be obtained from 2 km northeast of power house site within flood plain of the Chico river.

Saltan (2-8-5-15)

Saltan scheme is proposed as run-of-river type, consisting of main intake weir, sub-weir and power house connected each other by water way tunnel.

The proposed scheme is located on the Saltan river at 43 km upstream from Pinukpuk where is situated at confluence of the Chico and Saltan rivers in Kalinga-Apayao Province. The Saltan river flows at the main weir site (El. 675 m) toward east direction on east flank of Luzon Central Cordillera.

Main intake weir site is located on the Saltan river at 3 km southwest of Mt. Adalam (1732 m), sub-weir is located on the unnamed tributary of the Saltan river at 2 km east of Mt. Adalam and power house site is located at confluence of the Saltan river and unnamed tributary 5 km east of Mt Adalam. The water way tunnel is proposed at left bank of the Saltan river. Water way from sub-weir joins the main water way tunnel at 5 km from main intake weir.

According to the existing geological map of Northern Luzon in scale of 1/250,000 (JICA-MMAJ, Aug. 1981), regional geology is underlain by metavolcanics of Eocene Licuan Formation, metavolcanics of Oligocene Tineg Formation and middle Miocene Alava Formation (may be equivalent to Lubuagan Formation).

Eocene Licuan Formation consists of lower member and upper member. Lower member is composed of basaltic lava, basaltic andesite and its pyroclastics. Color is green to dark green. Locally its change to chlorite due to chloritization is dominant by small waved folding with south east trend axis, and dipping towards to north-northwest.

Upper member which is conformably to lower member is underlain by hard and compacted cryptocrystaline andesitic pyroclastics and green to dark greenish gray andesitic lava. The structure feature of upper member is repeated small waved fold with south east axis.

Tineg Formation belongs to Oligocene which is distributed in upper reach of the Chico river in Sadanga area, west of Bontoc.

Main bed rock is underlain by quartz andesitic pyroclastics and lava and its intersectted limestone, sandstone and siltstone. These clastic rocks show high indurated and compactness and well bedded. Bedding of bed rock is mono-incline towards east and gently dip. Tineg Formation is unconformably by Licuan Formation.

Middle Miocene Alawa Formation is mainly distributed at the Chico river basin and the Saltan river basin. Most of the sequence basement rocks consist of limestone, and clastic sedimentary rocks not including volcanic rocks. Structurally mono-syncline towards east gently well bedded with large scale foraminifera. Tineg Formation and Alawa formation are irregular contacted by northeast to south west direction fault.

Bed rock of main weir is underlain by andesite. Weir site is situated at immediately upstream of confluence of the Saltan river and the Maplog creek. Rock quality is probably hard and good indurated and well cemented. Joint has long interval spaced. Residual soil and weathered zone are relatively thin.

Bed rock is exposed at riverbed, huge scale of boulders are scattered on the riverbed. There is no problem for construction of intake weir.

The bed rock of sub-weir is underlain by dacitic rock. Rock quality of dacite is hard and well indurated. It is enough strength for sub-weir foundation and inlet of sub water way. Almost part of water way tunnel route is passed through the dacitic rocks at left bank of the Saltan river. However intake weir site is underlain by andesite, and outlet site is underlain by clastic sedimentary rocks.

Rock quality of dacite and andesite seems to be hard and well indurated. Dacite and andesite contact by fault each other. These area is needed by full supporting excavation. However most of route has enough thickness of overburden and strength for tunneling without special treatment.

Bed rock of power house site is underlain by Miocene sandstone and mudstone covered with thin residual soil. Rock quality of bed rock is hard but slightly weathered compared with other rocks of this area, even though it has enough strength for power house foundation.

Regulating reservoir area is probably underlain by andesite covered with river deposits. There is no water leakage from reservoir due to compacted formation, and slope of reservoir area is stable. Therefore, it is expected to be no special geotechnical and hydrological problem in the regulating reservoir area.

The suitable concrete aggregate is located at 1.5 km east of weir site which is underlain by well indurated and high strength dacitic pyroclastics and lava. Proposed sand and gravel borrow area is located at 0-2 km downstream from weir site within river flood plain.

<u>Pasil (2-8-6-22)</u>

Pasil scheme is proposed as run-of-river type, consisting of main intake weir, three additional intake weirs and power house.

Main intake weir is located at 1 km upstream of barrio Baton Buhay and about 23 km upstream from confluence of the Chico and Pasil rivers in east flanks of Luzon Central Cordillera.

Water way tunnel combined with three additional intake weirs, pass through left bank of the Pasil river. Approximately 350 m head is taken with 10 km long water way tunnel. The power house is proposed at near barrio Colong.

Regional geology of this site is similar to that of Saltan scheme. According to the existing geological map in scale of 1/250,000 (JICA-MMAJ, Aug. 1981), regional geology is underlain by Eocene Licuan Formation. Oligocene Tineg Formation and Miocene Alava sandstone Formation, are intruded by Neogene quartz diorite, and quartz andesitic or andesitic Quaternary volcanics.

Mt. Masimus (El. 2233 m) and Mt. Binuluan (El. 2322 m) are typical quaternary volcanics in this area which are situated at right bank of the Pasil river.

Main weir site is located at immediately downstream of confluence of the Pasil river and its tributary at 1 km southeast of barrio Batong Buhay. Both abutments consist of well compacted andesite of Eocene Licuan Formation which is covered with thin residual soil. Sand and gravel is scarcely deposited on the riverbed.

Bed rock is generally cryptocrystaline and remotely jointed, and shallow part of subsurface is slightly weathered. Foundation of these rocks will probably be watertight and have enough strength to built a concrete weir.

The water way tunnel passes through largely Quarternry volcanics which consist of andesitic lava and pyroclastic flow, or dacitic lava and pyroclastic flow. Partial supporting during tunnel excavation will be necessary because rock quality of pyroclastic flow is sometimes weakly welded.

And also, volcanics flow sometimes show high permeability because of porous structure of lava and pyroclastic flows. The bed rock of three additional intake weir are also probably underlain by Quaternary volcanics. It is probably necessary small scale treatment of foundation because of high permeability. The bed rock of inlet and outlet portions are underlain by Licuan Formation, which crops out along the Saltan river.

The power house is located at left bank of the Pasil river 500m northwest of barrio Colong. The bed rock of power house site is possibly underlain by sandstone which is covered with residual soil and talus deposits. These rocks are rather poorly indurated than the Licuan Formation, even though those have enough strength for construction of power house.

Regulating reservoir is underlain by andesitic rocks of Eocene Licuan Formation, which is covered with scarce river deposits, and is estimated to be watertight except fractured zone.

