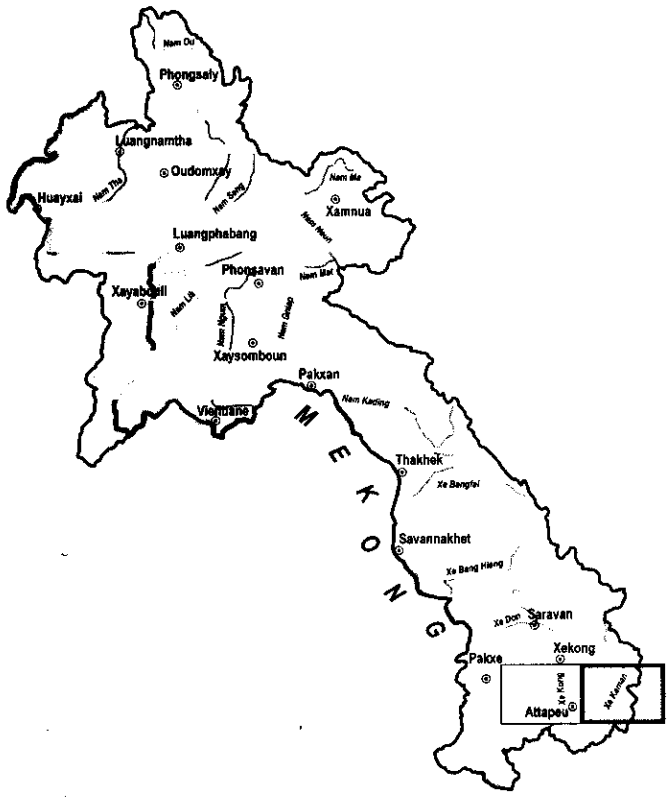
REPORT ON GEOLOGY OF THE B. DAKYOY DISTRICT
[illegible] SHEET MAP, 1: 200,000
[illegible] MAP NO.: D-48-XII

Geology of the B. Dakyoy District

Siphandone Vilayhack, Sixomxeun Duangsurigna, Sisaad Phomkenthao, Amkha Voravong,
Phonetalome Vilaysan, Thavone Khounchanthida, Khampha Phommakaysone,
Motomu Goto, Yoshimitsu Negishi, Kazuyasu Tsuda, Yasushi Watanabe and Yoshiaki Shibata

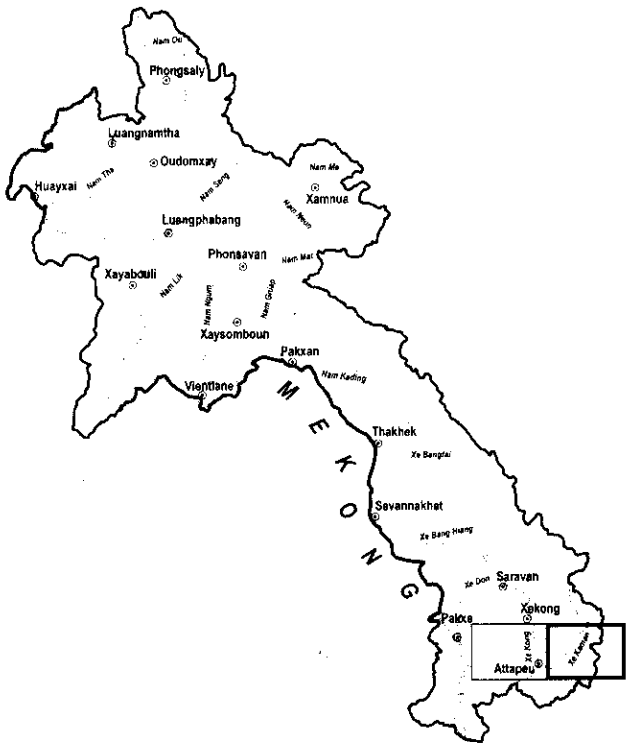


October 2008
Japan International Cooperation Agency
Department of Geology, Ministry of Energy and Mines, Lao. P.D.R.

REPORT ON GEOLOGY OF THE B. DAKYOY DISTRICT
GEOLOGICAL SHEET MAP, 1: 200,000
TOPOGRAPHIC MAP NO.: D-48-XII

Geology of the B. Dakyoy District

Siphandone Vilayhack, Sixomxeun Duangsurigna, Sisaad Phomkenthao, Amkha Voravong,
Phonetalome Vilaysan, Thavone Khounchanthida, Khampha Phommakaysone,
Motomu Goto, Yoshimitsu Negishi, Kazuyasu Tsuda, Yasushi Watanabe and Yoshiaki Shibata



October 2008
Japan International Cooperation Agency
Department of Geology, Ministry of Energy and Mines, Lao. P.D.R.

D-48-IV	D-48-V	D-48-VI
D-48-X	D-48-XI Attapu District (JICA/DGEO, 2008)	**D-48-XII** **B.Dakyoy District** **(JICA/DGEO, 2008)**
D-48-XVI	D-48-XVII	D-48-XVIII

REPORT ON GEOLOGY OF THE B. DAKYOY DISTRICT (2008)
1:200,000 GEOLOGICAL SHEET MAP
TOPOGRAPHIC MAP No.: D-48-XII

Geology of the B. Dakyoy District

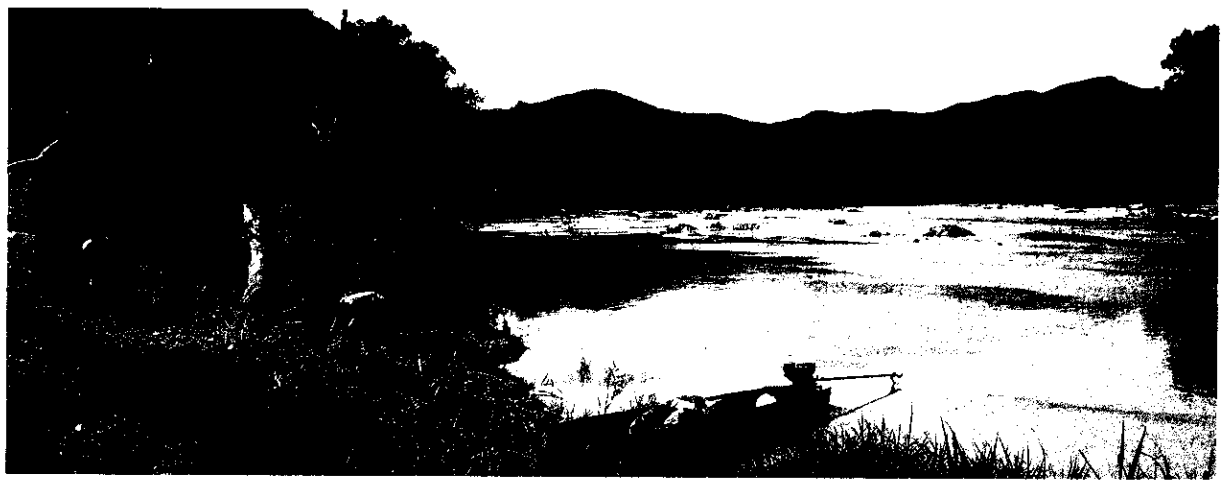
Siphandone Vilayhack*, Sixomxeun Duangsurigna*, Sisaad Phomkenthao**, Amkha Voravong***,
Phonetalome Vilaysan*, and Thavone Khounchanthida**, Khampha Phommakaysone*,
Motomu Goto****, Yoshimitsu Negishi****,Kazuyasu Tsuda****,
Yasushi Watanabe***** and Yoshiaki Shibata****

The geological sheet map of B. Dakyoy District at a scale of 1:200,000 was produced as a part of the project "The Geological Mapping and Mineral Information Service Project for Promotion of Mining Industry in the Lao People's Democratic Republic" agreed between Japan International Cooperation Agency (JICA) and the Ministry of Energy and Mines (MEM), Lao People's Democratic Republic (Lao P.D.R.) for promotion of investment to mining industry in 2005. This is a bilateral cooperation project between Japan and Lao P.D.R. for promotion of investment to mining sector through improving information system of mineral resources.

The field survey and preparation of the geological sheet map were conducted implementing capacity development of the Department of Geology (DGEO). A meeting was held in June 2006 for deciding the target area for geological mapping and mineral resources service, and the area including Attapeu, Champasak and Sekong provinces was selected. The selected area, 160km (East-West) X 80km (North-South), covers two quadrangles of topographic map sheets, D-48-XI and D-48-XI, at scale of 1:200,000. The geological sheet map of B.Dakyoy District corresponds to one quadrangle and the other corresponds to the geological sheet map of Attapu District.

The geological sheet map was produced through cooperation of DGEO staff, namely Mr. Chansone Senebouttalath, director, Mr. Khampha Phommakaysone, vice-director, Ms. Chansavath Boupha, deputy director general, and Mr. Oudom Phammakaysone, director of the information center for geology and mineral resources. Valuable suggestions were given to us by Mr. Thongphath Inthavong, director general of DOM, and Dr. Simone Phichit, deputy director general of DOM. During field work, much assistance was given by Mr. Khoune, director of DGEO Pakse branch office, Mr. Souksamay Chanthamath, director of the Department of Energy and Mines, Attapeu Province. Discussion concerning particularly the geological boundaries were held with Mr. Binh and staff of geological sheet map group of the INTERGEO, Vietnam for the deciding the some geological boundaries.

Finally, we wish to express our sincere appreciation to the officials of the Embassy of Japan in Lao P.D.R., JICA Lao P.D.R. office and the Ministry of Energy and Mines, LAO P.D.R. for their close cooperation extended to the project.



The view of Xe Kaman River and Annam Mountain in the B. Dakyoy District.

*: Department of Geology, LAO P.D.R., **: Department of Geology, Pakxe Office, ***: Department of Energy and Mine, Attapeu Province, ****: JICA Expert, *****: Geological Survey of Japan, AIST.

Contents

Figures, Tables and Appendix

I Geographical Features and Weather

The B.Dakyoy District for geological mapping covers mainly Attapeu Province and slightly Xekong Provinces in southern area of Lao P.D.R. The district is situated at latitude 14°40′ to 15°20′N and longitude 107°00′ to 108°00′E.

Annam mountain occupies the mostly of the B.Dakyoy District, which is the altitude of approximate 400m to 2,000m. Topographical feature of the mountain is classified into a mature topography. The most highest mountain is Ph.Pengmun, which has 2,052m in altitude, located at national border between Laos and Vietnam. The border line goes through the area of relatively high altitude ridges of the Annam Mountain. Directions of their ridges extend from NW-SE to N-S basically. Their extensions are reflected distributions and structures of strata. In the area of Paleozoic to Mesozoic strata consisted of metamorphic and sedimentary rocks, topographical topographical terrain shows a steep form. On the other hand, the terrain of gentle form is located in the area of granitic rock distribution.

There is a lake called on Nong Fa known as a beautiful and quiet place in the area. The lake locates in the northeastern part of district. In the peripheral area of Nong Fa Lake, Cenozoic basaltic rocks are distributed remarkably.

Topographical flat plain develops in the eastern part of Attapeu City. The plain spreads from Annam mountain to west direction as a forward margin of the mountain. Altitude of the flat plain is several hundred meters.

For the river system in the B.Dakyoy District, the main drainage consists of Xe Kaman and Xe Xou River system. Their river head are located in Vietnam. Their rivers flow into Xe Kong River as a big tributary river of Mekon River. The width of the main river such as Xe Kaman and Xe Xou River have maximum 50m in the western part of district which locates in downstream of their river. In the upstream, their river width become narrow such as several ten meters. The depth of water has several meters along downstream. In the upstream, their depth become shallow such as several meters to centimeters. Therefore, motorboat can access in their downstream located in the western part of district only.

The weather in the B.Dakyoy District characterizes tropical monsoon. A year is divided into three seasons in general. The hot season is hot and wet from March to May. The rainy season is June to October. The dry season is cool and dry from November to February. Period of spring and autumn is very short and shows transitional character. It is fresh in the periods and gets along easily. It extremely gets cold in the mountain area during the dry season. Temperature, humidity and rainfall in a year are shown in Fig. 1.

Main road networks in the B.Dakyoy District are slightly developed. In the area, the main road as a key of southern Lao networks is highway No. 18B (Route 18B). The road goes through Attapeu City and extends to east which head to the Lao Vietnam border as a international border. The Route 18B is made of asphalt. Sub-networks of the road develop in the peripheral of Attapeu City. Their sub-roads are almost made of cobble or soil only. Their road conditions have a bad condition especially rainy season. When the rainy season comes, their road condition for passage of vehicles becomes very difficult situation.

Population of Attapeu Province was 114,976 persons (female: 58,637) in 2006 and was estimated approximate 117,850 in 2007. Laos is a multiracial country. And Attapeu Province also is not an exception. The 40% of population in Attapeu Province is occupied by Lao Lum. 60% of the population consists of thirteen ethnic minorities of Lave, Gne, Talieng, Brous, Oy, Alack, Chroodark, Cheng, Chroobong, Gnaheun, Sadan, Kagnong and Ta-oy.

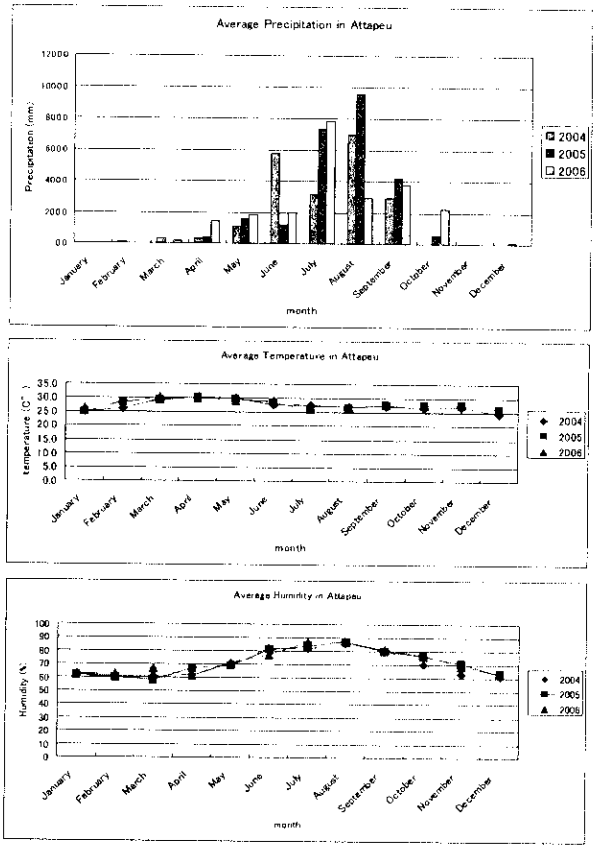


Fig. 1 Weather data of temperature, humidity and rainfall in Attapeu Province.

II General Geology

The geology of the B.Dakyoy area consists of many varieties of rocks such as gneisses which are thought to be connected with addition of continental crust, gabbro, granites, schists, slate, sandstone, conglomerate, marine to continental sedimentary rocks of chert and limestone, rhyolitic to basaltic volcanic rocks and basalt. Among these, gneisses and gabbro were considered to relate to collision process of continental crust. Distribution of these rocks is settled respectively and forms structural terrain (Fig. 2).

The geological age of each layer of geological unit tends to become younger toward a western part from an eastern area. However, since detailed geological survey has not been conducted until now, geological age classification is very questionable.

According to interpretations of the boundary of geological period by Annells and Coast (1990) and Phan Cu Tien *et al.* (1991), they were supposed that the age of gneisses and gabbro show Precambrian period, and granites correspond to Ordovician to Triassic period. Moreover, the age of metamorphic rocks is supposed to be Ordovician to Carboniferous period. For the post orogenic volcanic and sedimentary rocks, the age of rhyolitic to andesitic volcanic rocks, chert and limestone, marine sedimentary rocks and the continental sedimentary rocks correspond to Triassic, Triassic, Carboniferous to Jurassic and Jurassic to Cretaceous period respectively. For the basaltic volcanic rocks, Tertiary to Quaternary period were supposed.

According to the classification of Indochina Peninsula structure such as UN (1990) and Phan Cu Tien (1991), the geological structure province of the B.Dakyoy area belongs to Savannaket - Kontum Province. The structural province is further classified into three of sub-provinces such as post Mesozoic sedimentary basin, Caledonian fold belt and Kontum massif. Of these provinces, Caledonian fold belt consists of Paleozoic to Mesozoic sedimentary rocks, low grade metamorphic rocks and granites. Kontum massif consists of Precambrian basement rock. Among these, in the B.Dakyoy area, the lowlands of southwest part form a sedimentary basin, and the steep range of hills and mountain land are grouped as Caledonian fold belt. The Vietnamese side which is the eastern extension of B.Dakyoy area is classified into the Kontum massif.

These days, geological research of the Kontum massif in Vietnam is progressing and it is pointed out that the formation of basement rocks which is once considered to be Cambrian period is rejuvenated till Paleozoic to Mesozoic period (for example, Nagy *et al*, 2001, Osanai *et al.*, 2001, Tran Ngoc Nam *et al.*, 2001, Maluski *et al*, 2005, etc).

According to Nakano *et al* (2007), Osanai *et al* (2008) and so on, a possibility is also illustrated that western side extension of the Vietnam Kontum massif would be identical to the B.Dakyoy area in Laos. In the B.Dakyoy area, gneisses which is considered to be formed in Cambrian period are distributed. If the formative age of gneisses is Paleozoic to Mesozoic age same as the Kontum massif in Vietnam, the tectonic mode of the southern Lao may change a lot.

Geological and mineral resources map and schematic geological column of the B.Dakyoy District created by this JICA-DGEO Project study are shown in Fig. 3 and Fig. 4.

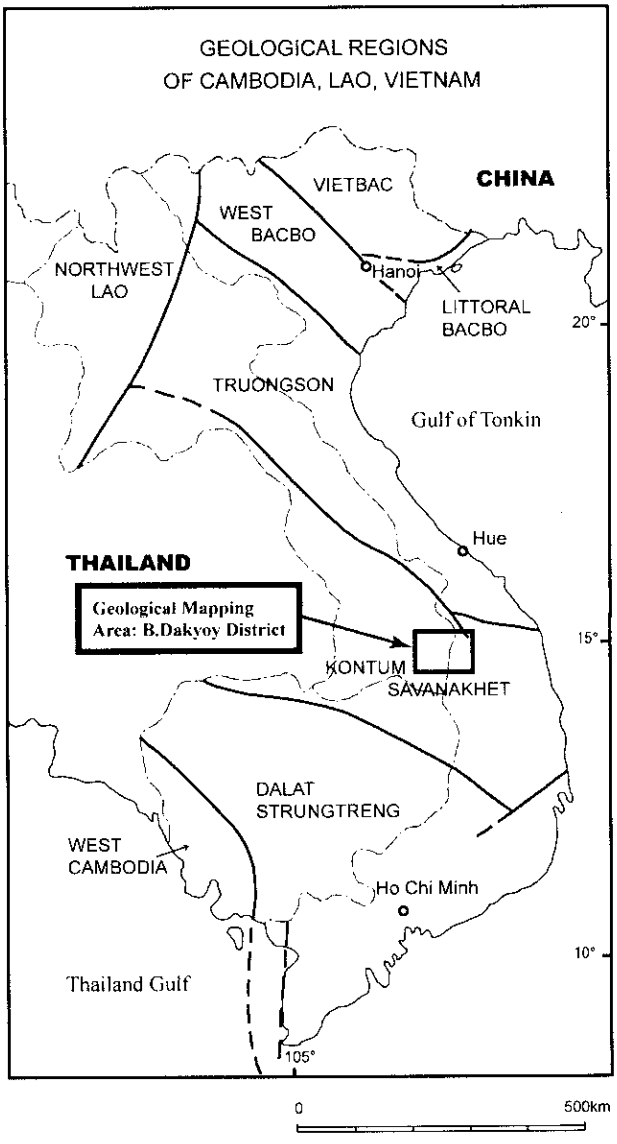


Fig. 2 Classification of geological regions in Indochina area(GSV, 1991) and location of the B.Dakyoy District.

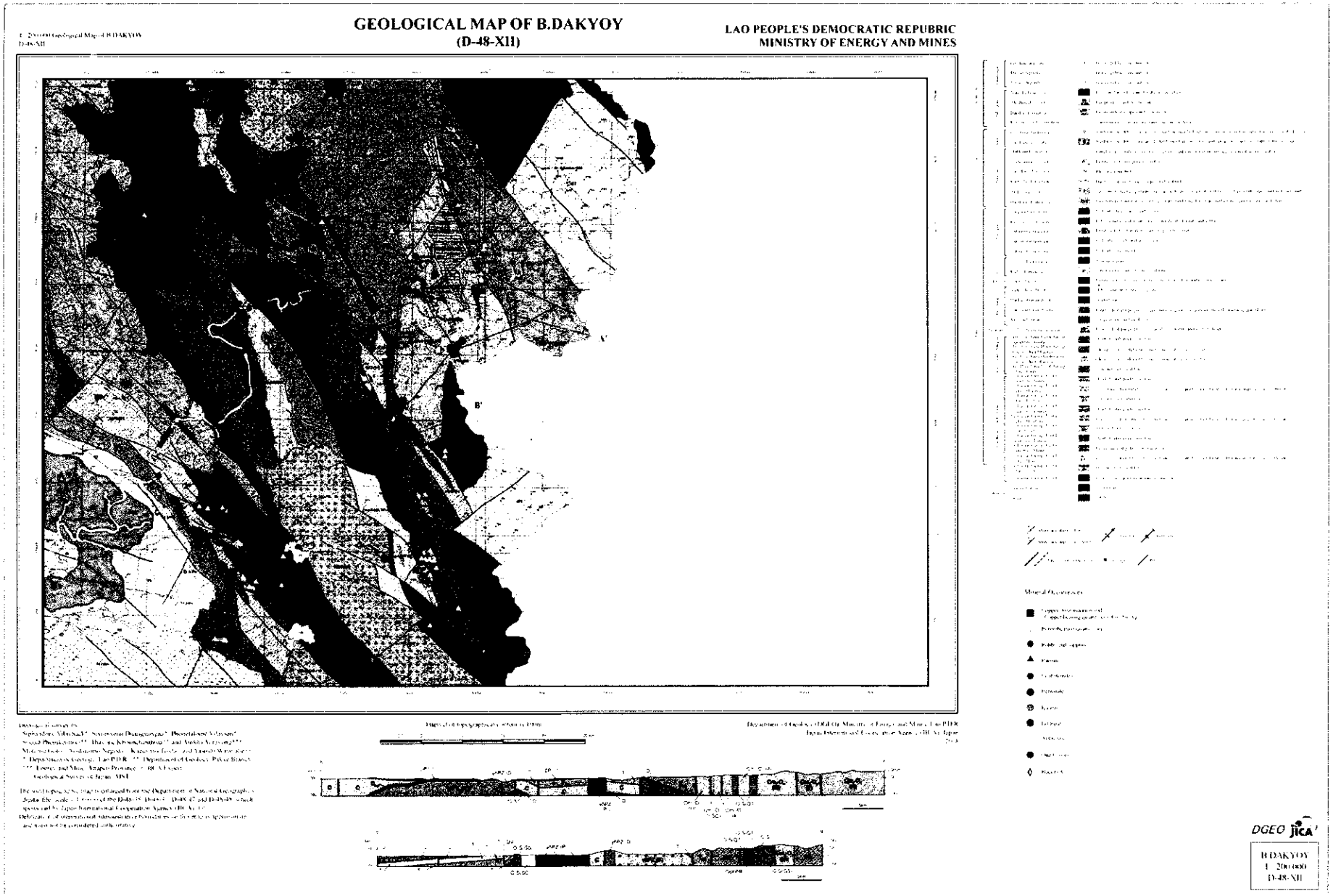


Fig. 3 Geological and mineral occurrences map of the B.Dakyoy District.

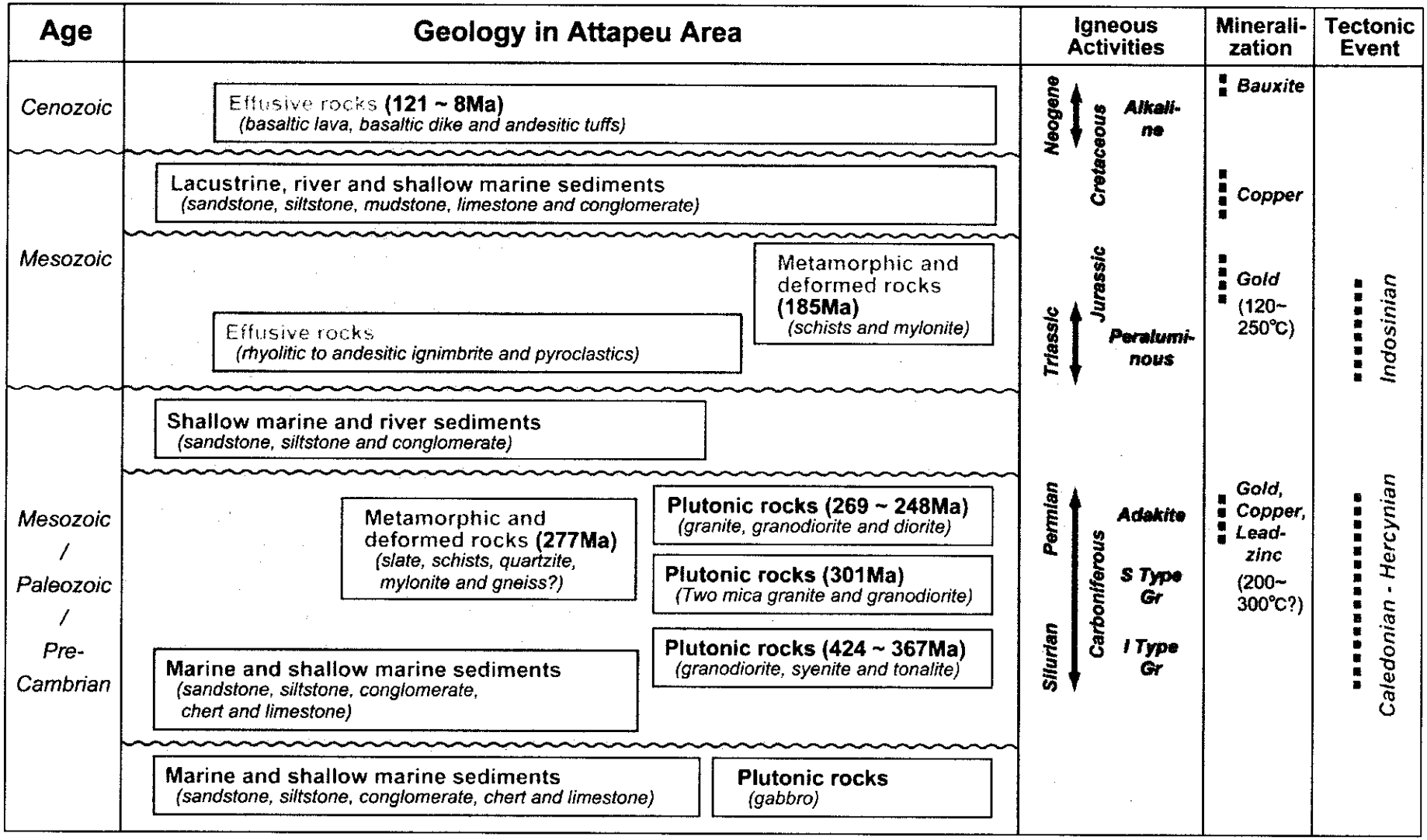


Fig. 4 Schematic geological column of the B.Dakyoy District.

III Unknown

According to Annells and Coast (1990) and Phan Cu Tien *et al.* (1991), basement rocks in the JICA-DGEO Project area are gneisses and gabbro. Among these, gneisses in the area are correlated with gneisses distributed in the Kontum massif of Vietnam located in the east of B.Dakyoy area. Those gneisses has been supposed as Proterozoic basement.

In the Vietnam Kontum massif, a joint research project by Japanese and Vietnamese researchers was performed from the latter half of the 90s. In the research, many radioactive age measurement for metamorphic rocks including gneisses and granites was performed (for example, Nagy *et al*, 2001, Osanai *et al.*, 2001, Tran Ngoc Nam *et al.*, 2001, Maluski *et al*, 2005, etc). Based on the result of these research, the dated age of gneisses which has been considered to be Proterozoic are shown in Permian to Triassic period, and the formative age of these rocks becomes fairly younger than conventional views.

As age datings for gneisses have not been accomplished in this study, here, we adopt the formative age of gneisses in the area given by the conventional views. However, as gneisses in this area have a close relation by mixing with sandstone facies in Cambrian to Ordovician system and the Ordovician to Silurian system distributed over the circumference, there is a high possibility that the formative age of gneisses in this region is also younger than the age given by conventional views.

III. 1 Annam Gneisses, Mp

Name: By the study of JICA-DGEO Project, the gneisses distributed in the area are named newly as Annam Gneisses by this study. According to Annells and Coast (1990) and Phan Cu Tien *et al.* (1991), these gneisses had been classified into Proterozoic basement rocks.

Type locality: A type locality is observed at about 2km from the Laos-Vietnam border of the Route 18B to the west.

Distribution: Annam Gneisses is distributed along the Route 18B of 20km northwest from the Laos-Vietnam border, along the Xe Xou River upper stream region of 10km west from the Lao-Vietnam border, near the Houay Nam Palonat River of middle stream of the Xe Kaman River, upper stream region of the Houay Nam Palonat River, along the Houay Nam Cha River of 20km south-southeast from the Nong Fa Lake and along the Nam Bi River as a tributary of the Xe Kaman River of 20km northeast from the Nong Fa Lake.

Although the scale of each masses are not clear, each width of distribution would be several 100m to 2km.

Stratigraphical relations: Near the boundary of Annam gneisses, it is quite common that rock facies changes gradually from the original gneiss to a sheared facies of cataclasite to mylonite facies. In that case, the correlation with gneisses and a circumference stratum is not determined. Gneisses in the Xe Kaman River area are gradually alternated gneiss with two mica granites and meta sandstone which are distributed around gneisses. Therefore, both two mica granites and meta sandstone may have been formed at the same period.

Lithofacies: Rocks consist of biotite gneiss, hornblende-biotite gneiss, (garnet)-biotite gneiss, and a biotite-graphite gneiss (Fig. 5). These gneisses show medium to coarse grain and heterogeneous face. Banded structures by mafic minerals are developed in these gneisses. When rocks contain abundant biotite and graphite in the rock, the facies shows melanoclatic. When feldspar and quartz are dominant, rock facies shows leucoclatic. The metamorphic facies of these gneisses are considered to be greenschist facies including biotite, garnet, and graphite.

Structure: Banded structures are observed notably by naked-eyes. Unit layers of banded structures have micro pattern of several centimeter order of wavelength. The direction of a plunge of folding axis does not show arrangements. When a gneiss mass body contact is located at a shear zone, gneiss shows alternation pattern of muscovite schist and biotite schist.

III. 2 Annam Gabbro, $UvPZ_1$

Name: The gabbro distributed in the area are given name newly as Annam Gabbro by this study.

These gabbro classified into Proterozoic basement rocks.

Type locality: A type locality is about 3km from the Laos-Vietnam border of the Route 18B to the west.

Distribution: Small masses of Annam Gabbro are distributed along the Route 18B of 5km northwest from the Laos-Vietnam border, along the Xe Xou upper stream of 10km northwest from the Laos-Vietnam border, along the Houay Nam Palonat upper stream of 8km northwest from Ban Ngieng Dak village.

Each mass are located near shear zone which elongate from northwest to southeast direction from near the Laos-Vietnam border to the Xe Kaman middle stream.

Although the dimension of each mass is not clear, each width of distribution would be several 1km to 3km.

Stratigraphical relations: The relationship with a circumference gabbro mass is unknown. In the case of the rock mass near the Laos-Vietnam border, the Annam Gabbro is surrounded by Annam gneisses. The gabbro mass near the northwest of the Ban Ngieng Dak village is located in east margin of shear zone which elongate from northwest to southeast direction. Gabbro mass distributes in block shape in Paleozoic slate and schist.

Unknown meta basalt are distributed in 3km

Banded biotite gneiss of Annam Gneisses
along Route 18B located near the Lao-Vietnam border

Biotite gneiss in mixed zone of Annam Gneisses
along Route 18B

Layered pyroxene gabbro of Annam Gabbro
along Route 18B located near the Lao-Vietnam border

Pyroxene gabbro of Annam Gabbro
along Route 18B located near the Lao-Vietnam border

Fig. 5 Photographs of an outcrop of Annam Gneisses and Gabbro along the Route 18B.

southeast of the gabbro mass near the Ban Ngieng Dak village. The relationship between this gabbro mass and basalt is also unknown.

Lithofacies: The main facies of this rock is hornblende gabbro (Fig. 5). Usually rock is massive and the grain size is medium to coarse. In west of the Lao-Vietnam border lithofacies shows layered structures reflecting arrangement of hornblende.

Structure: In west of the Laos-Vietnam border, the order of layered structure is several meters. Strike directions of layered structure is northwest to southeast with inclination of about 20 degrees to southwest. The strike direction is almost parallel to the extension of shearings which develop near rock bodies.

Weak schistose structures develop in the gabbro mass near the northwest of Ban Ngieng Dak. In the west side of their mass contacts, shear zones elongating in the direction of northwest to southeast covers areas from Xe Kaman River to Laos-Vietnam border. The directions of schistose structure is almost parallel to the direction of extension of the shear zone.

III. 3 Green rocks, $OphPR_3$

Type locality: A type locality is southeast 3km of the Vantat Gold Mine along the tributary river of the Xe Kaman River.

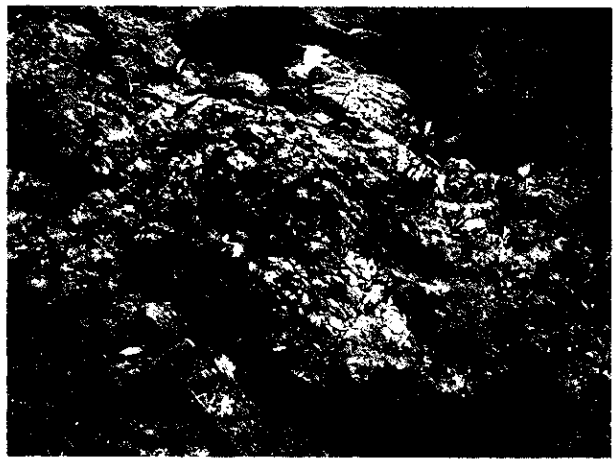
Distribution: Green rocks distribute near the Vantat Gold Mine area. The distribution extends from north to south direction. The scale of the body has 4km by 2.5km.

Stratigraphical relations: The relation with a circumference strata is bounded by shear zone. The west and east side of bodies contacts to quartzite and slate of the May Phao Sauu Phanh Group with shear.

Lithofacies: The main facies consists of meta basalt and amphibolite with schistose structures (Fig. 6). The east side of body graded into greenschist. Actinolite, pumpellyite and talc occur in locally as metamorphic minerals.

Structure: Schistosity of the green rocks extends from north to south with shear under cataclastic to gouge phase. The inclination angle is very steep near vertical.

Amphibolite with green copper dissemination near Vantat gold mine



Amphibolite with quartz veinlets near Vantat gold mine

Fig. 6 Photographs of an outcrop of green rocks in the Vantat area.

IV Paleozoic

Paleozoic strata are roughly classified into Cm_2-O_1 (Cambrian-Ordovician), O_3-S (Ordovician-Silurian), D_{2-3} (Devonian) and C (Carboniferous) by two Group and two Formation.

By the interpretation of Annells and Coast (1990), Paleozoic stratum was divided into three, namely, Pz_1 (Cambrian-Silurian), Pz_2 (Silurian-Devonian), and cPz_2 (Devonian-Carboniferous).

By the interpretation of Phan Cu Tien *et al.* (1991), the Paleozoic stratum was divided into four, namely, C-O_1 (Cambrian-Ordovician), O_3-S (Ordovician-Silurian), D_{1-2} (Devonian) and C (Carboniferous). JICA-DGEO study resulted in almost similar classification result (scales 1/100,000) by Phan Cu Tien *et al.* (1991).

IV. 1 Cambrian - Ordovician

IV. 1. 1 Xe Kaman Group, Cm_2-O_1

Name: A stratum distributing over the study area considered to be Cambrian to Ordovician judging from the feature of lithofacies and distribution among the slate, pelitic schist, quartzite, conglomerate and limestone are named newly as Xe Kaman Group by JICA-DGEO Project study.

Cm_2-O_1 (Cambrian-Ordovician) consist of slate and schist mainly. Near the shear zones, pelitic schist is dominated and this lithofacies distributed in a belt shape. In the eastern region and northeastern part of the area, quartzite, pelitic limestone and limestone are locally distributed. The distribution of their rocks shows distribution like a tectonic complex.

Moreover, sandstone is exposed in the central part, western part and northwestern part of distribution of the Xe Kaman Group. These combination pattern of lithofacies are regularly distributed from the eastern part to the western part of the region.

Xe Kaman Group is classified into four units as (I) to (IV).

The feature of each unit is as follows..

IV. 1. 1. 1 Xe Kaman Group Unit I, Cm_2-O_1 (I)

Name: Xe Kaman Group Unit I is a complex distributed in the northeastern margin of the B.Dakyoy area. Unit I consists of slate and pelitic schist mainly.

Type locality: A type locality is located at upper stream of the Xe Kaman in the B.Dakyoy area.

Distribution: Xe Kaman Group Unit I is distributed in northeastern part of the B.Dakyoy area. The Unit I elongates in the direction of northwest to southeast. The elongation is continued to east of the Dak Chung located in north of the B.Dakyoy area. Unit I is located in the northeast side of shear zone which develop along the Nam Lacha River of tributary river of the Xe Kaman River.

Stratigraphical relations: The relationship with a circumference stratum is unknown. The unit directly contacts the Annam Gabro distributed over the Xe Kaman region of southeast of the Dak Chung.

Lithofacies: Although lithofacies in the area is unknown, lithofacies of southeast at the Dak Chung which is a part of northwest extension, lithofacies mainly consist of dark gray colored slate.

Structure: Strike directions of slate elongate northwest to southeast concordant to the extension direction of elongation of Unit I. Although the inclinations of dip are very steep nearly perpendicular, the direction of dip varies from northeast to southwest showing undulation.

IV. 1. 1. 2 Xe Kaman Group Unit II, Cm_2-O_1 (II)

Name: Xe Kaman Group Unit II is a complex consists of slate, pelitic schist, quartzite, pelitic limestone and limestone. Based on the Geological Map of the DAK TO (D-48-XII) by Nguyen Van Trang *et al.* (1997), the extension of this unit to Vietnamese side is corresponding to the lower layer (C-S dlg_1) of Dak Long Formation.

Type locality: A type locality is located at the confluence of the Xe Kaman River and the Nam Klavai River at the northeast of the Nong Fa Lake.

Distribution: Xe Kaman Group Unit II is distributed in northeastern part of the Nong Fa Lake. The direction of elongated of the Unit II shows northwest to southeast. The elongation continues to the Kontum massif located in Vietnam. The Unit II is located at east side of shear zone which develop along the Nam Klavai River, a tributary river of the Xe Kaman River.

Stratigraphical relations: The boundaries between the Xe Kaman Group Unit II and surrounding strata are shear zones, and their stratigraphy of each stratum are unknown. The southwest margin of the Unit is a shear zone which consists of pelitic schist, and the margin contact with the Xe Kaman Group Unit III. The northeast margin of the Unit is also shear zone which consists of pelitic schist, and the margin contact with the Annam Gneisses. In southeast of the area near the Lao-Vietnam border, the Unit II contact with the Kham Duc Formation (PR_{2-3} kd_2) which consist of the Proterozoic gneisses and pelitic schist (Nguyen Van Trang *et al.*, 1997 and Trang Tinh *et al.* 1997).

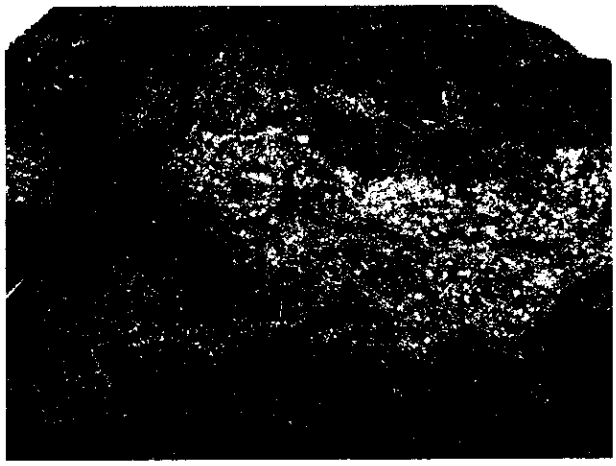
The stratigraphy of lithofacies in Unit II is unknown as the lithofacies shows low grade metamorphic facies which develop cleavage and schistose structures.

Lithofacies: The Unit II consists of slate, muscovite schist, muscovite-quartz schist, biotite schist, quartzite, pelitic limestone and limestone (Fig. 7 and Fig. 8).

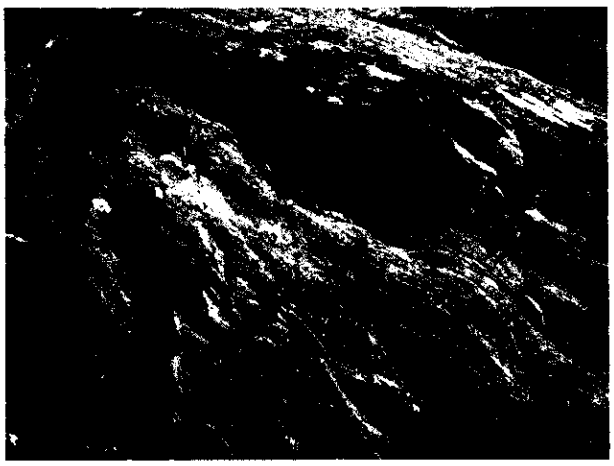
Slate shows dark gray color with remarkable cleavage structures. Slate include lens-like quartz veins (1cm-5cm) notably along with cleavage in many cases. Ptygmatic folds, kink bands and mylonitic structures develop in the lithofacies of the circumference of shear zones. Slate is distributed in belt like shape along the Nam Klavai River and the Nam Lacha River.

Pelitic schist distribute in an area of boundary with the Xe Kaman Unit III in west side of the Unit II, in an

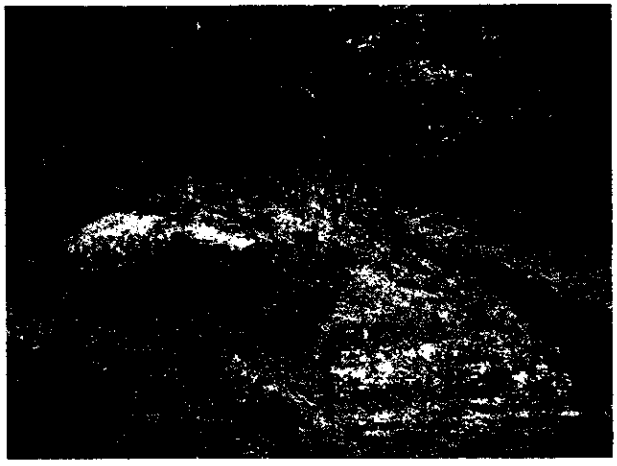
Muscovite schist of Xe Kaman Group Unit II in the Xe Kaman River



Biotite schist of Xe Kaman Group Unit II in the Nam Lacha River

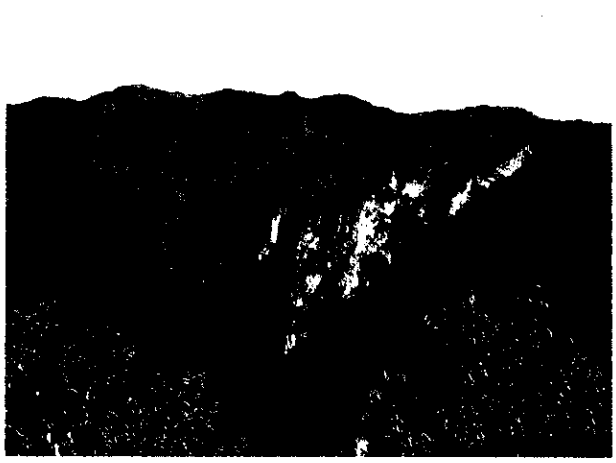


Slate of Xe Kaman Group Unit II in the Nam Klavai River

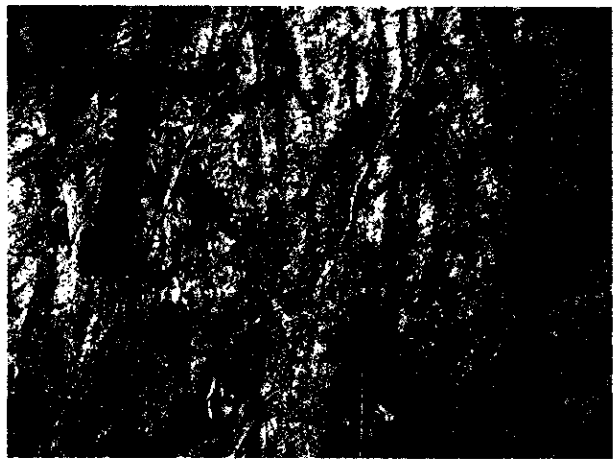


Slate with elongated quartz of Xe Kaman Group Unit II in the Nam Klavai River

Fig. 7 Photographs of an outcrop of the Xe Kaman Group Unit II in peripheral area of Xe Kaman River.



