CHAPTER 4 GEOLOGICAL SURVEY IN THE ATTAPEU AREA

4.1 Introduction

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

4.2 Current Status and Issues of the Geological Division, DGEO

4.2.1 Current Status

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

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

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

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

4.2.2 Issues

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

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

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

4.3 Work Plan for Geological Survey

4.3.1 Results of Preliminary Survey

A preliminary field survey was conducted to construct our work plan for field survey in the Attapeu area. Participants are Messrs. Goto and Negishi from Japanese side and Mr. Khampha from DGEO.

Road Conditions: The major road runs from Pakxe, via Paksong, B.Thateng, B.Mo and Attapeu to the border of Vietnam in the study area for geological mapping at scale 1:200,000. It is paved and sole road. There are a few unpaved minor roads available for car only around the western and southern Attapeu and Paksong. In the rainy season, unpaved roads will turn muddy and would not be available for car. There are unpaved roads on the other side of the rivers of Xe Kong and Xe Kaman. To get to the other side, two ferries are available. There is an unpaved 20km road from the village of Paam in the eastern Attapeu along the Xe Kaman River. Although it is available for car, bridges on the roads are seemingly heavily damaged.

Geological aspects: In the target area, there are, in general, only few outcrops useful for collecting geological information. Along the newly constructed mountainous paved road between Attapeu and the border of Vietnam, a series of outcrops on the cut slopes is observed, however. This offers an important traverse for making geological cross sections and identifying geological structures. The route along the Xe Namnoy River provides us with good observation points for geological aspects that form the Bolaven Plateau.

As such, the accesses are generally poor for geological survey. Especially in the eastern area, difficult conditions include dense forested jungles, mountainous areas, no road available for car, few villages, etc.

4.3.2 Survey Methodology and Survey Routes

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

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

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

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

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

4.4 Producing the Satellite Images of Attapeu Area

The satellite data obtained by two sensors, TERRA/ASTER (Advanced Speceporne Thermal Emission and Reflection Radiometer (ASTER)) and ALOS/PALSAR (Phased Array Type L-band Synthetic Aperture Rader (PALSAR)), both of which were developed and manufactured in Japan, were used for this study.

The specification of both data and acquired data are given below.

4.4.1 ASTER Data

Produced ASTER images are shown in Figures 4.4.1 and 4.4.2, and specification of ASTER data is given in Table 4.4.1. The surface observation by ASTER was conducted from 705km high at recurrent day of 16 days.

1) Used Data

The study area is covered by 14 sheets of ASTER data and the list of them is shown in Table 4.4.2. The geometric correction of the data was conducted before use of data.

2) Data Processing

For producing images and mosaiking of the ASTER Data, a image processing software of "Imagine", ERDAS, USA, was used. The coordinates obtained from the satellite orbit were used for geocoding of imaged data. The UTM projection was conducted to the obtained data of WGS84 (Zone 48).

After the geocoding, edge enhancement and contrast stretching were conducted for obtaining more visually clear images.

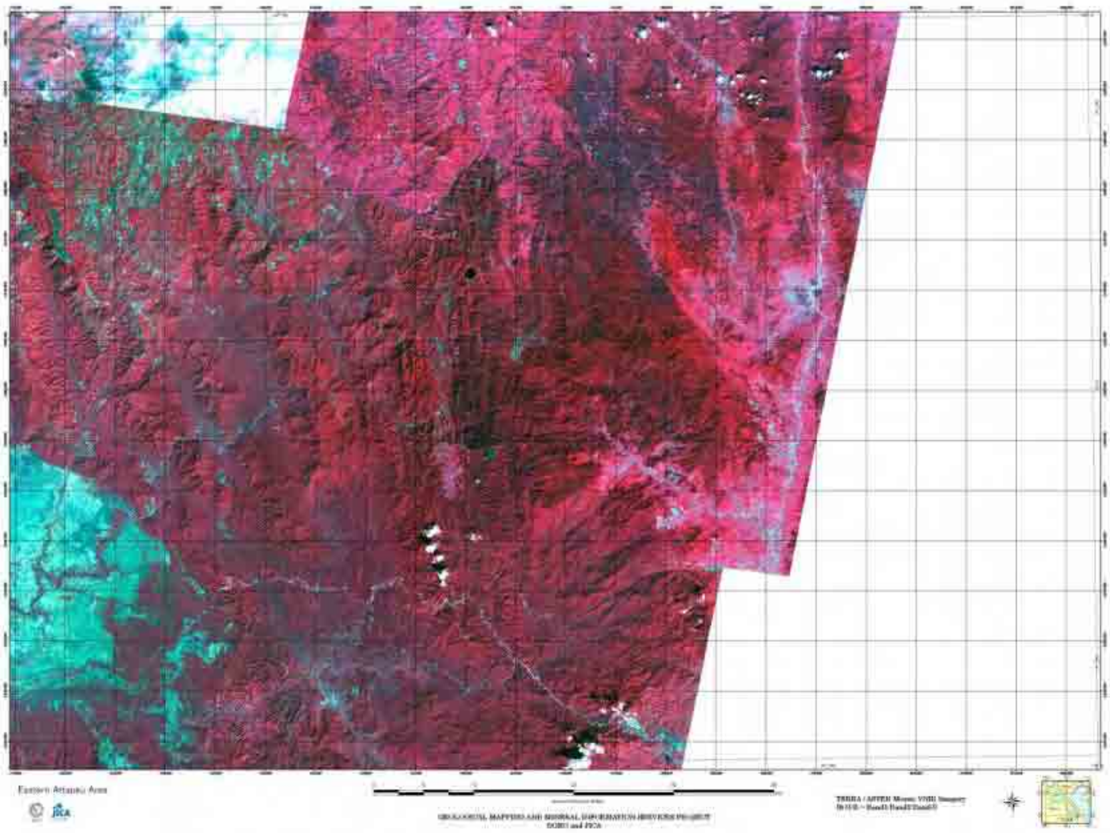

Figure 4.4.1 ASTER VNIR mosaic imagery of B.Dakyoy map sheet

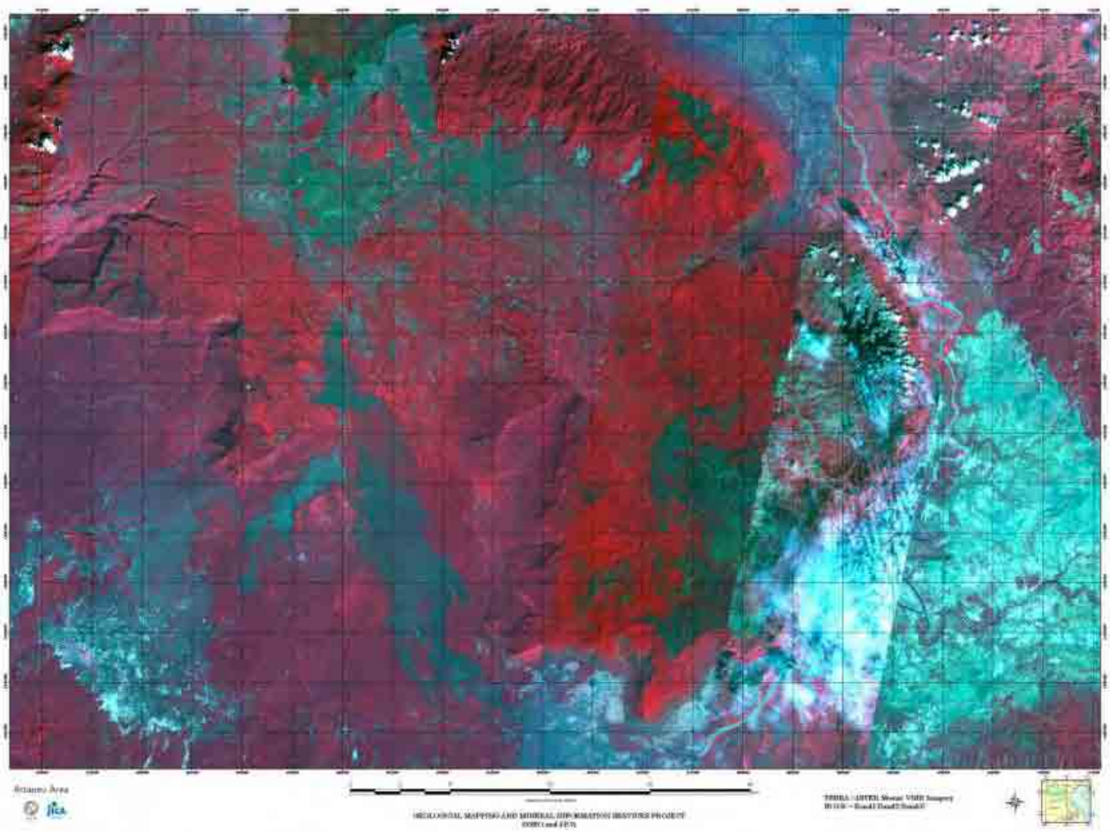

Figure 4.4.2 ASTER VNIR mosaic imagery of Attapeu map sheet

Table 4.4.1 Specification of ASTER Data

VNIR (Visible and Near-Infrared Radiometer)				
Band	Wave Length (μm)	Spatial Resolution (m)	Scan Width (km)	Remarks
1	0.52~0.60	15	60	Nadir viewing
2	0.63~0.69	15	60	Nadir viewing
3	0.76~0.86	15	60	Nadir viewing
Stereoscopic	0.76~0.86	15	60	Backward viewing (27.6°)
SWIR (Short Wave Infrared Radiometer)				
Band	Wave Length (μm)	Spatial Resolution (m)	Scan Width (km)	Remarks
4	1.600~1.700	30	60	Nadir viewing
5	2.145~2.185	30	60	Nadir viewing
6	2.185~2.225	30	60	Nadir viewing
7	2.235~2.285	30	60	Nadir viewing
8	2.295~2.365	30	60	Nadir viewing
9	2.360~2.430	30	60	Nadir viewing
TIR (Thermal Infrared Radiometer)				
Band	Wave Length (μm)	Spatial Resolution (m)	Scan Width (km)	Remarks
10	8.125~8.475	90	60	Nadir viewing
11	8.475~8.825	90	60	Nadir viewing
12	8.925~9.275	90	60	Nadir viewing
13	10.25~10.95	90	60	Nadir viewing
14	10.95~11.65	90	60	Nadir viewing

Table 4.4.2 ASTER Data

Path	Row	View	Date	Granule ID
125	141	2	2005-03-09	ASTL1A0503090329480503150765
125	140	2	2005-03-09	ASTL1A0503090329390503150764
125	139	2	2005-03-09	ASTL1A0503090329300503150763
125	141	5	2004-12-19	ASTL1A0412190329330501050148
125	140	5	2004-12-19	ASTL1A0412190329240501050147
125	141	2	2004-01-18	ASTL1A0401180331220403250019
125	140	2	2004-01-18	ASTL1A0401180331140403250018
125	141	4	2002-02-13	ASTL1A0202130331580202251022
125	140	4	2002-02-13	ASTL1A0202130331490202251021
125	140	1	2002-01-12	ASTL1A0201120332480202040776
124	140	1	2001-10-17	ASTL1A0110170329450110280623
125	141	4	2001-10-24	ASTL1A0110240335440111080434
125	140	4	2001-10-24	ASTL1A0110240335360111080433
125	139	4	2001-10-24	ASTL1A0110240335270111080432

4.4.2 PALSAR data

The produced PALSAR Fine Mode Images are given in Figures 4.4.3 and 4.4.4, and specification of PALSAR data in Table 4.4.3. The surface observation by PALSAR was conducted from 691km high at recurrent day of 46 days.

1) Used Data

A list of PALSAR data used for the study was shown in Table 4.4.4. The study area is covered by 15 sheets of PALSAR data. The geometric correction of the data was conducted before use of data. The data was obtained by the fine mode, HH and HY polaritization and at off-nadir angle of 34.3 degree.

2) Data Processing

For producing images and processing of the PALSAR Data, a image processing software of "Imagine", ERDAS, USA, was used. The coordinates obtained from the satellite orbit were used for geocoding of imaged data. The UTM projection was conducted to the obtained data of WGS84 (Zone 48). Because of foreshortening generated by topographic relief, ortho-correction was processed after making distortion model. The ortho-correction was conducted based on the topographic data of Shuttle Radar Topography Mission, USA.

After the geocoding and ortho-correction of the image data, filtering and contrast stretching were conducted for obtaining more visually clear images.