The suitable quarry site for concrete aggregate is proposed at 4.5 km east of weir site which is underlain by fresh indurated dacitic rocks of Quaternary volcanics.

No sand and gravel materials are expected along the Pasil river near the intake weir site, because the river in this section forms a narrow gorge and rapids. The possibility of sand and gravel is expected only remote area. So that fine aggregate materials will be exploited from quarry site of coarse aggregate.

Tanudan (2-8-6-23)

Tanudan scheme is proposed as run-of-river type. Approximately 248 m head is taken with 9 km long water way tunnel. Intake weir site of proposed scheme is located at 30 km upstream from confluence of the Tanudan and the Chico rivers, at east part of Luzon Central Cordillera.

The Tanudan river runs towards north, and then joins the Chico river at near barrio Naneng. After this confluence the Chico river flow shifts to east direction.

According to the geological map of north-western Luzon in scale of 1.250,000 (JICA-MMAJ, Aug. 1981), regional geology is almost same as that of Pasil scheme. However, only Alawa Formation which may be equivalent to Lubuagan Formation, is distributed around this area. In general the geologic stricture has north-south strike and dips east gently.

Intake weir site is located at 6 km south of barrio Dacalan, which is 30 km upstream from confluence of the Chico and the Tanudan rivers, and also border of Kalinga-Apayao and Mt. Province.

The bed rock of intake weir possibly consists of slightly to moderately weathered sandstone which is covered with thin residual soil. Rock quality of bed rock seems to be weakly compacted however it has enough strength for construction of low concrete intake weir. The permeability of bed rock is to be low value to watertight except moderately weathered zone.

All water way tunnel route is to be driven through the sandstone intercalated with claystone and conglomerate of Miocene Alawa Formation. Rock quality of the bed rock is rather weakly indurated and compacted. In general, excavation condition may not be so difficult except fractured zone and intensively jointed area. Overburden is enough for tunnel excavation.

Power house site is located at right bank of the Tanudan river 2 km southwest of Mt. Tangob (El. 1516 m). The bed rock of power house is also composed of slightly to moderately weathered sandstone of Miocene Alawa Formation covered with residual soil and terrace deposits. It is rather weakly indurated, however, it has enough strength for power house foundation.

Regulating reservoir area seems to be also underlain by sandstone and claystone. There is no evidence of water leakage and landslide, then there is no special problem on slope stability.

The suitable quarry site for concrete aggregate is not found near the weir site. It is necessary to investigate quarry site and borrow area for construction materials in the future stage.

Bantay (2-8-7-24)

Bantay scheme is proposed as dam and reservoir type. 63 m high dam has been considered at this site. Bantay scheme is located at wide and open dish type valley on the Paret river 34 km of north-northeast of Tuguegarao, capital of Cagayan Province and 30 km upstream from confluence of the Cagayan and the Paret rivers.

Proposed scheme site is to be located on Tertiary hilly area which rises upto 200-280 m above sea level. It is bounded on west by the Cagayan river flood plain, on the east by the Paret and the Paranan rivers flood plain basin.

The Paret and the Paranan flood Plain to be covered by a reservoir of 122 km^2 by Bantay scheme are composed of well developed rice field and many barrios. According to the existing general geological map of Cagayan River Flood Control Basin Wide Study in scale of 1/600,000, the Bantay scheme is underlain chiefly by sandstone of Miocene-Pliocene Cabagan Formation. Reservoir area is underlain by Quaternary alluvium and terrace deposits. The Cabagan Formation is unconformably overlies early to middle Miocene Lubuagan Formation and widely distributed within the Cagayan valley.

The basement rock of proposed damsite is underlain by moderately weathered rather soft to soft sandstone covered with thick residual soil at both abutments and very thick sand and gravel deposited on the riverbed.

The bedding of sandstone trends northeast-southwest and dips southeast gently. Permeability of basement rock is probably high value at loosened and fractured weathered zone. In order to reduce leakage through the loosened permeable zone of dam foundation and abutments, deep and highly concentrated grouting at the dam foundation will be necessary.

The bed rock of dam foundation is probably recognized to soft rock, then it is not suitable for concrete gravity dam or high dam. And also rock materials is remote from damsite. Then earthfill dam is only possible to be built here.

Power house site is underlain by soft to rather hard sandstone covered with alluvial sediment. It is necessary some treatment for power house foundation. Reservoir area occupies very wide area of about 122 km^2 which is composed of alluvial flood plain river terrace and sandstone hilly area. However reservoir is chiefly covered with rice field, therefore hydro-geologically, the reservoir is estimated to be impervious.

The suitable quarry site for rock materials is not found near the damsite, however sand and gravel is located at riverbed within several kilometers from damsite. The borrow area of earth materials to be proposed at 2 km east of dam, which is undelain by residual soil of sandstone and claystone.

DABBA (2-8-8-25)

Dabba scheme is proposed as dam and reservoir type. The damsite is located about 28 km upstream from Tuguegarao City and 1 km north-east of the barrio Dabba on the Pinacanauan de Tuguegarao river which flows at the northeastern part of the Cagayan Valley.

There, the Pinacanauande Tuguegarao river is running east-west crossing north-south trending rocky ridge which reaches about 200 m high above sea level. The elevation of riverbed is 38 m, and river width is about 50 m. A dam of approximately 83 m high has been considered at this site.

The existing geological maps show the regional geology to be white coral limestone of Callao Formation (Late Miocene), volcanic wackes, microbreccia and sandstone of Lubuagan Formation (Early Miocene), and andesite and dacite of Caraballo Group (Cretaceous-Paleogene).

The bed rock of damsite is underlain by Callao Formation which is composed of massive and bedded hard white coral limestone with rich open joints and many sink holes. The bedding strikes of limestone are mostly composed of south-north direction.

This limestone forms V-shaped gap. Right aboutment is formed by a very steep and high cliff. Top of the abutment is covered with dense forest and toe of the gap is covered with talus. Left abutment is formed by rather gentle slope with residual soil. The riverbed is occupied by sand, cobbles and boulders.

In the Reservoir area, topographic condition is flatter, and mainly covered with Quaternary alluvium and terrace deposits. The bed rock of reservoir area is underlain by Lubuagan Formation.

Watertightness of damsite is not expected due to solution channels and open joints of limestone. Damesite is composed of only this leakageable limestone from riverbed up to top of both abutments. Therefore, big amount of leakage is to be expected and accordingly extenseve cement grouting at the damsite will be necessary. Judging from such geological viewpoint, the damsite is not recommendable for the planning of high dam.

Maliano (2-8-14-34)

Maliano scheme is proposed as dam and reservoir type. Construction about 159 m high rockfill dam is planned on the Pinacanauan de Ilagan river.

