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

Geology of the Attapu District

Siphandone Vilayhack, Sixomxeun Duangsurigna, Sisaad Phomkenthao, Amkha Voravong,
Phonetalome Vilaysan, Thavone Khounchanthida, Khampha Phommakaysone,
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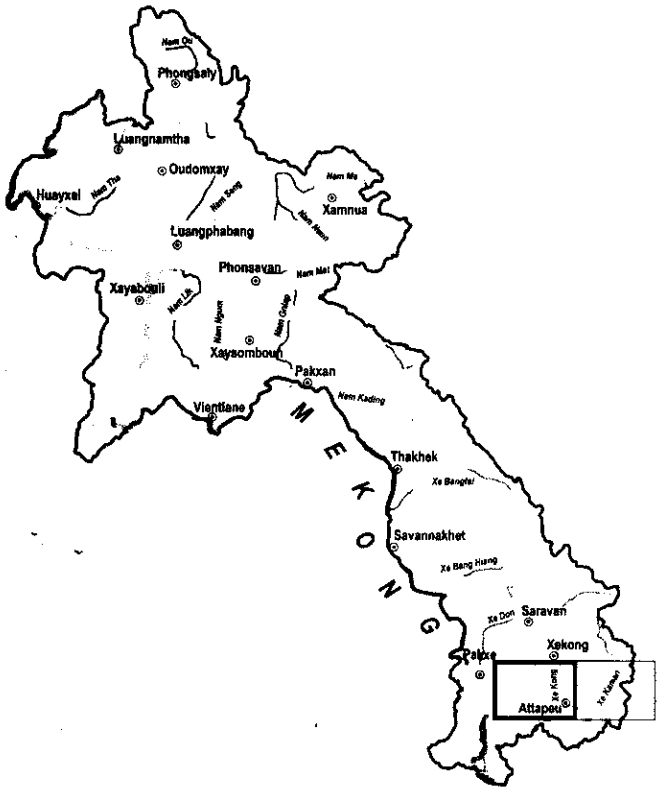

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October 2008
Japan International Cooperation Agency
Department of Geology, Ministry of Energy and Mines, Lao. P.D.R.

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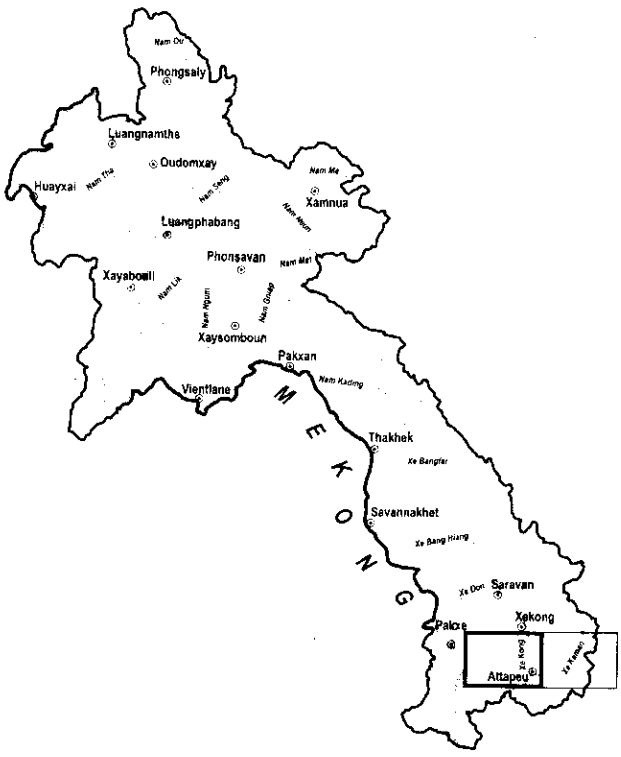

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D-48-IV	D-48-V	D-48-VI
D-48-X	**D-48-XI** **Attapu District** **(JICA/DGEO, 2008)**	D-48-XII B.Dakyoy District (JICA/DGEO, 2008)
D-48-XVI	D-48-XVII	D-48-XVIII

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(2008)

Geology of the Attapu 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 the Attapu 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 the Attapu District corresponds to one quadrangle and the other corresponds to the geological sheet map of the B.Dakyoy District.

The geological sheet map was produced through cooperation of DGEO staff, namely Mr. Chansone Senebouttalath, director general, Mr. Khampha Phommakaysone, deputy 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. During field work, much assistance was given by Mr. Khoune, director of DGEO Pakse branch office, Mr. Souksamay, 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.

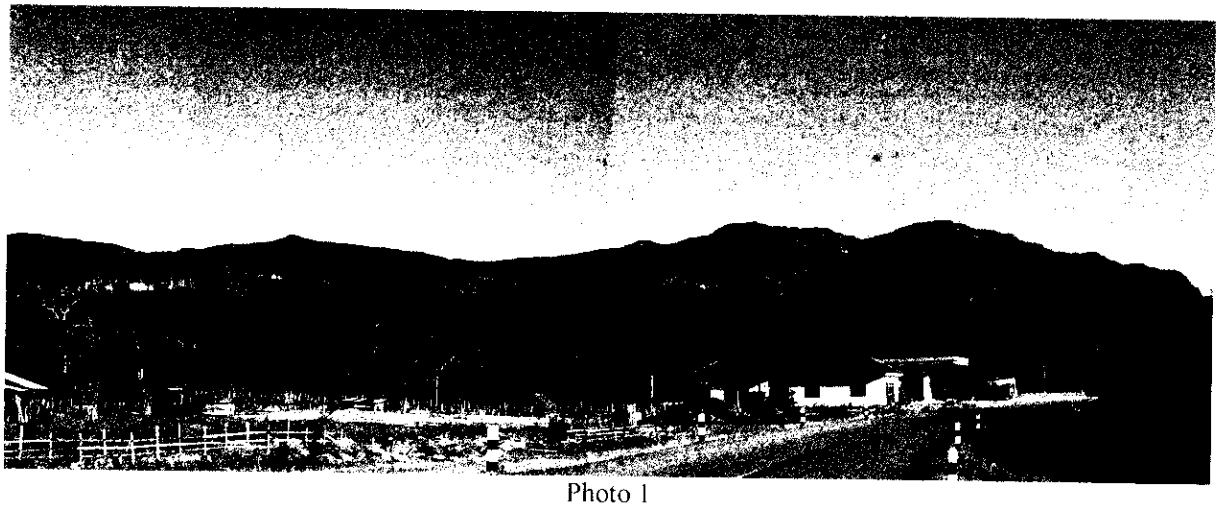


Photo 1
Photo 1 showing cliffs of Bolaven Plateau, looking from Attapeu City.

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

Contents

Figures, Tables and Appendix

I Geographical Features and Weather

The Attapu District selected for geological mapping covers mainly Attapeu Province and slightly Xe Kong and Champasak Provinces in the southern area of Lao P.D.R. The district is situated at latitude 14°40′ to 15°20'N and longitude 106°00′ to 107°00'E.

Bolaven Plateau occupies the central area of the Attapu District, which is the altitude of approximate 900m to 1,568m. The frat area of Bolaven Plateau has the altitude of approximate 900m to 1,100m. The northeastern area consists of mountains which is the altitude of 1,200m to 1,500m. The highest mountain is located on the mountain ridges situating in northeastern area of Bolaven Plateau, which is the altitude of 1,568m. The higher mountains of 1,509m and 1,276m in altitude are located in the northern area of Bolaven Plateau. The margins of Bolaven Plateau form the steep cliffs. In the southwestern part of Bolaven Plateau, the gentle slopes, which the lava flows are forming, are extended dipping southward. Mount Ph.Din of volcanic center is located in southern area of Pakxong City. The topographic feature is very clear that the lavas erupted from Mount Din flow out and down to southward. And the lavas are separated eastward and westward. Other volcanic craters are arranged to north-south direction.

In the eastern part of Xe Kong River which flows in the northeastern area of the Attapu District, the steep mountains of approximate 300m to 1,000m in altitude is formed. And the ridge-lines are spread to northwest-southeast trend. The mountains of 200m to 600m in altitude are distributed in southeastern margin of the Attapu District. And the mountains of 150m to 400m in altitude are distributed in southwestern margin of the Attapu District.

In the southeastern area of the Attapu District, a lowland area is spread among the Bolaven Plateau, the northeast steep mountains and the southeast mountains. Attapeu City is located in the lowland. Rice paddy fields have been widely made along Xe Kong River, Xe Kaman River and Xe Xou River in the district.

The water river systems in the Attapu District are mainly consisted of Xe Kong river drainages which are biggest river in the district. And other river systems are both of formed Xe Kaman and Xe Xou river systems and Xe Namnoy river system of tributaries of Xe Kong River. These river systems are occupied in 50 % of the Attapu District. Two river systems of Xe Khampho River and Xe Pian River exist in western part of the district and cover the distribution area of volcanic rocks.

Xe Kong River is more than 300m in maximum width, flows from northward to southward in the eastern part of the Attapu District and changes the flow westward in the southern part of the district. In the northeastern area, Xe Namnoy River flown from Bolaven Plateau flows into the Xe Kong River. And in the southeastern area, the Xe Kaman River flowing from east also joins it. Two rivers of Xe Pian River and Xe Khampho River are flowing southward from Bolaven Plateau in the southwestern part of the Attapu District.

The weather in the Attapu 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 from 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 Figure 3.

Main road networks in the Attapu District are slightly developed. The highway No. 16E, 16 and 11 are connected from Pakxe City to Attapeu City and the highway No. 18B is connected from Attapeu City to international border entering into Vietnam. These main roads are the paved roads. Other traffic networks are the non-paved roads in and around Pakxong City in Bolaven Plateau and the national road No. 18 of the non-paved road from Attapeu City to B. Sanamxai Village. There are other many small roads. However, the road, which cars can pass through in dry season, is the non-paved road from B. Sanamxai Village in the western part of Attapu to Thang Beng City in the southern part of Pakxe City and so on. Only four-wheeled vehicle can pass through the road in the dry season.

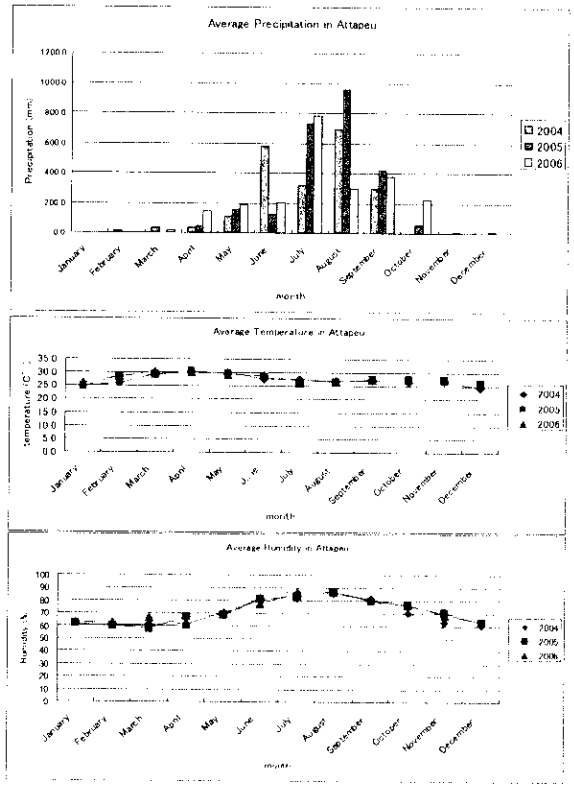


Fig. 1 Weather data in Attapeu Province (temperature, humidity and rainfall)

II General Geology

The tectonic classification in the Indochina area was compiled by geological Survey of Vietnam (1991) as shown Fig. 4. Tectonic Regions of Laos is divided into Northwest Lao Tectonic Region, Truongson Tectonic Region and Kontum-Savannakhet Tectonic Region from northern side. The Northwest Lao Tectonic Region is characterized by NNE-SSW structure. The Truongson Tectonic Region and the Kontum-Savannakhet Tectonic Region are characterized by the main structures of NW-SE trend.

The Northwest Lao Tectonic Region belongs to Himalayan orogenic belt characterized by folding and faulting of NNE-SSW trend. Truongson Tectonic Region relates to Hercynian orogeny characterized by the geological structure of NW-SE trend and is extended to southeast of Vietnam. The region is constructed by the geosyncline sediments of middle Paleozoic age and the granitic plutonic rocks. The Kontum-Savannakhet Tectonic Region belongs to Baikalian orogeny of Pre-Cambrian and Caledonian orogeny of early Paleozoic age. The region consists of basement rocks and platform sediments of Mesozoic age.

As shown Fig. 4, the Attapu District is situated in the central area of the Kontum-Savannakhet Tectonic Region. The district is located in and around the geologic boundary between the basement rocks of Baikalian orogeny and Caledonian orogeny and the platform sediments of Paleozoic. These rocks form mainly the Khorat Hill in the eastern part of Thailand. And the Attapu District is formed mainly by the platform sediments.

Geological map and geological sections of the Attapu District are shown in Fig. 5 and 6. Geologic column of each area is drawn in Fig. 7. Carboniferous rocks of Paleozoic are distributed in the northeast margin of the district. Continuously, the upper formations of Triassic to Cretaceous are distributed in westward from there. The formation of upper Cretaceous and the Bolaven Formation of Tertiary to Quaternary overlie widely the Bolaven plateau. The terrace deposits of Neogene and the alluvial deposits of Quaternary are distributed along main rivers. The geological stratigraphy in the Attapu District is summarized in Table 1.

Paleozoic is distributed in northeastern part of the Attapu District and consists of Kadon Formation of Carboniferous, which is deltaic deposit developed around continental margin. Mesozoic is widely distributed in the district and is stratified by Triassic, Jurassic and Cretaceous formations.

Triassic is stratified by Dakdouan Formation (T1-2), Alak/Katha-Tai Formation (vT1-2, vT1-3) and Makkhua Formation (T2). They are composed mainly of sedimentary rocks and acidic volcanic rocks of lacustrine to continental origin. Jurassic is stratified by Namhiang Formation (J1), Lavi Gnai Tai Formation (J2) and Kanglo Namho Formation (J3) from lower part. They are composed mainly of sedimentary rocks of shallow sea to continental origin. Upper formations gradually change to typical red-sedimentary lithofacies. The Kanglo Namho Formation of Upper Jurassic includes tuff fragments and tuffaceous patches. Cretaceous is stratified by Lagnao-Kang (K1) and Latsaluay Formation (K2). The Lagnao-Kang (K1) is composed mainly of fluvial sedimentary rocks, so called Deltaic deposit. It is unconformably covered by the Latsaluay Formation accompanying with a clay layer in geologic boundary. The Latsaluay Formation is limitedly exposed in the western part of Bolaven Plateau.

At a later time, the area is uplifted. And the plateau such as Bolaven Plateau is formed by erosion during Tertiary to Quaternary. In the period of Late Cretaceous and Paleogene, basaltic lavas of Bolaven Formation Lower Unit spewed out on the plateau. The volcanic activity such as basaltic magmas continued to Neogene or Quaternary. Olivine basalt lavas of Bolaven Formation Upper Unit spewed out including upper mantle materials composed of xenoliths of olivine nodule etc.

Geological Structure of the geological map of the Attapu District is formed by the faults of NNW-SSE trend developed in the northeastern marginal area, the folding with anticline and syncline extending NNW-SSE trend in the northeastern area and the volcanic activity on Bolaven Plateau.

The fault structures were formed by big scale faults dividing Carboniferous of Paleozoic and Triassic and Jurassic of Mesozoic. The fold structures situated in the west side of the faults were formed in a series of the faulting activity. From east to west, these structures change to syncline, anticline, monocline and flat structures in turn, which are controlled by NNW-SSE structures. Igneous activity changes from pyroxene basalt and plagioclase basalt of the Bolaven Formation Lower Unit to olivine basalt and nepherine-olivine basalt of the Bolaven Formation Upper Unit in turn. Especially, the alkaline basalt includes xenoliths of the upper mantle materials. The magmas are originated in the deeper part of mantle.

The survey results of geological survey reports and papers are summarized in the stratigraphic correlation table, as shown in Table 3. The stratigraphy of Laos is compiled from Geological Survey of Vietnam (1991) and British Geological Survey (1991). And other stratigraphy of the southern area of Laos is compiled from Gerhard H. Martin (1994) of LAOS HUNT OIL COMPANY. The geological stratigraphy of the Attapu District is compiled in the Table 3 together with these survey results.

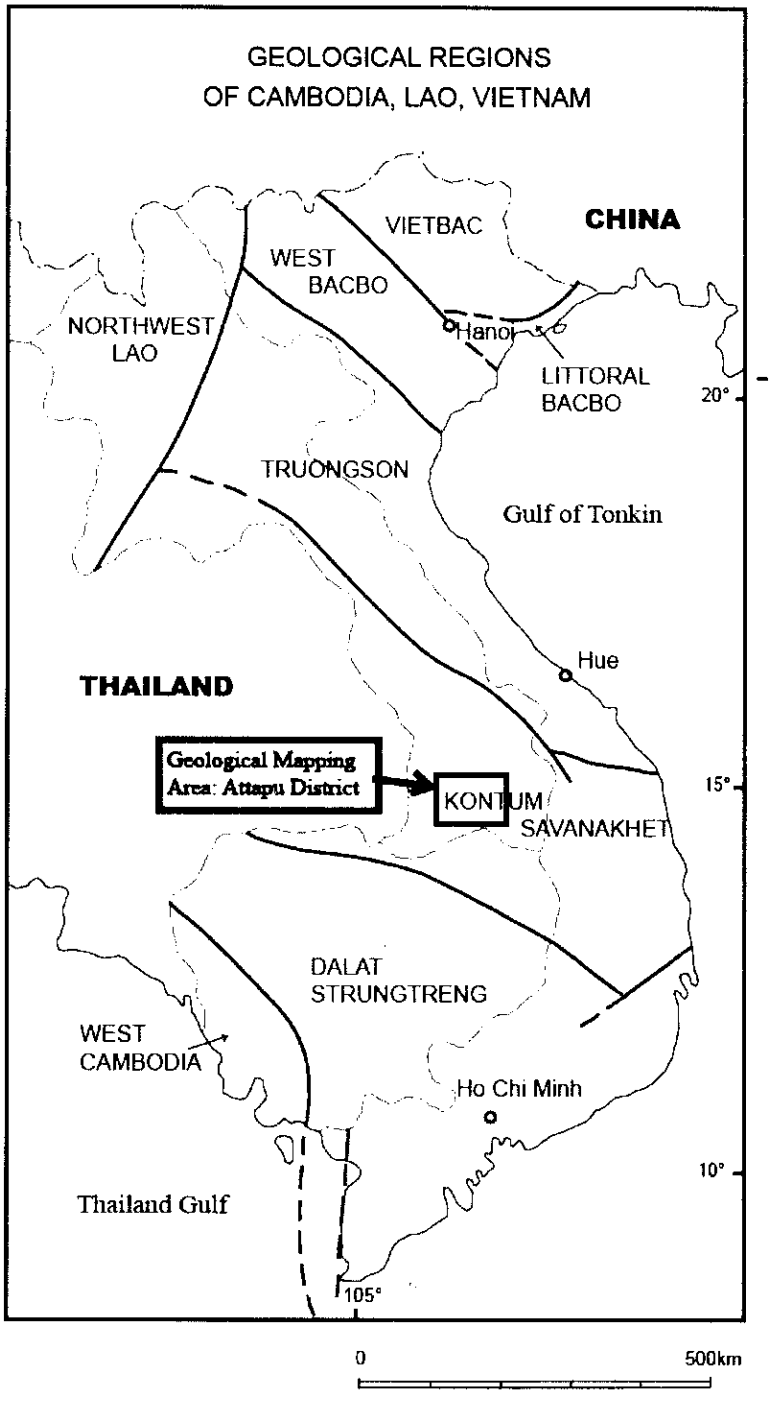


Fig. 2 Classification of geological regions in Indochina area (GSV, 1991) and location of the Attapu District

