982,000
6. Phongsaly Anthracite Deposit, Phongsaly Province	-	-	24,500,000	24,500,000
TOTAL	2,840,000	3,546,000	57,190,500	<u>63,576,500</u>

2. Tertiary Coal: This coal mostly of lignite type is present in Hongsa Babin, Viengphoukha Basin, Khangphaniang Basin and Muong Phane Basin which have medium to large reserves. Other lignite basins present in Ban Nateui, Ban Ai, Muong Ngeun.... have small reserve and no economic importance. In general, geological structure of lignite basins originated in Tertiary Era (Neogene) therefore they are not so complex like those of anthracite basins. Posttectonic movement was not strong and took

few times. Lignite in basins that have been explored has generally a calorific value between 2,000 and 6,500 Kcal/Kg. Table 2 shows lignite reserves in Lao PDR.

Table2: Lignite Reserves in Lao PDR

Lignite Deposit	C1 (Tons)	C2 (Tons)	P (Tons)	Total (Tons)
1. Khangphaniang Lignite Deposit, Xiengkhouang Province	-	2,526,413	-	2,526,413
2. Muong Phane Lignite Deposit, Xiengkhouang Province	35,837,536	13,910,771	-	49,748,307
3. Hongsa Lignite Deposit, Sayaboury Province	505,825,339	5,200,000	-	511,025,339
4. Viengphoukha Lignite Deposit, Vientiane Province	12,727,356	-	-	12,727,356
5. Ban Nam Ngeun Lignite Deposit, M.Namo, Oudomxay Province	-	510,000	-	510,000
6. Ba Ai Lignite Deposit, M.Namo, Oudomxay Province	-	-	115,450	115,450
TOTAL	554,390,231	22,147,184	115,450	<u>576,652,865</u>

3. Peat: In Lao PDR, survey of peat was firstly carried out by the Peat Survey Project of Lao Department of Geology and Mines (DGM) in 1985 at Ban Maknao – Ban Nalong, Vientiane Prefecture. From 1997, reconnaissance survey and exploration of peat has been performed in the whole area of the country by the DGM for use in the fertilizer manufacture.

Peat is mostly found in lakes (Nong). In Champassack and Attapeu province, peat is found in lakes of which bed and surrounding rocks are composed of N₂-Q₁ basalt. In the middle and northern part of the country, it is found in lakes of which beds are composed of clay. Peat of Quaternary Age or of 5-10 thousand years has similar characteristics in each region.

a/ Attapeu Province: Peat is found at Nong Oh, Nong Kaleum, Ban Tamoyod (Muong Samanxay) and Nonh Ouy (Muong Phouvong).

- Indicated reserve (C1) at Nong Oh 6,972 Tons
- Indicated reserve (C1) at Nong Kaleum 15,407 Tons
- Total: 22,379 Tons

(Reserve at Nong Ouy was not calculated as peat thickness is only 0.3 metres.)

b/ Champassack Province: Peat is found in Nam Nied swamp, Ban Thopsok, Nong San, Nong houad, Ban Nakham and Khiadgong swamp (Ban Khiadgong, Muong Pathoumphone).

- Inferred reserve (C2) at Nam Nied swamp 163,465 Tons
- Inferred reserve (C2) at Khiadgong swamp 904,719 Tons
- Hypothetical reserve at Nong Khiadgong 7,779,793 Tons
- Hypothetical reserve at Nong San and Nong Houad 361,062 Tons
- Total: 9,209,039 Tons

c/ Savannakhet Province: Peat is found at Ban Donedeng and Ban Khokhinkeo (Champhone district).

- Indicated reserve (C1) at Ban Donedeng 296,888 Tons
- Indicated reserve (C1) at Ban Khokhinkeo 66,993 Tons
- Total: 360,881 Tons

d/ Khammouan Province: Peat is found at Ban Thahe, Ban KhamAng (Muong Thakhek) and Nong Boua (Ban Donedou, Muong Hinboune).

- Indicated reserve (C1) at Ban KhamAng 9,975 Tons
- Indicated reserve (C1) at Ban Thahe 38,000 Tons
- Indicated reserve (C1) at Ban Donedou 57,000 Tons
- Total: 104,975 Tons

e/ Bolikhambay Province: Peat is found at Nong Veng (Ban Phonekhame), Khay swamp and Nong Khangkha (Ban Na Oh, Muong Bolikhanh).

- Inferred reserve (C2) at Nong Veng	160,170 Tons
- Hypothetical reserve (P1) at Nong Khangkha	42,750 Tons
- Hypothetical reserve (P1) at Khay swamp	5,700 Tons
Total:	208,620 Tons

f/ Vientiane Municipality: Peat is found at Nong Bouamay, Ban Noixiengda, Ban Thongsalakham and Ban Ylay Tay.

- Inferred reserve (C2) at Ban Nong Bouamay	130,000 Tons
- Inferred reserve (C2) at Ban Noixiengda	112,158 Tons
- Inferred reserve (C2) at Ban Nong Bouamay	58,000 Tons
- Inferred reserve (C2) at Ban Nong Bouamay	71,260 Tons
Total:	371,408 Tons

g/ Vientiane Province: Peat is found at Ban Namoy (Muong Sanakham).

- Hypothetical reserve (P1) at Ban Namoy	79,800 Tons
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h/ Louangnamtha Province: Peat is found at Ban Nam Thoung along Nam Thoung bank. As peat occurrence covers a small area, reserve was not calculated.

i/ Saravane Province: Peat is found at Ban Naxay (Muong Saravane). As peat covers only a small area and is about 0.5 metres thick, reserve was not calculated.

III. USE

Coal is principally used to produce energy (anthracite and lignite). Peat having carbon content higher than 15 % is used to produce energy. Peat having carbon content smaller than 15 % is used in the fertilizer manufacture.

IV. CONCLUSION

Coal is an important mineral fuel for industry. In Lao PDR, coal is used as raw material for cement manufacture, to produce energy for boiling salt water and for metallurgy. Besides it is exploited for export to Thailand. There are two types of coal in

Lao PDR: anthracite and lignite. According to results of coal exploration, measured reserve amounted to 557,230,231 tons, indicated reserve to 25,693,184 tons and inferred reserve to 57,305,950 tons.

Peat is principally used for fertilizer manufacture. In accordance to exploration in the middle and northern part of the country, reserve amounted to 10,300,000 tons.

CONSTRUCTION AND ORNAMENTAL ROCKS

By: Souksamay CHANTHAMATH, Vongthong, Bounnong

I. INTRODUCTION

Long ago until nowadays people in the world have been used rocks for building houses and for producing tools served in routine life. Through the natural evolution and development of society, in this epoch construction and ornamental rocks are necessary materials in the construction of houses, buildings, roads, bridges, etc.

Lao PDR is one country having potential in construction and ornamental rocks. These outcrop along mountainous chain, along rivers from north to south of the country. They are divided into groups as following:

- Igneous rocks (Granite, Diorite, Gabbro, Basalt, Andesite,)
- Sedimentary rocks (Limestone, Gypsum, Gravels, Sandstone, Sand, Clay,)
- Metamorphic Rocks (Gneiss, Marble, Quartzite,)

II. GEOLOGY AND ROCK DEPOSIT

1. Igneous Rocks

Igneous rocks originated from magmatic processes at high depth of earth core that was subjected to high temperature and earth movement. Thus magma was blown and ejected to the surface of the earth. In this process, some magma was crystallised at depth of earth surface: intrusive rocks such as granite, diorite, gabbro and others. Some magma was ejected to the surface of the earth: extrusive rocks such as basalt, andesite and others.