An Outcrop of quartzite of Xe Kaman Group Unit II in the Nam Lacha River



Quartzite of Xe Kaman Group Unit II along the Xe Kaman River

An outcrop of limestone of Xe Kaman Group Unit II along the Xe Kaman River

Pelitic limestone of Xe Kaman Group Unit II along the Nam Klavai River

Fig. 8 Photographs of an outcrop of the Xe Kaman Group Unit II in peripheral area of Xe Kaman River.

area of boundary with the Annam Gneisses in east side and shear zones within the unit II and peripheral area of shear zone. The distribution of pelitic schist shows belt like shape. The continuity of the belt like distribution develops well along the Nam Klavai River, along left bank of Nam Lacha River and along mountain ridge of left bank of the Xe Kaman. The boundary between pelitic schist and slate is a gradual change of change of lithofacies in these areas. The width of shear zone is 10m to 100m.

Quartzite shows white to creamy white color and massive and distributes in a form of block and enclosed by surrounding slate and pelitic schist. Size of rock body is around 100m to 500m in block shape and around 2km to 4km in belt like shape. Quartzite of belt like shape distributes remarkably in mountain edge of left bank of the Xe Kaman River.

Pelitic limestone and limestone are distributed in right bank of downstream of the Nam Klavai River and left bank of the Xe Kaman River. They distribute in a shape of block. The relationship with slate and quartzite which are distributed in/around limestones is unknown. The scale of distribution is around 1km by 2km. Among these, pelitic limestone shows dark gray to gray color. Lithofacies of the pelitic limestone show very rarely a alternative structure of pelitic layer and psammitic layer in 10cm order. Strike and dip of bedding of the alternation is NW-SE and vertical. Limestone shows white to creamy white color and dark gray color. The lithofacies of limestone show massive in many case. Bioclasts is observed rarely in the limestone by naked eye.

Structure: The Unit II distributes in direction of northwest to southeast. This direction is parallel to that of strikes of the cleavage and schistose structures of slate and pelitic schist. The direction is also parallel to that of quartzite. The inclination of slate and pelitic schist is steeply dipping almost vertical like the Unit I. Dip directions varies from northeast to southwest showing undulation.

In the slate micro foldings develops in an area of downstream of the Nam Klavai River. A angle of plunge of these foldings is about 30degree for north direction. A lens-like quartz (secondary) in the slate

sometimes show characteristic shape with ductile shear against cleavage of slate in brittle shearing. This fracture system in the slate seems like to be considered a composite planar fabric. The shear in this case shows right-lateral sense.

The shear zone in the Unit II is classified into three zones. These three zones are located in the southwest margin, in the northeast margin and in the central part of the distribution of the Unit II, respectively. The extension directions of shear zones show northwest to southeast same as the extension direction of the Unit II. Lithofacies of the shear zones consists of biotite schist or muscovite schist. In some part, alteration stratum is formed by these two schists. Inclinations of alternation have high angles.

IV. 1. 1. 3 Xe Kaman Group Unit III, Cm_2-O_1 (III)

Name: Xe Kaman Group Unit III is a complex consists of slate, pelitic schist, greenschist and quartzite. The Unit III is discriminated from the Unit II by the characteristics that limestone does not exist in the unit and the distribution of quartzite is relatively limited comparing with the Unit II.

Based on the Geological Map of the DAK TO (D-48-XII) by Nguyen Van Trang *et al.* (1997), the Unit III is correlated to the upper layer of Dak Long Formation (C-S dlg_2) of Vietnam.

Type locality: A type locality is located at around Ban Dak Pok village, the east of Nong Fa Lake.

Distribution: Xe Kaman Group Unit III is distributed in northeastern part of the Nong Fa Lake. The Unit III distributes in elongated shape from northwest to southeast extending to the Kontum massif located at Vietnam. The Unit III is surrounded by shear zones which elongate from the Van Tat Noi village to the Xe Xou River.

Stratigraphical relations: Boundaries between the Unit III and circumference strata are shear zones, and their stratigraphical relationships between the Unit III and circumference strata are unknown. Based on the 1:200,000 scale Geological Map of the DAK TO (D-48-XII) by Nguyen Van Trang *et al.* (1997), the Unit III is correlated to the upper layer of Dak Long Formation (C-S dlg_2) of Vietnam. It is highly possible that the lower layer of Dak Long Formation (C-S dlg_1) correspond to the Unit II and the Unit III would be equivalent to the upper of the Unit II.

Although the Unit III has possibility to be covered with the basal conglomerate facies of Triassic (T_{1-2}) which develops in the Xe Kaman River of the northern part of the area, the boundary between the Unit III and Triassic (T_{1-2}) are not confirmed without outcrops.

Lithofacies: Unit III consists of sandstone, slate, muscovite schist, biotite schist, greenschist and quartzite dominated by slate and quartzite (Fig. 9).

Sandstone shows creamy white to gray color with grain size of fine to coarse, showing hornfelsic structures in many cases.

Slate shows dark gray color. Cleavage structure is common in the slate. The slate include lens-like quartz veins (1cm to 5cm) along the cleavage similar to the Unit II slate, though the amount of quartz veins is less than the case of Unit II slate.

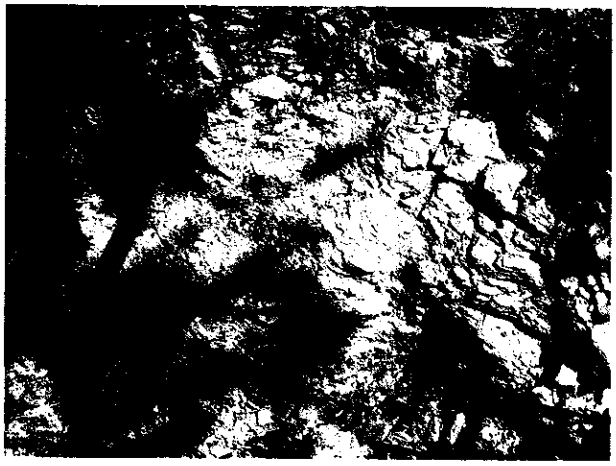
Pelitic schist is distributed in the boundary between the Unit III and Xe Kaman Group Unit II, in the boundary between Triassic Dakdouan Formation (T_{1-2}) and May Phao Sauu Phanh Group (O_3-S) in the east side of the Unit III and the peripheral area of Ban Dak Pok village in the east side of Nong Fa Lake. They distribute in a shape of a belt. The shear zone in the areas of slate distribution has a close relationship with generation of pelitic schist. The width of shear zone is about 10m to 500m. Chlorite schist is slightly distributed near boundary with west margin of Unit II and the south of Ban Dak Pok village of the eastern part of Nong Fa Lake. The chlorite schist distributes in shapes of belt and their width is several meters to 10m. Green schist forms alternation with muscovite schist in place.

Quartzite shows white to creamy white color and massive distributing in a shape of block to belt more broadly comparing with Unit II. Distribution scales of the Quartzite is 100m by 500m to 4km by 8km. In the left bank of Xe Kaman River to the northeast of Nong Fa Lake, quartzite distributes dominantly. The Quartzite has columnar joint rarely in the left bank of Xe Kaman River. In this case, the Quartzite looks like chert.

Structure: Direction of the Unit III is fundamentally northwest to southeast. The boundary of the west margin of the Unit is occupied by a shear zone which elongate south to north in the south of Nong Fa Lake. At this area, the Unit extends combined with the shear zone which elongate south to north direction. Strike directions of cleavage in the slate and schistose structure in the pelitic schist of Unit III correspond basically to the direction of distribution of Unit III. Among these, strike directions of cleavage in the slate show east-northeast to west-southwest and west-northwest to east-southeast in the eastern part of Nong Fa Lake. These directions slant to the elongation direction of the Unit. Directions of the strike of schistose structure show northeast to southwest and, in the southeast of Nong Fa Lake, north-northeast to south-southwest. These directions slant to the elongation direction of the Unit same as cleavage in slate. Inclinations of slate and pelitic schist have high angle of nearly vertical same with the Unit I. Inclination directions of these slate and schist show undulation of northeast or southwest directions.

IV. 1. 1. 4 Xe Kaman Group Unit IV, Cm_2-O_1 (IV)

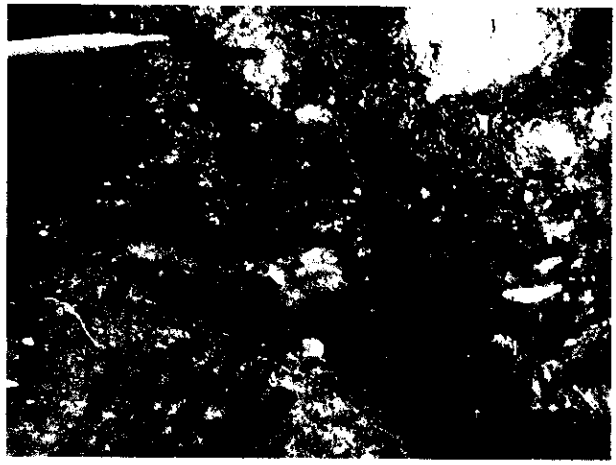
Name: Xe Kaman Group Unit IV is a complex consists of sandstone, alternative with sandstone and mudstone, slate, politic schist, greenschist and quartzite. Characteristics of the Unit IV is considered that sandstone and slate is dominant to comparing with another Unit of the Xe Kaman Group and that quartzite



Biotite schist of Xe Kaman Group Unit III in northern part of the Nong Fa Lake

Quartzite of Xe Kaman Group Unit III in northeastern part of the Nong Fa Lake

Muscovite-quartz schist of Xe Kaman Group Unit IV along Route 18B



Congromeric meta sandstone of Xe Kaman Group Unit IV along Route 18B

Fig. 9 Photographs of an outcrop of the Xe Kaman Group Unit IV in Annam mountain.

is rare in the Unit IV.

Type locality: A type locality is 10km northwest of the Van Tat along the Route 18B.

Distribution: The Xe Kaman Group Unit IV is distributed in the west of Ban Daklay village of the northwestern part of the district and over the area between a sign of 90km on the Route 18B and along the Xe Kaman River of the southeastern part of district. These area located in the west side of a shear zone which elongates over the Xe Xou River, the south of Van Tat Noi village and the west of Ban Daklay village. The elongation of distribution show northwest to southeast direction same as another unit of the Xe Kaman Group.

Stratigraphical relations: The boundary of the border of Unit IV is bounded by shear zones in many cases. Therefore, the relations with circumference stratum are not clear in many cases. Based on the relationship between Unit IV and Devonian to Permian granites in the tributary stream of Xe Xou River and the Xe Kaman River, field observation suggest that the Unit IV would be intruded by these granites.

Sandstones of the Unit IV are intruded by two-mica granite ($gdPz_3$ (Phase C)) which is considered to be Carboniferous period around the Route 18B of the tributary stream of Xe Xou River and the tributary stream of Xe Kaman River of the southern part of Van Tat Noi village. At this area, these sandstones of the Unit IV became quartzite by hornfels alteration. In the Xe Kaman River area, sandstones became hornfels by the intrusion of diorites which is considered to be Devonian (dPz_3 (Phase D2)) to Permian (dPz_3 (Phase P2)) period.

Unit IV would be covered by Triassic Dakdouan Formation (T_{1-2}) in the Xe Kaman River area.

Lithofacies: Unit IV consist of sandstone, alternation of sandstone and mudstone, slate, muscovite schist, biotite schist, chlorite schist and quartzite (Fig. 9). Dominant lithofacies is slate.

Sandstone shows creamy white to gray color and grain size varies from very fine to coarse grain. Hornfels altered from sandstones becomes by granite intrusion distributes along Route 18B and Xe Kaman River. Massive sandstones distribute in the west of

Ban Daklay village of the northwestern part of the district.

Alternation of sandstone and mudstone and conglomerate distribute around Route 18B of the tributary stream of Xe Xou River. Among these, the alternative of sandstone and mudstone shows dark gray to gray color and progresses bedding in the lithofacies. Conglomerate has a quartz-riched matrix and includes pebble of sub-angular shaped quartzite. Both these lithofacies continue over 3km in the tributary stream of Xe Kaman River.

Slate of the Unit IV shows dark gray to gray color and cleavage is well developed in the rock. Slate includes lens like quartz veins (1cm to 5cm) along cleavages. Amount of lens like quartz vein is not so remarkable as the case of Unit II.

Pelitic schist distribute in a near boundary with the Silurian granodiorites ($gdPz_3$ (S)) along the Route 18B and the May Phao Sauu Phanh Group (O_3-S) along the tributary stream of Xe Xou River. The distribution of pelitic schist shows a belt like shape. The shear zone in the slate distribution has a close relationship with generation of pelitic schist. The width of shear zone is about 10m to 500m.

Quartzite is massive and shows white to creamy white color. The distribution of quartzite shows block shape and closely relationship with distribution of granites. Distribution scales are 100m by 200m to 1km by 2km. This scale is smaller than another unit of the Xe Kaman Group.

Structure: The extension directions of Unit IV show northwest/ north-northwest to southeast/ south-southeast keeping harmony with other units. This direction is almost parallel with shear zone which elongates the east margin of the Unit IV from northwest to southeast.

Strikes of the cleavage in slate, of schistose structure in pelitic schist, of bedding of alternation of sandstone/mudstone, and of graded bedding of conglomerate are almost parallel to the extension direction of Unit IV. The inclinations of slate and schist show high angles, and directions of dip show undulated shape to southwest or northeast. The inclinations of the bedding in alternation of sandstone and mudstone and the graded bedding of conglomerate have high angles showing 60 to 70 degree same with slate and schist. This inclination angle is looser than the inclination angles of schistose structures surrounding slate and schist around 10 degrees.

IV. 2 Ordovician - Silurian

IV. 2. 1 May Phao Sauu Phanh Group, O_3-S

Name: May Phao Sauu Phanh Group is a group newly established by the JICA-DGEO Project study. Among politic/psammitic schist and quartzite distributed over the study area, Ordovician to Silurian are discriminated by lithofacies and distribution and grouped as the May Phao Sauu Phanh Group.

Lithofacies of this Group is same as lithofacies of the Xe Kaman Group. The features of the Group is pointed out that the layer of alternation of sandstone and mudstone mass in the region and the pelitic schist distribute around a shear zone as well as Xe Kaman Group.

Type locality: A type locality is 2km west of Ban May Phao Sauu Phanh along Route 18B

Distribution: This Group is distributed at B.Antoum village, Route 18B and at Xe Kaman River in the southwestern part of the district, and at Van Tat Noi village and Xe Kaman River in the southeastern part of the district. The extension direction of distribution is northwest to southeast same as the Xe Kaman Group.

Stratigraphical relations: The border of this Group is shear zones at many localities. Therefore, the relationship with surrounding stratum is indefinite. Based on the relationship between this Group and Devonian to Permian granites in the area, the field phenomenon suggest that this Group would be intruded by these granites.

Muscovite-quartz schist of this Group and mylonite of Permian granodiorites ($gdPz_3$ (Phase P1)) at Ban May Phao Sauu Phanh village show gradual change of lithofacies between these two.

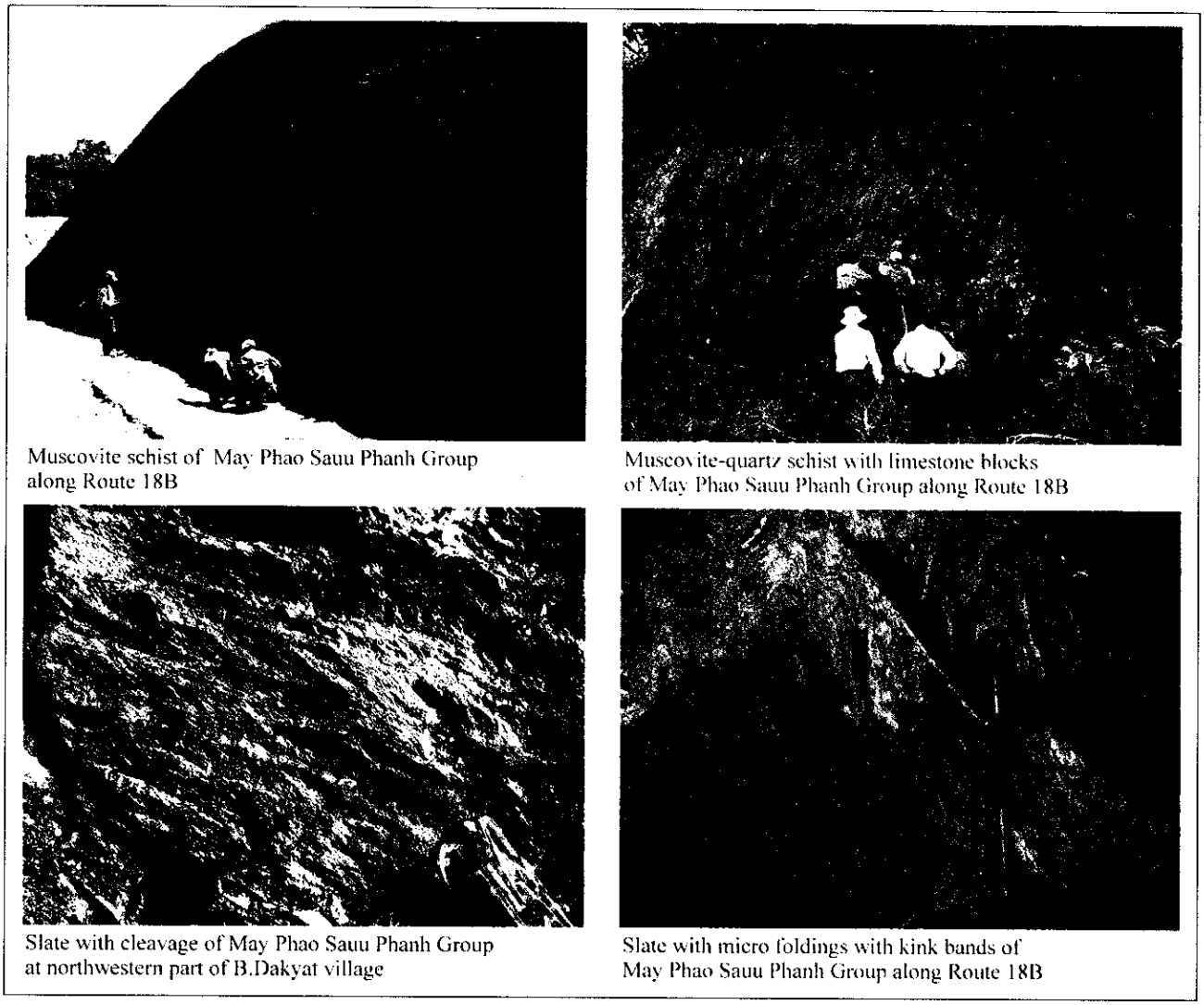
This Group would be covered by Triassic Dakdouan Formation (T_{1-2}) in southwestern part of the Ban May Phao Sauu Phanh village.

Lithofacies: The Ban May Phao Sauu Phanh Group consists of sandstone, alternation of sandstone and mudstone, slate, muscovite-quartz schist, biotite schist, chlorite schist and quartzite (Fig.10). Dominant lithofacies are slate and alternation of sandstone/mudstone at the Xe Xou River and at southern part of Van Tat Noi village, and muscovite-quartz schist and slate at May Phao Sauu Phanh village.

Sandstone and alternation of sandstone and mudstone mass at Route18B of the tributary stream of Xe Xou River and the southern part of Van Tat Noi village. The sandstone shows gray color and massive. Sandstones has been altered into hornfels by granite intrusion in the southern part of May Phao Sauu Phanh village. Alternation of sandstone/mudstone shows dark gray to gray color and bedding is apparent in the lithofacies.

Slate distribute widely in this Group. Slate shows dark gray to gray color and cleavage is apparent in the rock. Lithofacies of slate near in shear zones change to biotite schist or chlorite schist gradually. Slate includes lens like quartz veins (1cm to 5cm) along cleavages.

Muscovite-quartz schist is dominant among schist facies and develop well at Ban May Phao Sauu Phanh village and southern part of Van Tat Noi village. Biotite schist and greenschist are dominant in strongly sheared zone. The width of strongly sheared zone is 10m to 100m. At the May Phao Sauu Phanh village, muscovite-quartz schist change gradually to mylonite facies of Permian granites ($gdPz_3$ (P1)). The width of



Muscovite schist of May Phao Sauu Phanh Group along Route 18B

Muscovite-quartz schist with limestone blocks of May Phao Sauu Phanh Group along Route 18B

Slate with cleavage of May Phao Sauu Phanh Group at northwestern part of B.Dakyat village

Slate with micro foldings with kink bands of May Phao Sauu Phanh Group along Route 18B

Fig. 10 Photographs of an outcrop of the May Phao Sauu Phanh Group in Annam mountain.

this gradual facies is 50m to 100m.

Quartzite shows white to creamy white color and massive in the southern part of Van Tat Noi village. The distribution of quartzite shows block shape. Distribution scales are 100m by 200m to 1km by 2km. This scale is similar to the Xe Kaman Group Unit IV.

Structure: The extension directions of this Group show northwest to southeast and north-northwest to south-southeast same as the Xe Kaman Group Unit IV. This extension direction of the Group is almost parallel to extension directions of the cleavage and schistose structures in slate and bedding in alternation of sandstone/mudstone. The inclinations of those structures have high angles of 70-80 degree. Their dip directions undulate to southwest or northeast.

The general structure of the Group harmonizes with structures of the Xe Kaman Group. Therefore, this similarity suggests that both Group were formed by tectonic activities and metamorphic activities under almost same environment.

IV. 2. 2 Xe Xou North Granodiorites, $gdPz_3$ (S)

Name: Massive potassic feldspar porphyritic granodiorites distributing over the study area which is considered to be covered by post Silurian stratum are named newly as Xe Xou North Granodiorites by JICA-DGEO Project study.

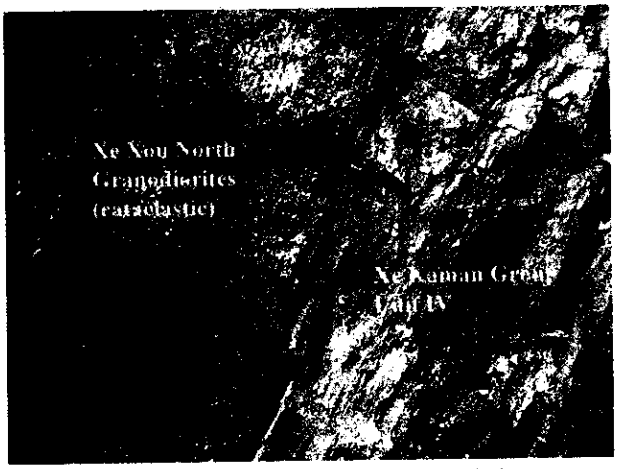
Type Locality:

A type locality is east 20km of the Ban May Phao Sauu Phanh village along Route18B .

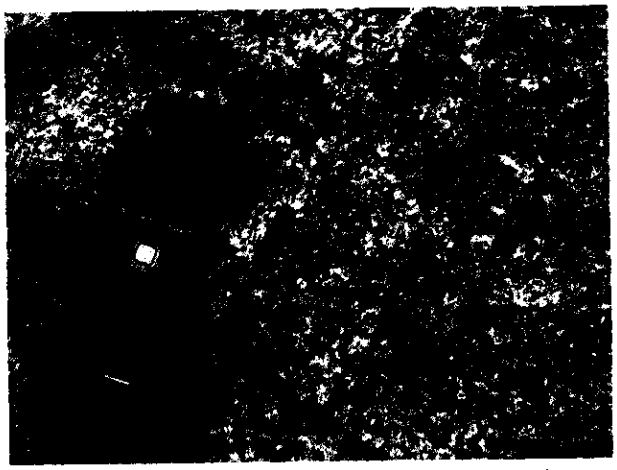
Distribution: Xe Xou North Granodiorites is distributed at Route 18B of eastern part of the Ban May Phao Sauu Phanh village and along the upstream of Xe Xou River. The distribution of this granodiorites elongates from northwest to southeast. Scale of the granodiorites is over 10km by 30km. The distribution of the granodiorites extends continuously to the Lao-Vietnam border at the south side of the district.

Intrusive relations: The boundaries between this granodiorites and the other strata are shear zones at almost all localities. Granodiorites in the east margin of the distribution is mixed with sandstone and pelitic

Boundary between Xe Xou North Granodiorites and Xe Kaman Group Unit IV along Route 18B



Boundary between granodiorite of Xe Xou North Granodiorites and schist of Xe Kaman Group Unit IV in Route 18B



Massive hornblede-biotite granodiorite of Xe Xou North Granodiorites along Route 18B

Weak foliated Hornblede-biotite granodiorite of Xe Xou North Granodiorites along Route 18B

Fig. 11 Photographs of an outcrop of the Xe Xou North Granodiorites along the Route 18B.

schist of Cambrian and Ordovician Xe Kaman Group Unit IV. It is suggested by the occurrence said above that the age of intrusion of granodiorites would be younger than the formation of Xe Kaman Group.

The granodiorites contact Devonian stratum at west margin and the granodaiorites are covered by Tertiary sedimentary rocks of Ban Kengmo North Formation (N_{1-2}) at some localities at the west margin.

Lithofacies: The main facies of this granodiorites consists of potassic feldspar porphyritic hornblende-biotite granodiorite which shows massive structure and coarse grain (Fig. 11). Granodiorites has porphyritic potassic feldspar of max 3cm by 2cm size. The dominant facies is massive face. Granitoides with foliated structures by arrangement of mafic minerals is observed at the east margin of granodiorite distribution. Moreover, the facies become mylonitic in the most east margin of the distribution.

In the eastern margin of the distribution, at contact zones between the Granodiorites and the Xe Kaman Group (Cambrian-Ordovician), mixed facies of mylonite of the Granodiorites and sandstone /mudstone of Xe Kaman Group are apparent.

Magnetic susceptibilities of the granodiorites resulted high content such as 4 to 7 in SI unit and the granodiorites is classified into magnetite series.

Structure: The Xe Xou North Granodiorites is distributed in from northwest to southeast direction with elongated shape. The elongation of foliated structures of mylonite in the granodiorites shows same direction with that of the distribution. Foliated structures incline east.

The width of apparent foliation zone is about 2.5km and, within this zone, mylonitic facies occupies about 300m in width.

Age determination: Ar-Ar ages of hornblende and biotite for the Xe Xou North Granodiorites were reported by JMEC (2006) as follows,

Age: 419 + 22 Ma (Silurian)
- Method: Ar-Ar method
- Mineral: hornblende

Age: 424 + 2 Ma (Silurian)
- Method: Ar-Ar method
- Mineral: biotite

IV. 3 Devonian

IV. 3. 1 San Xai Formation, D_{2-3}

Name: San Xai Formation was newly named by JICA-DGEO Project study. Non-metamorphosed conglomerate existing in formations of stratigraphicaly lower than Triassic Dakdouan Formation (T_{1-2}) and Carboniferous Kadon Formation (C) are discriminated among conglomerates and given a name of San Xai Formation.. This Formation covers strata of pre-Silurian and granites of Devonian by unconformity.

Type locality: A type locality is 15km south of Ban May Phao Sauu Phanh village in the northwest of half way of Xe Kaman River.

Distribution: San Xai Formation is distributed along the Xe Kaman River of the southwestern to central part of the district. The Formation extends from northwest to southeast and in elongated shape like a belt like of 1km by 10km in scale. The distributions of the San Xai Formation are closely related to the distribution of Carboniferous Kadon Formation, Triassic Dakdouan Formation and granites of Silurian to Permian.

Stratigraphical relations: San Xai Formation covers granites of Silurian to Devonian by unconformities. The formation corresponds to the lower than Carboniferous Kadon Formation and Triassic Dakdouan Formation.

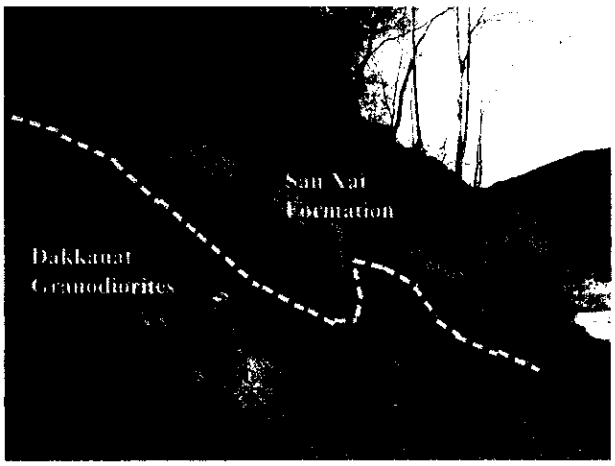
The relationship between the San Xai Formation and Carboniferous Kadon Formation or Triassic Dakdouan Formation are indefinite. At boundary of each two formations, both structures are similar without any shear zone. These evidences suggest that the Kadon Formation and the Dakdouan Formation would be covered the San Xai Formation by unconformity.

At the eastern part of Ban May Phao Sauu Phanh village along the Route 18B, a stratum of this formation has close relationship with Permian granites.

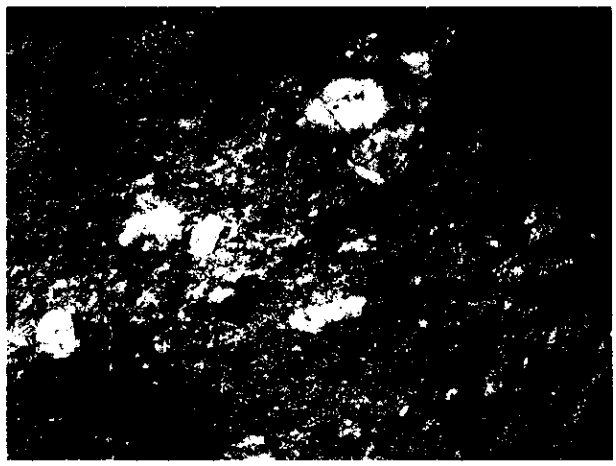
Thickness: The total thickness is estimated to be 50m to 500m.

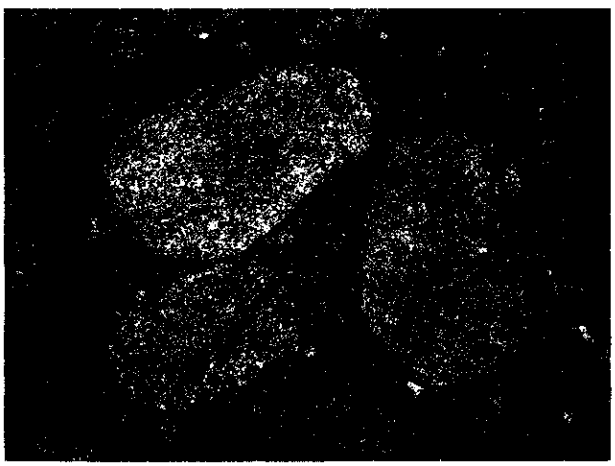
Lithofacies: The San Xai Formation consists of conglomerate and sandstone (Fig. 12 and Fig. 13). The conglomerate is dominant.

The conglomerate includes fragment of granule to boulder in size consists of quartz riched arenitic to



Boundary between San Xai Formation and Dakkanat Granodiorites along Xe Kaman River


Basement of San Xai Formation consisting of conglomeric sandstone along Xe Kaman River


Basement of San Xai Formation consisting of conglomerate at upstream of Xe Xou River


Basement of San Xai Formation consisting of conglomerate at upstream of Xe Xou River

Fig. 12 Photographs of an outcrop of the San Xai Formation in Annam mountain.

arkose sandstones. Varieties of gravel are composed of quartzite, sandstone, hornfels and granites. Shapes of the gravel show rounded to sub rounded. The content of gravel is 5 to 10% in the conglomerate. In the eastern part of Ban May Phao Sauu Phanh village, the conglomerate is compact with lesser matrix. Rounded boulders are apparent in the conglomerate showing accidental facies.

Sandstone layer lies on the conglomerate layer. Sandstone is medium to coarse in grain size. The sandstone is composed of quartz riched sub-arkose to arkose, same as the matrix of the conglomerate.

The occurrences above suggest that conglomerates and sandstones were deposited under a river or a littoral environments.

Structure: What distinguishes the San Xai Formation from other metamorphic rocks originated from lower units such as Cambrian - Ordovician and Ordovician - Silurian is that metamorphic and deformation structures are not recognized in the San Xai Formation. The layer strikes northwest to southeast keeping concordance with the extension of the Formation.

Metamorphic and deformation structures in stratum are recognizable until Silurian stratum. Based on the evidence above, regional metamorphism had terminated before Devonian period.

IV. 3. 2 Nam Ang Granodiorites, $gdPz_3$ (D_1)

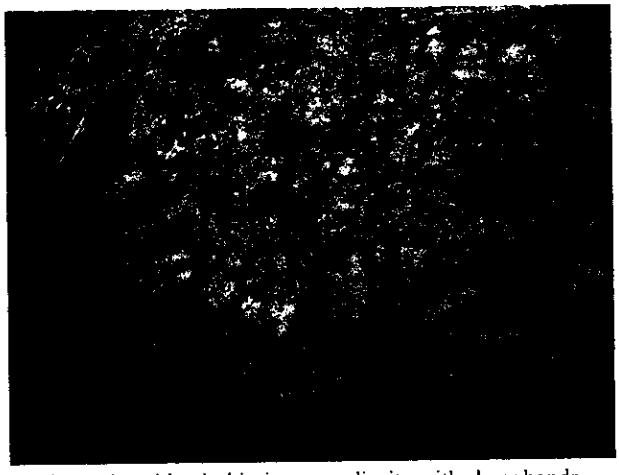
Name: Potassic feldspar porphyritic granodiorites distributing over the study area considered to be covered by after Devonian strata are named newly as Nam Ang Granodiorites by JICA-DGEO Project study.

Type Locality: A type locality is located at the junction between Xe Kaman River and Nam Ang river.

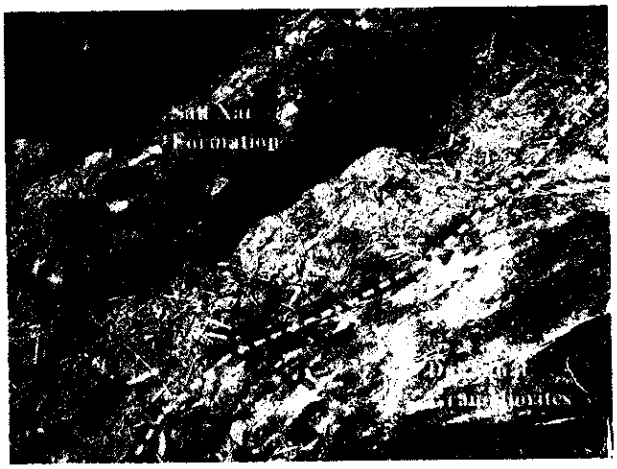
Distribution: Nam Ang Granodiorites distributed along the middle of the Xe Kaman River and the Nam Palovat River as the tributary of Xe Kaman River. The distribution of the granites extends from northwest to southeast direction and south to north direction. The distribution area is 5km by 30km in the middle of Xe Kaman River and 5km by 10km in the Nam Patouat River.

Intrusive relations: Nam Ang Granodiorites intrudes to the Xe Kaman Group Unit IV. On the other hand,

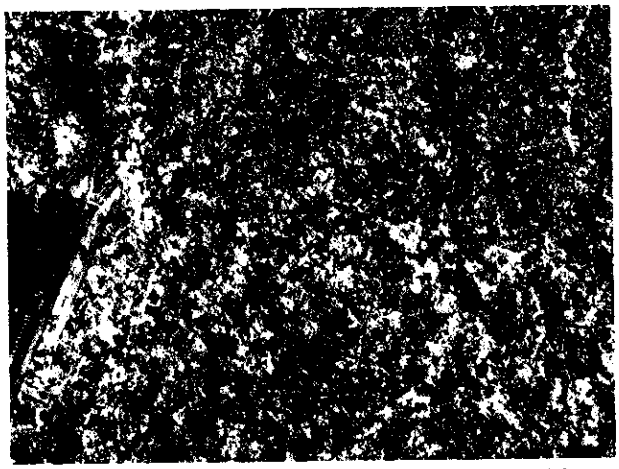
Massive hornblende-biotite granodiorite of Nam Ang Granodiorites along Xe Kaman River



Schistose hornblende-biotite granodiorite with shear bands of Nam Ang Granodiorites along Xe Kaman River



Congromeric sandstone of San Xai formation overlies Dakkanat Granodiorites by unconformity along Xe Kaman



Hetrogeneous and melanoclatic quartz diorite of Nam Tabeng Diorites along Xe Kaman River

Fig. 13 Photographs of an outcrop of the Nam Ang Granodiorites, Dakkanat Granodiorites and Nam Tabeng Diorites along the Xe Kaman River.

Devonian to Permian granites intrude to the Nam Ang Granodiorites. Distribution of the Nam Ang Granodiorites closely related to the distribution of the Annam Gneisses (Mp). The relation with both masses is unknown directly.

Relationship between Nam Ang Granodiorites and Ordovician to Silurian May Phao Sauu Phanh Group is unknown also. Therefore, their field phenomena suggest that both masses would be bounded by a shear zone in the upstream of the Nam Patouat river. Paleogene basaltic lava of Nong Fa Formation is overlied Nam Ang Granodiorites by an unconformity in north side of the main stream of Xe Kaman River.

Nam Ang Granodiorites closely related to Silurian Xe Xou North Granodiorites in the south of the Xe Kaman River. These relationship between both suggest that Nam Ang Granodiorites intrudes to the Xe Xou North Granodiorites.

Lithofacies: The main facies of this granodiorites consists of the potassic feldspar porphyritic hornblende-biotite granodiorite with coarse to medium grains same as the Xe Xou North Granodiorites (Fig. 13). Granodiorites has porphyritic potassic feldspar with max 3cm by 2cm. The facies shows massive, gneissose and schistose textures. Gneissose to schistose facies of the granodiorites have a heterogeneous and melanoclatic texture comparatively.

Their gneissose and schistose textures progress remarkably around margin of the Ban Dakpala East Diorites in the middle of the Xe Kaman River. Shear bands develop along schistose structures in the schistose granodiorite with a cataclastic shear and chlorite alteration.

Magnetic susceptibilities for the granodiorites show high content such as about 5 in SI unit to be classified into magnetite series. This feature is similar to the Xe Xou North Granodiorites.

Structure: Nam Ang Granodiorites extends from northwest to southeast and south to north direction. The directions of foliation of gneissose and schistose structures in the granodiorites show the same direction with the extension of the distribution. Dips of their foliated structures have high angle and incline to the northeast or southwest.

The formative area of the gneissose and schistose structures is overlapped around margin of the Ban Dakpala East Diorites. Among these, overlapped facies progresses about 1km width.

Age determination: Biotite K-Ar age for massive hornblende-biotite granodiorite of the Nam Ang Granodiorites was reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 396.6 ± 10.4 Ma (Devonian)

- Method: K-Ar method
- Target: biotite
- Sample ID: B081

IV. 3. 3 Dakkanat Granodiorites, $gdPz_3$ (D_2)

Name: Medium grained granodiorites distributing over the study area considered to be covered by after Devonian stratum and to be related closely with Nam Ang Granodiorites are named newly as Dakkanat Granodiorites by JICA-DGEO Project study.

Type Locality: A type locality is located at a junction with Xe Kaman River and Houay Yeng Kheng River.

Distribution: Dakkanat Granodiorites is distributed in right bank of the Houay Yeng Kheng River and Houay Po River and around Ban Dakkanat village located at a upstream of the Nam Ang River. Their river correspond to confluents of midstream of the Xe Kaman River. The distribution of this granodiorites extends from northwest to southeast and south to north. The scale of the granodiorites has 1.5km by 25km which shows a spindle shape. The scale of the granodiorites around the Ban Dakkanat village is 5km by 5km.

Intrusive relations: Dakkanat Granodiorites intrudes to the Nam Ang Granodiorites. On the other hand, Devonian sedimentary rocks of San Xai Formation and Paleogene basalt lava of the Nong Fa Formation cover the Granodiorites.

Lithofacies: The main facies of this granodiorites is medium to coarse grained massive hornblende-biotite granodiorite with homogeneous texture (Fig. 13). Development of foliation by mafic minerals and progression of deformation and gneissose textures are absent.

Silicification with quartz veinlets is locally found in along the Xe Kaman River and around the Ban Dakkanat village. The scale of alteration is very limited to around altered zone which is several meters width.

Magnetic susceptibilities for the granodiorites show high content such as 1 to 3 in SI unit to be classified into magnetite series. This feature is similar to the Xe Xou North Granodiorites and the Nam Ang Granodiorites.

Structure: The distribution of Dakkanat Granodiorites extends from northwest to southeast and south to north direction. Development of structures such as foliation, gneissose and schistose is unclear.

IV. 3. 4 Nam Tabeng Diorites, dPz_3 (D_2)

Name: Heterogeneous and melanoclatic diorites distributing over the study area considered to be related closely with Nam Ang Granodiorites are named newly as Nam Tabeng Diorites by JICA-DGEO Project study.

Type Locality: A type locality is located at the junction between Xe Kaman River and Nam Tabeng river.

Distribution: Nam Tabeng Diorites is distributed in around the junction with Xe Kaman River and Nam Tabeng River and the upstream of Dak Palouat River as the tributary of Xe Kaman River. The distribution area of Nam Tabeng Diorites is 1km by 3km in around the Nam Tabeng River. Around the Dak Palouat River, the area of mass is 2km by 4km. The scale of the masses is small. Their masses extend to northwest to southeast direction.

Intrusive relations: Nam Tabeng Diorites intrudes to

the Cambrian to Ordovician Xe Kaman Group Unit IV and Devonian Nam Ang Granodiorites. Hornfels generated by a contact metamorphism occur in near the boundary between diorites and their strata.

Lithofacies: Diorites consists of heterogeneous and melanoclatic pyroxene-hornblende quartz diorite to gabbro (Fig. 13). Among these, hornblende shows a gromeroporphyritic texture sporadically.

Magnetic susceptibilities for the diorites show very high content such as about 10 in SI unit to be classified into magnetite series. This feature is similar to Silurian to Devonian granites such as the Xe Xou North Granodiorites, Nam Ang Granodiorites and Dakkanat Granodiorites.

Structure: The distribution of Nam Tabeng Diorites extends from northwest to southeast and south to north direction. The structure in the mass is unclear.

Age determination: K-Ar age of hornblende for relatively massive pyroxene-hornblende tonalite of the Nam Tabeng Diorites was reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 367.3 ± 9.6 Ma (Devonian)

- Method: K-Ar method
- Target: hornblende
- Sample ID: B088

IV. 4 Carboniferous

IV. 4. 1 Kadon Formation, C

Name: Kadon Formation (C) is named newly by JICA-DGEO Project study.