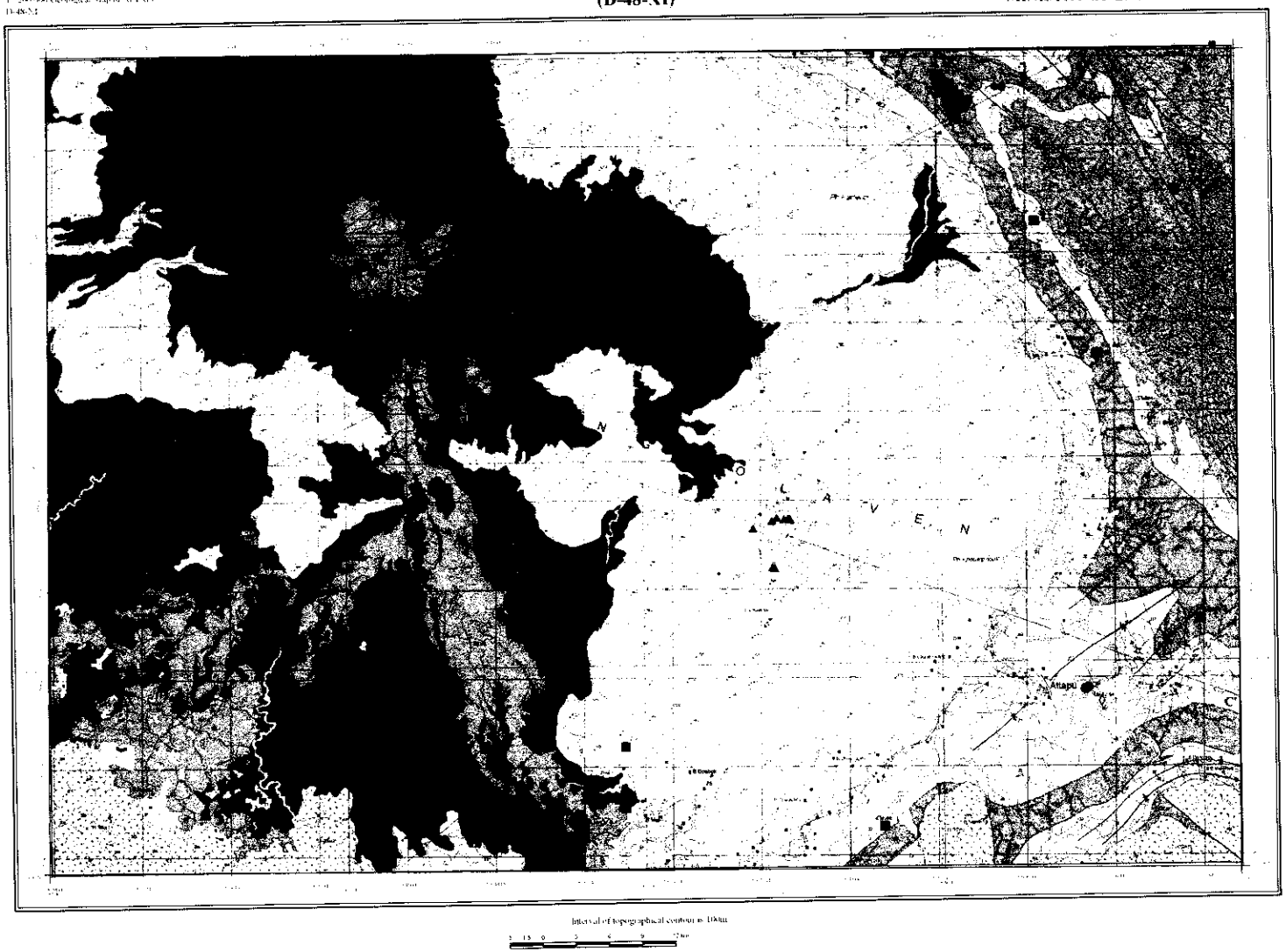


Fig. 3 Geological Map of Attapu District

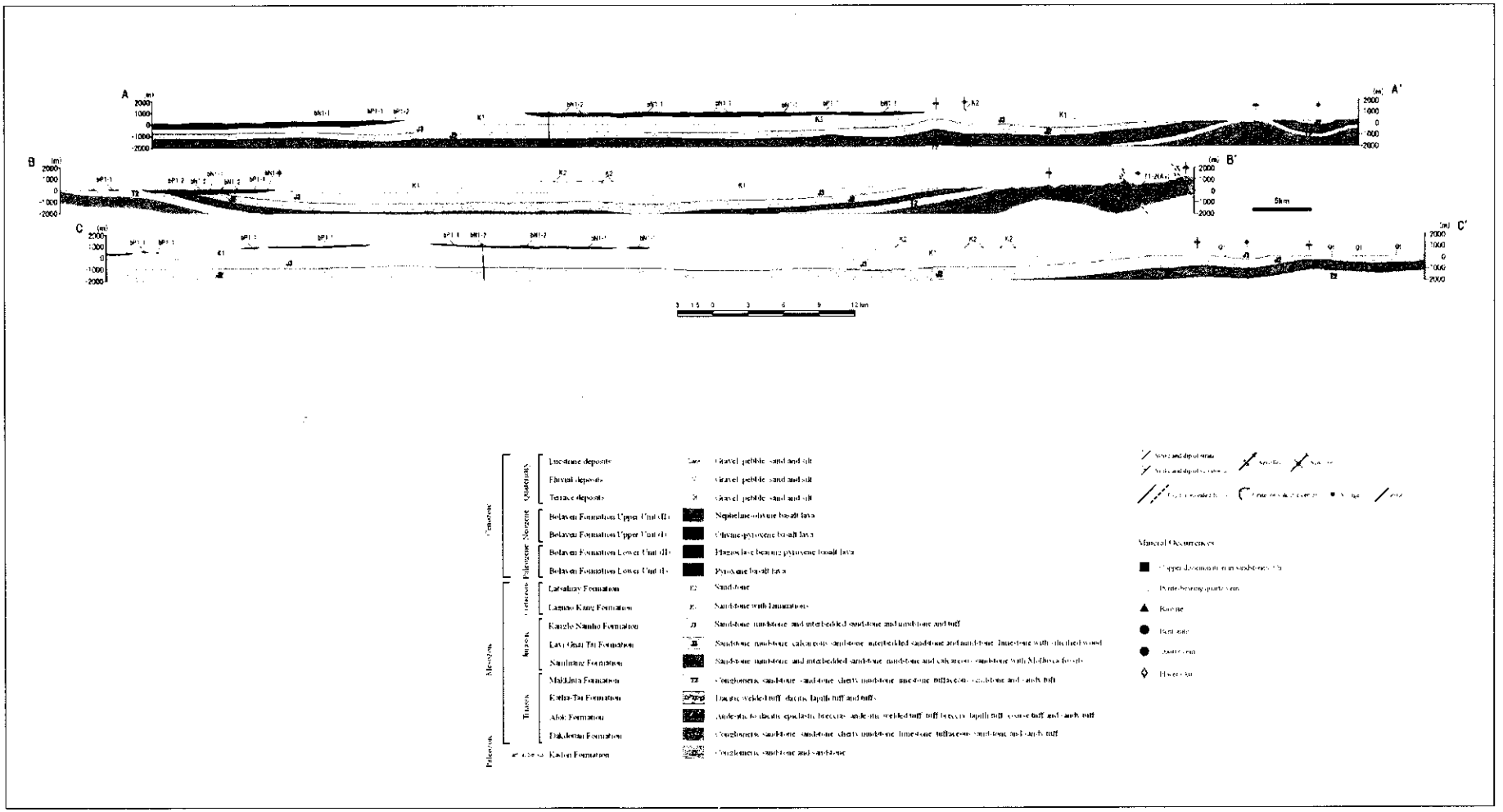


Fig. 4 Geological section and legend of the Attapu District

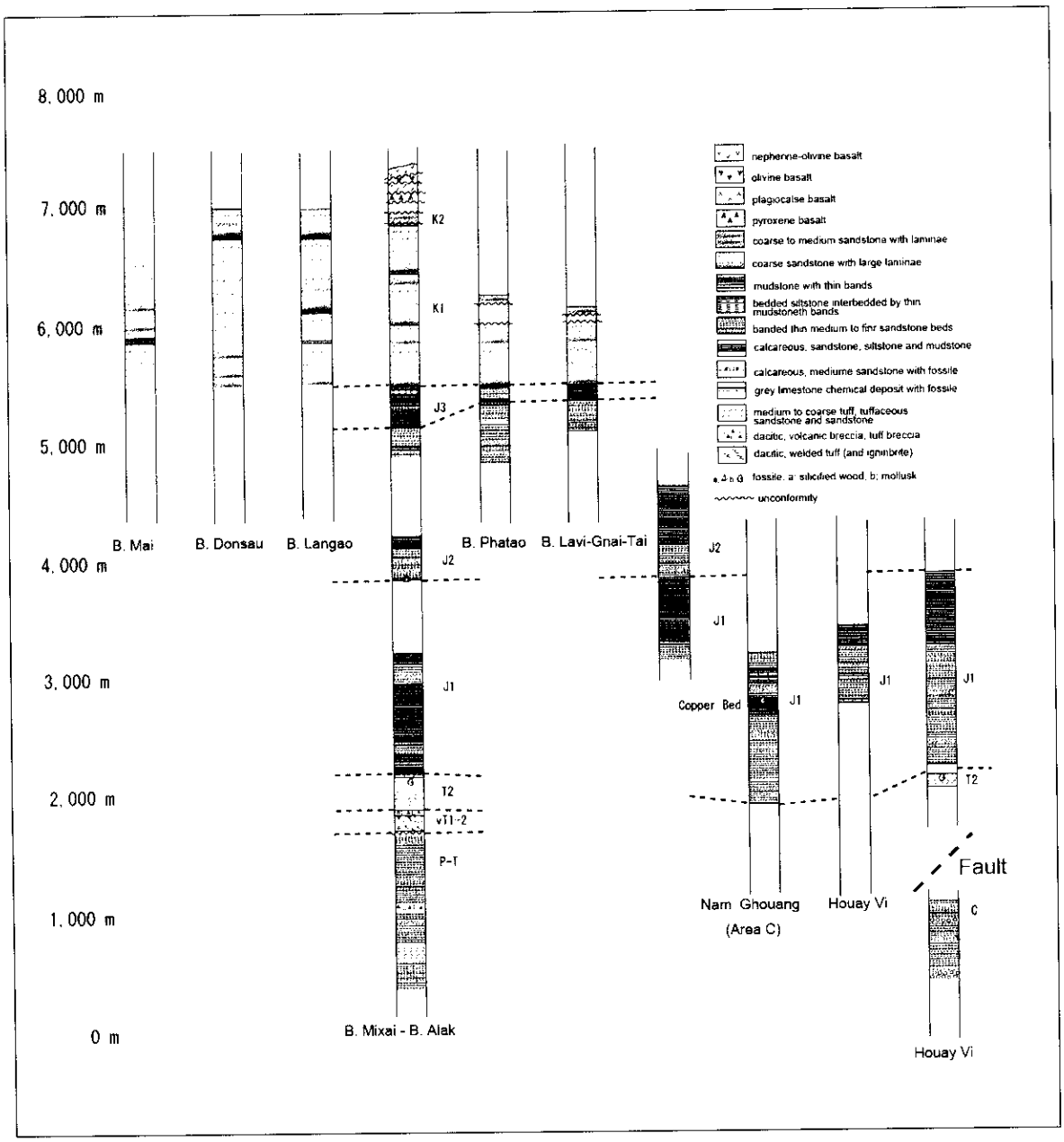


Fig. 5 Geologic columnar sections in each area

Table 1 Summary of Attapu geological sheet map area

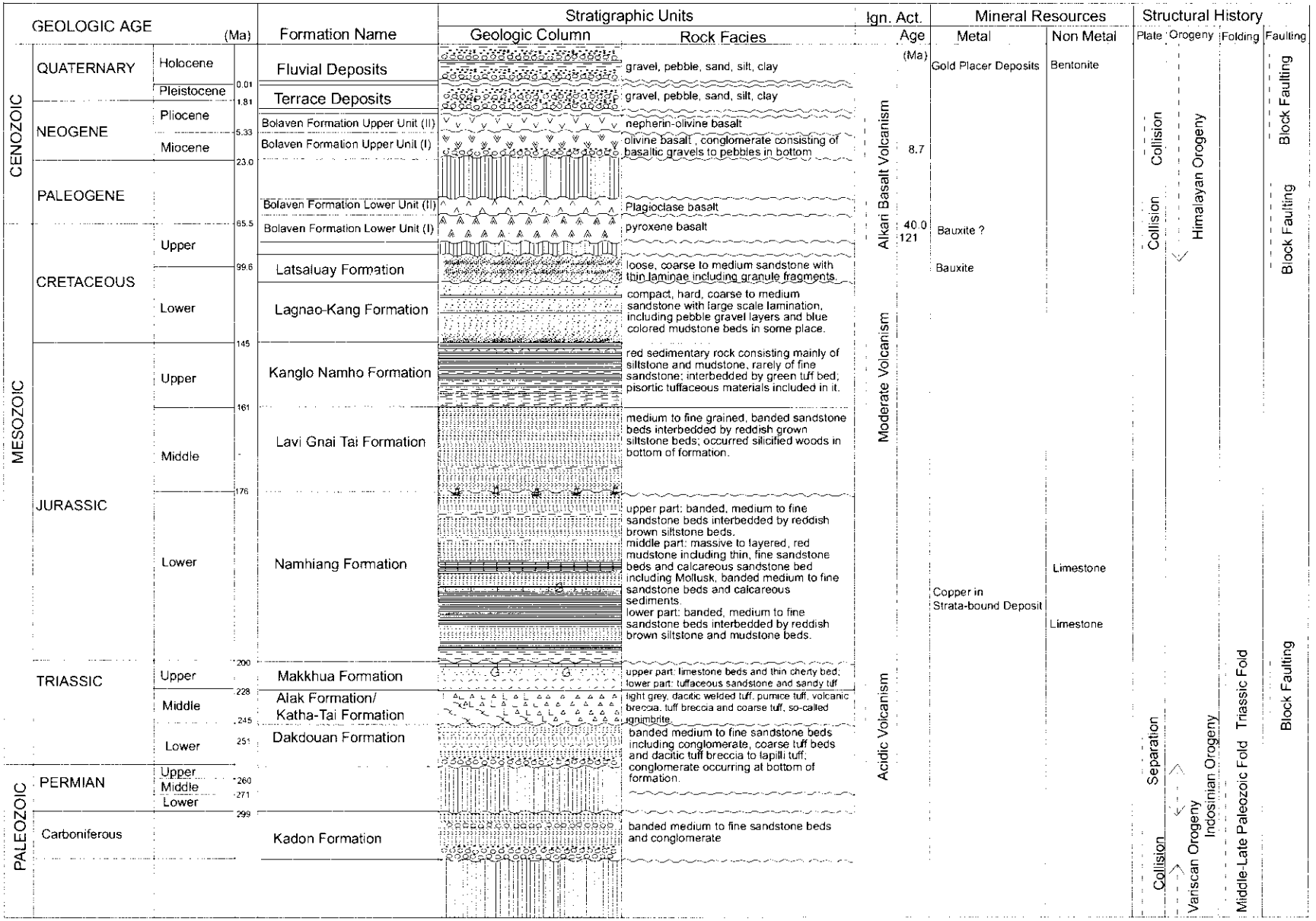
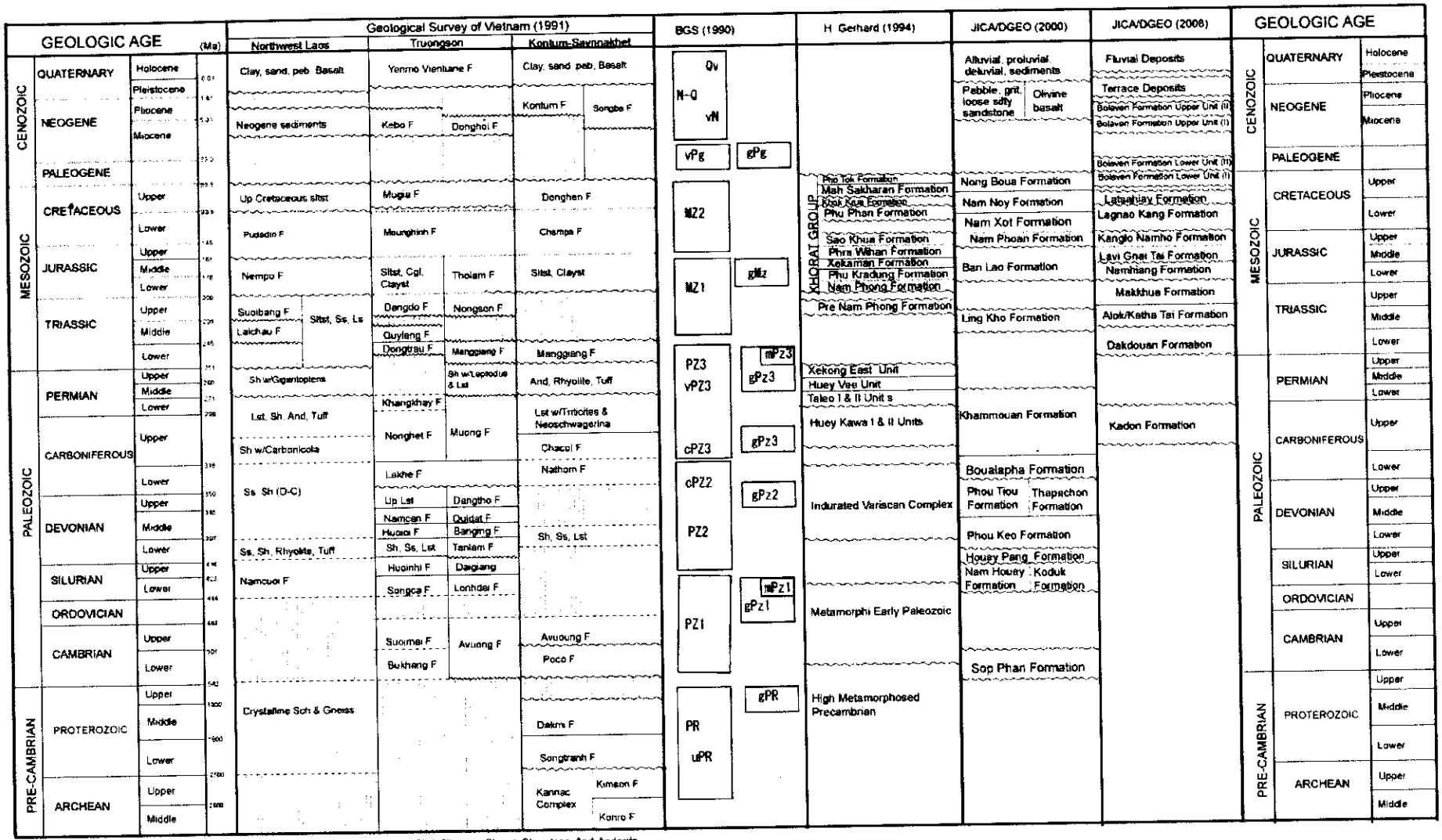


Table 2 Stratigraphic coloration of geology in the Attapu area



F: Formation, S: Suite, Ss: Sandstone, Siltst: Siltstone, Clay st: Clay stone, And: Andesite,
Lst: Limestone, Cgl: Conglomerate, Up: Upper, w/: with, Plest: Pleistocene

III Paleozoic

III.1 Carboniferous

III.1.1 Kadon Formation (C)

Formation Name: Kadon Formation was newly named in this report.

Type locality: The formation is observed in the outcrops along river and road surrounding B. Kadon Village, where is located at upper river of H. Vi River of tributary of Xe Kong River flowing in the eastern area of the Attapu District.

Distribution: The formation appears around B. Kadon Village in the northeastern area of the Attapu District.

Stratigraphic relationship: The formation overlies unconformably the lower formations of Silurian to Ordovician distributed in the geological mapping area of the B. DAKYOY District.

Thickness: The total thickness of the formation reaches about 800m.

Lithofacies: The formation accumulates in continental or neritic environment and consists of conglomerate/arenite alternating beds and sandstone beds.

The conglomerate/arenite alternating beds consist of massive conglomerate with pebble gravel and sandstone, as shown in Photo 2.

The sandstone beds are formed by massive to layered beds as shown in Photo 3. The beds show dark gray color and consist of hard and compact, fine to medium sandstone and interbed conglomerate beds. Quartz veins with comb structure are observed in the formation as shown in Photo 4.

Geologic Age: The formation is probably correlated to Carboniferous. The geologic environments are continental or fluvial.

Photo 2

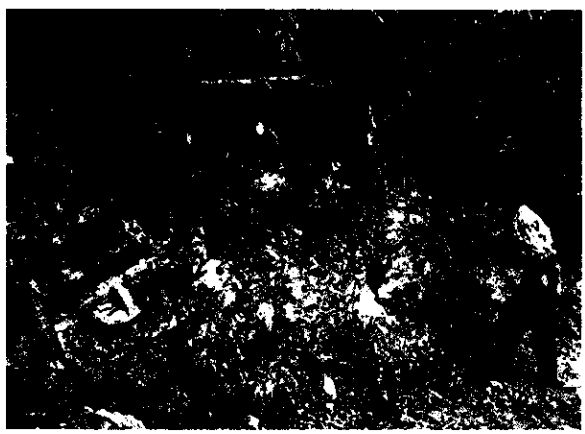


Photo 3

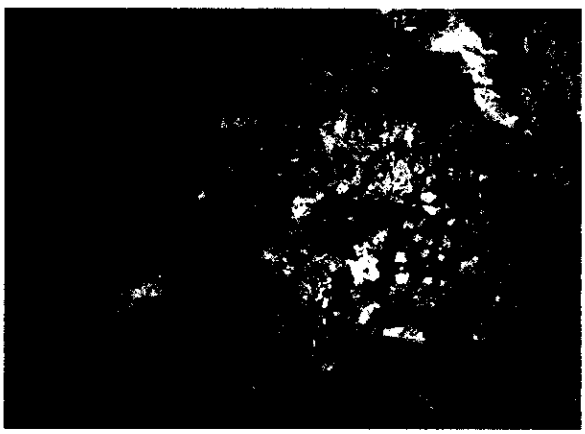


Photo 4

Fig. 6 Outcrops of Kadon Formation. Photo 2 showing conglomerate around B. Kadon Village located in upper river of H. Vi River of tributary of Xe Kong River. Photo 3 showing sandstone beds at a road connected to Attapeu City. Photo 4 showing comby quartz vein observed in sandstone beds.

IV Mesozoic

IV.1 Triassic

IV.1.1 Dakdouan Formation (T1-2)

Formation Name: Dakdouan Formation was newly named in this report.

Type locality: The formation is observed along upper-middle river of H. Po River located in east of B. Sapouan in eastern part of the Attapu District.

Distribution: The formation widely appears trending to north-south with 5km width on the middle-upper river of H. Po River in the east of B. Sapouan.

Stratigraphic relationship: The formation overlies conformably the Silurian to Ordovician formation distributed in the B. DAKYOY District.

Thickness: The total thickness of the formation reaches about 800m.

Lithofacies: The formation consists of sandstone beds and siltstone/sandstone alternating beds. It is interbedded by conglomerate beds and rhyolitic volcanics bed.

The sandstone beds are cumulated in the continental or lacustrine environment and consist mainly of massive, compact, hard siltstone and sandstone as shown Photo 5.

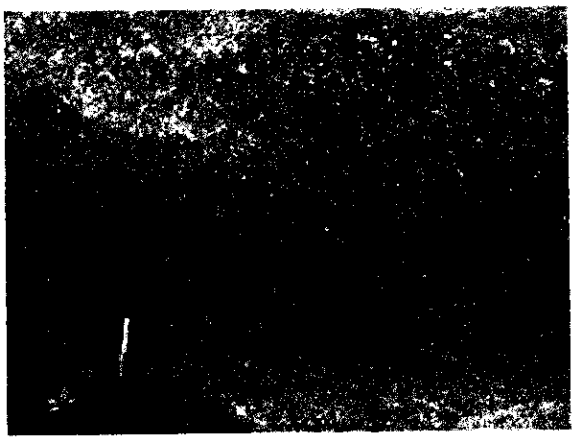


Photo 5

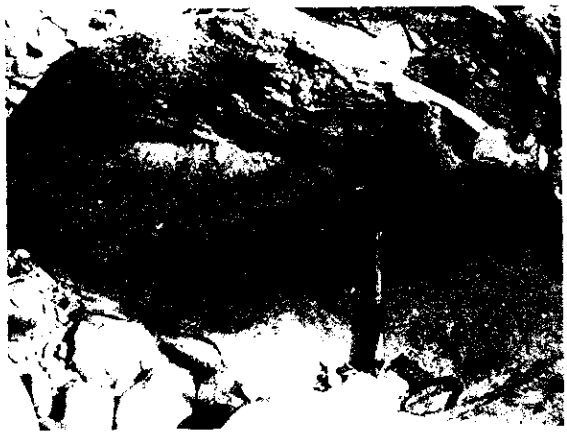


Photo 6

Photo 7

Photo 8

Fig.7 Outcrops of Dakdouan Formation (1). Photo 5 showing typical, massive, compact, hard siltstone and sandstone of Dakdouan Formation in H. Po River near B. Sapouan Village. Photo 6 showing black to dark gray, thin mudstone interbedded in the formation. Photo 7 showing fragments of black to gray mudstone in the beds. Photo 8 showing conglomerate bed interbedded in the beds.

The siltstone/sandstone alternating beds consist of layered or banded sandstone beds, which one bed is of several tens cm to 2 m in maximum thickness. The beds consist of alternating beds of fine to medium, lithic sandstone and lithic arenite accompanying with granule conglomerate and black rock fragments, which are composed of lake deposit. And the beds interbed black to gray, muddy thin bed as shown in Photo 6. In some

places, it interbed some black to gray, thin siltstone/mudstone beds (Photo7). The sandstone beds include the thin conglomerate beds and the conglomerate of lenticular- or spindle-shapes (Photo 8). The coarse lamination structures are indistinctly developed in a unit bed of the sandstone beds which gradually change into mudstone with 1cm to 15cm thick. Upper bed overlies the lower bed cutting its structure. The conglomerate beds show pale greenish gray, consist of well rounded granule and are composed of tuffaceous siltstone and sandstone in the matrix.

In addition, the sandstone beds interbed the thin beds of rhyoritic tuff breccia, lapilli tuff (Photo 9), coarse tuff (Photo 10), andesitic tuff and tuffaceous sandstone. The lapilli tuff shows greenish gray to gray, consists of subangular to subrounded fragments of rhyolite and andesite. The matrix is tuffaceous and includes crystal fragments of biotite and quartz. The lapilli tuff bed accumulates conformably on the lower sandstone bed with several mm thick, as shown in Photo 11. The coarse tuff shows pale greenish gray and includes small crystal fragments of biotite and quartz. The andesitic tuff shows greenish gray and consists of coarse tuff in matrix.

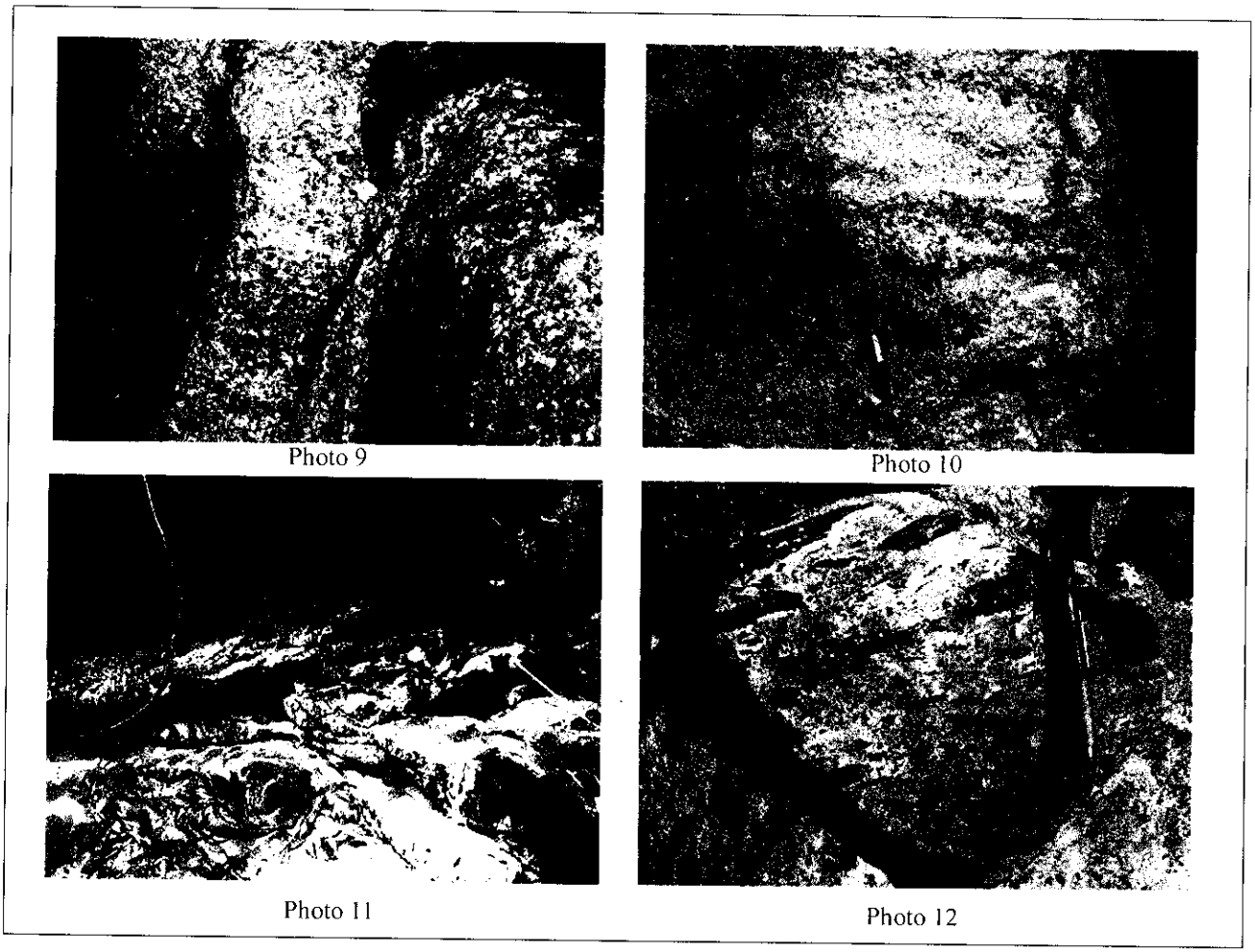


Fig. 8 Outcrops of Dakdouan Formation (2). Photo 9 showing rhyoritic tuff breccia to lapilli tuff interbedded in the sandstone beds in H. Po River in the east of B. Sapouan Village. Photo 10 showing conglomerate interbedded in the sandstone beds in H. Po River. Photo 11 showing conglomerate in H. Po River. Photo 12 showing a float stone of rhyolitic welded tuff in H. Po River.