In Lao PDR, igneous rocks outcrop in many sites like in the northern part, the north-eastern part and the central part (Vientiane province, Bolikhamxay province, Savannakhet province) and the southern part.

2. Sedimentary rocks

A/ Limestone, Merl, Chalk, Dolomite and Sandstone

These rocks are found in the whole area of the country. Limestone and dolomite are mostly present in Houaphan province, Xiengkhouang province and Louangphrabang

province; and a small quantity in Oudomxay and Louangnamtha province. In the middle part of the country, they are mostly found in Vientiane, Bolikhamxay, Khammouan and Savannakhet province. In the southern part, they outcrop in Saravan province.

B/ Gravels, Sand and Clay

These aggregates are present throughout the country, especially along the Mekong River and its tributaries.

3. Metamorphic Rocks

- Gneiss: It is one of metamorphic rocks. Granite subjected to chemical and physical changes due to pressure and high temperature lead to gneiss. In Lao PDR, gneiss is found in the area of Sepone district (Savannakhet province), Xiengkho district (Houaphan province), Pha Tao (Vientiane province), etc.
- Marble: It is one of metamorphic rocks. Limestone subjected to chemical and physical changes due to pressure and high temperature lead to marble. In Lao PDR, marble is found in Louangphrabang province, Houaphan province (Xiengkho district), Vientiane province, etc.
- Quartzite: It is metamorphosed from siltstone. In Lao PDR, quartzite is distributed in many locations such as in Khammouan, Savannakhet province, and others.

III. USE

Construction and ornamental rocks are quarried for use in industry, in construction and decoration. Limestone is used for cement manufacture, for road and building construction. Marble, gneiss and granite are used for decoration.

IV. CONCLUSION

Construction and ornamental rocks are natural resources and necessary raw materials for use in the construction, in-house decoration and in industry. Lao PDR has potential in construction and ornamental rocks like limestone outcropping in Khammouan, Bolikhamxay, Louangphrabang, Houaphan, Xiengkhouang and Vientiane province. Although this limestone is not widely quarried, some mining companies have mined approximately 550,000 tons per year.

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OIL AND NATURAL GAS

By: Thongphat INTHAVONG, Souvath SISOUTHAM, Khoune PHETSENGSY

I. INTRODUCTION

Oil or Hydrocarbon (H₂O) originated from prevailing of small organic cells (different marine fossils) which are died and accumulated in the floor of ocean where there is small quantity of oxygen. These small organic cells were then overlaid by sedimentary rocks. Oil and natural gas mostly originated in Triassic to Jurassic period.

Principal geological structure leading to oil deposit:

- Source rocks are rocks which lead to oil deposit
- Reservoir rocks are rocks having pores enabling to maintain hydrocarbon
- Cap rocks are rocks that prevent the leach of hydrocarbon.

II. OIL AND NATURAL GAS RESERVOIR IN THE WORLD

Oil and natural gas reservoir are present in many sites of the world such as Saudi Arabia, Kuwait, Iraq, Iran, Kata and countries surrounding Persia Golf. They also occur in the area of Mexican Golf, Texas, Alaska (United States), Siberia (Russia), Caspian Ocean, North Ocean of Britain and Norway. In South-East Asia, huge reservoir are present in Indonesia, Brunei Darussalam, Vietnam and Thailand. Cost of hydrocarbon in the world market is 21 to 22 US Dollars per barrel (1 barrel = 149 liters).

Countries with huge oil and natural gas reservoir are summarized as following:

- | | |
|------------------|--------------------------|
| 1. Saudi Arabia | 260,104 millions barrels |
| 2. Iraq | 100,000 million barrels |
| 3. Kuwait | 97,125 million barrels |
| 4. Iran | 92,860 million barrels |
| 5. Arabe Amired | 92,205 million barrels |
| 6. Venezuela | 58,504 million barrels |
| 7. Russia | 58,400 million barrels |
| 8. Mexico | 56,365 million barrels |
| 9. United States | 25,860 million barrels |

10. R D China 24,000 million barrels

III. EXPLORATION OF OIL AND NATURAL GAS IN LAO PDR

Chemical petroleum industry has not been developed yet in Lao PDR. Benzine and gas has been 100 % imported. Survey of crude oil and natural gas began in the 1930's. At that time oil seep in the middle part of the country was found. According to information collected by French geologist, the first drill hole was made in Mid-region of Laos however no detailed information of this drill hole is available. In 1986, the potash exploration project at Vientiane Plain made some drill holes for investigation of mineralisation. At depth of 127 meters of the drill hole No. 26 (Ban Tha Ngone, Muong Saythani) natural gas was seeped for 24 hours. Natural gas was seeped at deeper depth.

Besides mentioned information, the neighboring country (Thailand) reported that a large natural gas reservoir covering till the middle and central part of Laos in Khorat Basin (Nam Phong district, Khonekaen province) was discovered. In 1988, under the technical assistance project from the former Soviet Union, Russian specialists on oil and natural gas exploration undertook a reconnaissance survey in Laos. Due to inner political problem in Russia, the survey had been stopped.

When the government launched a new policy - open the door to foreign investors - three oil and natural gas companies came to carry out oil exploration in the Lao PDR:

1. Enterprise Oil Company

Enterprise Oil Company is an English registered company. In 1989, it received the license of exploration on oil and natural gas in the mid-southern part of the country (Khammouan, Savannakhet and Saravane province) covering the area of 20,200 square kilometers. After getting permit, the company carried out field geological survey, sample collection for analysis, mapping the concession area, aeromagnetic survey totaling 12,123 meters, interpretation of satellite images, gravity survey totaling 2,023 meters, gravity mapping and 2D seismic survey totaling 2,363 meters.

From results of the above mentioned survey, the company could evaluated that there were two sites which oil and natural gas could be found:

- Site 1 (Khorat Play): in the south-western part of the concession area

(Songkhone district) the Palaeozoic source rocks are considered to be gas prone at 2,000 to 2,500 meters depth. Resource of natural gas was estimated to be 785 million cubic meters (148 BCF).

- Site 2 (Banghiang Prospect): in the eastern part of the concession area (Muong Phine), crude oil might be found in the Upper Triassic lacustrine shale at 2,500 to 3,000 meters depth. Resource of crude oil was estimated to be 148 millions barrels.

Geological structures of both mentioned sites show many fractures, where gas seepage might be took place. Data collected in the survey are still not in detail for drilling exploration. For further survey work, 3D seismic survey that cost about 10 million US Dollars should be performed. At that time, the British Gas Company that is the joint venture partner of the Enterprise Oil Company 4v08q;D The latter could not find new partner to undertake further survey work, so it proposed to terminate the agreement in order to reduce risk. Expenditure for survey in Laos amounted to 16.8 million dollars.

2. Hunt Oil Company

Hunt Oil Company is a registered company from the United States. In 1990, the company was licensed to perform oil and natural gas exploration in four provinces in the southern part of the country (Champassack, Saravan, Attapeu and Xekong province) covering 26,000 square kilometres. After getting permit, the company carried out field survey such as field geological survey, collection of samples for analysis, mapping the whole area of concession, aeromagnetic survey totaling 5,159 meters, interpretation of satellite image, gravity survey totaling 967 meters, gravity mapping and 2D seismic survey totaling 2,450 meters.