The Kadon Formation consists of slate, non-metamorphosed conglomeratic sandstone, sandstone and alternation of sandstone/mudstone layers distributing over the study area and is considered to be stratigraphically upper than Devonian San Xai Formation (D_{2-3}) and lower than Triassic Dakdouan Formation (T_{1-2}) and Carboniferous.

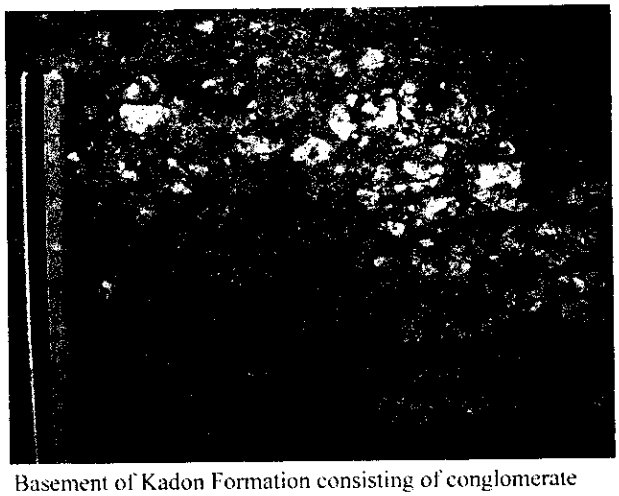
Type locality: A type locality is 15km south of Ban May Phao Sauu Phanh Hoku village in the northwest of halfway of Xe Kaman River.

Distribution: Kadon Formation is distributed along Xe Kaman River of the western to northwestern part of the district and the east of the Xe Kong River in the Attapu Sheet map. The distribution extends from

Slate of Kadon Formation in the east of Xe Kong River

Cataclastic slate of Kadon Formation near the boundary with Triassic stratum in the east of Xe Kong River

Slate of Kadon Formation in the northern part of Paam village



Basement of Kadon Formation consisting of conglomerate in the east of Xe Kong River

Fig. 14 Photographs of an outcrop of the Kadon Formation in peripheral area of Xe Kaman River.

northwest continuously to southeast and size of distribution is 10km by 40km.

Stratigraphical relations: Stratigraphical level of the Kadon Formation corresponds to the superior than Cambrian to Ordovician Xe Kaman Group Unit IV, Ordovician to Silurian May Phao Sauu Phanh Group and Devonian San Xai Formation, and to the inferior than Triassic Dakdouan Formation and Cretaceous to Paleocene volcanics.

Direct relationship between the Kadon Formation and other strata are indefinite. Among these, field observation suggests that the boundary between the Formation and Xe Kaman Group Unit IV would be contacted by fault. The bedding structures harmonize with a contact between May Phao Sauu Phanh Group and San Xai Formation. Based on these observation, it is suggested that Kadon Formation cover s Ordovician to Silurian strata and to be covered by Triassic Dakdouan Formation. On the other hand, volcanic landforms of Cretaceous to Paleogene volcanic rocks which cover Kadon Formation are remained in the area. The relationship between Kadon Formation and their volcanic rocks seems to be unconformity such as abut relationship.

Thickness: The thickness of the Kadon Formation in the district is estimated to be about 1,000m although the Formation might be cut by faulting reducing the thickness to several 100 m.

Lithofacies: The Kadon Formation consists of slate, non-metamorphosed conglomeratic sandstone, sandstone and alternation of sandstone/mudstone (Fig. 14). The dominant facies is slate.

The color of slate is dark gray to gray. At the boundary between the Formation and Ordovician to Silurian schists, cleavages develop well in the slate and intergradations are apparent between slates and schists.

Conglomeratic sandstone includes gravels of granule to pebble in size and the matrix consists of quartz riched arenitic to arkose sandstones. The varieties of gravel are composed of quartzite, sandstone and hornfels. Shapes of the gravel show rounded to sub-rounded. The content of gravel is 5 to 10% in the conglomerate. This lithofacies is corresponding to the most lowest layer of Kadon Formation. Thickness of the layer is about 10m.

Quartz riched sub-arkose to arkose sandstone are deposited in the upper portion of the conglomeratic sandstone. The thickness of the sandstone is several 10m.

Sandstone facies consists of alternation of fine to medium and fine to coarse sandstone. Sandstones show gray to ochre color. Sandstone are characterized by well-sorted, massive and compact form cross laminations. Field observations suggest that the thickness of sandstone would be over 500m.

Structure: The Kadon Formation C is dominated by slate with will developed cleavage. The extent directions of cleavage developed in the main facies of Formation is northwest to southeast same as other strata. Cleavages dip northeast or southwest by 80 to 50 degree. The inclination becomes high angle around shear zones. The bedding of conglomeratic sandstone and alternation of sandstone/mudstone strikes the northwest to southeast same as the elongation of stratum. Beddings dip southwest by 80 to 50 degree same as the extensions of cleavage.

Shear zone in the Formation extends from northwest to southeast. The inclination angles is about vertical. Shear pattern in the shear zone is classified into cataclastic facies. Hereby, it is suggested that the share zone in Kadon Formation was formed in the shallow environment rather than under the deeper environments which generate mylonitic to cataclastic facies.

IV. 4. 2 Xe Xou East Granites, $gdPz_3$ (C)

Name: Two mica granites distributing over the study area to be distributed in near the Lao and Vietnam national border are named newly as Xe Xou East Granites by JICA-DGEO Project study.

Type Locality: A type locality is located at near the border of Lao and Vietnam, upstream of the Xe Xou River.

Distribution: Xe Xou East Grainites is distributed in along Xe Xou River and midstream of the Xe Kaman River. The distribution shapes of granite masses show a stock or a block like body. The area of block like body has a wide exposure. The extension of the both bodies is northwest to southeast direction.

The most largest body of granites is located at near the border of Lao and Vietnam along the Xe Xou River. The area of exposed body is 5km by 8km. In the upstream of Xe Xou River and the tributary river of Xe Kaman River such as Dak Palouat River, the area of body is 2km by 4km. The exposed scale of stock like bodies of granites is very small which is several 100m to 10m.

The distribution of granites is closely related with the distribution of Annam Gneisses and Ordovician to Silurian May Phao Sauu Phanh Group.

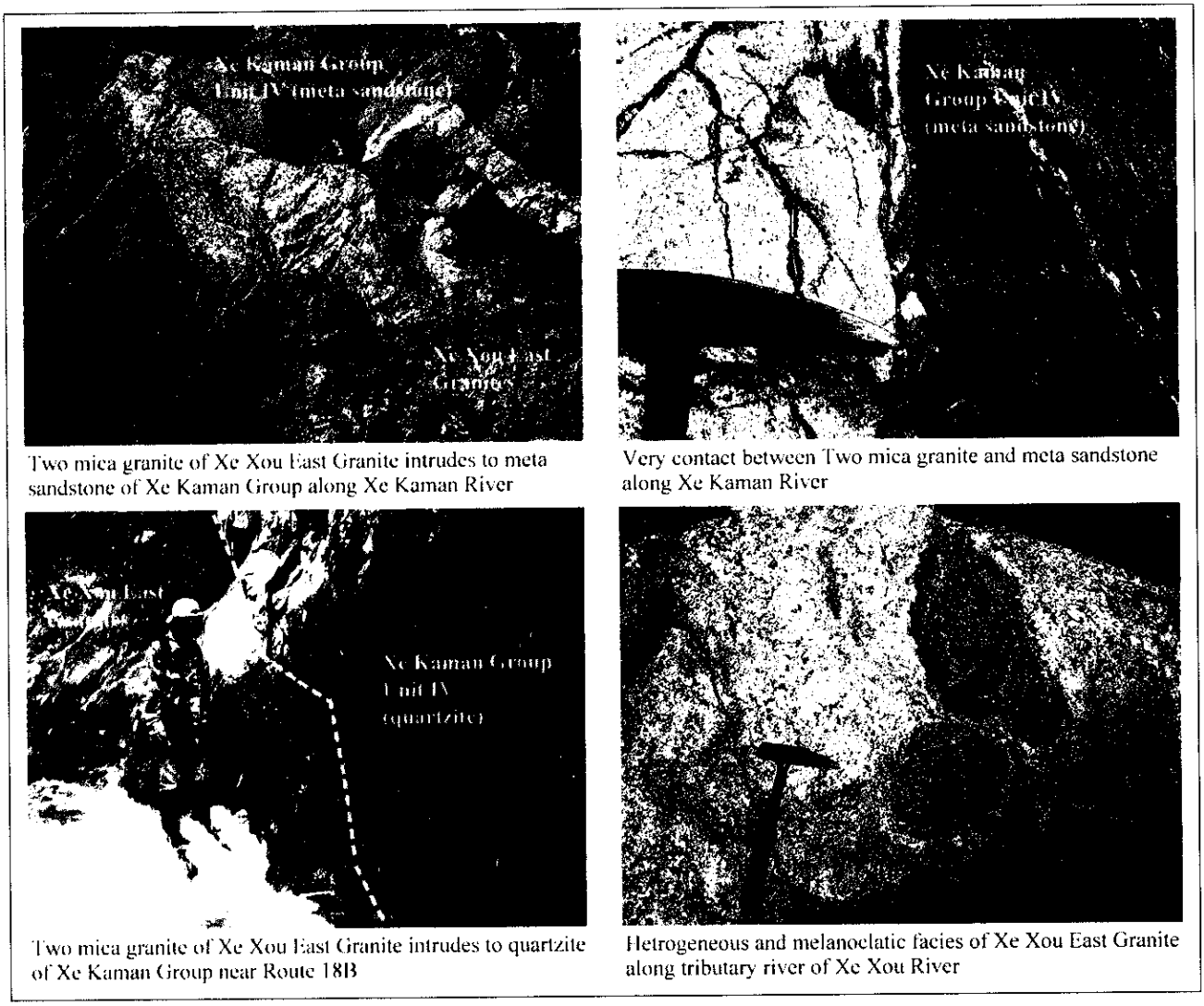
Intrusive relations:

Main masses of the Xe Kaman East Granites intrude to the Xe Kaman Group and May Phao Sauu Phanh Group. On the other hand, stock like bodies intrude to the Annam Gneisses.

Lithofacies: The main facies of this granites consists of leucoclatic two mica granite (Fig. 15). On the locally, melanoclatic and heterogeneous facies are progressed in the main facies. Their facies looks like an injection gneiss in place. These field phenomena suggest that both masses between granites and the Annam Gneisses were contaminated at the time of emplacement.

Magnetic susceptibilities for the granites show low content such as under 1 in SI unit to be classified into ilmenite series.

Structure: The distribution of Xe Xou East Granites extends from northwest to southeast direction. Foliations shown by arrangement of biotite is observed in the facies locally. Strikes of the foliation extend to



Two mica granite of Xe Xou East Granite intrudes to meta sandstone of Xe Kaman Group along Xe Kaman River

Very contact between Two mica granite and meta sandstone along Xe Kaman River

Two mica granite of Xe Xou East Granite intrudes to quartzite of Xe Kaman Group near Route 18B

Hetrogeneous and melanoclatic facies of Xe Xou East Granite along tributary river of Xe Xou River

Fig. 15 Photographs of an outcrop of the Xe Xou East Granite in peripheral area of Xe Xou River.

diversified direction which is not concordant to extension direction of the distribution. Their original structures suggest that their foliations indicate magmatic structures as a granite pluton.

Age determination: K-Ar age of biotite for massive two mica granite of the Xe Xou East Granite was reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 301.5 ± 7.7 Ma (Carboniferous)

- Method: K-Ar method
- Target: biotite
- Sample ID: A153

IV. 5 Permian

IV. 5. 1 Antoum Granodiorites (I), $gdPz_3$ (P_1)

Name: Grannodiorite facies in the mylonitic biotite-hornblende granodiorite distributing along midstream of the Xe Xou River are named newly as Antoum Granodiorites (I) by JICA-DGEO Project study.

Type Locality: A type locality is located at northwest 6km of the Antoum village in midstream of the Xe Xou River.

Distribution: Antoum Granodiorites (I) is distributed in along midstream of the Xe Xou River to southeastern part of the Xe Kaman River. The area of distribution is over 5km by 20km. The masses extend from northwest to southeast.

Intrusive relations: Antoum Granodiorites (I) intrudes to Ordovician to Silurian May Phao Sauu Phanh Group with mylonitic activities. On the other hand, mylonitic granodiorite masses contact to Silurian Xe Xou North Granodiorites with faults in the southern part of the district.

Lithofacies: The main facies is strong mylonitic medium grained biotite-hornblende granodiorite (Fig. 16). Chlorite alteration is found noticeably in the mylonitic granodiorites which shows pale green color. Elongated quartz grains and shear bands by deformation of the granodiorites are observed remarkably in strong mylonitic zone.

Quzrtz schist progresses near the boundary between mylonitic granodiorites and Ordovician to Silurian May

Phao Sauu Phanh Group in the western margin of mylonitic granodiorite bodies. Mylonitic garnodiorites are graded into quartz schists near the boundary of the both.

Dissemination with copper minerals such as chalcopyrite, bornite, tenolite and azurite with strong malachite stains are observed in the mylonitic granodiorites. Their copper mineralizations are intense in the northwestern and southeastern part of May Phao Sauu Phanh village.

Structure: Predominant structure developing in Antoum Granodiorites (I) is deformed structure as mylonite. Mylonite has a S-C strucuture by shearing. Direction of the mylonitic structure elongates mainly from northwest to southeast direction as well as distribution extension of the mylonitic granodiorite masses. Elongation of the mylonitic structure strikes from west-northwest to east-southeast direction in locally. The dip of mylonite inclines about vertical. The width of mylonite zone in Antoum Granodiorites (I) extends intermittently 5km which is regarded as a very large scale.

Cataclastic shear zones are found in the granodiorites locally. Their shears cut structures of mylonite as a ductile shear. Cataclastic shear zones extend from west-northwest to east-southeast direction for the most place. The width of cataclastic shear zone has 10m to 20m.

Age determination: Ar-Ar age of biotite and hornblende for massive hornblende-biotite granodiorite of the Antoum Granodiorites (I) were reported by this JICA-DGEO project.

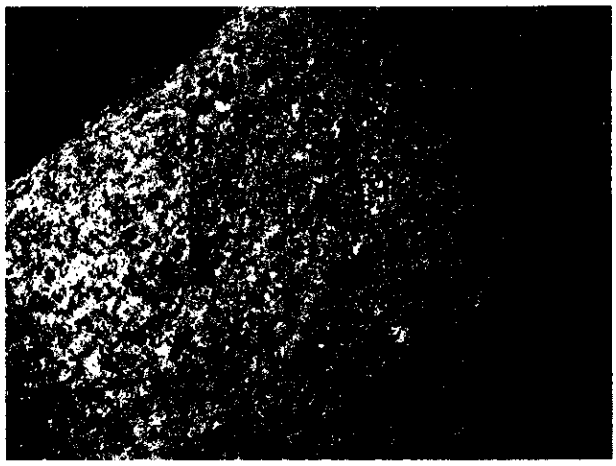
The reported ages are as follows,

Age: 248.61 ± 25.16 Ma (Permian)
- Method: Ar-Ar method
- Target: biotite
- Sámple ID: A083

Age: 269.35 ± 29.75 Ma (Permian)
- Method: Ar-Ar method
- Target: hornblende
- Sample ID: A083

IV. 5. 2 Antoum Granodiorites (II), dPz_3 (P_1)

Name: Diorite facies in the mylonitic



Biotite-hornblende granodiorite of the main facies of Antoum Granodiorites (I) located at the north of Antoum village

Mylonitic facies of Antoum Granodiorites (I) looks-like muscovite-quartz schist along Route 18B

Mylonitic biotite-hornblende granodiorite of Antoum Granodiorites (I) with malachite stains near the Route 18B

Heterogeneous and melanoclatic hornblende diorite of Kengmo Diorite located along midstream of Xe Xou River

Fig. 16 Photographs of an outcrop of the Antoum Granodiorite in peripheral area of the Xe Xou River.

biotite-hornblende granodiorite distributing along midstream of the Xe Xou River are named newly as Antoum Granodiorites (II) by JICA-DGEO Project study.

Type Locality: A type locality is located at northwest 4km of the Antoum village in midstream of the Xe Xou River.

Distribution: Antoum Granodiorites (II) is distributed in Antoum Granodiorites (I) as a stock like mass. The area of mass is small scale with 500m by 1,000m. The diorite mass extend from northwest to southeast.

Intrusive relations:

The relationship between Antoum Granodiorites (II) and Antoum Granodiorites (I) is unknown. Stock like shape of the body suggests that Antoum Granodiorites (II) will be intruded to Antoum Granodiorites (I).

Lithofacies: The main facies is strong mylonitic to cataclastic medium to fine grained biotite-hornblende diorite to quartz diorite. Chlorite alteration is found noticeably in the mylonitic to cataclastic diorites which shows pale green color. Elongated quartz grains and shear bands by deformation of the diorites are observed remarkably in strong shear zone.

Dissemination with copper minerals such as chalcopyrite, bornite, tenolite and azurite with strong malachite stains are observed in the mylonitic to cataclastic diorites.

Structure: Predominant structure developing in Antoum Granodiorites (II) is deformed structure with mylonite to cataclasite as well as Antoum Granodiorites (I). Mylonite has a S-C strucuture by shearing. Direction of the shearing structure elongates mainly from northwest to southeast direction as well as distribution extension of the masses. The dip of sheared structures inclines about vertical.

Age determination: K-Ar age of sericite for mylonitic hornblende-biotite diorite of the Antoum Granodiorites (II) were reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 277.0 ± 7.1 Ma (Permian)

- Method: K-Ar method
- Target: sericite
- Sample ID: B134

IV. 5. 3 Antoum Granodiorites (III), gPz_3 (P_1)

Name: Granite facies in the mylonitic biotite-hornblende granodiorite distributing along midstream of the Xe Xou River are named newly as Antoum Granodiorites (III) by JICA-DGEO Project study.

Type Locality: A type locality is located at northwest 8km of the Antoum village in midstream of the Xe Xou River.

Distribution: Antoum Granodiorites (III) is distributed in Antoum Granodiorites (I) as a stock like mass as well as Antoum Granodiorites (II). The area of mass is small scale with 500m by 1,000m. The mass extend from northwest to southeast.

Intrusive relations: The relationship between Antoum Granodiorites (III) and Antoum Granodiorites (I) is unknown. Based on the area of the granite mass of (III) is very limited in the granodiorite mass of (I), Antoum Granodiorites (III) will be intruded to Antoum Granodiorites (I).

Lithofacies: The main facies is massive medium to fine grained biotite granite to hornblende-biotite granodiorite and porphyritic granite. Silicification and chlorite alteration are found weakly in the diorites.

Structure: Remarkable mylonitic and cataclastic structures are absent in Antoum Granodiorites (III).

IV. 5. 4 Kengmo North Diorites, $gdPz_3$ (P_2)

Name: Diorites to granodiorites closely related to the mylonitic biotite-hornblende granodiorite of Antoum Granodiorites (I) distributing along midstream of the Xe Xou River are named newly as Kengmo North Diorites by JICA-DGEO Project study.

Type Locality: A type locality is located at northern part of the Ban Kengmo village in midstream of the Xe Xou River.

Distribution: Kengmo Diorites distributes in the northeast of Antoum Granodiorites located at Route 18B. The area of distribution is 2km by 7km.

Intrusive relations: The relationship between this diorites and Antoum Granodiorites (I) is unknown. Mylonites progress near the boundary with Antoum Granodiorites (I). Therefore, their boundary composed of a shear zone.

Lithofacies: Main facies of Kengmo North Diorites consist of medium to coarse grained diorite to granodiorite, tonalite and gabbro with heterogeneous and melanoclatic compositions (Fig. 16).

Structure: Gneissic structures shows in locally in the tonalitic facies. Their structures extend to variety of directions and do not correspond to the direction of mass.

Age determination: K-Ar age of whole rock for massive pyroxene-hornblende granodiorite of the Kengmo North Diorites was reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 252.0 ± 6.5 Ma (Permian)

- Method: K-Ar method
- Target: whole rock
- Sample ID: B531

IV. 5. 5 Dakpala East Diorites, dPz_3 (P_2)

Name: Mylonitic diorites distributing along the midstream of Xe Kaman River are named newly as Dakpala East Diorites by JICA-DGEO Project study.

Type Locality: A type locality is located at eastern part of the Dakpala village along the midstream of Xe Kaman River.

Distribution: Dakpala East Diorites distributes in midstream of the Xe Kaman River. The distribution direction of the mass show north to south along the Xe

Kaman River. The scale of elongation is 9km by 3km.

Intrusive relations: Dakpala East Diorites thought to be intrude to the Devonian Nam Ang Granodiorites.

Lithofacies: The main lithofacies consists of medium to fine grained mylonitic hornblende diorite to quartz diorites and granodiorites with heterogeneous and melanoclatic structures in part.

Structure: Mylonite structures develop remarkably in the mass. The elongation of mylonitic structures extends from north to south direction.

V Mesozoic

Mesozoic strata consist of Triassic to Jurassic. Among these, Triassic is divided into five strata as T_{1-2}, T_{1-2} (Av), T_{1-2} (Dv), T_{1-2} (Rv) and T_2. Jurassic is divided into two strata as J_1 and J_2.

Annells and Coast (1990) divided Mesozoic strata into three such as vPz_3 (Permian-Triassic), Pz_3 (Permian-Triassic), and Mz_1 (Triassic-Jurassic).

Phan Cu Tien *et al.* (1991) divided Mesozoic strata into two such as T_{1-2} (Early to Late Triassic) and Jurassic (J_{1-2}). This JICA-DGEO Project study resulted in detail more than both classification.

V. 1 Triassic

V. 1. 1 Dakdouan Formation, T_{1-2}

Name: The Dakdouan Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

Dakdouan Formation corresponds to the upper of Ordovician to Silurian May Phao Sauu Phanh Group (O_3-S) and Carboniferous Kadon Formation (C), and to the lower of Triassic Alok Formation (T_{1-2} (Av)), Katha-Tai Formation (T_{1-2} (Dv)) and Makkhua Formation (T_2).

Type locality: A type locality is upper to half of Houay Po River at the east of Ban Sapoung village in the eastern part of Attapu Sheet map.

Distribution: The Dakdouan Formation is distributed at the Nam Pa River and the Xe Kaman River in the western to southern part of the district continuously from northwest to southeast direction in 3km by 30km scale.

Stratigraphical relations: Dakdouan Formation lies over Ordovician to Silurian May Phao Sauu Phanh Group (O_3-S) and Carboniferous Kadon Formation (C) by unconformity and is covered by Triassic Alok Formation (T_{1-2} (Av)), Katha-Tai Formation (T_{1-2} (Dv)) and Makkhua Formation (T_2).

Conglomerate in the basement of Dakdouan Formation covers slate of May Phao Sauu Phanh Group by unconformity. While the relationship between Dakdouan Formation and the Carboniferous Kadon Formation is unknown directly, field observation of relationship between Dakdouan Formation and Kadon Formation suggest that Dakdouan Formation would cover Kadon Formation directly. On the other hand, upper strata such as Triassic Alok Formation, Katha-Tai Formation and Makkhua Formation cover Dakdouan Formation. Dips of Dakdouan Formation show high angles near the boundary to upper strata, while dip angles of the upper strata show gentle. Based on their relations, the boundary between Dakdouan Formation and upper strata implies a angular unconformity or a fault.

Thickness: The thickness of Dakdouan Formation is thought to be 100m to 500m in along Nam Pa River and Xe Kaman River.

Lithofacies: Basement of the Formation consists of conglomerate (Fig. 17). The conglomerate is distributed in around the Route18B in the southwestern part of the district. The matrix of conglomerate is composed of sandy materials. The varieties of gravel consist of quartzite, slate and biotite schist. The gravels show rounded to angular shapes and poorly sorting. The size of gravel is 7 to 30cm.

Lithofacies of the Formation is mainly fine to medium sandstone in the district. The sandstone is dark gray to gray in color and massive and compact in shape. Cross lamination in the sandstone is common in around the Xe Kaman.

Based on the lithofacies of Dakdouan Formation, it is suggested that Dakdouan Formation was found in environment of shallow marine to terrigenous condition.

Structure: The general directions of strike and shear plane of bedding show northwest to southeast. The dip direction trends to southwest. Inclination angles of the bedding and shear plane in the southwestern part of the district dip to southwest 50 to 60degree. On the other hand, inclination angles of the bedding and shear plane along Route 18B of the southwestern part of the district dip to southwest 30 to 40degree.

A formative environment of the shear in Dakdouan Formation seems to be a cataclastic condition.

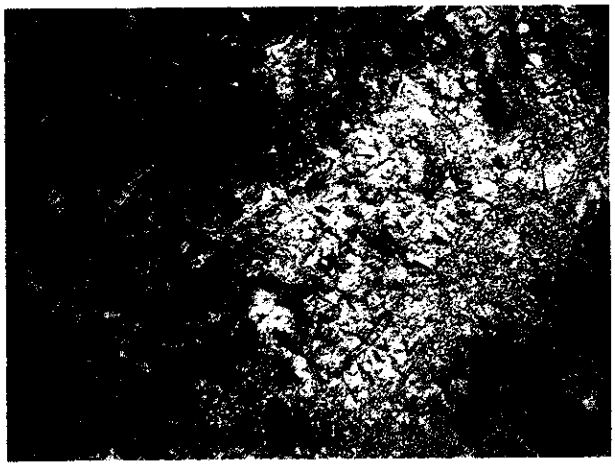
V. 1. 2 Alok Formation, T_{1-2} (Av)

Name: The Alok Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

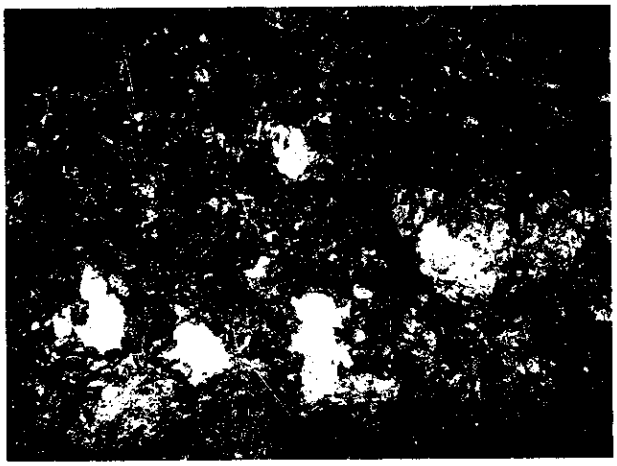
Alok Formation consists of andesitic pyrocrastic rocks. The Formation corresponds to the upper of Triassic Dakdouan Formation (T_{1-2}), and to the lower of Triassic Makkhua Formation (T_2). The main stratum of the Formation distribute in the Attapu Sheet map of the west side of the district.

Type locality: A type locality is located at along Houay Po River of the east of Ban Alok village in the eastern part of Attapu Sheet map.

Distribution: Alok Formation is distributed in along



Fine sandstone of Dakdouan Formation along Xe Kaman River located at the northeast of Paam village



Andesitic pyroclastic breccia of Alok Formation at the north of Paam village

Dacitic welded tuff of Katha-Tai Formation along Route 18B located at the east of Attapeu

Rhyolitic welded tuff of Namchang Formation along Route 18B located at the east of Attapeu

Fig. 17 Photographs of an outcrop of the Dakdoun Formation, Alok Formation, Katha-Tai Formation and Namchang Formation in the east of Attapeu.

the Nam Pa of the northern part of Paam village located at western to southern part of the district. The distribution area of the Formation corresponds topographically to the boundary between a plain and a mountain range. The distribution continues from west-northwest to east-southeast direction in 2km by 5km scale.

Stratigraphical relations: Aolk Formation lies over Triassic Dakdouan Formation and is covered by Triassic Makkhua Formation (T_2).

Epiclastic breccia facies of lower portion of Alok Formation covers Dakdouan Formation to comprising angular unconformity of high angle.

Dip angles of the upper part of Alok Formation and the Makkhua Formation show gentle slope and a conglomeric sandstone of Makkhua Formation is covered Alok Formation by an unconformity. Therefore, the relationship between Alok Formation and Makkhua Formation which corresponds to upper portion of Alok Formation is thought an unconformity.

Thickness: The thickness in along Nam Pa of the northern part of Paam village is thought to be 100m to 500m.

Lithofacies: Lithofacies of the Formation is mainly andesitic lapilli tuff to tuff in the district (Fig. 17). The color of the tuffs shows gray to ocher. Variety of gravel is andesite, slate and sandstone. Sandy tuff of the upper part of the Alok Formation and Makkhua Formation are intergradational. Cross laminations are observed in sandy tuffs.

The basement of the Formation consists of epiclastic breccia with matrix of poorly sorted sandy sands and andesitic clastics. Gravels are composed of andesite, slate and sandstone. The maximum size of gravels is 50cm. Shape of gravels is sub angular. Content of gravels is 5 to 10%. These lithofacies of the basement in the district indicate that the basement breccias were formed by re-sedimentation of andesitic pyroclastics.

Structure: The Alok Formation is distributed from west-northwest to east-southeast direction and dips to south-southwest direction in the district. The formation is steep about 50degree in northeast side where the basement is distributed while a gentle about 20degree in southwest side where the upper facies is distributed.

V. 1. 3 Katha-Tai Formation, T_{1-2} (Dv)

Name: The Katha-Tai Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

Katha-Tai Formation consists of dacitic pyroclastic rocks. The Formation corresponds to the upper of Triassic Dakdouan Formation (T_{1-2}), and to the lower of Triassic Namchan Formation (T_{1-2} (Rv)) and Makkhua Formation (T_2). The main stratum of the Formation is distributed in southern part of the Attapu Sheet map of the west side of the district.

Type locality: A type locality is located at around Ban Katha-Tai in the southern part of Attapu Sheet map.

Distribution: The Katha-Tai Formation is distributed in along the Xe Kaman, Xe Xou and Route18B of western to southern part of the district. The distribution area of the Formation topographically corresponds to the boundary between a plain and a mountain range. The formation extends from west-northwest to east-southeast direction in 2km by 5km scale along Route18B and in 10km by 10km scale along Xe Xou River.

Stratigraphical relations: Welded tuff and tuff breccia facies of basement of Katha-Tai Formation overlies Ordovician to Silurian May Phao Sauu Phanh Group (O_3-S) and Triassic Dakdouan Formation (T_{1-2}) by an angular unconformity. Rhyolitic welded facies of Triassic Namchang Formation (T_{1-2} (Rv)) is covered Katha-Tai Formation by an unconformity. Relationship between Katha-Tai Formation and Triassic Makkhua Formation (T_2) suggests that Katha-Tai Formation grade into Makkhua Formation which corresponds to upper stratum of Katha-Tai Formation.

Katha-Tai Formation and Triassic Alok Formation (T_{1-2} (Av)) is covered same facies of Dakdouan Formation by an angular unconformity. Therefore, Katha-Tai Formation and Triassic Alok Formation (T_{1-2} (Av)) seems like a contemporaneous heterotopic facies.

Thickness: The thickness of the formation is about 50m along Xe Kaman and Route18B and about 300m in Xe Xou of southwestern part of the district.

Lithofacies: Lithofacies of the Formation is mainly dacitic lapilli tuff, tuff breccia and welded tuff in the district (Fig. 17). The color of tuffs show greenish gray to pale gray. Among these, main facies is dacitic welded tuff. Basements of the Formation consists of interbed of lapilli tuff, tuff breccia and welded tuff.

Gravels of lapilli tuff and tuff breccia in the Formation are composed of andesite, slate and sandstone. The matrix of breccias consists of dacitic clasts. The size of gravels is 1cm to 4cm, and the shape of breccia shows sub angular. Content of breccia is about 5%.

Welded tuff facies has crystalline to glassy matrix and includes small flakes of quartz and plagioclase with devitrified lens. As the effusive facies have been chloritized weakly in the rock. Based on this phenomenon, it is thought that there was a hydrothermal activity after the emplacement of the Formation.

Structure: Katha-Tai Formation extends from west-northwest to east-southeast direction along the Xe Kaman and Route18B. Strike directions of welded structure in the Formation harmonize with the direction of extension. Inclination direction of the welded structures dips to shouthwest direction. The dipping is gentle as 5 to 10degree.

Welded structures strike from south to north and dip to west side with angle of 20degree along the Xe Xou River. The dip angle in the Xe Xou River becomes relatively steeper than in the Xe Kaman and Route18B.

V. 1. 4 Namchang Formation, T_{1-2} (Rv)

Name: Acidic pyroclastic rocks distributing over the study area considered to be rhyolitic pyroclastic rocks covers Triassic Dakdouan Formation (T_{1-2}) and is covered by Makkhua Formation (T_2) are named newly as Namchang Formation by JICA-DGEO Project study.

Type locality: A type locality is located at the Namchang River along Route18B in southwestern part of the district.

Distribution: Namchang Formation is distributed in the hill range along Namchang River in the southwestern part of district. The size of distribution is 5km by 10km and extends from north-northeast to south-southwest showing square to rhombic shapes.

Stratigraphical relations: Namchang Formation overlies Ordovician to Silurian May Phao Sauu Phanh Group (O_3-S) and Triassic Katha-Tai Formation (T_{1-2} (Dv)), and is covered by Makkhua Formation (T_2).

Although relationship between the Namchang Formation and May Phao Sauu Phanh Group is unknown, based on the topographical characteristics is gentle, it is thought to be the Formation overlie May Phao Sauu Phanh Group by angular unconformity as welded structures of the Namchang Formation.

The structures in Namchang Formation and Makkhua Formation near the both boundary shows very gentle. Therefore, the Namchang Formation is covered by Makkhua Formation in conformity. A topographical feature in western part of the Formation suggests that a part of both boundary would be contacted by fault.

Thickness: The thickness is 50m to 100m along the Namchang river.

Lithofacies: Lithofacies of Namchang Formation consists of rhyolitic welded tuffs (Fig. 17). The welded tuff consists of crystalline to glassy facies. The facies has a white to gray color and has massive, homogeneous and hard structures. Crystalline fragments in the tuffs consist of mainly quartz and feldspar. Lithic fragments include rarely in the tuffs. Therefore, a part of the lithofacies resemble to rhyolite lava. Welded structures in the tuffs develop in central part of the distribution area.

Whitish colored alteration are apparent in the Formation. These altered rocks are kaolinite, alunite and other altered minerals generated by acidic alteration after emplacement of their tuffs. The acidic alteration is

remarkable in the central area of distribution of the Formation. A chlorite alteration occurs around acidic alteration indicating an alteration zoning. Therefore, systematic hydrothermal activities took place during rhyolitic volcanism after the emplacement of the Formation same as Katha-Tai Formation in the area.

Structure: Although inclination angles of welded tuffs is very gentle, the shape of planar distribution of the Formation shows square to rhombic on the surface. Based on the topographical feature, their structures suggest a possibility that Namchang Formation show cauldron structure.

V. 1. 5 Makkhua Formation, T_2

Name: The Makkhua Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

The Makkhua Formation consists of sedimentary rocks closely related to Triassic tuffs such as Alok Formation (T_{1-2} (Av)) and Katha-Tai Formation (T_{1-2} (Dv)). The Formation corresponds to the upper of Triassic Dakdouan Formation (T_{1-2}), Alok Formation, Katha-Tai Formation and Namchang Formation (T_{1-2}(Rv)), and to the lower of Jurassic Namhiang Formation (J_1). Bedding structures become more gentle after depositions of the Makkhua Formation.

Type locality: A type locality is located along middle to down stream of the Houay Po River at the east of Ban Sapeuan village in the eastern part of Attapu Sheet map.

Distribution: Makkhua Formation is distributed along Nam Pa river, Xe Kaman River and Xe Xou River over 30km long and 2km to 5km width and extends continuously to the west side of Attapu Sheet map. The stratiform shape is formed by continuities of strike and dip of stratum.

Stratigraphical relations: Makkhua Formation overlies Triassic Dakdouan Formation (T_{1-2}), Alok Formation (T_{1-2}(Av)), Katha-Tai Formation (T_{1-2} (Dv)) and Namchang Formation (T_{1-2} (Rv)), and is covered with Namhiang Formation (J_1).

As weak schistose structures develop in Makkhua Formation near a boundary between Makkhua Formation and Dakdouan Formation along Xe Kaman River, the boundary between both strata is thought to be fault.

Relationship between Makkhua Formation and Alok Formation is thought to be unconformity based on the field phenomena such as strata of the Makkhua Formation and dacitic tuffs of the Alok Formation have gentle slopes and a conglomeric sandstone layer exists in the lower part of the Makkhua Formation.

Relationship between Katha-Tai Formation and Namchang Fotmation is unknown directly. Based on the slope angle of beddings of this Formation suggests that Makkhua Formation covers the Alok Formation by unconformity. A part of the boundary among the both strata is thought to be fault at the related topography.

Relationship between the Makkhua Formation and Namhiang Formation is unknown. As these slope of the Formation are very gentle near the boundary, and the Namhiang Formation overlies Makkhua Formation by unconformity.

Thickness: The thickness is approximately 400m along the Nam Pa river, Xe Kaman River and Xe Xou River.

Lithofacies: Main facies of the Makkhua Formation consists of fine to medium grained sandstone of relatively well sorted grains.

Thin layers of alternation of sandstone and siltstone in the middle of Formation are interbeded in sandstone facies. Their layers show dark gray to ocher color. It is thought that the thickness of a layer would be several meters to 10m.

As lithofacies of the Makkhua Formation closely relates to the formation of tuffs including welded tuff in the lower strata, it is suggested that the Makkhua Formation was formed in terrigenous environment.

Structure: The strike of beddings of the Makkhua Formation shows northwest to southeast in along the Nam Pa and Xe Kaman River, and from northeast to southwest in along Xe Kaman River of the southern part of the district. This direction is concordant to the direction of Annam mountain as a hinterland of the distribution of Makkhua Formation. Dip directions extend to the central part of the basin of Attapeu. Inclination angle of dips shows very gentle as approximately 10degree.

Depositional process of the sedimentary basin in the Attapeu area has been started at the period of sedimentation with Makkhua Formation. Therefore, the main activity of orogenic movement of the Annam mountain would be closed before the sedimentation of Makkhua Formation.

V. 1. 6 Acidic Intrusive Rocks, gT_2

Based on the 1:200,000 scale geological map of Vietnam side corresponding to the B.Dakyoy District of Lao side, there are acidic intrusive rocks such as biotite granite and granite porphyry in the area.

The detail information for their rocks is not clear in the B.Dakyoy district. The geological explanation of the DAK TO map by Nguyen Van Trang *et al.* (1997) suggests that the intrusive rocks will be emplaced Triassic period.

V. 2 Jurassic

V. 2. 1 Namhiang Formation, J_1

Name: The Namhiang Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

Namhiang Formation is characterized as development of interbedded sandstone and mudstone to mudstone. Calcareous sandstone is develop in a part of the Formation. Namhiang Formation is corresponded to the upper stratum of Triassic Makkhua Formation (T_2) and the lower stratum of Jurassic Lavi Gnai Tai Formation (J_2).

Type locality: A type locality is located along Houay Po River in the eastern part of Ban Sapeuan village, west side of the Attapu Sheet map.

Distribution: Namhiang Formation is distributed along Nam Pa river, Xe Kaman River and Xe Xou River. The distribution shows a stratiform shape with 5km to 10km width and extends to the west side of Attapu Sheet map. Since the inclination of a stratum is very gentle, the apparent distribution area is broad.

Stratigraphical relations: Namhiang Formation overlies Triassic Makkhua Formation (T_2), and the Formation is covered with Lavi Gnai Tai Formation (J_2). Directly relationship between Namhiang Formation and Makkhua Formation is unknown. Medium and calcareous sandstone facies are developed in the lower of Namhiang Formation near the boundary between Namhiang Formation and Makkhua Formation. Main facies of the Makkhua Formation consist of sandstone as well as Namhiang Formation. Similarity of both lithofacies suggests that the relation with both strata would be a conformity.

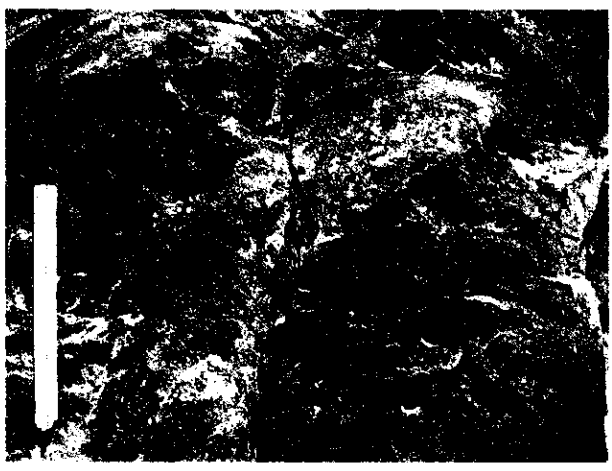
The relationship between Namhiang Formation and Lavi Gnai Tai Formation is unknown directly. Properties of lithofacies and bedding of their strata are similar. Similarity of both properties suggests that Lavi Gnai Tai Formation overlies Namhiang Formation.

Thickness: The thickness is about 1,000m along the Nam Pa river, Xe Kaman River and Xe Xou River.

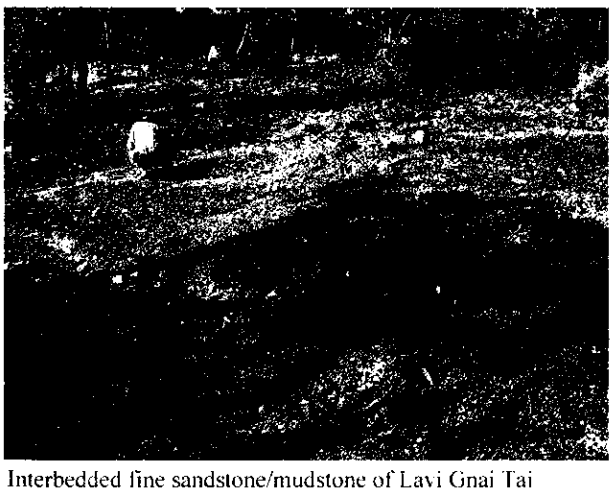
Lithofacies: Main facies of the Namhiang Formation consists of sandstone in the lower part and interbedded sandstone and mudstone in the middle to upper part of the Formation (Fig. 18). Sandstone shows gray to ocher color. The basement consists of interbedding of cross-laminated medium grained sandstone, calcareous sandstone and medium grained sandstone. Thickness of the lower part of stratum is 100 to 200m. Lithofacies of the middle to upper part of the layer consist of interbedded sandstone and mudstone showing apparent bedding structures. Among these facies, mudstone is dominated in the strata. The thickness of the layer is over 800m.

Based on the main facies of the Formation consist of alternations of sandstone and mudstone interbedded by calcareous sandstone, the depositional environment at

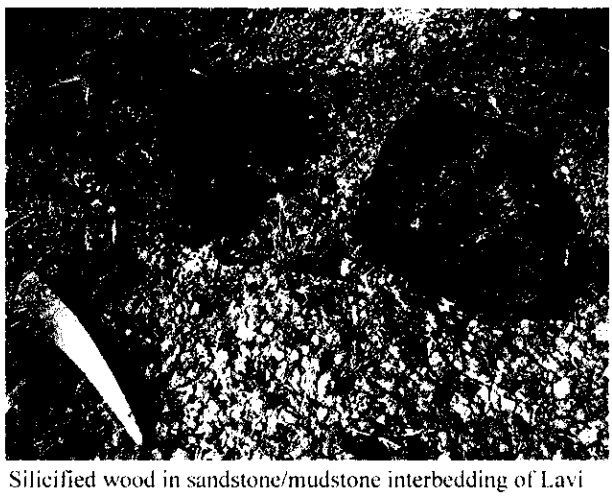
Fine to medium sandstone of Namhiang Formation along tributary river of Xe Kaman River



Fine to medium sandstone with a trace fossil of Namhiang Formation along tributary river of Xe Kaman River



Interbedded fine sandstone/mudstone of Lavi Gnai Tai Formation along tributary river of Xe Kaman River



Silicified wood in sandstone/mudstone interbedding of Lavi Gnai Tai Formation along tributary river of Xe Kaman River

Fig. 18 Photographs of an outcrop of the Nakhiang Formation and Lavi Gnai Tai Formation along tributary river of the Xe Xou River.

the period of Namhiang Formation is considered to be shallow marine.