As shown in Photo 12, many float stones of rhyolitic welded tuff are observed along the middle-upper river of H. Po River in the eastern part of B. Sapouan Village. These float stones are belong to the rhyolitic welded tuff consisting of Alak/Katha-Tai Formation.

Geologic Age: The Formation was probably correlated to Triassic. The geologic environments are continental, fluvial or lacustrine.

IV.1.2 Alak/Katha-Tai Formation (vT1-2, vT1-39)

Formation Name: Alak/Katha-Tai Formation was newly named in this report.

Type locality: The formation is observed in southern part of B. Katha-Tai Village located in the middle-lower part of H. Po River in the east of B. Alak of the northern part of Attapeu City, and is observed in the southern margin of the Attapu District.

Distribution: The formation appears in the middle-lower part of H. Po River and in the lower river of H. Pakpo in the east of B. Sapouan, where are located in the northern part of Attapeu City, and in the southern part of Xe Xou River of the east of B. Donngiou Village, where are located in the southern part of the Attapu District. The formation is distributed around B. Katha-Tai Village in south of Attapeu City and in the southern part of B. Phapho Village in the southwestern part of the Attapu District.

Stratigraphic relationship: The formation overlies unconformably the Dakdouan Formation, as the formation consists of continental acidic volcanic rock such as ignimbrite. And acidic pumice tuff overlies unconformably the Dakdouan Formation at 25km east from B. Paam Village in the B. DAKYOY District.

Thickness: The total thickness of the formation reaches more than 200m.

Lithofacies: The Alak Formation (vT1-2) of Alak/Katha-Tai Formation (vT1-2, vT1-3) consists mainly of volcanic breccia, tuff breccia and volcanic conglomerate and slightly of acidic welded tuff, which is distributed in the east part of B. Sapouan Village. The Katha-Tai Formation (vT1-3) consists of acidic welded tuff, which is distributed in the southern part of B. Donngiou Village, around B. Phapho Village and in B. Phapho Village in the southern parts of the Attapu District. In the southern part of B. Donngiou Village, the brown to pale brown welded tuff belong to Alak Formation of the lower formation and the light gray, pale yellow and pale green welded tuff belong to Katha-Tai Formation of the upper formation.

Photo 13

Photo 14

Photo 15

Photo 16

Fig. 9 Outcrops of Alak/Katha-Tai Formation (1). Photo 13 and 14 showing volcanic breccia and tuff breccia in H. Pakpo River of tributary of Xe Kong River. Photo 15 showing tuff breccia covered the volcanic breccia in Photo 13. Photo 16 showing volcanic breccia in H. Po River in the east of B. Sapouan Village.

The volcanic rock of Alak Formation concentrated in the eastern part of B. Sapouan Village shows brownish gray and pale gray to white, which consists mainly of lapilli tuff, volcanic breccia and volcanic conglomerate. Photo 13 and Photo 14 show volcanic breccia and tuff breccia distributed in the lower river of H. Pakpo of the tributary of Xe Kong River. The volcanic rocks include angular fragments of white rhyolite, welded tuff and tuff, which are 10cm in average diameter and 40cm in maximum diameter. Its matrix consists of white to gray coarse tuff comprising crystal fragments of biotite and quartz. Photo 15 shows rhyolitic tuff breccia, which forms upper bed of volcanic breccia observed in the same area. Its matrix shows white color. Photo 16 shows rhyolitic volcanic breccia, which is observed in middle-upper river of H. Po River of the east tributary of Xe Kong River.

The volcanic rocks of Katha-Tai Formation dispensed in the southern part of B. Donngiou Village show pale brown to pale green, which consist of acidic to neutral lapilli tuff and tuff breccia and coarse to fine tuff. The village is located in the southeastern part of the Attapu District. Fragments in the rocks consist of angular fragments of rhyolite, andesite and tuff. The matrix comprises many crystal fragments of biotite and quartz. Strike-slip fault is observed in acidic tuff as shown in Photo 17. The rock shows flow structure formed by faulting. In the southern part of the Attapu District where the volcanic rocks are distributed, the topography makes steep cliff and the taller waterfall is observed. In the area as shown in Photo 18, neutral volcanic rock unit is occurred in lower part and the acidic volcanic rocks overlie these rocks.

Photo 17

Photo 18

Fig. 10 Outcrops of Alak/Katha-Tai Formation (2). Photo 17 showing rhyolitic tuff elongated by the fault activity in south of B. Donngiou Village. Photo 18 showing the steep cliff formed by andesitic tuff in lower and rhyolitic tuff in upper.

The volcanic rocks of the Katha-Tai Formation, which is distributed in southern area of B. Phapho Village of the southwestern area of the Attapu District, consist of welded tuff, volcanic breccia and tuff breccia including many lenticular volcanic glasses. The welded structures are conspicuously observed in the rocks, which include volcanic glasses with several cm in long diameters and many fragments of tuff. The matrix is hard and compact, and comprises many crystal fragments of biotite and quartz.

Geologic age: The formation was probably formed at Triassic age.

IV.1.3 Makkhua Formation (T2)

Formation Name: Makkhua Formation was newly named in this report.

Type locality: The formation is observed in the middle-lower river of H. Po River, where flows in the eastern area of B. Sapouan Village located at north of Attapeu City.

Distribution: The formation appears at the middle-lower river of H. Po River and at the lower river of H. Pakpo River. It is distributed in the southern area of B. Donngiou Village located in the southeastern margin of the Attapu District. And it is distributed in the eastern area and the western area of the B. Phapho Village located in the southern part of Attapeu City.

Stratigraphic relationship: The formation overlies conformably the Alak/Katha-Tai Formation of lower formation.

Thickness: The total thickness of the formation reaches more than 400m.

Lithofacies: The formation, from lower to upper, consists mainly of fine to coarse tuff, tuffaceous sandstone or sandy tuff, medium sandstone, sandy limestone and cherty mudstone. The tuffaceous sandstone includes fossils of bivalve (Corbiculids).

The fine to coarse tuff shows pale gray and is rhyolitic tuff including crystal fragments of quartz and biotite in matrix. The tuffaceous sandstone or sandy tuff shows

pale greenish brown to brown. The sandstone shows yellow and is medium sandstone. The sandy limestone shows gray to dark gray and overlies the sandstone. And it is 2m thick. Photo 19 shows a layer of limestone in which white calcite veins are developed. The cherty mudstone shows greenish gray to bluish gray as shown in Photo 21. It conformably overlies the limestone and gradually changes to cherty fine sandstone.

The fossils of bivalve as shown in Photo 21 are occurred in the sandstone below the limestone bed. As the result of observation, the rock samples of No. A228a and No. A228b include fossils of bivalve. The fossils were identified as a species of Corbiculids. The species of Corbiculids shows the environment of fresh water and brackish water. As the fossils are in a poor state of preservation, the geologic age could not be decided.

Geologic age: The formation was probably formed at late Triassic age. However, there is possibility that the geologic age is Permian age according H.M. Gerhard (1994). He indicated that the formation includes the fossils of bivalve showing Permian age.

Photo 19

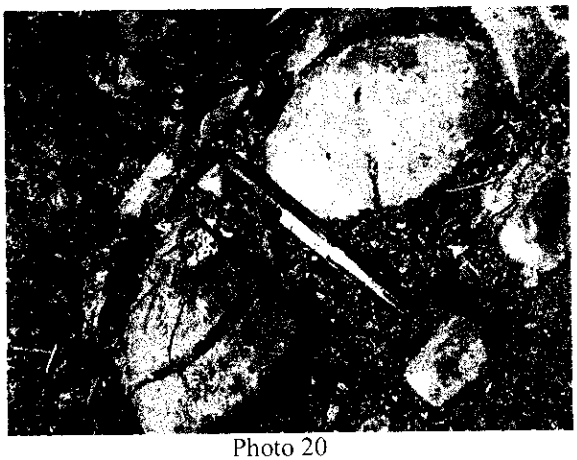


Photo 20

Fig. 11 Outcrops of Makkhua Formation (1). Photo 19 showing limestone in H. Po River in east of B. Sapouan. Photo 20 showing cherty mudstone in the mountain trail located in the same area.

Photo 21

Fig. 12 Fossils in Makkhua Formation. Photo 21showing bivalve fossils, species of Corbiculids, in the sandstone beds under the limestone bed in H. Po River in east of B. Sapouan Village.

IV.2 Jurassic

IV.2.1 Namhiang Formation (J1)

Formation Name: Namhiang Formation was newly named in this report.

Type locality: The formation is observed on the lower river of H. Po River in the eastern part of B. Sapouan Village, where located in the north of Attapeu City. It is exposed in the lower river of H. Vi River of the tributary of Xe Kong River in the northeastern part of the Attapu District.

Distribution: The formation widely appears from the mountains and hills to the flat plain in the eastern part of the Attapu District. It forms the west wing of fold with fold axis of NW-SE trend developed in the east area. The formation continuously extends from north to south in the eastern part of the Attapu District and expands to the B. DAKYOY District. It continues from the southwest area of the B. DAKYOY District to the southeast area of the Attapu District. Again, it is distributed from northeastern area to southern area, besieging the Bolaven Plateau in the southern part of the Attapu District.

Stratigraphic relationship: The formation overlies unconformably the Makkhua Formation (T2) of lower formation.

Thickness: The total thickness of the formation reaches more than 1,500m.

Lithofacies: The formation consists mainly of sandstone alternating beds layered and banded and it partly interbeds thin muddy limestone beds. The formation consists of the lithofacies of marine to continental sediments.

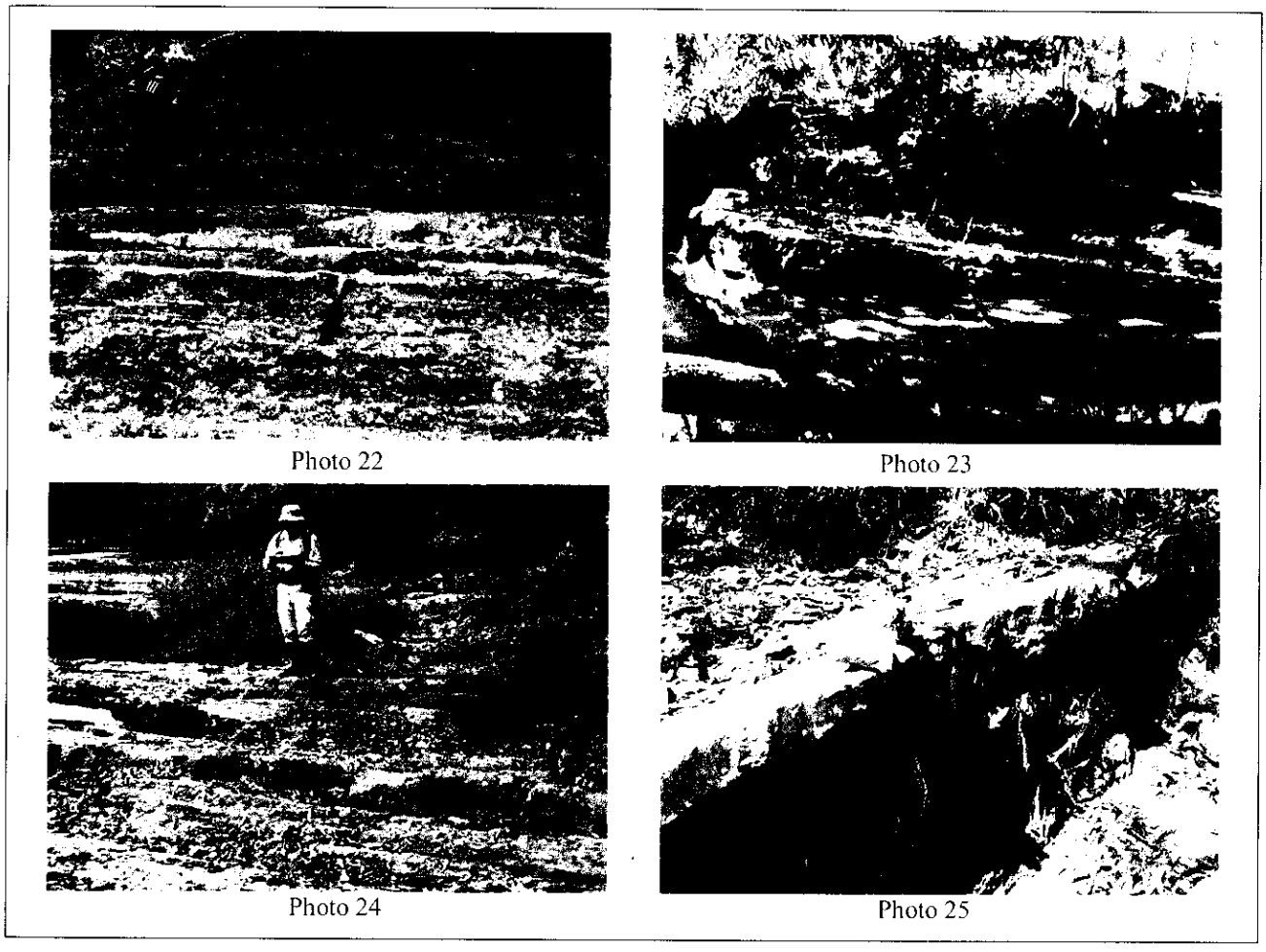


Photo 22 Photo 23

Photo 24 Photo 25

Fig. 13 Outcrops of Namhiang Formation (1). Photo 19, 20, 21 sowing sandstone alternating beds of turbidite in H. Vi River of tributary of Xe Kong River. Photo 22 showing sandstone alternating beds of turbidite on the hill near H. Chouang River of tributary of H. Vi River.

The formation, from lower, is piled up sandstone main and mudstone alternating beds, sandstone beds, mudstone main and sandstone alternating beds, sandy/muddy limestone beds and sandstone main and mudstone alternating beds.

The sandstone main and mudstone alternating beds appear along the lower river of H. Vi River, which flows from east to west in the east part of the Xe Kong River. The Namhian Formation continuously exposed along the lower river of H. Vi River. The alternating beds are gray

to pale gray and consist mainly of sandstone layered and banded. The formation is formed by turbidite sediments, which is characterized by graded bedding, moderate sorting, and well- developed primary structures.

The sandstone beds reach more than 500m in thickness in some places. As shown in Photo 23, a sandstone bed is banded layer of 10cm to 30cm thick in average and 1m thick in maximum. 95% of a bed consists of coarse to fine sandstone with sorting structure. Upper part of a bed gradually changes siltstone or mudstone sorted. Photo 25 shows the sandstone beds observed in the hills located in the west part of H. Chouang River, which is composed of the alternating beds varying from 10cm to 30cm thick.

The mudstone main and sandstone alternating beds show red to brown, which is observed in the area and consists mainly of mudstone. In some places, it shows bluish gray. The beds vary from 140m to 220m thick. The beds are formed by turbidite sediments of several cm to 20cm thick in a unit. Photo 26, 27 and 28 show a series of outcrops of the Namhiang Formation exposed along the lower river of H. Vi River. The formation mainly shows dark brown to reddish brown, consists mainly of siltstone and mudstone and interbeds medium to fine sandstone. As shown in Photo 29, vein type mineralization with copper high grade are occurred in the bluish gray mudstone beds, which includes copper minerals such as malachite, azurite, chalcopyrite, chalcocite etc.

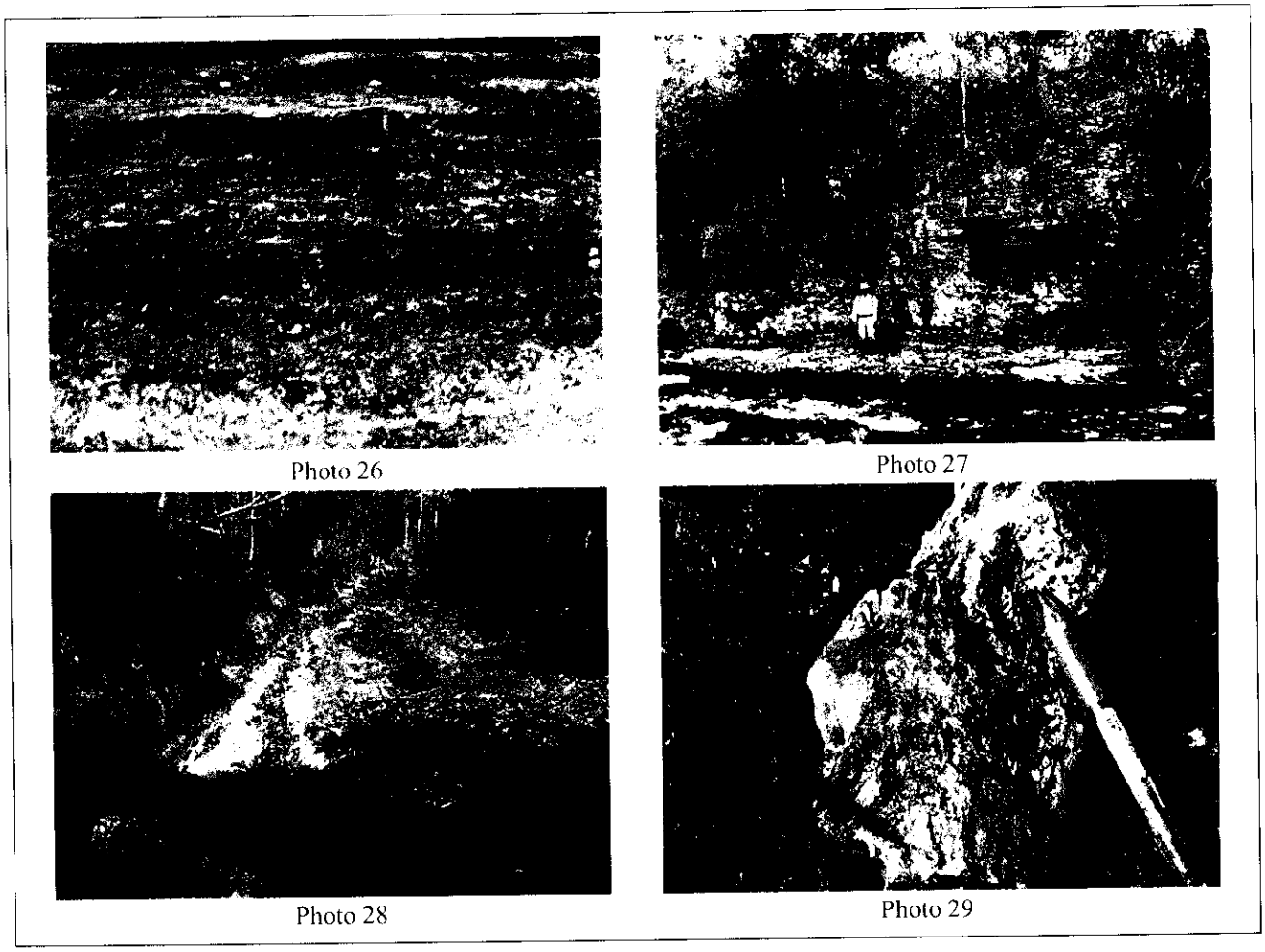


Photo 26 Photo 27

Photo 28 Photo 29

Fig. 14 Outcrops of Namhiang Formation (2). Photo 26 and 27 showing siltstone/mudstone alternating beds in H. Vi River the tributary of Xe Kong River. Photo 28 showing siltstone/mudstone alternating beds in H. Po River in the east of B. Sapouan Village. Photo 29 showing mineralized rock with copper mineral such as malachite, azurite, chalcopyrite, chalcocite etc. in H. Vi River of tributary of Xe Kong River.

A calcareous sandstone bed occurs in the upper part of the beds, which accompanies copper mineralization, so called strata-bound copper deposit of sandstone type. The thickness of bed varies from 10cm to 2m in maximum. The bed is covered by gray mudstone which is broken like flake shapes of several cm in size by weathering. Photo 30 and 31 show pale greenish gray, calcareous sandstone including fossil seashell, which is observed at the road running on the hill near the H. Chouang River of tributary of H. Vi River. Photo 31 shows calcareous sandstone with copper minerals. A fossil sample (B050) collected from the sandstone bed is perhaps identified a species of Balanus. The bed accompanies the copper mineralization with malachite,

azurite, chalcopyrite, chalcocite etc.

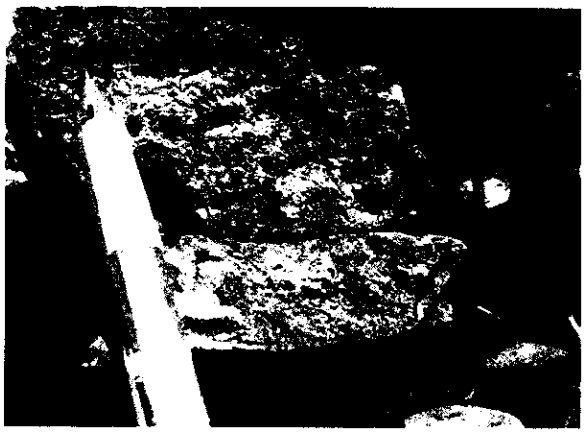


Photo 30

Photo 31

Fig. 15 Fossils in Namhiang Formation. Photo 30showing fossils of bivalve in the calcareous sandstone bed in lower river of Man Vi River. Photo 31 showing sample of No.B050 including a species of Balanus and a sandstone type copper mineralization accompanying the copper mineralization with malachite, azurite, chalcopyrite, chalcocite etc.

Again, the sandstone main mudstone alternating beds appear on the above-mentioned beds, which the thickness varies from about 150m to 100m.

The sandy/muddy limestone beds overlie the above-mentioned beds, which varies from 100m to 60m thick. A unit of the limestone beds varies from 10cm to 70cm thick and is formed by calcareous turbidite with clear lamination as shown in Photo 32. In some places, calcite veins are observed in the limestone beds. The footwall and hanging wall of the limestone bed consists of calcareous siltstone and mudstone, which is a series of turbidite. Fossil samples (Sample No. A256) collected from sandy/muddy limestone beds are identified a species of oyster, which shows the environment of brackish water.

The sandstone main and mudstone alternating beds on the above-mentioned beds reach more than 200m thick.

Massive, red mudstone beds are developed in the upper part of Namhiang Formation. Photo 33 shows the massive, red mudstone beds which are distributed around a ferry of Xe Kong City. The bed mudstone beds are characterized by typical, red continental sediments.

Geologic age: The formation was probably formed at early Jurassic age.

