

**Report Geology and minerals  
of mid-central Laos region  
Scale 1:200,000  
ed. Tran van Ban  
Intergeo Viet Nam  
2000**

Part 2: Mineral resources

**General Introduction**

Since a longtime, the Mid-Central Lao region has been surveyed, investigated and geological and mineral resources maps at various scales have been compiled. But the practically no documents have been remained.

According to the remaining documents, in the Mid Central Lao region 38 deposits and ore occurrences have been registered. In particular the Nam Paten tin deposit and Bunghouana - B.Tung gypsum deposit have been subjected to prospecting and exploration. Most of the remaining deposits and ore occurrences have just been discovered and not yet surveyed. Many occurrences are only registered on the map but with them there are no associating data.

In 1954, E. Saurin registered at Natoung an iron ore occurrence. On the 1:500,000 scale geological map of Vinh sheet (Vietnam), the Boualapha area has been registered to have phosphate in caves.

In 1983 a group of Soviet geologists headed by Iu. Baculin made a report on detailed exploration of tin ore in Nam Paten area at 1:25,000 scale. In particular the Phon Tiou, Bo Neng, Nong Xun areas have been subjected to evaluative prospecting at 1:2,000 scale.

In 1985, Bulgarian geologists (St. Moskorski, St. Sarov et al.) carried out air photo interpretation of Kham Mouan area and surveyed the crystalline quartz occurrences at Phou Toun, B. Houana, etc.

In 1990, Snowy Mountain Engineering Co. (SMEC, Australia) carried out site investigation for the Nam Theun hydroelectric project. Here the INTERGEO Division (of the Department of Geology and Minerals of Vietnam) drilled near 1,900m, discovered rock salt and gypsum (anhydrite).

In the first period of the 1990s, the geologists of the Department of Geology and Mines of Laos surveyed some construction materials sources in Mid Central Lao region.

From 1996 to 2000, the INTERGEO-2 Sub-division (I-2) (of INTERGEO Division, Department of Geology and Minerals of Vietnam) implemented the project " Mineral Investigation and Geological Mapping at 1:200,000 scale of Mid Central Laos region". As a prominent result of this project, 154 deposits, ore occurrences and mineral shows of 25

different kinds of minerals in the Mid Central Lao region. Many kinds of minerals were discovered for the first time, having great significance in working out economic development strategy of Lao State such as phosphorite, barite, gypsum, gold, construction materials, rock salt, etc..... mineral and chemical element dispersion haloes have been delineated (Drawing No : 6, 7).

These results serve as a scientific basis for adopting new views on the mineral resources and metallogenic characteristics of the region. Based on their characteristics, properties, using technology, the minerals are divided into the following groups:

I. Fuel minerals

Coal

II. Metals

- Ferrous metal group: iron,
- Non-ferrous metal group: Copper, polymetals, antimony- mercury
- Precious and rare metal group: Tungsten, tin, gold

III. Industrial minerals

- Chemical and fertilizer raw material group: barite, pyrite, gypsum-anhydrite, rock salt, phosphorite, dolomite.
- Technical raw material group: Crystalline quartz,
- Ceramic and porcelain raw material group: Ceramic clay
- Construction material group: Cement limestone, building limestone, cement clay, brick clay, facing stone, slate, building sand, gravel.

IV. Thermal water, salt water.

In the following we will present in sequence the above listed minerals:

## **I. FUEL MINERALS**

### **Coal**

Poung Bon coal occurrence (142) is the unique coal occurrence in the study area registered on the minerals resources map.

#### **Poung Bon coal (142)**

This coal occurrence is located about 2km South of B. Poung Bon, Boualapha district, Khammouan province, with geographic coordinates :

17°12'05" North latitude

105°51'35" East longitude

In 1985, a group of Bulgarian geologists came to carry out a survey and discovered some coal lenses 2.5-3m long and 0,4m thick. The result of analysis in the laboratory of Sophia University gave the result : Ash content  $A^K = 6.2\%$ , volatile  $V = 5.7\%$ , humite = 1.3%, vitrinite = 2.9%.

In March 1997, the geological survey team headed by geologist Nguyen Van Canh carried out general prospecting of this coal occurrence.

The amounts of work implemented included :

- Walking geological survey : 25.4km
- Collection of samples :
  - Petrologic samples : 95 samples
  - Thin section samples : 29 samples
  - Chemical samples : 8 samples
- Cleaning of outcrops : 74.6m<sup>3</sup>

The results of general prospecting show that the coal bearing sediments consist of quartzitic sandstone, silty sandstone of Boualapha formation (*C<sub>1</sub> bp*).

The coal is in the form of thin seams and lens with thickness 10-40cm, apparent length of 6 - 7 m. The coal is of black color, with strong luster. The analysis parameters include :

Dry ash content  $A^k$  : 9.31-21.88%, Analytical water content  $W^{pt}$  : 1.4-2.08%, burning volatile  $V^{ch}$  : 9.1-12.58%, burning calorific value  $Q^{ch}$  : 8499 -8874 cal/g.

The coal is ranked as semi-anthracite. The coal is of good quality. But as the seams are too thin and the length is inconsiderable and as the coal seams are under the stream water level, this coal occurrence is not much prospective.

Correlating with La Khe formation aged Early Carboniferous in Truong Son area of Vietnam, it is possible to conclude that it is difficult to discover commercial coal seams in Mid Central Lao region.

## **II. Metals**

### **1. Ferrous metal group**

Under this group, iron is the unique mineral existing in the study area.

#### **Iron:**

There are two iron deposits : Bo Neng (56) and Chalet (150). They are characterized by weathering type, composed of limonite - hematite - goethite. The most typical is the Bo Neng iron deposit.

#### **Bo Neng iron deposit (56)**

Bo Neng iron deposit is located in the North of Nam Pa Ten, near 30km NW of B.Bo Neng, in Hinboun district, Khammouan province, with coordinates:

17°59'00" North latitude

104°33'35" East longitude

This deposit has been recorded in the minerals resources map, belonging to the cluster of mineral deposits in Nam Paten area. In 1984, Soviet geologists came to carry out geological investigation here. But no data has been left. The only document is the isopach map of iron ore

bodies showing that the iron ore here is strongly weathered, occurring in eluvial and deluvial forms, as large blocks. They are distributed mainly in three areas:

- Lac Nong Ding area : around peak 351, covering near 1km<sup>2</sup>. The ore is usually located at the high points of the terrain. The ore bodies are 6-12m long.
- H. Ngiou area : covers about 0.3km<sup>2</sup>. The thickness of the ore bodies is 4-8m.
- H. Thoun area : covers about 0.2km<sup>2</sup>. The thickness of the ore bodies is 4-8m.

The ore minerals area mainly hematite limonite, little magnetite. The ore is of good quality. The reserve of this deposit is about 4-6Mt, of small size.

## 2. Non-ferrous metal group

### Copper

Copper ores in Mid Central Lao region are of two genetic types :

- Copper ore type in sandstone of Nam Phouan formation (J<sub>3</sub> *np*) : Under this type there are 4 ore occurrences : Ban Bo (78), Ban Lao (73), Phon Hai (30), Peak 802 (26), of which the Ban Bo ore occurrence is typical.
- Copper - sulfide ore type of hydrothermal genesis related with broken zone. Ban Hon ore occurrence is typical.

#### **Ban Bo copper ore occurrence (78)**

This ore occurrence is located within two villages : Ban Bo and Ban Thong Khong, Mahaxai district, Khammouan province, with coordinates :

17°35'34" North latitude

105°24'55" East longitude

This ore occurrence was subjected to preliminary general prospecting by Hoang Van Dai in 1997.

Taking part in the geological structure of the area are the sediments of Ban Lao formation (J<sub>1-2</sub> *bl*), consisting of clay shale, siltstone, calcareous shale ; quartz sandstone, arkosic sandstone, grey siltstone of Nam Phouan formation (J<sub>3</sub> *np*).

The ore is disseminated in the form of pockets in the fine quartz sandstone sequence. As no excavation has been made, the mineralization along the strike direction of this sandstone layer has not been observed. The ore minerals include: chalcopyrite, chalcocine, pyrite,

The result of channel sample analysis shows : Cu = 0.19-0.218%

In 1997 an Australian geologist collected two samples and analyzed in Australia, giving the following result :

N	Sample No	Cu content (%)
1	11,007	0,448

2	11,008	0,522
---	--------	-------

The analysis of mineralogical sample (TL.8060/3) shows the following mineral composition of the ore: xenomorphic chalcopyrite 6%, bornite and chalcosine % developed at the margin of chalcopyrite. The ore has disseminated and vein structure, xenomorphic granular texture.

The general prospecting shows that the ore manifestations on the surface are much covered. No excavations have been made for examination and observation. Thus this ore occurrence has not been fully evaluated. It must be further investigated.

Although no prospecting work has been carried out for evaluating the prospectiveness, the copper ores in sandstone are developed in favorable geological structure, and suggest the possibility to discover copper deposits of sandstone type. Therefore it is necessary to continue investing the stratigraphy, geochemistry and formation circumstance of these sediments and search for more significant copper ore occurrences.

#### **Ban Hon copper ore occurrence (144)**

Ban Hon copper ore occurrence is located in Khoay Mep commune, Boualapha district, Khammouan province, coordinates :

17°12'00" North latitude

106°14'11" East longitude

This ore occurrence was subjected to general prospecting by Le Thanh Van and Nguyen Van Canh in 1997.

The mineralization is in the broken and sheared zone of the black grey sandstone, siltstone and conglomerate of Boualapha formation ( $C_1 bp$ ). On the surface the outcrop is developed in NW-SE direction, with apparent length of 15-20m (controlled by outcrops TL.16046-TL.16104)

Sulfide mineralization is distributed in quartz veins and stockworks with thickness 0.1-2cm, in pocket forms filling fractures. Ore minerals include :

- Chalcopyrite is the form of big pockets the size 1-2mm, of golden color or fine threads evenly disseminated in the quartz veins.
- Galena of lead grey color, in the form of fine crystals the size 0.1x0.1cm-1,5x1.5 cm.
- Barite : forms small veins 1-2mm wide of muddy white color.
- Secondary minerals include: malachite, azurite of blue color occurring in the form of traces or filling the cavities.

The result of analysis of samples (TL.16046) is as follows : Cu : 0.887% ; Pb : 0.025% ; Zn : 0.007% ; Fe : 3.94% ; S : 0.95%.

#### **Polymetals**

#### **Pha Kat polymetal ore occurrence (152)**

(See the description of Pha Kat barite ore occurrence )

## Antimony- mercury

### **Nam Kang antimony- mercury ore occurrence (13, 15)**

The Nam Kang antimony ore occurrence is located within tree villages : Na Nhip, Houay Khai and Tha Phe, in Viang Thong district, Bolikhamxay province, with geographic coordinates :

18°28'35" North latitude

104°29'10" East longitude

The preliminary result of panning in 1997 show that in Nam Kang area exist a cinnabar dispersion halo of 10-50 grains.

In March 1998, Hoang Van Dai carried out general prospecting in Na Nhip and discovered mercury mineralization. In December 1999, Tran Sung and Hoang Van Dai carried out general prospecting in the area from Ban Tha Phe to ban Houay Khai and discovered a band of antimony ore boulders.

Within the general prospecting area are developed grey, black grey clay schist, thin bedded calcareous shale, siliceous shale of Boualapha formation ( $C_1 bp$ ), light grey limestone, in some places dolomitized limestone and weakly marbleized medium to thick-bedded (massive) limestone of Khammouan formation ( $C-P_1 km$ ).

The area, two main fault systems have been discovered :

- NW-SE trending fault system plays an important role as an ore conducting channel
- Sub-latitudinal fault system displacing the rocks and complicating the geological structure of the area

On the basis of the characteristics, ore bearing properties, the area may be divided into two zones characterized by different kinds of mineralization :

+ Ban Na Nhip zone is characterized by mercury mineralization (cinnabar). Here exists a broken zone extended in NE-SW direction, about 20km long 200-300m wide. The limestones have been dolomitized, strongly displaced, crushed, where is mercury ore is disseminated. Cinnabar crystals of crimson, brown red, blood red color and semi-metallic luster with grain size from 0.05 x 0.05mm - 0.3 x 0.5mm.

As a result of panning 65 bedrock samples, cinnabar ore was found in 49 samples, with contain 5-1000 grains, exceptionally one sample reached 800 grains (TL8621). In alluvial panning samples in most case cinnabar is found with 30-100grains/10dm<sup>3</sup>, in exceptional cases 0.97-17.94g/m<sup>3</sup>.



+ Houay Khai zone : is characterized by antimony ore. The ore is in boulder form developed from B. Houay Khai to B. Tha Phe, nearly 4km long, closely related with NW-SE trending faults. Here 4 areas with antimony ore boulders have been discovered, each 100-300m long, 50-100m wide. The ore boulders are 0.1 x 0.2m to near 0.5m<sup>3</sup> in size.

The antimony ore is of fine crystalline and platy form, with black color, with metallic to opaque luster, when weathered becomes valentinite with typical lemon yellow color. The ore is of radial, entangled structure. It is concentrated in small pockets, small veins filling fractures in quartz, brecciated dolomitic limestone. The size of the pockets and veins is from a few mm to 20 x 30cm.

The result of analysis show the following contents : Sb : 23.4-48.19% ; Pb<0.001% ; Cu : 0.0007-0.0022% ; S : 5.4-11.06% ; Fe : 0.96 -1.4%.

This ore occurrence has been only discovered in the form of boulders but has extensive distribution area. In the area are fairly widely developed the carbonate and terrigenous - carbonate rocks and fault systems, facilitating the formation of mercury - antimony ore. Therefore, investment should be made for further investigation and full evaluation of this ore occurrence and further mercury -antimony ore prospecting should be carried out in the distribution area of the sediments of Boualapha formation (C<sub>1</sub> bp) and Khammouan formation (C-P<sub>1</sub>km).

### 3. PRECIOUS AND RARE METAL GROUP

The minerals of this group include tungsten, tin and gold, of which tin has the largest extent and has been subjected to prospecting, exploration and exploitation.

#### **Tungsten**

##### **Tungsten Pong Kuak (44)**

Pong Kuak tungsten ore occurrence is located about 20km SE of Laksao, in Nam Veo commune, Khamkeut district, Bolikhamxay province, with geographic coordinates:

18°08'10" North latitude

105°13'20" East longitude

This ore occurrence was discovered based on the mineral dispersion haloes of tungsten and tin.

In November 1997, geologists Vu Van Chuong and Trinh Xuan Hieu carried out a general prospecting here.

The work carried out included :

- Survey area : 13 km<sup>2</sup>
- Collection of samples :
  - Petrologic samples : 114 samples
  - Mineralogical samples: 5 samples
  - Thin section samples : 26 samples
  - Bed rock panning samples: 10 samples

Fire assay samples	:	10 samples
Chemical samples	:	7 samples
- Trenching	:	24 m <sup>3</sup>
- Cleaning of outcrops	:	97 m <sup>3</sup>

Taking part in the geological structure of this ore occurrence are the sediments of to Nam Houay formation (O<sub>3</sub>-S<sub>1</sub> *nh*), consisting of quartz - sericitic schist, quartzitic sandstone intercalated with lenses of gravelite, weakly metamorphosed arkosic sandstone. The rock has foliated structure, lepidoblastic and micro-lepidoblastic textures. The rocks have monoclinial attitude, dipping WNW, with attitude 270∠20-60°.

The magmatic rocks of Poug Kuak complex ( $\gamma$  MZ<sub>3</sub> ? *pk*) form a large massif in the central part of the area, occupying about 2/3 of the study area. In petrographic composition they are composed of leucocratic fine to coarse grained two-mica granite, two-mica porphyritic granite. Their mineral composition is: potassium feldspar (microcline) 25-56%, quartz 25-35%, plagioclase 15-26%, biotite 2-5%, muscovite 2-7%. The rocks are of massive structure, porphyritic hypidiomorphic granular texture. They penetrated the rocks of Nam Houay formation (O<sub>3</sub>-S<sub>1</sub> *nh*).

In the area are developed two fault systems :

- NE-SW trending fault system displaced and complicated the geological structure of the area
- Sub-latitudinal fault system may be directly related with the tungsten ore formation.

In the area exist two type of mineralization : Quartz-tungsten and quartz-sulfide - gold types

+ The quartz-tungsten type

- Vein 1 : Quartz vein penetrates granite in the granite massif, with a thickness of 2m, an apparent length of 20m. Near-vein alterations include : chloritization, sericitization, etc. Mineral composition : wolframite 4-6%, black, with opaque luster, consisting of relatively large grains of platy form >1mm, disseminated in quartz, with hypidiomorphic granular texture; fine grained pyrrhotine disseminated in quartz, idiomorphic bismuthine as small inclusions in quartz. The result of analysis show the following contents : W : 1.6% ; Sn : 0.02% ; Au : 0.4g/t

- Vein 2 : Is located at the contact between granite and the two-mica quartz schist. The quartz veins are >5m thick, about 50m long. The results of chemical analysis give the following contents : W : 3.2% ; Sn : 0.02% ; Au : 0.4g/t

+ Quartz-sulfide - gold type :

Consists of white quartz veins with impregnation of sulfide, scattered in the area. The largest vein is 7m long.

The mineral composition of ore is : Pyrite (2-3%), arsenopyrite (2%), chalcopryrite < 0.5%, sphalerite < 0.01%, gold (TL.6444) with bright golden color, met at the same place with chalcopryrite (the size 0.02-0.06mm). The ore has disseminated structure, idiomorphic granular texture.

Sequence of forming the quartz - sulfide - gold ore

Mineral composition	Mineralization stage	
	I	II
Pyrite		
Arsenopyrite		
Chalcopyrite		
Gold		
Texture		Fine-grained, colloidal, xenomorphic platy

Genesis : Hydrothermal

Size : The size of this ore occurrence is still unknown.

**Tin**

Tin mineral in Nam Pa Ten valley has been known since along time. Traces of old mining works by Chinese were discovered in Nong Xun to date back to the middle of XII century. Then in the last year of last century the French geologists of Xeemi and Xerem groups came to Nam Pa Ten to carry out their survey.

In the twenties of this century, Xeemi Group extracted tin in Phon Tiou mine, whereas Xerem Group did in Nong Xun and Bo Neng mines (1928-1929). After that period, studies have been carried out continuously at various scales by geologists.

In 1975-1980 Boxaykham Vongdara made his Doctoral thesis "Geology, mineralogy and genesis of Nam Pa Ten tin deposit".

In 1977 a group of mining geologists of the USSR Ministry of Geology headed by Phominyk A. F, Pavlov A.V carried out an investigation on mineral raw materials in Laos such as copper, tin, gold. They reported that the tin reserve in Nam Pa Ten was about 80,000t, of which 10,000-20,000t were proved and 20,000-60,000t were inferred.



In the exploration (1984) the reserve categories in Nam Pa Ten valleys were evaluated as follows:

Reserve categories	Reserve	
	Ore (thousand tons)	Tin (tons)
C <sub>1</sub>	2,187	6,220
C <sub>2</sub>	7,516	15,030
C <sub>1</sub> + C <sub>2</sub>	9,703	21,250
Prognostic resource	20,332	49,800
C <sub>1</sub> + C <sub>2</sub> + Prognostic resource	30,032	71,000

At present, tin ore mining in Phon Tiou and Bo Neng mines is carried out in joint venture with People's Democratic Republic of Korea and Russian Federation.

In 1996-2000, when carrying out the 1:200,000 scale survey and geological mapping of the Mid Central Lao region we did not do any thing more in this area.

The tin deposits in Nam Pa Ten valley are characterized by the tin-sulfide ore type. Especially investment has been made for rather detailed investigation in some deposits such as Phon Tiou, Bo Neng, Nong Xun, of which Phon Tiou and Bo Neng deposits are most typical.