From survey results, occurrence of gas seep was found in the area of Dakchung district. Along the road from boat station to Dakchung, geological structure in the form of anticline that is called Souvannakhiri anticline was found. This indicates that oil and natural gas might be found in this area. Therefore the company decided to drill borehole. One borehole at Sanasomboun , Champassack province, was dilled up to 2,450 meters deep. Drilling result showed any occurrence of oil and natural gas; only gray volcanic tuff that is not related to oil and natural gas was found. Therefore, the company proposed

to terminate the agreement in 1997. The company spent approximately 25 millions US Dollars for the survey. Therefore the company proposed to cease the agreement in 1997.

3. Monument Resource (Overseas) Limited

Monument Resource (Overseas) Limited is a registered company from England. In 1991, it was licensed to undertake oil and natural gas exploration in the north and central part of Lao PDR (Sayaboury, Vientiane, Vientiane municipality, Bolikhamxay and Khammouan province) covering 37,250 square kilometers. After getting permit, the company carried out field survey such as field geological survey, collection of samples for analysis, geological mapping the whole concession area, aeromagnetic survey totaling 1,127 meters, interpretation of satellite images, gravity survey totaling 5,600 meters, gravity mapping and 2D seismic survey totaling 494 meters.

From results of the mentioned survey, geological structure indicated the possible presence of oil and natural gas at Thaphabath district (72 km from Vientiane municipality, along Road National Road No.13), Bolikhamxay province. Therefore the company took decision to drill borehole. One borehole was drilled up to 2,091 meters where granite had been found. This suggested that there is low probability discover oil and natural gas. In addition, electric logs proved that hydrocarbon would not be found at greater depth. Therefore, the Monument Resources (Overseas) Company Limited proposed to cease the agreement in 1998. Expenditure for exploration amounted to 17.5 million US Dollar.

IV. USE OF OIL AND NATURAL GAS

Crude oil and natural gas are very useful. They are used for producing energy, for chemical industry such as plastic industry, textile industry, etc. Although there are large reserves of crude oil and natural gas in many countries, the world might exhaust of crude oil and natural gas if people could not find other raw materials to produce energy.

V. CONCLUSION

Until today, the Lao PDR could not yet discover crude oil and natural gas reservoir. That does not mean that Laos would not have crude oil and natural gas, as the

three above mentioned companies had not performed detailed survey in some extent, for instance:

- 2D seismic survey had been carried out instead of 3D seismic survey that gives more detailed data for drilling survey.
- In the history of drilling survey for oil and natural gas, only one drill hole never met the reservoir. In fact, in order to be able to evaluate whether an area has oil reservoir, at least 4 boreholes should be drilled in the area estimated to have probability to contain oil. However, in Lao PDR only 1 borehole was drilled for each area.

Reasons for why the three licensed companies proposed to terminate the exploration agreement before getting to detailed exploration might be:

- Some regulations, laws are not appropriate so that companies are not confident to further invest.
- In the period of , there was very critical economic crisis in Asia and cost of crude oil went down.
- Infrastructure facilities of Lao PDR such as transportation, telecommunications...could not yet serve efficiently the business activities.

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SOME INFORMATION ON GOLD IN LAO PDR

(by: Laochou Sotuky and Dr. Simone Phichith)

I. INTRODUCTION

Gold (Au) is one of precious metals and contains in earth surface about 4.3×10^{-7} % being the smallest figure. The ocean contains approximately 3 - 4 mg /m³. To date, 15 minerals containing gold are found. Gold minerals of economic importance are native gold and sulfides bearing with gold. Native gold often contains elements such as Ag, Cu, Fe, Bi, Pb and Sb. Gold price in October 2001 was 280 \$ / oz (30 g).

Gold occurs in different form, in quartz veins and is distributed in sulfide minerals like pyrite, arsenopyrite, galena, sphalerite, etc. Primary gold deposits of economic importance should contain greater than 3 g Au / t, sulfide bearing gold deposits greater than 6 g Au / t and have a reserve amounted to 10 million ounces. Deposits of alluvial gold should contain greater than 0.1 g Au / t. Mentioned criteria changes with technical standard of mining, marketing, etc.

In history, people found about 25 - 30 bars of gold weighing more than 10 kilograms each. The greatest gold bar in the world was found in Australia and named Plyta Holtermans and has a weight of 285 kilograms.

In Lao PDR, the investigation on precious metal (Au) is not yet well developed. To date, there is a lack of detailed information on gold, metals as well as other minerals. Available data collected by Lao and foreign geologists (French, Japanese, Chinese, Vietnamese, Soviet, Tchech) and by private companies are not in detail. Some detailed gold information of some areas is available for instance Sepon gold deposit, Phou Bia area, Muong Sanakham, Muong Sangthong and some provinces in central Laos. Only information on gold occurrences and reconnaissance survey is available for other provinces.

II. GEOLOGY AND MINERAL DEPOSIT

According to previous geological information, it is known that gold deposits of industrial importance are deposits originated metasomatism and metamorphism, and

placer deposits weathered from primary gold deposits. In Lao PDR, gold mineralisation is mostly related to skarn and hydrothermal evolution. Gold is distributed in 8 areas:

- + Pakbeng - Paktha area
- + Sanakham - Nam Ou area
- + Phou Leui area
- + Nhotgeun - Vientiane area
- + Nam Xan - Nam Ngiep area
- + Nape - Raoko area
- + Sepon - Angkham area
- + South and South-East Laos

Primary Gold Occurrences

- Sayaboury Province (Muong Paklay):

Gold occurrence 1 (110° 07', 19° 90') is located on the slope of Phou Noi , at right site of Mekong river, 3 - 4 kilometers south from Ban Donemene. Quartz floats, sometimes pitted quartz and quartz with disseminated pyrite were found. Analytical results show that limonitic pitted quartz contains 107 - 134 g Au / ton, quartz with disseminated pyrite 36 g Au / ton.

Gold occurrence 2 is located at Houei Kin, about 8 kilometers downstream of Mekong River. Quartz veins similar to those of Paklay were found 15 kilometers from Ban Donemene.

- Louangnamtha Province:

+ Gold placers and quartz veins containing copper, gold, silver and pyrite were found in rivers of Pakbeng and Nam Tha area. A quartz vein being 90 meters long and containing 8 g Au / ton was found at Houei Saman and Houei Songgeuk.

+ At Xiengkok, Long district, Louangnamtha province (20 54 10 N, 100 40 48 E), minerals related to hydrothermal alteration and fault having NE-SW direction were found in fractures of granite, granodiorite, rhyolite tuff and dacite tuff. 3 zones were divided as following:

Zone 1 located north of investigated area and being 50 - 70 meters wide and 5 kilometers long is composed of pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, etc. Analytical results: Au = 0.5 - 4.0 g Au / ton; Ag < 10 g / ton.

Zone 2 situated at centre of investigated area and comprised dacite tuff is 40 - 60 meters wide and 700 - 1000 meters long containing pyrite, pyrrhotite, chalcopyrite, antimonite, rutile, limonite. Analytical result: Au = 2.7 g / ton; Ag < 10 g /ton.

Zone 3 located south of investigated area an being 30 - 80 meters wide and 4 - 5 kilometers long is composed of pyrite, pyrrhotite, chalcopyrite, arsenopyrite, spalerite, etc. Analytical result: Au = 0.6 - 1.4 g / ton; Ag < 10 g / ton.

+ While collecting heavy samples at Pha Louang north - west of Nam Pha rocks subjected to hydrothermal alteration (quartzification, chloritisation, etc.) were found. Fractures in granite that is associated with NE fault contains fine - grained pyrite in quartz nest. Analytical result: Au = 3.2 g / ton; Ag < 10 g / ton.