Maliano scheme is located at Isabela Province about 50 km east from Santiago, and 90 km upstream from Ilagan by the Pinacanauan de Ilagan river in Northern Sierra Madre Region. The accessibility of this site is very bad. The nearest all weathered road terminated at San Mariano about 60 km from damsite.

According to the existing geologic maps of Isabela Province in scale of 1/250,000 (BMG 1974) and in scale of 1/100,000 (Ilagan No. 1 Pre F/S Project, Philtech and Ministry of Public Works 1983), Almost all of typical geologic formation of North Sierra Madre is distributed at vicinity of this scheme.

The geology of proposed scheme site is underlain by andesite of Cretaceous-Paleogene metavolcanics, sandstone and conglomerate of early-middle Miocene Lubuagan Formation, sandstone and claystone of Miocene-Pliocene Cabagan Formation and diorite of Paleogene intrusive rocks. Geologic structure generally trends south-north without big scale of faulted structure.

The proposed damsite shows open V-shaped valley, on the Pinacanauan de Ilagan river running from east to west. The elevation of riverbed is about 145 m above sea level.

Both dam abutments are covered with deep forest, the bed rock is exposed only at riverbed and toe of flanks. The bed rock of damsite is underlain by well compacted andesite of Cretaceous-Paleogene metavolcanics covered with residual soil, which has enough strength for filldam foundation. The thickness of residual soil and weathered zone are increasing at higher elevation of abutments.

According to the feasibility study report of Ilagan-2 (damsite has been proposed at 1 km upstream from Maliano damsite) by Philtech and Ministry of Public Works 1983, Lugeon value is mostly less than 1 (one) and maximum value in 4.85, totally slightly higher Lugeon value in the right bank.

Power house site is located at left bank site which is underlain by metavolcanics andesite covered with residual soil. This is strong enough for foundation of power house.

The reservoir area of about 37.1 km^2 extend towards southeast from damsite which is underlain by diorite and quartz diorite.

Several small scale faults are expected to be in the reservoir area. Hydrologically reservoir area is expected to be watertight. During overflight survey, it was observed the reservoir area is densely covered with forest. Sedimentation problem in the reservoir area will be negligible.

The suitable location for rock materials is proposed at the fresh hard to very hard andesitic rock within 1.5 km upstream of damsite. Borrow area of sand and gravel is proposed at reverbed 5-6 km downstream from damsite. Residual soil of diorite to be suitable for earth material could be obtained 5 km southeast from damsite.

Ibulao (2-8-20-46)

Ibulao scheme is proposed as a run-of-river type. Approximately 253 m head is taken with 8.5 km long water way tunnel. The proposed scheme is located at Ibulao province, eastern part of the Luzon Central Cordillera mountain range and also western part of the Cagayan valley.

The intake weir (El. 810 m) is located at 5.5 km southeast of Mt. Napaluan (El. 2298 m) and immediately downstream of confluence of the Taong river and the Asin river.

The water way tunnel is located at right bank of the Taong river. One additional intake weir from the tributary is connected to the water way tunnel at 4.2 km from inlet.

The power house is located at about 10 km upstream from Ibulao gap (The cross point of Banaue road and the Ibulao river). Intake weir site and inlet of water way tunnel are located at further 10 km upstream from power house.

The existing geological maps show the regional geology to be largely silites and basalt of Cretaceous-Paleogene metavolcanics, and volcanic wackes, micro breccia and conglomerate of early to middle Miocene Lubuagan Formation. The Lubuagan Formation has an unconformable relationship with the underlying metavolcanics.

Very long fault on the left bank of the Taong and the Asin rivers is traceable almost north and southward. And one geologic lineament in the direction from northwest to southwest is inferred to cross the water way tunnel diagonally, which is probably corresponds to geologic contact of metavolcanics and Lubuagan Formation.

The basement rock of intake weir site may be underlain by very hard and compacted spilites and basalt which are covered with thin residual soil. These rocks are folded and jointed, however, they have enough strength for foundation of concrete intake weir. Watertightness of basement rock is to be fair except fractured zone of shallow part due to influence of N-S trending long fault on the left bank of the Taong river.

The geology of water way tunnel at the inlet side is probably composed of metavolcanics, and after the point of additional intake weir from tributary is occupied by volcanic wacke of the Lubuagan Formation.

The Lubuagan Formation overlies probably in fault contact along the northeastern boundary of the metavolcanics. The overburden of tunnel is to be enough thickness for excavation but rock quality of geologic contact zone is to be fractured. That area will require heavy supporting works.

Power house and penstock line near barrio Bugaoy are laid out on the volcanic wackes, micro breccia and conglomerate of Lubuagan Formation. No serious geologic hazards are estimated for the power house foundation.

The bed rock of the regulating reservoir area is composed of hard metavolcanics which exposed up to high flood water level. Permeability of reservoir is to be watertight because high water level of reservoir does not exceed high flood water level. Therefore the slope of regulating reservoir area will be stable.

The suitable quarry site for concrete aggregate is situated at 1.5 km north of damsite which is underlain by spilites and basalt of metavolcanics. They have enough strength and volume for concrete aggregate. Borrow area of sand and gravel materials are proposed at the Taong riverbed within 2 km from intake weir.

Cabingatan (2-8-28-52)

Cabingatan scheme is proposed as dam and reservoir type, at 1.5 km downstream from the barrio Cabingatan and 5 km upstream of Maddela on the Conwap river which is located at southern part of the Cagayan valley and southwest of the North Sierra Madre. A dam height of about 147 m has been considered at this site.

The existing geological maps show the regional geology to be Siculao limestone (may be equivalent to Ibulao Formation) and Metavolcanics. The Siculao Formation has unconformable relationship with the underlying metavolcaics.

Generally, limestone forms steep slope cliff and gap. Cabingatan scheme site is in the most biggest scale gap in the Cagayan valley.

The limestone consists of bedded and massive structure and also they have rich joints and some sink holes.

Bed rock of damsite is underlain by hard indurated massive and bedded white coral limestone. However several large cavities are found during the overflight survey. This limestone forms U-shaped typical gorge. Right abutment is formed by a steep cliff, top of the abutment is covered with dense forest and the toe of the cliff is covered with talus and big rock fall, left abutment is formed by more high cliff and horizontal caves. The riverbed is occupied by full width water flows, but it may be filled with sand, cobbles and boulders.

Watertightness of damsite is not expected due to solution channels and large cavities of limestone.

Damsite is composed of only this leakageable limestone from riverbed up to top of both abutments. Therefore, Cabingatan damsite is not recommendable from geological viewpoint.