#### **Phon Tiou tin deposit (62)**

Phon Tiou tin deposit belongs to the group of deposits in Nam Pa Ten valley. It is located about 1.5km SW of B. Phon Tiou, in Hin Boun district, Khammouan province, with geographic coordinates :

17°52'55" North latitude

104°36'05" East longitude

As mentioned above, the area of Phon Tiou deposit has interested geologists since a long time. At present the tin ore in this deposit is mined by a joint venture with a mining company of PDR of Korea to serve the economic development of Laos. The tin ore mining output in 1984 was 400 thousand tons of ore; in 1986 : 744.24 thousand tons.

Phon Tiou deposit is located in the Southern half of Nam Pa Ten valley, on the eastern slope of Phou Toun - Phou Soung mountain range. The area of this deposit is 4km<sup>2</sup>.

In their exploration the Soviet group of geologists (1984) implemented a fairly large amount of works, comprising : geological walking survey : 130 km of; drilling : 65 boreholes. The results show that the geological structure of the deposit is very complicated. It is composed of an alternation of layers of siltstone, arkosic sandstone aged T<sub>2</sub> (?), rarely intercalated with calcareous shale layer.

These sequences are 1-1.5km wide, forming two large anticlines at the top of Phon Toun and Phon Soung. The axial plane of the folds has NW-SE trend and dip NE. NE-SW trending and sub-meridian fault systems are fairly well developed. They are ore controlling and conducting channels in the area.

Along Phon Tiou-Bo Neng fault are concentrated arkosic sandstone and siltstone with development of veins and stockworks of quartz - sulfide of crossing and filling types. The thickness of the veins is from a few mm to 1.5m, they are oriented in meridian direction, with dipping angle nearly horizontal. As observed in quarries, quartz veins cross the milonite breccia layers forming breccia-quartz-sulfide beds. Here the tin content increases abruptly. In the condition of alteration brown ferruginous breccia is formed with fairly wide development within the ore field of the deposit.

The zone of quartz - sulfide veins also show clear geochemical anomalies with Sn = 0.01-1.0%. The length of the anomaly is up to 1.8km.

According to the calculations data, the occurrence depth of the tin mineralization zone is 3-5m to 30m.

The analysis results show that the tin grade of the ore varies greatly : Sn = 0.01-1%, in average 0.24 %.

The explored reserve of C<sub>1</sub> + C<sub>2</sub> categories of the deposit is :

Ore reserve : 5,689 thousand tons

Tin reserve : 10,980 t

Prognostic resource :

Ore : 4,400 thousand tons

Tin : 14,400 t

With the above reserve, according to the classification of deposits this deposit is a large one

### **Bo Neng tin deposit (58)**

Bo Neng tin deposit is located in the NE of Nam Paten valley, within B. Bo Neng, in Hin Boun district, Khammouan province, with geographic coordinates :

17°57'40" North latitude

104°35'15" East longitude

Since a long time, this deposit has been paid attention by many geologists. In 1979, this deposit was subjected to evaluative prospecting within an area of 1.4 km<sup>2</sup>. In 1980-1983, integrated evaluative prospecting works were carried out, consisting of the following works :

- Prospecting field trips
- Compilation of secondary geochemical map
- Electrical (self potential) and magnetic survey
- Trenching, pitting

- Core drilling
- Collection of various samples in the open pit mining areas and excavations

So far, a tin ore processing plant has been built 1.5 km SW of B. Bo Neng.

According to the data from the prospecting and exploration work, the Bo Neng deposit is located within Phou Mai Khien anticline in the NE of the area. The deposit is located at the boundary between the sub-volcanic rock (rhyolite) and the broken zone of Phon Tiou- Bo Neng fault.

The deposit is composed of terrigenous - carbonate rocks aged  $D_{1-2}$ ,  $C_1$ ,  $C-P_1$ ,  $T_2$  (?) and sub-volcanic rocks aged Triassic (T) with mainly acidic composition. Unconsolidated formations consist of cobbles, pebbles, gravel of Quaternary system (Q).

Sub-volcanic formations related with the mineralization include rhyolite, dacite and andesite of flow, fracture and interbed types, of which the most common is rhyolite of phase II (?).

The boundary between extrusive rocks and terrigenous sediments is unclear, as the weathering process here occurred intensively.

The fault systems in the area are fairly well developed, playing an important role in the ore forming process

The NW-SE trending fault system is relatively steep, related with quartz veins containing sulfide and gossans.

The NE-SW trending fault system is younger, displaced and destroyed geological structures.

Inside the area of the deposit are gently dipping fault systems. This system plays mainly the "ore controlling" role. It is related with a breccia layers. Its petrographic components of the breccia are sandstone, siltstone, rhyolite, quartz. The bottom and the top of the breccia are fractured, being the favorable environment for the concentration of ore with considerable thickness. Here hydrothermal processes such as greisenization in rhyolite kaolinization, quartzification are fairly well developed.

Tin mineralization in Bo Neng deposit is related with practically all geological formations except limestone, comprising veins, stockworks of quartz - sulfide. The main sulfide minerals are pyrite, arsenopyrite, chalcopyrite, galena sphalerite, rarely pyrrhotine, bismuthine.

The average tin grade is 0.21 %.

The explored reserve categories of the deposit are :

Reserve categories	Reserve	
	Ore (thousand tons)	Tin (tons)
$C_1$	374	1,941
$C_2$	1,515	3,338
$C_1 + C_2$	2,389	5,279

C <sub>1</sub> + C <sub>2</sub> + Prognostic resource	5,118	11,579
---	-------	--------

According to the mineral deposit classification table, the Bo Neng deposit is classified as a large deposit.

Tin in the area of Nam Paten valley has a large reserve potential. Most of deposits have been subjected to prospecting and exploration, and mining has been conducted in some areas.

The results of exploration show that: the tin grade in the area is not high but the ore bearing strata have a great volume. Here the tin ore has close relationship with:

- Fault systems, especially those with gentle dipping usually forming crushed zone being the favorable environment for concentration of ore bodies and veins.
- Sub-volcanic rocks with acidic composition (rhyolite, dacite, andesite).

These are the scientific bases for orienting the prospecting and evaluation of tin ore in the area as well as in neighboring areas.

### **Gold**

Gold is widely distributed in the study area. 14 ore occurrences and ore shows have been registered on the minerals resources map. Besides gold placer Nakadok which had been dug and panned by the local people before, nearly all of ore occurrences were discovered for the first time. Also for the first time.... gold dispersion haloes have been delineated.

Three type of gold ore have been discovered in the area:

- Gold-bearing quartz-sulfide type includes the ore occurrences : Nam Ke (35), Nam Houay (46), Nam Pheo (63), Linh Nho (57), Xoklek (60), Sop Chat (16), Phongnot (23), Phonkham (20). Typical for this type are Nam Ke and Nam Houay ore occurrences.
- Gold-bearing pyrite type (see in detail the Phon Xai pyrite ore occurrence).
- Placer gold type : Nakadok ore occurrence. This is unique ore occurrence paid attention by many geologists and has been dug and panned by local people.

Below are descriptions of some typical ore occurrences

#### **H. Namke gold ore occurrence (35)**

H. Namke gold ore occurrence is located in B. Na Nang and B. Pong Xang, Kham Keut district, Bolikhamxay province, with geographic coordinates :

18°14'22" - 18°12'08" North latitude

105°05'08" - 105°06'40" East longitude

The elevation in this area is 600-1,200m. The degree of denudation and destruction is high. The river and stream network is developed and flows nearly round the year. The transportation in the area is relatively favorable. From Laksao there is a road to the ore occurrence. The population is composed mainly of Lao Lum people. They live mainly on agriculture. The cultural standard of the people is low. The ore occurrence was discovered during the process of 1:200,000 scale mapping of the "Mineral Investigation and Geological

Mapping at 1:200,000 scale of Mid Central Laos region". In 1996 the panning team of Mr. Vu Quynh discovered a high grade gold dispersion halo ad quartz - sulfide boulders in the area.

In November 1997, Ha Xuan Binh and Kengchan Xenxathit carried out general prospecting at 1:25,000 scale and detailed prospecting at 1:10,000 scale with the following work quantities :

- General prospecting area at 1: 25,000 scale : 50 km<sup>2</sup>
- Detailed prospecting at 1: 10,00 scale : 12 km<sup>2</sup>
- Walking geological survey : 96.45 km
- Collection of samples :
  - Detailed panning samples : 140 samples
  - Slope geochemical samples : 387 samples
  - Petrologic samples : 569 samples
  - Thin section samples : 124 samples
  - Spectrometric samples : 240 samples
  - Mineralogical samples : 47 samples
  - Radiometric dating samples : 01 samples
  - Fire assay samples : 72 samples
  - Bed rock panning samples : 72 samples
  - Geophysical parameter samples : 50 samples
- Geophysical work
  - Preparation of geophysical lines : 8.8 km
  - Magnetic survey : 1,940 points
  - IP VES : 20 points
  - IP profiling : 1,828 points
  - Self potential survey : 1,990 points
- Excavation:
  - Trenching : 96.55 m<sup>3</sup>
  - Cleaning of outcrops : 350 m<sup>3</sup>

The ore occurrence is located on a limb of Nape - Nam Cham - Nam Sang anticlinorium in the broken zone of the I-order fault and II-order fault systems. In the area are developed the rocks of Nam Houay formation (O<sub>3</sub>-S<sub>1</sub> *nh*) (Fig.79), consisting of the following sub-formations :

- Lower sub-formation (O<sub>3</sub>-S<sub>1</sub> *nh*<sub>1</sub>) : consists of grey clay shale, clay-sericitic schist, intercalated with layers of black grey medium bedded siltstone, silty sandstone. Being in contact with the granite of Nape (γδ a C<sub>1</sub> *np*) complex, the rocks are strongly hornfelsified.

- Middle formation ( $O_3-S_1 nh_2$ ) : is composed of greenish grey sandstone, quartzitic sandstone, sericitic schist, siltstone, tuffaceous sandstone.

In general the rocks dip monoclinaly toward SW with dipping angles 20-40°, in some places locally crumbled and folded.

The Quaternary system is distributed along Nam Pheo valley and form alluvial fans at the stream outlets. with different composition in the two parts :

- The upper part consists of cobble, pebbles, sand with black brown, yellow grey color. 2-4 m thick.

- The lower part is composed of cobble, boulders weakly bound by clay, sand, ferruginous laterite, 1-2.5m thick, containing placer gold.

The rocks of Nam Houay formation ( $O_3 - S_1 nh$ ) are strongly destroyed by fault systems, of which the NW-SE trending landforms system plays the ore controlling role. The sub-meridian and sub-latitudinal fault systems form sheared and altered zones with development of gold bearing quartz-sulfide veins and stockworks. These two fault systems are related with the ore formation process in the area. The main hydrothermal alteration process in the area include sericitization, chloritization, quartzification.

As a result of prospecting here in the sheared and altered zones of the sub-meridian and sub-latitudinal fault systems are developed two systems of gold-bearing quartz-sulfide veins :

- Vein system developed in the sub-latitudinal broken zone : consisting of quartz - sulfide veins and stockworks with thickness 0.1-1.2m thick. The quartz is of white, smoky color, color, strongly broken and fractured. Sulfide minerals fill the fractures, disseminated in the form of pockets in quartz geodes and druses and constitutes >10%. Ore minerals include arsenopyrite, pyrite, sphalerite, chalcopyrite, galena and native gold. Quartz veins have large dipping angle, 60-80°. Adjacent to quartz veins are usually alteration zones with sericitization, chloritization, with dissemination of sulfide minerals.









The result of fire assay of gold gives Au = 1.0-24g/t, bed rock panning give 5-500grains/7kg. Especially at outcrop 7435 B and trench 702 the fire assay gave 62-24g/t, and bed-rock panning gave 400grains/7kg to 0.18g/7kg. The result of spectrometric analysis gave: As = 0.1-1%, Cu = 0.001-0.03%, Pb = 0.002-1%, Zn = 0.01-1%.

- Vein system developed in the sub-meridian broken zone: consisting of quartz - sulfide veins and stockworks with thickness 0.2-3m thick. The quartz is of muddy white, milky white color, strongly broken and fractured. Sulfide minerals constitute ≤ 5%, filling the fractures and disseminated in quartz. Ore minerals include are mainly fine grained pyrite, followed by arsenopyrite, chalcopyrite, galena and native gold. Quartz veins have low dipping angle, 30-50°. Some veins penetrated the bedding plane.

The result of fire assay of gold gives Au = 0.4-6g/t, bed rock panning give 1-185grains/7kg. The result of spectrometric analysis gave : As = 0.01-0.3%, Cu = 0.001-0.007%, Pb = 0.001-1%, Zn = 0.02%.

The result of mineralogical analysis gave the following sequence of mineral formation :

N	Ore minerals	Forming period
1	Quartz	_____
2	Arsenopyrite	_____
3	Pyrite	_____
4	Sphalerite	_____
5	Chalcopyrite	_____
6	Gold	_____
7	Galena	_____
8	Limonite	_____
9	Scorodite	_____

Ore minerals are of disseminated, pocket, micro vein, banded structure, fairly well idiomorphic and usually limonitized and scoroditised. There native gold is usually in paragenesis with sphalerite and chalcopyrite. Native gold is in nugget, flake, dendritic forms of golden yellow color. The size of gold nuggets varies from (0.05 x 0.05mm) to (0.7 x 0.2mm). As a result of mineralogical analysis of sample TL.743b/3, 2 gold nuggets of with size 0.1-0.2mm were met in contact with sphalerite and chalcopyrite.

The above gold bearing quartz - sulfide veins are developed mainly in two zones within the study area :

Zone 1 : Is distributed in the South and SW of peak 1127, in the sediments of O<sub>3</sub>-S<sub>1</sub> nh<sub>1</sub> sub-formation. Here 10 gold bearing quartz-sulfide veins and vein systems have been discovered.

(Summary table No 18). In the mean time the results if detailed alluvial panning gave 1-32grains/5dm<sup>3</sup>.

Zone 2 : Is distributed SE of peak 1085. in the sediments of O<sub>3</sub>-S<sub>1</sub> *nh*<sub>2</sub> sub-formation. Most of detailed panning samples have gold, from 1 to 150 grains/5 dm<sup>3</sup>, in exceptional samples reach 4.45-15.8mg/5dm<sup>3</sup>. Here 14 gold -bearing quartz - sulfide veins and two crushed and altered zones (TL.7535 and VL7824 with development of quartz-sulfide-gold veins have been discovered (Summary table No 18). In the mean time, as a result of geophysical survey, 7 anomalies characterised by the following geophysical parameters have been discovered :

At the  $\rho_k \sim 2000 - 1000 \Omega m$

$\eta_k \sim 5 - 10\%$

The geophysical anomalies are 50-180m wide, 500-1,200m. They are mainly developed in sub-latitudinal direction. In the mean time the result of interpretation of IP VES curves show that the anomalies exists to the depth of over 100m. Besides these two zones, individual quartz-sulfide-gold veins are met scattered in the area (Fig. 80).

As a result of fire assay analysis gave Au: 6g/t; bed rock panning gave 1-35grains/7kg. In general, this is a promising ore occurrence. As a result of analyzing 43 fire assay samples, is of 36 samples contained gold, constituting 83%. Of which the samples with Au < 1g/t accounts for 21%, those with Au = 1-5g/t accounts for 37%, those with Au = 5-20 g/t account for 18%, those with Au > 20g/t account for 7%. As a result of bed rock panning, 52 of 59 samples contain native gold, accounting for 88%, where samples with Au = 1-5grains/7kg account for 49.1%, those with Au 5-20grains/7kg account for 15.20%, those with Au > 25-500grains/7kg account for 23.7%. The result of spectrometric analysis of bedrock gave a contents of As = 0.1-1%.

This ore occurrence has relatively geographic location and transportation conditions. Although the quartz - sulfide - gold ore bodies have small thickness, they are relatively well concentrated and have high grade. Besides primary ore, gold placers have also been discovered. Therefore this is area is very promising in gold, it require investment for prospecting in further stages.

Summary table of ore bodies and their analysis results

Table 18

N	Sample No	Ore minerals composition	Analysis results		ness thick body	Rema rks
			Gold content	Spectrometric (%)		

			Fire assay (g/t)	Bed rock panning grain/7 kg	As	Cu	Pb	Zn		
1	VL.7857	Pyrite, arsenopyrite, sphalerite, galena		2	0.3	0.007	1	0.02	0.25	
2	VL.7802 A	Pyrite, arsenopyrite, sphalerite, chalcopyrite, galena	1.2		0.3	0.001	0.1	1.02	0.1-0.4	
3	VL.7800	Pyrite, arsenopyrite, sphalerite, chalcopyrite, galena	1.0	185	0.3	0.001	0.007	0.01	0.1-0.3	
4	VL.7799 A	Arsenopyrite, pyrite, galena		2	0.1	0.005	0.05	<0.01	0.1-0.3	
5	VL.7896 B	Arsenopyrite, pyrite, chalcopyrite		1	0.07	0.002	0.1	0.1	0.6	area 1
6	VL.7896 A	Pyrite, arsenopyrite, chalcopyrite, galena		5	0.01	0.005	0.005	<0.01	0.2	
7	VL.7496 B	Pyrite, sphalerite, galena	1.1	1	0.05	0.007	0.007	<0.01	0.25	
8	VL.7496 A	Arsenopyrite, pyrite, sphalerite, galena	1.6	2					0.25	
9	VL.7495/1	Pyrite, chalcopyrite, galena		1					0.3	
10	VL.7495	Pyrite, arsenopyrite, chalcopyrite, sphalerite, galena	0.8	51	0.07	0.03	0.002	0.01	0.2	
1	VL.7827	Pyrite, arsenopyrite, galena, sheelite		2					1.6	
2	VL.7450	Pyrite, arsenopyrite, chalcopyrite		4					0.1-0.5	
3	VL.7824	Arsenopyrite, pyrite, tourmaline	1.15	1,257	1	0.001	0.03	0.01	3.0	
4	VL.7535	Arsenopyrite, pyrite, galena, sielite	4.0	6	0.3	0.001	0.003	0.01	2.0	
5	VL.7439	Pyrite, arsenopyrite, galena, sielite	0.8	6	0.15	0.002	0.002	0.01	0.7	

N	Sample No	Ore minerals composition	Analysis results						Ore body thickness (m)	Remarks
			Gold content		Spectrometric (%)					
			Fire assay (g/t)	Bed rock panning grain/7 kg	As	Cu	Pb	Zn		
6	VL.7504	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena	11.0	500	0.7	0.005	0.5	0.2	0.2	
7	VL.7503	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena	2.12	4;65	0.3;0.5	0.001	0.02	0.001	0.25	
8	VL.7436	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena, Gold	2	20	0.15 - 1.2	0.03	0.01	0.5	0.7	area 2
9	VL.7436	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena	4;24;63	55;0.06g;0.18g					0.3	
10	H.702 (TL.7466)	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena	10;8;6;24	7;5;6;400	0.3;0.5;0.7	0.02	0.2-1	0.01-1	1.2	
11	TL.7467	Arsenopyrite, pyrite, chalcopyrite,	5;5;4	10; 30; 26	0.1 - 0.5				0.7	
12	TL.7380	Pyrite, arsenopyrite, galena		2					0.5-3	
13	TL.7432	Pyrite, arsenopyrite, galena	1	7	0.2	0.007	0.007	0.01	2	
14	TL.7430/1	Pyrite, arsenopyrite, chalcopyrite sphalerite, galena		1	0.03	0.001	0.001	0.01	0.5	
15	TL.7453	Arsenopyrite, pyrite, sphalerite, chalcopyrite, galena	2;4;11; 2.8	200;11; 500;70	0.2;0.5; 1;1	0.005	0.03	0.015	0.7	
16	TL.701	Pyrite, arsenopyrite	0.4	1					1	
17	TL.7756	Pyrite, arsenopyrite, galena		1	0.15	0.005	0.001	0.01	0.2	

N	Sample No	Ore minerals composition	Analysis results						Ore body thickness (m)	Remarks
			Gold content		Spectrometric (%)					
			Fire assay (g/t)	Bed rock panning grain/7 kg	As	Cu	Pb	Zn		
18	TL.7357	Pyrite, arsenopyrite, chalcopyrite sphalerite, galena	6	2;35						
19	TL.7387	Pyrite, arsenopyrite, galena		2					1.4	
20	TL.7835	Pyrite, arsenopyrite, chalcopyrite		2					1	
21	TL.7349	Pyrite, chalcopyrite, arsenopyrite, cassiterite		2					0.15	

#### **Nam Houay gold ore occurrence (46)**

This ore occurrence is located in B. Nam Houay, Nam Veo commune, Kham Keut district, Bolikhamxay province (Fig. 81), with geographic coordinates :

18°06'15" - 18°07'20" North latitude

105°07'56" - 105°10'45" East longitude





This is a high mountain area, with dissected topography. The maximum elevation is 1,085m, minimum 600m.