Photo 32

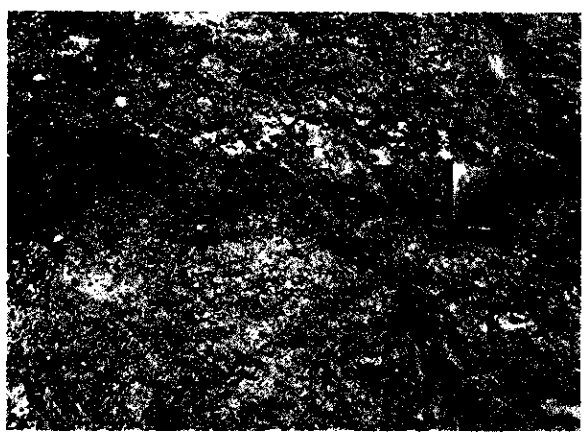


Photo 33

Fig. 16 Outcrops of Namhiang Formation (3). Photo 32 showing sandy and muddy limestone in H. Vi River. Photo 33 showing red mudstone bed.

IV.2.2 Lavi Gnai Tai Formation (J2)

Formation Name: Lavi Gnai Formation was newly named in this report.

Type locality: The formation is observed in the foot of a mountain of the west of B. Lavi Gnai Tai Village which is located in the northeast margin of the Attapu District. And it is also observed in the outcrops along the road running north to south in the eastern part of the district.

Distribution: The formation widely and continuously appears besieging the east to south margins of Bolaven Plateau which is situated in the center of the Attapu District. The formation is continuously distributed north to south district. Again, it is expanded from the southeast flat plain to the southwest flat plain.

Stratigraphic relationship: The formation overlies unconformably the Namhiang Formation (J1) of lower formation, because many bioturbation of trace fossils is observed in the lowest bed of Lavi Gnai Tai Formation which consists of calcareous sandstone and because many silicified woods of Pteridophyta are scattered along the near boundary between Namhiang Formation and Lavi Gnai Tai Formation.

Thickness: The total thickness of the formation reaches more than 400m.

Lithofacies: The formation shows red to brownish gray, which consists of calcareous sandstone beds, sandstone/siltstone alternating beds, siltstone/mudstone alternating beds and banded sandstone beds, from lower beds. It is decided that the stratigraphic boundary between Namhiang Formation and Lavi Gnai Tai Formation is composed of the calcareous sandstone beds including trace fossils.

The calcareous sandstone bed of the lowest beds is found in the B. DAKYOY District. The beds show light gray to greenish gray and consist of calcareous sandstone. The bioturbation of trace fossils is discovered in the sandstone bed as shown in Photo 34.

The sandstone/siltstone alternating beds are formed by alternation of strata, which consists of pale gray to pale purple, lithic, medium to fine sandstone and red to purplish gray siltstone. Each bed is formed by the turbidite sediments. Photo 35 shows the silicified woods of Pteridophyta. They occur in the lowest bed of the formation and are continuously scattered on the surface.

Photo 34

Photo 35

Fig. 17 Fossils in Lavi Gnai Tai Formation. Photo 34 showing many bioturbation of trace fossils in south of Route 18B. Photo 35 showing many silicified woods of Pteridophyta in the siltstone in the eastern part of the Attapu District.

The siltstone/mudstone alternating beds show red to purplish gray and are formed by the turbidite sediments, which a unit of the beds is several cm to 30cm thick.

The banded sandstone beds are observed along the paved roads running north to south or along the Xe Kong River. The beds show red to reddish brown and are formed by the turbidite sediments. Photo 36 and 37 show some fine sandstone beds banded.

Geologic age: The formation was probably formed at middle Jurassic age.

Photo 36

Photo 37

Fig. 18 Outcrops of Lavi Gnai Tai Formation. Photo 36 showing surface of the red siltstone/mudstone alternating beds in Xe Kong River near B. Namhiang Village. Photo 37 showing the red to purplish gray siltstone/mudstone alternating beds

IV.2.3 Kanglo Namho Formation (J3)

Formation Name: Kanglo Namho Formation was newly named in this report.

Type locality: The formation is observed along the road in the lower river of Xe Namnoy River flowed from Bolaven Plateau. And it is exposed along the mountain trail connected from B. Mixai Village to the top of the plateau, where H. Ho hydroelectric power plant exists.

Distribution: The formation widely and continuously appears along the eastern marginal cliff of the Bolaven Plateau. And it is linearly distributed toward east-west along the southern slope of the plateau. It is widely distributed along the road south of Xe Namnoy River and exposed along the mountain trail climbing the plateau from B. Mixai Village.

Stratigraphic relationship: The formation overlies conformably the Lavi Gnai Tai Formation.

Thickness: The total thickness of the formation varies from about 100m to 300m.

Lithofacies: The formation consists of red siltstone/ mudstone alternating beds, banded sandstone alternating beds, red siltstone/mudstone alternating beds, green tuff bed and red siltstone/mudstone alternating beds, from lower beds. The characteristics of the formation are that the red siltstone/mudstone alternating beds include rock fragments of green tuff and interbed the green tuff bed.

Photo 38

Photo 39

Fig. 19 Outcrops of Kanglo Namho Formation (1). Photo 38 showing red siltstone/mudstone alternating beds along the road in south of Xe Namnoy River. Photo 39 showing the massive, red siltstone bed and red siltstone/mudstone alternating beds near the Photo 38.

The lower red siltstone/mudstone alternating beds are composed mainly of reddish brown mudstone and siltstone and interbed reddish brown fine sandstone beds. It is formed by turbidite sediments as shown in Photo 38 and 39. And the mudstone in the red siltstone/mudstone alternating beds is red as shown in Photo 40. The beds include many granule size fragments of pisolitic tuff. The tuff fragments sometimes contain grains of malachite in some places.

The banded sandstone alternating beds are relatively massive and consist of red, medium to fine sandstone. As shown in Photo 41, the beds are stronger against erosion than the siltstone/mudstone alternating beds and form a big waterfall at the middle river of Xe Namnoy River.

The middle red siltstone/mudstone alternating beds in the formation consist mainly of reddish brown mudstone to siltstone as same as the lower siltstone/mudstone alternating beds. And the beds intercalate thin beds of red fine sandstone and contain granule fragments of pisolitic tuff.

The green tuff bed is composed of green, andesitic coarse tuff or green tuffaceous coarse sandstone and has weak parallel lamina structure. The beds contain lapilli size fragments of andesite and mudstone. Total thickness of the bed reaches more than 10m.

The upper red siltstone/mudstone alternating beds show reddish brown and contain granule fragments of tuff as shown in Photo 42. As shown in Photo 43, parallel and oblique lamina structures are observed in the beds, which a unit is several cm in thickness.

Photo 40

Photo 41

Fig. 20 Outcrops of Kanglo Namho Formation (2). Photo 40 showing the massive, red siltstone bed and red siltstone/mudstone alternating beds along the road in south of Xe Namnoy River. Photo 41 showing the layered sandstone alternating beds in the waterfall of Xe Namnoy River.

Photo 42

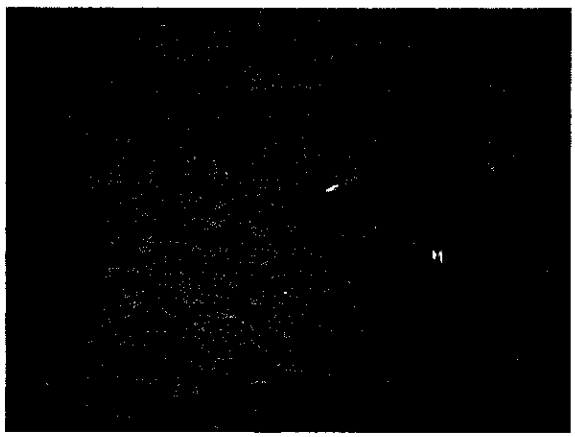


Photo 43

Fig. 21 Outcrops of Kanglo Namho Formation (3). Photo 42 showing the upper red siltstone/mudstone alternating beds including fragments of tuff in small mountain of 4km northeast of Attapeu City. Photo 43 showing red siltstone/mudstone alternating beds accompanying with fine lamination in the district.

IV.3 Cretaceous

IV.3.1 Lagnao-Kang Formation (K1)

Formation Name: Lagnao-Kang Formation was newly named in this report.

Type Locality: The formation is observed along the mountain trail climbing from B. Lagnao-Kang Village to the top of the Bolaven Plateau, which is located in the western part of Attapeu City. Especially, it is observed along the streams around B. Cheuk Mai Village, B. Dousau Village and B. Mixai Village. And it is clearly observed at the outcrops in the east margin and south margin of the Bolaven Plateau. The formation forms the steep cliffs in the eastern and southern margins of the Bolaven Plateau as shown in Photo 1.

Distribution: The formation widely appears from the northern area of north of Xe Namnoy River to the southern area of the Attapu District. The drainage of Xe Namnoy River widely covers the eastern part of the Bolaven Plateau. And it is also distributed in the basin areas of H. Parai River, Chaipai Rivey, Panallang River and Xe Pian River, which are flowing in the western part of the plateau.

Stratigraphic relationship: The formation overlies unconformably the Kanglo Namho Tai Formation.

Thickness: The total thickness of the formation varies from about 600m to 1,500m.

Lithofacies: The formation forms the steep cliffs in the eastern margin and southern margin of the Bolaven Plateau as shown in Photo 44. It is observed in the streams and along the mountain trails. The formation consists mainly of hard and compact coarse sandstone and intercalates hard mudstone beds with 2m to 6m in thickness.

The coarse sandstone is shown in Photo 45. The sandstone is observed in the upper river of H. Ouk River, which is flowing near B. Choumphoy Village. The sandstones of the formation are medium to coarse size and include coal fragments, which are solid and compact. The formation intercalates the pebble size conglomerate beds formed by fragments of lithic sandstone. The very rough lamination of several 10s cm to 2m in a scale is developed in the formation. In an outcrop located in the northern part of B. Cheuk-Mai as shown in Photo 46, very clear oblique laminas are observed. A Unit of lamination is several 10s cm to 2m in a scale. The formation is formed by the Delta sediments, which is accumulated in the continental environment where lamination is made in a big scale.

Three or more beds of hard mudstone are intercalated in the lower parts and the upper parts of the formation. The beds show bluish gray to blue-greenish gray. Photo 47 appears hard mudstone intercalated in the upper part of the formation, which shows blue-greenish gray. The bed is observed at 600m altitude in the upper stream of H. Ouk River. The float stone composed of pebble conglomerate is observed at 500m altitude in the stream as shown in Photo 48. And the bed is also observed in the cut earth of west of dam for hydroelectric power plant. In the place, the blue-greenish gray, hard mudstone bed is observed as shown in Photo 49, which is interbedded by the coarse sandstone beds of the footwall and hanging wall.

Photo 44

Fig. 22 Cliff of Lagnao-Kang Formation in Bolaven Plateau. Photo 44 showing general bed of sandstone alternating beds in the steep cliff of the Bolaven Plateau near B. Choumphoy Village.

Photo 45

Fig. 23 Outcrops of Lagnao-Kang Formation (1). Photo 45 showing oblique and parallel lamination in the coarse sandstone alternating beds in H. Ouk River near B. Choumphoy Village.

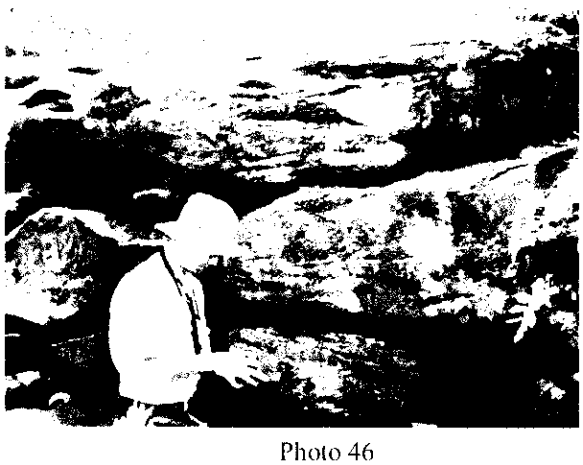


Photo 46

Photo 47

Fig. 24 Outcrops of Lagnao-Kang Formation (2). Photo 46 showing oblique lamina structures in north of B. Cheuk-Mai Village. Photo 47 showing bluish-greenish gray hard mudstone bed in H. Ouk River near B. Choumphoy Village.

Photo 48

Photo 49

Fig. 25 Outcrops of Lagnao-Kang Formation (3).Photo 48 showing float stone of pebble conglomerate in H. Ouk River near B. Choumphoy Village. Photo 49 bluish-greenish gray hard mudstone bed in the cut earth of west of dam for hydroelectric power plant.

IV.3.2 Latsaluay Formation (K2)

Formation Name: Latsaluay Formation was newly named in this report.

Type Locality: The formation is observed in the outcrops along the road in the east side of Xe Namnoy River, which flows in the eastern part of the B. Latsaluay Village located in the southeastern part of the Bolaven Plateau surface.

Distribution: The formation appears in the southeastern and southern parts of B. Namhan located in the upper stream of Xe Namnoy River in the southeastern part of the Bolaven Plateau surface. And it is distributed in the northeastern part of the B. Namhouni Village located in the middle river of Xe Namnoy River.

Stratigraphic relationship: The formation overlies unconformably the Lagnao-Kang Formation, because a clay bed underlies the bottom part of the Latsaluay Formation.

Thickness: The total thickness of the formation reaches about 100m.

Lithofacies: The formation consists of a clay bed, a massive sandstone bed and a laminated sandstone bed.

The clay bed is formed by the bed which sandstone and mudstone of the Latsaluay Formation are change to kaolinite clay. Photo 50 shows the blue-greenish gray, hard mudstone alternating beds of Lagnao-Kang Formation, which are distributed in the eastern part of upper river of Xe Namnoy River. Photo 51 shows clay by kaolinization of the formation. The clay bed is covered by the massive sandstone. In the western part of the bauxite exploration area, where located in the southern part of the B. Namhan Village, it is observed that the sandstone of the lower formation changes to kaolin clay. And the clay layer is covered by the massive sandstone bed including pisolitic bauxite pebble layer in the lower part as shown in Photo 52 and 53.

The massive sandstone composed of coarse sandstone shows white to pale gray and is soft and permeable. It contains much granule of angular quartz. Photo 54 shows the massive sandstone bed, which appears in the eastern part of the upper river of Xe Namnoy River.

The laminated sandstone bed composed of coarse sandstone shows pale gray, which is soft and permeable. Parallel and oblique laminae are conspicuously developed in the bed, which a unit of laminae is several cm to several 10s cm. Photo 55 shows the laminated sandstone bed in a outcrop near road located on the hill of eastern part of the Xe Namnoy River. Very clear oblique lamination is observed in the bed.

Geologic age: The formation was probably formed at late Cretaceous age.

Photo 50 Photo 51

Fig. 26 Outcrops of Latsaluay Formation (1).Photo 50 showing hard mudstone alternating beds of Lagnao-Kang Formation in east of Xe Namnoy River in Bolaven Plateau. Photo 51 showing kaolinite clay bed in the top of Lagnao-Kang Formation.

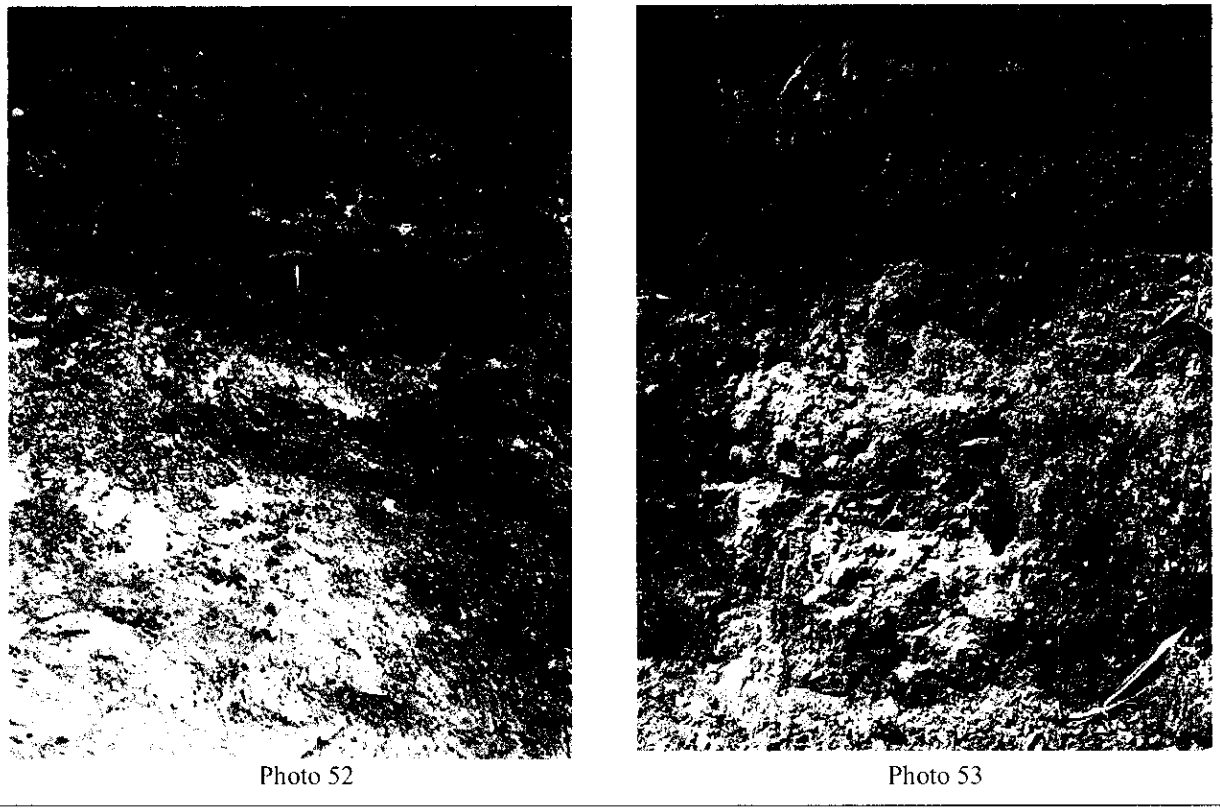


Photo 52 Photo 53

Fig. 27 Outcrops of Latsaluay Formation (2). Photo 52 and 53 showing the kaolinite clay bed of Lagnao-Kang Formation covered by sandstone bed of Latsaluay Formation in west of Xe Namnoy River, which pisolitic bauxite pebble layer occur in the lowest part of Latsaluay Formation.

Photo 54

Photo 55

Fig. 28 Outcrops of V Formation (3). Photo 54 showing massive sandstone bed of Latsaluay Formation in east of Xe Namnoy River on Bolaven Plateau. Photo 55 showing sandstone bed accompanying with very clear oblique lamination.

IV.4 Upper Cretaceous - Paleogene

IV.4.1 Bolaven Formation Lower Unit (I) (bP1-1)

Formation Name: Bolaven Formation Lower Unit (I) was newly named in this report.

Type Locality: The Lower Unit is observed in tourist waterfall situated in the southern part of Route 18 located in the western part of the Bolaven Plateau.

Distribution: The Lower Unit widely appears in the northwestern part, southwestern part and southern part of the Bolaven Plateau and is distributed in the northern part of the Xe Namnoy River of the tributary of Xe Kong River, which is located in the eastern part of the Bolaven Plateau. And the Lower Unit is slightly distributed in the top of mountain located in the eastern area of Xe Kong River.

Stratigraphic relationship: The Lower Unit overlies unconformably the Latsaluay Formation and Lagnao-Kang Formation of lower formation. The cobble gravel conglomerate of basalt occurs in the boundary between the sandstone of Lagnao-Kang Formation and the Lower Unit, which is distributed in northern part of B. Houaychiat Village located in the western part of Bolaven Plateau.

Thickness: The total thickness of the volcanic rock reaches about 100m.

Photo 56

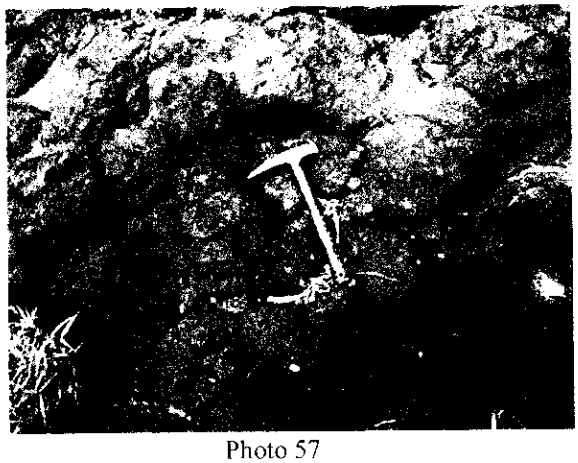


Photo 57

Fig. 29 Outcrops of Bolaven Formation Lower Unit (I). Photo 56 showing lava flows of pyroxene basalt in the tourist waterfall situated in the southern part of Route 18 located in the western part of the Bolaven Plateau. Photo 57 showing hexagonal columnar joints appear in surface of the eroded basaltic lava flows.

Lithofacies: The Lower Unit consists of basalt, which olivine crystal cannot be identified with the naked eye. In this report, we named the basalt as pyroxene basalt. Most of the rocks are vesicular. The Lower Unit is typically observed in the waterfalls of tourist resort located in the southern part of B. Lak 38 Village as shown in Photo 56. The Lower Unit is formed by accumulation of many lava flows, which consist of pyroxene basalt in the upper lavas. Hexagonal columnar joints appear in surface of the eroded basaltic lava flows as shown in Photo 57.

Characteristics under the microscope: Photo 1 shows the rock texture of pyroxene basalt (Sample; A127) by the microscopic observation of rock thin section.

Occurrence: In the lower river of H. Champi River in western part of Bolaven Plateau.

Texture: Porphyritic and intersertal texture.

Phenocryst: Augite.

Groundmass: Consisting of plagioclase, augite, opaque minerals and volcanic glass. Plagioclase shows lath-shape and acicular-shape with size of 0.1mm to 0.3mm. Augite shows euhedral and granular with size of 0.01mm to 0.1mm. Opaque minerals show euhedral and subeuhedral with size of 0.01mm to 0.02mm. Volcanic glass shows transparent and fills up in the spade among minerals of groundmass.

Alteration minerals: Consisting of a few of zeolite and illite. Zeolite minerals fill up vesicles. Illite minerals replace the volcanic glass.

Geologic age: Using the rock sample (A127) of pyroxene basalt of Bolaven Formation Lower Unit (I), the K-Ar dating analysis was conducted by ActLabs Ltd., Canada. The result of 121.4 $\pm$ 3.1 Ma in geochronology was obtained. The age ranges in Cretaceous age. On the other hand, other geologic age for the rock sample of basalt collected in the B. DAKYOY District shows 40.0 $\pm$ -1.3 Ma. The geologic age ranges in Paleogene age. Therefore, the pyroxene basalt of the Bolaven Formation Lower Unit (I) is probably erupted in the geologic age from Cretaceous age to Paleogene age.

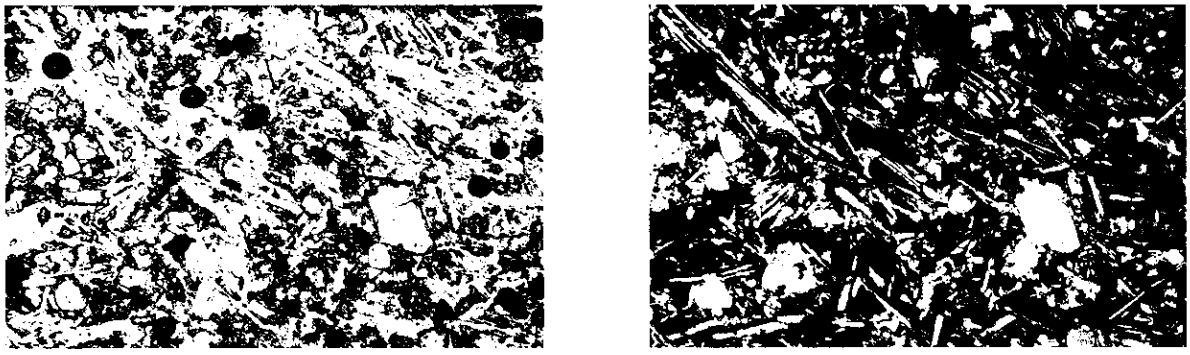


Fig. 30 Microscopic Photo 1. Pyroxene basalt (Sample No.: A127).

IV.4.1 Bolaven Formation Lower Unit (II) (bP1-2)

Formation Name: Bolaven Formation Lower Unit (II) was newly named in this report.

Type Locality: The Lower Unit is observed in outcrops along the road extending from Route 18 to northern part and passing B. Houaychiat Village, which located in the western part of the Bolaven Plateau.

Distribution: The Lower Unit appears like islands in the Attapu District and is distributed in the northwestern part and the southwestern part of the Bolaven Plateau. And the rocks are distributed surrounding the B. Houaytao Village and around the Dindeng Mountain.

Stratigraphic relationship: The Lower Unit overlies unconformably the Bolaven Formation Lower Unit (I).