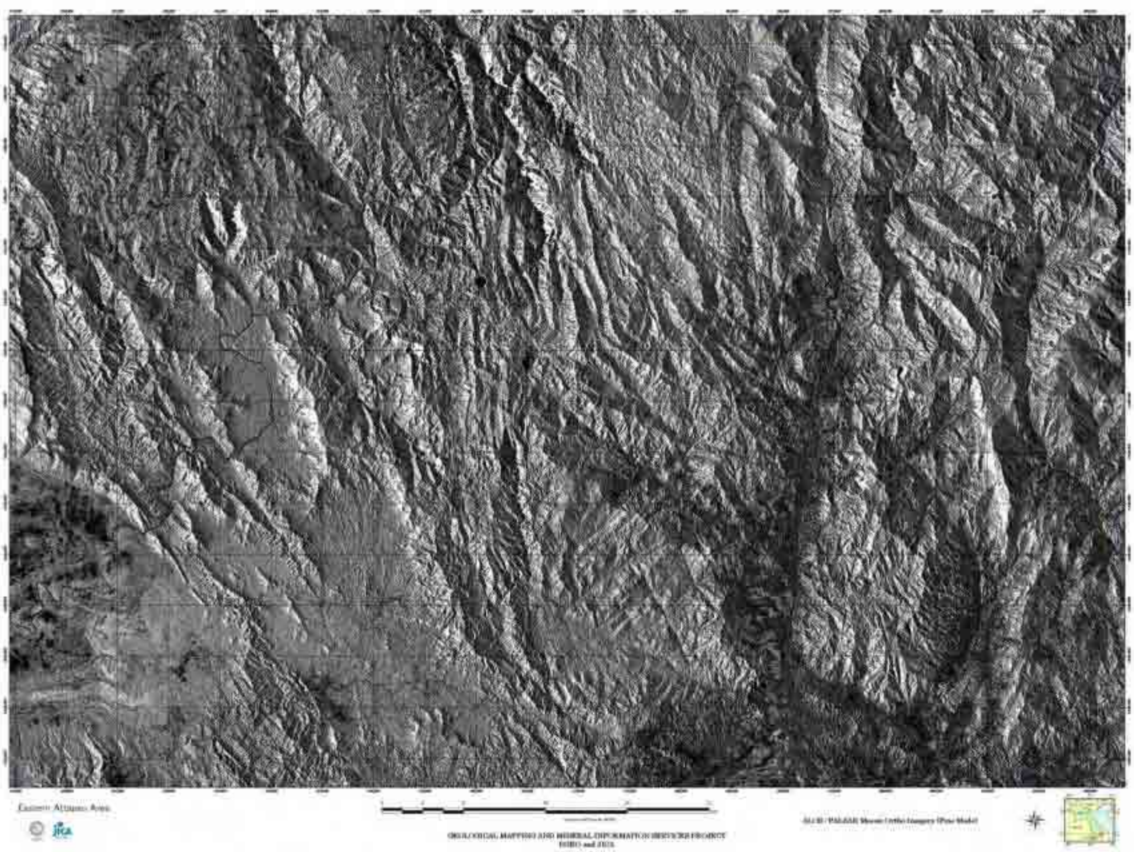

Figure 4.4.3 PALSAR Fine mode mosaic imagery of B.Dakyoy map sheet

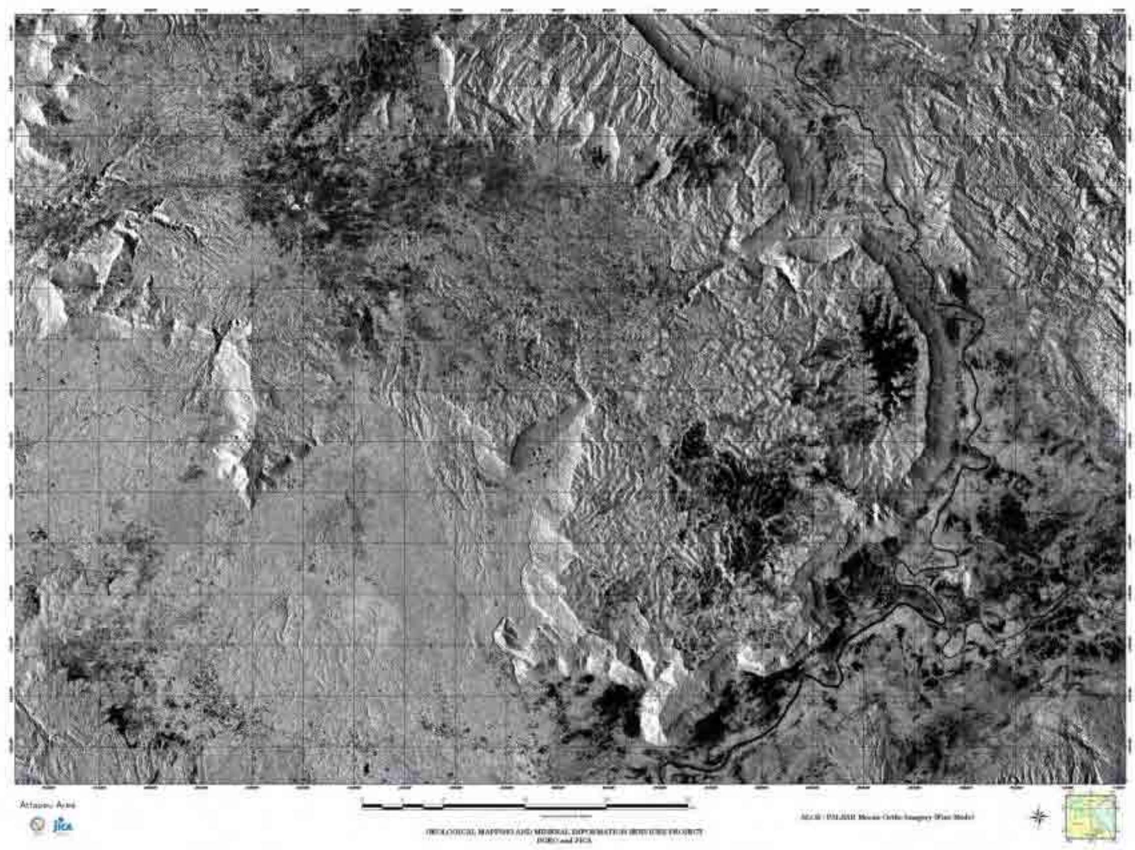

Figure 4.4.4 PALSAR Fine mode mosaic imagery of Attapeu map sheet

Table 4.4.3 Specification of PALSAR data

Mode	Polarization	Incident Angle (deg)	Spatial Resolution (m)	Scan Width (km)	NE sigma 0
High Resolution Mode	HH or VV / HH+HV or VV+VH	8 - 60 deg	10m (2 looks) 20m (4 looks)	70km	< -23dB
ScanSAR Mode	HH or VV	18 - 43 deg	100m (multilook)	250 - 350km	< -25dB
Polarimetric Mode	HH+HV+VH+VV	8 - 30 deg	30m	30km	< -29dB

Table 4.4.4 PALSAR data

Path	Row	Polarization	Off Nadir Angle (deg)	Date	Granule ID
473	28	HH	34.3	2007/2/14	PASL15007021415274207072 50006
473	29	HH	34.3	2007/2/14	PASL150070214152750070725 0007
473	30	HH	34.3	2007/2/14	PASL1500702141527580707250008
474	28	HH	34.3	2007/3/3	PASL1500703031529540707250012
474	29	HH	34.3	2007/3/3	PASL1500703031530020707250013
474	30	HH	34.3	2007/3/3	PASL1500703031530110707250014
475	28	HH	34.3	2007/2/2	PASL1500702021531560707250003
475	29	HH	34.3	2007/2/2	PASL1500702021532040707250004
475	30	HH	34.3	2007/2/2	PASL1500702021532120707250005
476	28	HH	34.3	2007/1/4	PASL1500701041533590709040001
476	29	HH	34.3	2007/1/4	PASL1500701041534070709040002
476	30	HH	34.3	2007/1/4	PASL1500701041534160709040003
477	28	HH	34.3	2007/1/21	PASL1500701211536130707250000
477	29	HH	34.3	2007/1/21	PASL1500701211536220707250001
477	30	HH	34.3	2007/1/21	PASL1500701211536300707250002

4.5 Geology and Geological Structure in the Attapeu Area

The survey work includes site investigation, route mapping, outcrop description, data input, etc. Drawing geological columnar section and geological cross section based on observation data were carried out. The geological descriptions and other background data for geological map at scale 1:200,000 are shown in Annex 4.

The geology of the Attapeu area based on the survey is given below. Figure 4.5.1 illustrates survey routes and Figures 4.5.2 and 4.5.3 show lithofacies distribution map based on field survey. The major tectonic elements of the area were compiled in the geological interpretation map of Figure 4.5.4.

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

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

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

b. Correlation of geological formation name and geological age

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

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

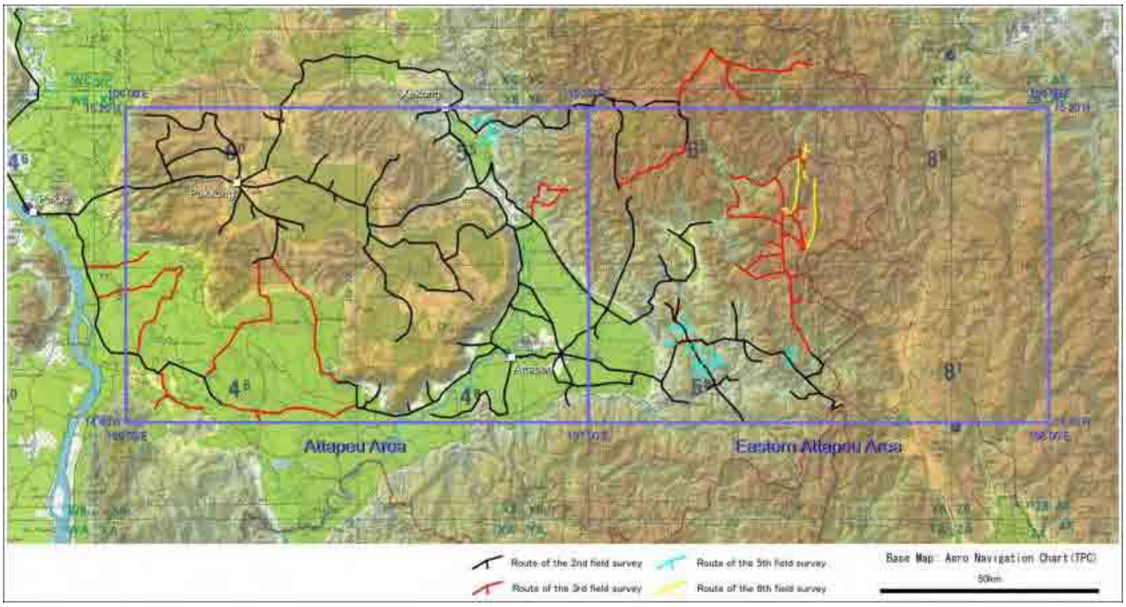

Figure 4.5.1 Field survey routes

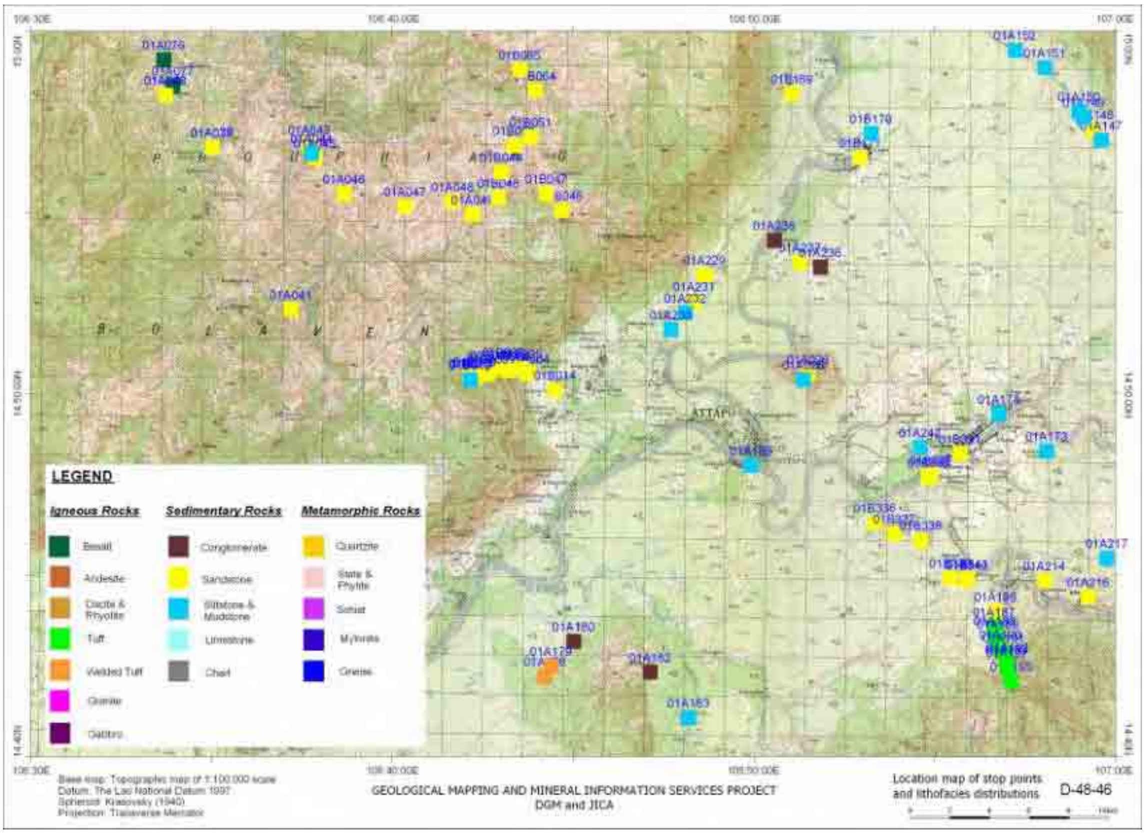

Figure 4.5.2 Lithofacies distribution map (D-48-46)

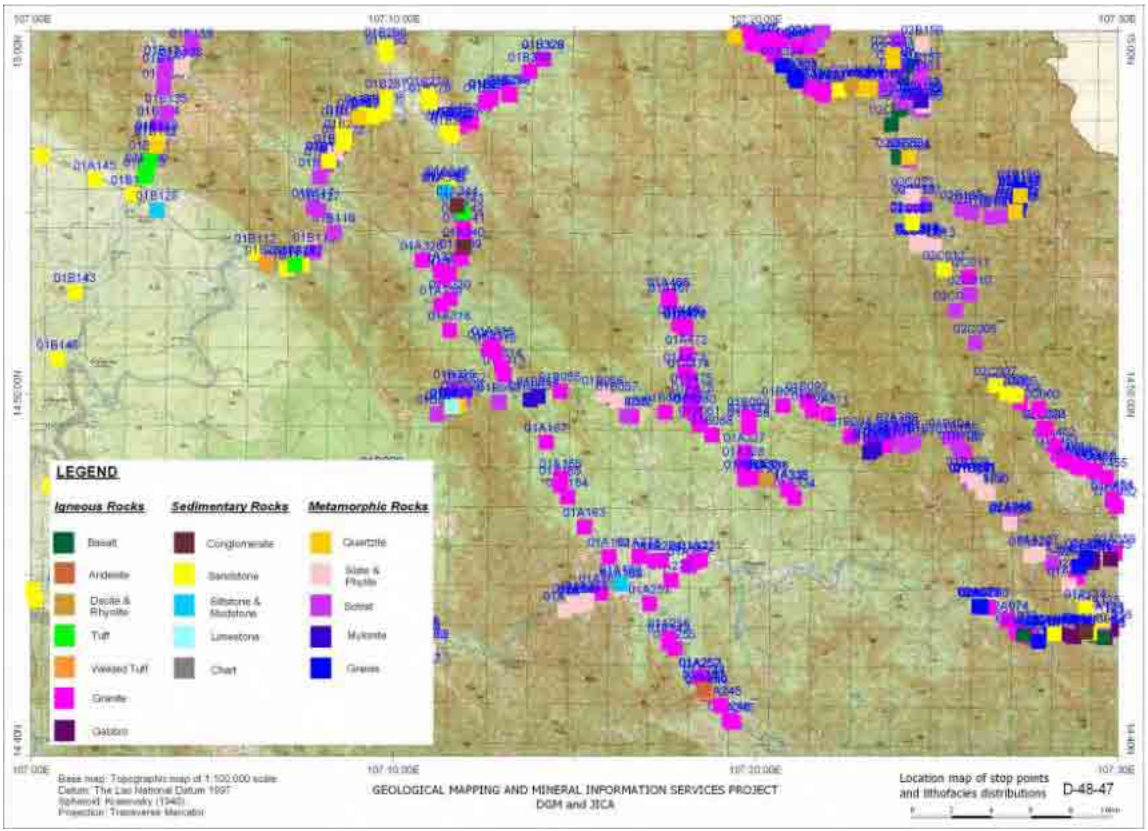

Figure 4.5.3 Lithofacies distribution map (D-48-47)