From Laksao there is a relatively good road to B. Nakadok, further to the ore occurrence with a distance of 2 - 3 km the materials and equipment must be carried by people or horses.

This ore occurrence was newly discovered during the 1: 200,000 scale. At the end of 1996, the prospecting team headed by Vu Van Chuong carried out detailed prospecting with the following work amount:

- Detailed prospecting : 15 km<sup>2</sup>
- Collection of samples :
  - Slope geochemical samples : 530 samples
  - Petrologic samples : 257 samples
  - Thin section samples : 65 samples
  - Spectrometric samples : 100 samples
  - Mineralogical samples : 20 samples
  - Bed rock panning samples : 57 samples
- Geophysical work
  - Magnetic survey : 1889 points
  - IP survey : 1932 points
  - Self potential survey : 1970 points
  - IP VES : 22 points
- Excavation:
  - Trenching : 115.5 m<sup>3</sup>
  - Cleaning of outcrops : 257 m<sup>3</sup>

Within the prospecting area are developed mainly the rocks of three sub-formations of Nam Houay formation (O<sub>3</sub>-S<sub>1</sub> *nh*) :

- Lower sub-formation (O<sub>3</sub>-S<sub>1</sub> *nh*<sub>1</sub>) : consists of quartz sericitic schist, sericitic schist, sandstone. The rocks are of monoclinial attitude, dipping WNW at 35-50°.
- Middle sub-formation (O<sub>3</sub>-S<sub>1</sub> *nh*<sub>2</sub>) : is distributed in the central part of the area, composed of sandstone, siltstone, silty sandstone, tuffaceous sandstone, sericitic schist. The rocks have foliated structure, crystalloblastic and micro-lepidoblastic texture. The rocks have monoclinial attitude, not much displaced.
- Upper sub-formation (O<sub>3</sub>-S<sub>1</sub> *nh*<sub>3</sub>) : is distributed in the western part of the area, composed of sandstone, siltstone, sericitic schist, dolomite-sericitic schist. The rocks have foliated structure, micro-lepidoblastic granular texture.

Two fault systems are developed : sub-meridian and sub-latitudinal.

- The sub-meridian fault system is relatively well developed in the area. This fault system not only has broken and altered the rocks, but also plays an important role as a channel to form ore bodies.

- The sub-latitudinal fault system has displaced the structures.

Based on the properties and characteristics of the mineralization, the study area is divided into two areas: Nam Houay and Houay Ha.

+ Nam Houay area : the mineralization here is characterized by two types of ore: the gold bearing quartz - sulfide ore and the gold -bearing sulfide ore disseminated in altered zone.

- Quartz - sulfide - gold type : Consists of quartz vein, vein zones crossing or occurring in conformity with the country rocks with dipping angle 40-50°. The quartz is of white, ivory white color, impregnated with sulfide, when weathered has a motley brown color. The veins have thickness varying from 0.2 to 1.5m. Ore minerals include pyrite, arsenopyrite, chalcopyrite, galena, sphalerite and native gold. Non ore minerals include only quartz.

- Gold - bearing sulfide ore type disseminated in altered zone: is closely related with the fault system in the area. Sandstone, gravelite, schist are relatively strongly broken and altered. Ore minerals include: pyrite, arsenopyrite, galena, sphalerite, tourmaline, hematite and gold.

The summary result of analysis are shown in table 19

Result of sample analysis in Nam Houay - Houay Ha area

Table 19

N	Samples No	Geological characteristics	Nam Houay		Houay Ha	
			Au fire assay (g/t)	Au Pannin g, grain	Au fire assay (g/t)	Au Pannin g, grain
1	H-2-M- 1	Arkosic sandstone, altered and broken, containing disseminated sulfide in small pocket form			5.0	
2	H-2-M- 2				1.0	
3	H-2-M- 3					1
4	H-2-M-6				2.0	
5	H-2-M- 8				1.0	
6	H-2-M- 10				1.2	
7	H-2-M- 13					40
8	H-2-M- 14				0.4	
9	6138/2				2.0	
10	6155/1	Quartz-sulfide vein	0.2			
11	6161/2	Quartz-sulfide vein	0.2			

N	Samples No	Geological characteristics	Nam Houay		Houay Ha	
			Au fire assay (g/t)	Au Pannin g, grain	Au fire assay (g/t)	Au Pannin g, grain
12	6205	Quartz-sulfide vein	0.0			
13	6216/3	Quartz-sulfide vein	0.3			
14	6348	Quartz-sulfide vein	2.0			
15	6374	Quartz-sulfide vein	0.4			
16	6378	Quartz-sulfide vein	0.0			
17	6384	Quartz-sulfide vein	1.0			
18	6387	Quartz-sulfide vein	1.2			
19	6390	Quartz-sulfide vein	0.0			
20	6405	Quartz-sulfide vein	0.8			
21	6437	Quartz-sulfide vein	0.2			
22	6531/1	Impregnated quartz vein zone	0.8	30		
23	6531/2	Broken and altered sandstone		1		
24	6533	Quartz-sulfide vein	1.2	1		
25	6550/1	Altered arkosic sandstone		6		
26	6552/1	Quartz-sulfide vein		1		
27	6580	Broken quartz vein		3		
28	6596	Sericitic schist disseminated with sulfide		5		
29	6690/1		0.4	3		
30	6706	Altered sandstone and gravelite, disseminated with sulfide		1		
31	6710	Altered arkosic sandstone impregnated with sulfide pockets		4		





Geophysical survey in Nam Houay area has determined the existence of two anomalies characterized by the following values (Fig. 82<sup>a</sup>) :

- Anomaly 1 : From line -II to line +II, 900m long, 40-50m wide, with the polarization value  $\eta_k$ : 10-3% on the background of 7-8%, resistivity  $\rho_k$  : 2000-5500 $\Omega$ m on the background of 500-1000 $\Omega$ m

- Anomaly 2 : is located in the central part of the area, extending from line -I to +II. Its characteristics are : polarization value  $\eta_k$ : 8-10% on the background of 5-6%, resistivity  $\rho_k$  : 2000-5500 $\Omega$ m on the background of 500-1000 $\Omega$ m.

+ Houay Ha area : Is located in the NW of the study area. Here exists a strongly altered broken zone, extending in NE-SW direction, with a length of about 900m and a wide of 60-140m. The sandstone and arkosic sandstone are weakly metamorphosed, impregnated with sulfide minerals. The ore mineral assemblage are : pyrite, pyrrhotine, chalcopyrite, arsenopyrite, galena, sphalerite, of which arsenopyrite is low, pyrrhotine and chalcopyrite are higher.

Geophysical survey has determined the existence of three anomalies characterized by the following values (Fig. 82<sup>b</sup>) :

- Anomaly 1 : Is located in the central part from line +II to line -II, 900m long, 60-140m wide, characterized by the polarization value  $\eta_k$  : 5-8% on the background of 3-4%, low resistivity about  $\rho_k$  : 1000-2000 $\Omega$ m.

- Anomaly 2 : is located on the positive (+) side of the geophysical lines, 700m long, 20-80m wide. It is characterized by: polarization value  $\eta_k$  : 5-7% on the background of 3-4%, resistivity  $\rho_k$  : 1000-1500 $\Omega$ m.

- Anomaly 3 : Is located on the negative side of the geophysical lines, 700m long, 40-60m wide, extending from line + II to line - I. It is characterized by the polarization value  $\eta_k$  : 4-5% on the background of 2-2.5%, resistivity  $\rho_k$  : 1500-2500 $\Omega$ m on the background of 1000 $\Omega$ m.

The Nam Houay ore occurrence is located in the structural plan favorable for ore formation. The magmatic rocks of Nape complex ( $\gamma\delta$  a  $C_1 np$ ) are widespread, fault systems are developed in many directions, forming broken zones favorable for mineralization with hydrothermal genesis. The sediments of Nam Houay formation ( $O_3$ -  $S_1 nh$ ) are the environment favorable for the ore to exist. Therefore investment should be made for the investigation in the next steps.

### **Nakadok placer gold ore occurrence (43)**

This is the unique placer gold ore occurrence in the area, located within B.Nakadok, Nam Veo commune, Kham Keut district, Bolikhamxay province, with geographic coordinates:

18°08'07" - 18°09'26" North latitude

105°06'48" - 105°09'45" East longitude

This ore occurrence had was mined by the French long time ago. The remaining traces are old shafts and drifts. Later, Soviet, Australian, British and Vietnamese geologists came to carry out surveys but have not left any documents.

In 1987, the geological team of INTERGEO Division (Vietnam) came here to make test mining during 23 days, obtained 550 g of gold. Nowadays the local people still come sparsely to dig and pan for gold along Nam Kata and Nam Houay streams.

In November 1996, the prospecting team headed by Trinh Xuan Hieu carried out detailed prospecting with the following work amount :

- Walking survey : 28.04 km
- Collection of samples :
  - Petrologic samples : 117 samples
  - Thin section samples : 29 samples
  - Areal panning samples:24 samples
  - Site panning samples : 139 samples
- Excavation :
  - Trenching : 4.6 m<sup>3</sup>
  - Shafting : 137.97 m
  - Cleaning of outcrops : 72.99 m<sup>3</sup>

The result of detailed prospecting here shows that the gold-bearing placer bodies occur along Nam Kata and Nam Houay streams (Fig.83). Gold is concentrated in the following sediments :

- Former river channel placer (mixed deluvial - proluvial - alluvial sediments).
  - Contemporary placer (alluvial sediments)
- + Former river channel placer (mixed) is mostly in the second terrace of Nam Kata. The sediments in downward sequence are as follows:
- 0-4m : Sand, sandy clay, in some places intercalated with thin lenses of cobble, gravel
  - 4-6m : Cobbles, gravel, sand mixed with some clay.
  - 6-6.4m : Productive layer, with thickness varying from 0.1 to 0.4m, composed of cobble, gravel, sand, directly overlying the bedrock. The cobbles are composed mainly of granite, quartz (accounting for 60-70%). Gold is usually highly concentrated close to the surface of the bed rock, especially in the open fractures of the bedrock (with depth 0.2-0.4 m).

Under this category there are 7 ore bodies

- Ore body No 1 : is located next to B. Nakadok, 600m long, 70m wide, controlled by shafts G.1, G.2, G.3. The thickness of the productive layer is 0.2-0.25m. The average Au grade is : 7.2g/m<sup>3</sup>. In particular in G1 the Au grade is 15.62g/m<sup>3</sup>. Also in this shaft there was a gold nugget of 2.25g. Gold is in the form of thin sheet, rugged, angular, the size usually  $\geq$  1mm.





The prognostic resource for ore body No 1 is 45.36 kg.

- Ore body No 2 : is located in the west of the study area, next to B. Gnoyhai, 400m long, 50m wide, controlled by shafts G.14, G.18, G.22. The thickness of the productive layer is 0.2m. The average Au grade is :  $2.55\text{g/m}^3$ , with few sudden changes. Gold is found in nearly all panned samples.

The prognostic resource for ore body No 2 is 10.44 kg.

- Ore body No 3 : is located next to B. Na Fuang, 600m long, 50m wide, controlled by shafts G.4, G.5, G.16. The thickness of the productive layer is 0.3m. The average Au grade is :  $1.96\text{g/m}^3$ .

The prognostic resource for ore body No 3 is 7.64 kg.

- Ore body No 4 : is located North of B. Gnoyhai, ~ 200m long, 50m wide, at the depth of 6.5-6.8m, controlled by shafts G.15 and G.17. The average Au grade is :  $2.18\text{g/m}^3$ .

The prognostic resource for ore body No 4 is 4.66 kg.

- Ore body No 5 : is located South of B. Na Fuang, 500m long, 50m wide, at the depth of 68m, controlled by shafts G.6, G.7, G.19. It is 0.9-1.6m under the water level of the stream. The thickness of the productive layer is 0.2m. The Au grade is :  $3.63\text{g/m}^3$ .

The prognostic resource for ore body No 5 is 18.15 kg.

- Ore body No 6 : is located East of B. Na Fuang, along the right bank of Nam Kata stream, 500m long, 50m wide, at the depth of 6.1m, controlled by shafts G.9, G.10. This placer ore occurrence has been dug and panned by the local people. The average Au grade is :  $3.63\text{g/m}^3$ .

The prognostic resource for ore body No 6 is 16.13 kg.

- Ore body No 7 : is located on the right side of Nam Houay stream, 200m long, 30m wide, at the depth of 4.5m, controlled by shafts G.8. The average Au grade is :  $2.66\text{g/m}^3$ .

The prognostic resource for ore body No 7 is 2.4 kg.

The prognostic resource of the above 7 placer ore bodies (from body No 1 to body No 7) is 114,98 kg of gold.

+ Contemporary placer (alluvial sediments)

Of this category there are 3 placer ore bodies distributed along Nam Houay in W-E direction. The downward stratigraphic sequence is as follows :

- 0-2.3m : Mainly cobbles, composed of sandstone, quartz, schist, poorly rounded,

- 2.3-2.5m : Productive layer overlying directly the surface of the bedrock. The productive layer is completely under the water level in the stream, causing difficulties for investigation and exploitation in the future. The sediments are mainly composed of cobbles (accounting for 600 %), gravel, sand. The gold nuggets in this productive layer is usually sharp-edged, rugged, irregular, 0.5-2mm in size.

- Ore body No 8 : is located on the left side of Nam Houay stream, 200m of B. Nong Nao 200m. It is 200m long, 20m wide, at the depth of 2.5m. The productive layer is 0.2m thick. The Au grade is :  $4.63\text{g/m}^3$ .

The prognostic resource for ore body No 8 is 4.53 kg.

- Ore body No 9 : is located at 900m SE of B. Nong Nao. It is 150m long, 20m wide, at the depth of 2.0m. The productive layer is 0.3m thick. The Au grade is : 4.63g/m<sup>3</sup>.

The prognostic resource for ore body No 9 is 4.17 kg.

- Ore body No 10 : is located at 1.4km SE of B. Nong Nao. It is 250m long, 20m wide, at the depth of 2.0m. The productive layer is 0.4m thick. The Au grade is : 4.63g/m<sup>3</sup>.

The prognostic resource for ore body No 10 is 9.28 kg.

The prognostic resource of the above 3 placer ore bodies (from body No 8 to body No 10) is 17,98 kg of gold.

The total prognostic resource for the whole area is 122.96 kg of gold. The Nakadoc gold placer is a promising ore occurrence. Most of ore bodies are higher than the stream water level, favorable for the exploitation. Although the productive layers are thin, their gold grade are high and relatively stable. Therefore small scale mining should be organized at this ore occurrence. Primary gold ore investigation in the adjacent areas is necessary to prove the gold prospectiveness in the area.

*Most of gold ore occurrences discovered in Mid Central Lao region are located in structural plan favorable in metallogenic aspect (in Nape uplifted zone). The magmatic rocks of Nape complex ( $\gamma\delta$ ,  $\gamma\alpha$  C<sub>1</sub>np) penetrated the terrigenous sediments of Nam Houay formation (O<sub>3</sub>-S<sub>1</sub>nh). Fault systems are intensively developed, breaking and altering the rocks. All of the above factors are favorable conditions for the forming process of valuable gold ore occurrences such as : Nam Ke, Nam Houay, Nam Pheo... Besides, another factor to be given attention is the sulfide which is fairly densely disseminated in the black clay schist of Boualapha (C<sub>1</sub>pb). Gold grains have been discovered in the bed rock panning samples (Nong Lieng, Pakpakan).*

*To evaluate fully the gold prospective potential, survey and prospecting should be carried out in some areas where ore occurrences, ore shows and dispersion haloes are concentrated at the scales of 1:25,000 or 1:10,000.*

### **III. Industrial minerals**

Industrial minerals in the study area are very abundant in quantity and diverse in types. They are distributed in may different stratigraphic units, closely related with fault systems in the area.

Practically all of these types of minerals have newly been discovered during the 1:200,000 scale geological survey and mapping of Mid Central Lao region.

Industrial minerals are divided into the following groups :

- Chemical and fertilizer raw material group
- Chemical and fertilizer raw material group: barite, pyrite, gypsum-anhydrite, rock salt, phosphorite, dolomite.
- Technical raw material group : Crystalline quartz,

- Ceramic raw material group : Ceramic clay
- Construction material group : Cement limestone, building limestone, cement clay, brick clay, facing stone, slate, building sand, gravel.

## 1. CHEMICAL AND FERTILIZER RAW MATERIAL GROUP

This mineral group constitute a large proportion in the study area. They account for nearly 1/2 the number of ore occurrences in the area. They are concentrated mainly in the sediments of Koduk formation ( $O_3-S_1 kd$ ), Boualapha formation ( $C_1 bp$ ), Khammouan formation ( $C-P_1 km$ ), Nong Boua formation ( $K_2 nb$ ). Ores are usually developed along tectonic broken zones and fault systems< they consist of barite, pyrite, gypsum-anhydrite, phosphorite.

### **Barite**

On the minerals resources map, two barite ore occurrences have been registered Phakat (153) and B. Hon (145). These barite ore occurrences were discovered during the 1:200,000 scale geological survey and mapping of Mid Central Lao region. The barite - galena ore type (here galena is associating mineral) characterizes the ore occurrences here, of which the Phakat ore occurrence is typical.

### **Phakat barite ore occurrence ( 153)**

This ore occurrence is located at the boundary between two administrative units, Chalet and Angkham communes, Boulapha and Vilabuli district, Khammouan and Savanakhet province, with geographic coordinates :

17°01'50" - 17°04'30" North latitude

106°08'00" - 106°10'37" East longitude

This is a high mountain area, with relatively well dissected topography, with lowest elevation 400m and highest over 1,000m.

The access to this area is very difficult. There is only one earthen road from Boulapha and Vilabuli district town. It takes one day to get there on car.

The ore occurrence was discovered by Ta Quoc Dat when he carried out 1:200,000 scale geological survey (in January 1997). In March 1998, the prospecting team headed by Trinh Xuan Hieu carried out general prospecting here (Fig. 84). The works carried out and their amount are the following:

- General prospecting area : 60 km<sup>2</sup>
- Walking survey : 72 km
- Collection of samples :



Petrologic samples	:	233 samples
Thin section samples	:	33 samples
Spectrometric bedrock samples:		52 samples
Mineralogical samples	:	13 samples
Chemical samples	:	10 samples
- Excavation	:	
Trenching	:	15 m <sup>3</sup>
Cleaning of outcrops	:	98 m <sup>3</sup>

The result of the general prospecting shows that :

- The oldest rock is that of Koduk formation ( $O_3-S_1 kd$ ), consisting of quartzitic sandstone, quartz - sericitic schist, conglomerate, breccia.
- Boualapha formation ( $C_1 bp$ ) : Black calcareous shale, siltstone, clay-sericitic schist.
- Khammouan formation ( $C-P_1 km$ ) : Light grey limestone, with medium bedded to massive structure.

Faults are developed in NW-SE direction. This is probably an important system related with the mineralization and controlling the ore bodies.

The results of prospecting show that the mineralization consists of three ore types: barite, barite- galena and polymetal.

+ Barite ore type : Four "stratiform" ore bodies of have been discovered, occurring nearly in conformity with the country rocks.