The project of North Laos mapping 1: 200000 found sulfide mineral (pyrite) occurrence being about 50 metres wide at Nam Kali. Sulfide minerals are scattered in quartz veins of quartz - sericitic schist, rhyolite, rhyolite - felsite which are crumbled. Analytical result: Au = 0.4 g / ton; Ag < 10 g / ton.

+ At Phagna Louang area, fractures with quartz veins containing pyrite and some chalcopyrite and being 2 - 15 centimeters thick are present between extrusive rocks and black shale.

+ At Ban Phonxay, there is a foliation of siltstone, tuffaceous siltstone and shale containing quartz and sulfide mineral veins of 1 - 2 centimeters thickness. Pyrite is major mineral. Analytical result: Au = 0.5 g / t, Ag = 10 g / ton.

- Louangphrabang province:

+ Nam Ngao (109 40, 22 12) is situated approximately 30 kilometers upstream of Mekong River from Nam Beng mouth. It is an old alluvial gold mining area being 1700 meters long. Quartz veins containing gold were found in this area. Gold is also present in Phu Leui area, Viengkham district and Pha Pon at Phonxay district.

- Xiengkhouang province:

+ Xiang Ai pyrite occurrence (112° 17', 21° 86') is located about 1 kilometre north - west of the village at right bank of Nam Phiang. Pyrite vein of 2 meters thickness were found. Analytical result: Au = 0.5 - 20 g / ton.

+ Ban Houei Peung pyrite occurrence (112 17, 22 17) is located about 3 kilometers east of Ban Houei Peung. Quartz floats bearing with pyrite, mispickel, chalcopyrite, etc. were found. Analytical result: Au = 5 g /t (Ref: Cheymol).

+ Ban Houei Lun pyrite occurrence (112 34, 22 06) is located about 1 kilometer north - west of Ban Houei Lun. Quartz veins of 1.7 meter thickness and 8 meters length intercalated in granite contain pyrite. Analytical result: Au = 0.5 - 5 g / t.

+ Phu Bia area: This area was surveyed by Australian company (Normandy). Survey results indicate that the area has economic importance. The company is applying for conducting feasibility study and mining in the future. The deposit is related to skarn mineralisation.

- Vientiane Province and Vientiane Municipality:

Gold in this area occurs in Sanakham and Sangthong district and is associated with hydrothermal and metasomatic mineralisation. Resource of gold is estimated at 36,000 ounces by Newmont company.

- Bolikhamxay Province:

At right bank of Nam Hong, Ban Thadeua, Vienthong district, Bolikhamxay province, are present high temperature silicified breccia containing pyrrhotite, chalcopyrite and malachite. Bedrock panning result shows 10 grains of Au in one sample, 80 % arsenopyrite and 10 % pyrite. Genesis is hydrothermal. Similar rocks are found 4 kilometres from this occurrence.

At Houei Kham, Ban Vangphe, Viengthong district (18 05 00, 104 20 00), quartz veins intercalated with Carboniferous rocks were found. Bedrock panning result shows that one sample contains 2 grains of Au. The genesis is hydrothermal.

At Ban Sopkhom, Viengthong district, Khammouan province (18 42, 104 55 00), are present quartz sulfide veins cutting across Devonian sedimentary rocks. Altered sandstone is about 10 meters long and 1 meter wide. Bedrock panning result shows that

one sample contains 3 grains of Au. Mineral composition: 90 % arsenopyrite. The genesis is hydrothermal.

At Ban Nongling, Viengthong district, Khammouan province (18 42 00, 104 55 00) are found black clay schist and siltstone sequence (3 - 4 km long) containing sulfide of Boualapha formation (C1 bp). Bedrock panning result shows that one sample contains 25 grains of Au. The genesis is hydrothermal.

At Sopchad area, Khamkeut district, Bolikhamxay province (18 26 30, 104 52 22), mineralisation occurs in distribution area of terrigenous sediment of the lower sub-formation of Nam Houay formation (O3-S1 nh1) comprising 2 main types of gold ore.

+ Gold - sulfide quartz vein and stockwork developed in NW-SE direction. Ore minerals are mainly pyrite of granular form in pocket small masses.

+ Gold sulfide in sheared and broken rock usually 0.5 - 10 meter wide and 2 - 10 meters long. Ore minerals are mainly pyrite in the form of small crystals disseminated in the rock. Analytical result: Au = 0.2 - 0.6 g / t. The genesis is hydrothermal.

At Ban Phonkham, Khamkeut district, Bolikhamxay province (18 18 29, 104 56 00) are present quartz veins about 0.4 - 0.7 meters thick and quartz stockworks forming zones 1 - 2 metres thick in clay schist, siltstone and quartzite sandstone. Ore minerals include pyrite, sphalerite and arsenopyrite. Analytical result: Au = 0.2 - 3 g / t. The genesis is hydrothermal.

At Ban Phomnot, Khamkeut district, Bolikhamxay province (18 16 18, 104 10 41 on map sheet E-47-67 1:100000 scale), mineralisation (10 m wide, 15 - 20 m long) occurs in broken zone of Nam Houay formation (O3-S1 nh1) developed NW - SE direction. Ore minerals include pyrite and sphalerite. Analytical result: Au = 0.2 - 1 g / t.

- At Ban Nam Houay, Khamkeut district, Bolikhamxay province (18 06 45, 104 09 24 on map sheet E-48-67 1:100000 scale) is present a placer deposit, where local people have mined for decades. Fire assay result shows that the content of Au is 0.4 - 2 g / t and bed panning result shows that they are 1 to 30 grains of Au in 7 kg of samples. Besides, hydrothermal alteration like sericitization and chloritization was observed.

- At Ban Nam Ke, Khamkeut district, Bolikhamxay province (18 11 45, 106 06 00 on map sheet 1:100000 scale), 2 vein systems were found:

+ Sub-latitudinal system comprises quartz - sulfide veins stockwork (0.1 - 1.2 meter thick) having slope of 60 - 80 degree. Minerals include arsenopyrite, pyrite, sphalerite, chalcopyrite, galena and native gold. Fire assay result shows Au = 1 - 63 g /t. Bedrock panning shows Au = 1 - 500 grains / 7 kg. Spectrometric analysis shows Au = 0.002 - 0.3 %, Cu = 0.001 - 0.007 %, Pb = 0.001 - 1 % and Zn = 0.02 %. The genesis is hydrothermal.

- Besides, other gold occurrences are present in the province.

- Khammouan Province:

At Xoklek, Nakay district, Khammouan province (17 56 29, 105 22 4 on map sheet E-48-79 1:100000 scale), quartz sulfide stockworks are found in fractures of granite (Nape complex γ C1 np). Analytical result shows that the gold content is 0.4 - 1 g / t. The genesis is hydrothermal.

- Savannakhet Province:

In accordance to exploration and feasibility study from CRA, Rio Tinto and Oxiana Resources Company, Sepon gold deposit is economic deposit. Gold and copper will be exploited by end of 2002. Reserve of gold is amounted to 3,500,000 oz and reserve of copper to 1,000,000 tons.

- Xekong and Attapeu Province:

In accordance to reconnaissance survey and information on local panning along Xekong river, Xekaman River and their tributaries, it is known that this area has potential in gold. If detailed survey is conducted in the nearest future, it is expected that gold deposit of economic importance in this area will be certainly found.

III. USE

Gold has been used since year 1000 in China, India, Egypt and Mongolia. Gold is mostly produced in the form of bars and coins for guarantee national foreign currency. The amount of gold in mentioned forms in developed countries is about 40 thousand tons.