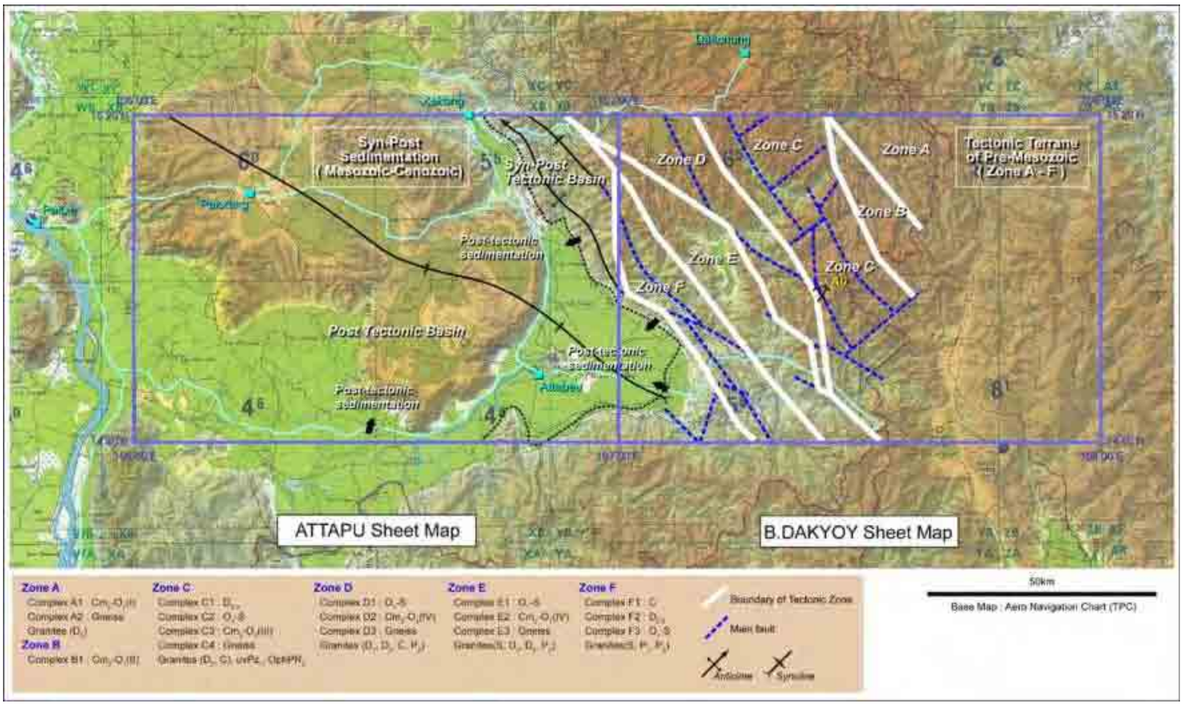

Figure 4.5.4 Comprehensive tectonic map of survey area

4.5.1 B.Dakyoy Area

1) Geology

The geology of the B.Dakyoy map sheet area consists of gneisses of possibly related to accretion of the continental crust, gabbro, granite, pelitic schist dominant metamorphic rocks, slate, metasandstone, conglomerate dominant low-grade metamorphic rocks, chert, limestone, marine to continental sedimentary rocks, rhyolitic to andesitic volcanic rocks, basalt lava, etc. Each group of lithological unit is distributed in a separate area, forming structural terrain. The geological map produced based on the second and third surveys is shown in Figure 4.5.5.

Gneiss and gabbro are observed in the eastern mountain fringe (Photo 4.5.1). Their occurrence extends in a northwest–southeast direction. Granite is interruptedly observed in the central mountain area and its occurrence is in a northwest-southeast direction as a whole. Their east to west width of granite bodies is about 30km long. It is not a single intrusive body but composite intrusive body consisting individual rock bodies of granites (biotite granite and two-mica granite), granodiorite (porphyritic granodiorite, schistose granodiorite and granodioritic mylonite) (Photo 4.5.2), quartz diorite and diorite. The mylonitic texture and schistose texture characterized by preferred orientations of quartz and colored mineral or mica-fish are observed in some of granodiorite and diorite. Those textures are observed in the border zones to pelitic schist or other granitic rocks. A sandstone and mudstone mixture occurs at the contacts of granodiorite or two-mica granite with pelitic schist.

Photo 4.5.1 Gneiss in the eastern mountain fringe along at Route 18B

Photo 4.5.2 Granodiorite in the central mountain area at Route 18B

Slate, metasandstone and conglomerate dominant low-grade metamorphic rocks are broadly observed in the mountain area, together with muscovite schist and greenschist dominant schistose rocks or quartzite (Photo 4.5.3). Pelitic schist is often observed locally in the low-grade metamorphic rock (Photo 4.5.4), suggesting that it is sheared zone. Quartzite is closely related to conglomerate in the north of Nong Fa Lake in the eastern part and to gneiss along the Route 18B in the southeastern part. The schist and quartzite extend in NW-SE to S-N in their occurrence and these metamorphic rocks sandwich the basement rocks of gneiss, gabbros and granites between themselves. The chert and limestone occur between slate, metasandstone, conglomerate dominant low-grade metamorphic rock and pelitic schist in the northeast mountain fringe in the eastern mountain area. Their occurrences are limited, however. The limestone does not include muddy facies and is homogeneous to the naked eye. Along the Xe Kaman River, white limestone of probably coral reef origin is rarely observes.

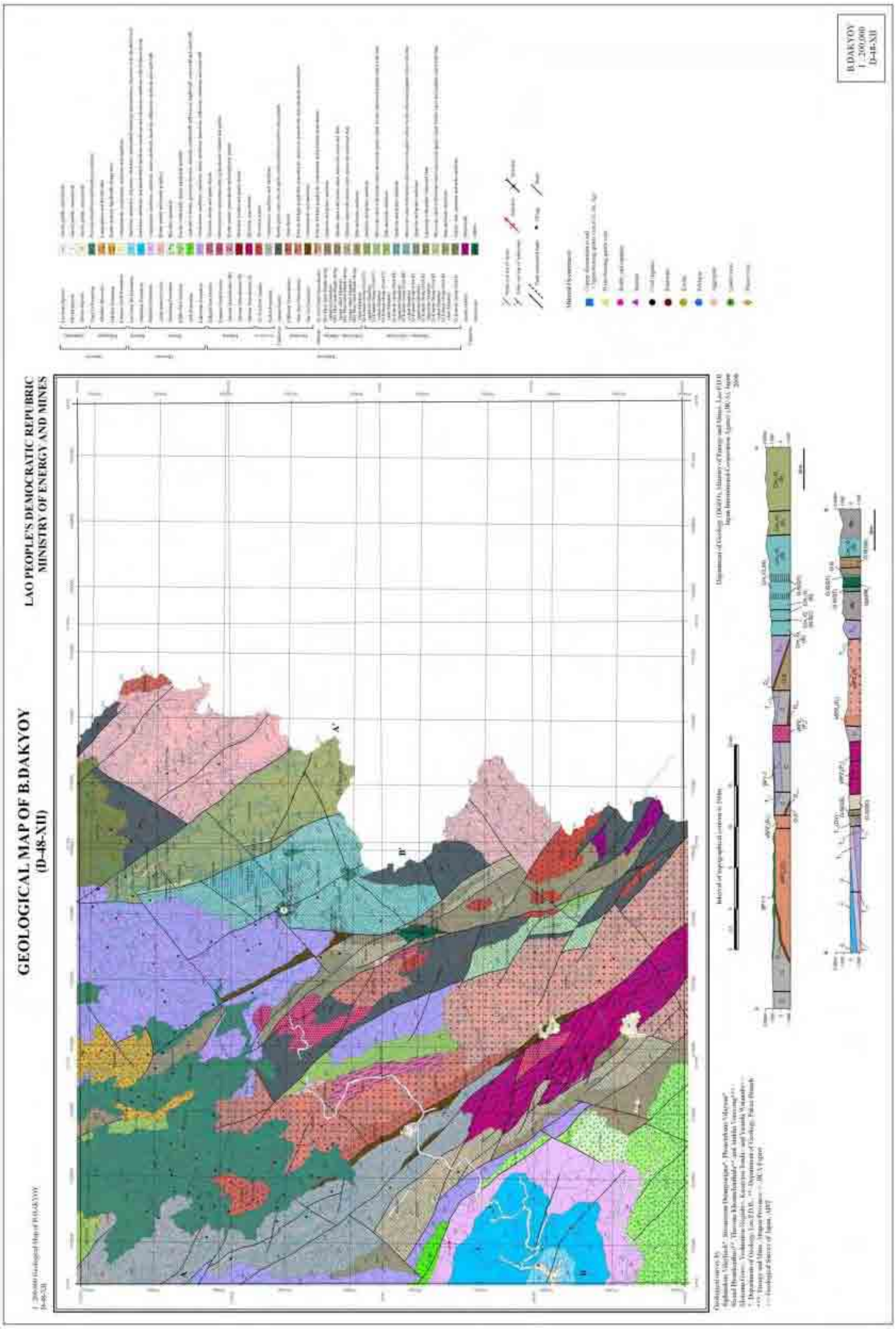

Figure 4.5.5 Geological map of B.Dakyoy map sheet

Photo 4.5.3 Pelitic schist in the central mountain area along Xe Kaman River

Photo 4.5.4 Slate with cleavage structure in the northern part

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

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

Felsic volcanic rocks occur in the northern fringe area. They show pale brown to brown and consist of fine to coarse dacitic tuff with abundant biotite and a small amount of hornblende and lapilli tuff (Photo 4.5.5). The geological age is considered to be Neogene.

Basic volcanic rocks occur in the northern fringe area. They consist of pyroxene basalt lava (Photo 4.5.6). They are considered to be erupted around the Neogene to Quaternary period.

Photo 4.5.5 Dacitic tuff in the northern fringe area

Photo 4.5.6 Basalt lava in the northern fringe area

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

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

2) Geological Structure

From geological situation of the B.Dakyoy map sheet area and structures observed in the formations and the rock bodies, five structures zones are identifiable in the pre-Carboniferous geological units that occur in the mountain area. The structural zones are classified as、 in westward direction, gneiss and gabbro dominant zone, quartzite dominant zone in metamorphic rock, granite dominant zone in metamorphic rock, pelitic schist dominant zone and slate dominant zone. They extend in NW-SE to S-N. The schistosity developed in individual formations in the structural zones is steeply inclined at an angle of 70 to 80 degree and extends in NW-SE to S-N harmonious with the extended direction of the structural zones. Ductile to brittle shear zones to have formed probably in the deep to medium/shallow area are observed in the granite and schist on every border between the structural zones. Mylonite, schist, cataclasite, etc. occur in these shear zones (Photos 4.5.7 and 4.5.8). 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.

Photo 4.5.7 Mylonite in the granite at Route 18B

Photo 4.5.8 Shear zones with fish-quartz of the slate in the eastern mountain area along the Xe Kaman River

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

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

4.5.2 Attapeu MapSheet Area

1) Geology

The geology of the Attapeu map sheet area tends, in general, to be younger toward the west. It consists of, in a westward direction, massive hard sandstone, intermediate to felsic volcanic rocks, three units of alternating beds of continental sandstone and mudstone, continental sandstone, basic to intermediate volcanic rocks and terrace sediments. Geological structures include, in a westward direction, an anticline, a monocline and a flat structure that forms the Bolaven Plateau. A gentle syncline in the southeast part and in its westward a monoclinic structure is observed. The geological map produced based on the results of the second and third surveys is shown Figure 4.5.6.

The massive hard sandstone occurs in the mid- to upper stream of the Houay Po River in the east of Sapeuan village in the north of Attapeu. This sandstone consists mainly of fine to coarse lithic sand and quartzose sand intercalated by thin layers such as conglomerate, rhyolitic tuff and tuffaceous sandstone, etc (Photo 4.5.9). They are considered to be formed in Carboniferous.

Photo 4.5.9 Massive hard sandstone in the mid- to upper stream of the Houay Po River in the east of Sapeuan village

Photo 4.5.10 Rhyolite in the upper stream of the Houay Po River

The intermediate to acidic volcanic rocks occur in the east, the northeast and the southeast of Sapeuan, in the northeast fringe of the survey area and in the east and west of the south part of survey area. They show pale gray to white and consist mainly of fine to coarse tuff, lapilli tuff, volcanic breccia, volcanic conglomerate (Photo 4.5.10) and welded tuff. Most of rubbles in the volcanic breccia and volcanic conglomerate are rhyolitic tuff and welded tuff. Although the geological ages of these have been considered as Triassic, it possibly is Permian, judging from fossils observed in the upper formation.

The alternating beds of continental sandstone and mudstone broadly occur in the east of the Bolaven Plateau and extend southwards. They are grouped into three units, i.e., the upper, middle and lower. The lower unit consists of medium calcareous sandstone with fossils, conglomeratic sandstone, alternating beds of thin dark gray siltstone and mudstone, dark gray limestone and pale green siliceous mudstone or thin chert in an ascending order. The calcareous medium sandstone includes fossil shell (Photo 4.5.11) and trace fossil and reddish brown mudstone includes silicified wood (Photo 4.5.12). The middle part consists of alternated thick pale gray to pale purple medium to fine quartzose sandstone and thick bluish gray to purplish gray siltstone intercalated by reddish brown fine sandstone. They include a small amount of small rubbles of tuff. The uppermost part is intercalated by green tuffaceous coarse sandstone.