- Ore body 1 : Is controlled by trench 1 and outcrop TL17030, is largest in size. Its thickness is about 4m and its apparent length is > 100m.

- Ore body 2 : Is met at outcrop TL17012/1. It has a thickness of about 2m and a estimated length of 200m.

- Ore bodies 3 and 4 : Have a thickness of 0.4m, extended discontinuously for about 200m.

The country rocks surrounding the ore bodies are conglomerate, sandstone, siltstone. The main ore minerals include barite (93-98%), of milky white, greenish grey color, relatively heavy, less galena forming small pockets. Secondary minerals include limonite, quartz.

The result of analysis gave : BaO : 59.34%.

+ Barite galena ore type : There is a ore vein of in situ (eluvial) form, located about 3.5km NW of B. Chalet. It is extended in NW-SE direction (?), with a width > 5m (outcrop TL.17086/2 and TL.17368/1). Barite is of milky white color, forming a massive band, intercalated with augen-like lenses of galena.

Ore minerals : barite, galena, limonite. Non ore kvinclude : quartz.

The result of analysis gave : BaO : 57.07%, Pb : 18.94%, Zn : 0.02%, Ag : 23.8ppm, SiO<sub>2</sub> : 1.54%, Fe<sub>2</sub>O<sub>3</sub> : 0,095%, CaO : 0.26%, S : 12.99%.

+ Polymetal ore type :

The mineralization is located at the upper course of a small stream 3.5km North of B. Phakat, is developed in a sub-latitudinal trending broken shear zone about 5m wide. The wall rocks include fine grained quartz sandstone, sandstone impregnated with sulfide. The rocks dip SW, with relatively steep angle ( $210 \angle 40-50^\circ$ ). Ore minerals : Sphalerite of crystalline form, of black blue color, with fairly even distribution in the rock; chalcopyrite, sparsely disseminated, usually concentrated in the places poor in sphalerite. Secondary minerals : limonite, malachite of attaching form. Results of analysis : Zn : 31.66%, Cu : 1.44%, Pb : 0.007%, Fe : 3.35%.

This ore occurrence is promising, the ore bodies are extensive and good quality. Investment must be made for investigation and evaluation in the next steps.

The barite ore occurrence in the study area have been only subjected to preliminary and general in prospecting stage. However, it has been recognised that ore has fairly wide distribution and the ore bodies have relatively large size (both thickness and length) and the ore is of good quality, especially in the area of B. Hon, where barite boulders are in large number. Therefore, further investigation and evaluation of barite ore occurrences is necessary to confirm their potential.

### **Pyrite**

Six ore occurrences and ore shows of pyrite have been registered on the minerals resources map. In particular the Natoung pyrite ore occurrence had been registered by E. Saurin as an iron ore occurrence (1954).

All of the ore occurrences were discovered during the geological survey. They are closely related with the fault systems, tectonic broken zones in the area.

The typical mineralization has two types of ore :

- Gold bearing pyrite type : Phonxai ore (129), Na Toung (105) occurrences. Typical of this type is Phonxai ore occurrence.
- Weathered pyrite type : Nahy (114), Muang Khai (98) ore occurrences. Nahy ore occurrence is most typical.

### **Phonxai pyrite ore occurrence (129)**

The Phonxai pyrite ore occurrence is located in B. Phonxai, Mahaxai district, Khammouan and Savanakheth province, with geographic coordinates :

17°20'00" - 18°20'50" North latitude

105°20'40" - 105°22'20" East longitude

In this area karst topography is developed, usually forming vertical escarpment, causing difficulties for travel and for geological investigation. One can go by car along an earthen road from road No 12 to the ore occurrence, but this is very difficult during the rainy season.

During the survey for project preparation (in August 1996), a limonite ore bolder accumulation was discovered extending from Phonlek to Phonxai. Later in January 1997, the prospecting team head by geologist Ha Xuan Binh carried out a detailed prospecting of this ore occurrence (Fig. 85). The amount of works carried out include :

- Survey area : 18 km<sup>2</sup>
- Geological walking survey : 22 km
- Collection of samples :
  - Petrologic samples : 76 samples
  - Thin section samples : 9 samples
  - Mineralogical samples : 2 samples
  - Fire assay samples : 2 samples
  - Chemical samples : 3 samples
  - Slope geochemical samples: 480 samples
- Geophysical work
  - Magnetic survey : 2161 points
  - Self potential survey : 2050 points
  - IP profiling: : 1988 points
  - IP VES : 17 points
- Excavation :
  - Trenching : 17 m<sup>3</sup>

The results of prospecting show that this ore occurrence is located in the area with sediments of Boualapha formation ( $C_1 bp$ ) and Khammouan formation ( $C-P_1 km$ ).

- Boualapha formation ( $C_1 bp$ ) constitutes more than a half of the Northern part of the study area. It is composed of black grey clay schist, clay - sericitic schist, siltstone, sandy siltstone, quartzitic sandstone intercalated with lenses of weakly dolomized limestone.

- Khammouan formation ( $C-P_1 km$ ) is composed of black blue, light grey dolomized limestone. The rock is of thick-bedded to massive structure.

The sub-latitudinal fault system is relatively well developed in the area. This system plays an important role both as ore conducting channel and ore controlling factor. They usually form a broken and sheared zone, where the rocks are strongly displaced. The length of these zones are about 5 km, their wide is 100-180m, where the ore fill the fractures, forming a string of discontinuous ore bodies. The thickness of ore bodies varies from 1.5 to 5.5m, their lengths are 100-200m. They dip Southwards with dip directions 170-190° and relatively steep dip angle 75-80°. Near-vein hydrothermal alterations include dolomization, chloritization.







Based on the characteristics and properties of the ore formation, the ores are divided into two types :

- Pyrite ore bodies distributed in terrigenous sediments : clay schist, silty sandstone
- Gold bearing pyrite ore bodies related with carbonate sediment intercalated in terrigenous sediments.

The main ore minerals are pyrite, less chalcopyrite, galena. The ore has disseminated, small pocket, fine vein and massive vein structure.

In the upper part pyrite is strongly oxidized, mostly has been transformed to limonite and goethite of brown color, in many places forming gossans with typical porous, skeletal and alveolar structure.

The result of sample analysis are summarized in the following table :

N	Sample No	Chemical analysis result					Fire assay (g/t)	
		S	Fe	Cu	Pb	Zn	Au	Ag
1	TL. 7262/1	14.62	2.09	0.002	0.044	0.0074	0.4	<10
2	TL. 7262/2	16.24	14.44	0.0032	0.043	0.0009	0.4	<10
3	H. 24/2 <sup>a</sup>	4.28	4.24	0.01	0.006	0.0085		
4	H. 24/3	3.54	3.29	0.018	0.005	0.008		
5	H. 24/4 <sup>a</sup>	6.73	6.55	0.0039	0.006	0.0468		
6	H. 23/4 <sup>b</sup>	3.83	4.26	0.0048	0.01	0.0469		
7	H. 26/5 <sup>a</sup>	36.45	32.87	0.0035	0.016	0.0053		
8	H. 26/5 <sup>b</sup>	34.60	30.60	0.0032	0.036	0.0013		
9	H. 30/2	17.86	14.28	0.004	0.017	0.0871		
10	H. 20/1		46.41	0.0015	0.004	0.15		
11	H. 20/2		51.47	0.0008	0.002	0.144	0.4	<10
12	H. 23/3						0.3	<10
13	H. 26/3						0.2	<10
14	H. 26/4						0.8	<10
15	H. 29/3						1.2	<10
16	H. 33/3						2.4	<10

The geophysical survey has determined here three anomalies characterized by the following values :

- Anomaly 1 : Is located on the negative side of the geophysical lines, over 1,000m long, from line -III to line +II. It is 40-80m wide. It is characterized by high polarization value  $\eta_k$  : 2.5-6% on the background of 1-2%, resistivity  $\rho_k$  : 300-500 $\Omega$ m on the background of 300 $\Omega$ m, fairly clearly differentiated self potential, reaching the value  $\Delta V = \pm 150$  V (Fig. 86).
- Anomaly 2 : is located in the central part of the area, extending throughout the whole line system from line +V to line -VI and further in both directions of the trunk line, with a width of 80-120m. It is characterized by high polarization value  $\eta_k$  : 4-8% on the background of 2-3%, resistivity  $\rho_k$  : 500-700 $\Omega$ m and the self potential  $\Delta V = \pm 150-250$ V.
- Anomaly 3 : is located in the positive side the geophysical lines, over 1,500m long, extending from line -IV to line +III, with a width of 50-100m. It is characterized by polarization value  $\eta_k$  : 3-6% on the background of 1.5-2%, resistivity  $\rho_k$  : 300-600 $\Omega$ m on the background 200 $\Omega$ m and the self potential  $\Delta V = \pm 150$ V.

The IP VES results show clearly that in the greater depth (30-70m) the polarization increases,  $\eta_k$  : 4-8% and the resistivity decreases  $\rho_k$  : 100-300 $\Omega$ m. Thus, at great depth probably exists a large ore body with high value, it must be considered.

This ore occurrence is of value not only for its pyrite but also for its considerable gold grade. Investment should be made for further investigation. So far it has only been subjected to preliminary assessment, its prospectiveness is still unknown.

#### **Nahy pyrite ore occurrence (114)**

This ore occurrence is located within the area of B. Nahy, Mahaxai district, Khammouan province, with geographic coordinates :

17°26'35" North latitude

105°21'26" East longitude

This ore occurrence was discovered in September 1996 during the 1:200,000 scale geological survey. In April 1997, the prospecting team headed by Ha Xuan Binh carried out the general prospecting of this ore occurrence. Within the area of general prospecting, taking part in the geological structure of the ore occurrence are sediments of Boualapha formation ( $C_1 bp$ ) composed of black grey clay schist, calcareous shale, siltstone, sandstone, thin layers of siliceous limestone; Khammouan formation ( $C-P_1 km$ ) composed of light grey weakly marbled thickly bedded to massive limestone. The rocks are much fractured, the fractures are filled with secondary calcite veins. Unconsolidated sediments include: cobbles, pebbles, gravel, sand of Quaternary system (Q), forming a narrow band along rivers and streams.

Faults in the area are developed in 2 systems : NW-SE and NE-SW. These fault systems cause breakage and shearing of rocks, creating favorable conditions for the ore accumulation.

The result of general prospecting has determined that there are here three mineralization zones :

- Mineralization zone 1 : is located 5km SW of B. Nahy. The ore occurs in the sediments of Boualapha formation ( $C_1 bp$ ). The ore is in the form of boulders. The boulder sizes are from a few  $cm^3$  to  $\Phi = 20$  cm. The pyrite is in pocket form, massive, of yellow color, with metallic

luster, mostly limonitized to brown and dark brown color. Besides, scattered boulders of milky white, relatively pure quartz are also met

- Mineralization zone 2 : is located at about 2 km South of B. Nahy. The ore is also in the form of limonite boulders of yellow brown color. The zone is extended in W-E direction, near 1 km long. The country rock are of attitude  $150\angle 30^\circ$ . Trenches have proved that the limonite boulders are the in situ weathering products of primary pyrite occurring deep underground (Trench 32). The ore is of pocket, vein form, massive, with a thickness 5-20cm, occurring according to the bedding plane of the rocks. The pyrite is of light yellow color, with metallic luster, when weathered has brown, dark brown color, friable. The results of chemical analysis gave (trench 32) : S = 6.67%, Fe = 46.94%.

- Mineralization zone 3 : is located at about 2.7km South of B. Nahy. Here also exist a band of limonite boulders 300m long. The boulders are  $\Phi \leq 25\text{cm}$  in size, of yellow brown color, massive.

In trench 31 is met a limonite ore body with a thickness  $\leq 1\text{m}$ , occurring in conformity with the foliation surface of the rock, with attitude  $190\angle 55^\circ$ .

In sum, at this pyrite ore occurrence, the upper part is strongly weathered, nearly transformed into limonite and exist in the form of boulders which are closely related with the primary ore underground (trench 31, 32) and the broken zone in the area.

The general prospecting was superficial and during limited time. However, it can be remarked that the ore bodies are of small size, the ore grade is low, not able to become a commercial deposit.

### **Gypsum - anhydrite**

Gypsum is formed in Nakay and Thakhek valleys, in red color evaporite sediments of Nong Boua formation ( $K_2nb$ ).

Gypsum has been met in most of geotechnical and geological and geological exploration boreholes.

In Nakay area, Nong Boua (69) and Nakay (67) gypsum occurrences were discovered when SMEC carried out the site investigation for Nam Theun hydroelectric project. Gypsum was met in boreholes (Fig. 89). In particular Tha Lang ore occurrence was discovered by Nguyen The Viet and Nguyen Duy Thanh in 1997 when they carried out geological survey along Nam Theun valley.

In the area of Thakhek depression, Bunghouana - B. Tung (148) gypsum deposit was explored by Thai Gypsum Products Public Co. Ltd. and a reserve of 16,570,570t was reported. Also according to the calculations of this company, with an annual production of 6,000 t, the lifetime of this mine is 27 years and 7 months.

Tha Lang ore occurrence and Bunghouana -B. Tung deposit are typical for the two above mentioned depressions.





### **Tha Lang gypsum ore occurrence (64)**

Tha Lang gypsum ore occurrence is located at about 3.5km East of B. Nam Theun, in Nakay district, Khammouan province, with coordinates :

17°50'05" North latitude

105°05'00" East longitude

The ore occurrence is located in Nakay depression (Fig. 87), has NW-SE structural trend, > 30km long, 4-6km wide, distributed along Nam Theun river.

In the study area, taking part in the structure of the ore occurrence are gypsum and rock salt bearing evaporite sediments of Nong Boua formation ( $K_2 nb$ ), consisting of red, red brown claystone, mudstone; grey medium-bedded sandstone, in some places intercalated within conglomerate layers.

The ore bed occurs on the left side of Nam Theun, covered by Quaternary alluvial unconsolidated sediments (Q). The exposed part is extends along the river bank with a length of 70-80m, the portion above the water is 4m, the one submerged under water is 2m, in some places the ore is covered by 1m thick alluvium. The top and bottom of the ore bed has not been observed.

Based on the borehole data, the stratigraphic units from bottom upward include :

- The lower part is composed of grey quartz sandstone intercalated with claystone.
- The middle part is composed mainly of gypsum, anhydrite, rock salt.
- The upper part : red brown claystone, mudstone, in some places intercalated with thin gravelite and conglomerate layers.

The gypsum is of white, grayish white color, forming a fairly thick bed, with bedded, string, augen-like, massive structure, with thin layers of fine crystalline gypsum in acicular form, relatively soft, of white color, mother of pearl luster, easy to split into small sheets, filling fractures.

According to the X-ray diffraction analysis, the mineral gypsum  $CaSO_4 \cdot 2H_2O$  accounts for more than 90%. According to industrial standards, the gypsum is classified as of class I.

This is a prospective ore occurrence. Although only one outcrop has been found, the thickness of the ore bed is relatively large, maintained in the strike direction. Investment should be made further to clarify the prospectiveness of this ore occurrence.

### **B. Bunghouana - B. Tung Nam gypsum deposit (148)**

B. Bunghouana - B. Tung gypsum deposit is located in Thakhek district, Khammouan province, with coordinates:

17°07'22" - 17°10'37" North latitude

105°00'00" - 105°01'41" East longitude



In 1995, Thai Gypsum Products Public Co. Ltd. carried out prospecting and exploration in the Eastern part of B. Bunghouana - B. Tung area from peak 217 to the upstream of H. Tung (peak 182). The exploration area was 10km<sup>2</sup>. 69 exploration boreholes were drilled.

The deposit is located in the SW of the Thakhek arc-like depression, belonging to Nong Boua formation (K<sub>2</sub>nb), consisting of gypsum- and rock-salt-bearing red color evaporite.

Gypsum is exposed in two locations upstream H. Takham, whereas in most cases it is met in exploration boreholes.

Of 69 boreholes, 41 encountered gypsum, accounting for approximately 60%. In most cases gypsum is met at the depth 1.8-3m, in average 1.9m. The thickness of the ore bed is 7 - 14.5 m, in average 8.55 m (Fig. 88).

Based on the result of chemical analysis, 3 methods are used to calculate the gypsum grade :

- Using the CaO content (%) as the basis : CaSO<sub>4</sub>.2H<sub>2</sub>O (gypsum) grade is 93.35%
- Using the SO<sub>3</sub> content (%) as the basis : CaSO<sub>4</sub>.2H<sub>2</sub>O (gypsum) grade is 91.86%
- Using water content as the basis : CaSO<sub>4</sub>.2H<sub>2</sub>O (gypsum) grade is only 84.56%

The result of analysis are shown in Table 20.

### Results of chemical analysis

(Thai Gypsum Products Public Co., LTD PROJECT: Lanxang Gypsum company)

Table 20

N	Samples	CaMg (CO <sub>3</sub> ) <sub>2</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (ppm)	SiO <sub>2</sub> (%)	CaO (%)	Gypsu m (%)	SO <sub>3</sub> (%)	Gypsu m (%)	Water content (%)	Gypsu m (%)
1	2-52(1213)	1.78	1.93	4.69	31.02	95.23	42.42	91.25	18.15	86.71
2	2-52 (1718)	1.55	2.57	1.46	31.47	96.63	45.24	97.28	17.71	84.63
3	1-26 (2324)	1.52	3.35	7.90	29.81	91.52	40.12	86.29	17.30	82.65
4	1- 26 (1617)	3.15	1.10	6.25	29.68	91.13	42.12	90.58	17.70	84.58
5	1-26 (910)	1.37	2.52	1.43	30.55	93.79	45.81	98.52	18.32	87.54
6	1-26 (45)	3.27	1.29	9.01	30.42	93.79	38.86	83.57	17.15	81.96
7	1- 10 (1011)	1.70	1.73	1.41	31.15	95.63	46.04	99.00	17.97	85.87
8	1- 10(34)	2.14	2.59	2.49	30.49	93.60	45.02	96.82	17.27	82.51
9	1- 20 (78)	1.66	3.70	1.23	30.79	94.54	45.10	96.98	17.52	83.72
10	1-20 (1415)	1.10	8.95	6.48	29.21	89.67	36.38	78.23	17.88	85.44
11	1- 20 (2122)	1.44	6.48	1.77	29.88	91.42	42.72	91.91	17.69	84.54

I. According to the classification for this mineral, the gypsum here is classified as of class

The reserve of gypsum  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  is 16,570,570 t.

This is a large deposit, deserving attention. Feasibility study for its exploitation and utilization should be carried out.

### **Rock salt**

Rock salt was discovered by borehole in two depressions Thakhek and Nakay.

In Nakay depression, during the geotechnical drilling of Nam Theun hydroelectric project, rock salt was discovered at B. Nong Boua, whereas in Thakhek depression, rock salt has been exploited in B. Tha Ngam.

### **Nong Boua rock salt ore occurrence (70)**

Nong Boua rock salt ore occurrence is located in Nakay district, Khammouan province, with coordinates :

17°43'25" North latitude

105°12'40" East longitude

This ore occurrence was discovered by SMEC (Australia ) during the geotechnical investigation for Nam Theun hydroelectric project (Fig. 89).

The rocks of the Nong Boua salt bearing formation ( $K_2 nb$ ) form a depression extending in NW-SE direction along Nam Theun river. They are composed of typical red color claystone, claystone, grey sandstone containing beds of rock salts and gypsum.

Borehole DD -1 at B. Nong Boua has encountered a bed of rock salt at the depth of 68.06 to 153.33m. The thickness of the salt bed is 85.27m. At the top and the bottom of the salt bed is gypsum-anhydrite, with thickness at the top 6.3m and at the bottom 1.67m. The rock salt is composed mainly of halite, of white grey color, with salty taste, not astringent, with fairly uniform structure.