And also hydrogeological condition of reservoir area is not good for water storage. Reservoir area of Cabingatan scheme is around 59 km^2. Bed rock of reservoir area is underlain by limestone and wacke and shale. Wacke and shale are usually watertight, but generally limestone has solution caves and fractured fissures. Metasediments (wacke and shale) are conformably overlain by thick bedded permeable limestone. In conclusion, the reservoir area is generally not watertight. Specially, water leakage can not stop at high elevation of caves and fissures of limestone.

Casecnan (2-8-29-58)

Casecnan scheme is proposed as run-of-river type, consists of about 6 m in height and 56 m in width concrete intake weir on the Casignan river at about 4.5 km north-northwest of barrio Maghanay and about 75 km upstream of Cabingatan scheme. Power house site is to be located on the left bank of Casecnan river at 1.5 km downstream of barrio Maghanay. The water way tunnel is proposed at left bank of the Casignan river. Approximately 88 m head is taken with 6 km long water tunnel.

The Casignan river flows at the intake site (El. 543 m) towards south direction and joins the Casecnan river at barrio Maghanay. The deforested and bared valley flanks are relatively widely distributed between proposed intake site and barrio Maghanay along the Casignan river. And also many land slide is there, the most biggest scale of landslide is situated at the right bank of Casignan river about 2 km dowmstream from damsite. To the contrary, upper stream of intake weir site, the valley flanks of proposed scheme site are stable and covered with dense virgin forest.

According to the existing geological map of Northeastern of Luzon Island in scale of 1/250,000 (JICA-MMAJ, 1977), regional geology of proposed scheme site is to be largely Caraballo Group, of Cretaceous to Eocene. It is probably equivalent to metavolcanics in geologic maps of Breau of Mines. Fold axis running east-west direction is developed. Two inferred faults are recognized at near scheme, one occurs along the right bank of the Casecnan river and another appears along the right bank of the Casignan river.

The Caraballo Group consists of three formations, namely Formation I, Formation II and Formation III in ascending order.

Formation I is underlain by andesitic tuff breccia, andesitic lava and well bedded alternation of sandstone and shale. Formation II is underlain by basaltic lava, diorite, basaltic tuff breccia and interbedded siliceous shale and sandstone. Formation III is underlain by andesitic lava, andesitic tuff breccia and interbedded siliceous shale and limestone.

Bed rock of weir site is underlain by hard to very hard indurated basaltic tuff breccia or lava and locally interbedded siliceous shale and sandstone with weathered zone covered by residual soil. The riverbed is filled with thick gravel and cobble throughout the flood plain. Assumed N-S trending fault occurs at 1 km west of intake weir, however may be no effect to low concrete weir. Regulation reservoir area is underlain by andesite and basalt, and slope of valley flanks will be stable and watertight.

Proposed water way tunnel route will pass through the hard indurated basaltic and andesitic basement rocks. There is no major fault intersecting the water way, and also enough thickness of overburden for tunnel excavation is expected. Therefore, no special treatment is necessary for tunneling works.

Proposed power house site is underlain by hard to very hard indurated Cretaceous to Eocene andesitic lava and tuff breccia and interbedded siliceous shale and limestone.

Construction materials of intake concrete weir is expected to hard to very hard basaltic lava and tuff breccia at the right bank flank of the Casignan river 2.5 km downstream of weir site. Sand material can be obtained from flood plain with 2 km downstream of intake weir site.

Upper Casecnan (2-8-29-59)

Upper Casecnan scheme is propoesed as run-of-river type, consists of about 7 m high and 47 m wide intake weir on the Casignan river at 8.5 km upstream from intake weir site of the Casecnan scheme. Power house site is located on the left bank of the Casignan river at 1 km upstream of intake weir site of Casecnan scheme and about 10 km upstream of barrio Maghanay.

The water way tunnel is proposed at the left bank of the Casignan river. Approximately 112 m head is taken with 7 km long water way tunnel. The Casignan river winds through the valley and flows at the intake site (El. 670 m) towards SSE direction. The valley flanks of proposed scheme site are stable and covered with dense virgin forest.

Regional geology at the site is almost similar to that of the Casecnan scheme. Several fold axis are observed and the principal structural trend is the east-west. Inferred faults occurred along the right bank of the Casignan river. Columbus limestone crops out in the 5 km east from the Casignan river, however, this is not effect on the scheme.

Intake weir site is probably underlain by hard to very indurated andesitic lava and tuff breccia interbedded siliceous shale and limestone.

The basement rock of intake weir is covered with thick sand gravel and cobbles on the riverbed and thick residual soil in higher elevation of both abutments. The permeability of weir site is probably watertight except shallow part of riverbed. Therefore, no special treatmet is necessary.

Regulation reservoir area is probably underlain by andesitic lava and its pyroclastic rocks. There is probably no water leakage, and slope of valley will be stable.

The proposed water way tunnel will pass through Caraballo Group which are subdivided into three formations, namely, andesitic lava and tuff breccia occured in the northern part, basaltic lava and tuff breccia in the middle part and andesitic tuff breccia and lava in the southern part of tunnel route. Rock quality of tunnel route is totally strong for tunnelling without full supporting, however, full supporting is necessary at several crossing points of gully.

Bed rock of proposed power house site is underlain by hard to very hard indurated andesitic tuff breccia and lava with well bedded alternation of sandstone and shale, Cretaceous to Eocene.

Construction materials is expected to hard to very hard basaltic lava and tuff breccia at 4 km SSE of weir site. Sand materials are located at river flood plain near weir site.

Upper Casecnan-3 (2-8-29-61)

Upper Casecnan-3 scheme is proposed as dam and water way type, consisting of about 87 m high dam on the Casignan river at the upstream of the Casecnan river, and trans-basin water way tunnel from the Casignan river to the Manga river of the uper stream of the Magat river. Approximately 342 m of head is taken with 14 km long water way tunnel from intake weir in the reservoir to power house at the Mange river.

Proposed damsite is located on the Casignan river at 2 km dowstream of barrio Manguit and 4 km upstream from intake weir of upper Casecnan scheme. Upper Casecnan-3 damsite froms V-shaped valley, where small creek occurs at immediately downstream of right bank. The reservoir water is conveyed through water way tunnel from reservoir intake at the 3 km upstream of damsite to the power house at the left bank of the Manga river.

Regional geology at the site is similar to that of the Casecnan scheme. General trending of fold axis is northeast to southwest. Inferred long fault N-W trending crosses the right abutment of the damsite and water tunnel route, and also passes through the west side of reservoir area.