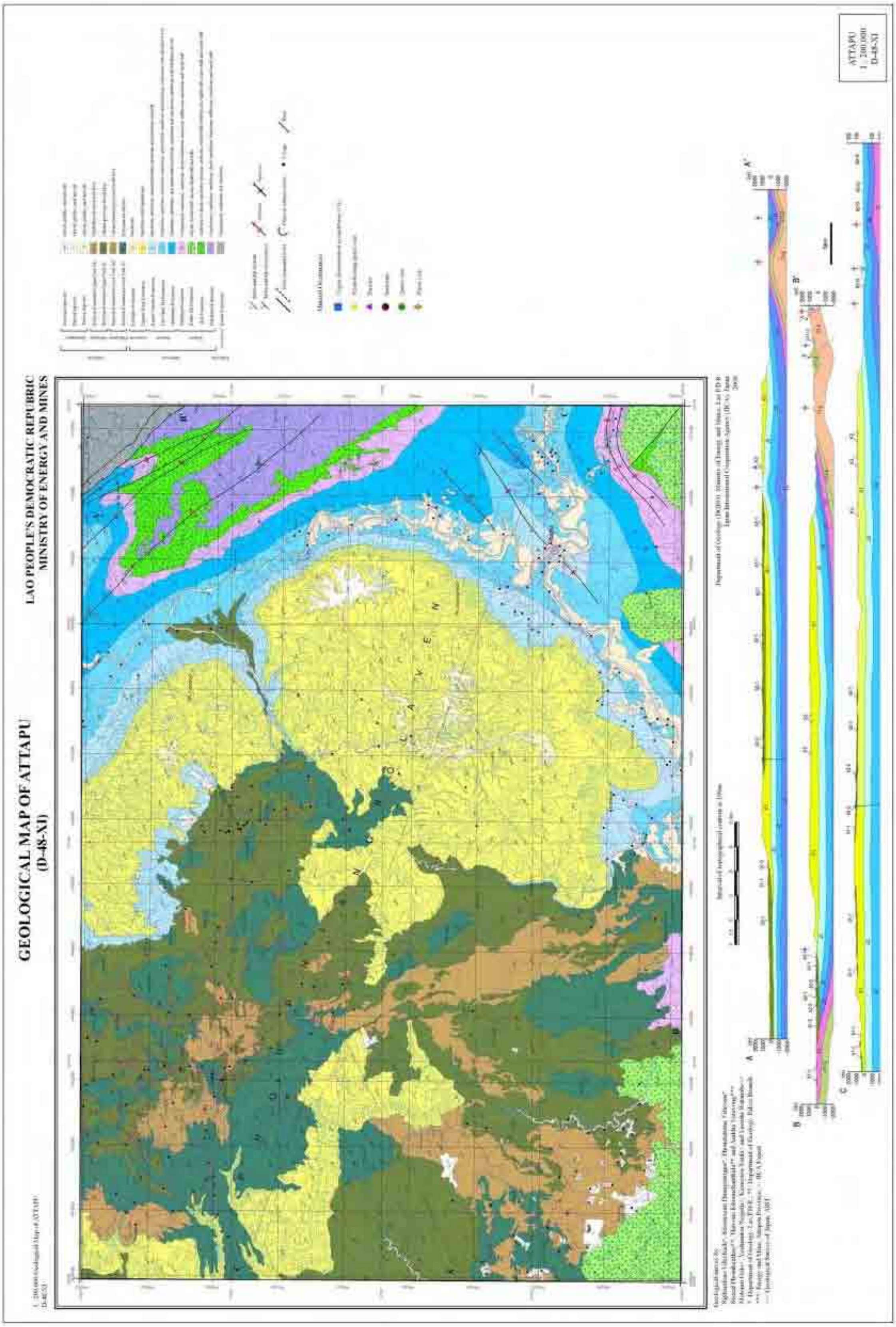

Figure 4.5.6 Geological map of Attapeu map sheet

Photo 4.5.11 Fossil shell in the midstream of the Houay Po River in the east of Sapeuan village

Photo 4.5.12 Silicified wood in reddish brown mudstone in the east of Attapeu

Photo 4.5.13 Parallel lamina in the continental sandstone near Choomphoy village in the west of Attapeu

Photo 4.5.14 Cross-lamina in the uppermost sandstone in the south Bolaven Plateau

The continental sandstone forms the Bolaven Plateau and extends westwards. It consists of medium to coarse quartzose and lithic sand (Photo 4.5.13), including carbonized wood fragments. Laminas are formed in the sandstone and its one unit ranges from several tens cm to one m. Thin reddish to bluish gray siltstone to mudstone overlays conglomerate and at least three units are observed. Sandstone in the uppermost part shows white to pale gray and has a high permeability (Photo 4.5.14). Parallel lamina and cross-lamina of ten to several tens cm are observed and angular quartz rubbles in the massive part are included. Since kaolin clay occurs on the contact with the lower alternating beds of sand and mud, it is possible to be the unconformity.

The basic to intermediate volcanic rocks occur in the western Bolaven Plateau. They consist, in ascending order, of pyroxene basalt, andesite, olivine basalt and nepheline-olivine basalt. The latter two are porous. The olivine basalt includes the mantle nodule of lherzolite, pyroxenite, etc. (Photo 4.5.15). The nepheline-olivine basalt has not suffered from erosion and the structure of pahoehoe ropy lava is observed (Photo 4.5.16). The geological ages of their eruption are believed to be Pliocene to Pleistocene for pyroxene basalt and andesite; Holocene for olivine basalt; and latest Quaternary for nepheline-olivine basalt.

Photo 4.5.15 Mantle nodule (lherzolite, pyroxenite, etc) in the olivine basalt in the north of Pakxong

Photo 4.5.16 Pahoehoe ropy lava in the nepheline-olivine basalt in the south of Pakxong

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

2) Geological Structure

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

4.6 Mineral Resources in the Attapeu Area

The Attapeu area is known as an area that have various mineral showings such as gold, copper, lead, zinc as shown on the mineral resources map at 1:1,000,000 issued by DGM in 1991 (Figures 4.6.1 and 4.6.2). This chapter describes mineral occurrences observed during the second and third surveys.

4.6.1 Metallic Mineral Resources

1) Gold

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

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

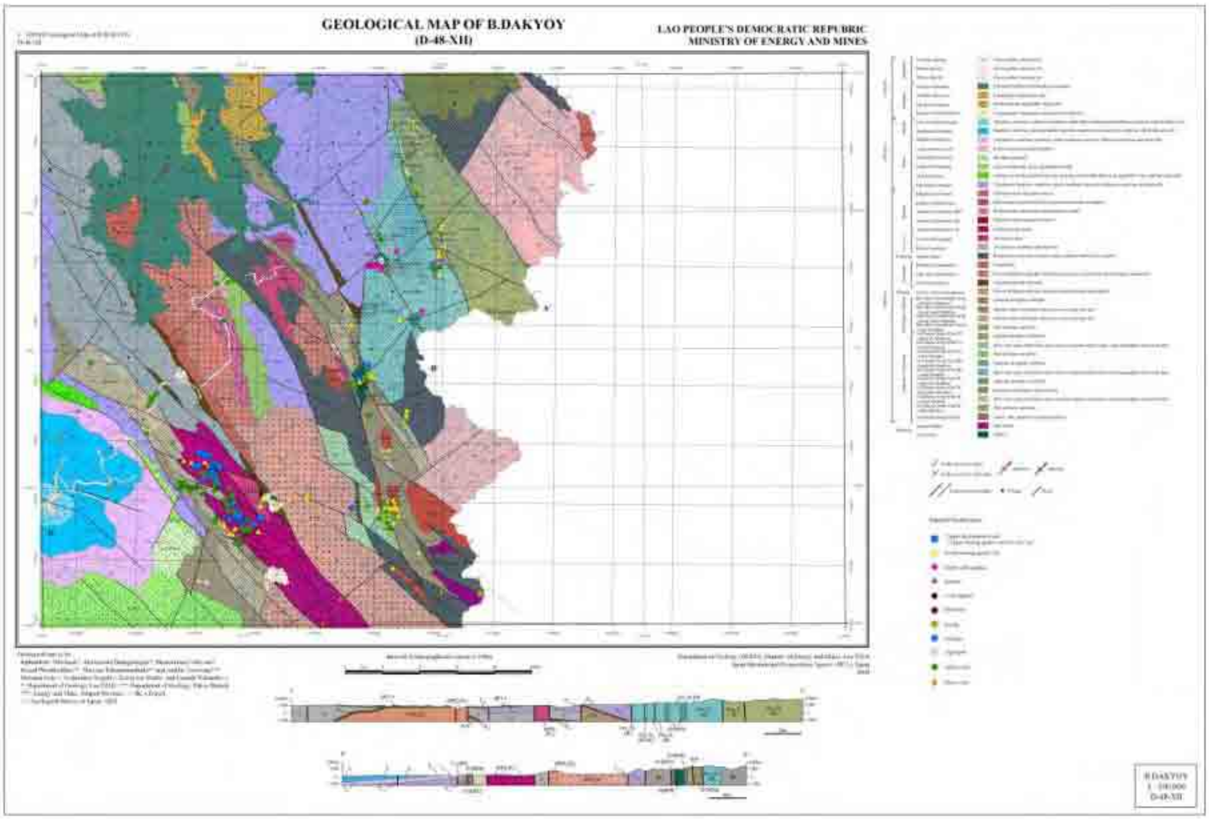

Figure 4.6.1 Geological and mineral occurrences map of the B.Dakyoy map sheet

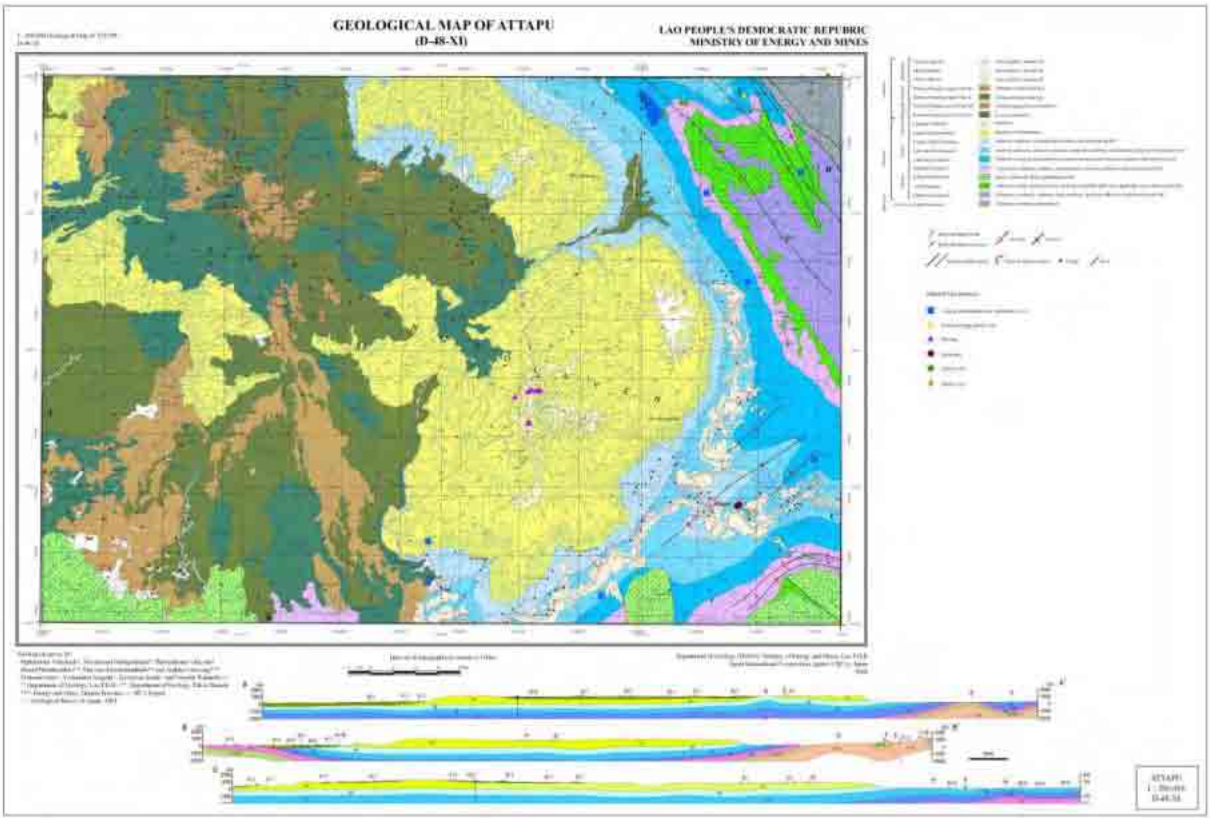

Figure 4.6.2 Geological and mineral occurrences map of the Attapeu map sheet

2) Copper

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

Mineralization occurs as dissemination along small-scaled fractures in the alternating beds of the Permian to Jurassic marine sandstone and mudstone. Copper minerals of malachite and azurite are observed (Photo 4.6.2). The country rock is not altered. It is highly possible to be a strata-bound deposit type; however, due to mineralization constrained in fractures, it is also possible to be related to hydrothermal fluids. The neighboring Triassic rhyolite is possible heat source for the hydrothermal fluids.

Photo 4.6.1 Gold mine in the north of Ban Dakyoy village

Photo 4.6.2 Copper mineral indicative (azurite) and fossil shell

3) Bauxite

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

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

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

4) Rare Earth Elements

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

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

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

5) Placer Gold

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

4.6.2 Non-Metallic Mineral Resources

1) Feldspar

Phenocrysts of alkali feldspar have a homogeneously large size of up to 3cm across in the granodiorite that broadly extends in the central mountain area of the B.Dakyoy map sheet. Some of granodiorite are weathered into soils and observed in various places (Photo 4.6.3). Weathered granodiorite turns brittle and feldspar phenocrysts are large; thus it will be easy to pick them by sieving or vibrating. They are good raw material for tile and ceramics.

2) Kaolinite

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

Photo 4.6.3 Weathered granodiorite

Photo 4.6.4 Brick manufacturing

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 (Photo 4.6.4).

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

4) Talc

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

5) Limestone

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

6) Gemstone

Villagers mine gemstone by panning around Nong Fa Lake located in the mountain area in the eastern part of the B.Dakyoy map sheet (Photos 4.6.5 and 4.6.6). They are chiefly sapphire, ruby and spinel. Nong Fa Lake is seemingly formed by the late Quaternary volcanic activities with the basalt erupted from a substantial depth. Spinel observed there is melted; thus, gemstone would also come from the deep place with the eruption.

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

Photo 4.6.5 Picking gemstone with sieve around Nong Fa Lake

Photo 4.6.6 Ruby (left) and Sapphire (right)collected

7) Rock

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.

4.6.3 Other Mineral Showings

1) Epithermal Alteration Zone

A relatively brittle shear zone of 100m long (east-west) in the Paleozoic slate and metasandstone is 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 (Photo 4.6.7). 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.

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 (Photo 4.6.8). Quarts veinlets are also locally observed. Thus, it is possible that acid-leached and enrichment alteration would be formed at formation of ignimbrite.

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

Photo 4.6.7 Pyrite dissemination and quartz veins in the shearzone

Photo 4.6.8 Leaching alteration in the ignimbrite

4.7 Geochemical Survey of Stream Sediments

4.7.1 Purpose of Survey

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

4.7.2 Survey Method

Sampling method, sample preparation and analytical method of geochemical survey are given below.

1) Sampling Method

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

A total of 479 stream sediments samples was collected and the sample location of them are given in Figures 4.7.1 and 4.7.2.

2) Sample Preparation

Sample preparation of stream sediments for chemical analysis was conducted in Vientiane office of ALS Chemex and chemical analysis was conducted at chemical laboratory of ALS Chemex Australia.