### **B. Thangam rock salt ore occurrence (140)**

Thangam rock salt ore occurrence is located in B. Thangam, about 15km South of Thakhek, Thakhek district, Khammouan province, with coordinates :

17°16'15" North latitude

104°50'30" East longitude

This rock salt ore occurrence is extracted by local people to serve their domestic use in the area.

In 1999, the drilling team of INTERGEO (Vietnam) carried out an exploration drilling contract here. The result of drilling work shows the stratigraphic sequence as follows from the top downwards (Fig. 90)





- 0-3m : Unconsolidated layer, consisting of sand, gravel and rotten tree roots.
- 3-54.5m : Red, red brown silty sandstone, sandstone
- 54.5-60.5m: Black grey smoky anhydrite
- 60.5-129.6m: Silty sandstone, claystone
- 129.6-200m: White, clearly white, smoky white halite, with salty taste, not astringent

The borehole was stopped at the depth of 200m, without penetrating through the salt bed. Thus, the salt bed here has a thickness > 70m.

The initial results of the investigation show that this rock salt ore occurrence is distributed in the favorable geological structure and stratigraphic units. The salt layer has large thickness, with high salt content, able to form a large scale rock salt deposit. Thus, investment should be made for exploration, determination of reserve and evaluation of exploitability for industry and export.

### **Phosphorite**

Phosphorite ore is the most common mineral in the study area. On the minerals resources map of the Mid Central Lao region, 56 ore occurrences have been registered. They are distributed in 5 areas : Boualapha, Mahaxai, Thakhek, Phon Tiou and Khamkeut (Fig. 91).

Since a long time, phosphorite ore was practically not given attention by geologists. In 1954, E. Saurin, when compiling the Vinh Sheet (Vietnam) of the 1:500,000 scale geological map of Indochina, noted that in some caves at Boualapha (Laos) there was phosphorite ore. But he has not left any data.

From 1995 to 2000, the project "Mineral Investigation and Geological Mapping at 1:200,000 scale of Mid Central Laos region" set forth the task of phosphorite prospecting as one of the key tasks of the project.

As a result of geological survey and mineral prospecting, a series of phosphorite ore occurrences have been discovered in the area as mentioned above. They are accumulated in karst caves developed in sediments of Khammouan (C-P<sub>1</sub> km), extending in NW-SE direction, in conformity with the general direction of the structure in the area.

Based on the characteristics, properties and depositional type of phosphorite, we divided them into two separate types of ores :

- Precipitation phosphorite ore accumulated on the floors of caves, in some places related with organic matter (guano) : Phosphorite ores of this type are relatively common in the study area. Typical are caves such as Tham Bing, Tham En, Tham Khau etc.
- Precipitation phosphorite ore filling the fractures. Typical for these type are phosphorite ores in Tham Khuon Cuc 1, Tham Non, etc..

In the following we will present some typical caves :













### **Tham Bing phosphorite ore occurrence (138)**

Tham Bing is located in the Pha Tham Bing limestone mountain, 4km SW of Boualapha district town, Khammouan province (Fig. 92<sup>a</sup>, 92<sup>b</sup>), with coordinates :

17°16'20" North latitude

105°44'48" East longitude

Pha Tham Bing mountain is extended in NW-SE direction, composed of light grey limestone, with thick-bedded to massive structure, belonging to Khammouan formation (C-P<sub>1</sub> km). The rock has the attitude of 40∠30°.

In 1998, this ore occurrence was subjected to general prospecting. Three shallow shafts were excavated, outcrops were cleaned and chemical analysis of 6 samples were carried out.

This karst cave is oriented in sub-meridian direction. The entrance is 20m above the local erosion level.

In the study area, the cave consists of two levels, with height difference about 15m and the ores on each level have different properties.

- The lower level : The cave is 143 m long, forming many small branches and hollows. The width is 3-4m to 10-15m. The height is 5-10m. Phosphorite is accumulated on the floor of the cave, 3-4m thick. The ore occurs in hard form. The ore is of grey, grey brown, yellow grey color, with banded and spotted structure.

The result of analysis gave P<sub>2</sub>O<sub>5</sub> : 3.81-29.1%.

- The upper level : is 15-20m higher than the lower level. The cave is developed into a wide chamber. The survey area is about 1500m<sup>2</sup> (40x37m). The ore thickness is minimum 1.7m, maximum 2.5m, in average 2.1m. The phosphorite here is soft, friable, of black, black brown color with white spots (mixed with guano).

The result of analyzing 4 samples gave P<sub>2</sub>O<sub>5</sub> = 6.5%, 14.2%, 18.4% and 19%, in average P<sub>2</sub>O<sub>5</sub> = 14.1%.

Prognostic resource : 4,200 t.

Size : This ore occurrence is prospective.

### **Tham Khau phosphorite ore occurrence (118)**

Tham Khau phosphorite ore occurrence is located on the western side of B. Tham, 6km ENE of Thakhek town, in Thakhek district, Khammouan province, with coordinates :

17°25'45" North latitude

104°51'55" East longitude



In 1998, this ore occurrence was subjected to detailed survey, with excavation of 3 shafts and collection of samples for analysis. Phosphorite is accumulated in karst cave of light grey thick-bedded limestone of Khammouan formation (C-P<sub>1</sub> km). The rock attitude is 310°/20° (Fig. 93<sup>a</sup>, 93<sup>b</sup>).

The cave extends in NW-SE direction. The total surveyed length of the cave is 120m, its wide is 3-10m, and its height is 7-10m. The ore is accumulated on the floor of the cave, with a thickness 3-4m. Here the local people have extract the ore to use as fertilizer.

Phosphorite is divided into 2 parts: The upper part has a thickness of about 0.5-0.7m, relatively firm, of alternately yellow and brown grey color, with defoliated, concentric, thinly banded structure. The lower part is friable, of motley blue, white, black color. The thickness is 0.8-1.5m.

Results of chemical analysis :

N	Sample No	P <sub>2</sub> O <sub>5</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	CO <sub>2</sub> (%)	MgO (%)
1	TL. 9711	23.90				
2	TL.G. 10/1	16.00	5.55	7.64	2.63	1.20
3	TL. G. 11/1	13.40	2.27	2.95	24.40	1.80
4	TL. G. 12/1	7.82	5.27	9.24	2.12	2.00
5	TL. G. 12/1	22.40	2.08	14.00	4.23	1.60

Prognostic resource : 3,200 t.

Size : This ore occurrence is prospective.

### **Tham En 1 phosphorite ore occurrence (50)**

Tham En 1 phosphorite ore occurrence is one of karst cave clusters located at about 2km NE of B. Thonglom, in Hinboun district, Khammouan province, with coordinates :

18°01'20" North latitude

104°25'40" East longitude

The cave is developed in the limestone mountain of Khammouan formation (C-P<sub>1</sub> km). The limestone is of blue, light grey color, with thick-bedded to massive structure (Fig. 94).

This ore occurrence has been subjected to general prospecting by prospecting team headed by Chu Van Chich in 1998. The ore is accumulated on the cave floor. The cave extends in NW-SE direction. The surveyed length is 230m, the width is 30-40m. The ore thickness is about 2m.



Phosphorite ore is of black grey, black brown color, Most of the ore is loose, with earthen structure. Some small part of the ore is hard, with thinly banded structure.

Result of chemical analysis :

N	Sample No	P <sub>2</sub> O <sub>5</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	CO <sub>2</sub> (%)	MgO (%)
1	TL. 9865/2	32.00	12.80	14.50	0.70	0.48
2	TL. 9865/4	6.30				
3	TL. 9865/6	14.30	3.97	2.63	1.20	2.16
4	TL. 9865/8	7.20				
5	TL. 9865/9	93.00	1.05	2.07	2.30	2.36

Prognostic resource : 16,000 t.

Size : This ore occurrence is prospective.

#### **Khuon Cuc 1 phosphorite ore occurrence (100)**

This ore occurrence is located at 2km NW of B. Latmek, 11km NE of Thakhek, in Thakhek district, Khammouan province, with coordinates :

17°30'07" North latitude

104°49'45" East longitude

The cave is formed in white grey weakly marbleized, dolomized medium - bedded limestone mountain, extending in NW-SE direction, pertaining to Khammouan formation (C-P<sub>1</sub> km). The rock attitude is 310∠20°.

This ore occurrence has been subjected to general and detailed prospecting. The results of the prospecting here show the following:

The cave is developed on the basis of the NW-SE (160-340°) trending tectonic fracture system, forming 3 parallel branches corresponding with three large fractures. The fractures are filled with phosphorite bearing products. The attitude of the fractures is 260° ∠70° (Fig. 95<sup>a</sup>, 95<sup>b</sup>).

Depending on the shape of the fracture, the ore bodies in some places are inflated (10m thick), in some places are reduced (0.1-0.2m), causing difficulties in evaluating the prospectiveness of the ore occurrence.

- Branch 1. The length of the surveyed branch is 94m, its width is varies between 2-5m, in some places up to 10m. Its height is 2-15m. Further inside the cave becomes narrower and is filled with phosphorite products. In some places large hollows up to 10m in size are formed. The end part of the cave tends to plunge down and is submerged under water.





The phosphorite ore is of black, black brown, yellow grey color. In the outer part of the fracture the ore is very hard. The ore is of banded, streaked structure. Inside the ore is softer.

- Branch 2. The surveyed length of this branch is 30m. Further it is submerged in water. Its wide is 3-4. The phosphorite ore is relatively hard, of black, black brown color, with streaked structure. The thickness is 0.5-1m, in some places reaches 1.5m.

- Branch 3. The length of the surveyed branch is 35m. The end part of the cave is filled with phosphorite of black grey color with calcium veins. The ore is of earthen, brecciated structure.

Analysis result :

N	Sample No	P <sub>2</sub> O <sub>5</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	CO <sub>2</sub> (%)	MgO (%)
1	LT. 9716	9.87	2.39	3.10	14.00	7.95
2	TL. 9717	32.70	1.72	1.87	4.57	2.95
3	TL.9718	18.4	3.27	4.62	5.39	2.10
4	TL.9719	17.00	2.39	2.87	9.97	3.60
5	TL.G. 13	17.00	3.67	4.48	5.51	2.10

Prognostic resource : 3,000 t.

Size : This ore occurrence is prospective (?).

*In sum, all of phosphorite ores discovered in the Mid Central Lao region are accumulated in karst caves in carbonate rocks of Khammouan formation (C-P<sub>1</sub> km). Broken zones are favorable factors for forming caves, which are favorable for the solution, precipitation and accumulation of phosphorite.*

*Although the caves in the regions are not big but they are in large number. Their investigations are still in preliminary stage. The analysis results show good ore quality, relatively uniform grade in the different caves. The ore potential is high. Thus, the investigation and evaluation in the next steps are necessary to delineate prospective areas and meet the requirements for exploitation of ore to serve the fertilizer production in particular and the economic development plan of Laos in general.*

### **Dolomite**

Dolomite is the main raw material for producing refractory material. Dolomite has been discovered during the 1:200,000 scale geological survey, in dolomite limestone occurrences : Nakok (110), TL.1225 (109) and TL.1195 (96) etc.

### **Nakok dolomite ore occurrence (110)**

Nakok dolomite ore occurrence is a limestone mountain located on the Northern side of National Road 12, close to B. Nakok,. about 30km West of Thakhek, in Mahaxai district, Khammouan province, with coordinates :

17°27'00" North latitude

105°08'00" East longitude

This ore occurrence was discovered during the 1: 200,000 scale survey. It consists of a limestone sequence extending for a length of > 2km, with a thickness of > 200m, with relative elevation approx. 100m.

The dolomitic limestone belongs to Khammouan formation (C-P<sub>1</sub> km). The rock is of blue grey color. It has granular fracture, strongly jointed, forming craggy topography, steep cliffs. The rock is of thick-bedded to massive structure.

The result of analyzing one sample shows : CaO : 30.51%, MgO : 21.1%, K<sub>2</sub>O : 0.035%, Na<sub>2</sub>O : 0.03%.

## 2. TECHNICAL RAW MATERIAL GROUP

On the minerals resources map 3 technical quartz ore occurrences have been registered : Phou Toum (1), Phon Keo (4) and B. Huana (18). Among these, the Phon Keo ore occurrence was recently discovered during the 1:200,000 scale geological survey, while the Phou Toum and B. Huana ore occurrences were discovered by the Bulgarian geologists in 1985. The Phou Toum ore occurrence is typical of these ore occurrences.

### **Phou Toum crystalline quartz ore occurrence (1)**

Phou Toum is located in the upstream area of Nam Gnala, about 2km West of peak 1215, in Bolikhaxay province, with coordinates :

18°42'30" North latitude

104°53'50" East longitude

This ore occurrence was surveyed by Bulgarian geologists (1985), with the following remarks : Quartz occurs at the contact between the schist aged (O<sub>3</sub>-S<sub>1</sub> ?) and granitoids of Nape complex (γδ, γ a C<sub>1</sub> np) (?). Quartz usually forms veins with clear boundary, occurring in conformity with the schistosity surface of the rocks. The veins have strike of 60-65°, dipping NW, at dipping angle 30-40°. Three quartz veins have been discovered which are 40 m long. The thickest vein has a thickness of 3-3.5m. Besides, there are two small veins with in considerable thickness, 15-30cm.

The veins are made up by massive quartz and single quartz crystals. The quartz crystals are of milky white, ivory white color, transparent, of prismatic form, with flat triangular facets, etc. The prismatic facets are surly related with certain strict rules. After being penetrated by X-ray, the quartz turns to black and smoky yellow color. The surface of some quartz crystals shows traces of solution process. The crystal surface is cracked, the cracks are filled with clay minerals with chestnut yellow color.



The near-head parts of quartz crystals have large volume, accounting for nearly 80% of the crystal volume. With this data, the crystals can be cut into thin, transparent specimens without twin crystals, with size 20 x 20 x 20 mm and weights of 20-100g. This means only 10% of the quartz crystals can be used.

According to the evaluation data, the crystalline quartz in Phou Toum ore occurrence can be used in the field of optics and piezoelectricity. The quartz here can be compared with those of the deposits in North Ural of Russia and in Minas Jerais of Brazil.

About 2km SE of this ore occurrence is Phon Keo ore occurrence which has been newly discovered, with similar size and geological setting. If combined investigation is carried out, this area will be definitely prospective in this kind of raw material.

### 3. CERAMIC AND PORCELAIN RAW MATERIAL GROUP:

#### **Nahuang ceramic clay deposit (19)**

The Nahuang clay deposit is located within the area of B. Nasalom - B. Nahuang - B. Houana, about 20km NW of Laksao, in Kham Keut district, Bolikhamxay province, with coordinates :

18°19'09" - 18°20'10" North latitude

105°02'00" - 105°02'55" East longitude

This is a area of low mountains and hills, usually with round peaks, gentle slopes, with relative height of Nahuang 50-60m. Transportation in the area is relatively favorable. National Road 8 passed near the mining area. From National Road 8 to the mining area one can go by car easily (Fig. 96).

The Nahuang clay deposit was subjected to detailed prospecting by geologist Chu Van Chich in 1996. The work amounts carried out include :

Geological survey for compilation of schematic geological map : 15km<sup>2</sup> ; hand drilling : 500m ; pitting and outcrop cleaning : 51m<sup>3</sup>, sampling : 32 samples.

Taking part in the geological structure of the study is the biotite granite of Nape complex Nape ( $\gamma\delta$ ,  $\gamma$  a C<sub>1</sub> np), which occupies 70% of the area. Unconsolidated Quaternary sediments (Q) form a valley extending in N- S direction, distributed in the central part of the area. The clay bearing area is confined within the valley, 3-4km long, 200-300m to 1,000 wide.

The Quaternary sediment are composed of sand, gravel, and clay layers with commercial value. The clay bodies have relatively stable thickness, distributed along the Na Huang valley.

The clay was formed mainly due to the weathering and re-deposition of granitic rocks the area. The structure of the clay bodies from to downward is as follows :

N	Layers	Depth (m)			Composi- tion	Brief description
		From	To	Thick		
1	Layer 1	0	0.2-1		Top soil	Plant remains, clayey sandstone

2	Layer 2	0.5-1	8	7.5-8	Clay	Yellowish white, relatively plastic clay, in some places with pockets of red brown laterite.
3	Layer 3	8	14	6	Sand, gravel	White quartz gravel, sand mixed with yellow clay
4	Layer 4	14.5	18	3-5	Clay	Grayish white clay, plastic clay, in some places intercalated with thin peat layers.
5	Layer 5	>18			Sand, gravel	Bottom later: white quartz coarse sand and gravel, with grain size 1- 5 mm.

Particle size distribution test result of the clay : The 0.1-0.005mm particle size constitutes 85-90%.

Chemical composition : SiO<sub>2</sub> : 55.3-60.17%, Al<sub>2</sub>O<sub>3</sub> : 22.62-25.22%, TiO<sub>2</sub> : 0.83-0.87%, LOI : 7.32-9.9%.

Result of X-ray diffraction analysis

N	Sample No	Non-clay minerals (%)		Clay minerals (%)	
1	TL.5115/1b	Quartz	~ 30-35	Mica	18-22
		Feldspar	5-8	Kaolinite	20-25
2	TL.5117	Quartz	13-17	Chlorite	Little
				Montmorillonite	5-10
				Mica	25-30
				Kaolinite	30-35
				Chlorite	Little
3	TL.5123/1b	Quartz	20-25	Montmorillonite	10-15
				Feldspar	8-10
				Mica	15-20
				Kaolinite	20-25
				Chlorite	Little
4	TL.5127/1b	Quartz	20-25	Montmorillonite	13-17
				Feldspar	7-10
				Mica	18-22
				Kaolinite	40-45
				Chlorite	Little
5	TL.5133	Quartz	10-15	Montmorillonite	13-17
				Feldspar	7-10
				Mica	18-22
				Kaolinite	20-25
				Chlorite	Little
				Montmorillonite	5-10

Prognostic resource : 4,475,000m<sup>3</sup>.

The Nahuang clay deposit has a rather large resource. The clay layer has a relatively large thickness. The area has infrastructure favorable for mining and utilization. The deposit has been investigated in detail.

For this clay deposit, some additional samples should be collected for determining the physical properties and tested for various uses. Pre-feasibility study should be carried out for mining. Here, besides clay as the main raw materials, a large quantity of other construction materials such as cobble, gravel, sand can be extracted.

#### 4. CONSTRUCTION MATERIAL GROUP

This is a mineral group abundant in quantity and diverse in type. They are scattered all over the study area. On the minerals resources map, 35 deposits and ore occurrences have been registered, of which : 14 are of cement limestone, 5 are of building limestone, 2 is of cement clay, 2 are of brick clay, 3 of facing stone and roofing slate, 3 are of gravel and 6 are of building sand.

The above minerals are concentrated within the area of Khammouan formation (C-P<sub>1</sub> km), Boualapha formation (C<sub>1</sub> bp) and the Quaternary unconsolidated alluvial sediments (Q) along Nam Khong river, Xebangfai river, etc.

At present, the limestone deposits along National Roads 13, 12, 8 and sand, gravel, cobble deposits along Nam Khong river, Xebangfai river, Nam Theun river are being extracted by the local authorities for building houses, roads, bridges, etc.

##### **Cement limestone - building limestone**

The mineral raw materials of this kind in the study area are in large quantity. They consist of the whole area of Khammouan formation (C-P<sub>1</sub> km), which builds up two limestone mountain ranges:

- The first range extends from Phon Tiou - Thakhek to Boulapha
- The second range extends from Khamkeut to Laksao.

These limestone mountain ranges run along National Roads 8, 13 and 12, favorable for geological investigation as well as future exploitation and utilization. Among the limestone deposits, detailed investigation has been carried out for some of them such as Naden (102), Nong Dong (65), etc.

##### **Naden cement limestone (102)**

Naden limestone deposit is located in the area of B. Naden, Mahaxai district, Khammouan province, about 40km West of Thakhek along the National Road 12, with coordinates :

17°29'40" North latitude

105°24'20" East longitude

This limestone mountain range extends from B. Naden to Khamhe and Hang Kang, > 20km long, 6-7km wide. The rocks belong to Khammouan formation (C-P<sub>1</sub> km), consisting of blue grey, white grey fine grained limestone with medium to thick-bedded (massive) structure.