The basement rock of damsite is probably underlain by hard to very hard andesitic lava and tuff breccia which are probably fractured at right abutment due to effect of fault. Probably these rocks are covered with sandy gravel on the reverbed and thick residual soil in higher elevation of both abutments, respectively. The intake foundation consists of dacitic tuff of Oligocene Mamparang Formation. No serious problem are seen geotechnically.

The water way tunnel will pass through the Oligocene dacitic tuff, andesitic lava and tuff breccia interbedded siliceous shale of Caraballo Group Formation III and basaltic lava and tuff breccia of Caraballo Group Formation II. The traversed zone of fault line on tunnel section will require full supporting works for the excavation. Furthermore, during the construction, water leakage into the tunnel is possible to happen under the Casignan river crossing point at 5.5 km from intake.

The power house site is underlain by hard indurated siliceous shale of Caraballo Group, Cretaceous to Eocene. However inferred fault along the Manga river should be effected to the basement rock of power house. Therefore, some foundation treatment will be required.

Reservoir area is about 17.7 km^2 where is underlain largely by dacitic tuff of Oligocene Mamparang Formation. The reservoir area is to be occupied of dish bottom of tectonic basin, so that valley flanks of reservoir area form commonly gentle slope except near damsite. Upper Casecnan-3 reservoir area seems to be watertight and stable.

Quarry site to work fresh and indutated andesitic lava and tuff breccia suitable for rock full, would be located at 1 km south of the damsite. Sand and gravel, suitable for rockfill filter, would be avairable in the riverbed within 2 km upstream of damsite. Earth materials is expected to residual soil of dacitic tuff which is located at 2 km north of the damsite.

Tabu (3-77-0-4)

The Tabu scheme is proposed as dam and reservoir type, consists of about 160 m high rockfill dam on the Agno river at Benguet Province, 26.5 km downstream of Binga dam. The Agno river runs in the wide fault valley (500 m in width) from Daluprint to Tet-bo, the river shifts from southeast to southwest just downstream of Tet-bo. And then the Agno river forms deep gorge between Tet-bo and Snrouqe along the several assumed northeast and northwest faults, which run parallel to the direction of the valley and dip steepy.

According to the existing geological maps, regional geology mainly consists of four geologic units which are Neogene quartz diorite (Qd) at damstie, metavolcanics (Mv) at left bank of wide fault valley, schist (Sc) located between metavolcanics and quartz diorite, and alluviual deposits in wide fault valley.

Proposed dam axis is located on V-shaped valley by quartz diorite which is situated about 5 km downstream from gorge entrance near Tet-bo. One assumed fault trending northwest occur at along the left bank site. Rock quality of damsite is probably hard to very hard covered with thin residual soil and deeply werthered rock at both abutments and locally fractured due to assumed fault along the left bank site.

Permeability of damsite is probably rather high at both abutments and high permeability at shallow part of riverbed covered with several meters thickness of gravel and boulders. Therefore excessive grouting will be required. The basement rock of damsite is generally sound and partly weathered. Chute type spillway is proposed at the upper part of right abutment because of hydraulic consideration, and therefore spillway works would require a deep cut and excessive excavation. It is necessary to study of rock excavation problem and slope stability in the future study. Proposed power house site will be underlain by a sequence quartz diorite of Neogene covered with some talus deposits, it seems to be ehough strength for power house foundation. However the power house site is also required large volume excavation.

The reservoir area of about 6.6 km^2, extends towards northeastward from damsite and then shifts to northwest direction at near Tet-bo. The Tabu reservoir in the gorge area is underlain by the quartz diorite and schists, and the upstream of reservoir in the wide fault valley area is underlain by the schists, metavolcanics and alluvium. The permeability and ground water condition of reservoir is probably watertight except fractured high permeable faulted zone.

Rock material will be supplied from the hard to very hard quprtz diorite at 1 km northeast of damsite on right bank of the Agno river. Sand and gravel materials are expected to alluvial and terrace deposits along the Agno river about 6 km upstream of damsite. Earth material may be collected from the residual soil of the quartz diorite.

Agno-1 (3-77-0-5)

The Agno-1 scheme is proposed as run-of-river type, consisting of intake weir, power house and water way tunnel. The proposed scheme is located at the Agno river basin in Benguet Province. The intake site is located on the Agno river at 1 km south of barrio Socong.

The power house site is located at 2 km downstream from the weir site and about 10 km from the Ambuklao damsite, and also immediately upstream of back water of Ambuklao reservoir. Both sites are connected by 2 km long water way tunnel, then 60 m head is taken.

The Agno river forms narrow and very deep canyon at the Ambuklao damsite, however the valley of this site is rather shallow. The steep slopes of the canyon area mainly form by outcropping weathered rock without any vegetation. Big land sliding scar occur at the right valley slope of the Agno river immediately downstream of power house.

According to the existing geological map of Benguet Province in scale of 1/250,000 (BMG Nov. 1974), regional geology of the Agno river basin is composed of four typical formation, namely UV Formation, N1Formation, N2 Formation and NI Formation, which are formed southern part of Luzon Central Cordillera.

The Cretaceous-Eocene UV Formation forms axial zone of Central Cordillera. This is probably equivalent to the Pugo Formation. The rocks mainly consist of metavolcanics. And NI Formation unconfromably overlies the UV-Formation. This formation is probably equivalent to the Zigzag Formation and early to middle Miocene which is composed of sedimentary rocks such as conglomerate, sandstone and wackes. Following to the aboves, there is N2 Formation, which is probably equivalent to Klondyke Formation, upper Miocene.

NI Formation is instrusives, which is probably equivalent to Agnobatholith. It intrudes the UV and early to middle Miocene rocks. NI Formation is a composite intrusive consisting of quartz diorite, grano-diorite, and related andesite-dacite prophyries.

Basement rock of intake weir site consists of hard and indurated with slightly to noderately wethered metamorphosed basalt and andesite. These rocks are covered by thin residual soil and talus deposits, however moderately weathered zone is seemed to be thick. Riverbed is filled with thick sand, gravel and debris.

The water way tunnel passes through the right bank of the Agno river and overburden rock of water way tunnel is underlain by hard and indurated metamorpnosed basalt and andesite. Tere are no major faults which intersect the water way. Therefore, no full supporting is necessary during the tunnelling.

Power house is located at confluence of the Agno river and its tributary, at near barrio Ambay. Basement rock is underlain by largely hard and indurated metamorphosed basalt and andesite with slightly to moderately weathered at shallow part and covered by thin residual soil special treatment is required.

Bed rock of regulating reservoir area consists of metamorphosed basalt and andesite which are almost stable and indurated with tight closed joints. Then no leakage is expected from reservoir.