Thickness: The total thickness of the volcanic rock reaches more than 50m.

Lithofacies: The Lower Unit consists of basalt to basaltic andesite including the visible plagioclase phenocrysts, which do not include the visible olivine phenocrysts. The rocks show dark gray to black and are vesicular. The Lower Unit typically contains columnar phenocrysts of plagioclase with size of 2mm to 3mm. We named the basalt as plagioclase basalt.

Characteristics under the microscope: Microscope Photo 2 shows the rock texture of plagioclase basalt (Sample; A122) by the microscopic observation of rock thin section.

Occurrence: In an outcrop of 5km north from B. Nongkali Village located in 6km north from Pakxong City in the western part of Bolaven Plateau.

Texture: Porphyritic and intersertal texture.

Phenocryst: Plagioclase, augite and olivine. Plagioclase with zonal structure shows column-shape with size of 0.5mm to 3.0mm. Augite shows euhedral and granular with size of 0.2mm to 0.3mm. Olivine show euhedral and granular with size of 0.3mm to 0.8mm.

Groundmass: Consisting of plagioclase, augite, opaque minerals and volcanic glass. Plagioclase shows lath-shape and acicular-shape with size of 0.05mm to 0.2mm. Augite shows euhedral and granular with size of 0.03mm to 0.8mm. Opaque minerals show euhedral and subeuhedral with size of 0.01mm to 0.02mm. Volcanic glass shows transparent and fills up in the spade among minerals of groundmass.

Alteration minerals: Consisting of a few of limonite. Olivine and augite minerals are replaced by the limonite, called as iddingsite.

Geologic age: The plagioclase basalt of Bolaven Formation Lower Unit (II) erupted on the pyroxene basalt of Bolaven Formation Lower Unit (I). Therefore, the plagioclase basalt of Bolaven Formation Lower Unit (II) probably is younger than the pyroxene basalt of Bolaven Formation Lower Unit (I).

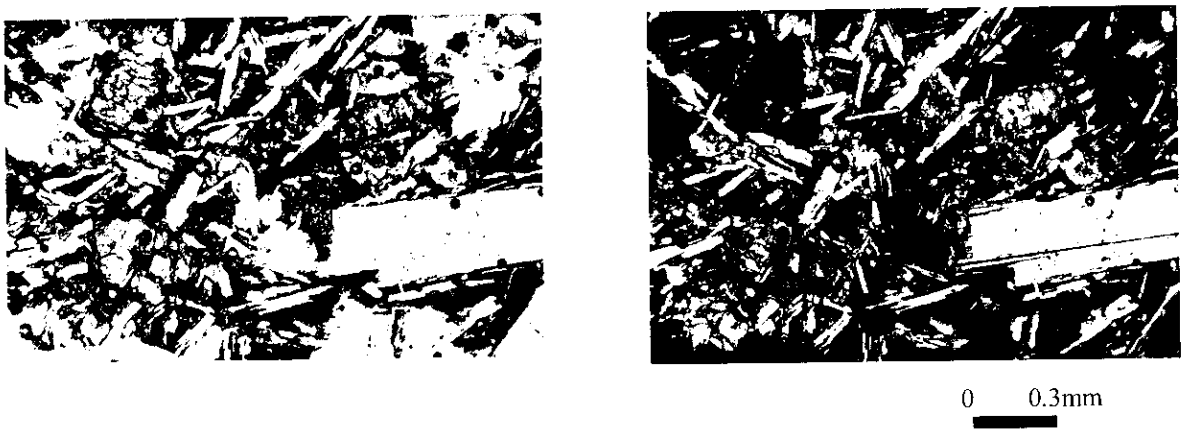


Fig. 31 Microscopic Photo 2. Plagioclase basalt (Sample No. : A122).

V Cenozoic

V.1 Neogene - Quaternary

V.1.1 Bolaven Formation Upper Unit (I) (bN1-1)

Formation Name: Bolaven Formation Upper Unit (I) was newly named in this report.

Type Locality: The Lower Unit is observed in outcrops along the road running toward north and passing B. Nongya Village, which located in the central-northern part of the Bolaven Plateau.

Distribution: The Upper Unit widely appears in the central-northern area, in the eastern area and in the southern area of the Bolaven Plateau of the Attapu District. The rocks are extensively distributed surrounding the B. Nongya Village and around the B. Nongmek Village in the central-northern area. And the rocks are widely distributed surrounding the B. Nongping Village and around the B. Nongset Village in the southern area and along the H. Goai River in the western area.

Stratigraphic relationship: The Upper Unit overlies unconformably the Bolaven Formation Lower Unit (I) and (II).

Thickness: The total thickness of the volcanic rock reaches more than 50m.

Lithofacies: The Upper Unit consists of dark gray to black basalt including the visible olivine phenocrysts, which are vesicular. We named the basalt as olivine basalt. Photo 58 shows massive olivine basalt, which are exposed in the lower river of the Xe Namnoy River of tributary of the Xe Kong River. The rocks are massive, which do not have columnar joints as shown in Photo 59. Photo 60 shows the olivine basalt exposed along the road around B. Nongya Village, which is located in the north-central part of the Attapu District. The rocks contain many xenoliths consisting of lherzolite and pyroxenite, so called mantle xenolith. And the rocks also include nodules of quenched magmatic glass. As shown in Photo 61, the olivine basalt laves capture xenolith of pyroxene basalt. The relationship explains that the olivine basalt laves have spewed out after the pyroxene basalt lava.

Photo 58

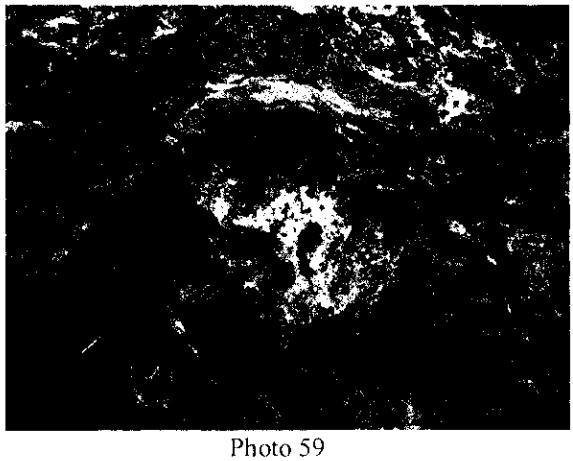


Photo 59

Fig. 32 Outcrops of Bolaven Formation Upper Unit (I) (1). Photo 58 showing olivine basalt under bridge of Xe Namnoy River of tributary of Xe Kong River. Photo 59 showing olivine basalt of outcrop of Photo48.

Photo 60

Photo 61

Fig. 33 Outcrops of Bolaven Formation Upper Unit (I) (2).Photo 60 showing olivine basalt including xenoliths of lherzolite, pyroxenite, primitive magma glasses. Photo 61 showing olivine basalt including xenolith of pyroxene basalt near B. Phakkuof-Noi Village.

Characteristics under the microscope: Microscope Photo 2 shows the rock texture of olivine basalt (Sample; A120) by the microscopic observation of rock thin section.

Occurrence: In an outcrop beside of road near B. Nongkali Village located in 6km north from Pakxong City in the western part of Bolaven Plateau.

Texture: Porphyritic and intergranular texture.

Phenocryst: Olivine and augite. Olivine shows euhedral and granular with size of 0.5mm to 0.8mm. Augite shows euhedral and granular with size of 0.2mm to 0.3mm.

Groundmass: Consisting of plagioclase, augite, olivine, opaque minerals and volcanic glass. Plagioclase shows lath-shape and acicular-shape with size of 0.1mm to 0.8mm. Augite shows euhedral and granular with size of 0.03mm to 0.1mm. Olivine shows euhedral and granular with size of 0.03mm to 0.1mm. Opaque minerals show euhedral and subeuhedral with size of 0.01mm to 0.04mm. A few of volcanic glass fills up in the spade among minerals of groundmass.

Alteration minerals: No alteration minerals.

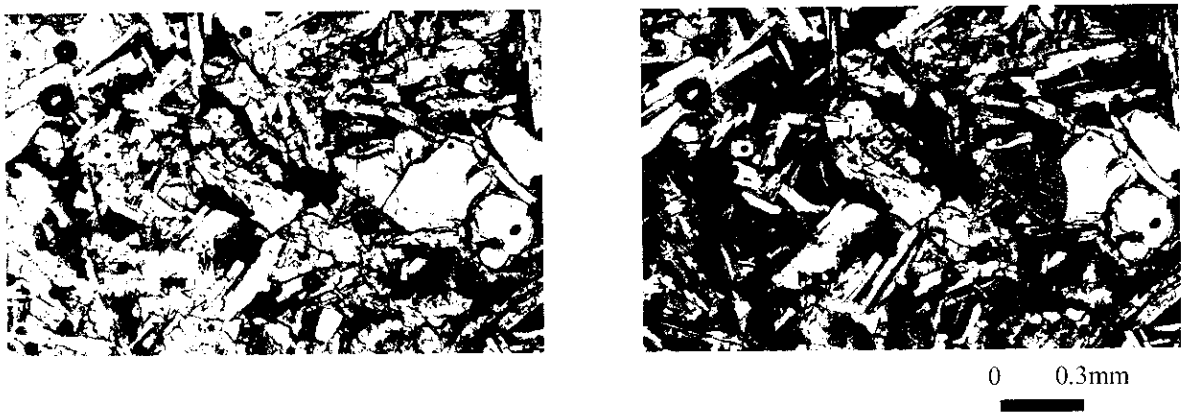


Fig. 34 Microscopic Photo 3 Olivine basalt (Sample No. : A120).

Geologic age: Using the rock sample (A117) of olivine basalt of Bolaven Formation Upper Unit (I), the K-Ar dating analysis was conducted by ActLabs Ltd., Canada. The result of 8.7 $\pm$ 0.4 Ma in geochronology was obtained. The age ranges in Neogene age. Therefore, the pyroxene basalt of the Bolaven Formation Upper Unit (I) is probably erupted in the geologic age from Neogene age to Quaternary age.

V.1.2 Bolaven Formation Upper Unit (II) (bN1-2)

Formation Name: Bolaven Formation Upper Unit (II) was newly named in this report.

Type Locality: The Upper Unit is observed in and around a mountain with crater, which located in the eastern part of Pakxong City located in the center-northern area of the Attapu District. And the rocks are also observed around the Din Mountain with crater, which located at 15km south from Pakxong City.

Distribution: The Upper Unit appears around a mountain located in the eastern part of Pakxong City and around the Din Mountain located at southern part of Pakxong City. The rocks are formed by lava flows, which are widely spewed out from these mountains. The lava flows, which flow out from Mount Din Volcano, reach at B. Nathongsomlong Village located in southern margin of the Attapu District. The distance of lava flows reaches about 50km.

Stratigraphic relationship: The Upper Unit overlies unconformably the Bolaven Formation Lower Unit (I) and (II), and the Bolaven Formation Upper Unit (I).

Thickness: The total thickness of the volcanic rock perhaps reaches more than 50m.

Lithofacies: The Upper Unit consists of dark gray to black basalt including visible olivine and nepherine phenocrysts. The rocks are vesicular. We named the basalt as nepherine-olivine basalt. Lavas of the rock is low in erosion progress and are remained the structures of ropy lava. Photo 62 shows the basalt lavas, which have reached until about 50km from Mount Din Volcano with a crater. Photo 63 shows the structures of ropy lava remained on the surface of the Upper Unit, which have been formed by lava flows with thickness of 30cm to 1m. Photo 64 shows a volcanic mountain with a crater (Photo 65) spewed out the basaltic lavas, which is located in the east part of Pakxong City. Photo 63 shows clinker characterized in the surface of lava flows.

Photo 62

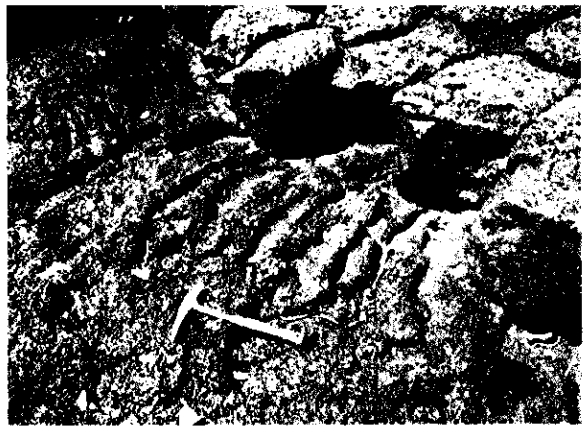


Photo 63

Fig. 35 Outcrops of Bolaven Formation Upper Unit (II) (1). Photo 62 showing basalt lavas flowing down to 4km from Mount Ph. Din. Photo 63 showing ropy lava structure observed in surface of the basalt lavas.

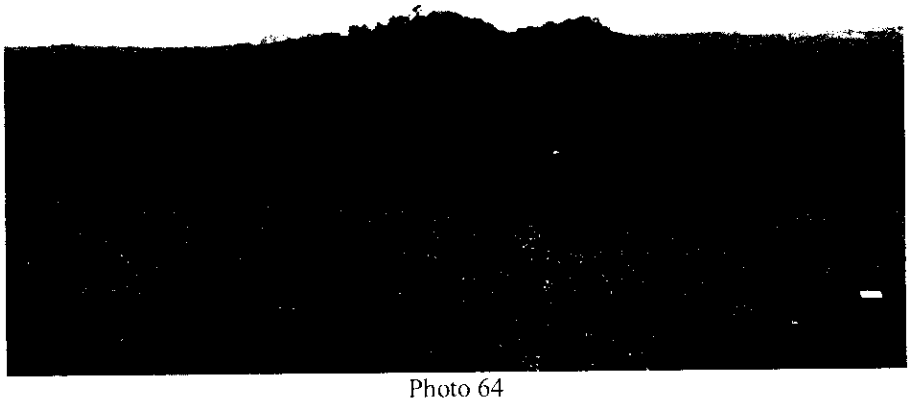


Photo 64

Fig. 36 Volcanic hill of Bolaven Formation Upper Unit (II). 64 showing a volcanic mountain of Ph. Thevada Mountain located in east of Pakxong City accompanying create crupted basalt lava flows.

Photo 65

Photo 66

Fig. 37 Outcrops of Bolaven Formation Upper Unit (II) (1). Photo 65 showing a crater located in the center of Ph. Thevada Volcano in east of Pakxong City. Photo 66 showing clinker structure characterized in the surface of lava flows around Ph. Thevada Volcano.

Characteristics under the microscope: Microscope Photo 2 shows the rock texture of nepherine-olivine basalt (Sample; A131) by the microscopic observation of rock thin section.

Occurrence: In an outcrop on road at 5km south of Mount Din (1.202m) located in 12km south from Pakxong City.

Texture: Porphyritic and intergranular texture.

Phenocryst: Olivine and nepherine. Olivine shows euhedral and granular with size of 0.3mm to 1.5mm. Nepherine shows subeuhedral and tabular-shape with size of 0.2mm to 0.3mm.

Groundmass: Consisting of plagioclase, augite, olivine, opaque minerals and volcanic glass. Plagioclase shows lath-shape and acicular-shape with size of 0.02mm to 0.2mm. Augite shows euhedral and granular with size of 0.02mm to 0.2mm. Olivine shows euhedral and granular with size of 0.03mm to 0.1mm. Opaque minerals show euhedral and subeuhedral with size of 0.01mm to 0.06mm. A few of volcanic glass fills up in the spade among minerals of groundmass.

Alteration minerals: No alteration minerals.

Geologic age: The nepherine-olivine basalt of Bolaven Formation Upper Unit (II) erupted on the olivine basalt of Bolaven Formation Upper Unit (I). Therefore, the nepherine-olivine basalt of Bolaven

Formation Upper Unit (II) probably is younger than the olivine basalt of Bolaven Formation Lower Unit (I) and shows geologic age of Neogene to Quaternary.

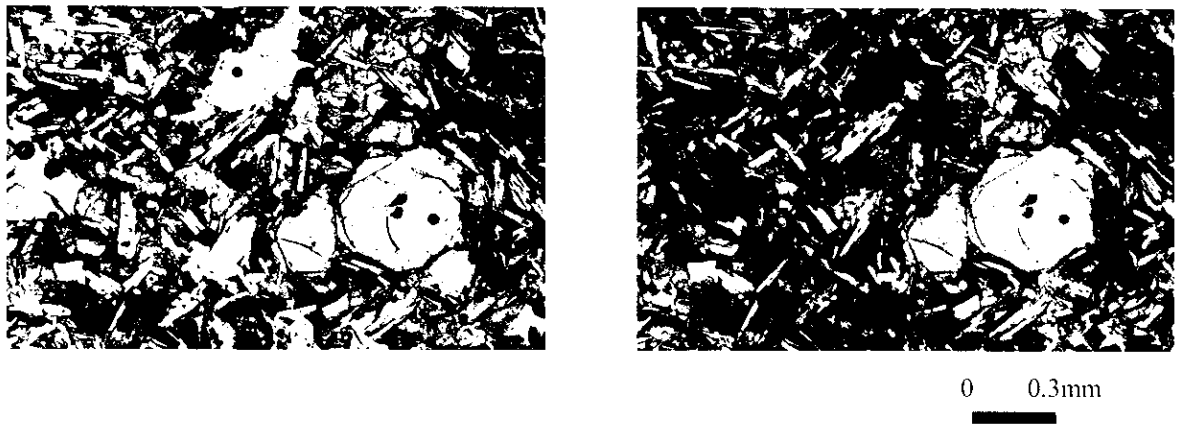


Fig. 38 Microscopic Photo 4 Nepherine-olivine basalt (Sample No. : A131).

V.2 Neogene - Quaternary

V.2.1 Terrace Deposits (Qt)

Type Locality: The deposits are observed in the river side of Xe Kong River around B. Xekaman Village located in south of Attapeu City. And the deposits are also observed in the river side of Xe Kong River near B. Hatsati Village located in 12km north of Attapeu City.

Distribution: The deposits are distributed surrounding Xe Kong River and Xe Kaman River, which flow in the eastern part of the Attapu District. And the deposits also appear surrounding the lower river of the Xe Pian River, which flow from north to south in central-south part of the district.

Stratigraphic relationship: The deposits overlie unconformably all lower formation along the rivers.

Thickness: The total thickness of the deposits perhaps reaches 5m in maximum.

Lithofacies: The deposits are sediments of river terrace, which are distributed mainly along the Xe Kong River and the Xe Kaman River. The terrace deposits consist of the rounded gravels with 3cm to 30cm in long diameter, which consist of basalt, sandstone, quartzite, muddy schist, sandy schist and granitic rocks. The matrix is composed of soft-sediments such as sand, silt etc.

As shown in Photo 67, the terrace deposits overlie unconformably the red mudstone beds of the Kanglo Namho Formation of upper Jurassic, which are observed around B. Xekaman Village located in the left river bank of Xe Kong River flowing in Attapeu City.

Geologic age: The deposit was probably formed in the Pliocene to Quaternary age.

Photo 67

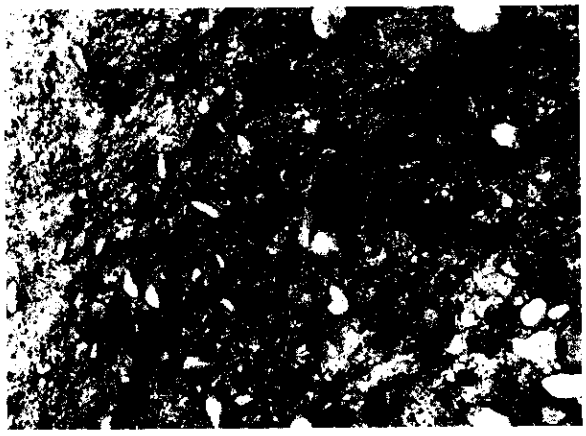


Photo 68

Fig. 39 Outcrops of Terrace Deposits. Photo 67 showing terrace deposits overlying the red siltstone/mudstone alternating beds on the ferry of B. Xekama Village near the riverside of Xe Kong River near Attapeu City. Photo 68 showing terrace deposits in the riverside of B. Hatsati Village located in the northern part of the Attapeu City.

V.2.2 Fluvial Deposits (Q)

Type Locality: The deposits are observed in the rivers of Xe Kong River, Xe Kaman River, Xe Xou River, Xe Namnoy River, Xe Pian River, Xe Khamphi River, etc., which flow in the Attapu District.

Distribution: The deposits are distributed in the rivers of Xe Kong River, Xe Kaman River, Xe Xou River, Xe Namnoy River, Xe Pian River, Xe Khamphi River, etc. , which flow in the Attapu District.

Stratigraphic relationship: The deposits overlie unconformably all lower formation along the rivers.

Thickness: The total thickness of the deposits perhaps reaches more than 5m.

Lithofacies: The fluvial deposits consist of the well-rounded gravels of bolder, cobble, pebble and granule. And the matrix is composed of soft sediments of sand, silt and clay.

Geologic age: The deposit was accumulated in the recent age of Quaternary.

VI Igneous Activity

The magmatic lavas and stock of basaltic rocks overlie the Bolaven Plateau of the geological map of the Attapu District. The rocks are divided into four kind of basaltic rocks by seeing with the naked eye. In order to clarify the geochemical features of the magmatic lava flows, chemical analysis of basaltic rocks was carried out in the laboratory.

1) Analyzed Sample

The analyzed rock samples are as follows. Basaltic rocks distributed in the B. DAKYOY District were also analyzed for the geochemical comparison.

2) Analytical Content

Analytical elements are 32 components as follows, consisting of major, trace and rare earth elements.
SiO2, TiO2, Al2O3, Fe2O3, MgO, MnO, CaO, Na2O, K2O, P2O5, LOI, Rb, Sr, Ba, Zr, V, Nb, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

3) Analytical Methods

Chemical analyses of all the elements except LOI (Loss of Ignition) were conducted by Inductively Coupled Plasma Mass Spectrometry (ICPMS) at ALS Chemex, Australia. LOI was determined gravimetrically after fusion in electric furnace.

4) Results of Chemical analyses

The analytical results of the Bolaven Formation Lower Unit and the Bolaven Formation Upper Unit are given in Annex 9. For understanding the geochemical nature of basaltic rocks, the results of chemical analyses were plotted on various petrochemical discrimination diagrams (Figures 4.8.1 to 4.8.15).