Chemical composition:

N	Sample No	CaO (%)	MgO (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	SiO <sub>2</sub> (%)
6	TL. 1200	55.43	0.30	0.012	0.029	0.13
7	TL.1201	54.23	0.79	0.010	0.055	0.34
8	TL.1235	53.73	0.29	0.015	0.140	1.84
9	TL. 1209	55.14	0.56	0.004	0.027	0.15
10	TL.1212	53.73	1.91	0.010	0.029	0.10

As described above, limestones occupy a relatively large area. Its survey and sampling was only carried out in combination during the general geological survey. However, the analysis results show that all of them meet industrial criteria as cement raw materials. Thus, they should be investigated further to delineate the prospective areas to meet the demand for industrial development.

### **Building limestone**

The limestone of Khammouan formation (C-P<sub>1</sub> km) is of light grey color, with medium to thick-bedded and massive structure. The rocks of this formation occupy near 1/6 of the surface of the study area. They form a band extending in NW-SE direction, about 200km long, 20-40km wide. Therefore, this raw material source is unlimited. Moreover, as this area is crossed by all of the main roads, the mining is convenient and transportation is very easy.

### **Cement clay- brick clay**

The clay formations in the area occur mainly in two forms :

- Clays accumulated in valleys, of depositional and re-depositional genesis.
- Clays distributed on slope, of in situ weathering genesis.

The river valleys and intermountain valleys are the land areas provided for farming and settlement of the people, no mining can be carried out. Therefore, during the geological survey, the locations where occur clay bodies of in situ weathering genesis (type 2) have been identified and selected for clay extraction.

Under this types are Nam Phao (40), Thaphe (11) clay occurrences .

### **Nam Phao clay deposit (40)**

Nam Phao clay deposit is located in the area of B. Nam Phao, about 3km SE of Laksao town, in Khamkeut district, Bolikhamxay province, with coordinates :

18°10'20" North latitude

104°59'50" East longitude

The distribution area is relatively large, along the basin of Nam Phao river, consisting of low hills with gentle slope, round tops. They are built up by the sediments of Boualapha

formation ( $C_1 bp$ ), mainly consisting of grey, greenish blue clay schist, sericitic schist, which are strongly weathered to form white grey, yellowish white clay. The clay is plastic when soaked in water. On the road slope one can see that the thickness of the weathered clay layer is about 6-7m. Here one sample was collected and analyzed, giving the contents :  $SiO_2$  : 61.52% ;  $Al_2O_3$  : 20.63% ;  $TiO_2$  : 0.71% ;  $Fe_2O_3$  : 3.11% ;  $CaO$  : 0.22% ;  $MgO$  : 0.99% ;  $K_2O$  : 3.1% ;  $Na_2O$  : 0.69%.

The indicators  $SiO_2$ ;  $Al_2O_3 + Fe_2O_3$ ;  $K_2O + Na_2O$  ;  $MgO$  are all satisfactory to be used as cement raw materials.

Thus, further investment should be made for checking to confirm the prospectiveness of this raw material source.

### **Nam Phao brick clay deposit (39)**

Nam Phao clay deposit is located within B. Nam Phao, 3km SE of Laksao town, in Khamkeut district, Bolikhamxay province, with coordinates :

18°11'00" North latitude

104°59'10" East longitude

B. Nam Phao is located on the Road No 8, favorable for geological investigation and mining in the future.

The clay here is the weathering products from clay schist and sericitic schist of Boualapha formation ( $C_1 bp$ ). On the road slope one can see the weathered layer is composed of clay with a thickness 5-6m. The clay is of yellow, white grey, in some places motley color, still having the bedding traces of the original rocks. The clay is relatively fine, when soaked in water is plastic. Here the local people has extracted clay for baking brick and tile for house construction.

### **Facing stone**

Within the area of Mid Central Lao region, one facing stone deposit has been recorded : Say Phou Ngou (55), bearing the same name as the Say Phou Ngou mountain range.

### **Say Phou Ngou facing stone occurrence (55)**

The location of the facing stone raw material source is in Say Phou Ngou mountain range, extending along the left side of Nam Khong at a distance of about 3km, in Hin Boun district, Khammouan province, with coordinates :



17°58'40" North latitude

104°18'30" East longitude

In the past, the local authorities already organized the extraction of stone here and polished it to serve the construction projects.

The rocks of Say Phou Ngou complex ( $\gamma P_2 sn$ ) consist of two types, red granite and white grey granite. The distribution area of this complex extends over 35km long, 0.5km wide. The rock is of massive structure, porphyritic texture, not much fractured. At an old quarrying area the rock is seen to be of good continuity, usually forming blocks with volume  $0.5-1m^3$ . The physico-mechanical test results are cited in Table 21.

The granite as raw material source for facing stone in Laos has not been investigated. This is a notable kind of mineral. It must be given investment for investigation, exploitation, processing and utilization to meet the ever increasing the construction demand of Laos.

### **Roofing slate**

Roofing slate distributed within the area of Nam Houay formation ( $O_3-S_1 nh$ ). Two roofing slate occurrences have been In the area only two roofing slate occurrences: Nakadok (42) and Tham Kouna (14) have been recorded, of which the Nakadok occurrence is most typical.

#### **Nakadok roofing slate occurrence (42)**

This ore occurrence is located in a small stream valley about 1km North of B.Nakadok, in Nam Veo commune, Khamkeut district, Bolikhamxay province, with coordinates :

18°09'30" North latitude

105°08'17" East longitude

This ore occurrence was discovered by geologist Trinh Xuan Hieu in 1977. Tran Van Ban collected one sample for analysis in 1999.

In this area are developed the rocks of Nam Houay formation ( $O_3-S_1 nh$ ), consisting of black blue clay slate with thickness 2-3m, intercalated in sandstone. The rock is easy to split into thin sheets with thickness 0.4-1cm.

The result of physico-mechanical tests of the rock are shown in the following table :



Rock description	Water absorption $W_{hn}$ %	Density		Specific gravity $\rho$ g/cm <sup>3</sup>	Porosity n %	Bending strength $\sigma_{nk}$ Kg/cm <sup>3</sup>	Test for climatic impacts (in hot-cold cycle)		Test for acid resistance (submerged in H <sub>2</sub> SO <sub>4</sub> ) d=1,145,240 (h)
		Dry $\gamma_k$ g/cm <sup>3</sup>	Saturated $\gamma_{bh}$ g/cm <sup>3</sup>				Number of test cycles	Description of rock after test	
Black clay slate	0.49	2.71	2.72	2.77	2.17	320	15	Specimen is not swelled, not split, not broken (good)	Specimen is not split, cracked, broken, the surface is not blistered, softened, not bubbles appear in the process

Result of testing according to BS 680 Part 2 : 1971 : The Nakadoc roofing slate is good to be used in construction. Further investigation must be carried out to confirm the prospectiveness of the ore occurrence.

### **Building sand, gravel**

Coarse clastic sediments consisting of Quaternary gravel and sand (Q) are accumulated forming flood plains, sand bars distributed mainly along major rivers in the area such as Nam Khong, Xebangfai, Nam Theun, Nam Gnouang etc.

On the minerals resources map, 9 deposits of sand and gravel have been registered, of which 3 are gravel deposits : Maloy (75), Nam Khou (33), SomSaat (149), 6 are building sand deposits : Dondon (108), Hinboun (79), B. Gngang Ngam (133), B.Bungxe (151), B. Hatkham (154) and B. Dang - Tai (141).

Among the above deposits, the Gnamngam deposit is being extracted by the local authorities for production .

### **B. Gngangngam building sand deposit (133)**

B. Gngangngam building sand deposit is located on the left side of Nam Khong, extending from B. Mouang Soun to B. Thahe , in Thakhek district, Khammouan, with coordinates :

17°19'00" North latitude

104°48'30" East longitude

This sand deposit belongs to the higher flood plain of Nam Khong river, on the left side and in the river channel, in the form of a sand bar 10km long, 200-600m wide, emerged 2m

above the water level. It is composed mainly of fine to medium grained quartz sand, mixed with fine white mica flakes. The sand is well sorted.



Here the local authorities are extracting the sand for construction in Thakhek and adjacent areas.

Along the left side of Nam Khong, building sand is found to occur in many places. The location is very favorable for mining and transportation.

#### **B. Somsaat gravel deposit (149)**

Gravel is distributed along both sides of Xebangfai river, from B. Somsaat to B. Dang, 40km SE of Thakhek, in Nong Bok district, Khammouan province, with coordinates :

17°06'00" North latitude

104°57'00" East longitude

The access by road to the mine is very easy, favorable for the mining and transportation in the future .

The productive layer occurs on both sides of Xebangfai river, extending for 1.5-2km long. The thickness of the gravel layer is 5-6m. The upper part is usually covered by a top soil layer 0.5-1m thick.

The gravel is composed mainly of quartzitic sandstone, less quartz. The gravel is well sorted.

### **IV. THERMAL WATER, SALT WATER**

#### **Thermal water**

Eight thermal water sources have been registered in the minerals resources map of the Mid Central Lao region : B. Pakouay (2), B. Sop Hong (6), B. Nam On (9), B. Me (10), B. Mot (8), B. POUNGKUAK (41), B. Nape (21). The sources are closely related with I-order zoning fault, tectonic broken zones. The temperature of the water is minimum 40°C, maximum 60°C. ( Nape source) . The analysis result show that the TDS is low, not sufficient for producing mineral water. But the water can be used for everyday life, bathing and medical treatment.

Among the above thermal water sources, the Nape source (21) is paid more attention.

#### **Nape thermal water source (21)**

The Pape thermal water source is located in a small stream Nam Heu, on the left of Nam Phao, about 1km ESE of B. Nape, in Khamkeut district, Bolikhamxay province, with coordinates :

18°17'55" North latitude

105°04'15" East longitude

This thermal water source has been recorded since a long time. The local people have used this water source for everyday life and bathing.

In 1985, the Bulgarian geologists also recognized and described this thermal water source.

In the area are developed old metamorphic rocks aged O-S and granite of Nape complex ( $\gamma\delta$ ,  $\gamma$  a C<sub>1</sub> np). The thermal water source is closely related with the I-order NW-SE trending

fault system. the water appears in a wide area. According to the description, after the thermal water has emerged and mixed with the stream water, one still can perceive it. the temperature of the water is 60°C.

According to the analysis, the water contains the cations : Na<sup>+</sup> and K<sup>+</sup> (with high concentration), Ca<sup>+2</sup> (low concentration); and anions Cl<sup>-</sup>, SO<sub>4</sub><sup>-2</sup> and HCO<sub>3</sub><sup>-</sup>, and free CO<sub>2</sub> gas.

This thermal water source is at present exploited to serve the local people and tourists for bathing and medical treatment.

### **Salt water**

Only two sources of salt have been discovered in Thakhek depression : Nong Khem (147) and Nonsila (146). They emerge from the rocks of Nong Boua formation (K<sub>2</sub> nb).

In particular the Nong Khem source is being extracted for producing table salt for the people in the area.

### **Nong Khem salt water source (147)**

The Nong Khem salt water source is located within B. Nong Khem, about 30km SE of Thakhek , in Nong Bok district, Khammouan province, with coordinates :

17°09'35" North latitude

104°58'50" East longitude

The salt water emerges through fractures and bedding planes of the rock, in an area of about 5 ha.

The rocks distributed in the area consist of red color claystone, mudstone, sandstone of Nong Boua formation (K<sub>2</sub> nb).

The emerging salt water form small streams flowing within a large area. The water is relatively salty (especially in dry season). Here the people dig wells to extract the salt water to boil for salt. According to the local people, the salt production reaches 1 t/month.

This is a prospective salt water source, requiring investment for investigation in the next steps. Especially it is probably related with a rock salt deposit with large reserve occurring underground.

## **Chapter IX**

### **DISTRIBUTION LAW AND PROSPECT ZONING OF MINERAL RESOURCES**

The results of the project "Mineral Investigation and Geological Mapping at 1:200,000 scale of Mid Central Laos region" have met the set out targets and tasks of the project. Ver 20 stratigraphic units and 4 magmatic complexes have been established. Direct and indirect

indications of secondary mineral and element dispersion haloes together of 154 deposits, ore occurrences and mineral shows have been registered on the minerals resources map.

The results of integrated study on stratigraphy, magmatism and tectonics described in the above chapters can allow to draw out the law of minerals resources distribution in the area and to divide the study area into areas with various degrees of prospectiveness as will be presented below :

## **I. Minerals resources distribution law**

### **1. Metallogenic factors**

*1.1. Stratigraphic factor* : Each geological formation, stratigraphic unit has its metallogenic characteristics. There it plays an important role in ore control and is a favorable environment for the mineralization process, is the place where valuable mineral bodies have been formed (Fig. 97). The following are the stratigraphic units which have close relationship with mineralization.

+ Nam Houay formation ( $O_3-S_1 nh$ ) : Is widespread in the NE area of the map sheet group belonging to Nape uplifted zone. It is composed of clay schist, quartzitic sandstone, quartz - sericitic schist, calcareous schist. NW-SE and sub-latitudinal fault systems are developed, crushing and destroying the sediments of the formation. This is the a favorable condition for the forming of the minerals with endogenous genesis. A series of quartz - sulfide and gold, tungsten-bearing quartz - sulfide veins and stockworks have been discovered. Their concentration and convergence have formed valuable ore occurrences such as : Nam Ke, Nam Houay gold ore occurrences, Pong Kuak tungsten ore occurrence.

+ Koduk formation ( $O_3-S_1 kd$ ) : Covers a small area in the SE of the study area. Quartz - sericitic schist, quartzitic sandstone, quartz sandstone and gravelite which have been destroyed, crushed and sheared are favorable for the formation of barite and polymetal mineral bodies in Phakat.

+ Boualapha formation ( $C_1 bp$ ) : is fairly widespread in Boualapha, Gnommalat, Hin Boun areas. It is composed of terrigenous sediments such as black clay schist silty sandstone containing coal lenses (Pong Bon ore occurrence), siliceous schist, calcareous schist. Along NW-SE trending fault systems the rocks of the formation are strongly destroyed and sheared.



Secondary alterations such as chloritization, sericitization and dolomitization are fairly developed. These factors are favorable conditions for the concentration of minerals of hydrothermal genesis such as antimony - mercury, pyrite. Besides, the products of weathering from clay schist, sericitic schist are the raw materials for cement and brick production.

+ Khammouan formation (C-P<sub>1</sub> km) : Is fairly widespread, occupying up composition 20% of the whole study area. The main lithologic component of the formation is light gray, blue gray limestone. The rock is of medium to thick-bedded or massive structure. The results of chemical analysis show that the light color limestone bands in some areas have CaO content 53.73-55.43%, with all harmful elements within the permissible limits. Thus limestone in some areas is of good quality, meeting the standards for cement production, while the rest are all satisfactory for construction. Especially karst caves are widely developed, favorable for the accumulation of phosphorite with sedimentary-infiltration genesis in Boualapha, Mahaxai, Thakhek, Hinboun and Khamkeut areas.

+ Lingkho formation (T<sub>2</sub> lk) : A large volume of this formation occurs in H. Lingkho area, bearing the name of the formation. It forms a band extending along the Say Phou Ngou mountain range, composed of intercalated terrigenous and extrusive rocks, consisting of sandstone, clay schist, tuffaceous sandstone, gravelite, rhyolite, dacite. As a result of bedrock panning, cassiterite has been discovered with a grade of 9.4-89.5g/m<sup>3</sup> and gold of 2 grains/sample. Especially in the tuffaceous sandstone and gravelite there is a rather dense dissemination of minerals such as sulfides. Thus the rocks of this formation are the favorable environment for the mineralization of gold and tin (?) in the area.

+ Nam Phouan formation (J<sub>3</sub> np) : Is widespread, with outcrops forming narrow bands on both limbs of Nam Theun synclinorium. In the green fine grained quartz sandstone there is a high copper content, and these sediments are considered as favorable environment for the accumulation of the copper mineralization. Pyrite of sedimentary genesis (?) has been discovered in Ban Bo, Ba Lao, Phonhai,... areas.

+ Nong Boua formation (K<sub>2</sub> nb) : is characterized by evaporite sediments with red brown color. They are distributed mainly in the central part of the two depression Nakay and Thakhek. In these areas, through the result of the site investigation and well as exploration boreholes, gypsum and rock salt beds have been encountered with large thickness (14-70m). Nong Boua formation (K<sub>2</sub> nb) has large potential in gypsum and rock salt.

+ Quaternary unconsolidated sediments (Q<sub>II-III</sub>, Q<sub>IV</sub>, Q) are distributed along the valleys of large rivers : Nam Khong, Xe Bangfai, Nam Theun, or in intermountain valleys such as Khamkeut, Gnommalat... These areas are the places of abundant concentration and accumulation of raw construction materials such as sand, gravel, and gold placer (Nakadok).

## 1.2 Magmatic factors

The distribution area of magmatic rocks in the Mid Central Lao region accounts for up to 10 % of the whole map sheet group area (~ 3,000km<sup>2</sup>), comprising 4 magmatic complexes. In petrographic composition, these complexes consist mainly of acidic rocks with age Late Paleozoic to Mesozoic. The magmatic rock complexes are not only related directly with the formation of minerals of endogenous genesis, but also are the favourable environment for the concentration and accumulation of ores.

+ Nape complex : The outcrop of the rocks of this complex is fairly wide, lying along the Vietnam-Laos border, extending from Muong Ngat - Nam Gnala - Nape to the upstream of Nam Theun, hundreds km long, 30-40km wide. The rocks of this complex penetrated the metamorphic sediments of Nam Houay formation causing hornfelsification. Together with the NW-SE trending fault system they caused the breakage and destruction of rocks, creating favorable conditions for the hydrothermal mineralization process.

In petrographic composition the complex consists mainly of granodiorite, coarse grained porphyritic biotite granite, medium grained biotite granite bearing cordierite and garnet, pegmatite, aplite. Characteristic minerals are plagioclase, potassium feldspar, quartz, biotite, muscovite. The rocks contain some amount of Mo (15-18g/t), 15-18 times the Clark value, Sn (17-18g/t), 6 times the Clark value. In the distribution area of the rocks of this complex some high grade dispersion haloes of gold reaching  $10 \geq 20$  grains, cassiterite  $> 10\text{g/m}^3$ , wolframite  $> 20\text{g/m}^3$  have been discovered. Especially in the area upstream of Nam Cham W  $> 100\text{g/m}^3$ .

The above data allow to infer that the Nape complex is probably related with the process of gold, tin and tungsten mineralization. The Namke, Xoklet, etc., gold ore occurrences are evidences of the relationship between the ore genesis and the acid rocks of the complex.

+ Phou Thoun complex ( $\gamma P_2 - T_1 pt$ ) : Makes up three small massifs with area  $0.3 - 0.5\text{km}^2$  distributed in the Nam Paten valley and some small points in Nam Khou area. In its petrographic composition the complex consists of fine to medium grained porphyritic granodiorite, biotite granite, aplite. Typical minerals include plagioclase (andesine), potassium feldspar, quartz, biotite, hornblende. Within the distribution area of magmatic rocks some geochemical dispersion haloes of copper have been discovered, with grade reaching 0.06 %. In extraordinary points the Cu content is : 0.015-0.05%.

The rocks contain some amount of Mo (25ppm), 25 times the Clark value. Besides, there are some elements with high contents : Pb(36 ppm), Bi (5 ppm), Ba (248-120g/t), Rb(102-202 g/t), Nb (6.8 -19 g/t).

The above data show that Phou Thoun complex is related with copper, iron, molybdenum, etc. mineralization.

+ Say Phou Ngou complex : This complex bears the name of the Say Phou Ngou mountain range. It is located to the west of National Road 13 and forms a band-like massif extending in NW-SE direction, about 20km long, 0.5-1km wide.