50 % of gold is used for jewelry, 30 % in (electronic, chemical,....) industry and 10 % in medicine.

IV. CONCLUSION

According to geological and mineral reconnaissance survey undertaken by Lao and foreign geologists since early 2000's, it is known that Lao PDR is one of countries having potential in mineral resources. However only few minerals were explored and mined for use. This is because the country was in situation of long war, in consequence the mineral industry has been slowly developed and facilities like budget, staff, etc. for primary investment has been lacked.

Detailed information of some gold deposits are available: Sepon gold deposit (Vilaboury district), Savannakhet province; Phoubia area, Xiengkhouang province; Special Zone Xaysomboun; Sanakham and Sangthong district, Vientiane province; Pha Pon - Phou Leui area, Viengham district, Louangphrabang province; Khamkeut district - Bolikhamxay province; Pakbeng district, Oudomxay province; Xekong and Xekaman river and their tributaries.

Gold is precious metal, used for guarantee national foreign currency, in jewelry and in industry like electronic, chemical, medical industry and others. If budget and human resources is available for invest in the exploration, gold would be mined for export, thus generating increasing national revenue. Gold and copper deposit at Sepon will be exploited for export by end of 2002.

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LEAD – ZINC ORE

By: Phaysavath Bandavong

I. INTRODUCTION

It is known that Lao PDR is endowed with mineral resources, of which are lead and zinc ore. These minerals are generally related to each other. According to available data and information collected by Phadeang Industry (Laos) Company Limited, lead and zinc ore occurring in Pha Louang area, Vangvieng district, Vientiane province are galena and spalerite.

Lead and zinc ore occurring in Namo district, Oudomxay province is also galena and sphalerite like those in Pha Louang.

Besides lead and zinc ore are found in Nhot Ou district (Phongsaly province), Long district (Louangnamtha province), Boua district (Xiengkhouang) province, Viengthong district (Bolikhmxay province), Boualapha district (Khammouan province), etc (Figure 1).

II. GEOLOGY AND MINERALS

In accordance to geological and mineral data gathered by Phadeang Industry (Laos) Co. Ltd., rocks bearing with lead and zinc include sandstone, Devonian calcareous sandstone, laminated sandstone, Lower Carboniferous limestone, Middle carboniferous _ Permian silicate rock, magmatic extrusive rocks like Permo – Triassic rhyolite, dacite and tuff, Triassic- Cretaceous sandstone.

Rocks outcropping in Kaiso village (Pha Louang) mostly comprise of carbonate rocks and Permian clastic rocks like shale, fine and coarse grained sandstone, brecciated limestone and dolomitic limestone chert nodule. They have NW-SE to WNW-SE-ESE.

Lead and zinc ore in Ban Kaiso are principally galena and sphalerite containing 37 % zinc. Reserve of lead – zinc at Kaiso deposit accounts approximately 23,000 tons. Up to now, about 20,000 tons were exported at 103 USD per ton.

According to reconnaissance survey data of lead and zinc ore at Nampheng village (Namo district, Oudomxay province) collected by Quebimec Company Limited (holding concession license between 1993 – 1998), lead – zinc deposit at Ban Nampheng,

Namo village, Oudomxay province has economic importance. At present, Chianghai Chintheu Construction Development Company is authorized to explore and mine lead – zinc in this area.

III. CONCLUSION

Lead is used for producing vehicle batteries, electric cables, X-ray protection materials, etc. Zinc is used for alloys manufacture, in electronic industry, etc.

Lead – zinc deposits are found in many locations in Lao PDR, however only two deposits have been investigated in detail, of which one has been mined. It is hoped that in the future lead and zinc would be explored and exploited for economic and social development if more good conditions and budget is available.

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COPPER

By: Boualay Saatsy, Soubinh Kongthippavong

I. INTRODUCTION

People have known and used copper thousand years ago. Copper is classified in colored metals. It mostly has yellow and red color. If it is native copper, it has pink color and sometimes red or brown. Its specific density is 8.94 g/cm³ and melting point 1083 °C. Earth surface contains about 0.01 %.

More than 200 minerals contains copper, however there are 14 copper minerals having industrial important as follows:

1. Native copper (Cu)	100 % Cu
2. Chalcopyrite (CuFeS ₂)	34 % Cu
3. Bornite (Cu ₅ FeS ₄)	63.3 % Cu
4. Covellite (CuS)	66.4 % Cu
5. Chalcocite (Cu ₂ S)	79.5 % Cu
6. Cuprite (Cu ₂ O)	88.8 % Cu
7. Malachite (CuCO ₃ Cu(OH) ₂)	57.4 % Cu
8. Azurite (2CuCO ₃ Cu(OH) ₂)	55.5 % Cu
9. Chrysocolla (CuSiO ₃ 2H ₂ O)	36.1 % Cu
10. Tennantite (3CuS As ₂ S ₃)	57.4 % Cu
11. Tetrahedrite (CuS Sb ₂ S ₃)	52.3 % Cu
12. Enargite (Cu ₃ As S ₄)	48.3 % Cu
13. Tenorite (CuO)	79.8 % Cu
14. Brochantite (Cu ₄ (SO ₄) (OH) ₆)	56.2 % Cu

Most industrial copper derive from sulfides such as chalcocite, chalcopyrite, bornite and covellite. These sulfides contain not only copper but also iron, antimony and arsenic. Copper also occurs as native copper. Copper minerals considered as industrial are as following:

- Copper minerals having very high Cu content (3-5 %)

- Copper minerals having high content Cu content (>2 %), but if they derive from porphyritic rocks (>1 %)
- Copper minerals having medium Cu content (>1 %), but if they derive from porphyritic rocks (>0.4 %)
- Copper minerals having low Cu content (>0.7 %), but if they derive from porphyritic rocks (>0.2 %)

In general, copper minerals also contain other elements, therefore there are 3 factors to note for evaluating the economic importance of copper deposits:

- Are there any zinc, sulfur, molybdenum, lead...?
- Are there any precious metals like silver, gold?
- Are there any rare elements like cadmium, indium, ...?

2 criteria were set:

- Copper deposit containing 1 – 2 % has economic importance if the deposit consists of unimetallic ore.
- Copper deposit containing 0.3 % has economic importance if the deposit consists of polymetallic ore.

Geological structure, metallic and non-metallic occurrences as well as precious stones of the Lao PDR has been investigated by geologists from France, Japan and geologists from former socialistic countries. Up to now, there is a lack of detailed information on metals or other minerals. Copper exploration has not been developed. In accordance to previous data, there are 46 copper occurrences in Lao PDR e.g. in Phongsaly, Luangnamtha, Oudomxay, Xiengkhouang, Vientiane, Luangprabang, Khammouan, Savannakhet, Champassack,.... Some deposits have been mined from foreigners.

II. GEOLOGY AND COPPER DEPOSITS

From summarizing data from geological and mineral reports, there are 46 copper occurrences that are in disseminated form or vein originated from granodiorite intrusion.

Phongsaly Province

Copper occurrence in Phongsaly province is found in Nhot Ou and Phongsaly district. They are associated with Jurassic – Cretaceous sandstone, siltstone and claystone. Found copper minerals include malachite, chalcocite, azurite, bornite and related minerals like, calcite, magnetite and limonite.