Structure: Beddings of the Namhiang Formation strike from northwest to southeast in along the Nam Pa and Xe Kaman River, and from east to west in along the Xe Xou River of the southern part of the district with dipping to the central part of the basin of Attapeu. Inclination is very gentle as approximately 10degree. Tendency of the strike and dip of the Namhiang Formation is similar to that of the Triassic Makkhua Formation extending along the Annam mountain while was one of a hinterland at the period of Jurassic.

V. 2. 2 Lavi Gnai Tai Formation, J_2

Name: The Lavi Gnai Tai Formation was named newly in the Attapu Sheet map (scale 1:200,000) by JICA-DGEO Project study.

The Lavi Gnai Tai Formation is characterized by dominance of interbedded sandstone and mudstone to mudstone same as Jurassic Namhiang Formation. The Formation is covered by Jurassic Kanglo Namko Formation (J_3).

Type locality: A type locality is located at the western part of Ban Lavi Gnai Tai village in the northeastern part of Attapu Sheet map. The locality belongs to the margin of the Bolaven Plateau.

Distribution: The Lavi Gnai Tai Formation is distributed around a junction of the Nam Pa river and Xe Kaman River with small distribution in the B.Dakyoy Sheet map. Distribution area of the Formation is about 4km by 4km. Stratum of the Formation extends to the west side of the Attapu Sheet map continuously and distribution spreads extensively.

Stratigraphical relations: The Lavi Gnai Tai Formation overlies Jurassic Namhiang Formation (J_1) and the Formation is covered with Jurassic Kanglo Namko Formation (J_3) in the Attapu Sheet map.

Direct relationship between the Lavi Gnai Tai Formation and Namhiang Formation is unknown. While the lower part of the Lavi Gnai Tai Formation consist of estuarine sediments such as sandstone layers with silicified woods and trace fossils, the upper part of Namhiang Formation consist of shallow marine sediments such as mudstone dominated sandstone/mudstone interbedding. Different depositional environments of both strata suggest that unconformity would exist between both these layers.

Relationship between Lavi Gnai Tai Formation and Kanglo Namko Formation is a conformity in the Attapu Sheet map located at west side of the district.

Thickness: The thickness is about 100m in the district. In the Attapu Sheet map, the thickness is over 1,400m.

Lithofacies: Main facies of the Lavi Gnai Tai Formation consists of sandstone in the lower part and sandstone/mudstone interbedding and siltstone/mudstone interbedding in the middle to upper part of the Formation. This tendency is similar to the case of Namhiang Formation of the lower stratum. The color of sandstone shows gray to ocher and sandstone/mudstone interbedding and siltstone/mudstone interbedding show reddish brown to dark gray. The basement facies consists of silicified woods and trace fossils bearing medium grained sandstone and calcareous sandstone. Sandstone/mudstone interbedding and siltstone/mudstone interbedding layers of the middle to upper of the Formation show reddish brown to dark gray color (Fig. 18).

Based on the main facies of the Formation consist of sandstone layers and sandstone/mudstone interbedding layers including silicified woods and calcareous sandstone, the depositional environment at the period of Lavi Gnai Tai Formation is considered to be under a shallow marine same as Namhiang Formation.

Structure: Bedding in the Lavi Gnai Tai Formation strikes from east-northeast to west-southwest direction in the district. The inclination of dip is very gentle.

VI Cenozoic

Cenozoic strata in the district consist of Paleogene Nong Fa Formation ($bP_{1\text{-}1}$), Kengmo North Formation (P_1), Ban Dakdray (lP_1 (Apy)), alkaline dike rock (lP_1 (Ldy)), terrace deposits and fuluvial deposits.

The strata of this period in the district correspond to the unit of vPg_3, N_2-Q and vN (Neogene - Quaternary) by Annells and Coast (1990) and the unit of aQ (Quaternary) by Phan Cu Tien *et al.* (1991).

VI. 1 Paleogene

VI. 1. 1 Nong Fa Formation, $bP_{1\text{-}1}$

Name: Nong Fa Formation consists of basalt lava and scoria deposits as the early stage of the alkaline basaltic activities in the district. Their basaltic rocks are corresponded to basaltic rocks of the early stage of Bolaven Formation.

Type locality: A type locality is located at south of the Nong Fa lake, northeastern part of the district.

Distribution: Basalt lava of the Nong Fa Formation is distributed in a highland along the Nam Ang River, a tributary of the Xe Kaman River, located at northwestern part of the district and the southeast of the Nong Fa lake located at northeastern part of the district. The area of distribution is over 400km^2. Scoria deposits are distributed in a highland near the Nong Fa lake. The distribution is very limited.

Stratigraphical relations: Nong Fa Formation covers strata until after Triassic period.

Thickness: The thickness of the basalt lava is 100m

to 200m and that of the scoria deposit is about 10m in the district.

Lithofacies: Lava of the Formation consist of pyroxene basalt (Fig. 19). Basalt lava shows dark gray and has textures of glassy and hard. Vesicular structures and cooling joints are remarkable in their rock.

Lava of the Formation consist of pyroxene basalt. Basalt lava shows dark gray and has textures of glassy and hard. Vesicular structures and cooling joints are remarkable in their rock.

Scoria deposits contains dark gray colored scoria grain and unconsolidated structure (Fig. 19). The grain size of scoria is 0.5 to 1.0cm. The matrix of deposit consists of unsorted scoriaceous to sandy grains. The occurrences of sandy grains in the matrix suggest that their deposits were formed by reworked process. Ruby and sapphire are included in the scoriaceous deposits in rare cases. Their crystal size is about 0.2cm.

Eruptive center: Eruptive center of basaltic rocks is unknown. Present geometric center of distribution of their basaltic rocks is around the Ban Dakla upstream of the Xe Kaman River and the south of Nong Fa lake and around Nong Fa lake. The present distributions strongly suggest that the eruptive center will be existed around their area.

Age determination: Whole rock K-Ar age for basalt lava of the Nong Fa Formation in northern part of the Paam village was reported by this JICA-DGEO project.

The reported ages are as follows,

Age: 40 ± 1.3 Ma (Paleogene)

- Method: K-Ar method
- Target: whole rock
- Sample ID: B044

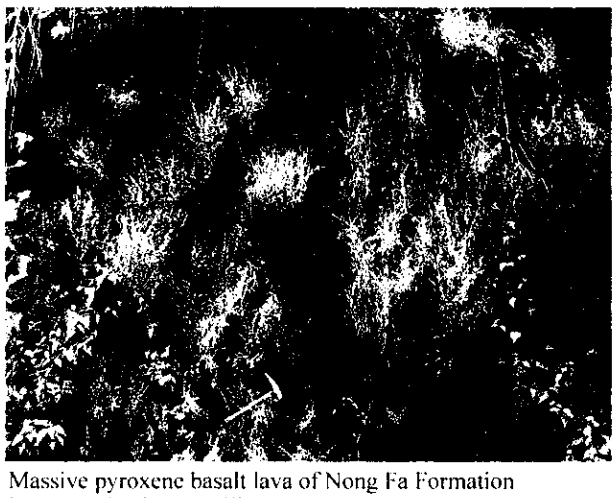
VI. 1. 2 Kengmo North Formation, P_1

Name: Kengmo North Formation consists of conglomerate and sandstone. The Formation is overlied the Silurian Xe Xou North Granodiorites and Devonian San Xai Formation by angular unconformity.

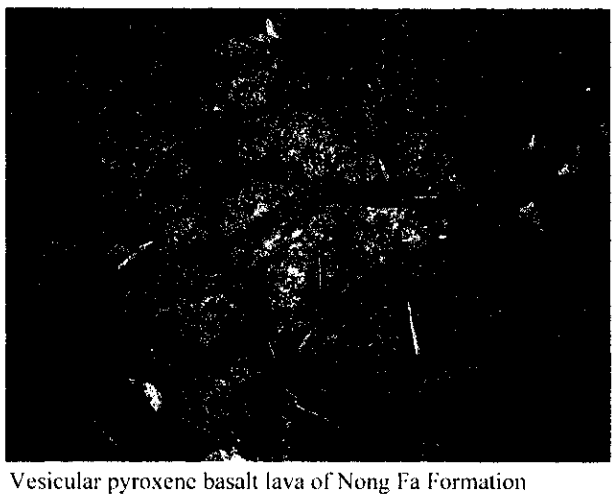
Type Locality: A type locality is around tributary rivers of the Xe Xou River along the Route 18B.

Distribution: Kengmo North Formation is distributed in the tributary of the Xe Xou River. The distribution area is small as 3km by 3km.

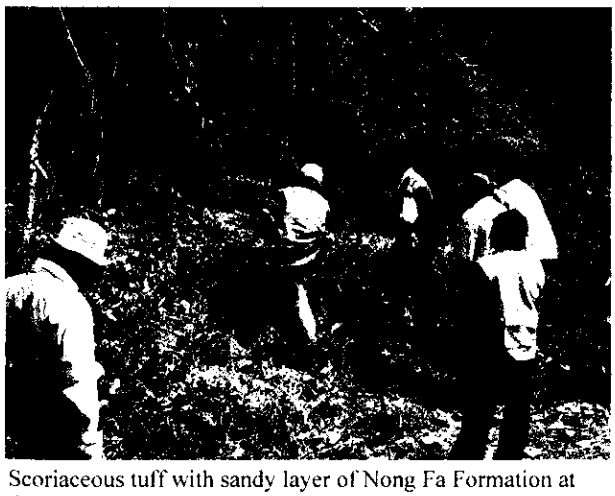
Stratigraphical relations: Kengmo North Formation is covered the Xe Xou North Granodiorites and San Xai



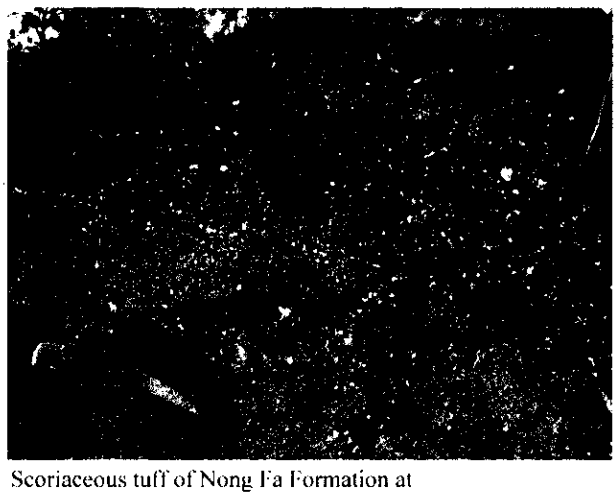
Massive pyroxene basalt lava of Nong Fa Formation in the north of Paam village



Vesicular pyroxene basalt lava of Nong Fa Formation along Xe Kaman River



Scoriaceous tuff with sandy layer of Nong Fa Formation at the lakeside of Nong Fa Lake



Scoriaceous tuff of Nong Fa Formation at the lakeside of Nong Fa Lake

Fig. 19 Photographs of an outcrop of the Nong Fa Formation in Annam mountain.

Formation by angular unconformity.

Thickness: The thickness of the Formation is about 50m.

Lithofacies: Kengmo North Formation consists of conglomeric sandstone, conglomerate and sandstone. The main facies of the Formation is conglomeric sandstone. The conglomeric sandstone and conglomerate have uncosolidated matrix. Varieties of gravel are composed of quartzite, sandstone and granite. The most abounding gravel is quartzite and the gravel size is pebble. Shapes of the gravel is sub rounded to rounded. Their matrix consists of medium to fine grained arkose sands which shows ocher to pale brown color and is poorly sorted. Sandstone facies is apparent in the basement of the Formation and is covered the Xe Xou North Granodiorites directly. The sandstone is composed of arkosic medium to very fine grained sandstone which shows ocher color. Bedding structures are remarkably in the sandstone. Their structure trends is parallel to the initial form of the granites under the Kengmo North Formation.

The field evidences such as above observation result suggest that the deposition of the Kengmo North Formation would be occurred by a landslide around the granites distribution.

VI. 1. 3 Dakdray Formation, IP_1 (Apy)

Name: Andesitic pyroclastic rocks to cover Triassic strata distributing in northern margin of the district are named newly as Dakdray Formation by JICA-DGEO Project study.

Type Locality: A type locality is located at 10km south from the Dakchung village.

Distribution: Their rocks distribute widely around the edge lines and top of mountains around B. Daktaok village and the south 10km of B. Dakchung located at northern part of the district.

Stratigraphical Relations: Dakdray Formation overlies Triassic strata and is covered by Paleogene Nong Fa Formation.

Thickness: The thickness of the Formation is over 200m around B. Daktaok village.

Lithofacies: Dakdray Formation consists of biotite porphyritic andesitic tuffs bearing feldspar, hornblende and biotite as fragmental phenocrysts and quartzite, pumice and tuff as accidental fragments.

Structure: Notable structure is absent in this Formation.

Age determination: Dating data for the andesitic tuff is not obtained. Based on the relationship with peripheral strata, the andesitic activity was occurred on Paleogene period.

VI. 1. 4 Alkaline dike rocks, IP_1 (Ldy)

Type Locality: A type locality is located at 5km north from the 90km sign along Route 18B.

Distribution and intrusive relations: Lamprophyre is distributed in the distribution of Devonian Dakkanat Granodiorites as a intrusive rock. Lamprophyre intrudes to the Dakkanat Granodiorites. The scale of the distribution of lamprophyre is very limited as 40cm to maximum 5m in width dyke. A boulder rock consisting of lamprophyre was found along the Nam Klavai River in northeastern part of the Nong Fa Lake.

Lithofacies: Lamprophyre shows dark brown to dark gray and includes phlogopite phenocrysts remarkably.

Structure: The direction of lamprophyre as dikes shows extends from northeast to southwest. The inclination of dyke dips to southwest steeply.

Age determination: Dating data for the lamprophyre is not obtained. Based on the lamprophyre intrudes to granites of Devonian and Paleozoic strata, the intruded age should be corresponded to after Paleozoic era.

VI. 2 Tertiary - Quaternary

VI. 2. 1 Terrace deposits, Qt

Terrace deposits are distributed along the Xe Kaman and Xe Xou River. Relatively large scale terrace deposits are located in shear zones with the boundary between Devonian granites and Carboniferous stratum in Xe Kaman River and the boundary between Silurian - Permian granites and Ordovician - Silurian strata in the Xe Xou River.

Terrace deposits consist of unconsolidated sediments with gravel, sand and silt. The thickness of the deposit is about ten meters and the terrace surface is only one.

VI. 2. 2 Fluvial deposits, Q

Fluvial sediments are distributed along Xe Kaman and Xe Xou River widely. The most extensive drainage system is developed along the Xe Kaman River which has most discharge around the area.

Fluvial sediments consist of unconsolidated sediments with gravel, sand and silt.

VII Igneous Activity

Remarkable igneous activity of the B.Dakyoy district is granitic activity in Paleozoic to Mesozoic era. Several varieties of granitic rocks were confirmed in field observations and chemical analyses by this JICA-DGEO Project study. Based on the JICA-DGEO study, granitic rocks were classified into eleven masses. Properties of their granitic masses to be earned by the study indicate that granitic magma activities were reorganized magmatic behavior in their activity age.

Whole rock chemical analyses were conducted to characterize, geochemically, the igneous rock distributed in the area and to consider the tectonic setting in which these igneous rock were generated.

Analysis procedures and interpretation result area as follows,

Analyzed samples: As shown in Annex 4, chemical analyses of 35 samples were conducted.

Contents of chemical analyses: Chemical analyses were conducted for 32 elements, including major elements, trace elements and rare earth elements (REE) as given below.

SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, MnO, CaO, Na_2O, K_2O, P_2O_5, LOI, Rb, Sr, Ba, Zr, V, Nb, Y, REE (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)

Analytical methods: Chemical analyses of all the elements except LOI (Loss of Ignition) were conducted by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) at ALS Chemex, Australia. LOI was determined gravimetrically after fusion in electric fumace.

Results of chemical analyses: The analytical results are given in Annex 4. For understanding the geochemical nature of granitic and basaltic rocks, the results of chemical analyses were plotted on various petrochemical discrimination diagrams (Fig. 20 to 25).

Based on the results of chemical analysis, geochemical characteristics of the granitic rocks are summarized as below,

a. Most of the granite bodies fall in the areas of sub-alkali and calc-alkali field in the alkali-silica and FeO-alkali-MgO (AFM) diagram except for Dakkanat Granodiorites (Fig. 20 and Fig. 21).

b. In the diagram of trace elements normalized to MORB, among the granite bodies, there are some differences in Ba , P, and Ti concentration and they are classified into 5 types (Fig. 22).

- Hornblende-biotite granodiorite of Xe Xou North Granodiorites and Nam Ang Granodiorites, distributed along Route 18B and in the area Xe Kaman River
- Biotite granite to granodiorite of Dakkanat Granodiorites, distributed in the area Xe Kaman and Xe Xou River
- Pyroxene-hornblende quartz diorite of Nam Tabeng Diorites, distributed in the area of Xe Kaman River
- Biotite-hornblende granodiorite of Antoum Granodiorites, distributed in the area of Xe Xou River
- Two mica granite of Xe Xou East Granites, distributed in the area of Xe Xou River

c. In chondrite normalized pattern of REE diagram, the granitic rocks are separated in 4 groups given below

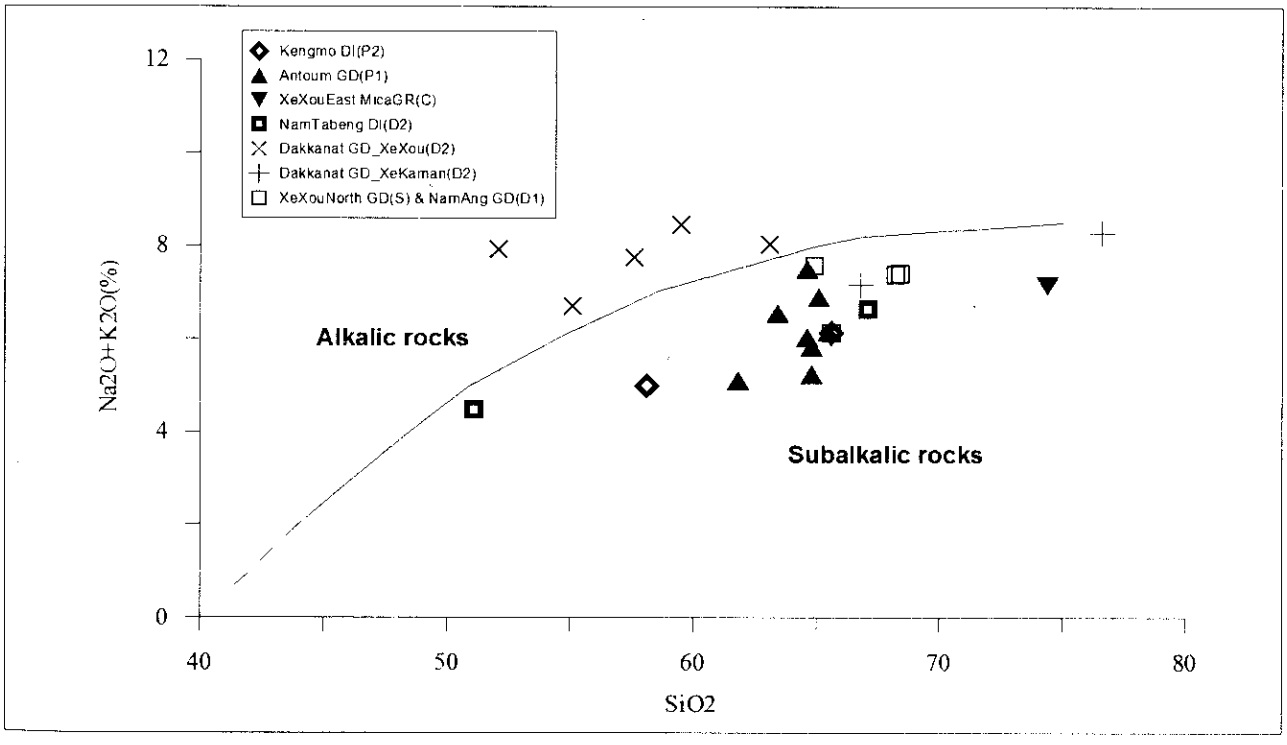


Fig. 20 Alkali-silica diagram of plutonic rocks.

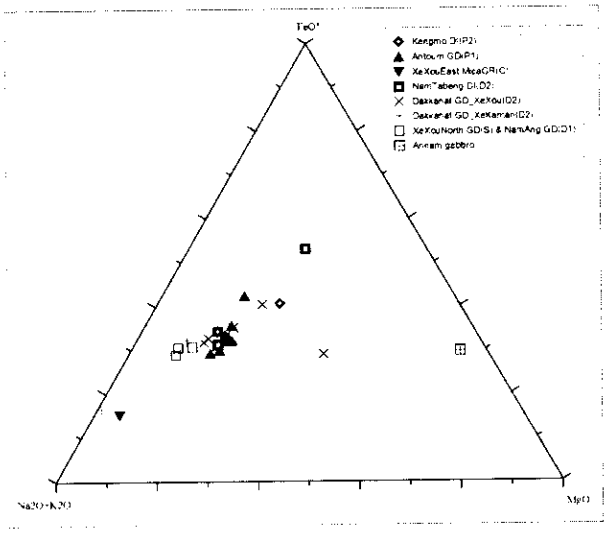


Fig. 21 AFM diagram of plutonic rocks.

by differences in concentrations of light REE, heavy REE and Eu (Fig. 22).

- Hornblende-biotite granodiorite of Xe Xou North Granodiorites and pyroxene-hornblende quartz diorite of Nam Tabeng Diorites, distributed along the Route 18B and in the area of Xe Kaman River.

- Biotite granite-granodiorite of Dakkanat Granodiorites, distributed in the area of Xe Kaman and Xe Xou River

- Biotite- hornblende granodiotite of Antoum Granodiorites, distributed in the area of Xe Xou River

- Two mica granite, distributed in the area of Xe Kaman River

Particularly, the biotite granite-granodiorite such as the Xe Xou North, Nam Ang and Dakkanat Granodiorites of the Xe Kaman and Xe Xou River area is more enriched in heavy REE with larger Eu anomaly compared with granitic rocks of other bodies.

d. The most of the granitic rocks occupy the field of VAG (Volcanic Arc Granite) in Nb-Y, Rb-(Y+Nb) diagrams of tectonic setting of granite (Fig. 23). The biotite granite to granodiorite of Dakkanat Granodiorites, on the other hand, have higher Nb and Y concentrations compared with other granite bodies and they are plotted in the field of WPG (Within plate granite).

e. The granitic rocks of the area are separated in three groups by the Al_2O_3-CaO-alkali discrimination diagram of granitic rocks (Fig. 24).

-Meta-aluminous I-type granite: hornblende-biotite granodiorite and biotite-hornblende quartz diorite

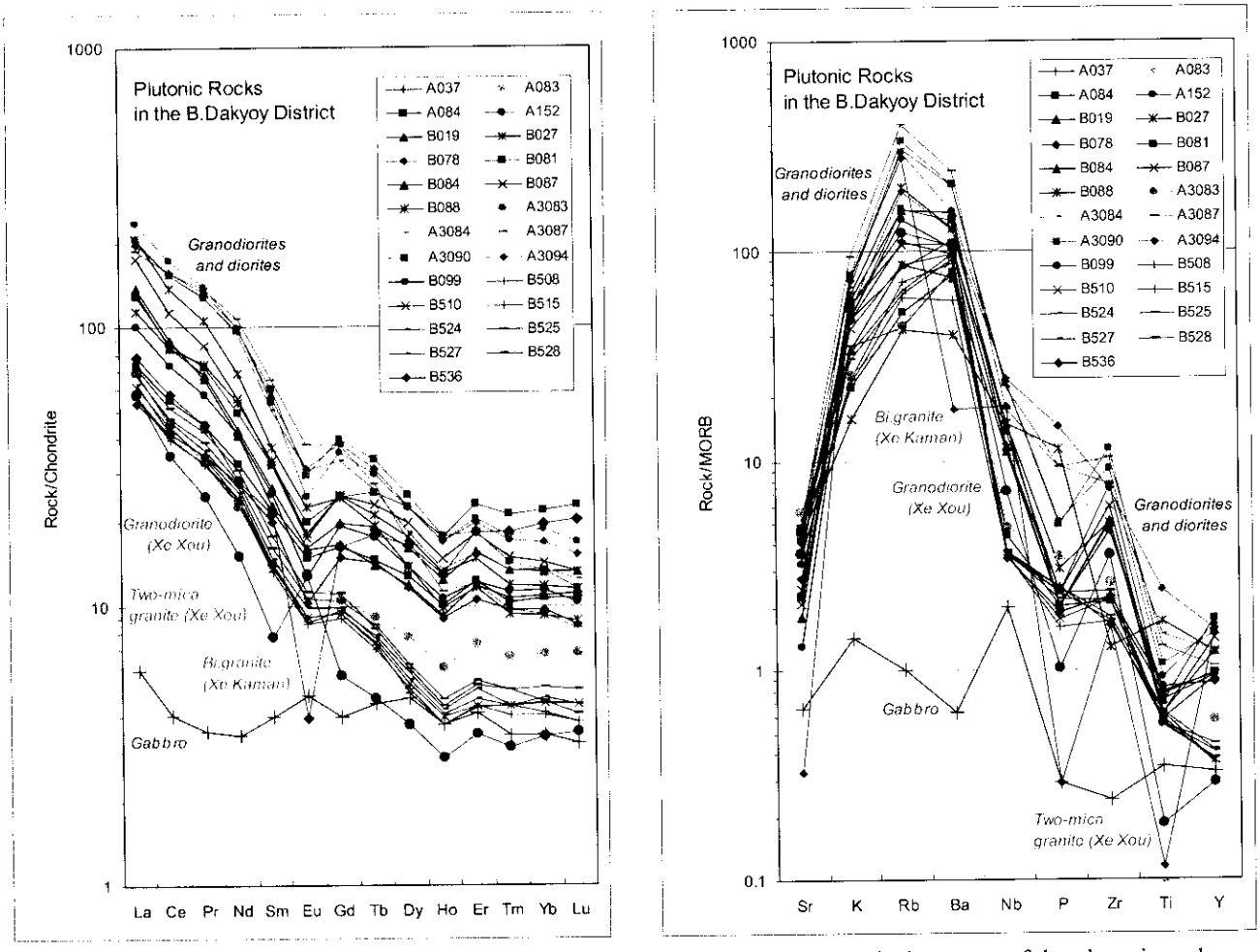


Fig. 22 MORB normalized spider diagram and chondrite normalized geochemical patterns of the plutonic rocks.

distributed along Route 18B and in the area of Xe Kaman River, biotite-hornblende granodiorite distributed in the area of Xe Xou River

- Per-aluminous S-Type granite: biotite-muscovite granite distributed in the area of Xe Xou River

- Meta-aluminous-per-alkaline I-A Type granite: biotite granite-granodiorite distributed in the area of the Xe Kaman River

f. The (Sr/Y)-Y discrimination diagram of tectonics for calc-alkali rocks shows that the granitic rocks of the area have different Y concentration depending on the each body (Fig. 25). Biotite-hornblende granodiorite of the Antoum Granodiorites and Two mica granite of Xe Xou East Granites distributed in the area of Xe Xou River are plotted in the field of adakite.

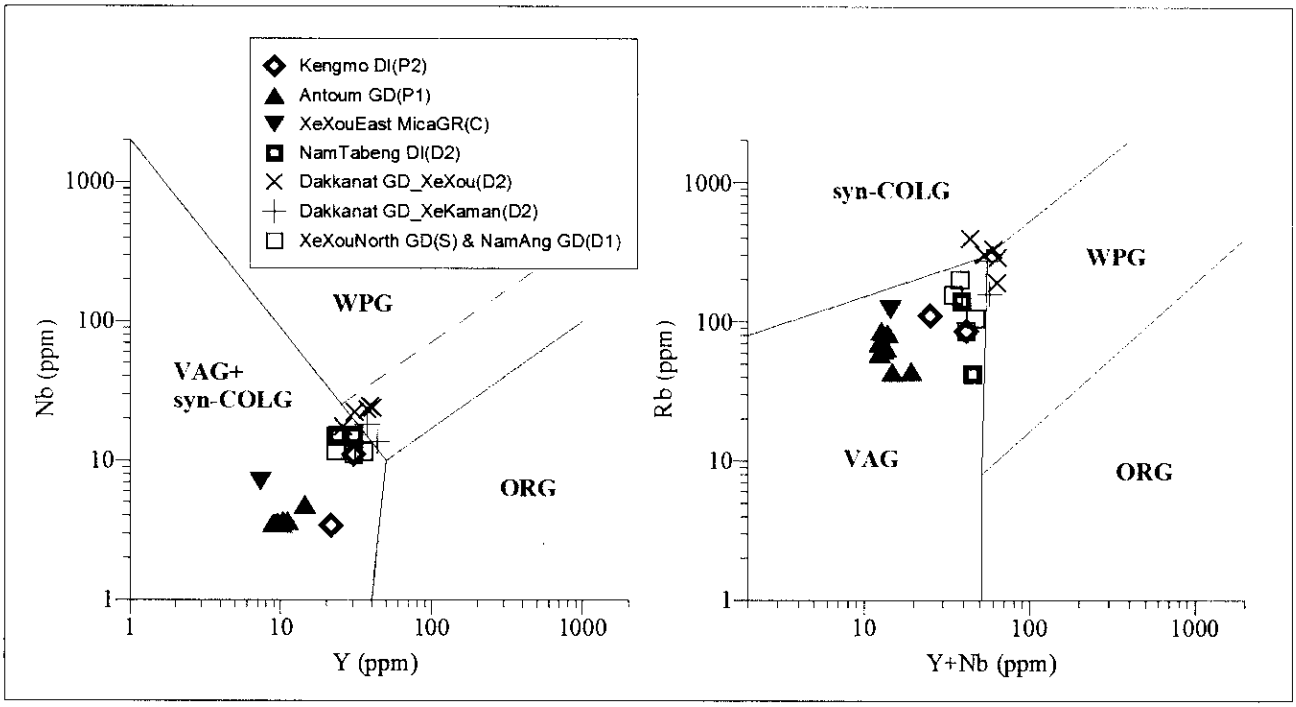


Fig. 23 Discrimination diagram of granitic rocks by trace elements.

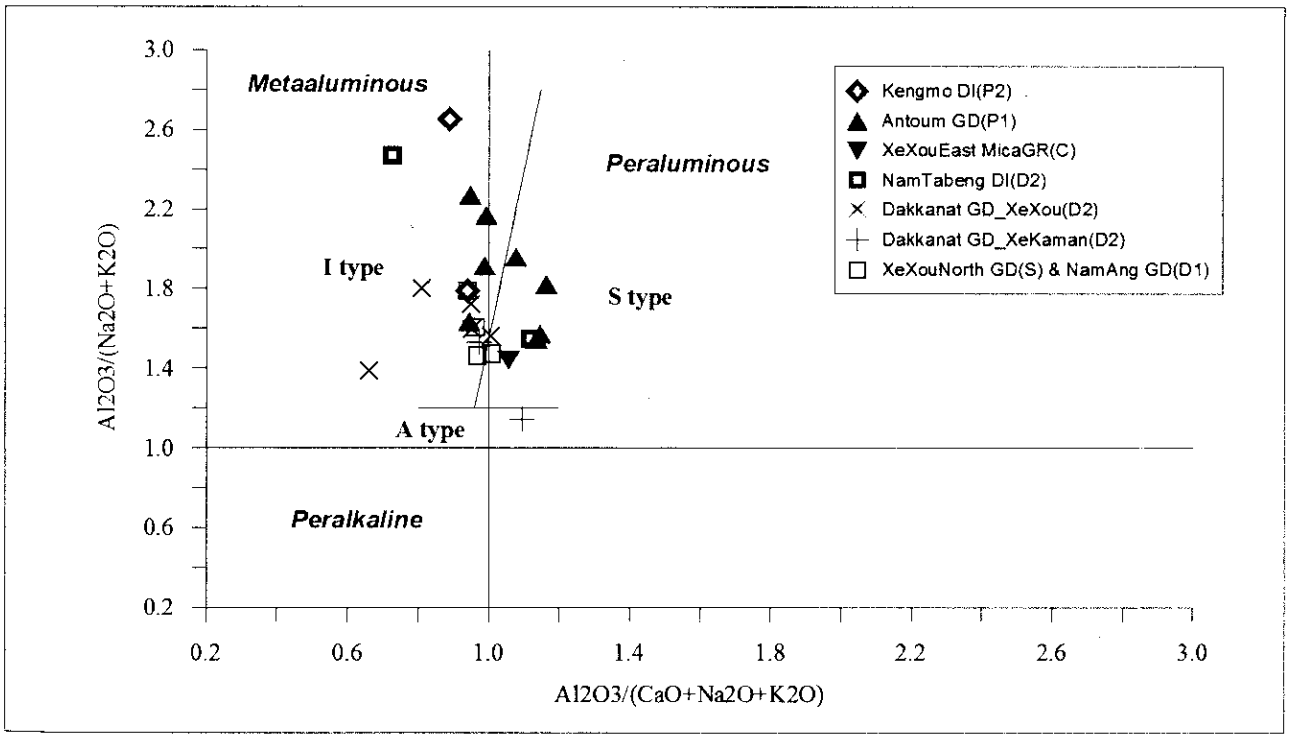


Fig. 24 Discrimination diagram of granitic rocks by Al2O3 index.

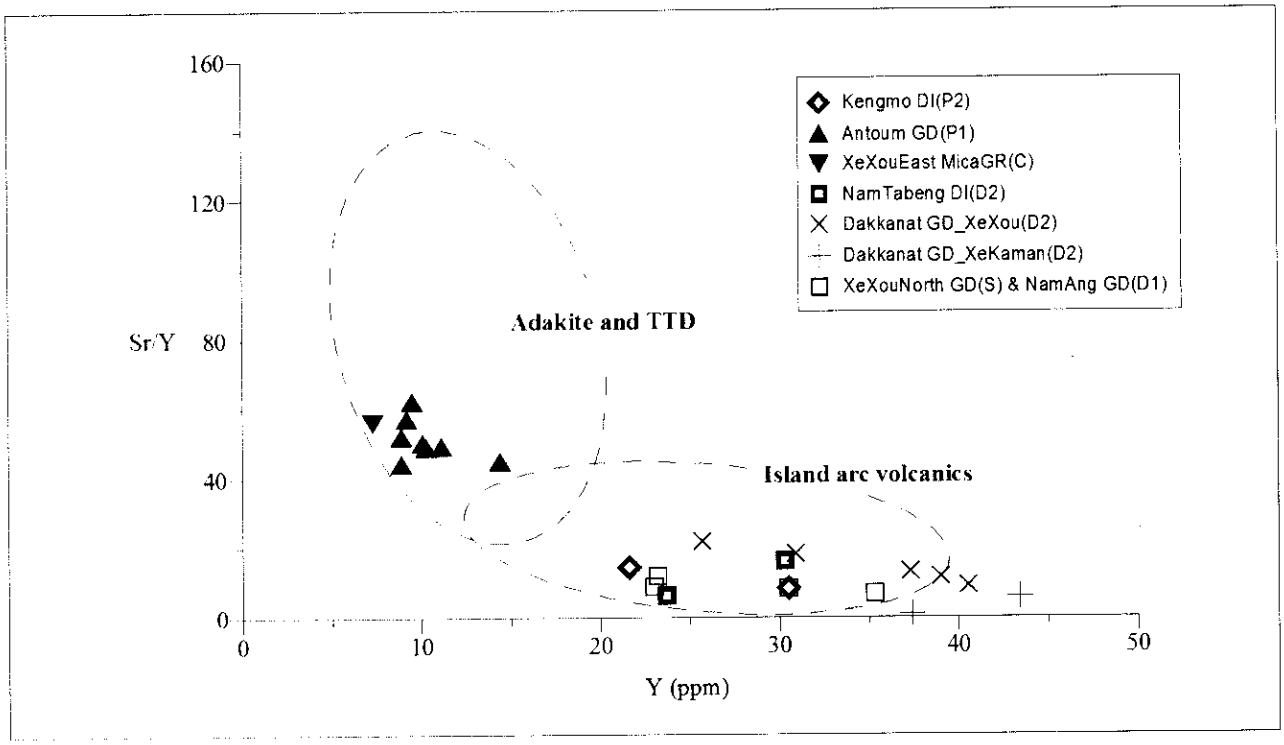


Fig. 25 (Sr/Y)-(Y) discrimination diagram of granitic rock.

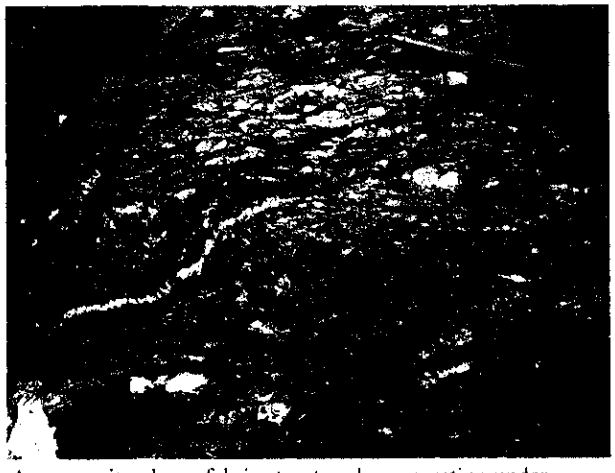
VIII Geological Structure

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

Based on the field observations, the style of shearings such as ductile and brittle differs in each tectonic zone of Paleozoic strata and granitic rocks distributions. Most dominant style of shearing is ductile phase to be characterized by generating mylonite. Among these condition, brittle shearing characterized by production of cataclasite and gouge occurs in Vantat area notably. Brittle shearings area accompanied with sulfide mineralization infrequently. Their brittle sheared direction extends from north to south.

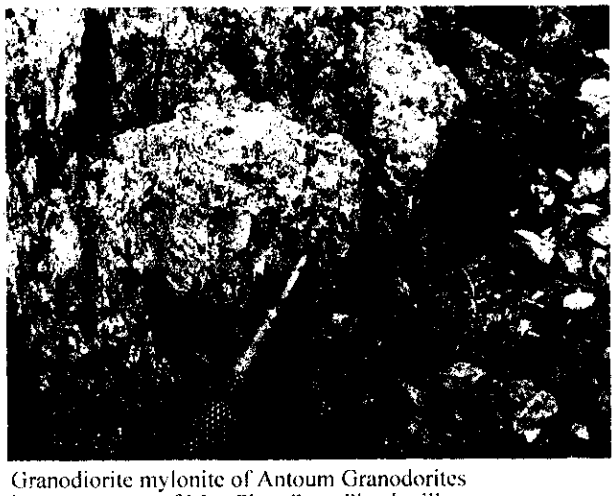
Shear sense of the deformed rocks such as mylonite and cataclasite of Paleozoic granites and schist suggest that tectonic movements in the Annam Mountain on Paleozoic era were occurred under right-lateral wrench tectonic condition (Fig. 26).

Mylonite with right-lateral shear sense of May Phao Sauu Phanh Group in Vantat area located at tributary stream of Xe Kaman River



A composite planar fabric structure by generating under ductile to brittle environment along the boundary between Xe Kaman Group (IV) and May Phao Sauu Phanh Group

Cataclasitic sandstone of May Phao Sauu Phanh Group in the eastern part of Xe Kong River



Granodiorite mylonite of Antoum Granodorites in western part of May Phao Sauu Phanh village

Fig. 26 Photographs of ductile to brittle shear progressing in Paleozoic strata

IX Mineral Resources

The Attapeu area is known as an area that have various mineral showings such as gold, copper, lead, zinc as shown on the mineral resources map at 1:1,000,000 issued by DGM and BGS in 1991 (Annells and Coast, 1990). This chapter describes mineral occurrences observed during JICA-DGEO Project study.

IX.1 Metallic Mineral Resources

IX.1.1 Gold

A prospect of gold is observed around Ban Dakyoy village in the northeast part of the B.Dakyoy map sheet area. Currently, the Lao PDR's National Army is exploring gold ore in the area and the operation of mine was started in 2007. Artisanal gold mining activities by panning are vigorous by villagers.

The mineralization is characterized by dominant sericite-quartz alteration, nearly 200C degree of homogenization temperature of fluid inclusion of quartz veins, similar salinity of fluid inclusion to the veins of orogeny type gold mineralization and close association to fracture zones. These features of mineralization suggest the gold copper mineralization of the Vantat area to be low-sulfidation, mesothermal orogeny type. A summary of mineralization of Vandat area is given in Table 1, Fig. 27 and Fig. 28.

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

Table 1 Gold-copper mineralization of Vantat

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

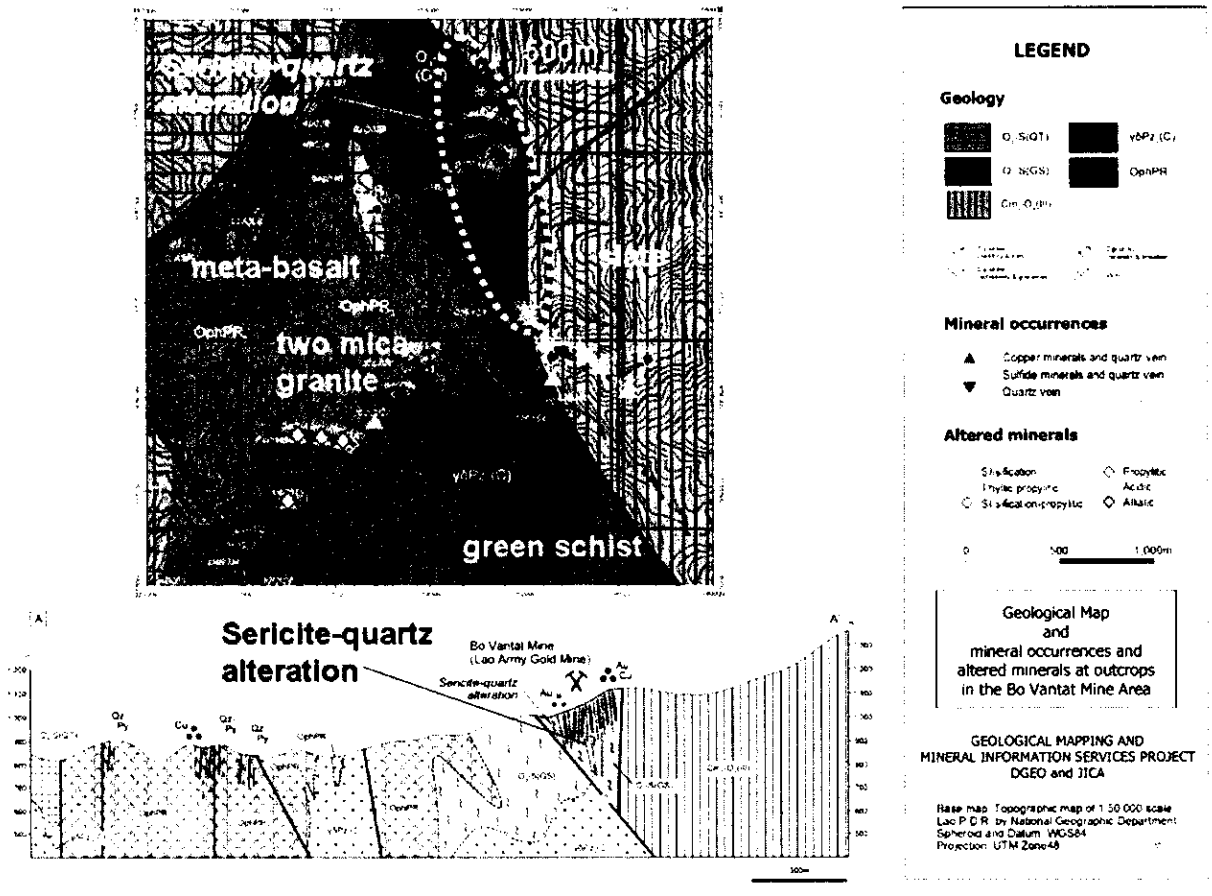
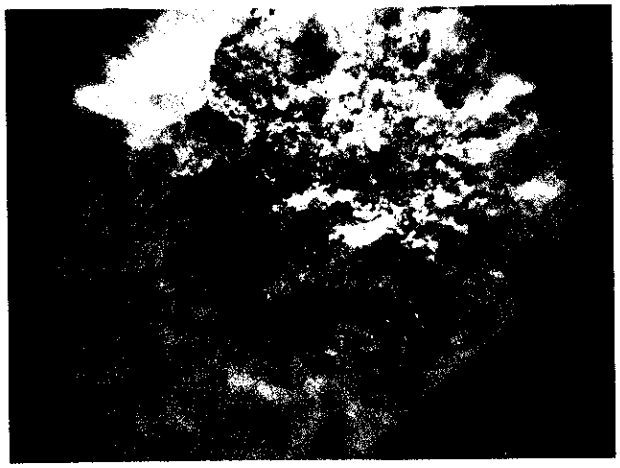


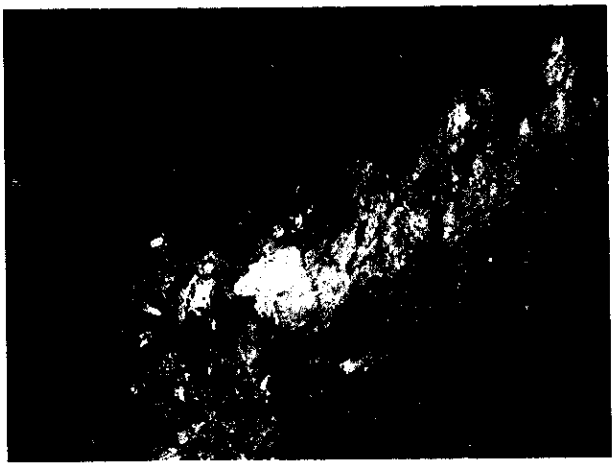
Fig. 27 Geological and mineral resources map and cross section with mineralization model (Vantat Area).