Geochemical characteristics of the basaltic rocks are summarized below.

a. The alkali-silica diagrams (Figures 4.8.8 and 4.8.9) show that the samples of the Bolaven Formation Lower Unit and the Bolaven Formation Upper Unit are sub-alkali basalt to basaltic andesite. And only samples of Nepherine-Olivine basalt (A005) of Bolaven Formation Upper Unit (II) in Bolaven Plateau is alkali trachy basalt.
b. In FeO-alkali-MgO (AFM) (Figure 4.8.10) diagram of discriminating igneous trend , all of the samples are plotted in the similar field and no clear trend of differentiation is identified.
c. All the samples of the Bolaven Formation Lower Unit and the Bolaven Formation Upper Unit show similar patterns in the spider diagram of trace elements normalized to MORB (Figure 4.8.11) except basalt sample of Nepherine-Olivine basalt (A005) of Bolaven Formation Upper Unit (II) in Bolaven Plateau which is more enriched to trace elements than other samples.
d. Similar chondrite normalized patterns of REE with a slight variation of light REE concentration were obtained from the samples of basaltic rocks in the district (Figure 4.8.12). The light REE is slightly enriched in the basalt Nepherine-Olivine basalt (A005) of Bolaven Formation Upper Unit (II) in Bolaven Plateau, while it is less in the basalt of pyroxene basalt (B024) of Bolaven Formation Lower Unit (I) in the Xe Kong River area.
e. In the (Ti/100))-Zr-3Y discrimination diagram of the tectonic setting of basalt generation (Figure 4.8.13), all samples fall in the field of WPB (within plate basalt).
f. All the basaltic rock samples are plotted in the fields of either WPA (within plate alkali) or WPI (within plate tholeiite) of the WPB (within plate basalt) in the 2Nb-(Zr//4)-Y discrimination diagram of tectonic setting (Figure 4.8.14).
g. In the TiO2-10MnO-10P2O5 discrimination diagram for basaltic rocks (Figure 4.8.15), most of the samples of basaltic rocks occupy the filed of OIA (oceanic-island alkali basalt or seamount alkali basalt) except one taken in the area of pyroxene basalt (B024) of Bolaven Formation Lower Unit (I) in the Xe Kong River which is plotted in the field of OIT (oceanic-island tholeiite of seamount tholeiite)

Table 3 Sample for rock analysis

Lithofacies	Sample No.
Laterization basalt	A004
Pyroxene basalt of Bolaven Formation Lower Unit (I)	A127, B024, B071
Plagioclase basalt of Bolaven Formation Lower Unit (I)	A114
Olivine basalt of Bolaven Formation Lower Unit (I)	A118, 117
Nepherine-Olivine basalt of Bolaven Formation Lower Unit	A005, A131
Pyroxene basalt in the B. DAKYOY district	B044, B071
Dorelite of Dyke	A146

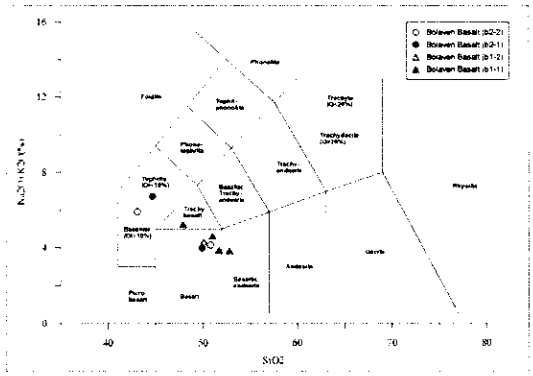


Fig. 40 TAS discrimination diagram of basaltic rocks

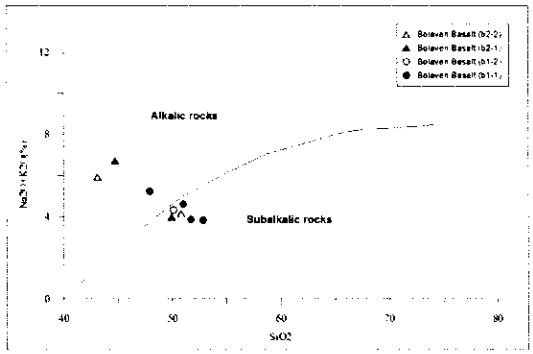


Fig. 41 Alkali-silica diagram of basaltic rocks

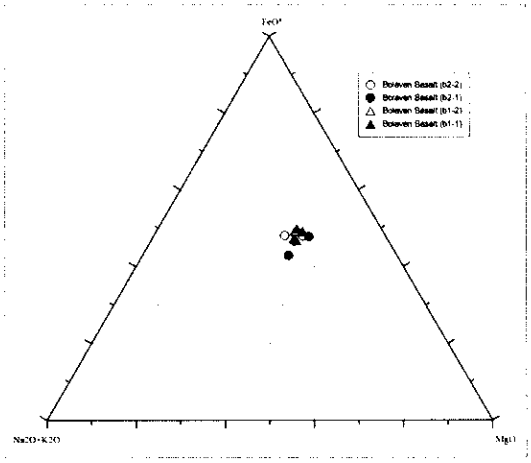


Fig. 42 AFM diagram of basaltic rocks

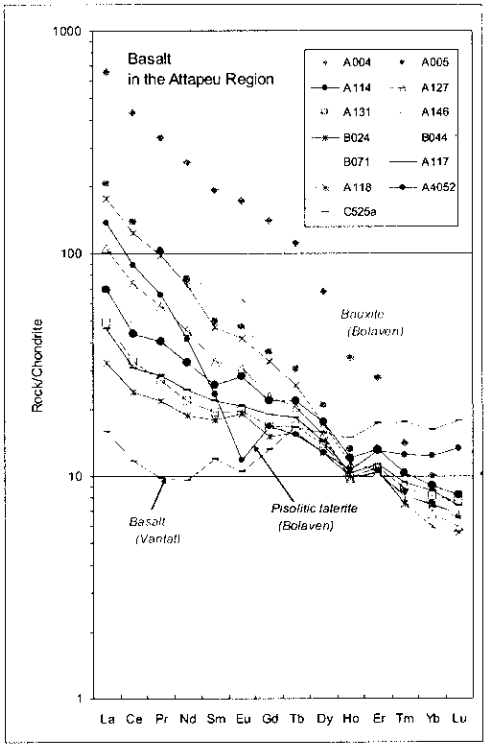


Fig. 43 Chondrite normalized geochemical patterns of the basaltic rocks

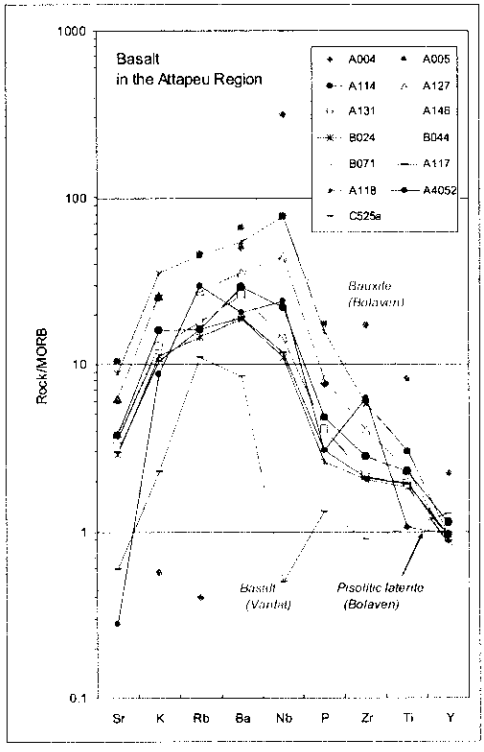
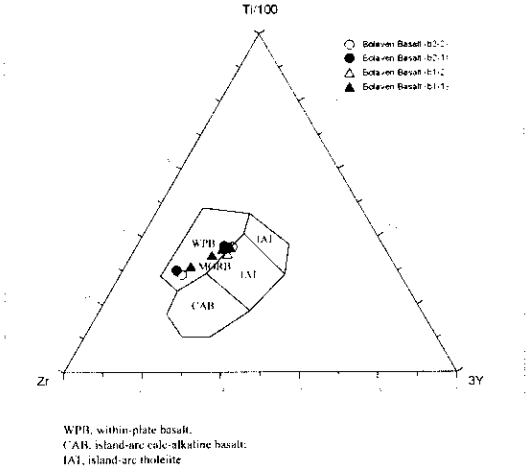
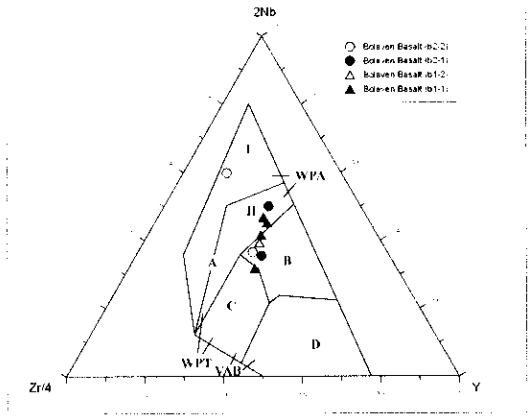


Fig. 44 MORB normalized spider diagram of the basaltic rocks



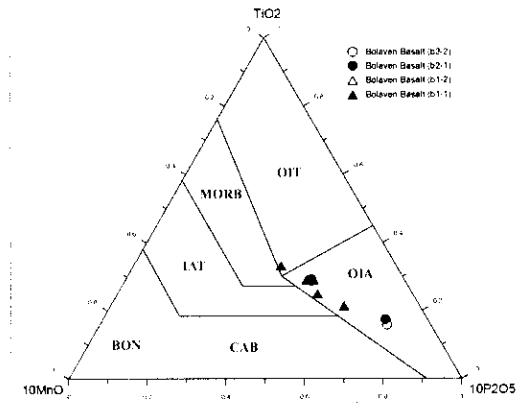
WPB, within-plate basalt;
CAB, island-arc calc-alkaline basalt;
IAT, island-arc tholeiite

Fig. 45 Y-Ti-Zr discrimination diagram of basaltic rocks



AI, within-plate alkali basalts; AII, within-plate alkali basalts and within-plate tholeiites;
B, E-type MORB; C, within-plate tholeiites and volcanic-arc basalts;
D, N-type MORB and volcanic-arc basalts.
WPA, within-plate alkali basalt; WPT, within-plate tholeiite; VAB, volcanic-arc basalt

Fig. 46 Y-Nb-Zr discrimination diagram of basaltic rocks



OIT, ocean-island tholeiite or seamount tholeiite;
OIA, ocean-island alkali basalt or seamount alkali basalt;
CAB, island-arc calc-alkaline basalt;
IAT, island-arc tholeiite; BON, boninite

Fig. 47 P-Ti-Mn discrimination diagram of basaltic rocks

VII Geological Structure

VII. 1 Tectonics

The geological mapping area of the Attapu District belongs to Kontum-Savannakhet Tectonic Region in the tectonic classification of the Indochina area. During the Indosinian orogeny from Cretaceous to Jurassic ages after Hercynian orogeny, the marine and continental sediments accumulated in the district. Especially, the continental acidic volcanic rocks had been erupted in Triassic age. After that, the Himalayan orogeny began in the Cretaceous age and the continental sediments such as a deltaic deposit were piled up in the calm geologic environment. In the Triassic age, Indian continent collided into Eurasian continent, and the entailed tectonic movement was caused. It was taken over to Quaternary and the plateau basalt which is characterized by within-plate basalt has been spewed out in the area.

Through these orogeny and tectonics, faulting and folding structures in eastern area, sedimentary basins in the central area and volcanic belt in the western area have formed as the geological structures in the Attapu District.

Presently, reverse fault with NNW-SSE trend was formed in the eastern margin of the Attapu District, which divides Carboniferous and Triassic. The clear structures of syncline and anticline with fold axis of NNW-SSE trend were constructed in Triassic and Jurassic sediments distributed in the western area. The monoclinal structure gently inclined westward with 10 degree was constructed in the western area of the structures of syncline and anticline. Considering Triassic distributed in the southwestern part of the district, the gentle syncline structure or the basin structure can is identified in the area. Furthermore, the plateau basalt widely covered the western area of the Bolaven Plateau.

The craters of Bolaven Formation Upper Unit, which erupted at Neogene to Quaternary age, were arranged in NNW-SSE trend. And the arrangement of craters superimposes basement structure. The basalt of Bolaven Formation Upper Unit includes the mantle xenoliths. And it suggests the deep mantle origin.

VII. 2 Fault

Fault structure is formed by NNW-SSE trend faults located in the northeast margin and WNW-ENE trend fault located in the southeastern area.

The NNW-SSE trend faults consist of three fault zones in the 5km width from B. Kasang-Kang Village to B. Kasang-Noy Village, which are developed in the upper river of H. Vi River located in the northeastern margin of the Attapu District.

- Eastern fault zone divides the conglomerate bed and the sandstone bed of Carboniferous. The faults are filled by fault clay in 20cm width.
- Central fault zone divides the sandstone beds of Namhiang Formation (J1) of Jurassic and the slate of Kadon Formation (C) of Carboniferous. The formation of slate strikes N51°W and dips high angle of 62°W.
- Western fault zone divides the acidic volcanic rocks of Alak/Katha-Tai Formation (vT1-2, vT1-3) of Triassic and the muddy schist of Namhiang Formation (J1) of Jurassic.

The WNW-ENE trend fault is formed in the Alak/Katha-Tai Formation (vT1-2, vT1-3) of Triassic, which is observed in the middle river of H. Khou-Gnai River located in the southeastern margin of the Attapu District.

- The fault is fault zone formed in the acidic tuff breccia with pale greenish gray color, which has more than 10m width. As shown in Photo 17, the volcanic glass and fragments of the acidic tuff breccia are elongated by fault activity and the fault shows the feature of left-lateral fault. According to the interpretation of ASTER satellite image, the fault cuts the Alak/Katha-Tai Formation, but dose not cut the Makkhua Formation (T2) of the upper formation.

VII. 3 Fold

The fold structure in the Attapu District is composed of NNW — SSE trend fold zone formed in the northeastern area and ENE — WSW trend fold zone in the southeastern area. The latter is made by the gentle fold structure.

From east to west in the northeastern area, the fold zone is formed by syncline structure with fold axis of NNW-SSE trend, syncline structure with same trend and anticline structure with same trend. In the western part of the fold structures, monocline structure is constructed, which gently dips westward. And the Bolaven Plateau also exists in the western part of the structure, which is formed by approximate flat structure.

- The syncline structure in the northeastern rim is made in the area besieged by two reverse faults with NNW-SSE trend, which located in the upper river of H. Vi River. In the area, the Alak/Katha-Tai Formation (vT1-2, vT1-3) of Triassic and the Namhiang Formation (J1) of Jurassic appear.
- The western syncline structure is divided by a reverse faults with NNW-SSE trend at the eastern side, which located in the middle-upper river of H. Vi River. The fold has a hold axis of NNW — SSE trend and inclines to NNW direction. According to the interpretation of ASTER satellite image, the Alak/Katha-Tai Formation (vT1-2, vT1-3) and Makkhua Formation (T2) of Triassic and the Namhiang Formation (J1) and the Lavi Gnai Tai Formation (T2)of Jurassic appear in the folding area.
- The anticline structure in the western area has a

hold axis of NNW-SSE trend and inclines to NNW direction, which located in the middle river of H. Vi River to the middle river of H. Po River. And it is also extended to the southeastern area. The width of the anticline structure is 10km and the extension is more than 40km. It is extended into the B. DAKYOY District and also into the northern map sheet (D-48 V), which has very long fold axis. In the western wing of the fold axis, the Dakdouan Formation (T1-2), the Alak/Katha-Tai Formation (vT1-2, vT1-3) and Makkhua Formation (T2) of Triassic and the Namhiang Formation (J1) and the Lavi Gnai Tai Formation (J2) of Jurassic appear and they gradually transit to the monocline structure. In their formation, many micro-folds appear and the folds show the hold axis of NNW-SSE trend and also incline to NNW direction.

These fold zones show the anticline and syncline structure constructed in the Mesozoic sediments at the boundary between basements and Mesozoic sediments. The basements consist of Paleozoic sediments and granitic rocks, widely distributed in the eastern area, and the Mesozoic sediments consist mainly of continental sediments.

On the other hand, the anticline and syncline structure are constructed in the southeastern area of the Attapu District, which is formed by gentle fold structures having ENE-WSW trend fold axis. The structure is formed in the Makkhua Formation (T2) of Triassic and in the Namhiang Formation (J1), the Lavi Gnai Tai Formation (J2) and the Kanglo Namho Formation (J3) of Jurassic.

- The anticline and syncline structures in the Makkhua Formation of Triassic are constructed in the northern area of acidic volcanic rocks of the Alak/Katha-Tai Formation (vT1-2, vT1-3). The fold axis of the fold structure is arranged parallel to geologic boundary between Alak/Katha-Tai Formation and Makkhua Formation. The formation gently dips northward or southward with 3 to 18 degrees.
- The anticline and syncline structures in the Namhiang Formation (J1), the Lavi Gnai Tai Formation (J2) and the Kanglo Namho Formation (J3) of Jurassic are constructed in and around Attapeu City, which have the fold axis of the ENE-WSW trend and the gentle dips northward or southward. A syncline structure having the fold axis of the ENE-WSW trend is located in Attapeu City. In the area, the Kanglo Namho Formation of Jurassic appears.

The Bolaven Plateau is formed by flat structure, which is covered by the Lagnao-Kang Formation (K1) and the Latsaluay Formation (K2) of Cretaceous. Broadly observing the Attapu District, the plateau seems to exist in the huge syncline structure with the hold axis of NW-SE trend. The hold axis passes at Attapeu City and is formed by very gentle dips. The latter anticline and syncline structure with the fold axis of the ENE-WSW trend is probably the small-scale fold structure within the huge syncline structure.

VII. 4 Arrangement of craters related to Bolaven Formation Upper Unit

According to the interpretation of the ASTER satellite image of the Attapu District, the thirteen craters related to the eruption of basalt of Bolaven Formation Upper Unit were found in the Bolaven Plateau. The craters are linearly arranged in and around Pakxong City and are distributed along about 30km distance from B. Nongya Village in north to Mount Ph. Din in south. Around the B. Nongya in north, the mantle xenoliths such as lherzolite, pyroxenite, etc. are discovered in the basalt of Bolaven Formation Upper Unit.

The arrangement of craters related to the eruption of Bolaven Formation Upper Unit suggests that basaltic magma have gone up through the NNW-SSE trend fracture zones connected from deep upper-mantle to surface.

VIII Mineral Resources

According to the mineral resources map of 1:1,000,000 in scale, which is published by the department of Geology, Ministry of Energy and Mine, Lao P.D.R., the Attapu area has been known as high mineral potential area such as gold, copper, bauxite, etc. The mineralization confirmed by this survey is explained in the report of the geology of the Attapu District.

VIII.1 Metal Resources

VIII.1.1 Copper

Strata-bound copper mineralization exists in the eastern tributaries of Xe Kong River located in the northeastern part to eastern part of the Attapu District. Mineral explorations by French in the 1950's and by the USA junior company in the 1990's have been carried out in the area. As it has been confirmed that the mineralization is small-scale, thereafter the explorations have never done.

In 2006, JICA and DGEO project has started. The sandstone bed including copper minerals of malachite and azurite is found on the north of river junction of Xe Kong River and H. Chouang River located in the northeastern area of the Attapu District. The bed includes shell fossils and is approximate 1m in thickness. According to Lao geologist of DGEO, the mineralization is continuously scattered to B. Sapouan Village located in 30km south from this outcrop.

Therefore, detailed geological survey was carried out in the area by this project in 2007. The survey area including the copper mineralization is north-south 4km and east-west 4km, which was named Area C. The geological and mineral resources mapping survey in 1:10,000 at scale has been carried out in the area. The geological map and the cross sections are shown in Fig. 51 and the geological map of the Attapu District.

The Area C is located in the eastern part of Xe Kong River and in the southeast from Xe Kong City. The area is besieged by northwest rim (687000E, 1693500N) and southwest rim (691000E, 1689500N) using UTM coordinates, which is 16km^2 of NS 4km x EW 4km. High potential copper mineralization is expected in the area.

The geology in the area is composed of the sedimentary rocks of early Jurassic, which strikes north to south and dips westward. The area is located in the southwestern wing of the anticline with fold axis of NW-SE trend. The sedimentary rocks of early Jurassic are composed of the lower sandstone beds, the siltstone/mudstone beds, the sandstone bed with copper minerals, the mudstone bed, the middle sandstone beds, the sandy and muddy limestone beds and the upper sandstone beds.

The sandstone beds show gray to pale gray, which reach about 500m in thickness. The beds are formed by the turbidite of layered beds. A unit of the beds consists of banded bed of 10cm to 30cm in thickness, which is formed by sorting structure.

The siltstone/mudstone beds show mainly red and brown and slightly bluish gray, which varies from 140m to 220m in thickness. The beds intercalate slightly the brown, medium to fine sandstone beds. Copper mineralization such as malachite, azurite, etc. occurs as spots in the mudstone.

The sandstone bed with copper minerals is formed a layer, which is good continuity. The bed occurs in the boundary between the lower reddish brown siltstone/mudstone beds and the upper gray layered mudstone bed. The bed is 10cm in thickness in the south and 2m in maximum thickness in the north, which change remarkably in thickness. The bed shows pale greenish gray and consists of calcareous sandstone including fossils of Brachiopods. The bed accompanies with copper mineralization including copper minerals such as malachite, azurite, chalcopyrite, chalcocite, etc.

The mudstone bed is formed by a banded bed and overlies the copper bearing sandstone bed, which varies from 1m to 2m in thickness. The bed shows dark gray and is broken like a knife-shape or flake-shape in the weathered outcrops.

The sandy and muddy limestone beds vary from about 60m to 100 in thickness. Limestone in the bed is rich in lamina structure and varies from 10cm to 70cm in thickness. Calcite veins occur in the limestone. The limestone beds are intercalated in the calcareous siltstone and sandstone.

The upper sandstone beds reach more than 200m in thickness.

The geological structure in the area is formed mainly by the monoclinic structure which shows the beds strike mainly N-S and dip westward. And it is also formed slightly by the small-scale ENE-WSW trend fault and the small-scale NNW-SSE trend fold structures. The ENE-WSW trend fault is accompanied with factures filled by quartz veins. The host rocks are silicified in 20cm width and are disseminated by pyrite minerals. The anticline and syncline fold structures are formed in the eastern area and in the western area, which have NNW-SSE trend fold axis and gentle dips as shown in Fig. 51.

The mineralization is disseminated along small-scale irregular fractures in the sandstone/mudstone alternating beds of Jurassic, which accompanies slightly with thin quartz veins. Ore minerals consist of chalcopyrite, malachite and azurite. Alteration of host rocks is very narrow. Type of mineralization seems to be the strata-bound ore deposit or the sandstone type copper ore deposits.

Ore samples for ore analysis are collected from the sandstone bed including copper minerals and the siltstone/sandstone bed accompanied with spotted copper mineralization, which are 21 samples in total. The samples were analyzed in the chemical laboratory of DGEO. Results of chemical analysis are shown in Table 4.

The values of ore analysis are shown in table and range from 0.6% to 9.7% in copper. Fourteen samples of the samples have more than 1% in copper value. The results of chemical analysis show very high in copper value. However, the thickness of the sandstone bed varies from 10cm to 1m and is 2m in maximum at the most.
Development of copper mineral resources seems to be very difficult because the bed is very thin in thickness.

VIII.1.2 Bauxite

The bauxite ore deposits in the Attapu District are widely distributed in the eastern part and the southeastern part of the Bolaven Plateau. Presently, the mineral exploration has been carried out in the southeastern area of Pakxong City on the Bolaven Plateau. The exploration in the area is conducted by joint company of Laos and China companies as shown in Photo 69. In the eastern part of Xe Kong River, the exploration has also been carried out by assistance of Vietnam government. And the member of staff of DGEO has also cooperated to the exploration.

The bauxite ore deposits are formed by two kinds of mineralization. One is ore deposit that is formed by pisolitic bauxite pebble concentrated in the lower part of sandstone bed of Latsaluay Formation of upper Cretaceous. Another is a residual deposit that aluminum oxide is concentrated in laterite soil of the weathered basaltic lavas.

The bauxite ore deposits observed in the Attapu District are composed of the pisolitic bauxite pebble, which is concentrated in the lower part of sandstone bed of the former. And the ore deposits are intensively concentrated by the lateritization. The ore deposits of bauxite are occurred in the southeastern area and the southern area of B. Namhan Village, which is located in the upper river of Xe Namnoy River.

The bauxite ore deposits are formed in the lower part of the sandstone bed on the clay bed. And the clay bed varies from 0.5m to 2m in thickness and is formed on the Lagnao-Kang Formation of lower formation. The ore deposits are consists of the pisolitic bauxite pebble (Photo 70). Photo 71 and 72 show the strong concentration part of the pisolitic bauxite pebble altered by the lateritization.

VIII.1.3 Gold

Placer gold in the geological map of the Attapu District has been known since the old days, which is placer deposit in the rivers. The developments of gold have been carried out in and along the main rivers such as Xe Kong River, Xe Kaman River, etc. The panning of gold has been conducted in the dry season when the amount of flowing water decreases in these rivers and when overlaps the off-season for the farmers. But now, the time has come to reconsider the gold placer development and the developments of gold have been stopped.