In petrographic composition the complex is composed of medium grained porphyritic biotite granite, pink biotite granite together with aplitic dikes and veins. The complex is characterized by the assemblage of minerals: potassium feldspar (orthoclase) plagioclase (oligoclase), quartz, biotite. Accessory minerals include apatite, zircon, ilmenite.

The result of analysis show that the content of elements Sn (265g/t) 80 times the Clark value, Mo (17-25ppm), Pb (11-36 ppm), Zn (34-58.2ppm), Bi ( $< 5\text{ppm}$ ). At the same time in the northern part of Nam Paten valley exist some small areas of intrusive- subvolcanic rocks of the complex. They are distributed mainly within the area North of B. Boneng. Petrographic composition of the extrusive rocks includes : andesite, rhyolite, dacite, trachyte. The result of chemical analysis show that the extrusive rocks contain Sn : 0.01-0.15% (Data from I. U. Baculin, 1983).

Within the distribution area of the rocks of the complex there are dispersion haloes of gold (1-10 grains). Especially in the Nam Paten valley there is a high grade dispersion halo of tin reaching a grade of 30-100g/m<sup>3</sup>, in an extraordinary point the tin grade reaches 2549g/m<sup>3</sup> and 3732g/m<sup>3</sup>. Therefore, the Say Phou Ngou complex is probably related with gold, tin mineralization and at the same time it is a source of raw materials for facing stone production.

+ Poug Kuak ( $\gamma$ MZ<sub>3</sub>pk) : The rocks of this complex are distributed in Poug Kuak area, at the upstream of Nam Pan, Nam Theun and Nam Pheo area. They make up large massifs covering 10-30km<sup>2</sup>, penetrating the metamorphosed sediments of Na Houay formation and the rocks of and Nape complex.

In petrographic composition, the complex consists of medium grained porphyritic two mica granite, porphyritic biotite granite, with typical minerals such as potassium feldspar (microcline) usually dominant over plagioclase (oligoclase-andesine), quartz, biotite. Accessory minerals include: tourmaline, apatite, ilmenite, zircon. Ore minerals : pyrite.

The rocks contain W(3- 6g/t) 2-4 times the Clark value, Sn(13-14g/t) 2-4 times the Clark value. The contents of Ba and Ti are from medium to high: Ba (147-753g/t), Ti (100-2000g/t), P (50-3500g/t).

With the above data, one can infer that the Poug Kuak complex may be related with tin, tungsten, titanium, etc. mineralization. The Poug Kuak tungsten ore occurrence is an evidence of this relationship.

### *1.3 Structural factor*

Fault systems, broken and sheared zones, folded structure, etc. are favorable factors for the accumulation of endogenous minerals.

#### *+ Fault system*

As described in the tectonics section, within the survey area of Mid Central Lao region besides the Thakhek - Da Nang zoning thrust fault, two other NW-SE and NE-SW trending fault systems are also clearly developed. These fault systems not only play the role of ore control, serve as ore conducting channels, ore concentration places, complicate the geological structure of the region, but also create favorable conditions for the magmatic complexes to be formed and developed.

- Thakhek - Da Nang ore controlling, structural zoning thrust fault: This is a multicycle activated fault. It plays the role of dividing structure zones, controlling the ore formation. On the Eastern and NE side of the fault are developed intensively various kinds of endogenous minerals such as iron, copper, tin, tungsten, gold, pyrite, polymetals, exogenous minerals such as phosphorite, gypsum, rock salt and construction materials. On the Western and SW side of the fault there are favorable conditions for the concentration of endogenous minerals such as gypsum, anhydrite, rock salt and construction materials.

Associating with the activities of the fault is the appearance of the magmatic intrusions of Say Phou Ngou complex together with manifestation of gold mineralization and thermal water sources.

- I-order ore conducting fault system : The faults of this system are mainly NW-SE, sub-latitudinal trending faults and usually have large scale and extensive. As a result of fault activities, the general structural plan of the area has been changed, structural zones and blocks

have been formed (Nape uplifted block, Nam Theun subsided block, etc.). Along this fault system on each section are developed intensively broken and sheared zones. The density of tectonic fracture systems is increased. They are ore conducting channels, ore containers and ore controlling factor. In relation with them, a series of ore occurrence of endogenous genesis have been formed such as gold, tungsten, mercury, antimony, pyrite, barite, etc. and most of thermal water sources are in close relationship with this fault system. Moreover, the occurrence of the magmatic intrusions in the area is the results of activities of the I-order crust-penetrating multi-cycle fault system.

- II- order fault system : This fault system is most intensively developed both in density, types and sizes. They are of mainly NE-SW, sub-meridian trends, less NW-SE trends. This is a young fault system, activated in later period, and probably not much related with the mineralization process (?), but they mainly displaced, broke and complicated the geological structure of the region.

+ Folded structures

All folded structures reflect the geotectonic circumstance within a certain space and time. In relation with them are assemblage of some group of minerals or a certain kind of mineral.

As described above, the study area consists of main folded structures: Nape anticlinorium, Hin Boun - Mahaxai, Nam Theun and Thakhek synclinoria. Practically all of folds are linear form, their axes extend in NW-SE direction, the same as the general structural trend of the region.

- Nape anticlinorium : Is distributed in the NE area of the map sheet group, consisting of NW-SE trending mountain ranges, with peaks 1000-1800m high, composed of metamorphosed sediments of Nam Houay, Sopphan, Houay Pang formations and the granites of Nape, Pong Kuak complexes. The SW limb of the anticlinorium is intensively broken and sheared, divided into blocks and plates due to the impacts of the I- and II-order fault systems. These factors are favorable conditions for the mineralization process of endogenous genesis. Nearly all of gold and tungsten ore occurrences in the region are in the distribution area of Nape anticlinorium.

- Hin Boun - Mahaxai synclinorium This is a synclinorium with large size, extending from Hin Boun though Thakhek - Mahaxai to Boualapha, with a length > 200km, a width of 20-40km. The carbonate rocks of Khammouan formation (C-P<sub>1</sub> km) account for the main volume making up the synclinorium. Besides, there are also terrigenous, intercalated terrigenous and carbonate sediments of Boualapha, Phon Tiou, Thapachon formations.

The NW-SE trending I-order zoning fault system plays the role of controlling the distribution area of the synclinorium in the general structural plan of the area. Inside the structure of the synclinorium are a series of locally formed anticlines and synclines. Along these structures and fault systems usually are developed intensively broken and sheared zones. These are favorable conditions for forming of minerals of hydrothermal genesis such as pyrite, barite, antimony, mercury. Especially the carbonate rocks are the favorable environment for formation of karst caves and leaching and infiltration processes, generating a series of valuable phosphorite ore deposits.

- Nam Kading - Nam Theun and Thakhek synclinoria : The Nam Kading - Nam Theun extends in NW-SE direction in the central part of the study area. Thakhek synclinorium is

located South of Thakhek town, is a part of Sakonnakhon depression (Thailand). They were formed and developed on continental crust basement of the Indosinia geoblock and Vietnam - Lao Paleozoic fold zone. In the geotectonic circumstance where the sea was retreated and closed, the lagoon regime was formed, which is characterized by the fairly typical red color evaporite sediments (of Nong Boua formation). In the favorable paleogeographic condition, thick beds of rock salt, gypsum and anhydrite were accumulated, such as the rock salt deposit in Nong Boua (Nakay depression), Thangam (Thakhek depression), or gypsum in Tha Lang (Nakay depression), Boung Huana - Ban Tung (Thakhek depression).

## 2. Metallogenic indications

Pan concentrate, geochemical dispersion haloes are indications reflecting favorable geological factors for the metallogenic process and showing their scope of influences. The results of such investigations and analyses serve as the basis for the determining the existence of significant geologic entities with the aim to orient the mineral prospecting work.

Nearly all pan concentrate and geochemical dispersion haloes which have been delineated on the minerals resources map are developed on uplifted structures such as anticlinoria, local anticlines, or along Thakhek - Da Nang structural zoning fault.

On the structural plan, Nape anticlinorium extends from Nam Gnala through Nape - Pong Kuak to the upstream of Nam Theun, built up by metamorphosed sediments of Nam Houay formation ( $O_3-S_1 nh$ ) and the intrusive rocks of Nape and Pong Kuak complexes. Here the most typical are dispersion haloes of gold with common grade of 1-10 grains, some haloes reach 10-20 grains. Cassiterite mineral dispersion haloes reach a grade of  $0.1-1 g/m^3$ , some haloes reach  $> 10 g/m^3$ . Wolframite dispersion haloes have fairly high grade,  $> 20 g/m^3$ , in upstream area of Nam Gnala the tungsten grade is  $> 100 g/m^3$ .

Viang Thong - Nam Kang anticline is developed along the Viang Thong I-order fault system, extending in NW-SE direction. the rocks of Thapachon and Phon Keo formations are intensively crushed and sheared together with the appearance of small magmatic bodies of Nape complex ( $\gamma a C_1 np$ ). Here are developed gold dispersion haloes with grade reaching 1-10 grains, scheelite dispersion haloes with grade reaching 1-10 grains, cassiterite dispersion haloes reaching  $3-10 g/m^3$ , cinnabar dispersion haloes with grade reaching  $> 10$  grains, with specially high grade points reaching  $95 \text{ grains}/10 \text{ dm}^3$  or  $2.35 g/m^3$ . The dispersion haloes of molybdenum and copper are also fairly concentrated in the area North of Viang Thong.

Nam Khou - Phon Tiou anticline is built up by terrigenous sediments of Phon Tiou formation ( $D_{1-2} pt$ ) together with the presence of magmatic rocks of Phou Thoun complex, the Say Phou Ngou subvolcanic complex. The most outstanding thing in the area is that the high grade dispersion haloes of cassiterite have been delineated with grade reaching  $15-30 g/m^3$  or from 30 to  $> 100 g/m^3$ . Especially many specially high grade points have been discovered, such as cassiterite reaching hundreds  $g/m^3$ , some points reaching  $2549 g/m^3$ ,  $3732 g/m^3$  (Boneng area). Geochemical dispersion haloes of Mo, Cu, Pb, Zn nearly coincide in location with mineral dispersion haloes.

Besides the above anticlines, along the zoning fault appear also dispersion haloes of chromite with grade reaching  $1-3 g/m^3$ . Geochemical dispersion haloes of Ni and Cr are fairly common, probably they are related with the mafic magmatic rocks (?) which occur deep underground.

### 3. Distribution law of some main minerals

Each kind of minerals, either of endogenous or exogenous genesis, has its own specific characteristics. They depend on various geological factors such as stratigraphy, magmatism, tectonic, metamorphism, etc. Studying and finding out the law of their distribution would offer scientific basis for inferring the possibilities of mineralization, at the same it would help to orient the mineral prospecting and discovery. In the following we will present the law of distribution of some main minerals such as tin, tungsten, gold, antimony, mercury, phosphorite, gypsum, rock salt, thermal water.

#### + Tin - tungsten

In the distribution area of magmatic rocks of Say Phou Ngou and Pong Kuak subvolcanic complexes, some high grade dispersion haloes of cassiterite reaching the grade of  $30-100\text{g/m}^3$ , tungsten reaching  $20\text{g/m}^3$ , some extraordinary points with tin grade  $1971.01\text{g/m}^3$  -  $3732.07\text{g/m}^3$  and wolframite reaching  $47\text{g/m}^3$  -  $125\text{g/m}^3$  have been discovered.

In relation with the Say Phou Ngou subvolcanic complex is a tin bearing area in Nam Paten valley (?). It consists of tin-bearing quartz-sulfide veins and stockworks occurring in a strongly sheared and altered zone. The productive layer has a relatively large thickness with average tin grade 0.24%. A representative of this relationship is the Phon Tiou tin deposit.

Pong Kuak magmatic complex : Tungsten bearing quartz veins have been discovered in this complex. They occur at the contact boundary between the schist with the biotite granite of the complex, especially there are quartz -tungsten veins inside the massif. The tungsten content is : 1.6-3.2%, typically in Pong Kuak tungsten ore occurrence.

+ Gold : Most of gold ore occurrences discovered are located within the stratigraphic units of Nam Houay formation (in Nape anticlinorium). They form a band extending in NW-SE direction from Sopchat - Phon Kham - Nam Ke to Nam Pheo. The distribution area of gold ore occurrences is in the form of bands and zones surrounding Nape complex. The magmatic rocks of the complex penetrated and disturbed the structure of the units of Nam Houay formation, together with the NW-SE trending I-order fault system which is intensively developed it caused intensively sheared and broken zones which are favorable environment for the hydrothermal solution to penetrate and fill the fractured. The concentration of ore in quartz - sulfide veins and stockworks has created valuable ore occurrences such as Nam Ke, Nam Houay, Nam Pheo...

+ Antimony - mercury, pyrite : Dispersion haloes of mercury, pyrite developed in the terrigenous-carbonate sediments of Boualapha and Khammouan formations have been discovered. The rocks are subjected to alterations such as dolomitization, quartzification, sericitization and chloritization. Along the I-order faults, in some sections the rocks are intensively broken. This is the favorable condition for the process of mineralization such as antimony - mercury in Nam Kang area and Nase - Phonxai - Mouang Khai pyrite ore zone.

The above factors were indications and premises for orienting the minerals prospecting in the area or the areas with similar geological structure (Viang Thong area).

+ Phosphorite : As already known, the large number of phosphorite ore occurrences discovered in Boualapha - Mahaxai, Thakhek, Hinboun and Khamkeut areas were all formed in the area with development of carbonate rocks of Khammouan formation. This is the limestone formation with large distribution area in the region. Broken zones are favorable

factor for the process of solution for karst caves to be formed and developed. In the caves are accumulated large amount of phosphorite ore of sedimentary-infiltration and organic (guano) genesis.

+ Gypsum-rock salt : Superimposed depression structures developed in Thakhek and Nakay areas have generated the red color evaporite sediments. They were formed in the lagoon and closed marine condition with hot and humid climate. In the favorable paleogeographic conditions, beds of gypsum and rock salt with relatively large thickness and considerable reserve have been formed.

+ Thermal water : All hot water springs are closely related with the NW-SE trending I-order crust-penetrating and structural zoning fault systems. These fault systems have great depth, developed in the crust and penetrate across the crust. Therefore an amount of heat is added to the water sources. The water emerging from springs has a temperature of 40-60°C

#### 4. History of metallogenic development

The integrated research work on stratigraphy, tectonic and magmatism in Mid Central Lao region show that mineral deposits, ore occurrences and mineral shows are related with and pertain to the following metallogenic stages :

+ Early Paleozoic metallogenic stage (O-S) : The sediments terrigenous and terrigenous - extrusive of Nam Houay & Kodux Formation. Endogenous minerals include gold, polymetals, barite, crystalline quartz. Exogenous minerals are roofing slate.

+ Late Paleozoic metallogenic stage (C-P) : In this stage were widely developed terrigenous - carbonate and carbonate sediments of Boualapha and Khammouan formations. Especially the presence of Nape magmatic complex was related with gold metallogeny. Endogenous minerals include pyrite, barite, copper, antimony, mercury. Exogenous minerals are abundantly developed with large number of ore occurrences such as those of phosphorite, cement clay, brick clay, cement limestone, etc.

+ Late Paleozoic - Early Mesozoic metallogenic stage (P-T). The fairly intensive intrusion of magmatic rocks of Phou Thoun complex ( $\gamma P_2-T_1 pt$ ) Say Phou Ngou complex ( $\gamma T_2 sp$ ) penetrating the terrigenous and intercalated different-extrusive sediments of Lingkho formation ( $T_2 lk$ ) is the favorable condition for the process of concentrating tin, gold, iron, copper mineralization. Especially the pink porphyritic biotite granite of Say Phou Ngou complex ( $\gamma T_2 sp$ ) may be used for facing stone.

+ Middle Mesozoic metallogenic stage : The sediments of Nam Phouan formation ( $J_3 np$ ) consist of sandstone and mudstone. In the greenish gray quartz sandstone are disseminated small pockets of copper ore of sedimentary genesis. The copper ore in sandstone type has been discovered in some places such as Ban Lao, Ban Bo, Phonhai....

+ Late Mesozoic metallogenic stage (K) : In this stage the general structural plan of the region was already rather stable. Ancient continental and micro-continental crust domains were formed, with firm consolidation. Especially in the central and Southern part survey area lagoonal regime still existed and the sea was gradually close, the red color evaporite sediment layer were formed, characterizing the hot and humid climatic conditions. Gypsum - anhydrite layers and rock salt beds with large thickness were formed.

In the NE area of the map sheet group, there appeared Pong Kuak magmatic complex ( $\gamma MZ_3pk$ ) composed of biotite granite, two mica granite related with tungsten - gold mineralization.

+ Cenozoic metallogenic stage (Q) : This is the main stage when occur the processes of weathering, transportation and accumulation. In this period were formed the ore occurrences of construction materials, placer ore occurrences (of gold, tin, etc).

## II. Zoning of mineral resources prospects

### 1. Prospective areas

On the basis of synthesis and analysis of data on geological structure, magmatism, tectonics as well as direct and indirect indications of deposits, ore occurrences, pan concentrate and geochemical dispersion haloes, the Mid Central Lao region may be divided into various areas with different prospectiveness (Drawing No 8) :

+*Prognostic areas of Class A* : The prognostic areas of class A are prospective areas coded from 1A to 8A, consisting of areas most prospective in minerals resources. Here are concentrated deposits and ore occurrences which have been subjected to general and detailed prospecting and have been determined to have industrial significance and have geological premise favorable for the mineralization process, where are concentrated high grade heavy mineral and geochemical dispersion haloes. Especially most of these areas have infrastructure favorable for geological investigation as well as for the exploitation, processing and utilization of the minerals resources in the future.

+*Prospective areas of Class B* : The prognostic areas of class B are areas with unclear prospectiveness, coded from 1B to 5B. These areas have lower information than areas of class A. They have stratigraphic, magmatic premises favorable for the mineralization process. Here some ore occurrences and mineral shows have been discovered and some heavy mineral and are concentrated some geochemical dispersion haloes of medium to high grade.

+*Prognostic areas of class C* : This class comprises areas with low prospect, coded from 1C to 3C. These are areas with few mineral indications. The stratigraphic premises are not much favorable for the mineralization process. The dispersion haloes are not concentrated or have low grade, more rarely medium grade.

#### 1.1. *Prospective areas (class A)*

- Area 1A : Nam Ke -Pong Kuak area : This area covers about 350km<sup>2</sup>. In this area are developed sediments of Nam Houoy formation ( $O_3-S_1 nh$ ), granites of Nape complex ( $\gamma C_1$ ) and Pong Kuak complex ( $\gamma K_2 P$ ) which are favorable environment. Gold-and tungsten-bearing quartz sulfide veins and stockworks have been discovered. Nam Ke, Nam Houoy, Pong Kouak ore occurrences have been subjected to detailed prospecting and are of industrial significance. The result of fire assay analysis the gold grade reach 0.6-4g/t, some samples give Au = 24-63g/t. Bedrock panning samples give 5-500 grains of Au in 7kg of ore. The results of chemical analysis for W give 1.6-3.2g/t. Especially in the area are developed high grade dispersion haloes of gold and tin. Besides, in the area there is a clay deposit (Nahuang) which is a source of ceramic and porcelain raw materials; thermal water sources: Nape (being tapped to serve tourism) and Pong Kuak.

- Area 2A : Forms a band North of National Road 8, extending from Kham Keut to Laksao, laid by carbonate rocks of Kham Mouan formation and terrigenous sediments of Boualapha formation, covering about 150km<sup>2</sup>. The carbonate rock is rather pure, with good quality, with harmful impurities within the permissible limits, meeting the requirements as raw materials for the cement production. Besides, a cement clay occurrence (Nam Phao), a brick clay occurrence and 5 cave phosphorite ore occurrences have been discovered. This area has favorable infrastructure, easy access, with favorable conditions for construction of an industrial zone for production of cement and fertilizer.