Construction materials are expected to metamorphosed basalt and andesite at 1.5 km south of damsite, which have enough strength for concrete aggregate. Sand materials are taken from riverbed at 0-2 km upstream of weir site.

Agno-2(3-77-0-6)

The Agno-2 scheme is proposed as run-of-river type, consisting of main intake weir, sub intake weir and power house connected together by water way tunnel.

The power house site is located at about 1 km upstream of Agno-1 scheme intake weir site on the Agno river.

The main intake weir site is located on the Agno river at barrio Lutab about 10 km upstream from power house site, and two additional sub weirs are proposed on tributaries of the Agno river 5 km southwest of main weir and 3.5 km upstream from power house site.

The water of sub-weir is conveyance by tunnel to lead the 4 km point into main water way tunnel from inlet site. The total length of main tunnel is bout 8.3 km and then 158 m head is taken. Main intake weir site is located at wide open V-shaped valley . Sub-weir site and power house site are located at steep and rather deep valley.

Regional geology is almostly similar to that of the Agno-1. Ambuklao fault occurs on the left bank of the Agno river. The east side of fault line is underlain by N1 Formation (It is probably equivalent to Zigzag Formation).

The valley flanks of intake weir site form steep slope at right bank and rice terrace at higher elevation on left bank. The center part of riverbed filled with sand and gravel. The gentle slope of left abutment is underlain by alternating beds of conglomerate and sandstone, and bedding plain is shown as parallel to the land surface.

Contrary, at the right bank bedding plain of conglomerate interbedded volcanic flow is shown as interseciton to the land surface. The general direction of joints is N 40-45° E/80° NE. Some of these joints are filled and tight and some are opened. Density of joints is 5-6 pcs/meter.

Rock quality of bed rock is probably hard enough strength for foundation of concrete gravity weir, however special curtain and consolidated grout may be necessary due to some open joints. The thickness of river deposits is seemed to be 6 to 8 m. The thickness of weathered zone is to be within 1 m. The talus deposits of about 6 m in thickness are deposited at left bank. Some conglomerate exposes only at toe of left bank site.

Basement rock of water way tunnel is probably underlain by Cretaceous to Eocene metamorphosed basalt and andesite and late Miocene to Pliocene sedimentary rocks. Inlet and upper route of water way tunnel will pass through the sedimentary rocks and the following lower part of tunnel and two sub-intake weir site is located at metamorphosed basalt and andesite. There is no special diffculties for tunnel excavation. However it may require some supprting work locally.

Basement rock of power house is underlain by metamorphosed volcanic rocks (Cretaceous to Eocene) covered with very thin residual soil. The special treatment is not necessary due to enough strength for power house fundation.

Regulation reservoir area is probably underlain by same basement rock of intake weir site so that there is no serious hydrogeological problem.

The suitable concrete aggregate is composed of river deposits, rock fall and terrace deposits which are located on the river flood plain of Agno river within 1 km from main intake weir. Sand materials also expected to be taken from river flood plain within 1 km from main weir.

Agno-3 (3-77-0-7)

Agno-3 scheme is proposed as run-of-river type, consisting of main weir, sub-weir and two additional intakes, power house, and water way tunnel at upstream of Agno-2 scheme. The power house is located at left bank of the Agno river at immediately upstream of main intake weir of Agno-2 scheme.

The main intake weir is located on the Agno river at about 8 km upstream of power house site. Sub intake weir is located on the unnamed tributary of the Agno river at 1 km southwest of main weir and 2.5 km upstream from confluence of the Agno river and its tributary.

The tunnel route runs through the left bank of the Agno river. The total length of water way tunnel is 7.5 km with total head of 184 m.

The water from sub-intake weir is conveyed by water way tunnel to the regulating pondage of main intake weir. The water way tunnel from main intake weir conveys the collected water to the outlet of water way, and on the way to the power house it collects water by additional intake weirs from small creeks overpassed.

Regional geology at the site is almost same as those of Agno-1 and Agno-2 schemes. Ambuklao fault is running south-north direction in parallel with the tunnel route. And also, this is through the main intake site and power house.

Intake weir site is located on the main Agno river. Intake water from tributary by sub-intake weir is supplied to the regulating reservoir. The riverbed is filled with 5-7 m thick sand and gravel.

Bed rock of right abutment consists of early to middle Miocene agglomerate and breccia covered with thin strongly weathered zone. Basement rock of left abutment is similar rock and covered with rather thick weathered zone. Rock quality of basement rock is fresh and well compacted, and slightly weathered at left bank site.

The fault zone has N 30°W strike with 80°E dip which is observed at right bank of downstream of intake weir axis. However, this fault could not confirmed at left bank site. Joints occurred 1-5 ps/meter with N60°W/70°NE trend. Weir site will be watertight or low pervious.

The bed rock of water way route is underlain by well compacted and slightly weathered Neogene instrucive quartz diorite. It intrudes the early to middle Miocene sedimentary rocks. Ambuklao fault crosses the outlet of main water way tunnel and connection tunnel from sub-intake weir.

The power house site is underlain by horizontally bedded conglomerate and sandstone interbedded volcanic flows of late Miocene to Pliocene covered with several meters weathered zone. The thickness of weathered zone is rather thick in higher elevation. Rock is good and well compacted but rich with parallel joints running N15°E direction.

Reservoir area is almost same area of flooded zone. There is no serious water leakage in riverbed, however several sliding scars form steep slope accumulating talus deposits existing along the river side.

The suitable concrete aggregate is composed of metavolcanic rock fall and river deposits located at the riverbed within 2 km downstream from intake weir. Sand and gravel is also to be taken from same place.

Kanan (4-7-0-1)

Kanan scheme is proposed as a rockfill dam and reservoir type on the Kanan river. The proposed dam has a height of approximately

208 m and crest length of about 300 m. Proposed scheme is located on the Kanan river at 5 km upstream from confluence of the Kaliwa and the Kanan rivers. Both rivers join into the Agos river and flow down to the east, then out into the Polillo strait. The Agos river basin is situated on the eastern coast of Quezon Province in southeastern Luzon.

According to the existing geological map, regional geology of this scheme is underlain by wackes and graywackes associated with reef limestone, basic to acidic lava flows and pyroclastics of Cretaceous age to Miocene age.

At the damsite the kanan river flows north to south in a V-shaped valley. There is scarely deposits on the riverbed where massive, hard, and tightly jointed graywackes crop out continuously.

The right abutment is underlain by hard and massive graywacke covered withe thin residual soil and forest. And a clear straight gully is recognized on the right abutment flanks during over flight survey. This may coincide with an estimated minor fault line in northwest to southeast direction.

Slope of left abutment is rather gentle and covered with sacttered trees. No bed rock exposes on the top of abutment. The surface is covered with thick residual soil without vegetation.