3) Chemical Analysis

Chemical analysis of following 51 elements was conducted.

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

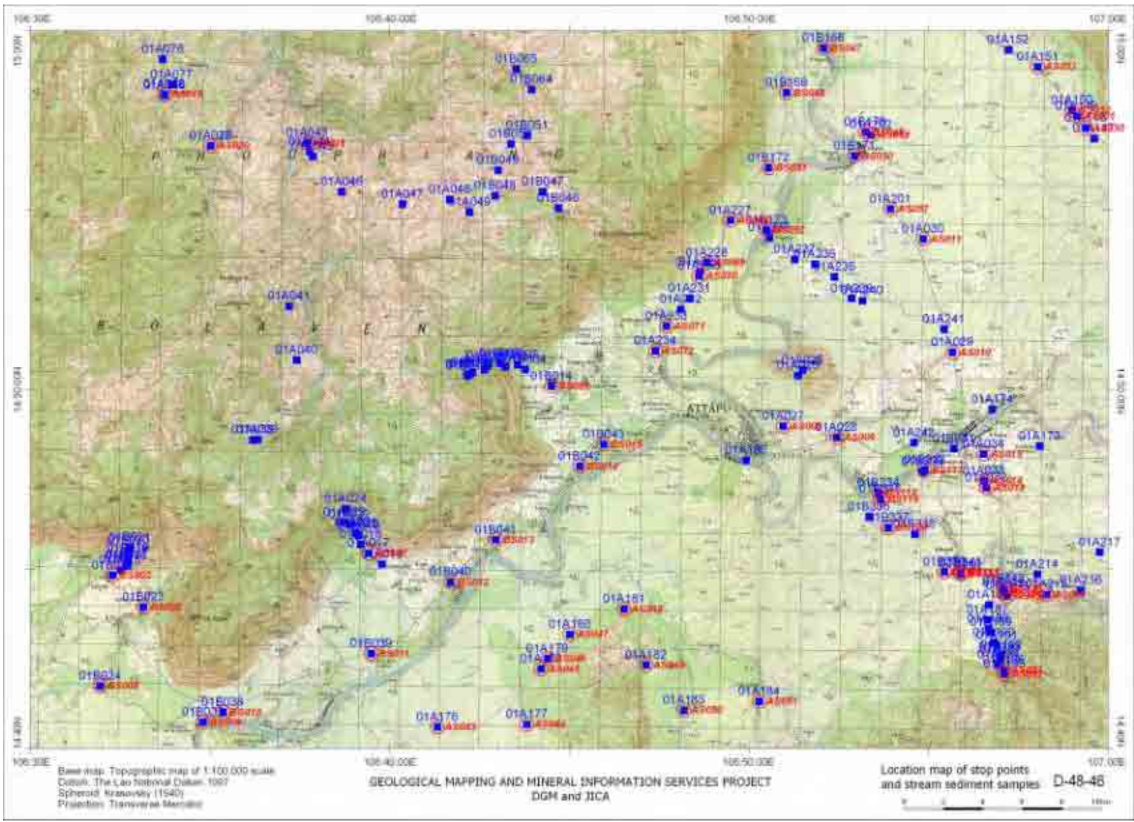

Figure 4.7.1 Sample location of stream sediments (1)

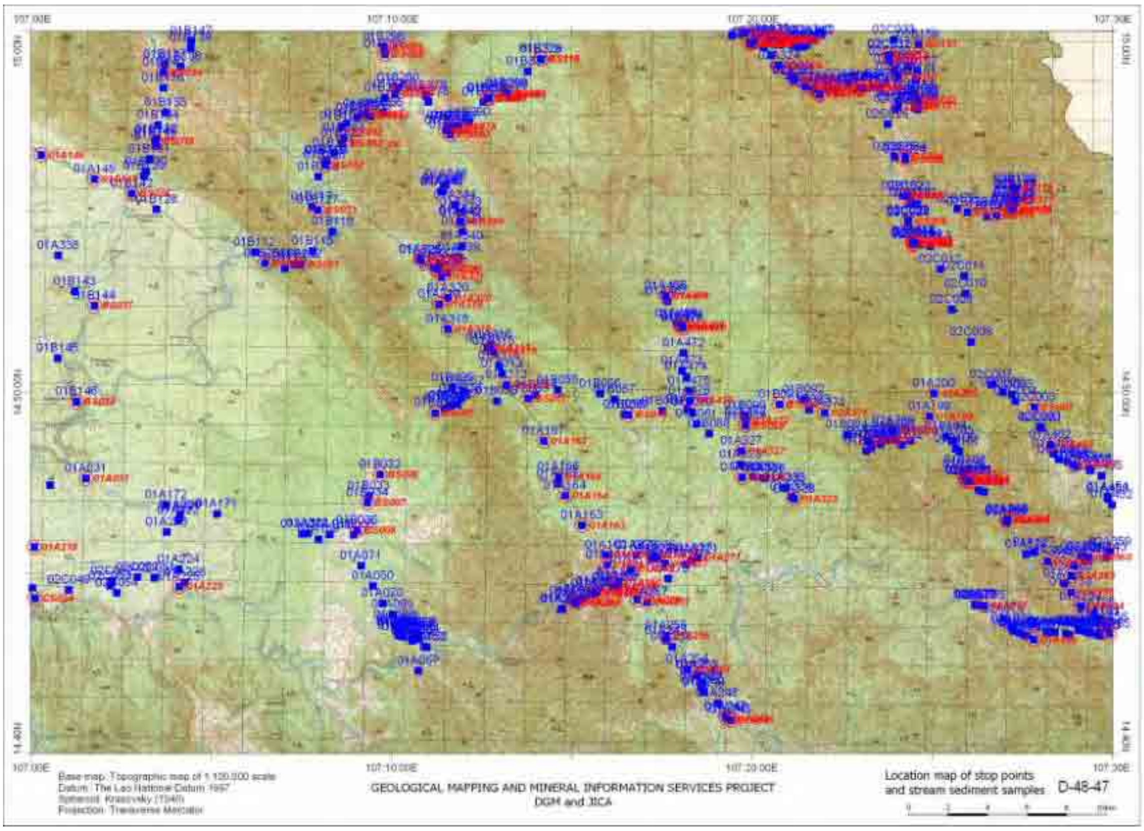

Figure 4.7.2 Sample location of stream sediments (2)

4.7.3 Data Analysis

Statistical treatment was conducted for all samples of stream sediments for understanding the chemical natures, particularly the one related to mineralization, of the survey area. The analytical results were proceeded by computer for calculation of statistical values, mono- and multi-variate analyses. Data analysis was conducted using logarithm value.

1) Mono-variate Analysis

Histogram and cumulative frequency curves were drawn and statistical values were calculated. For the samples with concentration less than detection limit, the value of half of the detection limits was used. The mean value used here is geometric means

For understanding the relationships among elements, correlation coefficients were calculated. For determination of threshold value to define anomaly, cumulative frequency curve and EDA (Exploration Data Analysis, Kurzl, 1988) were considered, and cumulative frequency curve was considered to be more appropriate for this study.

Results of statistical analysis of Au are given below, as an example.

The concentrations of Au in stream sediments range from the value less than detection limit (<0.1ppb) to 4,830 ppb.

As shown in cumulative frequency curve (Figure 4.7.3), bending points are confirmed on the cumulative frequency curve and it can be also seen some populations in the figure. Considering nature of mother population and variation of Au concentration, 200ppb seemed to be the most appropriate value for threshold value to define anomaly.

Based on the threshold values, geochemical anomaly map of Au was drawn and shown in Figure 4.7.4.

The geochemical anomaly maps of other elements were prepared using the same methods as Au.

2) Multi-Variate Analysis

Factor analysis is a method by which the factors, groups of closely related elements, controlling chemical natures of the area can be extracted. At first, factor analysis of all the analyzed elements of 51 elements was conducted to choose factors controlling the chemical nature of rock and mineralization. Then, using the results of this, 21 elements (Au, Af, As, Bi, Ce, Cr, Cu, Fe, La, Mo, Ni, Pb, S, Sb, Sn Th, U, W, Y and Zn) of related to mineralization were selected and factor analysis of only these 21 elements were conducted for further consideration of elements that related to the mineralization.

From the results of factor analysis conducted for 21 elements, factors related to chemical nature of rocks and mineralization were extracted and distribution map of high factor score for these factors were made.

Following five factors were obtained from the results of factor analysis of 21 elements.

(Factor)	(Relation)
Factor 1: Ag, Cr, Cu, Fe, Mo, Ni, Sn, Y, Zn	mafic rock
Factor 2: Ce, La, Th, U, Y	felsic rock: granitic rocks
Factor 3: As, Bi, Pb, Sb	acidic hydrothermal mineralization
Factor 4: W, (Bi)	acidic hydrothermal alteration
Factor 5:Au ((Bi))	gold mineralization

From the related elements and distribution of high factor scores, Factor 1 is considered to be reflect chemical nature of mafic rocks such as basalt and gabbro. Since the elements enriched in granitic magma were extracted by Factor 2 and high factor score of Factor 2 occur in the area of granite, Factor 2 is related to chemical nature of granitic rocks. The elements related to Au and Cu mineralization, particularly mineralization of acidic hydrothermal mineralization, were extracted by Factor 3. W and Bi, extracted by Factor 4, are elements related to mineralization associated to granitic rocks, and Au and ((Bi)), extracted by Factor 5, are directly related to Au mineralization.

4.7.4 Results of Geochemical Survey of Stream Sediments

The interpretation of the results of geochemical survey was conducted using distribution maps of high concentration anomalies and factor score for extracting the areas of high potentiality for mineral resources. The results of interpretation of key elements and each factors of factor analysis are given below.

1) Distribution of Au Anomaly

The distribution map of Au concentration is shown in Figure 4.7.4. The samples with Au concentration higher than threshold value of 200 ppb occur in following areas.

a. Surrounding area of south of the Nong Fa Lake

b. The Nong Fa Lake Area

c. Northeast of the Nong Fa Lake

d. Northwest of the Nong Fa Lake

e. Ho Chi Minh Trail area in south

f. Other areas

The samples with very high Au concentrations of more than 1,000ppb occur in:

a. Near the area of the gold mine of the army concession in the south of Nong Fa Lake

b. Ho Chi Minh Trail area in south

2) Distribution of Ag Anomaly

The distribution map of Ag concentration is shown in Figure 4.7.5. The maximum value of Ag is 16.4ppm. The samples with Ag concentration higher than threshold value of 0.13ppm occur in following areas.

a. The areas, such as the Bolaven Plateau, where basalt lavas of the Neogene, Tertiary and Quaternary occur.

b. Southeastern part of the gold mine of army concession

c. Northeastern part of the Nong Fa Area

3) Distribution of As Anomaly

The distribution map of As concentration is shown in Figure 4.7.6. The maximum value of As is 83.3 ppm. The samples with As concentration higher than threshold value of 20ppm occurs in following areas.

a. Surrounding area of the gold mine of army concession

b. Northwest part of the Nong Fa Lake

c. Near the border to Vietnam in the east of Route 18B

d. Northeastern part of the Nong Fa lake

e. Near Route 18B, southwest of the Ban Paam Village

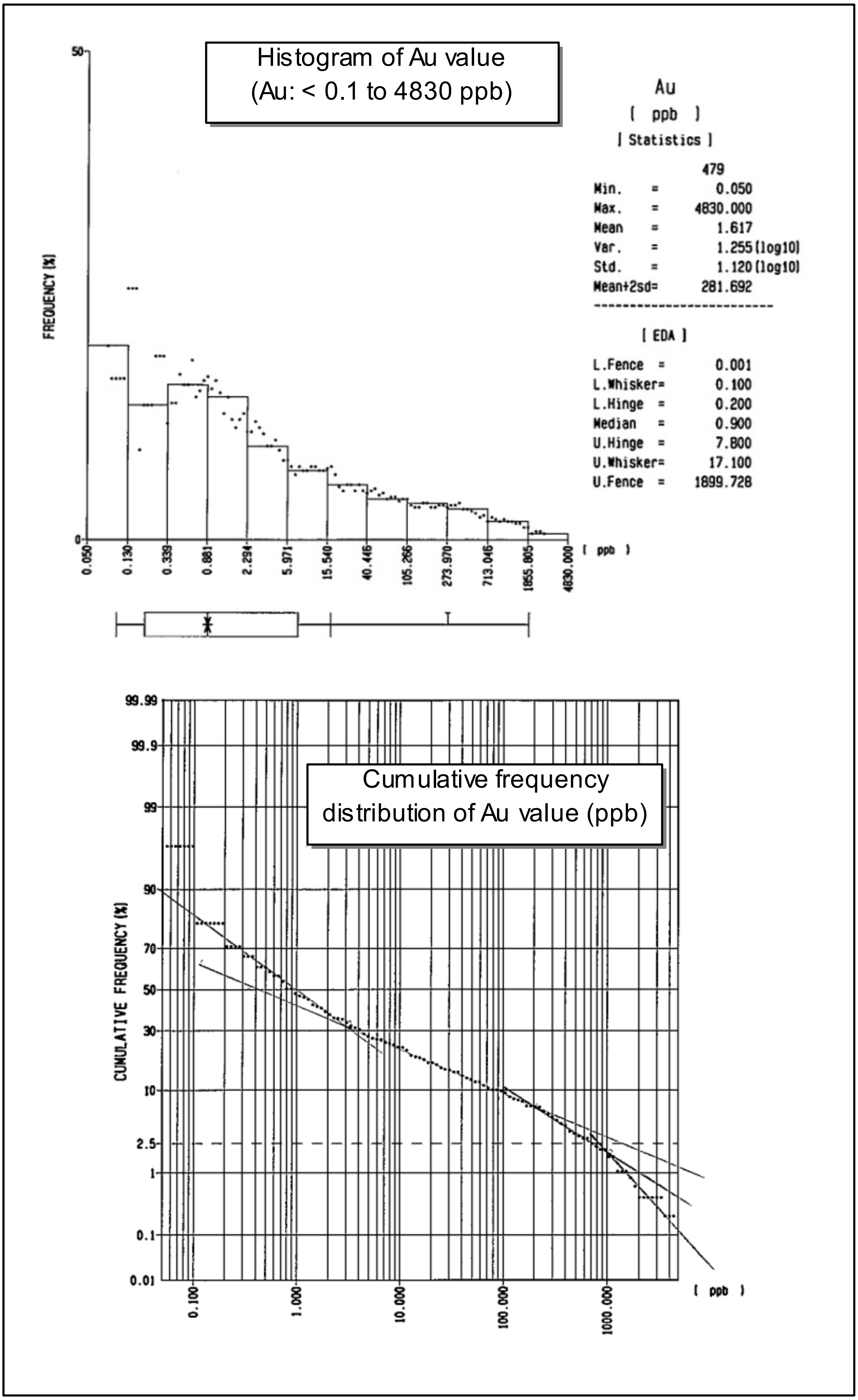

Figure 4.7.3 Histogram and cumulative frequency curve of Au

4) Distribution of Sb Anomaly

The distribution map of Sb concentration is shown in Figure 4.7.7. The maximum value of Sb is 2.97 ppm. The samples with Sb concentration higher than threshold value of 2.0ppm occu in following areas.