Louangnamtha Province (Long District)

Copper occurrence in this area has been mined by foreigners (French, Chinese, ...) since middle 2000's and is also present along fault having NS direction and intruding through Paleozoic rocks (Pz3). Thickness of layers bearing copper ranges between 1.20 to 2.00 meters and length between 100 to 200 meters. Mineralisation is in form of vein containing in massive basalt bearing white and grayish green chlorite. Found copper minerals are: chalcopyrite, bornite and related minerals like pyrite and galena. In accordance to analytical result copper content is 0.03 - 2.99 %.

Oudomxay Province (Namo and Phou Thong)

Copper occurrence in this area was found in breccia zone for example: Phou Thong area was intruded by porphyritic diorite. Found minerals are chalcocite, chalcopyrite, covellite, malachite and azurite. Native copper is also present in Triassic quartz vein and has hydrothermal origin.

Xiengkhouang Province

Copper occurrence is present at Phou San, Kham district, approximately 37 km north – east of Pek district. Copper minerals occur in marble, chalcedony and epidote – garnet skarn. Found copper minerals are malachite, azurite, covellite, chalcopyrite, chrysocolla and pyrrhotite. Surrounding rocks include schist, sandstone and limestone.

Vientiane (Ban Namthong)

Copper occurrence was found about 40 km south – west of Pek district. Mineralised area originated at contact between Carboniferous limestone. Found copper

minerals include chalcopyrite, pyrrhotite in epidote – garnet skarn and was originated from skarn.

Louangphrabang Province (Nam Leun)

Copper occurrence is located approximately 3 – 10 km north – west of Louangphrabang city. Copper minerals are of sulfide type bearing in andesite.

Xaignabouly Province (Ban Thadeua)

Copper occurrence is situated about 5 km north of ban Thadeua. Copper minerals present in andesite and gabbro include malachite and azurite.

Special Zone Saysomboun (Longcheng)

Longcheng, situated approximately 150 km north – east of Vientiane Municipality, is well endowed with copper minerals. In accordance to Japanese report (1974) Longcheng comprises of Indosinias, Permian and Devonian rocks. Analytical results of chalcopyrite in quartz vein show that copper content ranges from 7.50 to 22.70 %. Pyrite samples contain 0.02 – 0.89 %.

Khammouan Province (Ban Bo, Mahaxai district and Ban Hom, Boualapha district)

Copper of Ban Bo occurrence originated from Jurassic sandstone. Copper mineralisation of Ban Hom is associated with hydrothermal genesis in breccia zone. Copper minerals occur as stock work and in quartz vein. Found minerals include chalcopyrite, malachite and azurite. Lead, zinc and barite ore are also present in this occurrence.

Savannakhet (Sepon Copper Deposit, Vilabouly district)

Sepon copper deposit is located approximately 150 km from Savannakhet city and 45 km from Sepon. It is situated north – east of Khorat Basin and south of Paleozoic Annametic Fold belt. The uplift of copper deposit is subjected to tectonic movement. Fracture has E-W direction. The basin in this area comprises carbonate and siliclastic

rocks. Copper Mineralized zone occurs as stock work, vein, dyke and sill. The stratigraphy of this area is as following:

1/ Upper Paleozoic rocks are composed of porphyritic rhyodacite, non-calcareous mudstone and siltstone, calcareous mudstone, dolomite, limestone, andesite, volcanic rocks and sandstone.

2/ Mesozoic rocks comprise rocks of Khorat group. Found copper minerals include chalcocite, chalcopyrite, malachite, bornite, azurite and native copper. They are mostly sulfides bearing in porphyritic and carbonate rocks and skarn. Estimated reserve of copper amounted 1,675,200 tons.

Champassack Province (Phou Kao, Houei Phay, Nongkhounthong in Soukhoumma district)

In 1966-67, Japanese geologists carried out copper exploration at Ban Soukhoumma, Champassack Province. Phou Kao copper occurrence is located about ... km from Champassack city. Houei Phay and Nongkhounthong copper occurrences are situated about 4 km and 22 km south of Soukhoumma village respectively. According to geological survey, minerals which include malachite, azurite, chalcopyrite and chrysocolla bearing in Jurassic sandstone, shale and andesite were found in survey area of 15 km x 5 km. Mineralized zone is discontinuous and distributed in lens form. Analytical results show that copper content in this area amount 1-2 %, and some samples contain 5 – 6 % Cu.

Other sites

Besides mentioned occurrences, copper ores are also present at Houei Vi (Sekong Province), Houei Pho, Houei Takded, Sepiane (Attapeu Province).

III. USE

Men have used native copper or bronze to produce tools according to their characteristic properties like: good conductance, ductility and malleability. Copper is associated and necessary to men's live. It is popularly used in industry such as electric industry (electric cables, telephonic cables, refrigerators, motors, radios, televisions and

others). Bronze (copper added with 5-30 % tin) is used in sculpture work. Copper added with zinc is used to produce gun bullets, parts of watches, etc. In conclusion, 50 % of mined copper is used in electronic industry, 25 % in vehicle manufacture, and the rest in production of small ornamental things.

IV. CONCLUSION

In accordance to data collected by geological survey and by local people, there 46 copper occurrences, of which one has been in detail explored – Sepon deposit in Savannakhet Province that will be mined by Oxiana Resources Company in the nearest future. Two occurrences present in Special Zone Saysomboun were discovered by local people and surveyed by Japanese geologists who indicated that copper content ranges from 7.50 to 22.70 %. It is recommended that detailed exploration should be performed in order to evaluate the economic importance and get information to provide to local and foreign mining companies.

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TIN ORE

By: Laochou SOTOUKY, Vilay PHATHIVONG and Chanmany Saysombath

I. INTRODUCTION

The construction of the country aiming to become civilized should be related to the mineral development. Geological and mining activities are considered as one scientific sector that plays an important role in assisting the national GDP growth. Tin ore is one metallic mineral resource that can well generate the national and social revenue.

Tin ore investigation in Lao PDR has been not yet sufficiently developed. It has been mostly explored by French, Japanese, Lao, Chinese, Vietnamese, Russian, Tcheco geologists as well as local and foreign mining companies.

Tin content on earth surface amounts to 0.0025 %. There are about 24 typed of minerals containing tin: cassiterite (SnO_2 , 78.6 % Sn), thillite (PbSnS_4 , 30.4 % Sn), stannine ($\text{Cu}_2\text{FeSnS}_4$, 27.7 % Sn), xilindrite ($\text{Pb}_3\text{Sn}_4\text{Sb}_2\text{S}_{14}$, 26 % Sn) and frankeite ($\text{Pb}_5\text{Sn}_3\text{Sb}_2\text{S}_{11}$, 17 % Sn).

Tin reserves in capitalist and developing countries amount to 7.3 million tons, of which in Indonesia 0.7 million tons, Malaysia 0.6 million tons, Bolivia and Brazil 0.5 million tons and Thailand 0.4 million tons. Lao PDR has 26,000 tons of tin reserve.

- Largest tin deposit has tin reserve $Q > 100,000$ tons
- Large tin deposit has tin reserve $Q = 50 - 100,000$ tons
- Medium tin deposit has tin reserve $Q = 10 - 50,000$ tons
- Small tin deposit has tin reserve $Q < 10,000$ tons

The largest tin deposits in the world are Kita deposit of Malaysia and MaOu - Pisan deposit of Canada having tin reserve greater than 100,000 tons. 145,000 tons of tin have been produced up to 1985, of which 37,000 tons by Malaysia, 26,500 tons by Brazil, 22,000 tons by Indonesia and 17,000 tons by Thailand.