The bed rock of both abutments seems to be low permeability, however weathered rocks and residual soil on the left bank may be deep. Therefore large volume of excavation and grouting is to be required.

Power house site is proposed at right bank site on a sequence of tightly jointed graywackes which is covered with rather thick residual soil and talus. No serious geotechnical problems are there.

Reservoir area of about 16.6 km^2 is underlain largely by metamorphosed wackes and shale of Cretaceous to Paleogene. The bed rock of reservoir area is seemed to be watertight, and reservoir slope is to be stable and less sedimentation. Because the stream water of the Kanan river is always clean though the kaliwa river is muddy during rainy season. Drainage area of the Kanan river is mostly covered with virgin forest, and typical landslide is not observed.

Quarry site to work fresh sound, and hard graywackes of Cretaceous to Paleogene suitable for rock fill would be located at 1.5 km south of damsite. Sand and gravel, suitable for rockfill filter, would be located in the riverbed 1 to 5 km downstream from damsite. Earth materials is expected to residual soil of graywackes which is located at 1 km east of damsite.

Daraitan (4-7-0-2)

Daraitan scheme is proposed as dam and reservoir type on the Kaliwa river at 22 km upstream from confluence of the Kaliwa and Kanan rivers. The both rivers join into the Agos river and flows down to the east, then out into the Polillo strait. The Agos river basin is situated on the eastern coast of Quezon Province. A dam height of about 98 m has been considered at this site.

Regional geology of the Agos basin is underlain chiefly by wackes or graywackes associated with reef limestone, basic to acidic lava flows and pyroclastics of Cretaceous age to Miocene age. The distribution of these lithologic units seems to be extended in north-south direction by the movement of major fault zones which run eastern part of the Agos basin.

The major fault zones, which run from southeast to northeast in Luzon island, seem to pass through the Polillo strait. The major fault is a left-handed fault accompanied by derived minor faults in the direction of north-northwest to south-southwest.

According to the existing geological map of regional geological map of Agos river hydropower project in scale of 1:120,000 (NPC-JICA 1981), the proposed site is underlain by massive limestone of Oligocene to Miocene age. However several large cavities are reported in this limestone area.

The damsite is composed of steep topographic area overlain by massive limestone in which some vertical open joints and solution caves covered with forest are observed during the overflight survey.

Consequently, this limestone may be cavernous limestone in spite of massive appearances. The suitability for dam foundation has to be studied carefully on permeability in detail, however this may imply pervious condition of the foundation rocks. Therefore, Daraitan damsite is not recommendable from hydrogeological point of view.

Upper Agos-2 (4-7-0-5)

The Upper Agos-2 scheme is proposed consisting of about 157 m high concrete gravity dam and a reservoir. The proposed damsite is located on the Kanan river about 10 km upstream of Kanan damsite in the Quezon Province.

Damsite is located at high mountain range around 1,000 m in elevation. The riverbed is some 40 m wide and the elevation is 166 m above sea level, with scarely sediments of sand and gravel materials. The Kanan river at proposed site forms steep and deep gorge with outcrops of hard graywacke sandstone. The proposed damsite is covered with dense virgin forest, and hard bed rock outcrops are observed only at toe of both abutments and riverbed.

Steep mountainous topography of this area seems to indicate thin development of weathering. The exposed rock is seemed to be fresh and hard with tight joints. Therefore, the bed rock of damsite is to be underlain by hard and indurated graywacke, covered with very thin overburden. And probably depth of weathered rock is shallow. Then, the permeability at this scheme site will be very low.

A lineament, which is parallel to the straight river channel, is interpreted on the left abutment. However, the continuation of the lineament is not observed in a long extent implying a rather small scale of the fault if it exists. Therefore, the total geologic assessment at the damsite is excellent. It is recommendable to build high concrete gravity dam.

Power house site is proposed at right bank of the Kanan river immediately downstream of damsite. Proposed power house site is underlain by hard graywacke sandstone, covered with very thin residual soil. No serious geological problems are there.

Reservoir area is approximately 39.6 km^2. According to the existing geological map of Umiray Quadrangle in scale of 1:50,000 (BMG 1983), most part of the reservoir area would be underlain by graywacke sandstone, shale and conglomerate and pyroclastics of Paleocene-Eocene Maybangain Formation (probably equivalent to Baybas Formation).

General trend of the bedding planes of major faults and folds axis run in NE-SW to N-S within the reservoir area. Most part of the reservoir area is covered with dense virgin forest and no existing land sliding is observed during overflight survey. Only the toe of the reservoir slopes is free from vegetation and debris up to the high flood level.

The slope of the Kanan river seems to be stable, because the Kanan river is always clean even if it heavily rains during rainy season. The basement rock underlain and surrounding the reservoir area which would be impervious, because exposed rock at riverbed side seems to be tight and indurated.

The suitable location for concrete aggregate materials to be fresh graywacke sandstone on steep mountainous ridges about 1.5 km southeast of damsite. No sand and gravel materials are expected along the Kanan river near damsite, it will be manufactured from rock of quarry site.

Wawa (4-115-1-1)

Wawa scheme is proposed as a dam and reservoir type on the Wawa river. The proposed dam has a height of 136 m and a crest length of about 280 m.

Proposed scheme is located on the Wawa river at 6 km east of Montalban in Marikina valley, Quezon Province. There, the Wawa river running southeast-northwest crosses diagonally a generally north trending mountain ridge which reaches an elevation of 390 m above sea level at Mt. Binicayan on the left bank side and Mt. Pamitinan on the right bank side. The both abutments flanks of proposed damsite are formed very deep and steep canyon. The elevation of riverbed is 30 m above sea level, and river width is 35 m.

According to geological map of the Montalban Quadrangle in scale of 1/50,000 (BMG 1983), the bed rock of this area is underlain by largely alternated spilitic green basaltic flow, and interbedded hard sandstone and chert of Cretaceous Kinabuan Formation by fault unconformably.

Madurum Formation is composed of three members which are (from top to bottom) Buenacop limestone, Alagao volcanics, and lower clastics. Buenacop limestone contain many fossils, and color is cream to buff, upper part is massive to obscurely bedded, lower part is thin to medium thickness bedding plain.

Alagao member is composed of a sequence of agglomerate, tuff, argillite, indurated graywacke, basaltic flow and andesitic flow. Clastic member is composed of thin to thick bedded carbonaceous sandstone and a sequence series of silty shale accompanied with basal conglomerate.

Angat Formation is composed of well bedded or massive limestone locally accompanied with thin layered silicic layer and limestic sandstone. Lower clastics consists of a sequency thin layered that is carbonaceous shale, clayey sandstone, sandy limestone and conglomerate.