Gold Mine in the millitary prospective area, Vantat

Quartz vein in weartherd green schist, Vantat



Native gold in quartz vein, Vantat



Quartz vein in weartherd green schist, Vantat

Fig. 28 Photographs of Gold - cooper mineralization of the Vantat Area.

IX.1.2 Copper

A new copper-gold mineralization was found during the project in the east of Attapeu along the Rout 18B, south of currently under contraction dam , Xe Kaman 1, and it was named as Attapeu East Area.

Geological and mineral resources map of the area together with cross section of ore formation model are shown in Fig. 29.

Mineralization of the area is characterized by chlorite alteration of the host rock of the Cu-Au mineralization, sericite-quartz alteration at the center of mineralization, occurrences of stockwork quartz veins in the zone of sericite-quartz alteration. The features of mineralization and alteration of the area suggest that the mineralization of the Attapeu East Area is porphyry copper type (Table 2 and Fig. 30).

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

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

Table 2 Copper-gold mineralization of Attapeu

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

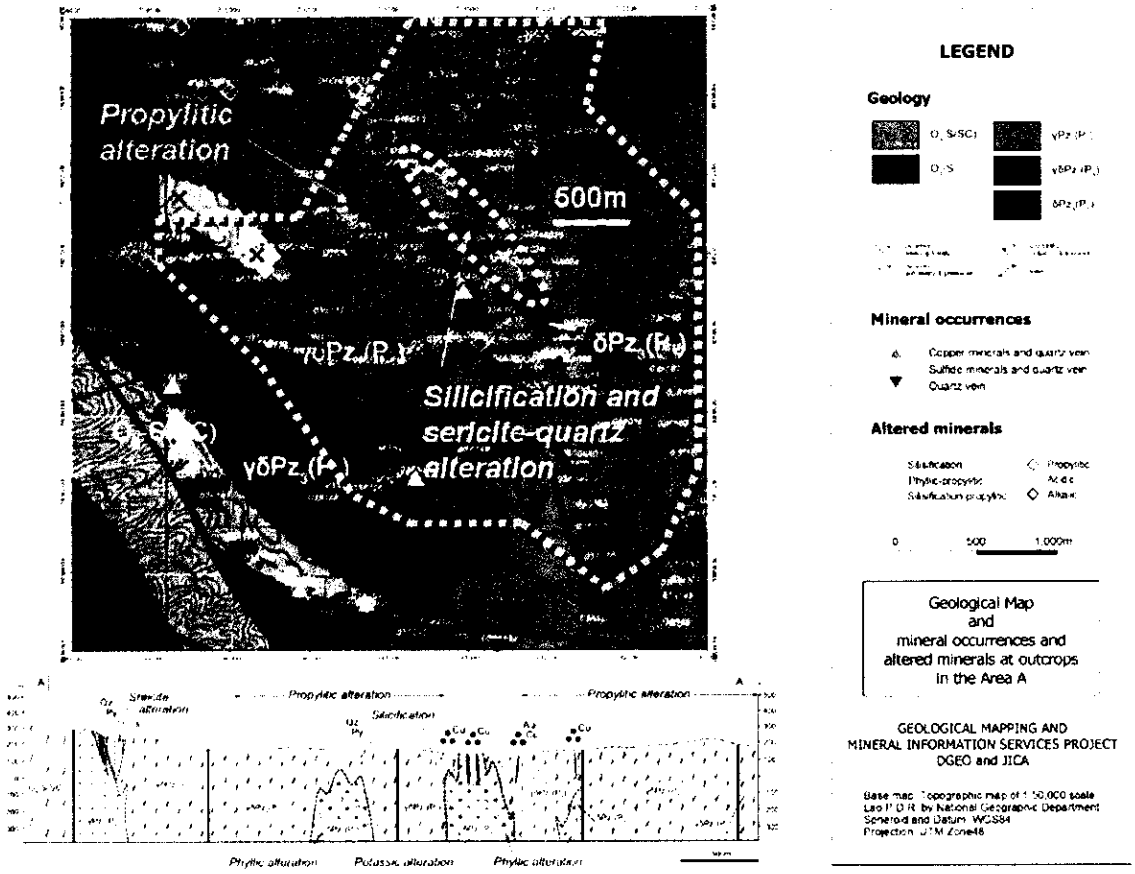


Fig. 29 Geological and mineral resources map and cross section with mineralization model (Attapeu East Area).

for understanding the scale of mineralization and assessing potentiality of the area.

IX.1.3 Bauxite

Lateritic soils extend in the plateau in the eastern upper-stream area of the Xe Kong River in the northern part of the B.Dakyoy map sheet, in which bauxite occurs. Currently, on the east side of the Xe Kong River, a Vietnamese cooperation project is carrying out exploration together with Attapeu's DEM staff members.

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

IX.1.4 Placer Gold

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

IX.2 Non-Metallic Mineral Resources

IX.2.1 Feldspar

Phenocrysts of alkali feldspar have a homogeneously large size of up to 3cm across in the granodiorite that broadly extends in the central mountain area of the B.Dakyoy map sheet. Some of granodiorite are weathered into soils and observed in various places (Fig. 31). Weathered granodiorite turns brittle and feldspar phenocrysts are large; thus it will be easy to pick them by sieving or vibrating. They are good raw material for tile and ceramics.

IX.2.2 Kaolin

Intrusions of rhyolite occur in a small scale in the B.Dakyoy map sheet. They are, in many cases, altered into kaolinite and some of them have a high degree of purity, which occur near the border between the Lao PDR and Vietnam. In a case with high purity, run-of-mine can be used for cosmetics and/or cement additives as it is. Due to the closeness to Viet Num that has a large demand potential for such materials it may make an easy commercialization (Fig. 31).

IX.2.3 Bentonite

The outer layer in the central Attapeu flat area includes

bentonite layers. Bricks are manufactured using mined bentonite in the suburb of Attapeu. They have a simple system, i.e., after a brick-forming machine powered through a farm tractor, dry under the sun and send the dried to the furnace for brick (Fig. 32).

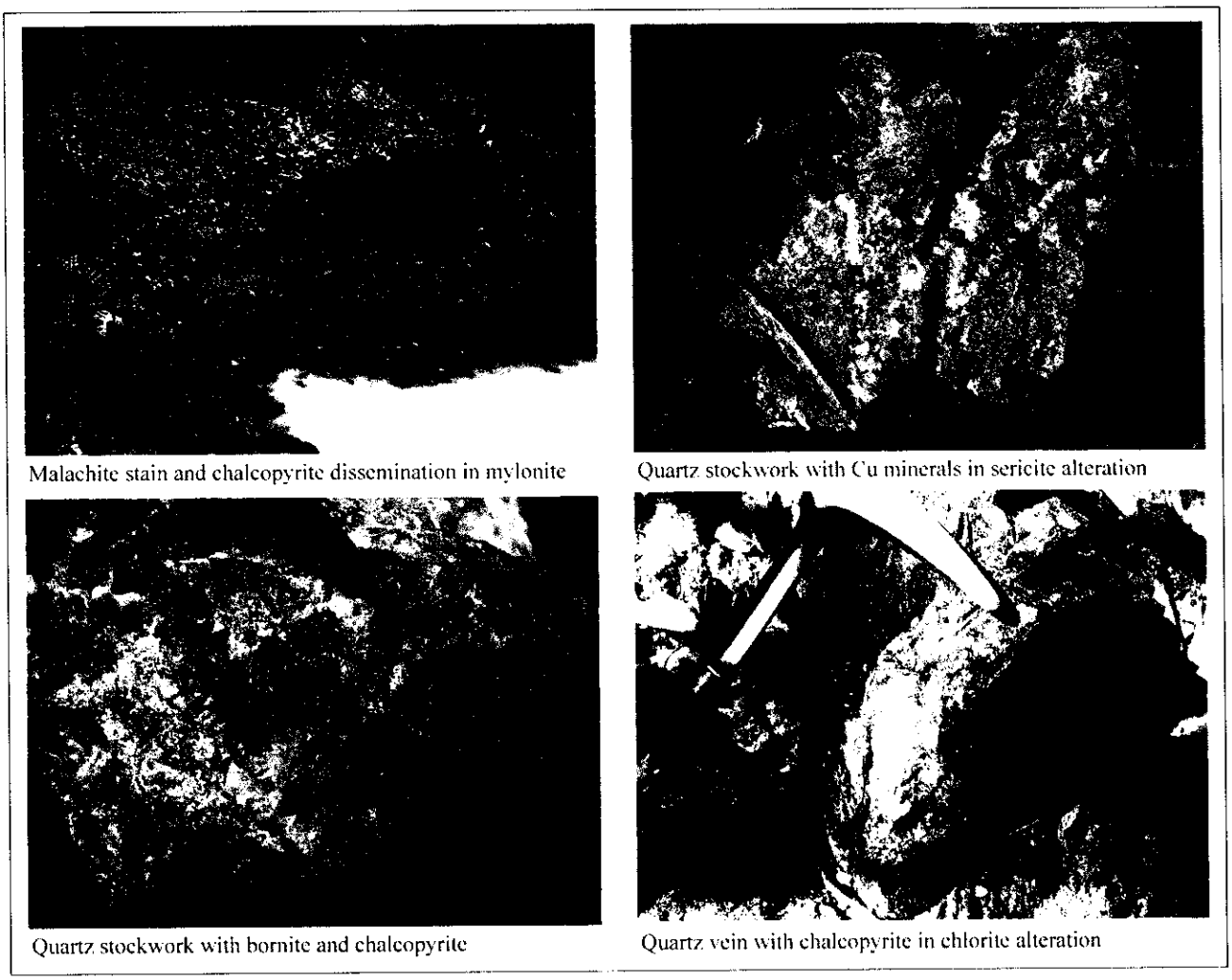


Fig. 30 Photographs of copper - gold mineralization of the Attapeu East Area.

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

IX.2.4 Talc

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

IX.2.5 Limestone

Limestone with a reasonable scale and high purity occurs along the Xe Kaman River in the east of the Nong Fa Lake. The extension is estimated at more than 1km by 2km, to which access is so difficult that it takes two days on food even in the dry season. Thus, it is not minable resources at present; however, once access has been established following hydropower development projects in the area, it would be promising (Fig. 31).

IX.2.6 Gemstone

Villagers mine gemstone by panning around Nong Fa Lake located in the mountain area in the eastern part of the B.Dakyoy map sheet . They are chiefly sapphire, ruby and spinel. Nong Fa Lake is seemingly formed by the late Quaternary volcanic activities with the basalt erupted from a substantial depth (Fig. 32). Spinel observed there is melted; thus, gemstone would also come from the deep place with the eruption.

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

IX.2.7 Aggregate

Rhyolitic welded tuff, granite and gneiss were used as subgrade for Route 18B national road construction aided by Vietnam. They are exposed along the road and quarries are observed where those rocks occur (Fig. 32).

IX.3 Other Mineral Showings

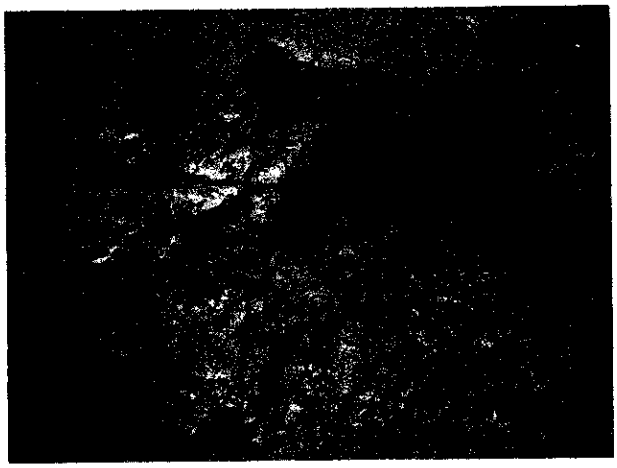
IX.3.1 Epithermal Alteration Zone

A relatively brittle shear zone of 100m long (east-west) in the Paleozoic slate and metasandstone is

Feldspar: K-feldspar porphyritic granodiorite at Route18 B

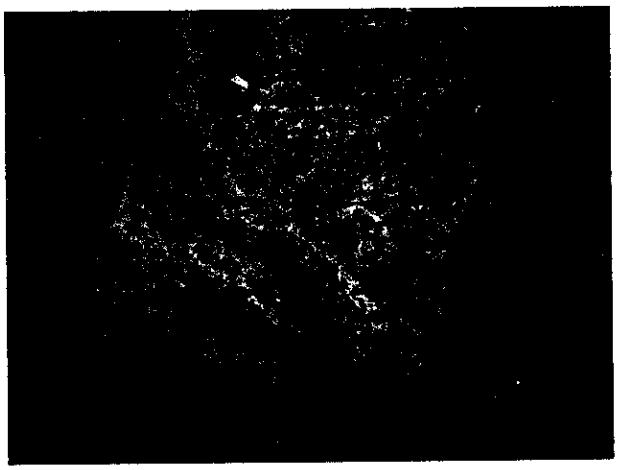
Feldspar: K-feldspar porphyritic granodiorite at Route18 B

Kaolin: high grade kaolin at Lao - Vietnam national border



Kaolin: high grade kaolin at Lao - Vietnam national border

Limestone: limestone outcrop in Xe Kaman River



Limestone: coral mudy limestone

Fig. 31 Photographs of non-metallic resources along the Route 18B and Xe Kaman River.

observed along the Xe Xou River on the Route 18B of the westwards border of Vietnam. Pyrite dissemination and opaline quartz stockwork veins occur in the shear zone. The groundwater level exists in the upper part of the outcrop, from which water flows down. Yellow mineral contained probably with arsenic and white sulfates occur along the water flow. The dissemination is constrained by the groundwater level. As such, it is possible that the origin source of sulfidic geothermal fluids that cause dissemination will be somewhere around the area.

Further exploration will be necessary around the area.

IX.3.2 Acid Alteration Zone

White rhyolitic ignimbrite interpreted as the Triassic occurs along Route 18B in the B.Dakyoy map sheet. Among others, some of the ignimbrite around the quarry provided Route 18 construction work with subgrade are characteristically altered into cristobalite and kaolinite. Quarts veinlets are also locally observed. Thus, it is possible that acid-leached and enrichment alteration would be formed at formation of ignimbrite (Fig. 32).

Since acid alteration zone frequently accompanies epithermal gold mineralization, further exploration will be necessary around the area.

Bentonite: digging of bentnite from fluvial plain

Bentonite: brick manufacturing by using bentonite

Ruby and sapphire obtained from digging in stream, Nong Fa

Ruby including in accidental conglomerate, Nong Fa

Aggregate: rhyolitic ignimbrite used for constraction material

Aggregate: altered massive rhyolitic ignimbrite

Fig. 32 Photographs of non-metallic resources in the peripheral area of Annam mountain.

Reference

Annells R.N. and Coast (1990) LAO P.D.R. GEOLOGICAL AND MINERAL OCCURRENCE MAP Scale 1:1,00,000. Asian Development Bank.

Department of Geology (2008) Map of Concession Areas up to May 2008.

Japan Mining Engineering Center for International Cooperation (2006) Internal Report for the Mineral Resources of Lao People's Domestic Republic (Southern Lao Area). 273p.

Maluski, H., Lepvrier, C., leyreloup, A., Tich Van Vu and Phan Truong Thi (2005) ^{40}Ar-^{40}Ar geochronology of the charnockites and granulites of the Kan Nack complex, Kon Tum Massif, Vietnam, Journal of Asian Earth Sciences, 25, 653-677.

Nagy, E.A., Maluski, H., Lepvrier, C., Schärer, U., Phan Truong Thi, Leyreloup, A. and Tich Van Vu (2001) Geodynamic significance of the Kontum massif in central Vietnam: composite ^{40}Ar-^{40}Ar and U-Pb ages from Paleozoic to Triassic. Journal of Geology, 109, 755-770.

Nakano, N., Osanai, Y., Owada, M., Tran Ngoc Nam, Toyoshima, T., Pham Binh, Tsunogae, T. and Kagami, H. (2007) Geologic and metamorphic evolution of the basement complexes in the Kontum massif, central Vietnam. Gondwana Research, 12, 438-453.

Nguyen Van Trang *et al.* (1996) Geological and Mineral Resources Map of Viet Nam on 1:200,000; BA NA (D-48-VI). Published and Copyright by Department of Geology and Minerals of Viet Nam, Hanoi.

Nguyen Van Trang *et al.* (1997) Geological and Mineral Resources Map of Viet Nam on 1:200,000; DAK TO (D-48-XII). Published and Copyright by Department of Geology and Minerals of Viet Nam, Hanoi.

Nguyen Van Trang *et al.* (1997) Geological and Mineral Resources Map of Viet Nam on 1:200,000; QUANG NGAI (D-49-VII & D-49-VIII). Published and Copyright by Department of Geology and Minerals of Viet Nam, Hanoi.

Osanai, Y., Owada, M., Tsunogae, T., Toyoshima, T., Hokada, T., Long, T.V., Sajeev, K and Nakano, N. (2001) Ultrahigh-temperature pelitic granulites from Kontum massif, central Vietnam: Evidence for East Asian juxtaposition at ca.250 Ma. Gondwana Research, 4, 720-723.

Osanai, Y., Nakano, N., Owada, M., Tran Ngoc Nam, Miyamoto, T., Nguyen Thi Minh, Nguyen Van Nam and Tran Van Tri (2008) Collision zone metamorphism in Vietnam and adjacent South-eastern Asia: Proposition for trans vietnam organic belt. Journal of Mineralogical and Petrological Science, 103, 226-241.

Phan Cu Tien *et al.* (1991) Geological Map of Cambodia, Laos and Vietnam, scale 1:1,000,000, Geological Survey of Vietnam, 2nd edition, Hanoi.

Phan Cu Tien *et al.* (1991) Geological Map of Cambodia, Laos and Vietnam, (Explanatory note to the geological map of Cambodia, Laos and Vietnam at 1: 1,000,000 scale), 2nd Edition. Geological Survey of Vietnam, 2nd edition, Hanoi.

Tran Ngoc Nam, Sano, Y., Terada, K., Toriumi, M., Phan Van Quynh and Le Tien Dung (2001), First SHRIMP U-Pb zircon dating of granulites from the Kontum massif (Vietnam) and tectonothermal implications. Journal of Asian Earth Science, 19, 77-84.

Trang Tinh *et al.* (1997) Geological and Mineral Resources Map of Viet Nam on 1:200,000; KON TUM (D-48-XVIII). Published and Copyright by Department of Geology and Minerals of Viet Nam, Hanoi.

United Nations (1990) Atlas of Mineral Resources of the ESCAP Region Vol.7, Lao People's Domestic Republic, 19p. (ESCAP, Explanatory Brochure).

United Nations (1995) Mineral Resources Potential and Policy for Development in the Asian Least Developed Countries and Viet Nam, Mineral Concentrations and Hydrocarbon Accumulations in the ESCAP Region Volume 9, 103-141.

GEOLOGICAL SHEET MAP, 1: 200,000
TOPOGRAPHIC MAP NO.: D-48-XII

Geology of the B.Dakyoy District

(ABSTRACT)

General remarks

The B.Dakyoy District of quadrangle of latitude 14°40′ to 15°20′ N and longitude 107°00′ to 108°00′ E is located in the southern part of Lao P.D.R. The district covers mainly Attapeu Province and slightly Xekong Province. Annam mountain occupies the mostly of the B.Dakyoy District. The mountain consists of mainly Paleozoic to Mesozoic metamorphic rocks, sedimentary rocks and granites with unknown age gneisses and mafic rocks. Their formative activities relate to tectonism around Indochina and Southchina cratons during Caledonian to Hercynian Orogeny. After their movement, Mesozoic to Cenozoic neritic to continental sedimentary rocks and rhyolitic to basaltic volcanic rocks overlied their strata under the calm environment. Terrace deposits and recent alluvial deposits develop along Xe Kaman River and Xe Xou River.

Unknown rocks

Unknown age rocks consist of gneiss, gabbro, meta basalt and amphibolite in the district. Their age has been estimated as Proterozoic era by former research in the field observations. According to latest research, their age were interpreted that become younger more than Proterozoic era. Their rocks were named newly as the Annam Gneisses (MP) for gneisses and the Annam Gabbro (Uv Pz_1) for gabbro by this JICA-DGEO Project study. Their distributions are very limited along shear zones.

Paleozoic metamorphic and sedimentary rocks

Paleozoic metamorphic and sedimentary rocks of the district are distributed in the main part of the Annam mountain. Their rocks classified into Cambrian - Ordovician Xe Kaman Group (Cm_2-O_1), Ordovician - Silurian May Phao Sauu Phanh Group (O_3-S), Devonian San Xai Formation (D_{2-3}) and Carboniferous Kadon Formation (C) named newly by JICA-DGEO Project study. Lithofacies of Xe Kaman Group and May Phao Sauu Phanh Group consist of mainly slate, schist and quartzite. Origin of their rocks are marine to netric sedimentary rocks basically. San Xai Formation and Kadon Formation are covered Xe Kaman Group and May Phao Sauu Phanh Group by unconformity. Their lithofacies consist of sandstone, interbedded sandstone/mudstone and conglomeric rocks such as to deposit under nitric to fluvial environments. The basement of Devonian stratum consists of conglomerate mainly.

Paleozoic granitic rocks

Paleozoic granitic rocks of the district are distributed locally in the Annam mountain Their rocks classified into Silurian Xe Xou North Granodiorites ($gdPz_3$ (S)), Devonian Nam Ang Granodiorites ($gdPz_3$ (D_1)), Devonian Dakkanat Granodiorites ($gdPz_3$ (D_2)), Devonian Nam Tabeng Diorites (dPz_3 (D_2)), Carboniferous Xe Xou East Granodiorites ($gdPz_3$ (C)), Permian Antoum Granodiorites(I) ($gdPz_3$ (P1)), Permian Antoum Granodiorites(II) (dPz_3 (P1)), Permian Antoum Granodiorites(III) (gPz_3 (P1)), Permian Kengmo North Diorites ($gdPz_3$ (P2)), Permian Dakpala East Diorites (dPz_3 (P2)) and Triassic Acidic intrusive rocks (gT_2) named newly by JICA-DGEO Project study. Their chemical properties are differ in each age. During Silurian to Devonian period, I type granitic activities were dominated in the area. S type activities were occurred in a limited area. From Permian period, adakitic activities were started in shear zone under the environment of mylonite phase.

Mesozoic sedimentary and volcanic rocks

Mesozoic sedimentary rocks of the district are distributed in the western and northern part of the area. Their rocks classified into Triassic Dakdouan Formation (T_{1-2}), Triassic Makkhua Formation (T_2), Jurassic Namhiang Formation (J_1) and Jurassic Lavi Gnai Tai Formation (J_2) named newly by JICA-DGEO Project study. Lithofacies of their rocks consist of nitric to fluvial sedimentary rocks. Basement of the Triassic consists of conglomerate mainly.

Mesozoic volcanic rocks are distributed in the western part of the district. Their rocks classified into Triassic Alok Formation (T_{1-2} (Av)), Katha-Tai Formation (T_{1-2} (Dv)) and Namchang Formation(T_{1-2} (Rv)) named newly by JICA-DGEO Project study. Their lithofacies consist of rhyolitic to andesitic welded tuffs and tuffs. Their strata cover Triassic Dakdouan Formation.

Cenozoic sedimentary and volcanic rocks

Cenozoic sedimentary rocks deposit in the limited area around granitic distribution. These rocks is named as Kengmo Formation (P_1) by JICA-DGEO Project study. These rocks consist of conglomeric sandstone mainly.

Cenozoic volcanic rocks distributed in the highland of Annam mountain. These rocks classified into Dakdray Formation (lP_1 (Apy)), Alkaline dike rocks (lP_1 (Ldk)) and Nong Fa Formation (bP_{1-1}) named newly JICA-DGEO Project study. Among these rocks, Dakdray Formation and alkaline dike rocks have a lamprophyric composition remarkably. Their rocks are corresponded relatively to Bolaven Formation consisting of basaltic rocks.

Late Cenozoic sediments

Late Cenozoic sediments are distributed along the river area of Xe Kaman and Xe Xou River. Their sediments consist of terrace deposit, fluvial deposit and lacustrine deposit.

Tectonics

B.Dakyoy District belongs to Kontum-Savannakhet Tectonic Region. From geological situation of the district and structures observed in the strata and the granitic rock bodies, five structural zones are identifiable in the pre-Carboniferous geological units that occur in the Annam Mountain. The structural zones are classified as westward direction into gneiss and gabbro dominant zone, quartzite dominant zone in metamorphic rock, granite dominant zone in metamorphic rock, pelitic schist dominant zone and slate dominant zone.

Their structural features were constructed under the tectonism relate to tectonism around Indochina and Southchina cratons during Caledonian to Hercynian Orogeny. These activities will be occurred under the right-lateral wrench tectonism.

Economic geology

B.Dakyoy district has many varieties of metallic and non-metallic mineral resources such as gold, copper, bauxite, feldspar, kaolin, bentonite, talc, limestone, gemstone, aggregate and coal. Among these, gold deposit, copper-gold mineralization and bauxite deposit have a good potential as economically.

The gold mine in Vantat area operating by Lao military was started productions in the 2007. The gold mineralization was generated under mesothermal system with shearing and granitic activities.

The copper-gold mineralization is located in the east of Attapeu City. The mineralization related to granitic activities such as a porphyry type. The ore grades derived from JICA-DGEO Project study present about maximum 6% Cu and 7g/t Au by quartz stockwork bearing copper minerals such as bornite, tenolite, chalcopyrite, and so on. The mineralization associates with phyllic and propylitic alterations.

Bauxite deposits are distributed in the highland on the northern mountain of the district. The formative mechanism of bauxite is same as the deposit of Bolaven Plateau.

For placer gold, the native gold panning have been carried out in and along the main rivers such as Xe Kaman River, and so on by local villager.

Sapphire and ruby are occurred around the Nong Fa Lake. Sieving for their gems have been conducted in small stream around the Nong Fa Lake by local villager.

Appendix

Annex 1 Microscopic Observation for Rock Thin Section (1/5)

Ser No.	Sample No	Coordination (tTM) E	Coordination (tTM) N	Rock Name	Texture	Fragments, Xenolith or Porphyritic Minerals: quartzite	sandstone	siltstone	mudstone	pumice	tuff	mudstone	lherzolite	pyroxenite	basaltic glass	quartz	K-feldspar	nepherine	plagioclase	muscovite	biotite/phlogopite	tremolite/amphibole	augite	olivine	Main Minerals, Groundmass or Matrix: quartz	K-feldspar	plagioclase	albite	muscovite	biotite	phlogopite	hornblende/amphibole	angite/clinopyroxene	olivine	apatite	zircon	sallanite	opaque minerals	glass	Secondary Minerals: quartz	biotite	muscovite	actinolite	tremolite	prehnite	pumpellyite	sericite	chlorite	epidote	carbonate	saponite	kaoline	zeolite	limonite	opaque minerals	Remarks
1	A003	669675	1668582	Olivine basalt	intersertal, porphyritic and vesicular texture																						◎	○	○			△	△	△						◎																		
2	A021	731737	1632166	Rhyolitic welded tuff (Ignimbrite)	pyroclastic and glassy textures						◎																														◎							△									
3	A031	774539	1627249	Altered rock by kaolinitization																																				△							○				◎					
4	A036	774102	1626702	Muscovite - biotite gneiss	porphyroblastic texture																						◎	○	○			△	△	△																△	△								
5	A037	771048	1627825	Amphibolite	porphyroblastic texture																								◎					○														○	△			·	·				
6	A040	769320	1629021	Gabbro	cumulate texture																								◎							◎												△	△	○		△					
7	A044	766755	1631598	Biotite schist	porphyroblastic texture																						◎	△			△	○	○																								
8	A061	709796	1627645	Rhyolitic tuff (Ignimbrite)	pyroclastic texture	○					◎																	·	△	△			△	△						◎												△			◎				
9	A083	747911	1632403	hornblende-biotite granodiorite	hypidiomorphic texture																						◎	◎	◎			△	△	○																								
10	A084	748476	1632725	Hornblende-biotite diorite	hypidiomorphic texture																						◎	◎	○			△	△	△																								
11	A101	734522	1647817	Hornblende-biotite granodiorite	hypidiomorphic texture																						◎	◎	○			△	△	△																								
12	A104	752752	1636350	Porphyry	porphyritic texture						·													·	◎	○	○			·	·							◎																		
13	A118a	632754	1690978	Olivine basalt	porphyritic and vitric texture								△	△				·							○			◎							◎	○				◎																	including mantle xenoliths
14	A118b	632754	1690978	pyroxenite	granular texture																													·	◎	△																				mantle xenolith
15	A118c	632754	1690978	Olivine basalt	porphyritic and vitric texture									△	○										○			◎							◎	○				◎																	including primitive magma
16	A120	633381	1684772	Olivine basalt	intersertal, porphyritic and vesicular textures																								◎							◎					◎																	
17	A122	632986	1688398	Plagioclase andesitic basalt	intersertal, porphyritic and vesicular textures														△						△	△			◎							◎					◎																	
18	A127	618039	1683025	Pyroxene basalt	intersertal, porphyritic and vesicular textures																				△				◎							◎					◎																	
19	A130	641026	1662044	Nepherine-olivine basalt	intersertal, porphyritic and vesicular textures																				△	△			◎							◎					◎																	
20	A131	639197	1659562	Nepherine-olivine basalt	intersertal, porphyritic and vesicular textures																				△				◎							◎					◎																	
21	A146	643587	1689495	Olivine basalt	intersertal, porphyritic and vesicular textures															·					·	△			◎							◎					△																	
22	A150	765264	1628742	Gneiss	granoblastic texture																						◎	◎		○	○	◎																										
23	A152	765978	1638698	Biotite-muscovite granite	hypidiomorphic texture																						◎	◎	◎		△	◎		·			·	·												△	△								
24	B009	736195	1641309	Muscovite schist	granoblastic texture											△	△	△							◎				△																					◎									
25	B012	732639	1636826	Andesitic tuff (Ignimbrite)	pyroclastic and glassy textures					△	△	△							△						○															◎												△			△				
26	B013	732092	1635725	Dacitic pumice tuff (Ignimbrite)	pyroclastic and glassy textures					△	△					·	△			·																					·	◎																	
27	B017	741432	1641218	Biotite granite	hypidiomorphic granular texture																						◎	◎	○			○					·	·	·												△	△							·	
28	B018c	744754	1640030	Schist (cataclasite)	cataclastic texture																						◎																																
29	B019	748373	1639578	Hornblende-biotite granodiorite	hypidiomorphic granular texture																						◎	○	◎			△		△			·	·	·													△								
30	B024	683442	1696702	Pyroxene basalt	intersertal textures																				○				◎							○					◎																	

◎: abundant, ○: common, △: a little, ·: rare

Annex 1 Microscopic Observation for Rock Thin Section (2/5)

Ser. No.	Sample No.	Coordination (UTM) E	Coordination (UTM) N	Rock Name	Texture	Fragments, Xenolith or Porphyritic Minerals: quartzite	sandstone	siltstone	mudstone	pumice	tuff	mudstone	lherzolite	pyroxenite	basaltic glass	quartz	K-feldspar	nepherine	plagioclase	muscovite	biotite/phlogopite	tremolite/amphibole	augite	olivine	Main Minerals, Groundmass or Matrix: quartz	K-feldspar	plagioclase	albite	muscovite	biotite	phlogopite	hornblende/amphibole	augite/clinopyroxene	olivine	apatite	zircon	allanite	opaque minerals	glass	Secondary Minerals: quartz	bicitite	muscovite	actinolite	tremolite	prehnite	pumpellyite	sericite	chlorite	epidote	carbonate	saponite	kaoline	zeolite	limonite	opaque minerals	Remarks
31	B027	753663	1640861	Hornblende biotite granodiorite	hypidiomorphic granular texture														△						◎	○	◎			△		△			·	·	·																		
32	B029	757540	1638625	Migmatite	granoblastic texture																				◎	○	○		△	△																	△								
33	B041	723034	1658881	Slate	schistose texture																				◎	△		△																		◎								
34	B042	727700	1664472	Pyroxene basalt	porphyritic texture and intersertal texture																			△			◎							○					◎															
35	B043	724463	1675495	Biotite granodiorite	hypidiomorphic granular texture												△								◎	◎	○			△					·	·		·							△	△							
36	B044	728088	1665289	Pyroxene basalt	aphanitic texture and intersertal texture																						◎							○					◎							·								
37	B061	734339	1696932	Slate	schistose texture																				◎	△		△																		◎								
38	B062	734023	1696997	Quartzite	sutured texture																				◎																													
39	B065	723931	1697302	Pyroxene basalt	aphanitic texture and intersertal texture																						◎							○					◎															
40	B069	721777	1681705	Olivine pyroxene basalt	intersertal texture																			△			◎							○					◎															
41	B070	720764	1684355	Dacitic tuff	pyroclastic texture						△																												◎							△								
42	B071	719403	1697948	Olivine basalt	intersertal, porphyritic and vesicular textures																			△			◎							○					◎															
43	B078	736022	1654653	Biotite granodiorite	hypidiomorphic granular texture																				◎	◎	○			△					·	·		·							△	△							
44	B079	726809	1647568	Ignimbrite	pyrolcastic texture and welded texture					△	△					△	△		△																				○					·	△	△							
45	B080	731676	1661421	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	◎	○			△			△		·	·	·								·	·							
46	B081	737580	1655897	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	◎	○			○			△		·	·	·	·							·	·							
47	B084	740087	1661080	Hornblende biotite granodiorite	hypidiomorphic granular texture												△								◎	○	◎			△			○		·	·	·								·								
48	B086	735627	1664812	Hornblende biotite granodiorite	hypidiomorphic granular texture												△		△						◎	○	◎			△			○		·	·	·	·							·								
49	B087	734050	1666728	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	◎	○			○			△		·	·	·	·							·	·							
50	B088	738498	1668467	Biotite Pyroxene Hornblende c.orite	hypidiomorphic granular texture														△						○	△	◎			△			○		·	·	·	·															
51	B091	741802	1669469	Biotite gneiss	granoblastic texture																				◎	◎		◎			◎														·	·							
52	B092	741507	1669290	Biotite gneiss	granoblastic texture																				◎	○		△	△	◎																							
53	A182	762306	1630496	Biotite hornblende gneiss	granular texture																				◎	◎	○			△			○		·																			
54	A210	739457	1702096	Phlogopite basaltic tuff	pyroclastic texture					△	◎								◎	△	◎																																	Lamprophyre origin
55	A244	757983	1657617	Amphibolite	granoblastic texture																							○					◎	△												△		○	○					
56	A252	752187	1658997	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	◎	◎			△				△	·	·	·															
57	A259	765865	1632578	Hornblende biotite gneiss	granular texture																				◎	○	◎			○			△		·	·	·															
58	A261	763807	1634645	Muscovite biotite schist	granoblastic texture																				◎	○		○	○	○																							
59	B098	748527	1669194	Rhyontic tuff (Ignimbrite)	pyroclastic texture						◎						○		○	△																											○	△							·
60	B099	748590	1669280	Biotite granite	hypidiomorphic granular texture																				◎	◎	○			○					·	·										△	△							

◎ abundant, ○ common, △ a little, · rare

Annex 1 Microscopic Observation for Rock Thin Section (3/5)

Ser No	Sample No	Coordination (UTM) E	Coordination (UTM) N	Rock Name	Texture
61	B102	769312	1637244	Biotite granite	hypidiomorphic granular texture
62	B103	769131	1637726	Biotite syenite	hypidiomorphic granular and pegmatitic texture
63	B104	768515	1638801	Muscovite biotite granite	hypidiomorphic granular texture
64	B111	758436	1679851	granule conglomerate	clastic texture
65	B121	612469	1646952	Olivine basalt	Porphyritic texture/ intergranular texture
66	B122	614662	1647135	Pyroxene basalt	Porphyritic texture/ intersertal texture
67	B124	617627	1641582	Nepherine-olivine basalt	intergranular texture
68	B126	626822	1634112	Nepherine-olivine basalt	intergranular texture
69	B129	632057	1626490	Rhyoritic tuff (Ignimbrite)	pyroclastic texture
70	B130	648144	1625972	Olivine basalt	Porphyritic texture/ intergranular texture
71	B131	658417	1625091	Olivine basalt	Porphyritic texture/ intergranular texture
72	B140	764050	1651790	Biotite schist	granoblastic texture
73	B148	628119	1635055	Olivine basalt	Porphyritic texture/ intergranular texture
74	B149	636854	1641701	Nepherine-olivine basalt	Porphyritic texture/ intergranular texture
75	B150	640622	1648295	Olivine basalt	Porphyritic texture/ intergranular texture
76	C010	758208	1655872	Amphibolite	granoblastic texture
77	A3027	740692	1636963	Cataclasite	cataclastic texture
78	A3028	740432	1636993	Hornblende biotite granodiorite	hypidiomorphic granular texture
79	A3034	741539	1635717	Hornblende biotite granodiorite	hypidiomorphic granular texture
80	A3051	741805	1637945	Biotite hornblende biotite granodiorite	hypidiomorphic granular texture
81	A3058	744415	1634280	Hornblende biotite granodiorite	hypidiomorphic granular texture
82	A3065	744915	1639592	Hornblende biotite diorite	hypidiomorphic granular texture/ cataclastic texture
83	A3083	762440	1638073	Hornblende biotite granodiorite	hypidiomorphic granular texture/ cataclastic texture
84	A3084	762550	1638333	Biotite granite	hypidiomorphic granular texture
85	A3087	762660	1638538	Lamprophyre	Porphyritic texture
86	A3090	762744	1639009	Hornblende biotite diorite	hypidiomorphic granular texture
87	A3094	762330	1639550	Hornblende biotite diorite	hypidiomorphic granular texture
88	A3095	762183	1639775	Lamprophyre	Porphyritic texture
89	A3099	762460	1638370	muscovite biotite gneiss	porphyroblastic texture
90	A117	628448	1690054	Olivine basalt	Porphyritic texture/ intergranular texture

Fragments, Xenolith or Porphyritic Minerals

Ser No	quartzite	sandstone	siltstone	mudstone	pumice	tuff	mudstone	lherzolite	pyroxenite	basaltic glass	quartz	K-feldspar	nepherine	plagioclase	muscovite	biotite/phlogopite	tremolite/amphibole	augite	olivine
61																			
62																			
63																			
64	◎	○	○	○															
65																		○	△
66																		△	
67													△	△					△
68													△	△					△
69					◎	◎						△		△	△				
70																			△
71																			△
72																			
73																		△	△
74													△						△
75																			△
76																			
77																			
78																			
79																			
80																			
81																			
82																			
83												△							
84																			
85																○			
86																			
87																			
88																○			
89																			
90																		△	△

Main Minerals, Groundmass or Matrix

Ser No	quartz	K-feldspar	plagioclase	albite	muscovite	biotite	phlogopite	hornblende/amphibole	augite/clinopyroxene	olivine	apatite	zircon	allanite	opaque minerals	glass
61	○	◎	·			○		·			·	·			
62	○	◎				○									
63	○	○	○		△	○					·	·			
64	◎														
65			◎						○	○					△
66			◎						○						○
67			◎						○	○					△
68			◎						○	○					△
69															
70			◎						○						△
71			◎						○	△					△
72	◎	○		○	○	◎									
73			◎						◎	△					△
74			◎						◎	○					△
75			◎						◎	△					△
76	◎			○		△		◎	△						
77	◎	◎	◎			△									
78	◎	◎	◎			○		△			·	·			
79	◎	◎	○			○		△			·	·	·		
80	◎	◎	○			△		○			·	·	·		
81	○	◎	○			△		○			·	·	·		
82	○	○	◎			○		△			·	·	·		
83	○	◎	○			○		○			·	·	·		
84	○	◎	◎			○					·	·	·		
85		◎	△				○		○	○	·				
86	○	○	◎			○		○			·	·	·		
87	○	○	◎			○		○			·	·	·		
88		◎	△				○				·				
89	◎	△	△		○	○					·				
90			◎						○	△					

Secondary Minerals

Ser No	quartz	biotite	muscovite	actinolite	tremolite	prehnite	pumpellyite	sericite	chlorite	epidote	carbonate	saponite	kaoline	zeolite	limonite	opaque minerals	Remarks
61								△	△								
62																	
63								△									
64								△	·								
65																	
66																	
67																	
68																	
69	△		△					△									
70								·	·					·			
71																	
72																	
73																	
74																	
75									·								
76							△		○								
77																	Cataclastic
78								○	○	△						·	Altered
79	△							○	○	△						·	Altered
80	△							◎	○	○						·	Altered
81	△							◎	○	△						·	Altered/ Cataclastic
82	△							◎	○	△	△					·	Altered/ Cataclastic
83								·	△	·						·	Cataclastic
84								·	·	·						·	
85																·	
86								·	·	·						·	Cataclastic
87								·	·	·						·	Partly Cataclastic
88									△		△					·	
89										·						·	
90															·	·	

◎: abundant, ○: common, △: a little, ·: rare

Annex 1 Microscopic Observation for Rock Thin Section (4/5)