Tin exploration and exploitation in Lao PDR have been undertaken since the period of French colonization. Nowadays, two companies are carrying out exploration and mining activities. Bo Baikal Company is holding an exploration concession area of 5641ha and a mining concession area of 40 ha which is located in Boneng area, Hinboun district, Khammouan province. Another company, Lao – Korea Tin Company is holding

an exploration concession area of 4018 ha and a mining concession area of 50 ha which is situated in Phontiou area, Hinboun district, Khammouan province.

The amount of mined and sale tin in fiscal year 1999 – 2000 was 584 tons, and in 2000 – 2001 (October 2000 – June 2001) 490 tons. Lao tin is exported to Thailand at 3.2 \$ per ton.

In this decade, tin price is declining in the world market due to increase of opening of new deposits and of decreasing of tin consumption. Tin price was 12 –14 \$ per ton during 1980 – 1985. However, in 2000 tin price in Malaysia was only 19.80 RM per kg.

According to available information on tin in Lao PDR, many tin occurrences are present throughout the country: 5 occurrences in Houaphan, 1 in Louangnamtha, 2 in Oudomxay, 1 in Xaygnabouly, 8 in Xiengkhouang, 1 in Vientiane, province, 1 in Vientiane Municipality, 7 in Bolikhamxay, 1 in Champassack, 1 in Sekong and 1 mineralised zone in Nam Pathene Basin of Khammouan province.

II. GEOLOGY AND TIN DEPOSITS

Tin deposits are classified into six types: pegmatite, skarn, greisen, pluton hydrothermal, volcano hydrothermal and alluvial deposit.

As mentioned above, there are 33 tin occurrences in Lao PDR:

- Houaphan Province:

Reconnaissance survey indicated that 5 tin occurrences are present in Houaphan province: Houei Cheut, Ban Nasamong, Ban Nakhoun, Ban Sousoi and Tham Lao Tua.

- Louangnamtha Province:

Tin occurrence was found at Phou Mon Lem, Ban Meo, Long district, situate approximately 25 km south – west of Sing district. Tin ore is of quartz cassiterite type.

- Oudomxay Province:

Two tin ore occurrences were found at Pakbeng. The first one contains tin, gold and pyrite, the second one tin, lead, gold, wolfram and bismuth. Another tin ore occurrence bearing with gold, mercury, barium and tin is present at Ban Sing.

- Xaygnabouly Province:

Reconnaissance survey showed that tin ore occurrence bearing with gold is present at Ban Donemene.

- Xiengkhouang Province:

According to reconnaissance survey data, 8 tin ore occurrences were found in Xiengkhouang province: Pha Hia, Ban Nathong which also contains copper, Nong Pet, Chamun, Na Men, Song Hat and Lat Buoc.

- Vientiane Province:

Tin ore samples were collected at Phou Houat in contact with intrusive granite, pegmatite and greisen, located about 11 km south – east of Pha Hia. Cassiterite and gold are present in these samples.

Tin ore occurrences were also found along Nam Thane - one of Mekong tributaries, at Linh Xan, Nam La and Phialat where gold is present in addition with tin.

- Bolikhamxay Province:

Tin occurrence is present at Ban Nam Khou with coordinates 18° 11' 20" and 104° 18' 50". Mineralisation occurs in quartzitic sandstone of Phon Tiou Formation D₂₋₃ pt) and biotite granite of Phou Thoun Complex γ P₂-T1 pt which is composed of 2 mineral type:

+ Quartz - tourmaline cassiterite. Analytical results: Sn = 0.01 – 0.03 % ; Pb = 0.001 – 0.003 % ; Zn = 0.002 – 0.008 %.

+ Quartz sulfide cassiterite. Analytical results: Sn = 0.01 – 0.11 % ; Pb = 0.002 – 1.77 % ; Zn = 0.02 – 0.027 %.

Genesis is hydrothermal.

Another tin occurrence is present at Ban Nong Khouay with coordinates 18° 11' 45" and 106° 06' 00". Mineralisation occurs in skarn alteration between biotite granite of Nape complex γ C_{1np} and calcareous shale, carbonate – flogopite schist of Nam Houay formation (O₃-S₁ nh₁). Analytical result showed that some ore bands contain 98 % pyrite, little galena, little arsenopyrite and some cassiterite grains. Genesis: skarn?

Besides there are other tin ore occurrences at Lak Sao, Ban Nape, Ban Nakadok, Sop Chat and Nam Pan. Nakadok, Sop Chat and Nam Pan tin occurrences are also bearing with gold.

- Khammouan Province:

Mineralisation of Phontiou tin ore deposit (17° 52' 55", 104° 36' 05"), located in Hinboun district, includes quartz veins, stockworks penetrating the schist, sandstone, milonite breccia containing quartz sulfide of 30 m thickness. Tin reserve was estimated to be $C1 + C2 = 4,400$ tons. Hypotetical reserve amounted to 14,400 tons at 70 % Sn. Phontiou tin ore deposit is classified as medium deposit.

Boneng tin deposit (17° 57' 40", 104° 35' 15") is situated north - east of Nam Pathene. Exploration and evaluation of Boneng tin deposit was undertaken in 1979. In 1981, the final draft on exploration compiled by geologists of the former Soviet Union has been submitted. The investigated area comprises Middle – Late Devonian and Early Carboniferous terrigenous carbonate sediments, Quaternary acidic sub – volcanic rocks with fractures being important for mineralisation. Tin ore occur as quartz sulfide veins. Minerals include pyrite, arsenopyrite, galena and sphalerite. Tin mineralisation is accumulated in all rocks except limestone. Analytical result show that tin content is 0.21 %. Reserve of tin ore was estimated at $C1+C2+P = 5,118,000$ tons equivqlent to 11,579 tons of tin. Boneng deposit is classified as medium deposit.

Nong Sun tin deposit (17° 57' 10", 104° 31' 35") has been explored using drilling, trenching, well digging and other methods. Exploration result indicated that tin ore is associated with Ordovician – Silurian terrigenous sediments and Triassic rhyolite. The area was subjected to muscovitisation, pyritisation and limonitisation processes. It is composed of quartz limonite, sulfide, iron oxide vein zone being 0.4 – 0.6 m thick. Mineralisation occurs as stockworks of 1 – 5 m length and 0.5 to 5 m thickness. Mineralised zone extends from 40 m to 350 m length with 60 - 80° slope. Ore includes cassiterite, stannine and arsenopyrite. Tin content ranges from 0.2 to 0.7 %, in eluvial rhyolite 5 %.

Savannakhet Province:

Tin occurrence, present in Ban Souei north – east of Savannakhet, is related to granite.

Champassack Province:

Tin occurrence was found at Phou Khoun according to reconnaissance survey.

Sekong Province:

In Xekong province, one tin occurrence was discovered at Phou Xekong.

III. USE

Our society has been known to use tin in metallic period, 4000 years before Christ. Nowadays, the use of tin is widely expanding for instance in the production of containers for goods transportation, machinery, electrical industry, electronics, construction materials, chemical industry, etc.

IV. CONCLUSION

As mentioned above, tin ore generally originated in relation with 6 mineralisation types. In Lao PDR, tin deposits of economic importance that have been mined up to date are alluvial deposits located in Nam Pathene basin, Hinboun district, Khammouane province. Deposits in this area have been investigated and exploited since early 20th century by French geologists and joint – venture company at present.

Tin is one of metals which our society has been known to use long ago, for example in the production of food and goods container, machinery, electrical industry, electronics, chemical industry, etc.

There are many tin occurrences in Lao PDR, some of which have been not yet detailedly investigated and exploited for use. This is due to a lack of facilities like concrete market, budget, staff and others. If these facilities are available in the future, it is hoped that these deposits would be certainly developed and mined for efficient use.