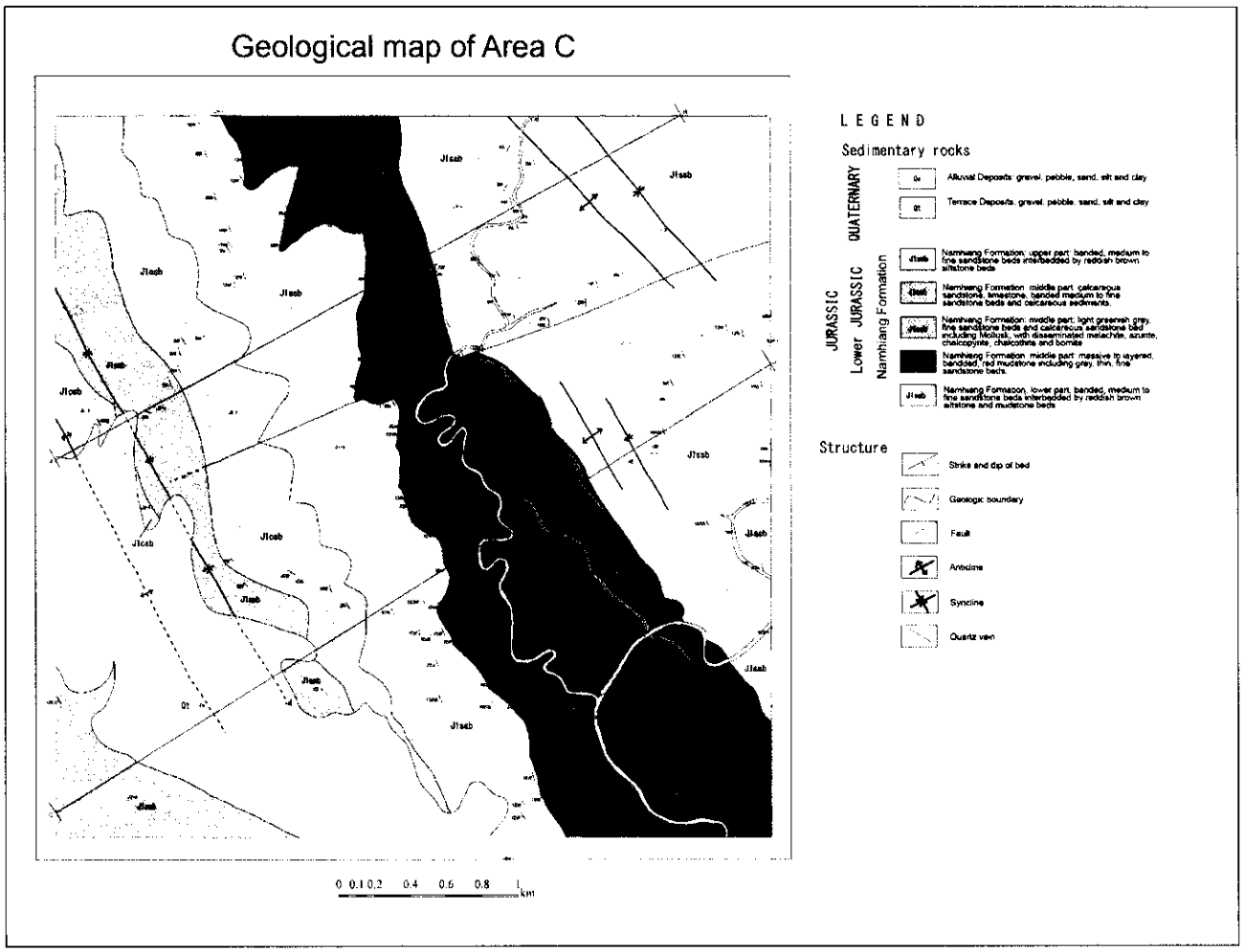


Fig. 48 Geological map of Area C

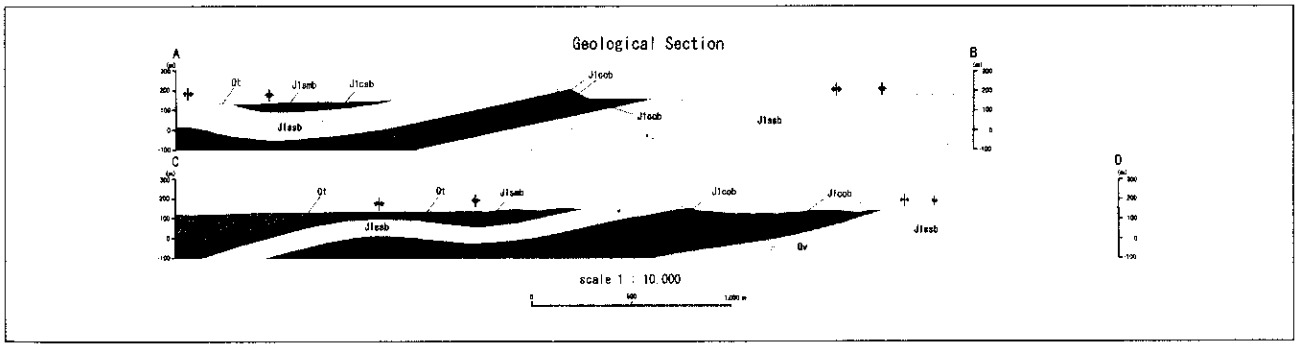


Fig. 49 Geological section of Area C

Photo 69

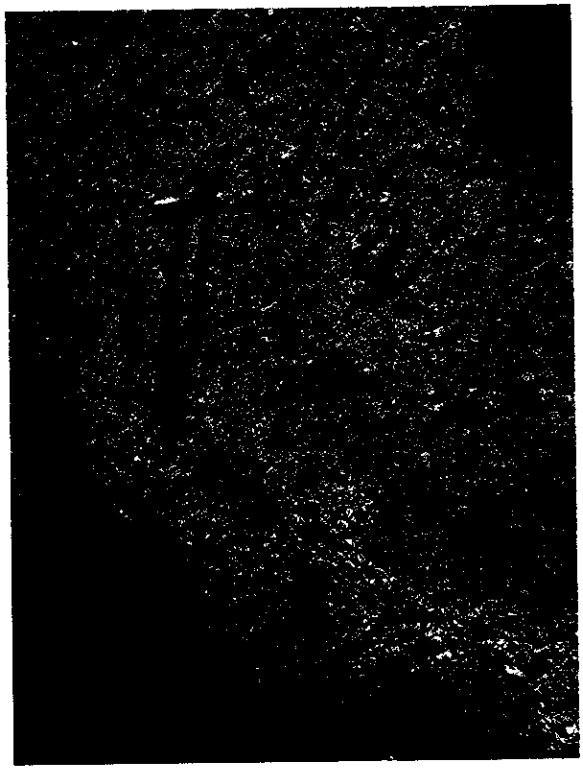


Photo 70

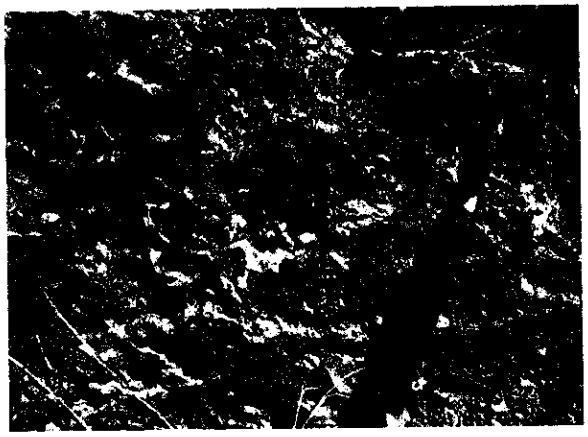


Photo 71

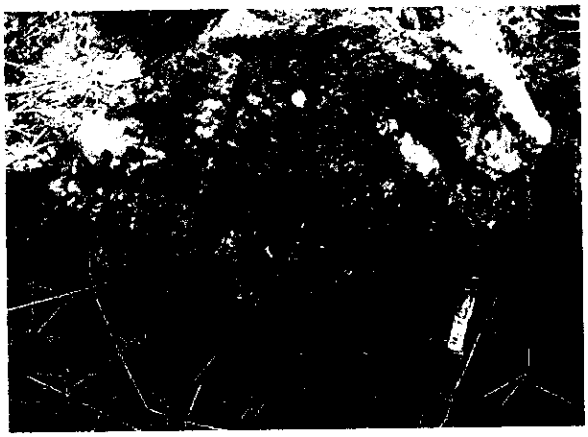


Photo 72

Fig. 50 Outcrops of bauxite exploration area. Photo 69 showing a trench located in the bauxite exploration area in south of B. Namhan Village near Xe Namnoy River. Photo 70 showing pisolitic bauxite pebble concentrated in the lower part of the weathered sandstone bed in the trench. Photo 71, 72 showing concentration of bauxite and iron formed by lateritization.

VIII.2 Non-metal mineral resources

VIII.2.1 Bentonite

Bentonite deposits are formed in the surface of flat plain of Attapu area. The bentonite is mined in the deposits (Photo 73) and bricks have been produced in and around the suburbs of Attapeu City. The production of bricks has been carried out using the plastic machine (Photo 74), which the engine of the cultivator was improved.

The production method is very simple. The processes are firstly making blocks of plastic bentonite, secondly drying them for about one month (Photo 75), and finally firing the bricks in oven house (Photo 76). The produced bricks are used widely as the building materials of the house.

The bentonite deposits seem to be widely formed in the flat plain of Attapu area.

Photo 73

Photo 74

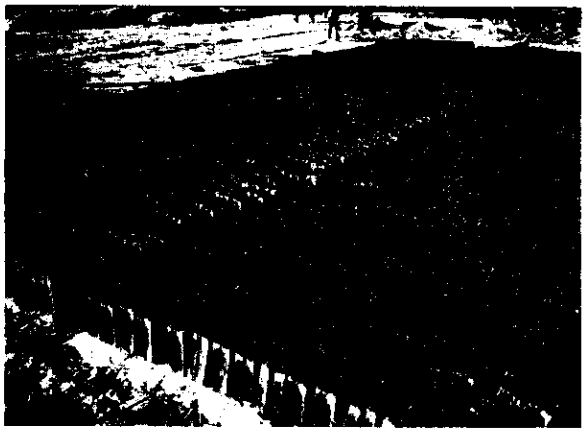


Photo 75

Photo 76

Fig. 51 Production of bentonite. Photo 73 sowing the mining of bentonite produced in the east of Attapeu City. Photo 74 showing the process making brick-shape of plastic bentonite by a machine. Photo 75 showing the drying process for bentonite bricks. Photo 76 showing the firing process of the bricks in oven house.

References

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

Eldonl L. Nahring (1992) Field Evaluation of the Non-Potroleum Potential of the Pakse area, Laos. LAO HUNT MINERALS CORPORATION.

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

Gerhard H. Martin (December 1994) LAOS, PAKSE CONTRACT AREA, GEOLOGICAL FIELD SURVEY. LAO HUNT OIL COMPANY.

Ian D. Maycock, Chrisopher Stone, Edward Fenk and Gerhard Martin (1994) Guidebook for Fieldtrip, Pakse Contract Area, Lao P.D.R.

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, 1997.

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, 1996.

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, 1997.

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-1991.

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-1991.

Tran van Ban (2000) Report on Geology and minerals of mid-central Laos region, Scale 1:200,000. FINAL REPORT Part 1 General Geology ON THE PROJECT. Intergeo of Viet Nam.

Tran van Ban (2000) Report Geology and minerals of mid-central Laos region Scale 1:200,000. Part 2: Mineral resources. Intergeo of Viet Nam.

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, 1997.

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, pp.103-141.

GEOLOGICAL SHEET MAP, 1: 200,000
TOPOMAP NO.: D-48-XI

Geology of the Attapu District

(ABSTRACT)

General remarks

The Attapu District of quadrangle of latitude 14°40′ to 14°40′ N and longitude 106°00′ to 107°00′ E is located in the southern part of Lao P.D.R. The district covers mainly Attapeu Province and slightly Xe Kong and Chanpassak Provinces. Bolaven Plateau of upland, lowland and hills characterize the geomorphology of this district. The hills and mountains are constructed by continental and neritic sedimentary rocks and the pyroclastic rocks of Upper Paleozoic and Lower Mesozoic. The lowland consists mainly of continental and neritic sedimentary rocks of Middle Mesozoic. The Bolaven Plateau is formed mainly by continental sedimentary rocks of Upper Mesozoic. Surface of the Bolaven Plateau is covered by continental basalt lavas. Volcanic craters of post-Cretaceous are distributed linearly from north to south on the plateau. Terrace deposits and modern alluvial deposits are distributed along Xe Kong River and Xe Kaman River.

Paleozoic sedimentary rocks

Paleozoic sedimentary rocks are distributed in the northeastern area of the Attapu District, which belong to the Kadon Formation of Carboniferous. The formation is characterized by continental sedimentary rocks which are composed of conglomerate/arenite alternating beds and sandstone beds. Based on the fault zone of NW-SE trend, the formation is divided from Triassic and Jurassic sedimentary rocks of Mesozoic distributed in the southwestern side of the fault.

Mesozoic sedimentary rocks and volcanic rocks

Mesozoic sedimentary rocks and volcanic rocks are widely distributed in the western area of the Attapu District, which are divided into the following formations of Triassic, Jurassic and Cretaceous Units toward western area from NW-SE trend fault zone in the Attapu District. Triassic unit is stratified by Dakdouan Formation (T1-2), Alak/Katha-Tai Formation (vT1-2, vT1-3) and Makkhua Formation (T2) from lower part, which are composed mainly of sedimentary rocks and acidic volcanic rocks of lacustrine to continental origin. Jurassic unit is stratified by Namhiang Formation (J1), Lavi Gnai Tai Formation (J2) and Kanglo Namho Formation (J3) from lower part, which are composed mainly of sedimentary rocks of shallow sea to continental origin. Upper formations gradually change to typical red sedimentary lithofacies. The Kanglo Namho Formation of upper most Jurassic formation includes tuff fragments and tuffaceous patches. Cretaceous unit is stratified by Lagnao-Kang (K1) and Latsaluay Formation (K2). The Lagnao-Kang (K1) is composed mainly of fluvial sedimentary rocks, so called Deltaic deposit. It is unconformably covered by the Latsaluay Formation accompanying with clay layer in unconformity boundary. The Latsaluay Formation limitedly appears in the western part of Bolaven Plateau.

Cenozoic volcanic rocks

Cenozoic volcanic rocks originated in continental basalt are distributed mainly in the Bolaven Plateau located in the western area of the Attapu District, which are divided into following formations of Bolaven Formation Lower Unit and Bolaven Formation Upper Unit. The Bolaven Formation Lower Unit is divided into the older lavas consisting of pyroxene basalt (Bolaven Formation Lower Unit (I)) and the younger lavas composed of younger plagioclase basalt (Bolaven Formation Lower Unit (II)). The Bolaven Formation Upper Unit is divided into the older lavas consisting of olivine basalt (Bolaven Formation Lower Unit (I)) and the younger lavas of younger olivine-nepherine basalt (Bolaven Formation Lower Unit (II)). The basalts are characterized by the sub-alkali basalt to basaltic andesite and are plotted in the fields of WPB (within plate basalt) in the 2Nb-(Zr//4)-Y discrimination diagram of tectonic setting.

Late Cenozoic sediments

Late Cenozoic sediments are distributed along the river areas of Xe Kong River and Xe Kaman River in the Attapu District, which are divided into the following two units of Terrace deposits Units and Fluvial deposits. The deposits are composed of the sediments of river terrace, which are distributed mainly along the Xe Kong River and the Xe Kaman River. The fluvial deposits are observed in the many rivers flowing in the Attapu District.

Tectonics

The Attapu District belongs to Kontum-Savannakhet Tectonic Region, which have undergone the Indosinian orogeny from Cretaceous to Jurassic ages after Hercynian orogeny. During the orogeny, the marine and continental sediments have accumulated in the district. Presently, reverse fault with NNW-SSE trend was formed in the eastern margin of the

Attapu District, which divides Carboniferous and Triassic. The clear structures of syncline and anticline with fold axis of NNW-SSE trend were formed by Triassic and Jurassic distributed in the western area. Furthermore, the plateau basalt widely covered the western area of the Bolaven Plateau. The volcanic craters of Bolaven Formation Upper Unit are arranged in NNW-SSE trend. The basalt of Bolaven Formation Upper Unit includes the mantle xenoliths of deep mantle origin.

Economic geology

Copper mineralization, bauxite deposits and bentonite deposits occur in the Attapu District. The copper mineralization is a stratabound copper type, which occurs in the Jurassic sedimentary rock. The values of ore analysis are shown in annex 4 and range from 0.6% to 9.7% in copper. However, the thickness of the sandstone bed varies from 10cm to 1m and is 2m in maximum at the most.

The bauxite ore deposits are widely distributed in the Bolaven Plateau in the Attapu District. The bauxite ore deposits are formed by two kinds of mineralization. One is ore deposit that is formed by pisolitic bauxite pebble concentrated in the lower part of sandstone bed of Latsaluay Formation of upper Cretaceous. Another is a residual deposit that aluminum oxide is concentrated in laterite soil of the weathered basaltic lavas.

Gold mineralization is placer gold deposits in the Attapu District. The developments of gold have been carried out in and along the main rivers such as Xe Kong River, Xe Kaman River, etc.

Bentonite deposits are formed in the surface of flat plain of the Attapu District. The bentonite is mined in the deposits. And bricks have been produced in the suburbs of Attapeu City.

Annex

1 Microscopic Observation of Rock thin section
2 Result of K-Ar dating by ActLabs Ltd
3 Results of Rock Chemical Analysis
4 Results of Ore Assay analysis
5 List of Mineral Occurrences in Attapu District

Annex 1 Microscopic Observation of Rock thin section

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	aegirine/diopyroxene	olivine	apatite	zircon	sillanite	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	A118a	632754	1690978	Olivine basalt	porphyritic and vitric texture								△	△				·						○					◎						◎	○				◎																					including mantle xenoliths
3	A118b	632754	1690978	pyroxenite	granular texture																											·		◎	△																								mantle xenolith
4	A118c	632754	1690978	Olivine basalt	porphyritic and vitric texture									△	○									○					◎						◎	○				◎																								including primitive magma
5	A120	633381	1684772	Olivine basalt	intersertal, porphyritic and vesicular textures																								◎						◎					◎																							
6	A122	632986	1688398	Plagioclase andesitic basalt	intersertal, porphyritic and vesicular textures														△				△	△					◎						◎					◎																							·
7	A127	618039	1683025	Pyroxene basalt	intersertal, porphyritic and vesicular textures																		△						◎						◎					◎																						△	
8	A130	641026	1662044	Nepherine-olivine basalt	intersertal, porphyritic and vesicular textures																		△	△					◎						◎					◎																							
9	A131	639197	1659562	Nepherine-olivine basalt	intersertal, porphyritic and vesicular textures																			△					◎						◎					◎																							
10	A146	643587	1689495	Olivine basalt	intersertal, porphyritic and vesicular textures													·					·	△					◎						◎					△																							
11	B024	683442	1696702	Pyroxene basalt	intersertal textures																			○					◎						○					◎																							
12	B121	612469	1646952	Olivine basalt	Porphyritic texture/ intergranular texture																		○	△					◎						○	○				△																							
13	B122	614862	1647135	Pyroxene basalt	Porphyritic texture/ intersertal texture																		△						◎						○					○																							
14	B124	617627	1641582	Nepherine-olivine basalt	intergranular texture													△	△					△					◎						○	○				△																							
15	B126	626822	1634112	Nepherine-olivine basalt	intergranular texture													△	△					△					◎						○	○				△																							
16	B129	632057	1626490	Rhyoritic tuff (ignimbrite)	pyroclastic texture	·				◎	◎						△		△	△																							△		△			△														
17	B130	648144	1625972	Olivine basalt	Porphyritic texture/ intergranular texture																			△					◎						○					△																						·	·
18	B131	658417	1625091	Olivine basalt	Porphyritic texture/ intergranular texture																			△					◎						○	△				△																							
19	B148	628119	1635055	Olivine basalt	Porphyritic texture/ intergranular texture																		△	△					◎						◎	△				△																							
20	B149	636854	1641701	Nepherine-olivine basalt	Porphyritic texture/ intergranular texture													△						△					◎						◎	○				△																							
21	B150	640622	1648295	Olivine basalt	Porphyritic texture/ intergranular texture																			△					◎						◎	△				△																							
22	A117	628448	1690054	Olivine basalt	Porphyritic texture/ intergranular texture																		△	△					◎						○	△																						·	·

Annex 1

Annex 2 Result of K-Ar dating by ActLabs Ltd

Ser. No.	Sample No.	Coordinate (UTM)		Rock Name	K-Ar dating	Estimate Age	%K	$^{40}Ar_{rad}$, nl/g	% $^{40}Ar_{air}$	Age (Ma)	Age	Remarks
		EW	NS									
1	A117	628448	1690054	Ol.BA lava	whole rock	Neogene	0.64	0.212	89.8	8.7±0.4	Tertiary	Loc.01A373 Bolavene
2	A127	618039	1683025	Px.BA lava	whole rock	Neogene	1.59	7.611	12.2	121.4±3.1	Cretaceous	Loc.01A393 Bolavene
3	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)

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

Annex 3 Results of Rock Chemical Analysis

	Sp. Name / Element		A004	A005	A114	A127	A131	A146	B024	A117	A118
			Laterite (bauxite)	Basalt	Andesite	Basaltic andesite	Ol. basalt	Dolerite	Px. basalt	Basalt	Olivine basalt with lherzolite
Loc.	E		665200	634896	614765	618039	639197	643587	683442	628448	632754
Loc.	N		1671046	1676522	1687178	1683025	1659562	1689495	1696702	1690054	1690978
Major element	SiO2	%	0.97	43.10	50.10	47.90	50.80	49.90	51.70	51.80	44.70
Major element	TiO2	%	7.22	2.61	2.00	2.02	1.70	1.74	1.59	1.67	2.61
Major element	Al2O3	%	33.10	14.95	15.70	14.60	14.75	14.50	15.00	15.50	14.20
Major element	Fe2O3	%	37.90	14.05	11.95	13.00	11.90	12.25	11.75	11.40	13.15
Major element	MnO	%	0.19	0.18	0.16	0.18	0.14	0.14	0.14	0.15	0.16
Major element	MgO	%	0.16	7.71	6.80	7.90	7.47	8.07	7.06	7.12	9.05
Major element	CaO	%	0.02	8.25	8.35	8.36	8.69	8.60	8.53	7.84	8.07
Major element	Na2O	%	0.01	4.17	3.19	3.41	3.24	3.05	3.07	2.76	4.28
Major element	K2O	%	0.04	1.75	1.12	1.82	0.90	0.93	0.79	0.73	2.44
Major element	P2O5	%	0.52	1.20	0.33	0.56	0.28	0.28	0.18	0.21	1.08
Major element	Cr2O3	%	0.04	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Major element	LOI	%	19.29	1.65	0.16	0.02	-0.28	0.30	-0.16	0.78	0.00
Major element	Total	%	99.46	99.64	99.89	99.80	99.62	99.79	99.68	99.99	99.77
Trace element	Rb	ppm	0.4	45.8	16.2	27.6	17.9	13.6	14.6	16.2	45.2
Trace element	Ba	ppm	402	524	231	284	211	162	150	152.5	439
Trace element	Zr	ppm	857	301	140	201	106	113	101	104	292
Trace element	Y	ppm	55.4	28.7	28.1	21.8	22.6	20.8	21.0	23.8	23.9
Trace element	Cs	ppm	0.03	0.77	0.3	0.53	0.48	0.21	0.55	0.63	0.69
Trace element	Ta	ppm	17.4	4.9	1.3	2.7	0.8	1.0	0.7	0.6	4.1
Trace element	U	ppm	7.83	2.10	0.53	1.17	0.75	0.56	0.50	0.54	2.14
Trace element	Sr	ppm	691	1195	428	711	406	408	329	338	1020
Trace element	V	ppm	459	191	210	208	186	201	191	193	177
Trace element	Nb	ppm	314	77.3	22.1	44.4	14.1	15.4	11.1	11.7	77.8
Trace element	Hf	ppm	19.7	6.8	3.7	4.7	2.9	3.0	2.7	2.8	6.5
Trace element	Pb	ppm	12	6	<5	<5	<5	<5	<5	5	16
Trace element	Th	ppm	28.00	8.17	2.49	4.42	2.84	2.01	1.79	2.24	7.75
Trace element	Ni	ppm	41	153	123	170	162	172	165	145	214
Trace element	La	ppm	221.0	69.9	23.5	35.9	16.7	14.2	11.0	15.6	60.1
Trace element	Ce	ppm	392.0	126.0	39.6	66.0	29.6	28.3	21.6	27.9	112.0
Trace element	Pr	ppm	39.90	12.55	4.89	6.99	3.26	3.32	2.64	3.43	11.80
Trace element	Nd	ppm	163.5	49.1	20.7	28.7	13.9	14.7	12.0	15.6	46.0
Trace element	Sm	ppm	37.50	9.68	5.01	6.37	3.76	3.94	3.49	4.25	9.07
Trace element	Eu	ppm	12.65	3.44	2.04	2.23	1.43	1.50	1.39	1.51	3.03
Trace element	Gd	ppm	36.50	9.37	5.68	5.94	4.36	4.27	3.90	4.93	8.46
Trace element	Tb	ppm	5.23	1.42	1.02	0.96	0.79	0.75	0.74	0.86	1.21
Trace element	Dy	ppm	20.20	6.22	5.24	4.62	4.18	3.87	3.80	4.27	5.11
Trace element	Ho	ppm	2.72	1.05	0.96	0.78	0.79	0.74	0.79	0.83	0.91
Trace element	Er	ppm	5.54	2.58	2.64	2.10	2.18	1.93	2.06	2.25	2.14
Trace element	Tm	ppm	0.45	0.27	0.33	0.24	0.28	0.25	0.26	0.30	0.24
Trace element	Yb	ppm	2.23	1.65	2.00	1.48	1.79	1.58	1.64	1.89	1.30
Trace element	Lu	ppm	0.22	0.22	0.28	0.20	0.26	0.22	0.23	0.25	0.19
Trace element	ΣREE	ppm	939.6	293.5	113.9	162.5	83.3	79.6	65.5	83.9	261.6
Trace element	ΣREE +Y	ppm	995.0	322.2	142.0	184.3	105.9	100.4	86.5	107.7	285.5