Ser. No.	Sample No.	Coordination (UTM) E	Coordination (UTM) N	Rock Name	Texture	Fragments, Xenolith or Porphyritic Minerals: quartzite	sandstone	siltstone	mudstone	pumice	tuff	mudstone	lherzolite	pyroxenite	basaltic glass	quartz	K-feldspar	nepheline	plagioclase	muscovite	biotite/phlogopite	tremolite/amphibole	augite	olivine	Main Minerals, Groundmass or Matrix: quartz	K-feldspar	plagioclase	albite	muscovite	biotite	phlogopite	hornblende/amphibole	augite/clinopyroxene	olivine	apatite	zircon	allanite	opaque minerals	glass	Secondary Minerals: quartz	biotite	muscovite	actinolite	tremolite	prehnite	pumpellyite	sericite	chlorite	epidote	carbonate	saponite	kaoline	zeolite	limonite	opaque minerals	Remarks
91	B504	735349	1641751	muscovite schist	granoblastic texture											○									◎	△	△		○																															
92	B508	735842	1643185	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	◎	◎			○		△			·	·	·											△	○	△					·	Altered/ Cataclastic
93	B509	735830	1642992	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	○	◎			○		△			·	·	·											◎	○	△					·	Altered
94	B510	736064	1642202	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	◎	○			○		△			·	·	·											◎	△	△					·	Altered/ Cataclastic
95	B512	737976	1643311	Altered granodiorite	hypidiomorphic granular texture																				○	?	?			○		△			?	?	?			○								◎	◎	△					·	Altered/ Cataclastic
96	B514	739558	1639367	Sericite calcite rock (?)																																													◎			◎						Altered
97	B515	740800	1637132	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	△	○			○		△			·	·	·					△							△	○	△					·	Altered
98	B524	742855	1634985	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	○	◎			?		?			·	·	·											△	◎	○					·	Altered/ Cataclastic
99	B525	742952	1635212	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	?	?			?		?			?	?	·			○		○					△		△					·	Altered/ Myronitic
100	B526	742930	1635295	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	◎			○		△			·	·	·					△							△	○	○	△				·	Altered/ Myronitic
101	B527	742868	1635689	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	○	◎			○		△			·	·	·											◎	○	△					·	Altered
102	B528	742931	1636763	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	◎			○		?			·	·	·											◎	○	△					·	Altered/ Cataclastic
103	B529	743171	1637288	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	◎			○		○			·	·	·											◎	△	△					·	Altered
104	B531	745065	1636793	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	○	◎			○		?			·	·	·					△							◎	△	△					·	Altered/ Myronitic
105	B535	744152	1640144	Hornblende biotite diorite	hypidiomorphic granular texture																				○	△	○			◎		○			·	·												○	○	△					·	Altered
106	B536	744689	1639492	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	○			○		○			·	·	·					△							○	○	△	·				·	Altered
107	B539h	738892	1641559	Hornblende biotite granodiorite	hypidiomorphic granular texture																				○	◎	○			○		?			·	·	·											·	·	·					·	Cataclastic
108	B541	737896	1643332	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	○			◎		?			·	·	·					△							○	○						△	Altered/ Cataclastic
109	B546	760488	1638836	Meta granodiorite	hypidiomorphic granular texture																				◎	○	○			?		?			·	·						△			○				○	○	△	·					Metamorphosed
110	B552	744488	1638668	Biotite granite	hypidiomorphic granular texture																				◎	○	○			○		?			·	·	·											◎	○		○				·	Altered
111	B553	744529	1638574	Hornblende biotite granodiorite	hypidiomorphic granular texture																				◎	○	○			○		?			·	·	·											◎	△		△				·	Altered
112	A4046	768997	1673550	Amphibolite schist	porphyroblastic texture																		△					◎			○													◎	△												
113	B580	757777	1655421	Amphibolite schist	granoblastic texture																							○			○	◎													○											Gabbro metamorphosed
114	B582	757495	1655170	Amphibolite schist	granoblastic texture																				○			○			◎																		○	○						Basalt metamorphosed
115	B583	757123	1654960	Epidote-amphibolite schist	granoblastic texture																				○			◎			◎																		○	○	△					Basalt metamorphosed
116	B584	756818	1654800	Limestone	granular texture																									○																					◎				△	=Marble
117	B586	756475	1654910	Muscovite schist	granoblastic texture																				◎	?		○	◎																											
118	B587	756245	1654946	Biotite schist	granoblastic texture																				◎	○	△		△	○																										·	
119	B593	745037	1639663	Hornblend biotite tonalite	hypidiomorphic granular texture																				○	◎	○			○		△	?		·	·												△	○	△	○				△	Altered with pyrite
120	C523a	758344	1656016	Gabbro? (Muscovite calcite rock)																																						○									◎			◎				·	

◎: abundant, ○: common, △: a little, ·: rare

Annex 1 Microscopic Observation for Rock Thin Section (5/5)

Ser. No.	Sample No.	Coordination (UTM) E	Coordination (UTM) N	Rock Name	Texture	Remarks
121	C523b	758344	1656016	Gabbro? (Muscovite calcite rock)		
122	C533	759143	1656208	Muddy slate	schistose texture	
123	C536a	759548	1656037	Lamprophyre	porphyritic texture and ophytic texture	

Fragments, Xenolith or Porphyritic Minerals

Ser. No.	Sample No.	quartzite	sandstone	siltstone	mudstone	pumice	tuff	mudstone	lherzolite	pyroxenite	basaltic glass	quartz	K-feldspar	nepheline	plagioclase	muscovite	biotite/phlogopite	tremolite/amphibole	augite	olivine
121	C523b																			
122	C533																			
123	C536a																			

Main Minerals, Groundmass or Matrix

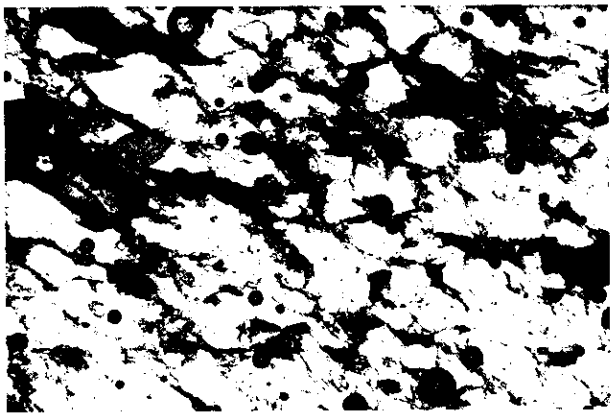
Ser. No.	Sample No.	quartz	K-feldspar	plagioclase	albite	muscovite	biotite	phlogopite	hornblende/amphibole	augite/clinopyroxene	olivine	apatite	zircon	allanite	opaque minerals	glass
121	C523b															
122	C533				◎											
123	C536a		◎		○			○								

Secondary Minerals

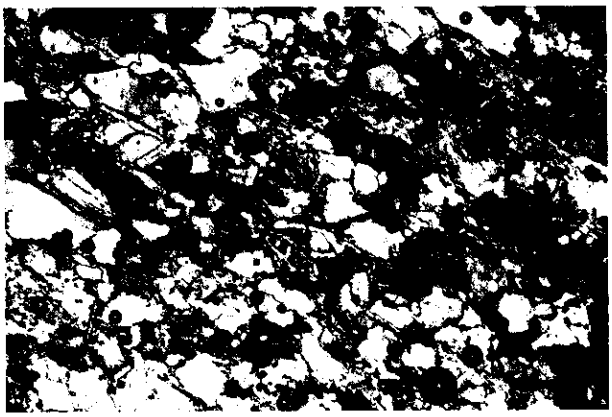
Ser. No.	Sample No.	quartz	biotite	muscovite	actinolite	tremolite	prehnite	pumpellyite	sericite	chlorite	epidote	carbonate	saponite	kaoline	zeolite	limonite	opaque minerals
121	C523b			○					◎			◎					·
122	C533	○		◎													
123	C536a	○										△					

◎: abundant, ○: common, △: a little, ·: rare

Rock Sample No: B091
Location or Coordination: (741802E, 1669469N, UTM48 WGS84)
Rock Name: Biotite gneiss
Geologic Unit: Annam Gneisses, Mp



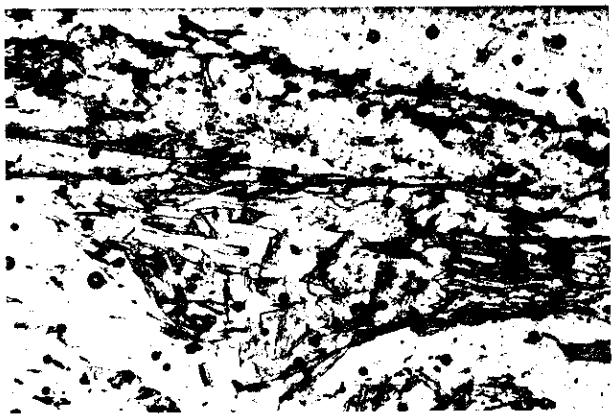
(polarizer only)



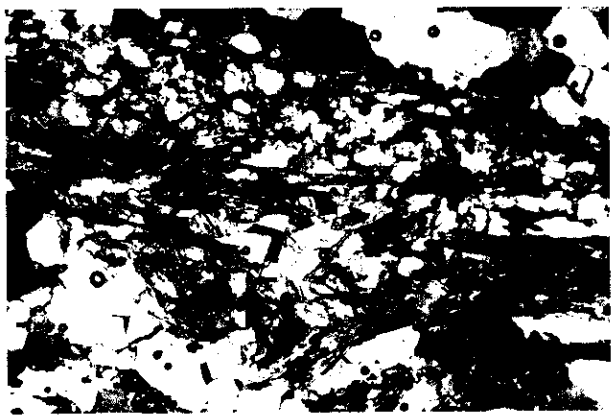
(crossed nicols)

Description in outcrop: migmatitic zone, developed many gneissose structure.
Rock Texture: The rock shows granoblastic texture. Rock forming minerals consist of quartz (Qz), plagioclase (Pl), K-feldspar (Kf), biotite (Bi) and muscovite (Mu).

Rock Sample No: A044
Location or Coordination: (766755 E, 1631598 N, UTM48 WGS84)
Rock Name: Biotite schist
Geologic Unit: May Phao Sauu Phanh Group, O_3-S



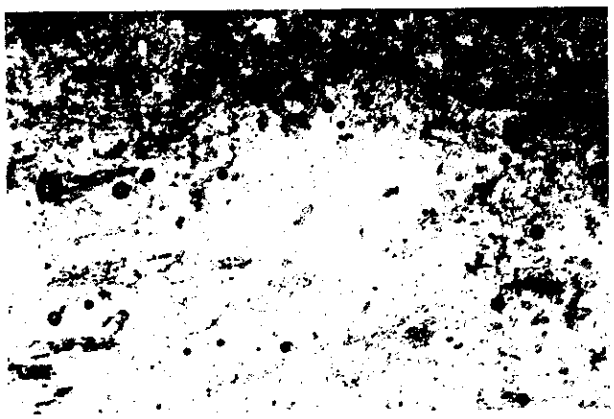
(polarizer only)



(crossed nicols)

Description in outcrop: light grey, pelitic slate
Rock Texture: The rock shows porphyroblastic texture and consists of quartz (Qz), K-feldspar (Kf), muscovite (Mu) and biotite (Bi).

Rock Sample No: B009
Location or Coordination: (736195E, 1641309N, UTM48 WGS84)
Rock Name: Muscovite schist
Geologic Unit: May Phao Sauu Phanh Group, O_3-S

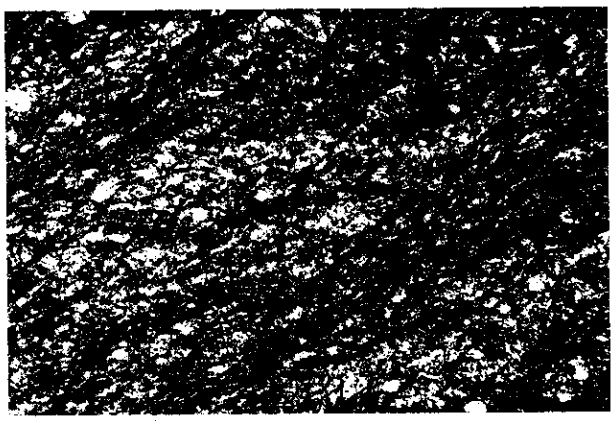


(polarizer only)

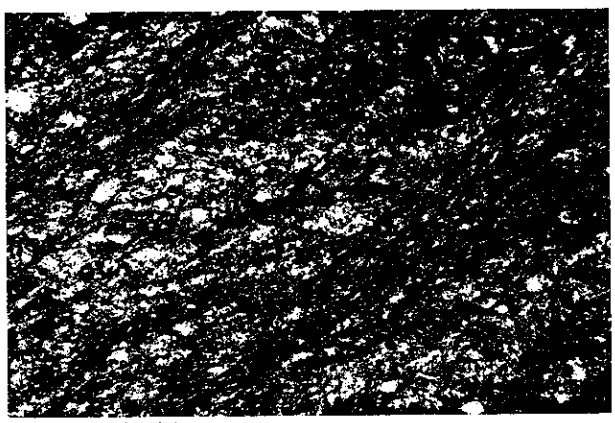
(crossed nicols)

Description in outcrop: quartz lenses included along fractures, white to light grey.
Rock Texture: The rock shows granoblastic texture and consists of quartz (Qz) and muscovite (Mu). A part of quartz shows porphyroblastic texture.

Rock Sample No: B041
Location or Coordination: (723034E, 1658881N, UTM48 WGS84)
Rock Name: Slate
Geologic Unit: May Phao Sauu Phanh Group, O_3-S



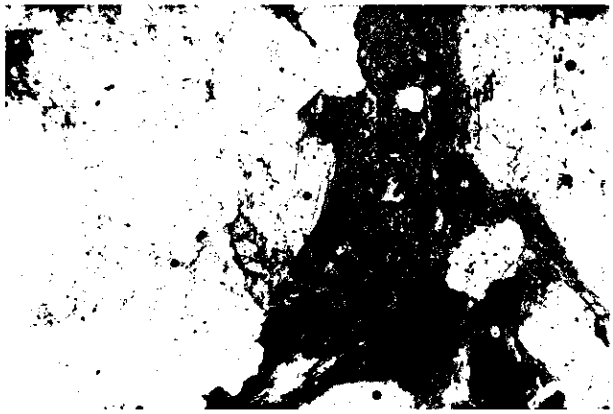
(polarizer only)



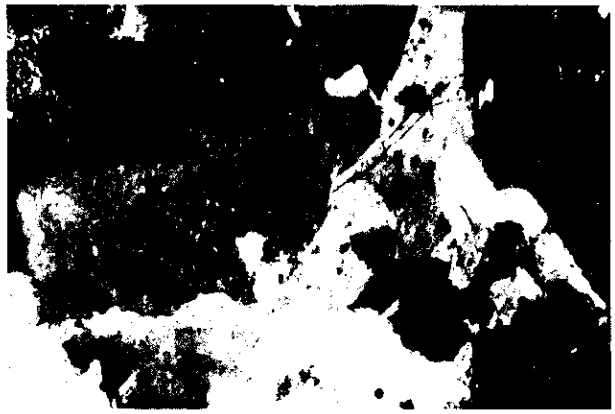
(crossed nicols)

Description in outcrop: gradually change to slate, light to pale grey.
Rock Texture: the rock shows schistose texture consisting of quartz, feldspar and sericite. The rock has been intensely deformed producing a pervasive slaty cleavage and at the same time, original fine scale bedding has been disrupted by folding.

Rock Sample No: B027
Location or Coordination: (753663E, 1640861N, UTM48 WGS84)
Rock Name: Hornblende biotite granodiorite
Geologic Unit: Xe Kaman North Granodiorites, $\gamma\delta Pz_3$ (S)



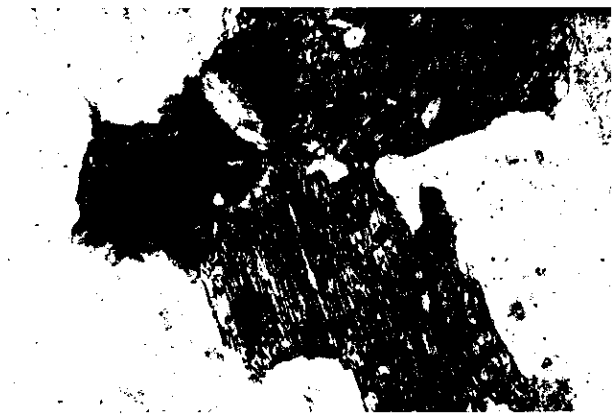
(polarizer only)



(crossed nicols)

Description in outcrop: coarse, k-feldspar porphyritic, weak foliated, magnetic susceptibility: 9.03(SI)
Rock Texture: The rock shows porphyritic texture and hypidiomorphic granular texture. Rock forming minerals are consisting mainly of quartz (Qz), K-feldspar (Kf), plagioclase (Pl) biotite (Bi) and hornblende (Ho). Accessory minerals are allanite, apatite and zircon. Porphyritic mineral is plagioclase of 4mm in size.

Rock Sample No: B081
Location or Coordination: (737580E, 1655897N, UTM48 WGS84)
Rock Name: Hornblende biotite granodiorite
Geologic Unit: Nam Ang Granodiorites, $\gamma\delta Pz_3$ (D_1)

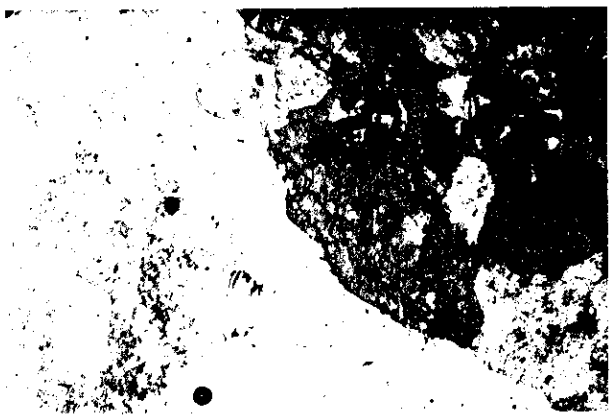


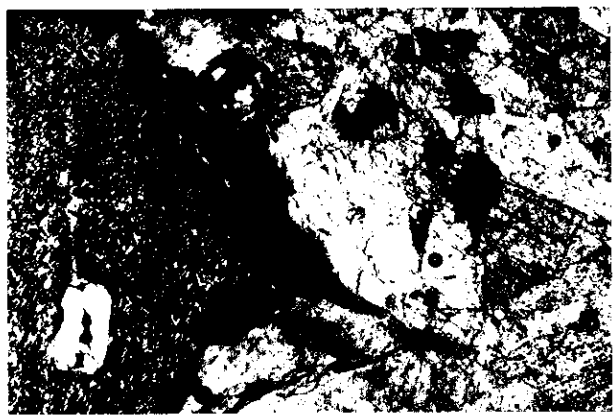
(polarizer only)

(crossed nicols)

Description in outcrop: massive, coarse grain, same as 01B292, weak epidote chlorite alteration.
Rock Texture: The rock shows porphyritic texture and hypidiomorphic granular texture. Rock forming minerals are consisting mainly of quartz (Qz), K-feldspar (Kf), plagioclase (Pl), biotite (Bi) and hornblende (Ho). Porphyritic mineral consists of plagioclase. Accessory minerals are allanite, apatite and zircon. Alteration minerals are sericite in feldspar and chlorite in biotite and hornblende.

Rock Sample No: B087
Location or Coordination: (734050E, 1666728N, UTM48 WGS84)
Rock Name: Biotite hornblende granodiorite
Geologic Unit: Nam Ang Granodiorites, $\gamma\delta Pz_3$ (D_1)


(polarizer only) 0.5mm


(crossed nicols) 0.5mm

Description in outcrop: K-feldspar porphyritic (pinkish), coarse, massive
Rock Texture: The rock shows porphyritic texture and hypidiomorphic granular texture. Rock forming minerals consist mainly of quartz (Qz), K-feldspar (Kf), plagioclase (Pl), biotite (Bi), hornblende (Ho) and opaque mineral. Accessory minerals are allanite, apatite and zircon. Alteration minerals are sericite in feldspar and chlorite in biotite and hornblende.

Rock Sample No: A021
Location or Coordination: (731737E, 1632166N, UTM48 WGS84)
Rock Name: Rhyolitic welded tuff (Ignimbrite)
Geologic Unit: Namchang Formation, T_{1-2} (Rv)


(polarizer only) 0.5mm


(crossed nicols) 0.5mm

Description in outcrop: Rhyolitic welded tuff: white green, pumice tuff with green pumice and glass elongated.
Rock Texture: The rock shows pyrolcastic and glassy textures. Porphyritic crystal fragments consist of quartz (Qz), K-feldspar (Kf) and biotite(Bi). Lithic fragments are tuff and quartzite. Matrix is composed of glass, tuff, etc. The glass materials show light brown color. Biotite and glass weakly changed to sericite of altered minerals.

Annex 3 (1/2) Result of K-Ar Dating by Activation Laboratories, Canada

Ser. No.	Sample No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Rock Name	K-Ar dating	Estimate Age	%K	$^{40}Ar_{rad}$ nl/g	% $^{40}Ar_{air}$	Age (Ma)	Age	Remarks
1	A153	769685	1636008	Two-mica GR	biotite	Permian to Triassic	5.44	68.077	1.5	301.5±7.7	Carboniferous	Loc.01A464 Xe Kaman (upstream)
2	B081	737580	1655897	Hbl.Bio.GD	biotite	Carboniferous	2.71	45.84	2.4	396.6±10.4	Devonian	Loc.01B293 Xe Kaman (middle)
3	B088	738498	1668467	Bio.Px.Hbl.DI	hornblede	Permian to Triassic	0.54	8.389	9.2	367.3±9.6	Devonian	Loc.01B316 Xe Kaman (middle)
4	B531	745065	1636793	Bio.Hbl.GD	whole rock (> hornblende)	Permian to Triassic	1.83	18.871	5.4	252.0±6.5	Permian	Loc.03B196 Area A
5	B546	760488	1638836	Bio.Hbl.GD	amphibole (> hornblende)	Permian to Triassic	n.d.***	6.429	15.1	n.d.	n.d	Loc.03B302 Area B
6	B134	740337	1640961	Mylonite	sericite (muscovite)	Permian to Triassic	4.07	46.46	3.5	277.0±7.1	Permian	Loc.01B054 Area A&D (Route 1B3)
7	B147	759162	1656212	Mylonite	whole rock (> muscovite)	Permian to Triassic	0.58	4.325	21.3	185.7±5.0	Jurassic	Loc.02B159 Army Mine
8	B044	728088	1665289	Px.BA lava	whole rock	Neogene	0.72	1.111	71.9	40.0±1.3	Tertiary	Loc.01B155 northern Xe Kaman (north of Paam)
9	C520	740800	1637132	Two-mica GR	whole rock (> muscovite)	Carboniferous	0.05	0.708	84	364.2±13.4	Devonian	Loc.04C041 Army Mine
10	C525a	758430	1656200	Meta BA	whole rock	before Carboniferous	0.15	1.624	57.9	272.1±8.1	Permian	Loc.04C046 Army Mine
11	B515	757929	1655788	Hbl.Bio.GD	biotite	Permian	1.82	18.77	18.9	251.6±6.5	Permian	Loc.03B095 Area A

The K concentration was performed by ICP.
The argon analysis was performed using the isotope dilution procedure on noble gas mass spectrometer.

Annex 3 (2/2) Result of Ar-Ar Dating by Hiruzen Institute for Geology and Chronology, Japan

Ser. No.	Sample No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Rock Name	Ar-Ar dating	Estimate Age	Age (Ma)	Age	Remarks
1	A083	747911	1632403	Hbl.Bio.GD	biotite	Permian to Triassic	248.61±25.16	Permian	82.3% of ^{39}Ar released Loc.01A270 south of Area A
2	A083	747911	1632403	Hbl.Bio.GD	hornblende	Permian to Triassic	269.35±29.75	Permian	57.7% of ^{39}Ar released Loc.01A270 south of Area A
3	B099	748590	1669280	Heterogeneous Hbl.Bio.GD	biotite	Permian to Triassic	-33.25±11.65	-	Loc.02B015 west of Ban Tat Noi
4	B099	748590	1669280	Heterogeneous Hbl.Bio.GD	hornblende	Permian to Triassic	-6.96±9.35	-	Loc.02B015 west of Ban Tat Noi

The step heating was performed by argon ion laser.
The temperatures on heating was measured using infrared temperature indicator.
The argon analysis was performed using the isotope dilution procedure on noble gas mass spectrometer.

Annex 4 Result of Rock Chemical Analysis by ALS Chemex, Australia (1/2)

Element			A037	A083	A084	A152	B019	B027	B044	B078	B081	B084	B087	B088	A3083	A3084	A3087	A3090	A3094	A3095	B099	B508
Sp. Name			Hb. gabbro	Hb.-bi. grano-diorite	Hb.-bi. grano-diorite	Bi. granite	Hb.-bi. grano-diorite	Hb.-bi. grano-diorite	Px. basalt	Bi. grano-diorite	Hb.-bi. grano-diorite	Hb.-bi. grano-diorite	Bi.-hb. grano diorite	Bi.-px.-hb. gabbro	granodiorite	granodiorite	granodiorite	granodiorite	granodiorite	granodiorite	Gneissic granite	Bi.granodiorite
Loc	E		771048	747911	748476	765978	748373	753663	728088	736022	737580	740087	734050	738498	762440	762550	762660	762744	762330	762183	748590	735842
	N		1627825	1632403	1632725	1638698	1639578	1640861	1665289	1654653	1655897	1661080	1666728	1668467	1638073	1638333	1638538	1639009	1639550	1639775	1669280	1643185
Major element	SiO2	%	48.40	61.80	58.20	74.40	68.40	64.90	52.80	76.60	66.80	65.60	68.20	51.10	63.10	57.60	52.10	59.50	55.10	59.50	67.10	65.10
	TiO2		0.30	0.48	0.66	0.16	0.51	0.62	1.64	0.10	0.61	0.54	0.54	1.48	0.80	1.28	1.12	0.93	2.09	0.81	0.68	0.51
	Al2O3		13.35	16.75	16.80	13.90	14.50	16.10	14.55	12.35	15.15	15.60	14.70	16.60	16.15	17.40	12.95	17.40	16.20	13.00	14.00	16.35
	Fe2O3		6.63	5.82	7.65	1.52	3.85	4.49	11.20	1.86	4.43	4.60	4.14	11.05	5.20	6.41	7.91	5.76	7.76	5.11	4.41	4.37
	MnO		0.12	0.12	0.13	0.02	0.07	0.07	0.14	0.02	0.07	0.08	0.07	0.12	0.10	0.10	0.14	0.10	0.13	0.07	0.06	0.12
	MgO		13.10	2.03	3.48	0.46	1.13	1.56	6.32	0.08	1.24	1.83	1.12	4.32	1.99	2.92	9.43	2.24	3.60	3.97	2.12	2.30
	CaO		14.95	5.65	5.89	1.94	2.79	3.69	8.75	0.26	3.11	4.32	2.51	8.87	3.13	4.52	5.64	4.06	6.06	4.22	1.91	2.12
	Na2O		0.95	3.32	2.99	3.35	3.35	3.27	2.94	3.27	3.84	3.75	3.56	3.36	2.92	3.08	1.34	3.07	3.09	2.01	3.29	5.25
	K2O		0.10	1.78	1.57	3.81	4.06	4.30	0.89	5.02	3.32	2.37	3.82	1.11	5.12	4.66	6.58	5.39	3.61	6.22	3.35	1.64
	P2O5		0.02	0.24	0.14	0.07	0.14	0.21	0.26	0.02	0.16	0.14	0.16	0.78	0.35	0.64	0.63	0.34	1.00	0.42	0.14	0.11
	Cr2O3		0.12	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.05	<0.01	<0.01	0.02	0.01	<0.01
	LOI		2.01	1.91	2.44	0.36	0.92	0.50	0.38	0.44	1.13	1.04	1.02	1.01	0.82	1.05	1.64	0.80	1.08	4.23	2.52	2.04
	Total		100.05	99.90	99.95	99.99	99.72	99.71	99.89	100.02	99.86	99.87	99.84	99.81	99.68	99.66	99.53	99.59	99.72	99.58	99.59	99.91
Trace element	Rb	ppm	1.0	43.8	51.1	122.5	157.0	202.0	18.2	276.0	159.5	86.7	107.0	42.0	292.0	305.0	401.0	334.0	192.0	390.0	141.0	59.7
	Ba		5	744	616	849	1225	1015	203	140	1115	596	857	320	1240	1640	1920	1655	1000	1910	820	464
	Zr		12	130	106	177	256	251	111	81	378	249	303	64	455	380	509	562	363	448	230	85
	Y		8.1	14.4	24.0	7.3	23.0	23.2	20.1	37.4	43.4	30.5	35.3	30.3	40.5	30.9	25.7	37.3	39.0	21.6	23.7	8.9
	Cs		0.13	0.76	1.02	3.47	2.93	5.58	0.65	4.75	2.85	1.41	1.26	1.56	7.94	10.4	14.45	11.15	9.57	12	3.52	2.48
	Ta		0.2	0.4	0.3	0.8	0.9	0.9	1.2	3.4	1.9	1.1	0.7	1.0	1.8	1.2	0.9	1.0	1.6	1.4	1.1	0.2
	U		0.06	0.91	1.38	2.89	5.34	6.58	0.65	14.30	7.16	4.39	2.44	2.40	12.70	7.70	3.81	5.80	6.80	11.60	4.30	1.67
	Sr		74.4	648	522	411	205	277	361	37.1	257	258	239	491	368	568	564	495	462	485	149.5	395
	V		185	98	220	34	67	81	172	16	69	91	70	369	92	220	199	116	241	106	86	115
	Nb		2	4.8	4.4	7.1	11.7	14.9	19.5	18.1	13.7	11	11.5	15	23.9	22.1	17.6	23.2	24.7	22.2	15.2	3.5
	Hf		0.4	3.4	3.2	4.7	6.5	6.7	3.0	3.5	9.1	6.0	7.4	1.9	12.4	10.2	14.0	15.0	9.3	12.8	5.9	2.5
	Pb		<5	11	9	20	25	30	<5	42	30	16	20	11	34	29	26	34	30	38	24	12
	Th		0.26	5.10	8.06	9.54	22.40	35.70	2.87	35.30	12.75	16.25	14.15	5.42	58.70	38.70	30.10	34.90	28.10	64.10	16.20	6.59
	Ni		175	11	17	9	11	15	138	5	14	27	12	101	8	7	223	10	8	105	27	16
	La		2.0	23.5	24.9	19.5	47.0	70.8	16.5	26.4	43.9	45.4	59.6	39.1	79.8	68.7	63.6	70.6	67.2	76.7	34.0	19.3
	Ce		3.7	40.7	49.9	31.5	81.6	125.5	30.6	52.0	79.6	77.5	103.0	76.4	157.5	140.5	143.0	140.0	142.5	155.0	66.6	36.7
	Pr		0.43	3.97	5.42	2.98	7.90	12.80	3.58	5.43	8.70	8.15	10.40	8.95	16.85	15.60	16.60	15.45	16.15	16.90	6.96	3.89
	Nd		2.2	14.5	20.8	9.7	26.2	43.8	15.0	18.1	31.5	27.3	35.5	34.3	63.3	60.9	68.9	62.1	63.3	65.0	26.4	14.9
	Sm		0.78	2.77	4.29	1.51	4.45	7.19	3.87	4.17	6.24	5.16	6.30	6.49	10.50	9.81	12.60	11.75	10.95	10.90	4.92	2.58
	Eu		0.35	0.96	1.09	0.94	1.16	1.65	1.50	0.29	1.47	1.18	1.28	1.33	1.80	2.24	2.78	2.14	2.26	2.36	0.94	0.63
	Gd		1.04	2.73	4.24	1.47	4.35	6.36	4.32	4.24	6.46	5.17	6.52	6.53	9.24	8.68	9.88	10.30	9.91	8.53	5.06	2.35
	Tb		0.21	0.43	0.69	0.22	0.66	0.91	0.76	0.85	1.20	0.90	1.09	1.00	1.40	1.23	1.28	1.58	1.46	1.07	0.83	0.33
	Dy		1.40	2.33	3.85	1.13	3.58	4.16	3.86	4.93	6.81	4.85	5.95	5.30	6.75	5.50	5.10	7.46	6.77	4.25	4.14	1.52
	Ho		0.30	0.48	0.81	0.23	0.74	0.79	0.70	1.04	1.41	0.99	1.18	1.05	1.37	1.08	0.90	1.42	1.36	0.75	0.85	0.30
	Er		0.83	1.46	2.46	0.70	2.38	2.33	1.97	3.66	4.61	3.13	3.62	2.96	4.10	3.08	2.41	3.68	3.96	2.03	2.43	0.88
	Tm		0.11	0.21	0.33	0.10	0.34	0.30	0.23	0.59	0.68	0.43	0.48	0.38	0.57	0.43	0.31	0.46	0.55	0.29	0.36	0.13
	Yb		0.76	1.48	2.35	0.75	2.39	2.03	1.47	4.31	4.84	2.91	3.14	2.59	4.13	2.97	2.06	2.96	3.72	1.92	2.50	0.89
	Lu		0.11	0.23	0.36	0.12	0.38	0.30	0.21	0.69	0.78	0.45	0.45	0.39	0.57	0.42	0.28	0.39	0.52	0.27	0.35	0.13
	ΣREE		14.2	95.8	121.5	70.9	183.1	278.9	84.6	126.7	198.2	183.5	238.5	186.8	357.9	321.1	329.7	330.3	330.6	346.0	156.3	84.5
	ΣREE +Y		22.3	110.2	145.5	78.2	206.1	302.1	104.7	164.1	241.6	214.0	273.8	217.1	398.4	352.0	355.4	367.6	369.6	367.6	180.0	93.4

Annex 4 Result of Rock Chemical Analysis by ALS Chemex, Australia (2/2)

Element	Sp. Name		B510 Bi.-hb. granodiorite	B515 Hb.-bi. granodiorite	B524 Hb.Qz.diorite	B525 Hb.Qz.diorite	B526 (Bi.)Hb.Qz. diorite	B527 Bi.-hb. granodiorite	B528 Bi.-hb. granodiorite	B531 Bi.-hb. granodiorite	B536 Bi.hb.Qz. diorite	B541 Bi.-hb. granodiorite	B546 Bi.-hb. granodiorite	A4052 Pisolotic laterite	B553 Bio.-hbl granodiorite	C520 Two-mica granite?	C525a Px.Basalt
Loc	E		736064	740800	742855	742952	742930	742868	742931	745065	744689	737896	760488	734184	744529	758430	757929
	N		1642202	1637132	1634985	1635212	1635295	1635689	1636763	1636793	1639492	1643332	1638836	1641707	1638574	1656200	1655788
Major element	SiO2	%	64.60	63.40	65.50	64.80	66.80	64.80	64.60	65.10	58.10	62.70	45.90	21.20	61.40	42.30	61.70
	TiO2		0.49	0.54	0.49	0.48	0.44	0.47	0.55	0.51	0.72	0.45	0.11	0.91	0.70	0.03	0.91
	Al2O3		15.75	16.00	16.05	16.05	13.40	16.05	16.15	15.70	16.90	14.75	17.85	16.40	15.90	1.44	14.35
	Fe2O3		4.50	4.78	4.38	4.38	3.37	4.38	4.47	4.22	6.40	3.60	5.08	51.60	6.57	6.77	11.15
	MnO		0.09	0.10	0.08	0.13	0.11	0.07	0.07	0.06	0.11	0.09	0.09	0.01	0.10	0.60	0.17
	MgO		2.17	2.54	2.20	1.98	1.33	1.90	2.20	2.07	3.43	2.09	11.95	0.15	3.02	22.60	1.90
	CaO		4.23	3.91	2.73	3.68	5.17	4.82	2.06	2.22	6.95	4.57	15.15	0.08	4.52	0.65	2.97
	Na2O		3.03	4.83	3.86	3.37	3.95	3.11	4.19	4.99	1.74	3.72	0.75	0.04	2.88	0.02	5.23
	K2O		3.00	1.72	2.29	2.46	1.48	2.12	3.31	2.16	3.25	2.60	0.08	0.61	1.91	0.04	0.16
	P2O5		0.12	0.17	0.16	0.16	0.12	0.15	0.17	0.17	0.13	0.12	<0.01	0.21	0.15	0.02	0.09
	Cr2O3		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	0.08	<0.01	0.26	<0.01
	LOI		1.68	1.75	2.10	2.47	3.63	2.11	1.97	2.71	2.22	5.17	2.77	8.61	2.73	25.06	1.28
	Total		99.66	99.74	99.84	99.96	99.80	99.98	99.74	99.91	99.95	99.86	99.84	99.90	99.88	99.53	99.91
Trace element	Rb	ppm	86.4	71.5	64.8	43.2	43.2	62.8	82.7	67.0	111.0	87.0	3.2	29.4	64.0	1.5	11.0
	Ba		775	696	769	654	387	730	896	529	774	766	10.7	163	523	191	68.5
	Zr		108	83	86	119	81	107	90	106	112	100	4	315	116	3	45
	Y		9.2	8.9	10.1	11.1	8.2	9.5	10.3	9.1	21.6	6.5	3.5	24.0	20.7	1.7	31.7
	Cs		4.13	1.96	1.72	1.38	1.31	1.36	1.91	1.25	1.9	3.61	0.47	3.2	1.32	0.57	2.15
	Ta		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	<0.1	1.8	0.2	<0.1	<0.1
	U		1.82	1.43	1.37	1.49	1.39	1.30	1.95	1.55	1.60	1.62	<0.05	3.42	1.61	0.14	0.27
	Sr		526	465	509	549	361	593	506	267	314	235	87.1	31.8	465	7.6	68
	V		120	112	111	128	104	112	121	119	186	99	105	513	159	18	120
	Nb		3.5	3.5	3.5	3.7	3.2	3.6	3.7	3.9	3.4	3.9	<0.2	24	4.9	0.5	0.5
	Hf		3.3	2.4	2.5	3.4	2.2	3.0	2.8	3.0	3.3	2.9	<0.2	9.1	3.4	0.2	1.9
	Pb		10	36	14	14	20	15	12	7	13	8	<5	53	21	13	13
	Th		8.28	6.50	6.43	6.55	6.13	6.48	7.07	6.24	6.46	8.41	0.06	64.40	7.82	0.78	0.72
	Ni		11	6	13	13	7	7	8	12	16	8	242	16	26	1260	21
	La		20.8	18.9	21.3	22.8	18.4	23.1	24.2	19.3	18.0	11.1	1.6	46.5	22.8	17.7	5.4
	Ce		39.7	36.1	37.9	42.8	34.6	42.2	46.9	38.9	38.1	20.0	1.1	81.1	48.1	21.7	10.6
	Pr		4.09	3.95	4.22	4.66	3.73	4.40	5.09	4.18	4.22	2.20	0.19	7.86	5.36	1.82	1.19
	Nd		15.5	15.4	16.4	17.9	14.5	17.1	19.8	16.5	17.7	8.5	0.7	26.3	20.6	5.3	6.1
	Sm		2.67	2.75	2.74	3.14	2.44	2.87	3.46	2.98	3.90	1.58	0.25	4.52	4.16	0.56	2.33
	Eu		0.67	0.67	0.64	0.78	0.52	0.72	0.82	0.71	0.75	0.33	0.12	0.86	0.98	0.20	0.76
	Gd		2.45	2.45	2.52	2.71	2.16	2.55	2.88	2.57	3.87	1.36	0.42	4.35	3.98	0.67	3.41
	Tb		0.35	0.34	0.37	0.40	0.29	0.36	0.39	0.35	0.67	0.22	0.10	0.72	0.67	0.08	0.78
	Dy		1.58	1.47	1.73	1.85	1.39	1.64	1.78	1.54	3.48	1.08	0.58	3.82	3.37	0.27	4.70
	Ho		0.32	0.30	0.34	0.37	0.28	0.33	0.35	0.32	0.72	0.22	0.12	0.85	0.75	0.06	1.19
	Er		0.88	0.87	1.01	1.08	0.83	0.93	1.04	0.90	2.10	0.64	0.36	2.60	2.06	0.17	3.46
	Tm		0.14	0.14	0.14	0.16	0.13	0.14	0.16	0.12	0.31	0.11	0.06	0.40	0.31	0.04	0.56
	Yb		0.99	0.91	1.03	1.12	0.85	1.00	1.00	0.83	2.13	0.79	0.36	2.72	1.91	0.14	3.55
	Lu		0.15	0.13	0.15	0.17	0.13	0.15	0.14	0.12	0.29	0.12	0.05	0.45	0.31	0.03	0.60
	ΣREE		90.3	84.4	90.5	99.9	80.3	97.5	108.0	89.3	96.2	48.3	6.0	183.1	115.4	48.7	44.6
	ΣREE +Y		99.5	93.3	100.6	111.0	88.5	107.0	118.3	98.4	117.8	54.8	9.5	207.1	136.1	50.4	76.3

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (1/6)

Code	Sample	Location	Coordinate (UTM)		Description for mineralization	Concentration (ppm)							%		
	No.	No.	EW	NS		Ag	Au	Cu	Pb	Zn	Mn	Ni	Fe	Sn	TiO2
1	A050	01A132	762440	1636338	mineralized block in slate	n.d.	n.d.	43.7	31.3	19.4	188	- -	2.11	- -	- -
2	A080	01A267	743521	1630963	pyrite dissemination with quartz vein in pale green, granodiorite	n.d.	n.d.	n.d.	50.7	31.8	257	- -	3.67	- -	- -
3	A081	01A265	743521	1630963	pyrite dissemination with quartz vein in pale green, granodiorite	n.d.	n.d.	481	61.3	59.7	0.544%	- -	14.7	- -	- -
4	A104	01A332	752752	1636350	weak dissemination of chalcopyrite and pyrite in grey, porphyry	n.d.	n.d.	10.5	43.8	28.3	389	- -	1.65	- -	- -
5	A147	01A434	768558	1629141	malachite films in greenish grey, argillized gabbro with serpentine and talc	n.d.	n.d.	36.7	146	30.2	577	- -	3.30	- -	- -
6	B031	01B105	761128	1638824	quartz vein (w:5m) with green copper in muscovite schist	n.d.	n.d.	17.1	38.2	<15	634	- -	0.480	- -	- -
7	B032	01B106	761256	1638444	quartz vein and pyrite dissemination (strong) in muscovite schist in shear zone (w:4m, brittle to ductile)	n.d.	n.d.	105	49.4	19.9	167	- -	5.78	- -	- -
8	B033a	01B108	761748	1637343	quartz vein and pyrite dissemination (strong) in slate in shear zone (w:15m, brittle)	n.d.	n.d.	49.0	34.5	<15	72	- -	6.55	- -	- -
9	B033b	01B108	761748	1637343	quartz vein and pyrite dissemination (strong) in slate in shear zone (w:16m, brittle)	39.6	n.d.	29.4	21.4	21.3	192	- -	3.75	- -	- -
10	B034a	01B110	762011	1636821	quartz vein and pyrite dissemination (strong) in slate, in shear zone (w:80m, brittle)	n.d.	n.d.	158	34.5	47.2	151	- -	15.9	- -	- -
11	B034b	01B110	762011	1636821	quartz vein and pyrite dissemination (strong) in slate, in shear zone (w:81m, brittle)	n.d.	n.d.	289	26.3	24.8	177	- -	3.48	- -	- -
12	B074	01B265	712959	1696327	quartz vein in quartz arenite medium grain, massive	n.d.	n.d.	4.66	24.5	26.1	5.54	- -	1.59	- -	- -
13	B078	01B276	736022	1654653	quartz vein in biotite granodiorite massive, coarse grain, cover by conglomerate, quartz sandstone, weathered	n.d.	n.d.	36.2	34.5	<15	33.4	- -	0.820	- -	- -
14	B090	01B321	740863	1668883	quartz vein in sandy schist/ granite migmatitic, many micro folding including, granite: two mica, schist: biotite including	n.d.	n.d.	5.35	222	22.5	112	- -	1.21	- -	- -
15	S001	02B035	758371	1679507	stream sediments near outcrop of light grey to light reddish grey, quartz network developed (w:1 to 5cm).	n.d.	n.d.	1.19	69.4	<15	72.0	- -	0.490	- -	- -
16	A148	01A438	767982	1629128	malachite films in sheared zone of reddish brown, strongly argillized, isotropic gabbro, sheared	n.d.	n.d.	256	441	851	235	37.3	235	- -	- -
17	A161	02A004	761657	1670850	quartz veins (W:10 cm, N60W40N) in muddy slate	n.d.	157	12.4	2280	29.5	673	8.59	673	- -	- -
18	A178	02A039	763031	1664011	quartz vein in white, quartzite, hard and compact, mineralized rocks from exploration pit	0.98	n.d.	< 7	n.d.	n.d.	6.2	n.d.	6.2	- -	- -
19	A179	02A041	763005	1663798	quartz vein in grey, muddy slate in gallery of old mine	2.56	n.d.	20.3	< 45	105	20.4	10.6	20.4	- -	- -
20	A186	02A078	762416	1630474	quartz veins (W20 - 30 cm, L: 30m, N45W65W) in grey, biotite - hornblende gneiss	n.d.	n.d.	7.99	< 45	18.6	137	10.7	137	- -	- -
21	A232	02A245	727175	1679780	pyrite dissemination and quartz vein in bluish grey, biotite schist to green schist	n.d.	n.d.	131	79.7	24.4	2050	102	2050	- -	- -
22	B105	02B035	758371	1679507	quartz network dev(w:1 to 5cm) in quartzite light grey to light reddish grey	n.d.	n.d.	8.55	n.d.	40.6	33.4	20.8	33.4	- -	- -
23	B135	02B138	761229	1650684	quartz vein in muscovite schist mylonitic, quartz crystal orientated, light grey, strong weathered	n.d.	n.d.	< 7	n.d.	68.6	67.0	13.1	67.0	- -	- -
24	C007	02C022	758774	1650097	bounding quartz vein (L:approximatel .5m, W: approximate 5cm) along schistosity, grey -light brown in weathered slate?, reddish purple- light brown	n.d.	n.d.	16.6	n.d.	< 15	293	19.1	293	- -	- -
25	C010	02C027	758208	1655872	pyrite dissemination in basalt, dark green -dark grey, massive	n.d.	n.d.	362	< 45	49.5	563	39.9	563	- -	- -
26	C023	02C080	748756	1679229	pyrite dissemination in week weathered very fine to fine sandstone, well bedded, light green -pale green, including fractured zone (W:5cm)	n.d.	n.d.	44.7	< 45	126	46.3	39.8	46.3	- -	- -
27	P0733a	-	759006	1651315	quartz veins in muscovite schist in Gold mine	< 0.5	n.d.	397	n.d.	33.8	94.4	38.1	94.4	- -	- -
28	P0733d	-	759006	1651315	quartz veins in muscovite schist in Gold mine	< 0.5	n.d.	94.3	n.d.	n.d.	59.5	17.4	59.5	- -	- -
29	P0733e	-	759006	1651315	quartz veins in muscovite schist in Gold mine	n.d.	n.d.	11.3	n.d.	26.3	132	16.2	132	- -	- -
30	P0733f	-	759006	1651315	quartz veins in muscovite schist in Gold mine	47.6	28.4	3160	50.5	23.5	63.2	63.7	63.2	- -	- -