a. Surrounding area of the gold mine of army concession

b. Northwest part of the Nong Fa Lake

c. Near the border to Vietnam in the east of Route 18B

d. Northeastern part of the Nong Fa Lake

e. Southeast part of the gold mine of army concession

f. Near Route 18B, southwest of the Ban Paam Village

g. The area of basalt lavas erupted on the Bolaven Plateau

5) Distribution of Bi Anomaly

The distribution map of Bi concentration is shown in Figure 4.7.8. The maximum value of Bi is 57.7 ppm. The samples with Bi concentration higher than threshold value of 1.1 ppm occur in following areas.

a. Southeast part of the gold mine of army concession

b. Surrounding area of the Nong Fa Lake

c. Northeast part of the Nong Fa Lake

6) Distribution of Cu Anomaly

The distribution map of Cu is shown in Figure 4.7.9. The concentrations of Cu range from 0.7 to 79.6 ppm. The bending of cumulative frequency curve, dividing the mother population, occurs at 3, 9, 13, 50 and 78ppm. The samples with Cu concentration higher than threshold value of 50ppm occur in following locations.

a. The areas, such as the Bolaven Plateau, where basalt lavas of the Neogene, Tertiary and Quaternary occur.

b. The gold mine of army concession in south part of the Nong Fa Lake

c. The area distributed by Gabbro in the border area to Vietnam, east of Route 18B

d. Neat Route 18B, southwest of the Ban Paam Village

7) Distribution of Pb Anomaly

The distribution map of Pb concentration is shown in Figure 4.7.10. The maximum value of Pb is 884 ppm. The samples with Pb concentration higher than threshold value of 50 ppm occur in following areas.

a. The area of basalt lavas erupted on the Bolaven Plateau occur

b. Surrounding area of the gold mine of army concession

8) Distribution of Zn Anomaly

The distribution map of Zn concentration is shown in Figure 4.4.11. The maximum value of Zn is 193 ppm. The samples with Zn concentration higher than threshold value of 82ppm occur in following areas.

a. The areas, such as the Bolaven Plateau, where basalt lavas of the Neogene, Tertiary and Quaternary occur.

b. Southwest of the gold mine of army concession

9) Distribution of High Factor 1 Score

Factor 1 is represented by close relation of Ag, Cr, Cu, Fe, Mo, Ni, Sn, Y, Zn and is related to mafic rocks. The distribution of Factor 1 score is shown in Figure 4.7.12. The samples with Factor 1 scores higher than 1.0 occur in following area.

a. The area of basalt lavas erupted on the Bolaven Plateau occur

b. The area near the gold mine of army concession, being distributed by mafic rocks such as dolerite,

c. The area distributed by Gabbro in the border area to Vietnam, east of Route 18B

10) Distribution of High Factor 2 Score

Factor 2 is represented by close relation of Ce, La, Th, U, Y and is related to granitic rocks. The distribution of Factor 2 score is shown in Figure 4.7.13. The samples with Factor 2 score higher than 1.0 occur in following area.

a. The areas of the Silurian granite

b. The area of two-mica granite of unknown ages

c. Upper stream area of the Xe Kaman River

11) Distribution of High Factor 3 Score

Factor 3 is represented by close relation of As, Bi, Pb, Sb and is related to acidic hydrothermal mineralization. The distribution of Factor 3 score is shown in Figure 4.7.14. The samples with Factor 3 scores higher than 1.0 occur in following area.

a. Surrounding area of the gold mine of army concession

b. Northeast part of the Nong Fa Lake Area

c. Northwest part of the Nong Fa Lake Area

d. Surrounding area of the Nong Fa Lake

e. Near the border to Vietnam, east of Route 18B

f. Near the Route 18B, southeast of Ban Paam Village

g. Near Ho Chi Minh Tail, northwest of Ban Paam Village

12) Distribution of High Factor 4 Score

Factor 4 is represented by W and is related to acidic hydrothermal mineralization. The distribution of Factor 4 score is shown in Figure 4.7.15. The samples with Factor 4 scores higher than 1.0 occur in following area.

a. Surrounding area of the gold mine of army concession

b. Southeast part of the gold mine of army concession

c. Northeast part of the Nong Fa Lake

d. Surrounding area of the Nong Fa Lake

e. Near Ho Chi Minh Tail, north of Route 18B

13) Distribution of High Factor 5 Score

Factor 5 is represented by Au and is related to acidic gold mineralization. The distribution of Factor 5 score is shown in Figure 4.7.16. The samples with Factor 5 scores higher than 1.0 occur in following area.

a. Surrounding area of the gold mine of army concession

b. Northeast part of the gold mine of army concession

c. Northeast part of the Nong Fa Lake

d. Surrounding area of the Nong Fa Lake

e. The area distributed by Gabbro in the border area to Vietnam, east of Route 18B

f. Near Ho Chi Minh Tail, north of Route 18B

g. Near Ho Chi Minh Tail, south of Route 18B

4.7.5 Discussion

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

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

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

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

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

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

   a. Surrounding area of the gold mine of army concession in the south of the Nonga Fa Lake.

   b. Surrounding area of the Nonga Fa Lake

   c. Northeast of the Nong Fa Lake

   d. Northwest of the Nong Fa Lake

   e. Surrounding area of Ho Chi Minh Trail

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

   - Factor 3: As, Bi, Pb, Sb (Acidic hydrothermal mineralization)

   - Factor 4: W, (Bi) (Acidic hydrothermal mineralization)

   - Factor 5: Au, ((Bi)) (Gold mineralization)

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

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

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

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

1) Surrounding area of the gold mine of army concession in the south of Nong Fa Lake