Loc.: Location

Annex 4 Results of Ore Assay analysis

Code	Sample No.	Location No.	Coordinate (UTM)		Description for mineralization	Concentration (ppm)							%		
			EW	NS		Ag	Au	Cu	Pb	Zn	Mn	Ni	Fe	Sn	TiO2
1	AS117	01A351	609531	1676331	stream sediments in river including boulders of pyroxene basalt	n.d.	n.d.	67.6	34.5	86.6	680	- -	15.1	- -	- -
2	A4019	04A062	687935	1693525	malachite, pyrite dissemination in fracture of calcareous, medium sandstone (Thickness: 50cm) with fossils, chlorite + silicification	<2.5	<0.5	1.16%	109	63.0	0.241%	<30	0.150	0.07	0.43
3	A4021	04A065	688040	1693155	malachite and azurite, chalcopyrite and pyrite dissemination in fracture of calcareous, medium sandstone (Thickness: 50cm) with fossils, chlorite + silicification	<2.5	<0.5	0.649%	186	53.7	65.3	<30	2.45	0.08	0.49
4	A4020	04A064	688060	1693263	malachite, pyrite dissemination in fracture of calcareous, medium sandstone (Thickness: 30 - 40cm) with fossils, chlorite + silicification	<2.5	<0.5	1.69%	62.7	85.7	0.100%	<30	2.89	0.06	0.45
5	A4017	04A043	688262	1692785	malachite and azurite in fracture of calcareous, medium sandstone (Thickness: 50cm) with fossils, chlorite + silicification	11.7	<0.5	1.31%	<45	72.2	0.118%	<30	2.54	0.07	0.49
6	A4018	04A045	688355	1693248	malachite and azurite in fracture of calcareous, medium sandstone (Thickness: 50cm) with fossils, chlorite + silicification	<2.5	<0.5	1.91%	<45	85.3	0.109%	<30	2.81	0.06	0.45
7	A4016	04A040	688585	1692890	malachite and azurite in fracture of calcareous, medium sandstone (Thickness: 2m) with fossils, chlorite + silicification	6.2	<0.5	0.609%	<45	84.8	0.113%	<30	2.82	0.06	0.41
8	A4012	04A033	688712	1692023	malachite, chalcopyrite dissemination in fracture of calcareous, medium sandstone (Thickness: 4m), chlorite + silicification	<2.5	<0.5	1.23%	74.3	72.6	0.120%	<30	4.09	0.07	0.43
9	A4015	04A039	688720	1692850	malachite in fracture of calcareous, medium sandstone (Thickness: 1m) with fossils, chlorite + silicification	<2.5	<0.5	0.859%	47.6	98.8	0.142%	<30	2.74	0.07	0.41
10	A4013	04A037	688730	1692593	chalcopyrite dissemination, malachite and azurite films in fracture of calcareous, medium sandstone (Thickness: 1m) with fossils, chlorite + silicification	<2.5	<0.5	0.679%	<45	69.2	0.128%	<30	2.69	0.07	0.43
11	A4010	04A031	688741	1691981	malachite and azurite, chalcopyrite dissemination in fracture of calcareous, medium sandstone (Thickness: 3m), chlorite + silicification	<2.5	<0.5	1.33%	51.7	66.6	970	<30	6.51	0.12	0.60
12	A4022	04A073	689095	1692626	malachite and azurite, quartz veins in fracture of calcareous, medium sandstone (Thickness: 50cm) with fossils, chlorite + silicification	53.7	<0.5	6.22%	199	132.1	0.118%	<30	4.06	0.08	0.34
13	A4023	04A086	689165	1690635	malachite in fracture of calcareous, medium sandstone (Thickness: 19cm) with fossils, chlorite + silicification	59.9	<0.5	1.97%	70.2	73.4	57.4	<30	3.82	0.09	0.67
14	B050	01B178	689188	1692096	malachite, azurite and green copper dissemination in fine sandstone/ very fine sandstone, mollusca fossil including, bedded, pale greenish grey	92.0	n.d.	0.763%	61.9	75.3	0.110%	- -	3.10	- -	- -
15	B558	03B379	689438	1690245	azurite and malachite, mollusca fossil not including remarkably, pale green in very fine sandstone which grey upper and lower layer is reddish brown very fine sandstone	n.d.	n.d.	7.56%	223	154	0.12%	49.1	3.59	0.11	0.710
16	B559	03B389	689483	1692101	malachite, mollusca fossil not including remarkably, sandstone in very fine sandstone + siltstone: pale green to grey, siltstone: dark grey to grey, lower layer of mineralization show reddish brown	n.d.	n.d.	1.57%	<45	149	0.12%	50.3	2.44	<0.05	0.690
17	A3108b	03A380	689570	1692352	alternation of grey sandstone (10-20cm) and red mudstone to siltstone (5-10 cm) and float stone of quartz vein	n.d.	n.d.	0.950%	<45	29.3	171	<30	2.39	<0.05	0.23
18	A4024	04A100	689665	1689836	malachite in fracture of calcareous, medium sandstone (Thickness: 20cm) with fossils, chlorite + silicification	29.2	<0.5	1.52%	94.2	113.4	74.1	<30	3.97	0.06	0.58
19	A4029	04A134	689929	1691515	malachite in fracture of calcareous, medium siltstone (Thickness: 20cm) with fossils, chlorite + silicification	<2.5	<0.5	0.796%	48.9	75.0	734	<30	2.59	0.09	0.72
20	A4025	04A103	690090	1690854	malachite in fracture of calcareous, medium sandstone (Thickness: 20cm) with fossils, chlorite + silicification	<2.5	<0.5	1.46%	<45	208.0	728	66.1	2.19	0.07	0.76
21	A4027	04A112	690294	1690642	malachite and azurite in fracture of bluish grey, medium sandstone (Thickness: 20cm) with fossils, and chlorite + silicification, chalcopyrite + Malachite + azurite mass	<2.5	<0.5	1.45%	68.2	52.4	345	<30	2.54	0.08	0.67
22	A4028	04A112	690294	1690642	malachite and azurite in fracture of bluish grey, medium sandstone (Thickness: 20cm) with fossils, and chlorite + silicification, chalcopyrite + Malachite + azurite mass	<2.5	<0.5	9.73%	461	45.3	0.171%	<30	14.2	0.09	0.44
23	B045	01B166	699082	1662071	green copper dissemination along fractures in very fine sandstone, well bedded, light reddish brown	n.d.	n.d.	65.3	48.8	57.9	760	- -	2.87	- -	- -
24	B062	01B235	701707	1693591	green copper dissemination in siltstone, fine sandstone interbedded (w:10cm), weak bedded, light reddish brown	n.d.	n.d.	15.0	38.8	<15	17.0	- -	1.26	- -	- -

Annex 5 List of Mineral Occurrences in Attapu District (1/2)

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-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 48 ″	688881	1691898	malachite, azurite and green copper dissemination in a sandstone bed, including mollusca fossil, bedded, pale green	B050: Cu:0.76%, Fe:3.11%		mineral showing	01B178
2	D-49-XI ATTAPU	Cu	stratabound (sandstone)	B.Sapouan	106 ° 51 ′ 6 ″	15 ° 1 ′ 35 ″	699082	1662071	green copper dissemination along fractures in a sandstone bed, well bedded, light red brown	B045: Fe:2.87%		mineral showing	01B166
3	D-50-XI ATTAPU	Cu	stratabound (sandstone)	B.Kasang-Kang	106 ° 52 ′ ## ″	15 ° 18 ′ 39 ″	701707	1693591	green copper dissemination in a fine sandstone bed (w:10cm), weak bedded, light red brown			mineral showing	01B195
4	D-51-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ 2 ″	15 ° 18 ′ 41 ″	687935	1693525	malachite and pyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification	A4019: Cu:1.16%		small deposit	04A062
5	D-52-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ 5 ″	15 ° 18 ′ 29 ″	688040	1693155	malachite and azurite, chalcopyrite and pyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification	A4021: Cu:0.65%, Fe:2.45%		small deposit	04A065
6	D-53-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ 6 ″	15 ° 18 ′ 32 ″	688060	1693263	malachite and pyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 30 - 40cm) with fossils, chlorite and silicification	A4020: Cu:1.69%, Fe:2.89%		small deposit	04A064
7	D-54-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 17 ″	688262	1692785	malachite and azurite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification	A4017: Ag:11.7ppm, Cu:1.31%, Fe:2.54%		small deposit	04A043
8	D-55-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 23 ″	688300	1692985	malachite and azurite along fractures of calcareous sandstone, in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification			small deposit	04A044
9	D-56-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 32 ″	688355	1693248	malachite and azurite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification	A4018: Cu:1.91%, Fe:2.81%		small deposit	04A045
10	D-57-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 21 ″	688485	1692912	malachite along fractures of calcareous sandstone, in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification			small deposit	04A042
11	D-58-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 20 ″	688585	1692890	malachite and azurite along fractures of calcareous sandstone, in a medium sandstone bed (thickness: 2m) with fossils, chlorite and silicification	A4016: Ag:6.2ppm, Cu:0.61%, Fe:2.82%		small deposit	04A040
12	D-59-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 51 ″	688700	1692000	malachite and chalcopyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 4m), chlorite and silicification			small deposit	04A032
13	D-60-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 52 ″	688712	1692023	malachite and chalcopyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 4m), chlorite and silicification	A4012: Cu:1.23%, Mn:0.12%, Fe:4.09%		small deposit	04A033
14	D-61-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 19 ″	688720	1692850	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 1m) with fossils, chlorite and	A4015: Cu:0.86%, Mn:0.14%, Fe:2.74%		small deposit	04A039
15	D-62-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 10 ″	688730	1692593	chalcopyrite dissemination, malachite and azurite films along fractures of calcareous sandstone in a medium sandstone bed (thickness: 1m) with fossils, chlorite and silicification	A4013: Cu:0.68%, Mn:0.13%, Fe:2.69%		small deposit	04A037
16	D-63-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 51 ″	688741	1691981	malachite and azurite, chalcopyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 3m), chlorite and silicification	A4010: Cu:1.33%, Fe:6.51%		small deposit	04A031
17	D-64-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 57 ″	688746	1692165	malachite and chalcopyrite dissemination along fractures of calcareous sandstone in a medium sandstone bed (thickness: 3m) with fossils, chlorite and silicification			small deposit	04A034
18	D-65-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 10 ″	688812	1692595	chalcopyrite dissemination, malachite and azurite films along fractures of calcareous sandstone in a medium sandstone bed (thickness: 10cm) with fossils, chlorite and silicification			small deposit	04A038
19	D-66-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 48 ″	688889	1691902	azurite and malachite in sandstone with mollusca fossil, sandstone showing pale green (bleaching spot), in siltstone showing red brown (oxidized zone), sandstone dominant, well			small deposit	03B368
20	D-67-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 42 ″	688921	1691732	azurite and malachite in sandstone with mollusca fossil, a sandstone bed showing pale green (bleaching spot), siltstone showing red brown (oxidized zone), sandstone dominant, well			small deposit	03B370
21	D-68-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 44 ″	688926	1691783	azurite and malachite and mollusca fossil in a sandstone bed, pale green to light gray, well bedded			small deposit	03B369
22	D-69-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 29 ″	688988	1691336	azurite and malachite in a sandstone bed with mollusca fossil, pale green to light gray, well bedded			small deposit	03B373
23	D-70-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 18 ′ 11 ″	689095	1692626	malachite and azurite, quartz veins along fractures of calcareous sandstone in a medium sandstone bed (thickness: 50cm) with fossils, chlorite and silicification	A4022: Ag:53.7ppm, Cu:6.22%, Mn:0.12%, Fe:4.06%		small deposit	04A073
24	D-71-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 24 ″	689122	1691175	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification			small deposit	04A089

Annex 5 List of Mineral Occurrences in Attapu District (2/2)

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	E.W	N.S					
25	D-72-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 12 ″	689140	1690785	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification			small deposit	04A087
26	D-73-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 18 ″	689181	1690988	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification			small deposit	04A088
27	D-74-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 5 ″	689220	1690589	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification			small deposit	04A090
28	D-75-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 16 ′ 54 ″	689438	1690245	azurite malachite in a sandstone bed, mollusca fossil slightly included, pale green to gray, upper and lower layer conposed of red brown very fine sandstone	B558: Cu:7.56%, Mn:0.12%, Fe:3.59%		small deposit	03B379
29	D-76-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 54 ″	689474	1692107	malachite along fractures of calcareous sandstone in a medium siltstone bed (thickness: 20cm) with fossils, chlorite and			small deposit	04A104
30	D-77-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 54 ″	689483	1692101	malachite in a sandstone bed in a sandstone bed, with mollusca fossil slightly included, sandstone showing pale green to gray, siltstone showing dark gray to gray, lower layer of mineralization show red brown	B559: Cu:1.57%, Mn:0.12%, Fe:2.44%		small deposit	03B389
31	D-78-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 16 ′ 41 ″	689665	1689839	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification	A4024: Ag:29.2ppm, Cu:1.52%, Fe:3.97%		small deposit	04A100
32	D-79-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 27 ″	689689	1691270	malachite along fractures of calcareous sandstone in a medium siltstone bed (thickness: 10cm) with fossils, chlorite and			small deposit	04A137
33	D-80-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 46 ′ 0 ″	15 ° 16 ′ 37 ″	689715	1689715	malachite and azurite along fractures of bluish grey, in a medium sandstone bed (thickness: 20cm) with fossils, and chlorite and silicification, chalcopyrite + malachite + azurite			small deposit	04A120
34	D-81-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 46 ′ 8 ″	15 ° 17 ′ 35 ″	689929	1691515	malachite along fractures of calcareous sandstone in a medium siltstone bed (thickness: 20cm) with fossils, chlorite and	A4029: Cu:0.80%, Fe:2.59%		small deposit	04A134
35	D-82-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 46 ′ ## ″	15 ° 17 ′ 14 ″	690090	1690854	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 20cm) with fossils, chlorite and silicification	A4025: Cu:1.49%, Fe:2.19%		small deposit	04A103
36	D-83-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 45 ′ ## ″	15 ° 17 ′ 7 ″	689165	1690635	malachite along fractures of calcareous sandstone in a medium sandstone bed (thickness: 19cm) with fossils, chlorite and silicification	A4023: Ag:59.9ppm, Cu:1.97%, Fe:3.82%		small deposit	04A086
37	D-83-XI ATTAPU	Cu	stratabound (sandstone)	H. Chouang	106 ° 46 ′ ## ″	15 ° 17 ′ 7 ″	690294	1690642	malachite and azurite along fractures of bluish grey, in a medium sandstone bed (thickness: 20cm) with fossils, and chlorite and silicification, chalcopyrite + malachite + azurite	A4027: Cu:1.45%, Fe:2.54%, A4028: Cu:9.73%, Mn:0.17%		small deposit	04A112
38	D-83-XI ATTAPU	Al	residual, bauxite	B. Namtang	106 ° 32 ′ ## ″	15 ° 6 ′ 35 ″	665200	1671046	laterite basalt altered to rock of bauxite, gibbsite, goethite, opal	A004: Al_2O_3:33.10, Fe_2O_3: 37.90%, REE:939ppm,		mineral showing	01A014
39	D-84-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 35 ′ ## ″	14 ° 56 ′ 38 ″	671225	1652728	laterite of pisolitic bauxite and brecciated bauxite in loer part of sandstone in pit (3m in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A303
40	D-85-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 36 ′ ## ″	14 ° 56 ′ 59 ″	672895	1653393	light brown clay under bauxite in loer part of sandstone in the open pit (old mine, 4m in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A304
41	D-86-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 36 ′ ## ″	14 ° 54 ′ 43 ″	672983	1649218	yellowish white, clay and kaolinitization in sandstone (lower) and laterite of pisolitic bauxite layer (10m, upper)	A4056a: Al_2O_3:36.35, Fe_2O_3: 7.87%, REE:2,4230ppm, A4056b: Al_2O_3:13.14%, Fe_2O_3:1.01%, REE:745ppm,	exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A311
42	D-87-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 36 ′ ## ″	14 ° 54 ′ 41 ″	673172	1649146	laterite of pisolitic bauxite in loer part of sandstone in pit (3m in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A312
43	D-88-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 36 ′ ## ″	14 ° 57 ′ 8 ″	673353	1653660	laterite of pisolitic bauxite and iron silica deposit in loer part of sandstone in pit (4m in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A305
44	D-89-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 37 ′ 5 ″	14 ° 57 ′ 4 ″	674020	1653538	laterite of pisolitic bauxite and iron silica deposit in loer part of sandstone in pit (5m in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A306
45	D-90-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 37 ′ ## ″	14 ° 57 ′ 8 ″	674431	1653666	laterite of pisolitic bauxite in loer part of sandstone in pit (3mm in depth)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A307
46	D-91-XI ATTAPU	Al	residual, bauxite	B. Namhan	106 ° 37 ′ ## ″	14 ° 57 ′ 3 ″	674577	1653530	pisolitic bauxite layer (1.5cm+) and grey moderate sandstone (upper, 30cm)		exploratng by Italian - Thai Development Public Co. Ltd., 2008	large deposit	04A310

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GEOLOGICAL MAP OF ATTAPU
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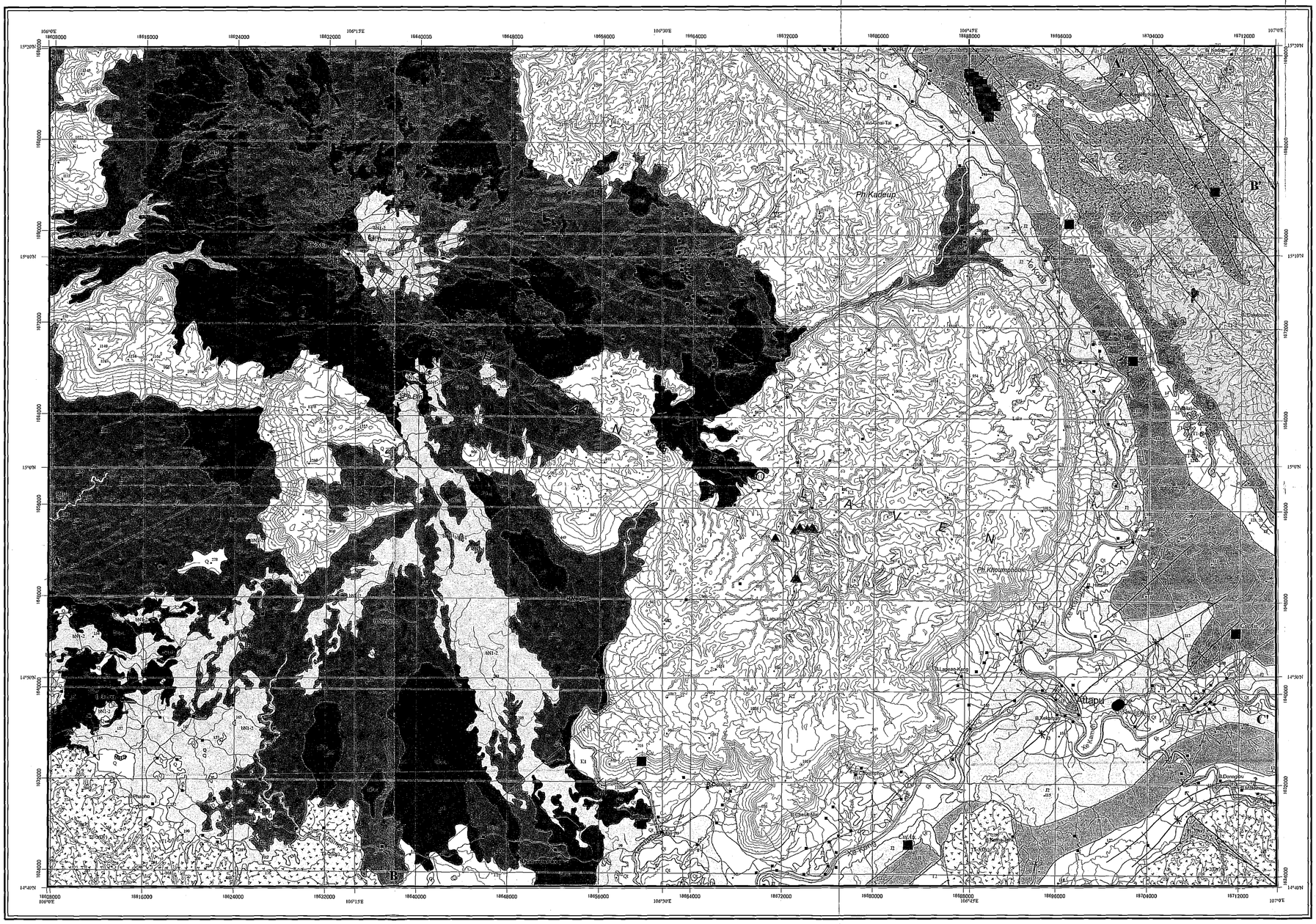
LAO PEOPLE'S DEMOCRATIC REPUBRIC
MINISTRY OF ENERGY AND MINES



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
	Neogene	Bolaven Formation Upper Unit (II)	bN1-2	Nepheline-olivine basalt lava
		Bolaven Formation Upper Unit (I)	bN1-1	Olivine-pyroxene basalt lava
	Paleogene	Bolaven Formation Lower Unit (II)	bP1-2	Plagioclase bearing pyroxene basalt lava
		Bolaven Formation Lower Unit (I)	bP1-1	Pyroxene basalt lava
Mesozoic	Cretaceous	Latsahlay Formation	K3	Sandstone
		Lagnao Kang Formation	K1	Sandstone with laminations
	Jurassic	Kanglo Namho Formation	J3	Sandstone, mudstone, and interbedded sandstone and mudstone and tuff
		Lavi Gnai Tai Formation	J2	Sandstone, mudstone, calcareous sandstone, interbedded sandstone and mudstone, limestone with silicified wood
		Namhinng Formation	J1	Sandstone, mudstone, and interbedded sandstone, mudstone and calcareous sandstone with Mollusca fossils
	Triassic	Mafakhua Formation	T2	Conglomeric sandstone, sandstone, cherty mudstone, imestone, tuffaceous sandstone and sandy tuff
		Katha-Tai Formation	T1-2(Av)	Dacitic welded tuff, dacitic lapilli tuff and tuffs
		Alok Formation	T1-2	Andesitic to dacitic epiclastic breccias, andesitic welded tuff, tuff breccia, lapilli tuff, coarse tuff and sandy tuff
		Dakdouan Formation	T1-1	Conglomeric sandstone, sandstone, cherty mudstone, limestone, tuffaceous sandstone and sandy tuff
Paleozoic	Carboniferous	Kadon Formation	C	Conglomeric sandstone and sandstone

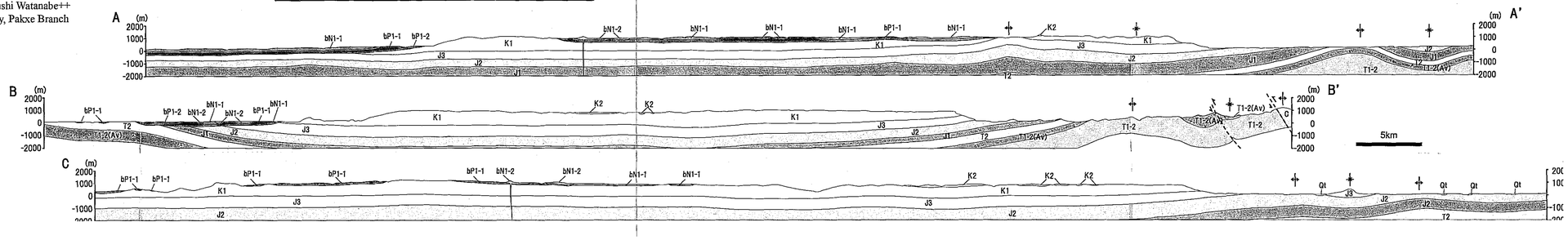
- Strike and dip of strata
- Strike and dip of schistosity
- Anticline
- Syncline
- Fault (concealed fault)
- Crater or volcanic center
- Village
- Road

Mineral Occurrences

- Copper dissemination in sandstones (Cu)
- Pyrite-bearing quartz vein
- Bauxite
- Bentonite
- Quartz vein
- Placer (Au)

Interval of topographical contour is 100m

5 2.5 0 5 10 15 20 km



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

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