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (2/6)

Code	Sample No.	Location No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Description for mineralization	Concentration (ppm) Ag	Au	Cu	Pb	Zn	Mn	Ni	% Fe	Sn	TiO2
31	P0746a	-	758800	1657530	quartz veins in muddy and sandy schist in Gold mine	1.04	n.d..	26.9	< 45	46.9	28.7	11.7	28.7	- -	- -
32	P0747	-	758830	1657570	quartz veins in muddy and sandy schist in Gold mine	93.4	< 2.5	100	53.9	21.9	74.1	31.4	74.1	- -	- -
33	P0748b	-	758300	1657180	quartz veins in muddy and sandy schist in Gold mine	1.43	n.d..	23.3	n.d..	< 15	716	15.2	716	- -	- -
34	P0753	-	758300	1657180	quartz veins in muddy and sandy schist in Gold mine	1[illegible]	< 2.5	944	77.6	58.4	479	83.6	479	- -	- -
35	A259	02A364	765865	1632578	quartz veins and pyrite dissemination in muddy and sandy schist (N35W85E)	n.d..	n.d..	84.4	n.d..	83.1	176	58.6	176	- -	- -
36	A260	02A365	765865	1632578	quartz veins and pyrite dissemination in muddy and sandy schist (N35W86E)	n.d..	n.d..	29.2	n.d..	59.2	77.2	27.6	77.2	- -	- -
37	B137	02B143	764001	1650696	pyrite dissemination in garnet gneiss banded, there are strong sulphides ore as floats in stream	n.d..	n.d..	264	< 45	33.2	113	121	113	- -	- -
38	B138	02B145	764035	1651007	pyrite dissemination in garnet gneiss banded, there are strong sulphides meta- sandstone, as floats in stream	n.d..	n.d..	81.9	n.d..	16.8	45.3	45.9	45.3	- -	- -
39	B139	02B149	764079	1651645	quartz vein with pyrite dissemination in biotite gneiss with pyrite dissemination, quartz lenses, banded structure and quartz lenses is concordant	n.d..	n.d..	247	< 45	161	591	14.1	591	- -	- -
40	B141a	02B152	759036	1656418	muscovite schist Gold Mine, with quartz vein (w;80cm), can't observe sulphides, with shearing	n.d..	n.d..	12.0	n.d..	n.d..	20.2	n.d..	20.2	- -	- -
41	B141b	02B152	759036	1656418	quartz vein (w:81cm), can't observe sulphides, with shearing in muscovite schist in Gold Mine	n.d..	n.d..	< 7	n.d..	n.d..	21.4	n.d..	21.4	- -	- -
42	B143	02B153	759036	1656418	quartz vein (w:82cm), can't observe sulphides, with shearing in muscovite schist in Gold Mine	n.d..	n.d..	204	n.d..	22.4	690	14.5	690	- -	- -
43	B144	02B151	759014	1656444	quartz vein (w:140cm), can't observe sulphides in Gold Mine	n.d..	n.d..	16.8	n.d..	n.d..	204	n.d..	204	- -	- -
44	B145	02B157	759150	16561100	quartz vein with barite(w:15cm) in muscovite schist	n.d..	n.d..	9.2	n.d..	n.d..	50.8	n.d..	50.8	- -	- -
45	A3002	03A021	734910	1641167	quartz vein (W: 30cm, N45W90) in slate with sericite and limonite.	n.d.	n.d.	38.5	<45	171.9	1.74%	<30	12.5	<0.05	<0.05
46	A3003	03A025	735162	1639415	quartz, φav:10cm, φmx:20cm in breccia to conglomerate with fragments	n.d.	n.d.	54.5	<45	150.7	0.22%	53.7	11.9	<0.05	0.23
47	A3004b	03A053	733749	1640827	quartz vein (W:40cm, 10cm, N40W90) in muddy, slate with sericite	n.d.	n.d.	68.3	<45	21.9	142	<30	1.19	<0.05	0.49
48	A3005	03A058	733930	1641144	muddy, slate with sericite quartz vein (W:50cm,, N30W90)	n.d.	n.d.	81.2	85.2	17.7	119	<30	1.08	<0.05	0.11
49	A3007	03A061	737611	1642836	pyrite dissemination in biotite-hornblende granodiorite with alteration of sericite, epidote and chlorite	n.d.	n.d.	13.2	<45	29.8	112	<30	1.46	<0.05	0.17
50	A3009	03A065	737030	1642588	vein (W:40cm, N65W90) in biotite-hornblende granodiorite quartz with sheared zone between granodiorite and biotite schist	n.d.	n.d.	30.7	<45	116.1	238	<30	3.63	<0.05	0.12
51	A3010	03A068	736921	1642442	quartz vein in biotite-hornblende granodiorite with malachite films along the fractures	n.d.	n.d.	0.304%	<45	214.6	796	<30	5.46	<0.05	0.58
52	A3011	03A077	737020	1641497	malachite films in biotite-hornblende granodiorite	n.d.	n.d.	529	<45	77.7	558	<30	2.61	<0.05	0.58
53	A3019b	03A105	740130	1638676	quartz veins (Width:20cm, N80W75N) in biotite-hornblende granodiorite, medium grained, epidote-chlorite, sheared	n.d.	n.d.	32.7	<45	44.5	378	<30	1.92	<0.05	0.43
54	A3023	03A114	740690	1638899	quartz veins (W:1-2cm, malachite along fractures in biotite-hornblende granodiorite, epidote-chlorite, sheared (N45W25E)	n.d.	n.d.	2.40%	<45	25.7	376	32.0	1.28	n.d.	0.36
55	A3024	03A114	740690	1638899	quartz veins (W:1-2cm, malachite along fractures in biotite-hornblende granodiorite, epidote-chlorite, sheared. N45W25E	n.d.	n.d.	453	<45	63.6	782	<30	2.04	n.d.	0.73
56	A3036	03A163	741682	1634523	quartz vein (Width:2.5m, NS90)	n.d.	n.d.	12.8	<45	<15	73.7	<30	0.57	n.d.	0.22
57	A3037	03A169	740860	1634791	quartz vein width:3m+, N30W70W, in silicified breccia, in sheared granodiorite.	n.d.	n.d.	25.9	55.8	<15	33.0	<30	0.43	n.d.	0.18
58	A3041	03A174	740439	1634886	quartz vein and silicified breccia (Width:2m, N80W70S) in granodiorite	n.d.	n.d.	86.3	<45	<15	114	<30	1.09	n.d.	0.26
59	A3042	03A177	740397	1634954	quartz vein and silicified breccia (Width:3-2cm, N40W70N) in sheared granodiorite	n.d.	n.d.	51.7	<45	<15	182	<30	0.41	n.d.	0.19
60	A3044	03A185	739710	1635828	quartz vein (N30W70W) and sheared slate in mylonite of granite	n.d.	n.d.	130	<45	127.3	1.11%	<30	10.4	n.d.	0.51

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (3/6)

Code	Sample No.	Location No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Description for mineralization	Concentration (ppm) Ag	Au	Cu	Pb	Zn	Mn	Ni	% Fe	Sn	TiO2
61	A3045	03A186	739695	1635955	quartz veins and many pyrite vein and films, N45W90 in Trench with sheared slate	n.d.	n.d.	85.0	0.109%	62.5	155	<30	3.52	n.d.	0.51
62	A3046	03A188	739638	1636180	quartz veins and many pyrite vein and films, N30W80W, in Trench with sheared slate	n.d.	n.d.	290	<45	31.3	20.2	<30	4.26	n.d.	0.39
63	A3048	03A198	738716	1636956	mylonite of granite (N60W65N)	n.d.	n.d.	18.1	<45	26.6	41.5	<30	1.39	n.d.	0.45
64	A3061	03A249	743762	1636167	quartz vein with malachite, covelline, gold?, width, 1.5m to 2m, length: more than 30m, direction, N40E65S	n.d.	n.d.	0.358%	59.0	<15	181	<30	1.38	n.d.	0.64
65	A3070	03A285	734130	1644622	quartz vein in quartz floats in hornblende-biotite granodiorite, medium grained, epidote>chlorite in hill ridge	n.d.	n.d.	97.7	<45	18.1	72.1	<30	1.45	n.d.	0.26
66	A3072	03A289	741221	1633607	quartz veins in pale grey, sheared, muscovite schist with quartz veins, chlorite, including fragments of fine sandstone	n.d.	n.d.	13.5	<45	80.1	0.52%	<30	5.02	n.d.	0.48
67	A3073	03A299	762458	1636246	quartz lenses and pyrite dissemination in turbidites of very fine sandstone, siltstone and mudstone	n.d.	n.d.	21.5	<45	15.6	121.8	<30	1.85	n.d.	0.35
68	A3074	03A300	762390	1636275	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	n.d.	n.d.	6.8	<45	<15	51.2	<30	1.25	n.d.	0.46
69	A3075	03A301	762400	1636316	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	n.d.	n.d.	60.9	<45	<15	86.5	<30	3.78	n.d.	0.60
70	A3076	03A299	762400	1636316	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	n.d.	n.d.	240	<45	<15	144	<30	10.6	n.d.	0.44
71	A3077	03A300	762400	1636316	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	n.d.	n.d.	29.4	<45	<15	201	<30	1.83	n.d.	0.65
72	A3078	03A301	762350	1636580	quartz veins (W:1m, N30E 8-W) in biotite-muscovite schist	n.d.	n.d.	20.7	<45	<15	151	<30	0.44	n.d.	0.66
73	A3079	03A308	762852	1637392	quartz veins (W:1m, N30E 8-W) in biotite-muscovite schist	n.d.	n.d.	16.0	87.9	20.0	31.7	<30	3.04	0.0	0.59
74	A3080	03A308	762852	1637392	quartz veins (W:1m, N30E 8-W) and pyrite dissemination in biotite-muscovite schist	n.d.	n.d.	19.4	52.6	99.5	87.1	<30	1.26	n.d.	0.52
75	A3091	03A324	762627	1639152	pyrite dissemination and quartz veins with pyrite in heterogeneous, hornblende - biotite granodiorite, many biotite segregated, medium to coarse grained	n.d.	n.d.	322	<45	32.7	83.1	97.7	7.58	<0.05	0.08
76	A3099	03A337	762460	1638370	float of mylonite of granodiorite with pyrite dissemination	n.d.	n.d.	57.6	<45	<15	77.7	<30	2.46	n.d.	0.75
77	A3102	03A348	763083	1637460	quartz vein in turbidites of medium to fine sandstone with pyrite dissemination	n.d.	n.d.	26.1	<45	<15	21.4	<30	0.52	<0.05	0.07
78	A3107	03A373	741709	1636747	network quartz vein (1 - 2mm) in hornblende-biotite granodiorite, moderate chlorite	n.d.	n.d.	27.6	<45	35.7	549	<30	1.61	n.d.	0.41
79	A3111b	03A398	741278	1638767	pyrite dissemination in pale green, cataclasite of granodiorite, sheared, chlorite, very few pyrite dissemination and biotite andesite dyke (NS85W)	n.d.	n.d.	13.2	<45	26.8	925	<30	1.59	0.68	0.44
80	A3115	03A403	741062	1639180	quartz vein (W:3cm, N30E85N) in hornblende-biotite granodiorite, chlorite>>epidote, weak sheared	n.d.	n.d.	46.0	<45	49.6	727	<30	2.31	<0.05	0.26
81	B501	03B001	735303	1640924	quartz veins in muscovite schist including boudinage quartz lenses (2cm), weathered, light brown	n.d.	n.d.	11.8	<45	<15	14.2	<30	0.31	1.04	0.08
82	B512	03B075	737976	1643311	malachite dissemination (strong) in hornblende ,biotite granodiorite with shear (mylonitic) and foliation of granodiorite: silicified (moderate to strong), with kaolinite argillization over mineralization	n.d.	n.d.	1.59%	<45	48.9	628	<30	2.96	<0.05	0.28
83	B513	03B075	737976	1643311	malachite dissemination (strong) and quartz vein in shear (mylonitic) and foliation of saprolite of hornblende -biotite granodiorite: silicified (moderate to strong), with kaolinite argillization over mineralization	n.d.	n.d.	47.1	<45	35.7	307	<30	3.20	<0.05	0.45
84	B517	03B104	740225	1638112	quartz vein in biotite hornblende granodiorite medium grained, weathered to light brown including quartz stockwork vein (w:5cm) with pseudotachylyte to have slicken side	n.d.	n.d.	19.1	<45	25.5	227	<30	1.10	<0.05	0.39
85	B523	03B139	741933	1633715	quartz vein in sandy schist (quartz schist), origin is biotite hornblende granodiorite, including quartz lenses (boudinage), weathered to light brown	n.d.	n.d.	340	<45	<15	373	<30	0.67	<0.05	<0.05
86	B530	03B172	741779	1636894	malachite and pyrite dissemination on terrace as float, in hornblende diorite to granodiorite, dioritic granodiorite., fine, foliated (mod), glassy, pale green, there are many quartz boulder	n.d.	n.d.	0.280%	<45	17.1	370	<30	0.82	0.19	0.08
87	B532	03B200	744672	1637088	copper dissemination in mylonite (granodiorite) with malachite along shear, mylonite show S-C	n.d.	n.d.	0.292%	<45	16.6	930	<30	0.68	0.28	0.20
88	B539a	03B243	738892	1641559	saprolite of biotite hornblende granodiorite in trench, massive, medium grained, epidote alteration, weathered (strong)	79	n.d.	5.93%	527	63.8	369	<30	5.28	<0.05	0.28
89	B539e	03B243	738892	1641559	saprolite of biotite hornblende granodiorite in trench, massive, medium grained, epidote alteration, weathered (strong)	n.d.	n.d.	269	<45	57.3	15.4	<30	2.42	<0.05	0.48
90	B539f	03B243	738892	1641559	saprolite of biotite hornblende granodiorite in trench, massive, medium grained, epidote alteration, weathered (strong)	n.d.	n.d.	436	<45	62.4	0.27%	<30	3.21	n.d.	0.48

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (4/6)

Code	Sample No.	Location No.	Coordinate (UTM)		Description for mineralization	Concentration (ppm)							%		
			EW	NS		Ag	Au	Cu	Pb	Zn	Mn	Ni	Fe	Sn	TiO2
91	B539g	03B243	738892	1641559	saprolite of biotite hornblende granodiorite in trench, massive, medium grained, epidote alteration, weathered (strong)	n.d.	n.d.	43.9	<45	65.2	615	<30	1.74	n.d.	0.60
92	B540	03B245	738575	1642379	quartz vein in mylonite (granodiorite), muscovite generated, foliated (strong) with schistose, weathered (strong) to white to pale grey	n.d.	n.d.	43.1	<45	59.1	138	<30	1.43	<0.05	0.35
93	B542	03B286	761460	1637813	pyrite dissemination quartz lenses in slate in shear zone (w:10cm, ductile to brittle), biotite schist in part, slate facies is ditto to 03B285	n.d.	n.d.	56.9	<45	40.9	159	<30	3.71	n.d.	0.33
94	B544	03B298	760290	1638390	pyrite dissemination, quartz veins (5-10cm) in biotite gneiss mixed facies sandstone, and granite	n.d.	n.d.	203	<45	56.0	541	36.6	4.31	n.d.	2.66
95	B549	03B325	762384	1636117	pyrite dissemination ,quartz vein (10cm) including, Bio. gene.? in late / very fine sandstone alternation of slate/ sandstone	n.d.	n.d.	175	<45	<15	41.5	<30	2.75	n.d.	0.05
96	B555	03B344	741759	1636829	malachite quartz vein (14cm), massive, medium to fine, epidote-chlorite argillization (moderate) in biotite hornblende granodiorite	n.d.	6.92	0.77%	266	<15	37.2	<30	2.36	0.12	0.140
97	B556	03B347	741797	1637113	malachite quartz vein (15cm), mylonitic, medium to fine, epidote alteration (weak) in biotite hornblende granodiorite /	n.d.	n.d.	268	<45	16.9	266	<30	1.42	n.d.	0.140
98	B557	03B353	741482	1637883	malachite quartz vein, shear-band gene., fine grain, chlorite argillization (moderate) in biotite hornblende granodiorite	n.d.	n.d.	0.397%	<45	91.5	970	<30	2.47	n.d.	0.470
99	A4003	04A009	742180	1636281	malachite and black copper (A4003, 50cm x 3m) along fracture in granodiorite (cataclasite) with network quartz and quartz vein (20cm, N80W80N, A4007)	18.0	<0.5	2.48%	47.6	125	996	<30	5.64	0.05	0.51
100	A4007	04A009	742180	1636281	Malachite and black copper (A4003, 50cm x 3m) along fracture in granodiorite (cataclasite) with network quartz and quartz vein (20cm, N80W80N, A4007)	<2.5	<0.5	1.77%	<45	<15	154	<30	0.290	0.06	0.12
101	A4008	04A022	742202	1636515	malachite films along fractures in granodiorite, chlorite + epidote + silicification	<2.5	<0.5	0.726%	74.3	172	970	<30	6.28	0.15	0.49
102	B560a	04B005	741220	1637482	malachite dissemination (w:10m<), including quartz vein (2cm) with malachite, direction of vein close to mylonite foliation, medium to fine, chlorite alteration (moderate), in mylonite (granodiorite)	12.3	<0.5	0.685%	262	<15	207	<30	1.19	0.10	0.31
103	B560b	04B005	741220	1637482	malachite dissemination (w:10m<), including quartz vein (3cm) with malachite, direction of vein close to mylonite foliation, medium to fine, chlorite alteration (moderate), in mylonite (granodiorite)	97.9	<0.5	0.281%	243	<15	269	<30	2.05	0.09	0.22
104	B561	04B006	741289	1637442	malachite dissemination (w:10m<) and quartz vein (10cm) with malachite, direction of vein close to mylonite foliation, medium to fine, chlorite alteration (moderate) in mylonite (granodiorite)	47.8	<0.5	2.00%	510	<15	215	<30	0.980	0.10	0.13
105	B562a	04B007	741307	1637444	quartz stockwork with malachite dissemination (w:5m<), sericite and silicification, argillization (strong), direction of stockwork veins cross to mylonite foliation in mylonite (granodiorite)	19.7	<0.5	0.214%	166	<15	331	<30	0.620	0.10	0.38
106	B562b	04B007	741307	1637444	quartz stockwork with malachite dissemination (w:6m<), sericite and silicification, argillization (strong), direction of stockwork veins cross to mylonite foliation in mylonite (granodiorite)	19.7	<0.5	1.26%	346	<15	147	<30	0.510	0.11	0.34
107	B562c	04B007	741307	1637444	quartz stockwork with malachite dissemination (w:7m<), sericite and silicification, argillization (strong), direction of stockwork veins cross to mylonite foliation in mylonite (granodiorite)	19.5	<0.5	0.825%	779	21.4	156	<30	1.17	0.10	0.33
108	B563	04B011	741279	1637468	quartz vein (4cm) and malachite chalcocite (?), bornite (?), strong schistose, shear-band developed, medium to fine, in cataclasite (granodiorite)	125	0.7	3.81%	388	<15	738	<30	1.67	0.11	0.22
109	B565	04B014	741313	1637419	quartz vein (lenses) in cataclasite (granodiorite) float	<2.5	<0.5	0.178%	181	<15	80.3	<30	0.670	0.10	0.30
110	B566	04B016	741730	1636911	malachite azurite dissemination along shear, moderate schistose, chlorite argillization (moderate) in biotite hornblende granodiorite	<2.5	<0.5	1.65%	106	<15	711	<30	1.79	0.13	0.31
111	B567a	04B018	741740	1636780	strong sericite, silicification and chlorite argillization, granodiorite, and saprolite in biotite hornblende granodiorite in trench A-01,	<2.5	<0.5	301	72.3	20.0	33.8	<30	2.67	0.10	0.74
112	B567b	04B018	741740	1636780	strong sericite, silicification and chlorite argillization, granodiorite, and saprolite in biotite hornblende granodiorite in trench A-01,	<2.5	<0.5	356	82.6	17.6	0.221%	<30	3.19	0.10	0.50
113	B567c	04B018	741740	1636780	strong sericite, silicification and chlorite argillization, granodiorite, and saprolite in biotite hornblende granodiorite in trench A-01	<2.5	<0.5	452	93.5	29.3	0.187%	<30	5.92	0.12	0.53
114	B567d	04B018	741740	1636780	strong sericite, silicification and chlorite argillization, granodiorite, and saprolite in biotite hornblende granodiorite in trench A-01	<2.5	<0.5	385	59.9	24.7	574	<30	4.74	0.10	0.62
115	B567e	04B018	741740	1636780	strong sericite, silicificaton and chlorite argillization, granodiorite, and saprolite in biotite hornblende granodiorite in trench A-05,	<2.5	<0.5	376	57.9	26.0	386	<30	3.92	0.10	0.62
116	B570	04B025	741256	1637476	quartz vein (w:5cm*2) with malachite chalcocite (?),bornite, in mylonite (granodiorite)	133	0.7	6.55%	564	<15	256	<30	1.48	0.12	0.24
117	B571	04B008	741346	1637344	quartz vein (2cm) with malachite, shear-band developed, looks like sericite quartz schist., folded in parts (NE plunging) in cataclasite (granodiorite) strong schistose	83.8	<0.5	0.983%	272	17.1	386	<30	11.0	0.13	0.27
118	B572	04B026	741326	1637397	Silicified and bleached rock of biotite hornblende granodiorite, strong silicified and bleached boulder with malachite	7.2	<0.5	0.242%	592	<15	91.2	<30	0.390	0.13	1.84
119	B573c	04B027	741295	1637460	strong sericite, silicification and argillization granodiorite, and saprolite in biotite hornblende granodiorite in Trench A-02	<2.5	<0.5	193	52.4	42.1	0.181%	<30	3.83	0.13	0.44
120	B573d	04B027	741295	1637460	strong sericite, silicification and argillization granodiorite, and saprolite in biotite hornblende granodiorite in Trench A-03	<2.5	<0.5	337	95.6	32.8	641	<30	3.87	0.05	0.56

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (5/6)

Code	Sample No.	Location No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Description for mineralization	Concentration (ppm) Ag	Au	Cu	Pb	Zn	Mn	Ni	% Fe	Sn	TiO2
121	C501	04C004	741637	1636740	malachite and chalcopyrite, chlorite and silicified alteration, light green-light grey, in weak sheared, width: 2m+-, granodiorite	<2.5	<0.5	0.111%	142	20.6	181	<30	0.620	0.06	0.40
122	C502	04C005	741785	1636795	chlorite argillization, include dissemination malachite, in sheared (cataclastic) granodiorite, pale grey-light brown	<2.5	<0.5	0.351%	82.6	22.6	221	<30	0.570	<0.05	0.33
123	C503	04C006	741730	1636909	dissemination malachite and azurite, in sheared (cataclastic) granodiorite, chlorite ; silicified +sericite argillization, pale light green-light brown	11.1	<0.5	1.66%	109	<15	312	<30	1.76	0.06	0.26
124	C505	04C019	738247	1642457	massive granodiorite, light grey-light pale grey, weak chlorite and silicification argillization, moderate epidote alteration, include few malachite	<2.5	<0.5	0.139%	78.5	37.3	556	<30	2.86	0.07	0.56
125	C507	04C022	738060	1644027	weak sheared (cataclastic) granodiorite with dissemination malachite, light greenish grey-light brown, chlorite and silicification argillization, weak weathered	<2.5	<0.5	0.187%	57.8	59.6	0.169%	<30	2.61	0.06	0.44
126	C508	04C023	738115	1644081	sheared (cataclastic) granodiorite with dissemination malachite, light grey-greenish light grey, weak chlorite and silicification and epidote alteration, weak weathered, partly include kaolinite?	<2.5	<0.5	0.252%	50.9	48.4	945	<30	2.13	0.07	0.44
127	C509	04C024	738130	1644083	sheared (cataclastic) granodiorite with dissemination pyrite and chalcopyrite?, light grey-light pale grey, weak chlorite and silicification and epidote alteration, weak weathered, partly include kaolinite?	<2.5	<0.5	962	50.9	71.3	0.135%	<30	2.75	0.06	0.39
128	C510	04C025	738174	1644109	dissemination malachite and pyrite, include muscovite and kaolinite?, in mylonitic (sheared) granodiorite light grey-light pale grey, weak chlorite and silicification argillization, with quartz vein (W: 5cm)	<2.5	<0.5	0.369%	51.0	36.7	483	<30	1.67	0.06	0.50
129	C511	04C026	738180	1644132	float, sheared (cataclastic) granodiorite with dissemination malachite, light grey-light greenish grey, chlorite and silicification argillization	<2.5	<0.5	0.125%	48.9	61.3	889	<30	2.54	0.06	0.44
130	C512	04C027	738253	1644146	cataclastic-mylonitic granodiorite with dissemination malachite, light grey- light pale grey, chlorite and silicification argillization, partly include kaolinite?	<2.5	<0.5	0.312%	47.5	51.3	0.110%	<30	2.05	0.06	0.39
131	C514	04C029	738670	1644152	dissemination malachite, in weak sheared (cataclastic) granodiorite, light greenish grey-light grey, weak chlorite and silicification and moderate epidote alteration	<2.5	<0.5	608	48.2	59.7	868	<30	2.33	0.06	0.38
132	C515	04C030	739006	1643863	dissemination malachite in weak sheared (cataclastic) granodiorite, light grey-greenish light grey, weak chlorite and silicification and epidote alteration	<2.5	<0.5	966	53.0	66.8	935	<30	2.43	0.05	0.39
133	C516	04C033	736281	1645710	weak sheared (cataclastic) granodiorite with dissemination malachite, light greenish grey-pale light grey, chlorite and silicification and epidote alteration	<2.5	<0.5	0.188%	<45	50.2	782	<30	1.92	0.06	0.51
134	C517	04C035	736926	1645446	dissemination and veinlet pyrite in massive granodiorite, light grey-partly light greenish grey, weak chlorite and silicification argillization	<2.5	<0.5	108	46.8	46.3	806	<30	2.91	0.06	0.63
135	C518	04C036	736954	1645467	dissemination malachite in weak sheared granodiorite, light grey-greenish light grey, chlorite and silicification argillization	3.7	<0.5	0.893%	46.8	76.1	0.102%	<30	3.09	0.06	0.62
136	C519	04C038	737574	1645288	dissemination malachite in weak sheared (cataclastic?) granodiorite, light grey-light greenish grey, chlorite and silicification and epidote alteration, weak weathered	25.1	<0.5	0.721%	90.9	58.5	741	<30	2.56	0.06	3.56
137	A4036	04A250	768327	1669935	float of quartz veins with pyrite dissemination (Au in pyrite?), and purplish grey to brown, muddy slate and sandstone	<2.5	<0.5	<7	<45	19.5	n.d.	<30	2.97	n.d.	0.36
138	A4037	04A253	768387	1670975	floats of dark grey biotite schist, quartzite with veins including pyrite dissemination (1cm to 3mm), muddy slate, sandstone	<2.5	<0.5	<7	<45	<15	57.0	<30	3.59	n.d.	<0.05
139	A4040	04A264	768144	1673251	pyrite dissemination in grey to dark grey, limestone (chemical deposit type)	<2.5	<0.5	50.7	<45	25.7	50.1	<30	6.60	n.d.	0.08
140	A4042	04A274	767949	1675490	pyrite dissemination in marble	<2.5	<0.5	12.5	<45	46.1	680	<30	1.34	n.d.	<0.05
141	A4045	04A295	768918	1673539	quartz veins (2cm, N75W70S), and network quartz veins and pyrite veins (5 to 10 cm, NS75E), in sheared zone of grey muddy slate	<2.5	<0.5	772	234	23.6	276	55.4	16.1	n.d.	0.36
142	A4047	04A295	768918	1673539	quartz veins (2cm, N75W70S), and network quartz veins and pyrite veins (5 to 10 cm, NS75E), in sheared zone of grey muddy slate	<2.5	<0.5	425	<45	24.7	255	72.1	20.7	n.d.	0.20
143	B576	04B046	758890	1657226	smoky quartz vein ,(10cm) and lenses (10cm) in schist (basalt) strongly weathered to reddish -light brown, append ant shear sense shows normal, origin would be basalt	<2.5	<0.5	<7	<45	18.9	18.0	<30	1.63	n.d.	0.12
144	B577	04B047	758829	1657167	quartz stock works (w:2-5mm), zone width is 5m, in quartzite Zone of strong silicification and sericite argillization, and origin of quartzite is two mica granite?	<2.5	<0.5	<7	<45	<15	6.8	<30	0.180	n.d.	0.15
145	B578	04B048	758889	1657257	quartz lenses (5cm) in schist (basalt) strong sericite argillization zone (w:20m), bearing talc?, and origin would be basalt	<2.5	<0.5	8.2	<45	15.5	5.5	<30	1.00	n.d.	0.23
146	B581	04B051	757777	1655421	malachite chalcopyrite and quartz vein, (w:0.6m*3m), vein developed along schistosity in meta- basalt / chlorite schist including	<2.5	<0.5	0.232%	687	70.0	950	<30	3.98	n.d.	0.11
147	B585	04B059	756815	1654847	quartzite, strong pyrite dissemination zone with brittle shearing (w:5m*50m), near boundary between quartzite / two mica granite	<2.5	<0.5	<7	<45	25.0	85.0	<30	16.9	n.d.	0.14
148	B589	04B083	764685	1690475	quartz vein -lets (w:1cm-5cm) and pyrite dissemination (moderate), in muscovite quartz schist, generate Fe-Mn oxides, storing limonitized in parts	<2.5	<0.5	<7	<45	<15	15.3	<30	1.77	n.d.	0.32
149	C526	04C047	757800	1655800	dark green, including dissemination pyrite and barren quartz vein, chlorite and silicification argillization	<2.5	<0.5	111	<45	91.5	872	<30	5.06	n.d.	0.78
150	C527	04C048	757666	1655725	dark green, including dissemination malachite and pyrite and chalcopyrite?, chlorite and silicification and epidote (partly veinlet) argillization	<2.5	<0.5	790	<45	78.1	667	<30	0.230	n.d.	2.12

Annex 5 Result of Ore Assay Analysis by Department of Geology, Ministry of Energy and Mine, Lao (6/6)

Code	Sample No.	Location No.	Coordinate (UTM) EW	Coordinate (UTM) NS	Description for mineralization	Concentration (ppm) Ag	Au	Cu	Pb	Zn	Mn	Ni	% Fe	Sn	TiO2
151	C528	04C049	757751	1655449	dark green-light greenish grey, including dissemination pyrite, chlorite and silicification and epidote alteration	<2.5	<0.5	53.7	177	51.8	493	<30	0.170	n.d.	0.31
152	C529a	04C051	758775	1657331	quartz vein, (width:3cmand 5cm) in schistosed basalt, chlorite argillization	<2.5	<0.5	63.2	<45	54.0	190	<30	0.330	n.d.	0.22
153	C529b	04C051	758775	1657331	quartz vein, (width:3cmand 6cm) in schistosed basalt, chlorite argillization	<2.5	<0.5	76.1	<45	25.1	213	<30	0.250	n.d.	0.21
154	C530	04C052	758841	1657420	quartz vein ,and iron oxides in schistosed basalt, chlorite argillization, reddish brown -light greenish grey	22.2	237	1.64%	184	82.0	403	92.5	48.3	n.d.	0.16
155	C531	04C053	758823	1657560	copper? and quartz vein, (width:70cm, partly include pyrite and iron oxides) in schistosed basalt, chlorite and sericite and kaolinite? argillization, light brown -light greenish grey	<2.5	<0.5	291	<45	16.9	18.1	<30	10.2	n.d.	0.76
156	C532	04C054	758824	1657587	quartz vein and dissemination chalcopyrite and pyrite in float of pale grey massive,	<2.5	<0.5	<7	<45	<15	45.9	<30	0.040	n.d.	0.11
157	C534a	04C057	759109	1656296	dissemination pyrite and quartz vein let in graphite schist (width:1m, N10W90), and dissemination pyrite in black to dark grey slate, dark grey-light grey, silicification and alteration	<2.5	<0.5	70.6	<45	21.1	92.2	<30	0.280	n.d.	2.48
158	C534b	04C057	759109	1656296	dissemination pyrite and quartz vein let in graphite schist (width:1m, N10W91), and dissemination pyrite in black to dark grey slate, dark grey-light grey, silicification and alteration	<2.5	<0.5	63.4	<45	15.6	68.5	<30	0.110	n.d.	2.46
159	C535a	04C059	759411	1656162	dissemination pyrite in slate, partly graphite schist is same direction and include dissemination pyrite along schistosed fracture, light grey-pale grey, silicification and alteration	<2.5	<0.5	33.7	<45	<15	41.1	<30	0.090	n.d.	3.18
160	C535b	04C059	759411	1656162	dissemination pyrite in slate, partly graphite schist is same direction and include dissemination pyrite along schistosed fracture, light grey-pale grey, silicification and alteration	<2.5	<0.5	17.2	<45	27.8	23.1	<30	1.76	n.d.	3.07
161	C538b	04C062	765302	1681353	quartz vein ,with dissemination pyrite in slate, dark grey-greenish dark grey, silicification and sericite? and chlorite argillization	<2.5	<0.5	115	98.2	40.7	707	<30	2.46	n.d.	0.31

Annex 6 List of Mineral Occurrences in B.Dakyoy District (1/6)

Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No.: JICA DGEO, 2008)	Stage of investigation	Size	Outcrop No. (JICA DGEO, 2008)
					Longitude	Latitude	EW	NS					
1	D-48-XII (B.DAKYOY)	Au	Vein	B. Vantat-Kang	107° 26′ 4″	15° 6′ 0″	761657	1670850	quartz veins (width:10cm, N60W40N) in muddy slate	A161: Au157ppm, Pb:2280ppm		mineral showing	02A039
2	D-48-XII (B.DAKYOY)	Au	Vein	Vantat, Gold Mine	107° 24′ 22″	14° 58′ 42″	758775	1657331	quartz vein (width:3cm and 5cm) in schistosed basalt with chlorite alteration	C529a C529b	operating gold mine	modeate	04C051
3	D-48-XII (B.DAKYOY)	Au	Vein	Vantat, Gold Mine	107° 24′ 24″	14° 58′ 45″	758841	1657420	quartz vein and iron oxides in schistosed basalt, chlorite alteration, reddish brown-light greenish gray	C530: Cu:1.64%, Pb:184ppm, Mn:403ppm, Fe:48.2%	operating gold mine	modeate	04C052
4	D-48-XII (B.DAKYOY)	Au	Vein	Vantat, Gold Mine	107° 24′ 26″	14° 58′ 39″	758889	1657257	quartz lens (5cm), origin would be basalt, strong sericite alteration zone(w:20m), bearing talc?	B578	operating gold mine	modeate	04B048
5	D-48-XII (B.DAKYOY)	Au	Vein and dissemination	Vantat, Gold Mine	107° 24′ 24″	14° 58′ 49″	758823	1657560	copper? and quartz vein (width:~0cm) in schistosed basalt, partly include pyrite and iron oxides), chlorite, sericite and kaolinite ? alteration, light brown-light greenish gray	C531: Fe:10.2%	operating gold mine	modeate	04C053
6	D-48-XII (B.DAKYOY)	Au	Vein and dissemination	Vantat, Gold Mine	107° 24′ 24″	14° 58′ 50″	758824	1657587	float of pale gray, massive, quartz with disseminated chalcopyrite? and pyrite	C532	operating gold mine	modeate	04C054
7	D-48-XII (B.DAKYOY)	Au, Cu	Vein and dissemination	Vantat, Gold Mine	107° 24′ 33″	14° 58′ 39″	759094	1657237	Vantat Gold Mine, quartz stockwork (width:300cm) along drift in muscovite schist	Ag:1.04-93.4ppm, Au:28.4ppm, Cu:3160ppm in maximum	operating gold mine	modeate	02B161
8	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 11′ 46″	14° 52′ 32″	736281	1645710	disseminated malachite in weak sheared (cataclastic) granodiorite, light greenish gray-pale light gray, chlorite +silicification +epidote alteration,	C516: Cu:0.19%, Mn:782ppm, Fe:1.92%		mineral showing	04C033
9	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 6″	14° 50′ 45″	736921	1642442	malachite films along the fractures in biotite-hornblende granodiorite	A3010: Cu:0.30%, Mn:796ppm, Fe:5.46%		mineral showing	03A068
10	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 8″	14° 52′ 23″	736954	1645467	disseminated malachite in weak sheared granodiorite, light gray-greenish light gray, chlorite and silicification alteration	C518: Cu:0.89%, Mn:0.10%, Fe:3.09%		mineral showing	04C036
11	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 29″	14° 52′ 17″	737574	1645288	disseminated malachite in weak sheared (cataclastic?) granodiorite, light gray-light greenish gray, chlorite +silicification +epidote alteration, weak weathered,	C519: Cu:0.72%, Mn:741ppm, Fe:2.56%		mineral showing	04C038
12	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 39″	14° 51′ 14″	737896	1643332	disseminated malachite along fractures in hornblende biotite granodiorite, massive, med grain schistose in part, silicification			mineral showing	03B247
13	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 42″	14° 51′ 13″	737976	1643311	disseminated malachite (strong) in shear (mylonitic) and foliation, granodiorite; silicified (moderate to strong), with kaolinite alteration covered mineralization	B512: Cu:1.59%, Mn:628ppm, Fe:2.96% B513: Mn:307ppm, Fe:3.20%		mineral showing	03B075
14	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 45″	14° 51′ 36″	738060	1644027	disseminated malachite in weak sheared (cataclastic) granodiorite, light greenish gray-light brown, chlorite and silicification alteration, weak weathered,	C507: Cu:0.19%, Mn:0.17%, Fe:2.616%		mineral showing	04C022
15	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 47″	14° 51′ 38″	738115	1644081	disseminated malachite in sheared (cataclastic) granodiorite, light gray-greenish light gray, weak chlorite +silicification epidote alteration, weak weathered, partly include kaolinite?	C508: Cu:0.25%, Mn:945ppm, Fe:2.13%		mineral showing	04C023
16	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 47″	14° 51′ 38″	738130	1644083	disseminated pyrite and chalcopyrite? in sheared (cataclastic) granodiorite, light gray-light to pale gray, weak chlorite +silicification epidote alteration, weak weathered, partly include	C509: Cu:0.10%, Mn:0.14%, Fe:2.75%		mineral showing	04C024
17	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 49″	14° 51′ 40″	738180	1644132	disseminated malachite in float, sheared (cataclastic) granodiorite, light gray-light greenish gray, chlorite and	C511: Cu:0.37%, Mn:483ppm, Fe:1.67%		mineral showing	04C026
18	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 51″	14° 50′ 45″	738247	1642457	few malachite in massive granodiorite, light gray-light to pale gray, weak chlorite and silicification alteration, moderate	C508: Cu:0.14%, Mn:556ppm, Fe:2.86%		mineral showing	04C019
19	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 12′ 51″	14° 51′ 40″	738253	1644146	disseminated malachite in cataclastic-mylonitic granodiorite, light gray-light to pale gray, chlorite and silicification alteration, partly include kaolinite?	C512: Cu:0.31%, Mn:0.11%, Fe:2.05%		mineral showing	04C027
20	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 13′ 5″	14° 51′ 40″	738670	1644152	disseminated malachite in weak sheared (cataclastic) granodiorite, light greenish gray-light gray, weak chlorite +silicification moderate epidote alteration,	C514: Cu:0.06%, Mn:868ppm, Fe:2.33%		mineral showing	04C029
21	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 13′ 12″	14° 50′ 16″	738892	1641559	massive, medium grain, epidote alteration, weathered (strong) in a trench	B539a: Ag:79ppm, Cu:5.93%, Mn:369ppm, Fe:5.28%, B539f: Mn:0.27%, Fe:3.21%		mineral showing	03B243
22	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 13′ 16″	14° 51′ 31″	739006	1643863	disseminated malachite in weak sheared (cataclastic) granodiorite, light gray-greenish light gray, weak chlorite +silicification epidote alteration,	C515: Cu:0.10%, Mn:935ppm, Fe:2.43%		mineral showing	04C030
23	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 13′ 58″	14° 47′ 45″	740333	1636930	few malachite along fracture in light pinkish grey, biotite-hornblende granite, medium grained, chlorite,			mineral showing	03A130
24	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 11″	14° 48′ 49″	740690	1638899	quartz veins (width:1-2cm) and malachite along fractures sheared, N45W25E, in biotite-hornblende granodiorite, epidote-	A3023: Cu:2.40%, Mn:376ppm, Fe:1.28%, A3024: Mn:782ppm, Fe:2.04%		mineral showing	03A114
25	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 28″	14° 48′ 2″	741220	1637482	malachite, dissemination (width:10m<), including quartz vein (2cm) with malachite, direction of vein cross to mylonite foliation, in mylonitic granodiorite medium to fine, chlorite	B560a: Cu:0.69%, Mn:207ppm, Fe:1.19%, B560b: Cu:0.28%, Mn:269ppm, Fe:2.05%		mineral showing	04B005
26	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 29″	14° 48′ 2″	741256	1637476	quartz vein (width:5cm*2) with malachite, chalcocite (?) and bornite (?) in mylonite of granodiorite	B570: Ag:83.8ppm, Cu:6.55%, Mn:256ppm, Fe:1.48%		mineral showing	04B025

Annex 6 List of Mineral Occurrences in B.Dakyoy District (2/6)

Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No.: JICA/DGEO, 2008)	Stage of investigation	Size	Outcrop No. (JICA/DGEO, 2009)
					Longitude	Latitude	EW	NS					
27	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 30″	14° 48′ 2″	741279	1637468	quartz vein (width:4cm) with malachite, chalcocite (?) and bornite (?) in cataclasite of granodiorite, strong schistose, shear-band dev. medium to fine.	B563: Ag:125ppm, Au:0.7ppm, Cu:3.81%, Mn:738ppm, Fe:1.67%		mineral showing	04B011
28	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 31″	14° 48′ 1″	741289	1637442	malachite, dissemination (width:10m<), including quartz vein (width:10cm) with malachite, direction of vein cross to mylonite foliation, in mylonite of granodiorite medium to fine, chlorite alteration (moderate)	B561: Ag:47.7ppm, Cu:2.00%, Mn:215ppm		mineral showing	04B006
29	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 31″	14° 48′ 1″	741307	1637444	quartz stockwork with malachite, dissemination (width:5m<), sericite and silicification alteration (strong), direction of stockwork veins cross to mylonite foliation in mylonite of	B562a: Ag:19.7ppmCu:0.21%, Mn:331ppm, B562b: Ag:19.7ppm,Cu:1.26%, B562c: Ag:19.5ppm, Cu:0.83%		mineral showing	04B007
30	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 31″	14° 48′ 0″	741313	1637419	float, quartz vein (lens) in cataclasite of granodiorite	B565: Cu:0.18%		mineral showing	04B014
31	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 32″	14° 47′ 60″	741326	1637397	strong silicified and bleached boulder with malachite in biotite hornblende granodiorite	B572: Ag:7.2ppm, Cu:0.24%		mineral showing	04B026
32	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 32″	14° 47′ 58″	741346	1637344	strong schistose, including quartz vein (width:2cm) with malachite in cataclasite of granodiorite, shear-band developed, looks like sericite-quartz schist, folded in parts (NE plunging)	B571: Ag:83.8ppm, Cu:0.98%, Mn:386ppm, Fe:11.07%		mineral showing	04B008
33	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 37″	14° 48′ 15″	741482	1637883	with malachite, quartz vein in biotite hornblende granodiorite, shear-band gene, fine grain, chlorite alteration (moderate)	B557: Cu:0.40%, Mn:970ppm, Fe:2.47%		mineral showing	03B353
34	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 42″	14° 47′ 38″	741637	1636740	malachite and chalcopyrite in weak sheared (width:2m ·) granodiorite, chlorite and silicification alteration, light green -	C501: Cu:0.11%, Mn:181ppm		mineral showing	04C004
35	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 45″	14° 47′ 44″	741730	1636911	malachite and azurite disseminated along shear in granodiorite, moderate schistose, chlorite alteration (moderate)	B566: Cu:1.65%, Mn:711ppm, Fe:1.76%		mineral showing	04B016
36	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 45″	14° 47′ 44″	741730	1636909	dissemination of malachite and azurite in sheared (cataclastic) granodiorite, chlorite + silicification +sericite alteration, pale light green-light brown	C503: Ag:11.1ppm, Cu:1.66%, Mn:312ppm, Fe:1.76%		mineral showing	04C006
37	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 46″	14° 47′ 40″	741742	1636814	quartz network-sericite alteration, azurite +malachite, chalcopyrite, bornite and tenolite dissemination related to porphyry copper system in granodiorite: massive with shear, epidote-chlorite alteration, schistose in parts			mineral showing	03B343
38	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 46″	14° 47′ 40″	741750	1636805	1st: quartz vein and chlorite, and 2nd: sericite and chalcopyrite malachite, azurite and covelline related to porphyry copper system mineralization in hornblende biotite granodiorite	A3108a: Cu:0.95%, Mn:171ppm, Fe:2.39%		mineral showing	03A374
39	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 46″	14° 47′ 41″	741759	1636829	malachite, quartz vein (width:14cm) in hornblende biotite granodiorite, massive, medium to fine, epidote-chlorite alteration (moderate)	B555: Au:6.92ppm, Cu:0.77%, Fe:2.36%		mineral showing	03B344
40	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 47″	14° 47′ 43″	741779	1636894	dioritic granodiorite, fine, foliated (moderate), glassy, pale green there are many quartz boulder with malachite and pyrite	B530: Cu:0.28%, Mn:370ppm		mineral showing	03B172
41	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 47″	14° 47′ 40″	741785	1636795	disseminated malachite in sheared (cataclastic) granodiorite, chlorite alteration, pale gray-light brown	C502: Cu:0.35%, Mn:221ppm		mineral showing	04C005
42	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 53″	14° 47′ 41″	741976	1636820	malachite films along fractures in granodiorite, chlorite +epidote+ silicification			mineral showing	04A023
43	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 60″	14° 47′ 23″	742180	1636281	malachite and black copper (A4003, 50cm x 3m) along fracture in granodiorite (cataclasite) with network quartz and quartz vein (width:20cm, N80W80N)	A4003: Ag:18.0ppm, Cu:2.48%, Mn:996ppm, Fe:5.64%, A4007: Cu:1.77%		mineral showing	04A009
44	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 14′ 60″	14° 47′ 23″	742180	1636281	malachite and black copper along fracture in granodiorite (cataclasite) with network quartz and quartz vein			mineral showing	04A018
45	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 15′ 53″	14° 47′ 19″	743762	1636167	quartz vein with malachite, covelline, gold? (width: 1.5m to 2m), length: more than 30m, direction: N40E65S	A3061: Cu:0.36%, Mn:181ppm, Fe:1.38%		mineral showing	03A249
46	D-48-XII (B.DAKYOY)	Cu, Au	Porphyry	May Phao Sauu Phanh	107° 16′ 24″	14° 47′ 48″	744672	1637088	malachite along shear in mylonite of granodiorite, showing S-C direction	B532: Cu:0.29%, Mn:930ppm		mineral showing	03B200
47	D-48-XII (B.DAKYOY)	Cu, Au	Vein and dissemination	Vantat	107° 23′ 45″	14° 57′ 50″	757666	1655725	disseminated malachite, and pyrite and chalcopyrite (?) in chlorite schist, dark green, chlorite +silicification epidote (partly veinlet) alteration	C527: Cu:0.08%, Mn:6678ppm		mineral showing	04C048
48	D-48-XII (B.DAKYOY)	Cu, Au	Vein and dissemination	Vantat	107° 23′ 48″	14° 57′ 40″	757777	1655421	including quartz vein (width:0.6mx3m) with malachite, chalcopyrite, vein developed along schistosity, in meta-basalt	B581: Cu:0.23%, Mn:950ppm, Fe:3.98%		mineral showing	04B051
49	D-48-XII (B.DAKYOY)	Cu, Au	Vein and dissemination	Route18, 90km	107° 25′ 34″	14° 48′ 39″	761128	1638824	quartz vein (width:5m) and green copper in muscovite schist	B031		mineral showing	01B105
50	D-48-XII (B.DAKYOY)	Cu, Au	Vein and dissemination	Route18, 90km	107° 26′ 5″	14° 47′ 33″	762069	1636799	quartz vein and pyrite dissemination (strong) with green copper along shear zone (width:80m, brittle) in slate			mineral showing	01B111
51	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 10′ 20″	14° 49′ 54″	733749	1640827	quartz vein (width:40cm, 10cm, N40W90) in muddy slate with sericite	A3004		mineral showing	03A053
52	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 10′ 26″	14° 50′ 4″	733930	1641144	sericite quartz vein (width:50cm, N30W90) in muddy slate	A3005		mineral showing	03A058

Annex 6 List of Mineral Occurrences in B.Dakyoy District (3/6)

Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No.: JICA DGFO, 2008)	Stage of investigation	Size	Outcrop No. (JICA DGFO, 2008)
					Longitude	Latitude	EW	NS					
53	D-48-XII (B.DAKYOY)	Qz	Vein	B. Klan	107° 10′ 47″	15° 20′ 20″	734023	1696997	quartz vein (width:5cm) in pale gray, mica schist in place	B062		mineral showing	01B235
54	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 10′ 59″	14° 50′ 4″	734910	1641167	quartz vein (width:30cm, N45W90) in slate with sericite and limonite	A3002: Zn:172ppm, Fe:12.5%		mineral showing	03A021
55	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 11′ 12″	14° 49′ 56″	735303	1640924	boudinage quartz lenses (width:2cm), in muscovite schist, weathered, light brown	B501		mineral showing	03B002
56	D-48-XII (B.DAKYOY)	Qz	Vein	B. Paam	107° 11′ 40″	14° 57′ 22″	736022	1654653	biotite granodiorite, massive, coarse grain, cover by conglomerate, quartzite and sandstone, weathered	B078		mineral showing	01B276
57	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 12′ 10″	14° 50′ 50″	737030	1642588	quartz vein (width:40cm, N65W90) in biotite-hornblende granodiorite, with sheared zone between granodiorite and biotite schist	A3009: Zn:116ppm, Fe:3.63%		mineral showing	03A065
58	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 13′ 1″	14° 50′ 42″	738575	1642379	quartz vein in granodiorite mylonite, muscovite generated, foliated (strong) with schistose, weathered (strong) to white to	B540		mineral showing	03B245
59	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 13′ 52″	14° 48′ 42″	740130	1638676	quartz veins (width:20cm, N80W75N) in biotite-hornblende granodiorite, medium grained, epidote-chlorite, sheared	A3019b		mineral showing	03A105
60	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 13′ 55″	14° 48′ 23″	740225	1638112	quartz stockwork vein (width:5cm) in biotite hornblende granodiorite, medium grain, weathered to light brown including with pseudotachylyte to have slicken side	B517		mineral showing	03B104
61	D-48-XII (B.DAKYOY)	Qz	Vein	B. Dakklong	107° 14′ 27″	15° 5′ 4″	740863	1668883	migmatitic, many micro folding including, two mica granite and biotite schist	B090: Pb:222ppm, Zn:23ppm		mineral showing	01B321
62	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 19″	14° 48′ 10″	740950	1637710	quartz vein (width:90cm) in in granodiorite mylonite, no sulphide and copper.			mineral showing	04B023
63	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 24″	14° 48′ 58″	741062	1639180	quartz vein (width:3cm, N30E85N) in hornblende-biotite granodiorite, chlorite>>epidote, weak sheared	A3115		mineral showing	03A403
64	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 27″	14° 45′ 56″	741221	1633607	quartz veins in schist, pale grey, sheared, muscovite schist with chlorite, including fragments of fine sandstone	A3072		mineral showing	03A289
65	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 43″	14° 47′ 42″	741668	1636851	network quartz veins (width: 10m, N30W-N20W) with chalcopyrite, azurite, malachite in granodiorite, accompanying with alteration of chlorite +sericite +silicification			mineral showing	04A001
66	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 43″	14° 46′ 26″	741682	1634523	quartz vein (width:2.5m, NS90) in granodiorite	A3036		mineral showing	03A163
67	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 44″	14° 47′ 38″	741709	1636747	network quartz vein (width:1-2mm) in hornblende-biotite granodiorite, moderate chlorite	A3107		mineral showing	03A373
68	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 47″	14° 47′ 50″	741797	1637113	malachite, quartz vein (width:15cm) in mylonitic, medium to fine, epidote alteration (weak)	B556		mineral showing	03B347
69	D-48-XII (B.DAKYOY)	Qz	Vein	May Phao Sauu Phanh	107° 14′ 51″	14° 45′ 60″	741933	1633715	quartz lenses (boudinage) in biotite hornblende granodiorite, weathered and light brown	B523		mineral showing	03B139
70	D-48-XII (B.DAKYOY)	Qz	Vein	B. Konglay	107° 24′ 17″	15° 10′ 43″	758371	1679507	quartz network development (width:1 to 5cm) in quartzite, light gray to light reddish gray	B105		mineral showing	02B035
71	D-48-XII (B.DAKYOY)	Qz	Vein	Vantat	107° 24′ 24″	14° 58′ 37″	758829	1657167	quartz stockwork (width:2-5mm), zone width is 5m, zone of strong silicification and sericite alteration, origin of quartzite; two mica granodiorite?	B577		mineral showing	04B047
72	D-48-XII (B.DAKYOY)	Qz	Vein	Vantat	107° 24′ 26″	14° 58′ 38″	758890	1657226	smoky quartz vein (width:10cm) and lens (width:10cm), appendant shear sense shows normal, origin would be basalt, strongly weathered to red-light brown	B576		mineral showing	04B046
73	D-48-XII (B.DAKYOY)	Qz	Vein	Route18, 90km	107° 26′ 31″	14° 47′ 52″	762852	1637392	quartz veins (width:1m, N30E 8-W) in biotite-muscovite schist	A3079: Fe:3.04%, A3080		mineral showing	03A308
74	D-48-XII (B.DAKYOY)	Qz	Vein	B.Klabai	107° 29′ 49″	15° 6′ 2″	768387	1670975	veins including pyrite dissemination (width:1cm to 3mm) in floats of quartzite,			mineral showing	04A253
75	D-48-XII (B.DAKYOY)	Qz	Vein	B. Thakkanat	107° 6′ 52″	15° 11′ 3″	727175	1679780	bluish grey, biotite schist to green schist	A232: Mn:2050ppm,		mineral showing	02A245
76	D-48-XII (B.DAKYOY)	Qz	Vein	B. Paam	107° 9′ 3″	14° 57′ 37″	731329	1655047	pyrite dissemination in conglomeratic, mylonite-like, schistose, silicified			mineral showing	01B125
77	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 10′ 36″	14° 51′ 58″	734205	1644670	pyrite dissemination in mylonitic hornblende-biotite granodiorite, medium grained, epidote>chlorite			mineral showing	03A275
78	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 11′ 10″	14° 51′ 50″	735235	1644422	pyrite in hornblende biotite granodiorite, mylonitic and schistose (weak), silicification and epidote alteration,			mineral showing	03B239
79	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 12′ 7″	14° 52′ 23″	736926	1645446	dissemination and veinlet pyrite in massive granodiorite, light gray-partly light greenish gray, weak chlorite and silicification	C517		mineral showing	04C035
80	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 12′ 11″	14° 51′ 52″	737030	1644495	pyrite disseminated in biotite-hornblende granodiorite, medium grained, epidote-chlorite	A3019a		mineral showing	03A099
81	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 12′ 28″	14° 51′ 36″	737550	1644025	pyrite disseminated in heterogeneous, hornblende-biotite granodiorite, many biotite segregated, medium to coarse grained			mineral showing	03A096

Annex 6 List of Mineral Occurrences in B.Dakyoy District (4/6)

Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No.: JICA/DGE/O, 2008)	Stage of investigation	Size	Outcrop No (JICA/DGE/O, 2008)
					Longitude	Latitude	EW	NS					
82	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 12′ 49″	14° 51′ 39″	738174	1644109	disseminated malachite, and pyrite, include muscovite and kaolinite? in Mylonitic (sheared) granodiorite with light gray-light to pale gray, weak chlorite and silicification alteration, weak weathered, include quartz vein (width:5cm)	C510: Cu:0.37%, Mn:483ppm, Fe:1.67%		mineral showing	04C025
83	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 11″	14° 47′ 38″	738910	1636710	pyrite films (N65W70SW) in grey, sheared sandy slate			mineral showing	03A194
84	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 35″	14° 47′ 20″	739638	1636180	quartz veins and many pyrite vein and films, N30W80W, in sheared slate, in trench	A3046		mineral showing	03A188
85	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 36″	14° 47′ 14″	739666	1635980	quartz veins and many pyrite vein and films, N40W90, in sheared slate, in trench			mineral showing	03A187
86	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 37″	14° 47′ 13″	739695	1635955	quartz veins and many pyrite vein and films, N45W90, in sheared slate, in trench	A3045: Pb:0.11%, Mn:155ppm, Fe:5.52%		mineral showing	03A186
87	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 37″	14° 47′ 9″	739710	1635828	quartz vein (N30W70W) in mylonite of granite, and sheared slate	A3044: Zn:127ppm, Mn:1.11%, Fe:10.4%		mineral showing	03A185
88	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 13′ 60″	14° 46′ 40″	740397	1634954	quartz vein and silicified breccia (width:3-2cm, N40W70N) in sheared granodiorite	A3042		mineral showing	03A177
89	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 14′ 1″	14° 46′ 38″	740439	1634886	quartz vein and silicified breccia (width:2m, N80W70S) in granodiorite	A3041		mineral showing	03A174
90	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 14′ 15″	14° 46′ 35″	740860	1634791	silicified breccia (width:3m +, N30W70W), sheared granodiorite	A3037		mineral showing	03A169
91	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 14′ 37″	14° 47′ 39″	741474	1636770	epidote-chlorite-pyrite, foliation:N45W75E, in cataclastic, biotite-hornblende granodiorite, medium grained			mineral showing	03A116
92	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 16′ 10″	14° 46′ 46″	744285	1635167	pyrite dissemination in granodiorite porphyry			mineral showing	03A226
93	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 16′ 18″	14° 48′ 40″	744488	1638668	pyrite dissemination in parts, in hornblende biotite granodiorite, massive, medium to coarse, schistose, epidote-chlorite alteration (moderate), including biotite (diameter: 5mm in average)			mineral showing	03B341
94	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 16′ 34″	14° 49′ 23″	744969	1639992	pyrite dissemination (weak) in hornblende biotite granodiorite, medium, potassium feldspar porphyritic, epidote alteration in place (moderate), ,			mineral showing	01B062
95	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route 18	107° 18′ 28″	14° 49′ 8″	748373	1639578	pyrite dissemination (weak) in hornblende biotite granodiorite, medium, potassium feldspar porphyritic, epidote alteration in place (moderate),			mineral showing	01B061
96	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Dakmaluk	107° 18′ 55″	15° 10′ 38″	748756	1679229	fractured zone (width:5cm) with pyrite in week weathered, very fine to fine sandstone, well bedded, light green-pale green	C023		mineral showing	02C080
97	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route 18	107° 19′ 48″	14° 49′ 22″	750772	1640027	pyrite dissemination in place, in hornblende biotite granodiorite, moderate to coarse, potassium feldspar porphyritic, magnetic susceptibility: 10.46 (SI)			mineral showing	01B090
98	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 16″	14° 57′ 22″	756815	1654847	strong pyrite dissemination zone with brittle shearing (width:5mx50m), near boundary between quartzite and two mica granite,	B585		mineral showing	04B059
99	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 16″	14° 57′ 20″	756818	1654800	pyrite dissemination intense, in garnet two mica granite intrude to quartzite, bearing garnet?			mineral showing	04B058
100	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 21″	14° 57′ 19″	756957	1654753	pyrite dissemination (moderate) in sheared, near boundary between quartzite and gabbro			mineral showing	04B057
101	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 26″	14° 57′ 26″	757123	1654980	pyrite (moderate) in pyroxene-hornblende gabbro, medium to fine grain, chlorite alteration (moderate) would be gabbro facies of met-basalt			mineral showing	04B055
102	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 47″	14° 57′ 41″	757751	1655449	disseminated pyrite in chlorite schist, dark green-light greenish gray, chlorite + silicification + epidote alteration,	C528: Pb:177ppm, Mn:493ppm		mineral showing	04C049
103	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 49″	14° 57′ 52″	757800	1655800	disseminated pyrite and barren quartz vein in chlorite schist, dark green, including, chlorite and silicification alteration	C526: Mn:872ppm, Fe:5.-6%		mineral showing	04C047
104	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 53″	14° 57′ 52″	757929	1655788	disseminated pyrite and stock worked quartz veinlet in basalt (chlorite) and meta-sandstone, massive, chlorite and silicification alteration, dark green mass, silicified?), including disseminated pyrite and barren quartz vein (width:10cm),			mineral showing	04C046
105	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 23′ 57″	14° 57′ 51″	758040	1655769	disseminated pyrite in basalt (chlorite), massive, epidote and chlorite and silicification alteration, light greenish gray,			mineral showing	04C045
106	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 23′ 55″	14° 48′ 50″	758162	1639131	pyrite dissemination in porphyry, porphyritic, development of schistosity (weak), , pale greenish gray,			mineral showing	01B100
107	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 3″	14° 57′ 55″	758208	1655872	pyrite in massive basalt, dark green-dark gray	C010		mineral showing	02C027
108	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 30″	14° 58′ 13″	759014	1656444	Vantat Gold Mine, quartz vein (width:140cm) in muscovite schist, can't observe sulphide	B144		mineral showing	02B151

Annex 6 List of Mineral Occurrences in B.Dakvov District (5/6)

Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No. JICA/DGEO, 2008)	Stage of investigation	Size	Outcrop No. (JICA/DGEO, 2008)
					Longitude	Latitude	EW	NS					
109	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 31″	14° 58′ 12″	759036	1656418	Vantat Gold Mine, quartz vein (width:80cm) in muscovite schist, can't observe sulphide, with shear	B141a,b, B142a,b,c, B143		mineral showing	02B152
110	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 33″	14° 58′ 8″	759109	1656296	disseminated pyrite and quartz veinlet in graphite schist (width:1m, N10W90), black-dark gray, and disseminated pyrite in slate, dark gray-light gray, silicification alteration	C534a, C534b		mineral showing	04C057
111	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 34″	14° 58′ 2″	759150	1656100	quartz vein with barite (width:15cm) in biotite schist	B145		mineral showing	02B157
112	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 40″	14° 58′ 5″	759319	1656218	disseminated pyrite and quartz veinlet in slate, light gray-dark gray, strong silicification alteration			mineral showing	04C058
113	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 43″	14° 58′ 4″	759411	1656162	disseminated pyrite in slate, partly graphite schist is same direction and include disseminated pyrite along schistosed fracture, light gray-pale gray, silicification alteration	C535a C535b		mineral showing	04C059
114	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Vantat	107° 24′ 48″	14° 57′ 60″	759548	1656037	disseminated pyrite in slate, light gray-gray, weak silicification alteration, float, massive biotite alkali granite?, light reddish gray-greenish light gray	C536b		mineral showing	04C060
115	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 6″	14° 48′ 25″	760290	1638390	pyrite dissemination quartz veins (width:5-10cm and 3m *, N30W70W) in mixed facies sandstone and granite	B544: Mn:541ppm, Fe:4.32%		mineral showing	03B298
116	D-48-XII (B.DAKYOY)	Qz and Py	Vein and disssmination	Route18, 90km	107° 25′ 38″	14° 48′ 27″	761256	1638444	quartz vein and pyrite dissemination (strong) in muscovite schist and black schist in shear zone (width:4m, brittle to	B032: Fe:5.78%		mineral showing	01B106
117	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 40″	14° 48′ 31″	761289	1638577	pyrite and quartz along shear in slate and sandstone, alternative of slate and sandstone, with micro-folding and faults			mineral showing	03B266
118	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 45″	14° 48′ 6″	761460	1637813	pyrite dissemination and quartz lens (width:10cm, ductile to brittle) in slate in shear zone , biotite schist in part, slate facies is ditto to 03B285			mineral showing	03B286
119	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Dakpala	107° 25′ 55″	14° 52′ 44″	761675	1646358	hematite in muscovite schist, light gray-reddish brown			mineral showing	02C010
120	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 52″	14° 47′ 41″	761675	1637031	pyrite, schistose (moderate), medium grain, bluish gray			mineral showing	03B277
121	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 52″	14° 47′ 44″	761682	1637135	pyrite in slate, bedding of slaty, schistose (weak), dark gray,			mineral showing	03B278
122	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 54″	14° 47′ 51″	761748	1637343	quartz vein and pyrite dissemination (strong) in slate with shear zone (width:15m, brittle)	B033: Fe:5.78-6.55%		mineral showing	01B108
123	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 56″	14° 47′ 50″	761805	1637314	pyrite and quartz along shear, alternative of slate and sandstone, with micro-folding and faults			mineral showing	03B272
124	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 57″	14° 48′ 29″	761812	1638506	pyrite disseminated along fault and fault breccia (width:1m, N30W80N)) in cataclasite of hornblende-biotite granodiorite			mineral showing	03A345
125	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 58″	14° 48′ 27″	761842	1638455	pyrite dissemination in porphyritic, heterogeneous, hornblende-biotite granodiorite, many biotite segregated			mineral showing	03A344
126	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 25′ 59″	14° 48′ 27″	761863	1638460	pyrite dissemination in porphyritic, heterogeneous, hornblende-biotite granodiorite, many biotite segregated			mineral showing	03A343
127	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 3″	14° 47′ 34″	762011	1636821	quartz vein and pyrite dissemination (strong) in slate along shear zone (width:80m, brittle)	B034: fe:3.48-15.9%		mineral showing	01B110
128	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 12″	14° 47′ 4″	762275	1635900	pyrite dissemination in slate with biotite schist in locally, dark gray,			mineral showing	03B327
129	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 13″	14° 48′ 28″	762278	1638490	pyrite disseminated along fault and fault breccia (width:1m, N70E70N)) in cataclasite of hornblende-biotite granodiorite			mineral showing	03A339
130	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 15″	14° 49′ 2″	762330	1639550	pyrite disseminated in heterogeneous, hornblende-biotite granodiorite, many biotite segregated, and aplite dyke			mineral showing	03A328
131	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 14″	14° 47′ 26″	762350	1636580	quartz lenses and pyrite dissemination in turbidites consisting of very fine sandstone, siltstone and mudstone	A3078		mineral showing	03A303
132	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 15″	14° 47′ 11″	762384	1636117	pyrite dissemination and quartz vein (width:10cm) including, biotite generate (?) in alternation of slate and sandstone	B549		mineral showing	03B325
133	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 15″	14° 47′ 16″	762390	1636275	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	A3074		mineral showing	03A300
134	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 16″	14° 47′ 17″	762400	1636316	quartz lenses and pyrite dissemination in sheared zone of turbidites of very fine sandstone, siltstone and mudstone	A3075,A3076, A3077		mineral showing	03A301
135	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 17″	14° 48′ 28″	762400	1638500	pyrite disseminated, and aplite dyke (width:1m, N15W60W) in mylonite of heterogeneous, hornblende-biotite granodiorite			mineral showing	03A338
136	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	near border	107° 26′ 14″	14° 44′ 7″	762416	1630474	grey, biotite-hornblende gneiss, medium grained, and quartz veins (width:20-30 cm, L: 30m, N45W65W)	A186		mineral showing	02A078
137	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 18″	14° 47′ 15″	762458	1636246	quartz lenses and pyrite dissemination in turbidites of very fine sandstone, siltstone and mudstone	A3073		mineral showing	03A299
138	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 23″	14° 48′ 50″	762581	1639160	pyrite dissemination in heterogeneous, hornblende-biotite granodiorite, many biotite segregated, medium to coarse grained			mineral showing	03A325

Annex 6 List of Mineral Occurrences in B.Dakyoy District (6/6)

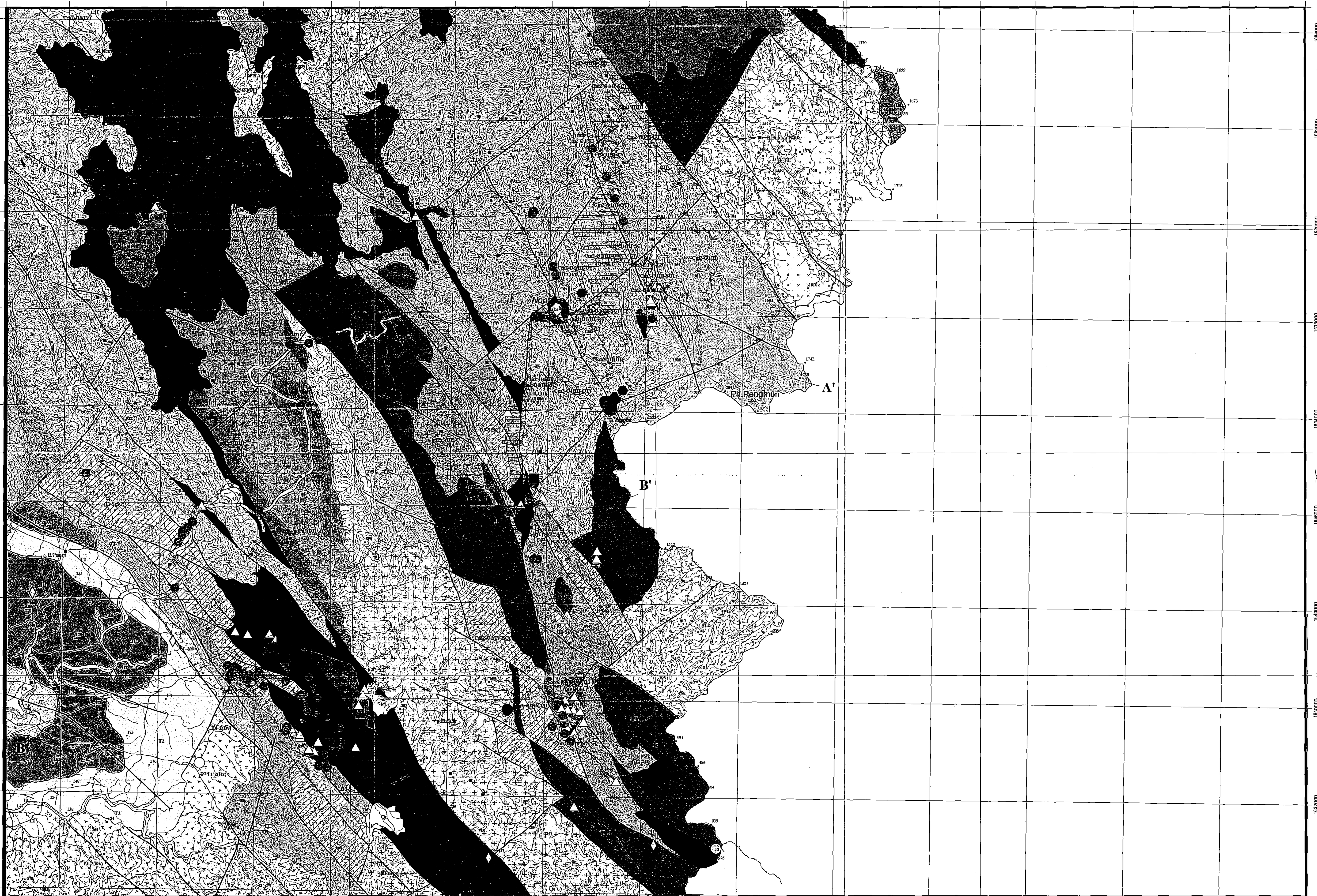
Ser. No.	Topomap No. (1:200,000)	Mineral	Type	Area	Coordinate		Coordinate (UTM, WGS84)		Characteristics of mineral showing and ore deposit	Results of ore analysis (Sample No. and analytical values) (Sample No.: JICA/DGEO, 2008)	Stage of investigation	Size	Outcrop No. (JICA/DGEO, 2008)
					Longitude	Latitude	EW	NS					
139	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 24″	14° 48′ 49″	762627	1639152	pyrite dissemination and quartz veins with pyrite in heterogeneous, hornblende-biotite granodiorite, many biotite segregated, medium to coarse grained	A3091: Cu322ppm, Fe:7.58%		mineral showing	03A324
140	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 30″	14° 48′ 37″	762790	1638780	pyrite disseminated in heterogeneous, hornblende-biotite granodiorite, many biotite segregated, medium to coarse grained			mineral showing	03A321
141	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 31″	14° 48′ 24″	762830	1638365	pyrite dissemination and films in turbidites of medium to fine sandstone			mineral showing	03A357
142	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 35″	14° 47′ 53″	762949	1637411	pyrite dissemination and films in turbidites of medium to fine sandstone			mineral showing	03A346
143	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B. Dakpala	107° 26′ 46″	15° 2′ 11″	763005	1663798	grey, disseminated pyrite in muddy slate, in tunnel	A179: Ag:2.56ppm, Fe:20.4%		mineral showing	02A041
144	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B. Dakpala	107° 26′ 47″	15° 2′ 18″	763031	1664011	mineralized rocks in white quartzite, hard and compact, collected from pit for exploration	A178: Ag:0.98ppm, Fe:6.2%		mineral showing	02A039
145	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 39″	14° 47′ 54″	763083	1637460	quartz vein in turbidites of medium to fine sandstone with pyrite dissemination	A3102		mineral showing	03A348
146	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 40″	14° 47′ 54″	763118	1637466	pyrite dissemination and films in turbidites of medium to fine sandstone			mineral showing	03A350
147	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Route18, 90km	107° 26′ 40″	14° 47′ 55″	763120	1637490	pyrite dissemination and films in turbidites of medium to fine sandstone			mineral showing	03A349
148	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	East of B.Dakpala	107° 27′ 15″	14° 55′ 4″	764001	1650696	strong sulphide ore in garnet gneiss, banded, as floats in stream	B137		mineral showing	02B143
149	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	East of B.Dakpala	107° 27′ 16″	14° 55′ 14″	764035	1651007	strong sulphide ore in garnet gneiss, banded, as floats in stream	B138		mineral showing	02B145
150	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	East of B.Dakpala	107° 27′ 18″	14° 55′ 35″	764079	1651645	pyrite dissemination and quartz lens in biotite gneiss, banded structure and quartz lens in concordant	B139		mineral showing	02B149
151	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Palong-Gnai	107° 27′ 52″	15° 16′ 38″	764685	1690475	quartz vein-lets (width:1cm-5cm), pyrite dissemination (moderate) in muscovite quartz schist, generate Fe-Mn oxides, strong limonitized in parts	B589		mineral showing	04B083
152	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Palong-Gnai	107° 27′ 54″	15° 16′ 32″	764742	1690302	strong limonitized, pyrite dissemination (moderate), generate Fe-Mn oxides			mineral showing	04B082
153	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	Nam Klabai	107° 28′ 10″	15° 11′ 41″	765302	1681353	quartz vein with disseminated pyrite in slate, dark gray-greenish dark gray, silicification and sericite? and chlorite alteration	C538b: Mn:707ppm, Fe:2.46%		mineral showing	04C062
154	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	near border	107° 28′ 10″	14° 45′ 14″	765865	1632578	mineralization of pyrite veins and dissemination and quartz veins in dark grey, biotite schist	A259,A260		mineral showing	02A364
155	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 36″	15° 8′ 28″	767938	1675455	pyrite dissemination in marble (lower part), and dark grey mudstone to muddy slate (upper part)			mineral showing	04A275
156	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 36″	15° 8′ 29″	767949	1675490	pyrite dissemination in marble	A4042		mineral showing	04A274
157	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 42″	15° 7′ 16″	768144	1673251	grey to dark grey, limestone (chemical deposit type)	A4040		mineral showing	04A264
158	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 47″	15° 5′ 28″	768327	1669935	float of quartz veins with pyrite dissemination (golg in pyrite?) in purplish grey to brown, muddy slate and sandstone	A4036		mineral showing	04A250
159	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 50″	15° 5′ 52″	768426	1670667	floats of white quartzite with quartz veins including pyrite dissemination (width:1cm to 2mm), muddy slate, sandstone			mineral showing	04A252
160	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 59″	15° 9′ 6″	768620	1676640	pyrite dissemination in grey, silicified limestone, brecciated			mineral showing	04A282
161	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 29′ 59″	15° 7′ 31″	768656	1673715	pyrite dissemination in grey, massive limestone (chemical deposit)			mineral showing	04A293
162	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	B.Klabai	107° 30′ 8″	15° 7′ 25″	768918	1673539	quartz veins (width:2cm, N75W70S), and network quartz veins and pyrite veins (width:5 to 10 cm, NS75E) in sheared zone of grey muddy slate	A4045: Cu:772ppm, Fe:16.1%, A4047: Cu:425ppm, Fe:20.7%		mineral showing	04A295
163	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 11′ 28″	14° 51′ 30″	735760	1643811	pyrite dissemination with malachite along fractures in biotite hornblende granodiorite, massive, medium grain			mineral showing	03B231
164	D-48-XII (B.DAKYOY)	Qz and Py	Vein and dissemination	May Phao Sauu Phanh	107° 11′ 28″	14° 51′ 30″	735771	1643811	malachite, pyrite dissemination along fractures in biotite hornblende granodiorite, massive, medium grain			mineral showing	03B232

【付属資料】

1 : 200,000 Geological Map of B.DAKYOY
D-48-XII

GEOLOGICAL MAP OF B.DAKYOY
(D-48-XII)

LAO PEOPLE'S DEMOCRATIC REPUBRIC
MINISTRY OF ENERGY AND MINES



Era	Period	Name	Symbol	Description
Cenozoic	Quaternary	Lucstrine deposits	Lake	Gravel, pebble, sand and silt
		Fluvial deposits	Q	Gravel, pebble, sand and silt
		Terrace deposits	Qt	Gravel, pebble, sand and silt
	Paleogene	Nong Fa Formation		Pyroxene basalt lava and basaltic pyroclastics
		Alkalline dike rocks	P1 (Ldk)	Lamprophyre and rhyolite dike
		Dakdray Formation	P1 (Agy)	Biotite andesitic lapilli tuffs (lamproites)
		Kengmo North Formation	P1	Conglomerate, conglomeric sandstone and sandstone
Mesozoic	Jurassic	Lavi Gnai Tai Formation	J2	Sandstone, mudstone, calcareous sandstone, interbedded sandstone and mudstone, limestone with silicified wood
		Namhiang Formation	J1	Sandstone, mudstone, and interbedded sandstone, mudstone and calcareous sandstone with Mollusca fossils
	Triassic	Makkhua Formation	T2	Conglomeric sandstone, sandstone, cherty mudstone, imestone, tuffaceous sandstone and sandy tuff
		Acidic intrusive rocks	gT2	Biotite granite and granite porphyry
		Namchang Formation	T1-2(Rv)	Rhyolitic ignimbrite
		Katha-Tai Formation	T1-2(Dv)	Dacitic welded tuff, dacitic lapilli tuff and tuffs
		Alok Formation		Andesitic to dacitic epiclastic breccias, andesitic welded tuff, tuff breccia, lapilli tuff, coarse tuff and sandy tuff
		Dakdouan Formation	T1-2	Conglomeric sandstone, sandstone, cherty mudstone, limestone, tuffaceous sandstone and sandy tuff
Paleozoic	Permian	Dakpala East Diorites		Mylonitic diorite and quartz diorite
		Kengmo North Diorites		Heterogeneous and melanoclatic granodiorite, tonalite and gabbro
		Antoum Granodiorites (III)		Biotite granite, granodiorite and porphyritic granite
		Antoum Granodiorites (II)		Mylonitic tonalite and quartz diorite
		Antoum Granodiorites (I)		Mylonitic granodiorite
	Carboniferous	Xe Xou East Granites		Two mica granite
		Kadon Formation	C	Conglomeric sandstone and sandstone
	Unknown	Annam Gneiss		Biotite gneiss, mix zone of gneiss, meta-sandstone and two mica granite
	Devonian	Nam Tabeng Diorites		Heterogeneous diotite and gabbro
		Dakkanat Granodiorites		Granodiorite
		Nam Ang Granodiorites		Potassic feldspar porphylitic granodiorite, gneissose granodiorite and cataclastic granodiorite
		San Xai Formation		Conglomerate and sandstone
	Silurian	Xe Xou North Granodiorites		Potassic feldspar porphyritic granodiorite and mylonitic granodiorite
	Ordovician - Silurian	May Phao Sauu Phanh Group (quartzite Member)		Quartzite and quartz sandstone
		May Phao Sauu Phanh Group (green schist Member)		Chlorite schist with biotite schist, muscovite schist and slate
		May Phao Sauu Phanh Group (green schist Member)	O-S (GC)	Chlorite schist with biotite schist, muscovite schist and slate
		May Phao Sauu Phanh Group (slate Member)	O-S	Slate and meta sandstone
	Cambrian - Ordovician	Xe Kaman Group (Unit IV) (quartzite Member)		Quartzite and quartz sandstone
		Xe Kaman Group (Unit IV) (schist Member)		Muscovite schist with biotite schist, muscovite-quartz schist, biotite schist and graphite schist with slate
		Xe Kaman Group (Unit IV) (slate Member)		Slate and meta sandstone
		Xe Kaman Group (Unit III) (quartzite Member)		Quartzite and quartz sandstone
		Xe Kaman Group (Unit III) (schist Member)		Muscovite schist with biotite schist, muscovite-quartz schist, biotite schist and graphite schist with slate
		Xe Kaman Group (Unit III) (slate Member)		Slate and meta sandstone
		Xe Kaman Group (Unit II) (quartzite Member)		Quartzite and quartz sandstone
		Xe Kaman Group (Unit II) (limestone Member)		Limestone with pelitic schist and slate
		Xe Kaman Group (Unit II) (schist Member)		Muscovite schist with biotite schist, muscovite-quartz schist, biotite schist and graphite schist with slate
		Xe Kaman Group (Unit II) (slate Member)		Slate and meta sandstone
		Xe Kaman Group (Unit I)		Schists, slate, quartzite and meta sandstone
Unknown		Annam Gabbro		Meta basalt
		Green rocks		Gabbro

30 Strike and dip of strata
30 Strike and dip of schistosity
Anticline
Syncline
Fault (concealed fault)
Village
Road

Mineral Occurrences

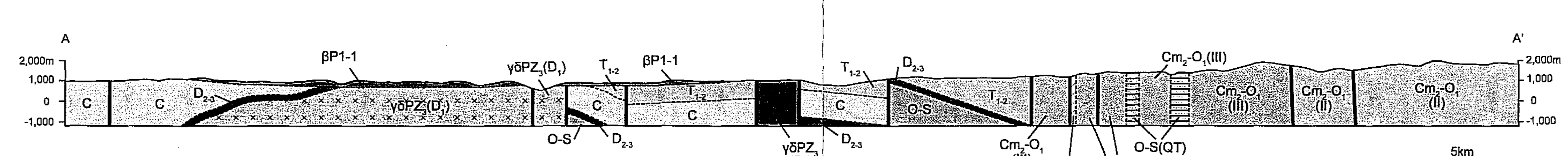
- Copper dissemination and Copper-bearing quartz vein (Cu, Au, Ag)
- Pyrite-bearing quartz vein
- Rubby and sapphire
- Bauxite
- Coal (lignite)
- Bentonite
- Kaolin
- Feldspar
- Aggregate
- Quartz vein
- Placer (Au)

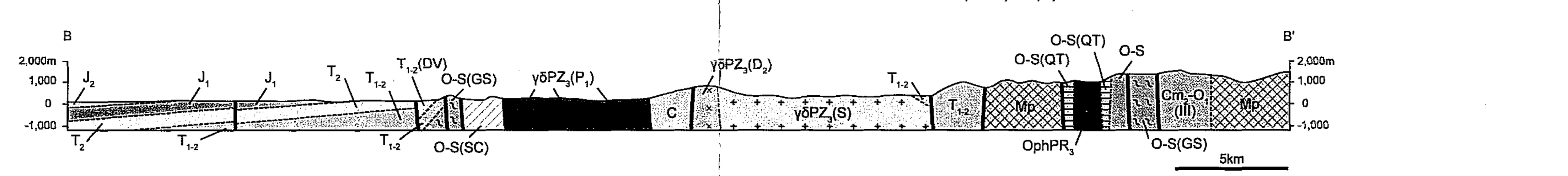
Geological survey by
Siphandone Vilayhack*, Sixomxeun Duangsurigna*, Phonetalome Vilaysan*
Sisaad Phomkenthao**, Thavone Khounchanthida** and Amkha Voravong***
Motomu Goto+, Yoshimitsu Negishi+, Kazuyasu Tsuda+ and Yasushi Watanabe++
*: Department of Geology, Lao,P.D.R.; **: Department of Geology, Pakxe Branch
***: Energy and Mine, Attapeu Province; +: JICA Expert
++: Geological Survey of Japan, AIST

The used topographic map is enlarged from the Department of National Geography's digital file, scale 1:100,000 of the D-48-35, D-48-36, D-48-47 and D-48-48, which sponsored by Japan International Cooperation Agency (JICA), 1996.
Delineation of international administrative boundaries on this map is approximate and must not be considered authoritative.

Interval of topographical contour is 100m

5 2.5 0 5 10 15 20 km





Department of Geology (DGEO), Ministry of Energy and Mines, Lao P.D.R
Japan International Cooperation Agency (JICA), Japan
2008

DGEO JICA

B.DAKYOY
1 : 200,000
D-48-XII

Report on Geology of the B. Dakyoy District,
Geological Sheet Map, 1: 200,000 in scale
Topographic Map No.: D-48-XII

Produced by: Japan International Cooperation Agency and
Department of Geology, Ministry of Energy and Mines, Lao. P.D.R.

Date of Print: October 30th, 2008