2) Surrounding area of the Nong Fa Lake

3) Northeast of Nong Fa Lake

4) Northwest of the Nong Fa Lake

5) The area near the cross point of Route 18B and Ho Chi Minh Trail

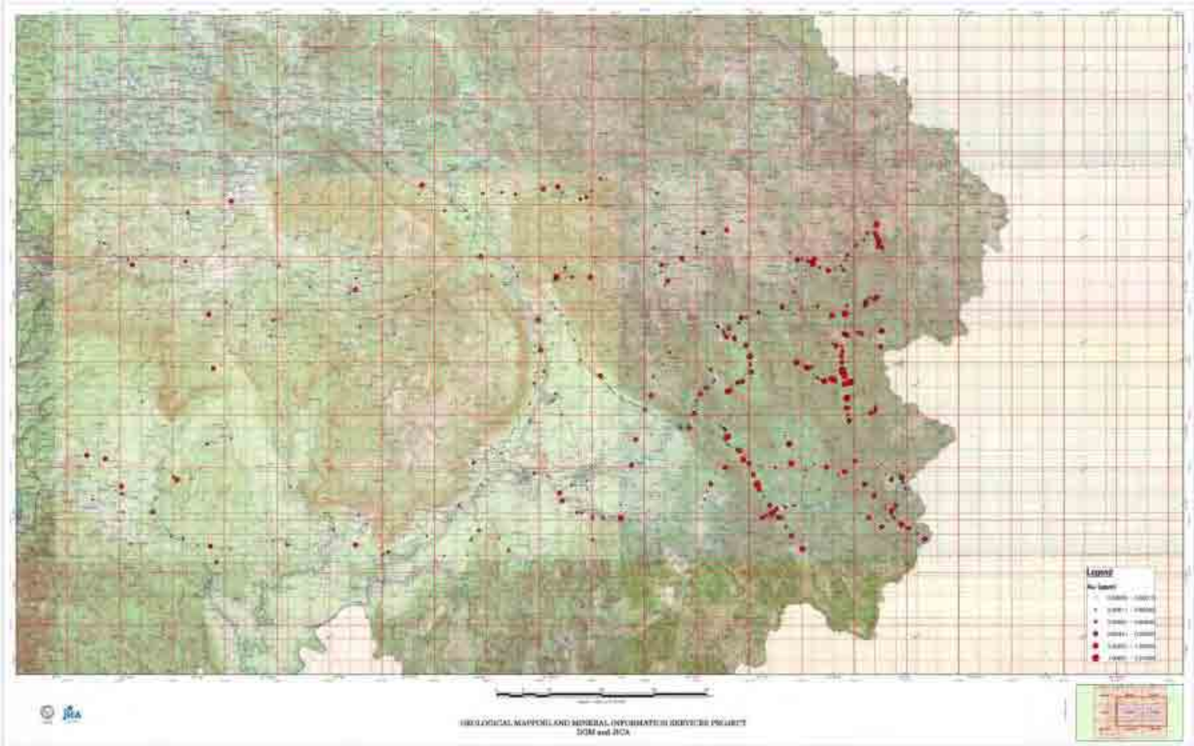

Figure 4.7.4 Distribution map of Au anomaly

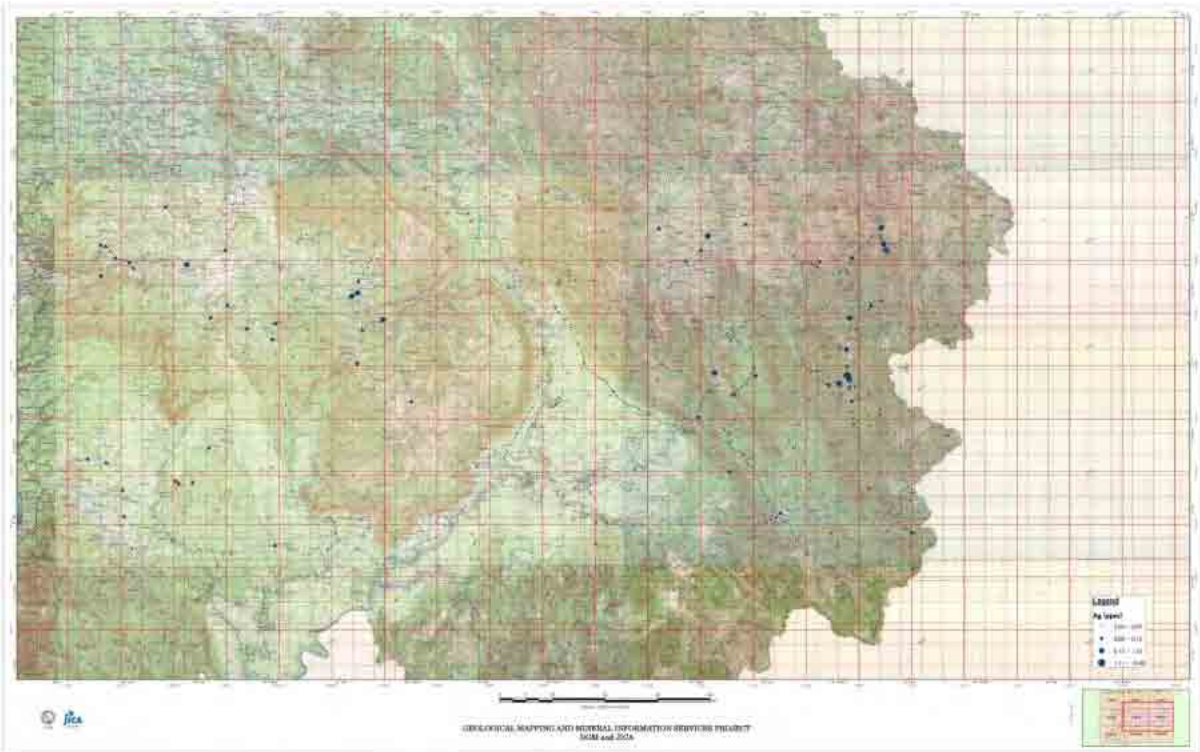

Figure 4.7.5 Distribution map of Ag anomaly

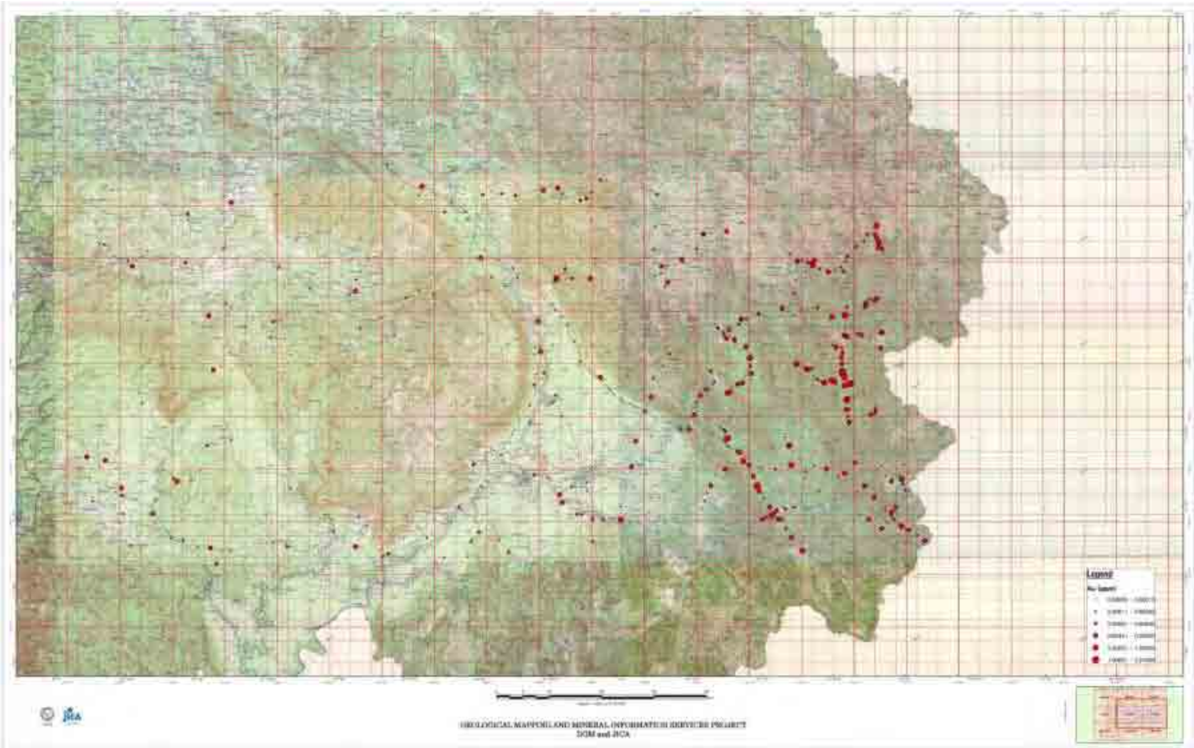

Figure 4.7.6 Distribution map of As anomaly

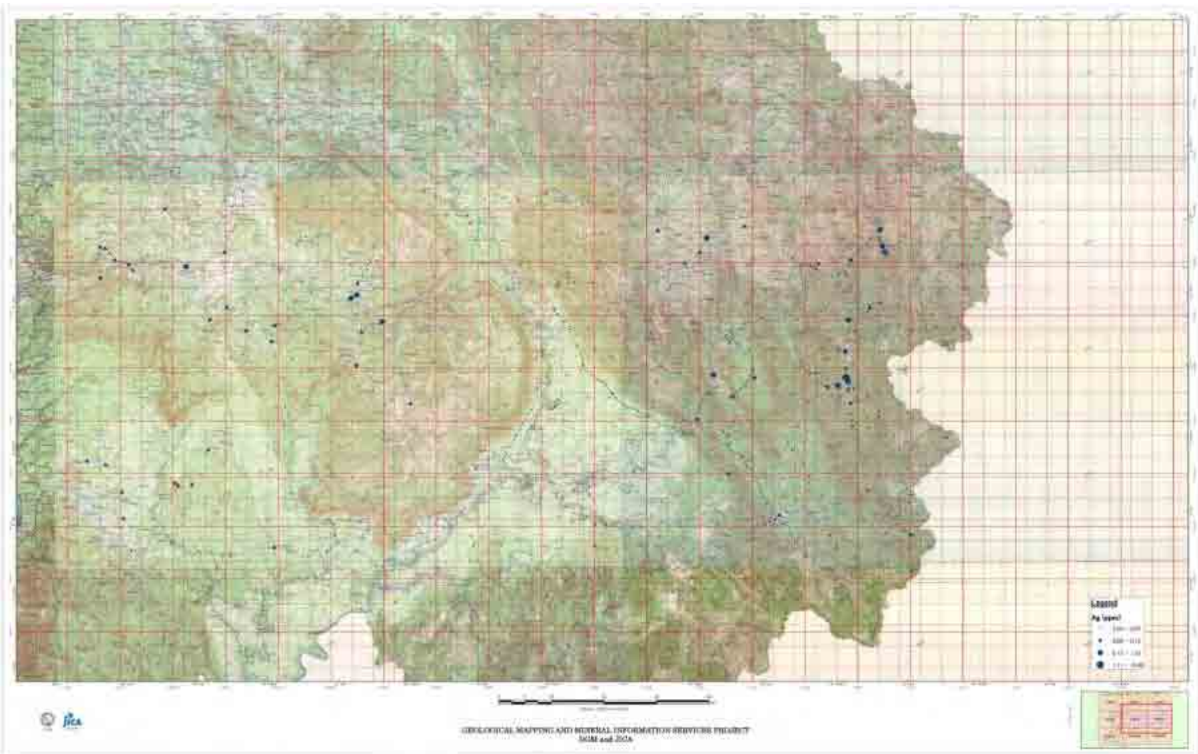

Figure 4.7.7 Distribution map of Sb anomaly

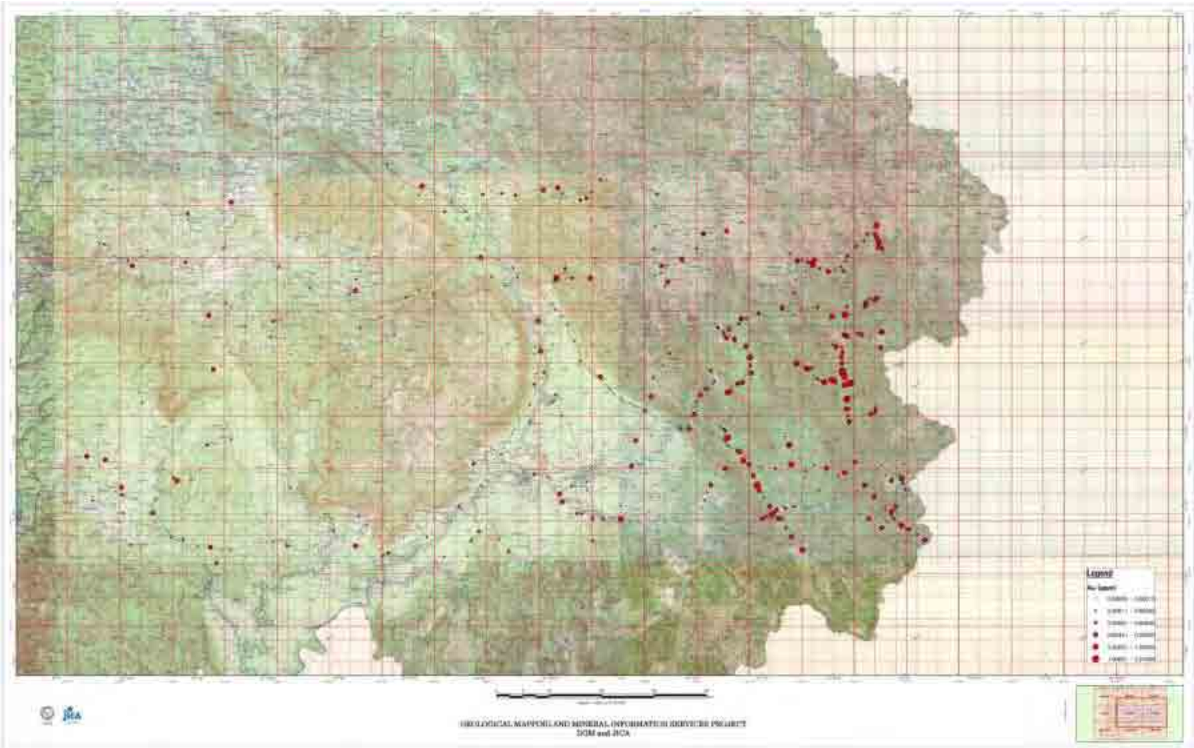

Figure 4.7.8 Distribution map of Bi anomaly

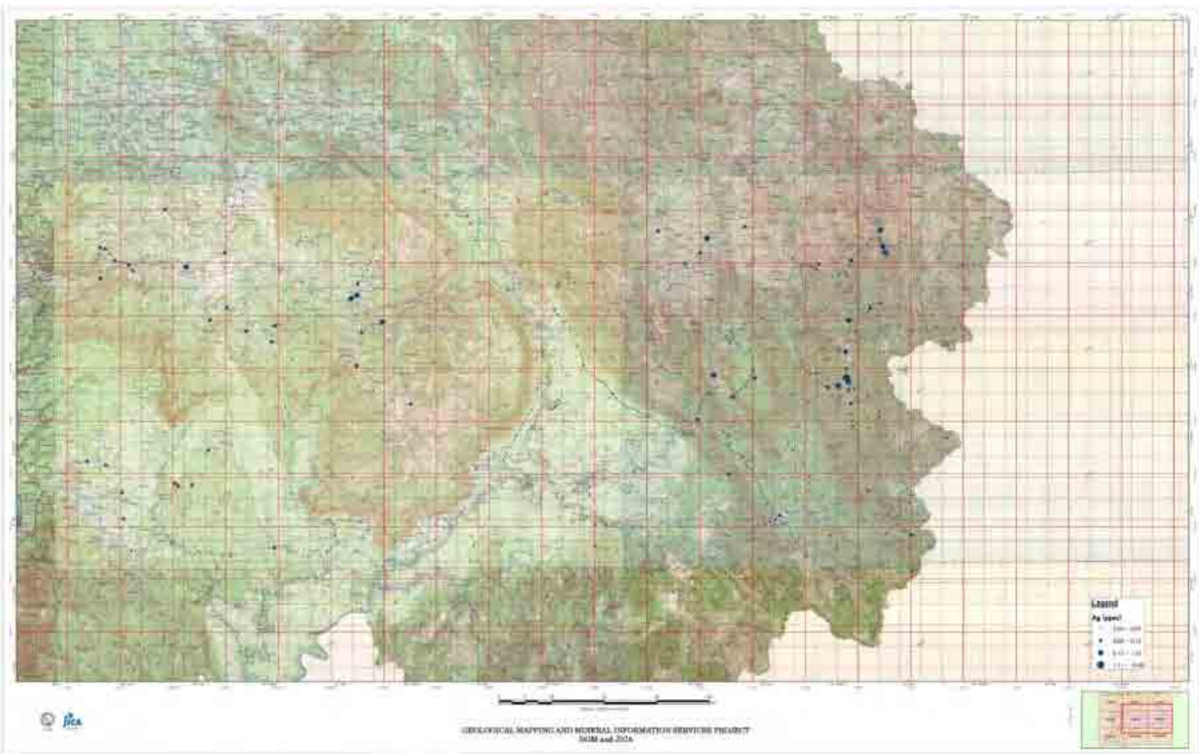

Figure 4.7.9 Distribution map of Cu anomaly