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IRON ORE

By: Inpong HOMSOMBATH

I. INTRODUCTION

Geological and mineral investigation of Khammouan and Xiengkhouang province has been undertaken by Dussault during 1912 – 1923. Feasibility study on iron ore deposit in Xiengkhouang area has been carried out by Cheymol in 1959 – 1960 and by Geological Survey (Intergeo) of Department of Geology and Minerals of SR Vietnam in 1980's.

Previous geological information indicated that there are 36 iron ore occurrences in Lao PDR, of which 28 are located in the north – eastern part of the country especially in Xiengkhouang provinces (21 occurrences of which some have been in detail investigated).

Iron ore occurs in the nature in many mineral types. These are divided into 3 major groups: oxides, silicates and sulfides.

- Oxide group includes magnetite (Fe_3O_4), hematite (Fe_2O_3)
- Sulfide group includes pyrite (FeS_2), marcasite (FeS_2)
- Silicate group includes chamosite ($(\text{Fe, Mg, Al})_6(\text{OH})_2(\text{Si, Al})_4\text{O}_{10}$),
Glauconite ($(\text{K, Na})(\text{Al, Fe}^{3+}, \text{Mg})_2(\text{Al, Si})_4\text{O}_{10}(\text{OH})_2$)

Minerals that give high percentage of iron and are classified as industrial include magnetite and hematite.

Physical properties of hematite (Fe_2O_3): Hardness = 3 – 6, specific gravity = 4.8 – 5.3.

Physical properties of magnetite (Fe_3O_4): Hardness = 5 – 6, specific gravity = 5.

Magnetite may change into hematite and limonite. In general, magnetite is widely distributed in igneous and metamorphic rocks, and sometimes present in acidic igneous rocks. It is associated with apatite and zircon.

II. GEOLOGY AND IRON ORE DEPOSITS

Iron ore deposits having economic and industrial importance are alluvial deposits. In Lao PDR, iron ore deposits having economic and industrial importance include Phou

Nhouan deposit (Ban Mone, Xiengkhouang province) and Phalek deposit (Special Zone Saysomboun). These deposits were subjected to geological processes as following:

1. Phou Nhouan Iron Ore Deposit

The mineralized zone of Phou Nhouan, located in the northern part of Xiengkhouang province, extends to 5 km length along east – west direction. Phou Nhouan crest is 1887 m high.

Phou Nhouan comprises schist, sandstone, limestone, granodiorite bearing iron ore, schist. Sandstone lies in Indosinias formation E – ENE to S – WSW direction and SSE 40° dip. Uralian Permian limestone elongates along both sides of Phou Nhouan. Granite and diorite are present in the south.

The upper part of Phou Nhouan slope is composed more sandstone than schist bearing with iron ore. The mineralized zone is elongated over 4 km along the slope of the mountain. This deposit comprises mostly magnetite associating with granite and diorite. Iron ore has good quality (70 % Fe) and a hypothetical reserve P of 30,000,000 tons.

2. Pha Lek Iron Ore Deposit

Pha Lek is situated approximately 60 km SSW of Khoune district and covers over 60 square kilometers. It comprises schist, sandstone, limestone and Devonian granodiorite. Sedimentary rocks have WNW – ESE direction and 50° N dip. Pha Lek deposit is divided into 8 occurrences as following:

- Occurrence 1: located about 2 km NW of Ban Pha Nokkok 1. Mineralized zone expands

to 500 meters length and consists of magnetite, pyrrhotite and little chalcopyrite. Surrounding rocks include marble.

- Occurrence 2: located 1 km NW of Ban Pha Nokkok. Mineralized zone, expanding to 300 meters, may be continued from occurrence 1 as it has similar structure and composition.

- Occurrence 3: located about 3.7 km NE of Ban Pha Nokkok. Mineralized zone expands to 300 meters length, 50 meters width and 40 meters thickness. Major mineral include magnetite and limonite.

- Occurrence 4: located about 2 km from Ban Pha Nokkok 2. Mineralized zone expands to 2 kilometers length and 100 meters width.

-Occurrence 5: magnetite deposit was found about 1 kilometer east from Ban Pha Nokkok 1. Mineralized zone outcrops as block in NS direction with 1.7 kilometer length and 100 meters width.

- Occurrence 6: located 4 kilometers ENE of Ban Pha Nokkok 1. Mineralized zone is similar to that of occurrence 5 and outcrops along WSW-ENE direction. It is 1 kilometer long and 100 meters wide.

- Occurrence 7: Magnetite deposit is present approximately 750 meters WSW of Ban Kokmay. Mineralized zone is 150 meters long and 60 meters wide.

Pha Lek deposit is associated with metasomatic process. Major minerals include magnetite and limonite. Iron sulfides were rarely found. Pyrrhotite and chalcopyrite were found in elluvium.

III. PRODUCTION AND USE OF IRON ORE IN THE WORLD

Production of iron ore has been quite constant from 1997. Production by China, European Union, Russian, Japan and North America covers 82 % of world production. The production of iron ore is constant in Japan, North America and European Union, and steadily increases in China and Russian as well as in Asia especially in India, Korea and Taiwan. Production and reserves of iron ore in some countries in the world are shown in Table 1.

Table 1: Production and reserves of iron ore in some countries in the world

Country	Iron Production in 1996 (million tons)	Iron Production in 1997 (million tons)	Reserve of crude ore (million tons)	Reserve of iron (million tons)
America	62	62	25,000	6,000
Australia	147	150	32,200	20,100
Brazil	180	190	17,000	10,000
Canada	36	38	26,000	10,000
China	250	260	49,700	14,900
India	67	70	12,000	6,300
Kazarstan	13	15	9,300	3,500
Lybania	-	-	1,600	800
Romania	11	12	700	300
Russia	70	70	42,000	15,600
South Africa	31	30	9,300	5,900
Sweden	20	20	4,600	2,400
Ukraine	48	45	27,000	10,000
Others	86	70	16,000	6,300
Total	1,020	1,030	272,000	112,000

World reserve amounts to 800,000 million tons.

In Lao PDR, it is estimated that reserve of iron ore at 70 % Fe is about 30,000,000 tons.

Table 2: Iron Price in World Market

Year	Price (\$/M. tons)
1993	24.65
1994	24.49
1995	28.36
1996	30.76
1997	30.41

Quality of iron ore that can be classified as industrial:

Fe > 23 %; Al₂O₃ + SiO₂ < 25 %; P < 0.25 %; S, Pb, Zn, As, Cu < 0.1 %.

Small iron ore deposit: < 20 million tons

Medium iron ore deposit: 20 – 100 million tons

Large iron deposit: > 100 – 300 million tons

Very large iron deposit: > 300 million tons.

USE

Iron is widely used in industry for instance: metallurgy, oil industry, military industry (tanks, guns, bullets, etc.).

IV. CONCLUSION

Iron is widely used in the world. In Lao PDR, iron ore deposits with good quality are mostly present in Xiengkhouang province (Phou Nhouan deposit) and Saysomboun Special Zone (Pha Lek deposit). However iron ore has not been mined yet for development, as only reconnaissance survey data are available. Further detailed investigation should be undertaken in order to develop mineral industry sector. In accordance to geological conditions, iron ore is associated to many groups of minerals and rocks. Phou Nhouan and Pha Lek deposits are estimated to have an hypothetical reserve of about 70 million tons.

According to mentioned information and needs of iron in the economic and social development, it is hoped that iron ore in the Lao PDR would certainly be exploited for national development in the nearest future.

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