- Area 3A : Comprises the whole Nam Paten valley, covering about 250km<sup>2</sup>. The granites of Phou Thoun complex and subvolcanic rocks of Say Phou Ngou complex together with the NW-SE trending fault system are closely related with the mineral manifestations of the area.

In area 3A the most prominent minerals include tin and iron. They have been evaluated to be of large reserve. Phon Tiou, Boneng, Nong Xun deposits have been subjected to exploration. In particular Boneng, Phon Tiou deposits is being mined.

- Area 4A : Is distributed in the Na Kay depression. The whole area is the central part of Nam Theun syncline, covering about 130km<sup>2</sup>.

It is laid by very characteristic red color evaporite sediments, of which the typical minerals are gypsum and rock salt. The Lang gypsum ore occurrence has a thickness > 7m, in Nong Boua the rock salt bed is 85.27 m thick and the gypsum bed is near 8m thick. This area needs investment for investigation and evaluation in the stages.

- Areas 5A and 6A : These two areas form a band extending in NW-SE direction from Hin Boun through Thakhek - Mahaxai to Boualapha, covering about 4000km<sup>2</sup>. These areas are laid by carbonate rocks of Khammouan formation and are affected by the zoning and I-order fault systems which caused breakage and shearing, which is the favorable condition for forming karst caves and accumulation of phosphorite of sedimentary-infiltration genesis.

In the area, over 30 phosphorite containing caves with considerable potential have been discovered. Besides phosphorite, pyrite ore occurrences have been subjected to general and detailed prospecting in Phonxai, Muang Khai, Nahy. In particular the raw construction materials are of very great potentials, can meet the demand for construction and development of cement industry.

- Area 7A : Is distributed to the South of Thakhek town in Thakhek depression. It covers ~ 600km<sup>2</sup>. The whole area is laid by the red evaporite sediments of Nong Boua formation). The main minerals here are gypsum and rock salt. The Bunghouana gypsum deposit has been explored by Thai Gypsum Products Co. Ltd. with a reserve of 16.5 Mt. Thangam rock salt deposit has a thickness of the salt bed > 70m, is now being mined for domestic use of the people in the area.

Along Nam Khong and Xebangfai rivers are developed Quaternary sediments with sand, gravel deposits for construction such as Gngangam, Dongtai, Bungxe, Somsaat.

- Area 8A : Is developed in Phakat - Chalet area, covering about 60km<sup>2</sup>, laid by sediments of Koduk formation (O<sub>3</sub>-S<sub>1</sub> kd). Along the NW-SE fault system the rocks are broken and crushed. Associated minerals are pyrite and polymetals as discovered in Phakat. The results of chemical analysis gave the contents : BaO : 57.07-59.34%, Pb : 18.89%, Zn : 31.66%. Here there is a dispersion halo of barite with grade >100g/m<sup>3</sup>.

### *1.2 Areas with unclear prospectiveness (Class B)*

- Area 1B : Is distributed in the Northern and NE part of the map sheet group, in Nape uplifted zone, extending from Nam Cham - Nape to the upstream of Nam Theun. The area is laid by Nam Houay, Sop Phan, Huoi Pang, Phon Keo formations and magmatic rocks of Nape, Pouang Kuak complexes. Petrographic, magmatic and structural factors are favorable for the mineralization. besides there are mineral shows of gold such as Phan Kham, Sop Chat; crystalline quartz such as Phou Toum, Phon Keo and fairly concentrated dispersion haloes of cassiterite, scheelite, wolframite, gold, cinnabar, etc.

In the next steps, detailed survey and prospecting should be carried out in areas such as Nam Pheo, Phon Keo, Phon Kham.

- Area 2B : Is controlled by Viang Thong - Nam Kang NW-SE trending I-order fault. The area is in Viang Thong anticline, composed of the sediments of Thapachon, Phon Keo, Boualapha and Khammouan formations together with small magmatic massifs of Nape complex. Along the fault an ore show of antimony - mercury has been discovered in Nam Kang, of gold in Tha Dua and thermal water sources in Sop Hong and Pakouay. Here are developed dispersion haloes of minerals such as cinnabar, gold, scheelite. The Nam Kang antimony-mercury ore occurrence should be given investment for detailed investigation.

- Area 3B : Is controlled by Thakhek - Danang structural zoning thrust fault extending from Pakading through Hinboun to Thakhek.

Area 3B is laid by sediments of Phon Tiou, Boualapha, Khammouan formations and magmatic rocks of Phou Thoun complex, and subvolcanic rocks of Say Phou Ngou complex. Stratigraphic, magmatic and structural factors here are very favorable for endogenous and exogenous metallogeny. Nam Khou tin ore occurrence, Ling Kho gold ore occurrence, Say Phou Ngou facing stone deposit, phosphorite ore occurrences etc. are examples.

Besides, in the area have been delineated mineral dispersion haloes with medium to high grade of cassiterite (Nam Khou), cinnabar, gold, chromite, geochemical dispersion haloes of chromium, nickel, copper, zinc, lead, etc.

- Area 4B : Is distributed in the area from Thakhek - Mahaxai to Boualapha, laid by carbonate rocks of Khammouan formation, terrigenous sediments of Boualapha formation ( $C_1 bp$ ).

The petrographic factor together with fairly developed fault system are favorable condition for forming karst caves with phosphorite ore accumulation. This is an area with large potential in terms of raw materials for construction and fertilizer production industry.

In the area are developed geochemical dispersion haloes of Ni, Cr, Co, probably elated with plutonic ultramafic magmatic bodies (?) along the Thakhek - Da Nang structural zoning thrust fault.

- Area 5B : Is distributed in the SE of the study area, from Phakat to Ban Hon. It is developed in anticline composed of sediments of Koduk, Boualapha and Khammouan formations. Along the NW-SE trending fault system the rocks are broken and crushed, usually associated with minerals such as barite, polymetals in Phakat, Ban Hon, iron in Chalet. Besides, there is a mineral dispersion halo of barite.

### *1.3 Areas with low prospectiveness (class C)*

Areas of class C are coded from 1C to 3C, accounting from 35% of the study area. This area has been subjected to geological survey of 1:200,000 scale with panning and geochemical analysis.

The results of study in stratigraphy, structure and sample analysis show that the area has not many favorable conditions for mineralization, mineralogical and geochemical dispersion haloes here are not concentrated, they usually have low grade level (level 1). In particular the area 1, due to the difficult condition (objective factor), geological walking survey have not been carried out. Therefore the adequate information on the minerals resources prospectiveness in this area is still lacking. Further survey and investigation should be carried out when appropriate.

## 2. Proposed areas for further investigations

### 2.1. Areas for 1:10,000 or larger scale geological survey and mineral prospecting

+ Area 1 : (Nam Ke - Pong Kuak) covers about 60km<sup>2</sup>. Here occur metamorphosed sediments of Nam Houay formation (O<sub>3</sub>-S<sub>1</sub> *nh*), magmatic rocks of Nape complex ( $\gamma$  a C<sub>1</sub> *np*) and Pong Kuak complex ( $\gamma$  MZ<sub>3</sub> ? *pk*). The main minerals here are primary gold (Nam Ke, Nam Houay), placer gold (Nakadok), tungsten (Pong Kuak), roofing slate (Nakadok).

+ Area 2 : (Kham Keut - Laksao) covers about 150km<sup>2</sup>. Here occur carbonate sediments of Khammouan formation (C-P<sub>1</sub> *km*), terrigenous sediments of Boualapha formation (C<sub>1</sub> *bp*). Minerals here include phosphorite, cement limestone, cement clay, building limestone, brick clay. The potential of these resources must be evaluated for planing the development of construction material and fertilizer production industries.

+ Area 3 : (Na Kay) : Is distributed at the center of Na Kay syncline, covering about 130km<sup>2</sup>.

This area is lade by sediments of Nong Boua formation (K<sub>2</sub> *nb*), which are characterized by red color evaporite beds containing rock salt and gypsum with large thickness, such as Tha Lang gypsum ore occurrence (> 7m thick) Nong Boua rock salt ore occurrence (>80m). Besides there are two gypsum mineral shows in Ban Bo and Na Kay.

+ Area 4 : (Nongbok) : Is distributed South of Thakhek, in Thakhek depression, covering near 600km<sup>2</sup>.

Here occur mainly sediments of Nong Boua formation (K<sub>2</sub> *nb*) bearing rock salt and gypsum. Here besides Bunghouana gypsum deposit which has been subjected to exploration, there is Thangam rock salt ore occurrence with a relatively large thickness (>70m). Besides, salt water sources Nong Khem and Nonsila which occur within a wide area, are probably related with thick rock salt beds located deep underground. Quaternary unconsolidated sediments supply abundant construction material sources such as sand and gravel.

### 2.2. Areas for 1:50,000 or 1:25,000 scale geological survey and mineral prospecting

+ Area 1 : Is located in the NE of the map sheet group, extending from Nam Cham - Nape Nam Pheo, covering about 2,000km<sup>2</sup>.

The stratigraphic, magmatic and structural factors are favorable for the endogenous mineralization process. Key minerals of the area are gold, tungsten, crystalline quartz. Besides there are also roofing slate, clay, thermal water, etc. In the area are concentrated numerous dispersion haloes of tin, tungsten, gold.

+ Area 2 : Is distributed in Nam Kang - Viang Thong, extending in NW-SE direction, covering ~ 900km<sup>2</sup>. In this area are developed intercalated terrigenous-carbonate and carbonate sediments of Thapachon, Khammouan formations, small intrusive bodies of Nape complex ( $\gamma$  a  $C_1 np$ ). The above factors are favorable environment for mineralization of hydrothermal genesis. The minerals in the area include Nam Kang tungsten- mercury ore occurrence, Tha Dua gold show, Tha Phe brick clay ore occurrence, thermal water sources along the I-order fault. Besides, here are concentrated mineral dispersion haloes of cinnabar, gold, scheelite, geochemical dispersion haloes of Mo, Ba, Cu.

+ Area 3 : Is distributed in the West of the map sheet group, from Nam Khou through Nam Tion to Thakhek, covering about 1900km<sup>2</sup>.

Endogenous minerals include: tin, mainly in Nam Paten valley, some in Nam Khou; gold mineral shows in Lingkho, Vang Phe, Pakpakan. Exogenous are mainly cave phosphorite in carbonate sediments of Khammouan formation, copper in sandstone of Nam Phouan formation; construction materials such as limestone ; sand, gravel, facing stone.

In the area are distributed some dispersion haloes of cassiterite, chromite, copper, molybdenum.

+ Area 4: Is distributed in Thakhek - Mahaxai - Boualapha area and upstream of Xebangfai, covering about 4000km<sup>2</sup>.

Here commonly occur carbonate sediments of Khammouan formation( $C-P_1 km$ ), terrigenous sediments of Boualapha formation ( $C_1 bp$ ), metamorphic rocks of Koduk formation ( $O_3-S_1 kd$ ). Endogenous minerals include barite in Ban Hon, iron in Chalet, pyrite in Phonxai and Muang Khai, copper in Ban Bo. Exogenous minerals include large amount of phosphorite cement limestone and building limestone. This is the area with large potential of supplying raw materials for cement and fertilizer production in the future.

## CONCLUSION

The Project "Mineral Investigation and Geological Mapping at 1: 200,000 scale of Mid Central Laos region" implemented by the collective of the staff of the Department of Geology and Mines of Laos and INTERGEO Division of Department of Geology and Minerals of Vietnam from 1996 to 2000 has been completed.

During the implementation process the plan of the project was changed many times due to various objective and subjective reasons. Nevertheless the project always followed closely the objectives and tasks set forth. Although there were many difficulties during the field work such as: the study area was extensive, the topography was dissected, the transport was not favorable, and especially the malaria was rampant, but the collective of Vietnamese and Lao staff of the project have tried their best to overcome the difficulties and basically have fulfilled the objectives and tasks of the project.

This is the first geological survey and mineral prospecting project carried out in The Mid Central Lao region, with the integrated application of various methods at 1:200,000 scale where many encouraging results in geological investigation and mineral prospecting have been achieved.

In geological investigation: as a result of the project a 1: 200,000 scale geological map of the Mid Central Lao region has been compiled with 15 stratigraphic units (formations) with fairly adequate backgrounds for subdivision. These are new formations for the first time established in the Mid Central Lao region, which serve as the basis for correlation and comparison with the adjacent areas in the territory of Vietnam and Thailand. Many fossil sites characterizing the formations subdivided. The composition of the formations has been fully investigated through detailed sections. The distribution areas of the Precambrian metamorphosed sediments of Sop Phan formation ( $PR_3-C\ sp$ ) has been much diminished as compared to the previous one. The subdivision of sediments of Nam Houay formation ( $O_3-S_1\ nh$ ) into three sub-formations has important significance in the prospecting of minerals resources especially primary gold. The sediments of Phon Keo formation ( $D_{1-2}\ pk$ ) consist mainly of terrigenous sediments, in the min time the Middle - Upper Devonian sediments have a shifting from West to East. In the West are the terrigenous sediments of Phon Tiou formation ( $D_{2-3}\ pt$ ), whereas in the East are the carbonate sediments of Thapacho formation ( $D_{2-3}\ tc$ ). The results of the survey show that the sediments of Khammouan formation ( $C-P_1\ km$ ) overlies transitionally the sediments of Boualapha formation ( $C_1\ bp$ ), instead of "charriage" (overthrust displacement) as suggested by the former Soviet geologists (E. D. Sulydy Kondratiev et al., 1990). For the first time the terrigenous - extrusive formations have been discovered in the West of Say Phou Ngou mountain range (Lingkho formation -  $T_2\ lk$ ) which was described as red color sediments aged Late Triassic. Jurassic marine sediments have been discovered. This has an important significance for the regional geological investigation in Mid Central Lao region in particular and in Indochina in general. The evaporite sediments have been grouped into Nam Theun series, serving as the basis for the correlation with Khorat series distributed in the West in the territory of Thailand. The Neogene - Quaternary sediments were investigated in conformity with the 1:200,000 scale.

The magmatic rocks have been investigated and 4 typical magmatic complexes have been established with firm grounds in the Mid Central Lao region. For the first time the Poug Kuak complex ( $\gamma\ MZ_3\ ?\ pk$ ) has been discovered and established, which is composed mainly of leucocratic two mica granite related with tungsten mineralization. Subvolcanic formations related with tin mineralization in Nam Paten valley and subvolcanic-intrusive rocks in the West of Say Phou Ngou mountain range have been also investigated. The result of investigation show that they are of the same origin, forming the pluton-volcanic series and Say Phou Ngou subvolcanic-intrusive complex ( $\alpha\xi^\pi, \xi^\pi-\lambda^\pi, \tau\lambda^\pi-\gamma\ T_2\ sn$ ). The petro-mineralogical and petro-geochemical characteristics of each complex have been clarified. The genetic petrology of magmatic rocks have been also investigated by quantitative analysis of main elements, trace elements and establishment of related diagrams. The rocks of each complex were formed in a certain geodynamic circumstance, which assists in tectonic investigation and contributes to the clarification of the geological development history of the region. The related minerals resources have been investigated and gradually have been clarified.

The project involved some combined researches such as those in geomorphology, hydrogeology and tectonics. A geomorphologic map of Mid Central Lao region with 23 landform surfaces with the same genesis and age, a 1:500,000 scale tectonic diagram showing the typical structural units of the Mid Central Lao region in the general structural plan of Indochina have been compiled. The water bearing characteristics of various dc formations in the region have been described.

As regards minerals resources : The project has closely followed the tasks set forth, i.e. to search for, discover and assess the prospectiveness of all minerals resources in the region, with attention paid to the minerals such as gold, tin, construction materials, fertilizer raw materials, gypsum and rock salt, etc. In a region which had been considered to be poor in minerals resources, by integrated application of various methods, for the first time the project has discovered many new mineral occurrences. The results of prospecting show that the Mid Central Lao region is very abundant in minerals resources. The prominent minerals of the region include: tin, gold (primary and placer gold), phosphorite, rock salt, gypsum, barite, tungsten, polymetals, mercury - antimony, piezo-electrical quartz and raw construction materials. The potentials of some ore occurrences such as Nakadok placer gold, Nam Ke and Nam Houay primary gold, Phaixai pyrite and some phosphorite containing caves. In general, the minerals resources investigation has met the requirements for the 1:200,000 scale geological survey. The discovery of phosphorite in karst caves of C-P1 limestone has a great practical significance. Evaluation of phosphorite potential will serve as a basis for the design and construction of microbiological fertilizer factories, to assist in the development of agriculture in the Lao PDR. The discovery and initial assessment of some kinds of minerals such as gold, mercury - antimony, barite, polymetals, tungsten, etc. will give the initial important data serving as the basis for their further investigation and evaluation. Many high grade mineralogical dispersion haloes of gold, cinnabar, cassiterite, barite, etc., and geochemical dispersion haloes of Sn, Cu, Pb, Zn, etc.

Through the synthesis of all data, the project has established a mineral resources prognostication and prospect zoning scheme of Mid Central Lao region.

- Endogenous minerals such as gold, tungsten are usually distributed in the Eat (Nam Houay - Nam Heung - Nam Sang) uplifted zone, where are distributed the sediments of Nam Houay formation ( $O_3-S_1 nh$ ). Besides, technical raw materials (piezo-electric quartz) and thermal water sources also occur here.

Barite and polymetal ores are distributed in the NE (Xaibouthong - upstream Xe Bangfai uplifted zone), where are distributed the sediments of Koduk formation ( $O_3-S_1 kd$ ).

- Phosphorite is distributed in karst caves of C-P1 limestone (Khamkeut - Viang Thong, Phon - Tiou, Mahaxai - Boualapha subsided zones). Tin, mercury, antimony are usually related with local uplifts inside the above subsided zones.

Rock salt, gypsum and copper are distributed in depressions (Nam Kading - Nam Theun and Thakhek depressions)

- Thermal water sources are usually related with I-order deep seated faults in the crust.

The project has recommended the areas to carry out further investigations at various scales. For minerals such as primary gold, barite, polymetals, mercury - antimony, gypsum, geological investigations at 1:10,000 or larger scale can be carried out to evaluate their potential. In particular for phosphorite, exploration of caves should be carried out, the reserves should be assessed to serve timely the design and construction of microbiological fertilizer factories. Areas proposed for carrying out 1:50,000 or 1: 25,000 scales geological investigations for particular minerals.

Although it has obtained the results as presented in the report. The project still has some outstanding problems as follows :

- Some detailed sections are still lacking for some stratigraphic units and their direct contacts are still unclear (Thaphachon formation, Koduk formation).
- Due to some difficulties, geological walking survey have not been carried out in the South of Xiang Khoang province and the North of Viang Thong district. The geological boundaries here were drawn based on the interpretation of air photos, therefore their accuracy is still limited.

In 1996 - 2000, the collective of Lao-Vietnamese staff had the honor to carry out the geological survey and mineral prospecting in Mid Central Lao region, which the Government of the Lao PDR selected as the key region for the economic development of the country. Although they met with many difficulties, the collective of Lao-Vietnamese staff have well fulfilled the assigned plan, have established a set of basic investigation data which serve the implementation of long term and short term development plans of the Mid Central Lao region. It is hoped that the results obtained will meet the requirements of the Government of the Lao PDR in the cause of the national development in general and of the Mid Central Lao region in particular.

Before completing this report, once more the collective of authors would like to sincerely thank the Director General of the Department of Geology and Mines of Laos, the Chairman of the Program, the Director of INTERGEO Division of the Department of Geology and Minerals of Vietnam, the geologists of INTERGEO Division, the leading experts of the Department of Geology and Minerals of Vietnam, Research Institute of Geology and Mineral Resources of Vietnam, the people of Khammouan, Bolikhamxay who have provided assistance and created favorable conditions for the staff of the project to fulfil efficiently field works and final reporting works.

**Director of  
INTERGEO Division**

*Vientiane, 25 - 8 - 2000*  
**Editor - in - chief**

**Hoang Duc Xa**

**Tran Van Ban**