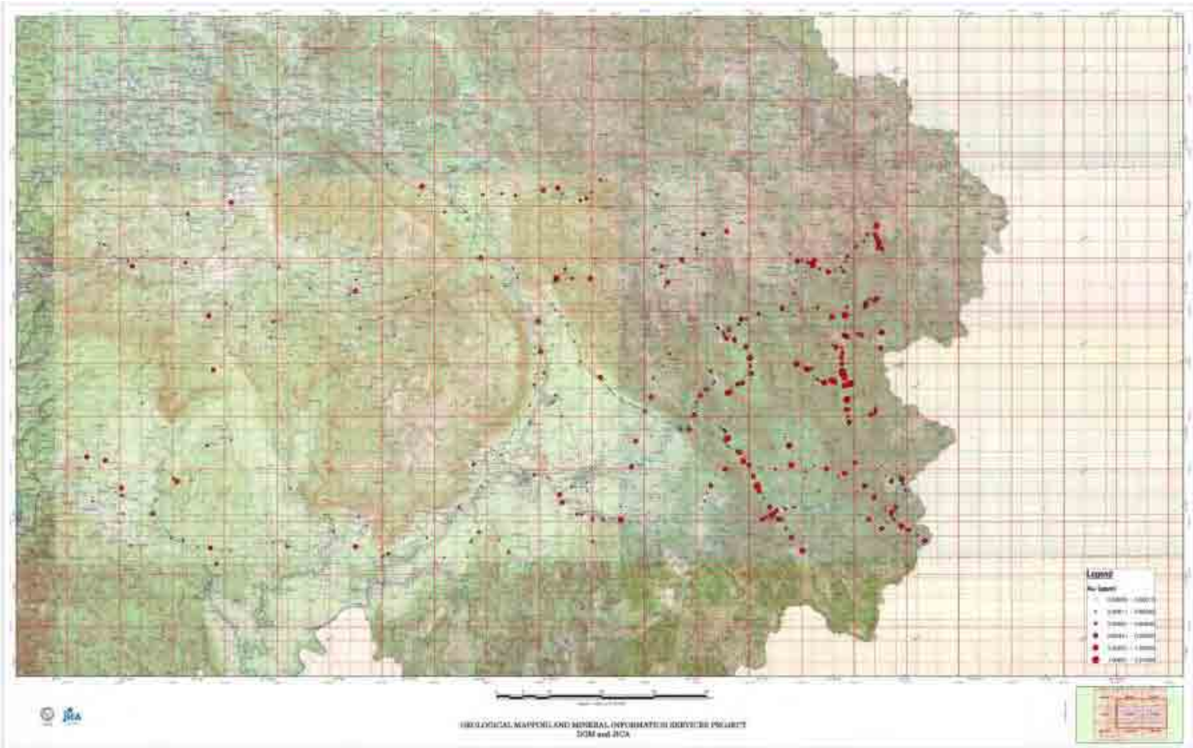

Figure 4.7.10 Distribution map of Pb anomaly

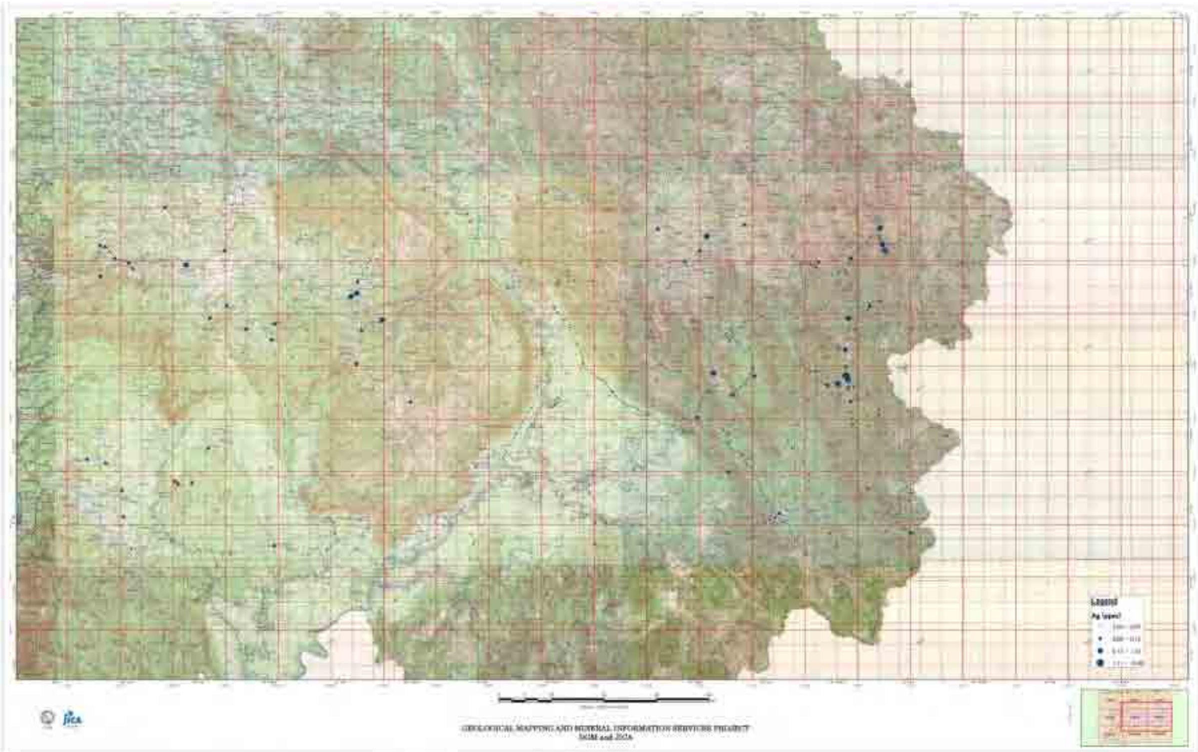

Figure 4.7.11 Distribution map of Zn anomaly

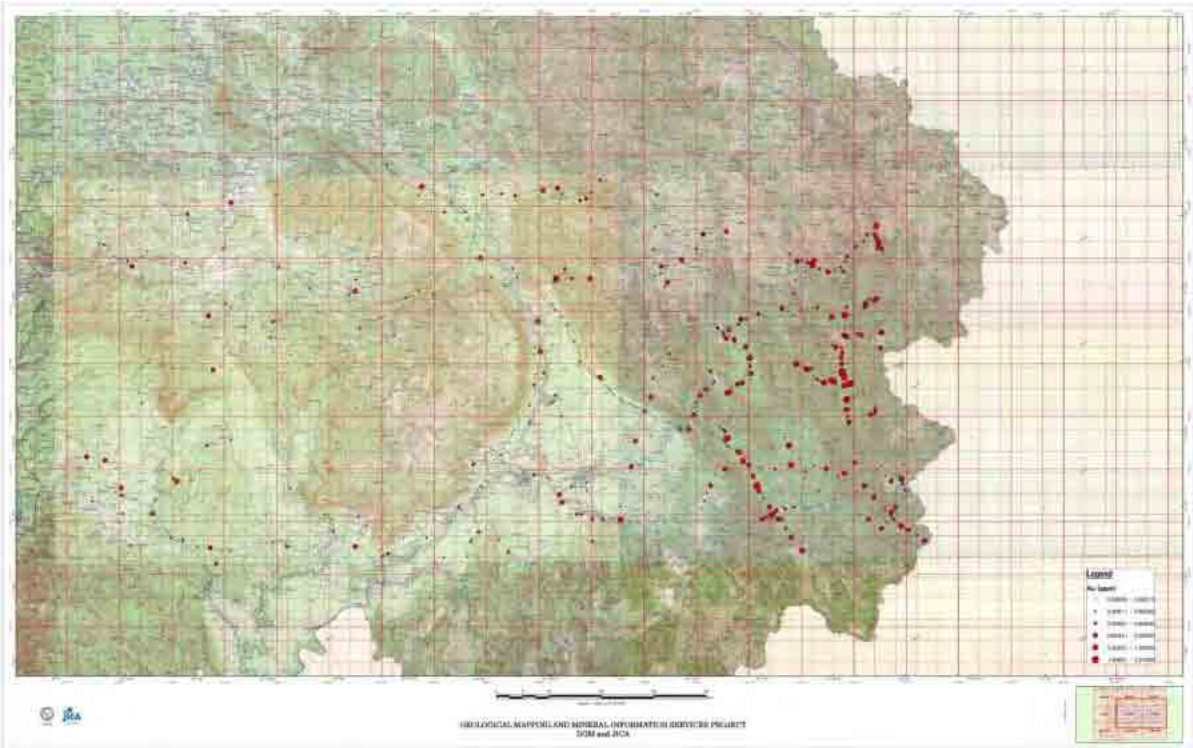

Figure 4.7.12 Distribution map of high factor 1 score

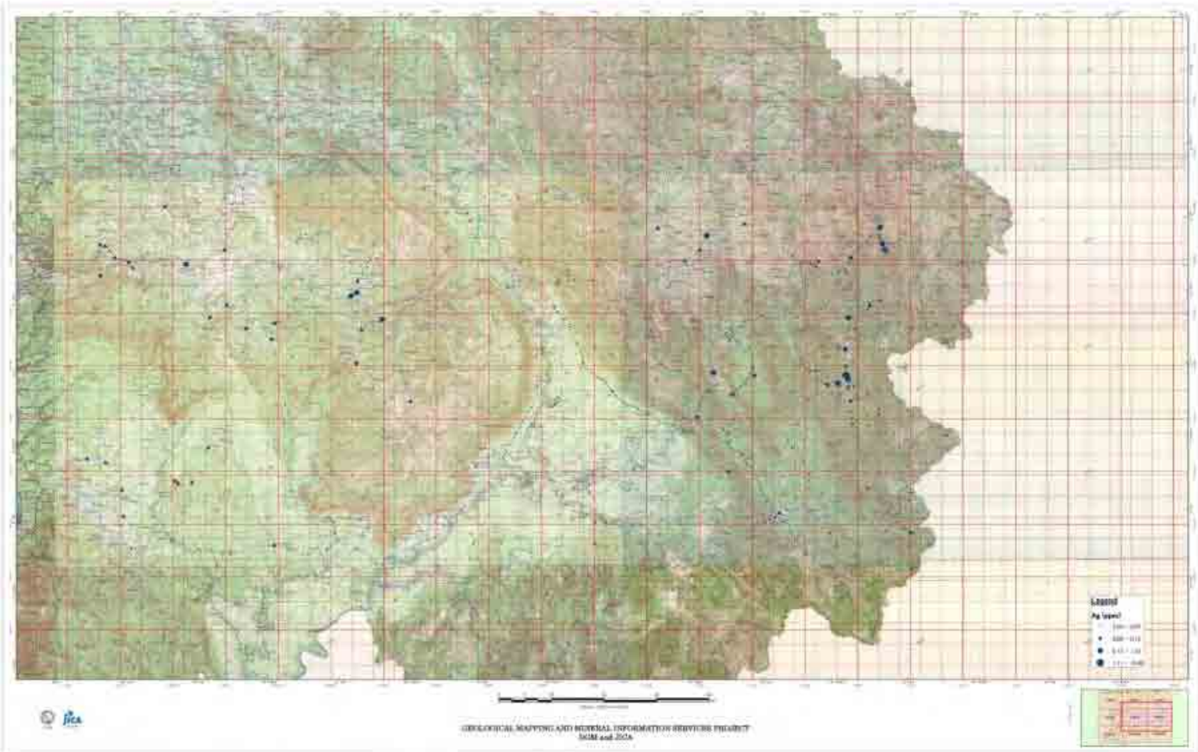

Figure 4.7.13 Distribution map of high factor 2 score

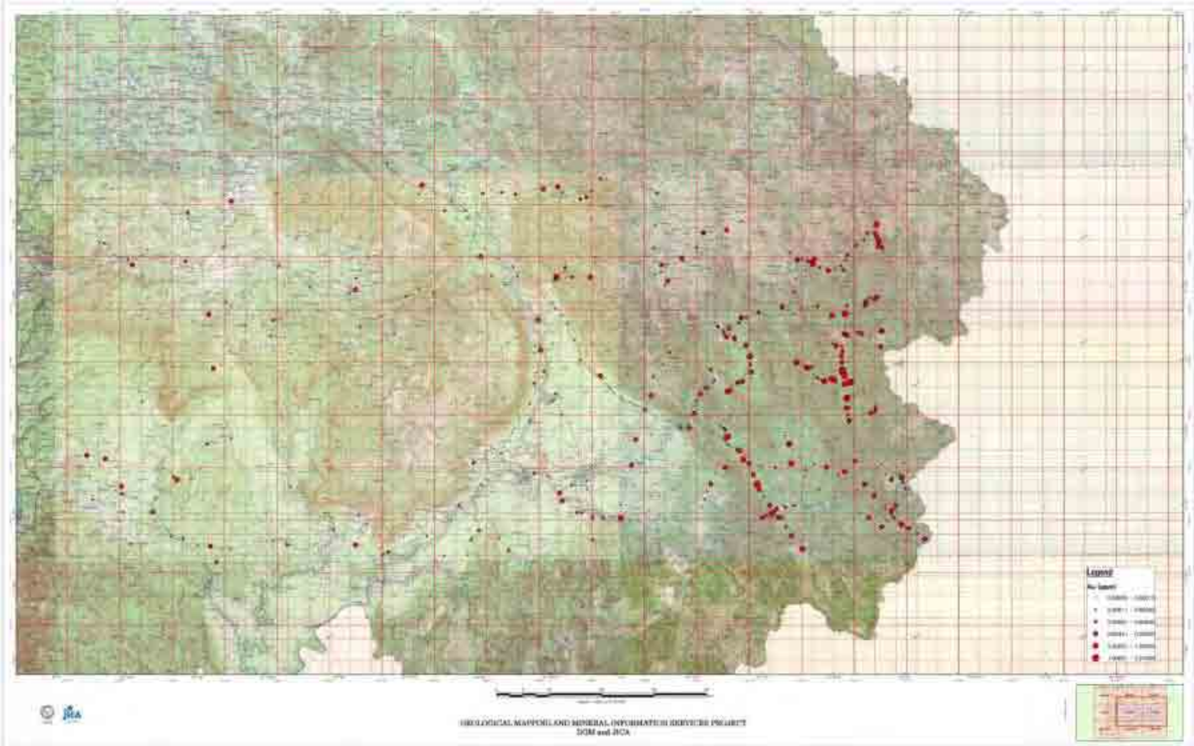

Figure 4.7.14 Distribution map of high factor 3 score

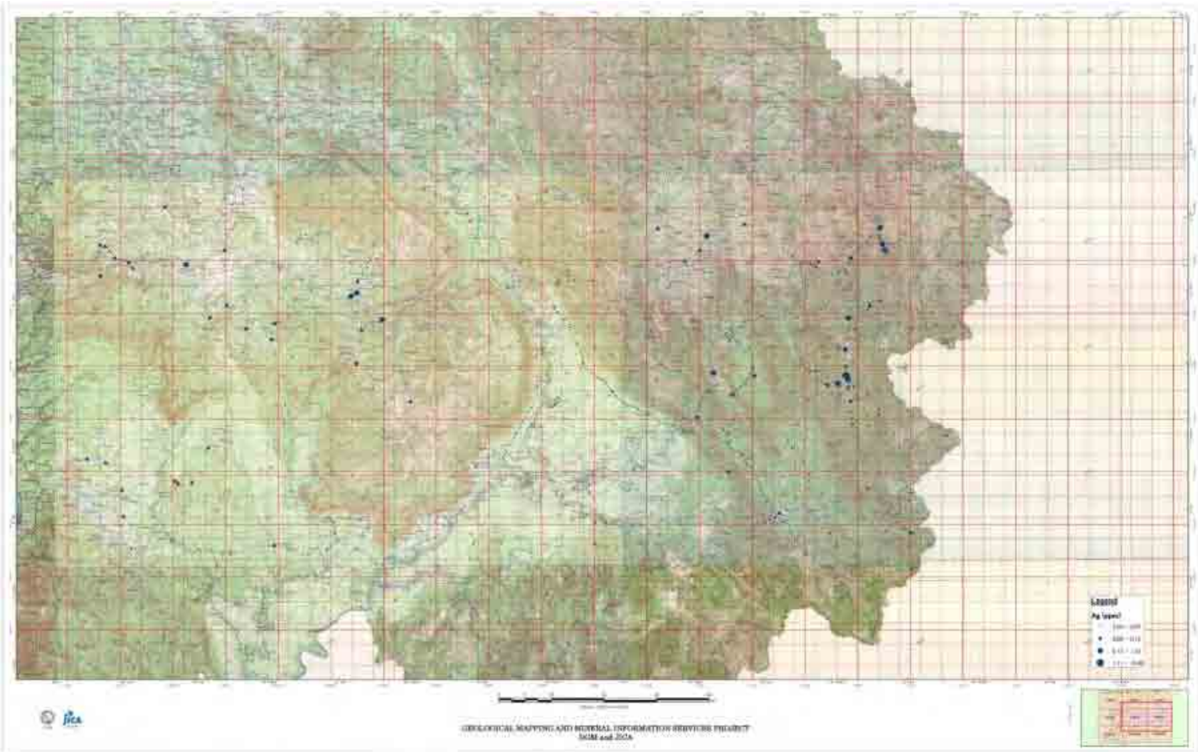

Figure 4.7.15 Distribution map of high factor 4 score

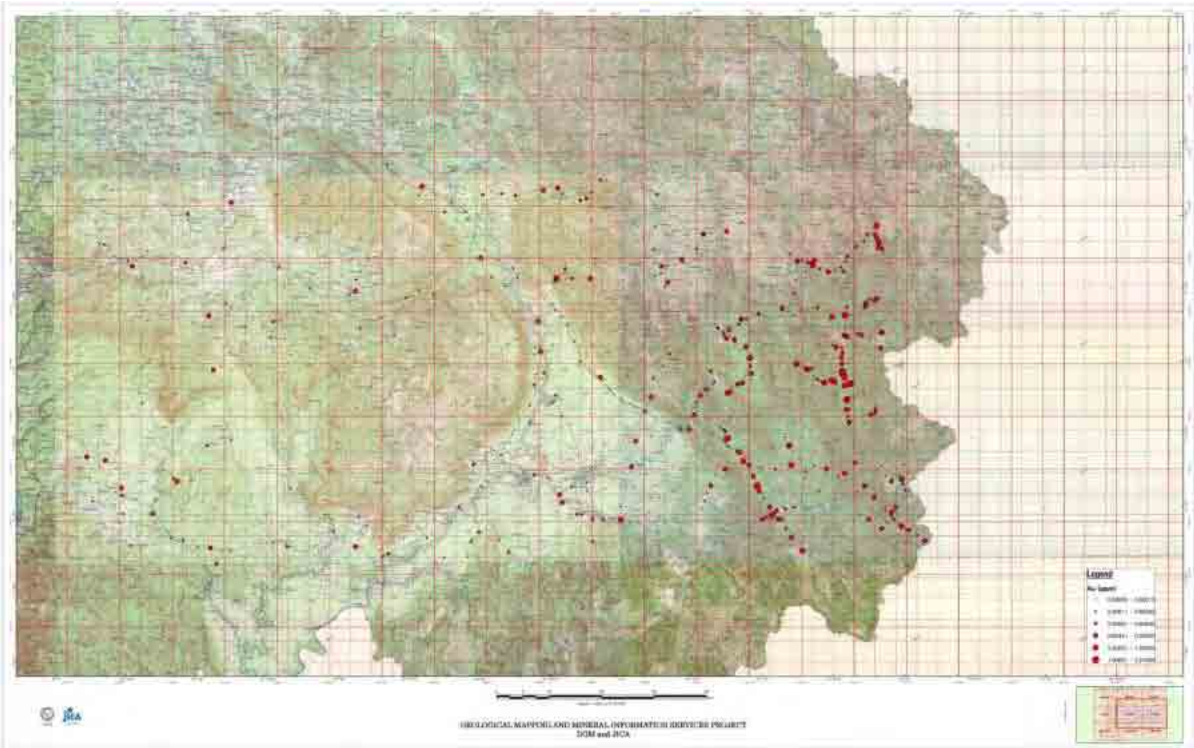

Figure 4.7.16 Distribution map of high factor 5 score