The strike of each formation is almost south-north direction. Dip is around 40-90°. Folding is strong in Madarum formation and Angat formation.

One pair of nearly parallel inclined faults, namely Marikina fault, from the 3 km in width graven structure alluvial plain along the San Mateo river. The Montalban fault, strikes N45°W, dipping steeply to the northeast, occurs along the right bank of Wawa river.

According to the "Geology and Foundation Problems of the Projected Marikina Arch Dam" (Generoso R. Oga Jose F. Potenciano, Dec. 1983 The Philippine Geologist Vol.XVII, No. 4), The Marikina dam is proposed as arch dam on same location of the Wawa dam on 29 September 1953 for the multipurpose dam, and construction of the dam was authorized on 16 June 1955.

The dam will be about 170 m high, and has a crest length of 214 m. Thickness of arch is 25 m at the base, and 5 m on the top.

However, the Marikina dam project is suspended on 1960 due to environmental and financial problem. According to the review of IECO Apr. 1973, the Marikina dam was evaluated as feasible from technical and economic standpoints.

According to the report of Marikina dam project, the bed rock has enough strength for construction of arch dam (and concrete gravity dam). However, permeability is so high in higher elevation, special foundation treatment is required. It is not only at dam axis but also at high elevation of abutments and reservoir area.

Proposed damsite is underlain by white hard Miocene limestone, and thin layers of chert are interbedded with the limestone. The intake weir of Manila Water Supply System is located at immediately upstream of proposed dam axis. The weir is concrete gravity non-gated type, with crest elevation of 62 m above sea level.

The riverbed of damsite is occupied by very big size rock falls and huge boulders from immediately downstream of existing weir to 300 m downstream. These rock consists of white cream caves solution limestone, probably these are fall from cliff of both abutments. Both abutment form vertical very intense fractured limestone wall, which are exposed from riverbed up to top of abutment.

There is one connection foot pass from barrio Wawa to upstream area on the left abutment through excavated limestone tunnel and flank of abutment.

On the right abutment, several waterfalls flowing into the river from lateral solution holes are observed. According to the survey results of Marikina river multi-purpose project, four major caves were conspicuously developed at different levels along the limestone canyon. All these caves are situated downstream of the proposed dam. In general, these caves follow NS to NE line.

The results of boring survey indicated that limestone was generally sound and tight joints and low permeability, however sometimes numerous strong fractures intersect. And results of test tunnels and adits, indicated that the fractures and fault were commonly tight so that during the excavation, tunnel was generally unsupported and dry especially below riverbed.

However, maximum recorded seepage flow in tunnel was 75.8 l/sec at 11 m below than water level of MWSS intake weir. In order to prevent leakage and uplift, consolidation and curtain grouting under and around the dam is required. The Montalban fault is the only major structure in the damsite at right abutment. But, the basement rock of damsite has enough strength for dam foundation.

The power house is proposed at left bank near barrio Wawa. This area is enough space for power house area. As river deposits widely spread on the rocks, it is necessary some special treatment. There are some vertical fissure, fractured zone, which are supposed to be fault of limestone. It is necessary special treatment such as concrete plug.

In the reservoir area, topographic condition is flatter, and covered with residual soil. Generally residual soil is impervious and weathered rock zone probably rather thick. The bed rock of reservoir area is underlain by so called Kinabuan Formation alternated spilitic basalt.

The most suitable concrete aggregate will be collected from the riverbed near damsite and supplied from the Mt. Naponang Bandy 1 km north of damsite. Sand materials is expected within 1 km down- and upstream from damsite which are aggregated by local people.

Bosigon (5-14-1-1)

Bosigon scheme is located on the Bosigon river at about 35 km west of Daet city, Capital city of Camarines Norte Province. This scheme is proposed as dam and reservoir type. Rockfill type dam of about 63 m high has been considered.

Bosigon river is situated at Camarines Norte of Bicol peninsula. Camarines Norte contacts to Bondog peninsula by the Philippine fault at south western part and thrust fault at northern. The mountain Labo (942 m) is located at 25 km southwest of damsite. This area is an eminent heavy rain fall area of this country.

The altitude of the Bosigon river at damsite is only 20 m above sea level. Main stream of the Bosigon river is almostly flat and while the tributaries has rather steep gradient. The mountain range of reservoir area is formed by flat and rather low mountain of about 200 m high above sea level.

According to Geological maps of the Bayabas and Panganiban Quadrangle in scale of 1/50,000 (BMG 1984), the regional geology of this area is underlain by largely Macogon Formation (late Pleicocene) and together Bosigon Formation (early Miocene) and underlies Tigubinan Formation (Cretaceous) and Labo volcanics (quaternary volcanics) distributed at southern part.

The following descriptions summarize each formation:

Tigunan Formation consists of graywackes, spilites, chert, andesite, cherty limestone, black tuffufaceous shale and Arkosic sandstone.

Bosigon Formation is composed of lower member and upper member. The lower member consists of rhythmical facies of conglomerate, sandstone, black carbonaceous shale and limestone. The upper member consists of basaltic flow, volcanic wackes, brecciaceous tuff, chert and limestone.

Macogon Formation consists of essentially andesitic pyroclastic interbed few basaltic flow and tuffaceous black shale. Labo volcanics consists of alternated of andesite and diorite and unconsolidated tuff and pyroclastics.

The bedding strikes of scheme area are largely composed of northwest to southeast direction, fault direction and fold axis are also same direction. A thrust fault is situated at along the Achiban bay locating at northeast of damsite, and also another thrust fault is located at the source of the Bosigon river 14 km southwest of damsite. The fault across the Bosigon river at 7 km upstream of damsite bounded Bosigon Formation and Tigbinan Formation.

The proposed scheme area consists of flat hill and the Bosigon river valley. The bed rock is underlain by fresh hard and jointed lava flow and andesite rock which are exposed at riverbed. Both abutments is strongly and deeply weathered and no fresh rock expose as outcrops. Locally, some weathered rock fragment is still remained in the residual soil. And also moderately weathered tuff breccia and conglomerate is recognized at the toe of left abutment.

The outcrop of damsite riverbed is underlain by hard lava flow which has enough strength for fill dam foundation. However, due to rich open cracks and joints, permeability of underlying dam foundation is probably high.

Power house is proposed at right bank of the Bosigon river. Bed rock of power house site is underlain by hard andesitic pyroclastics flow covered with several meters slightly weathered rock, terrace deposits and residual soil. It may be strong enough for power house foundation.

Reservoir area of about 37.1 km^2 is underlain by largely andesitic pyroclastic interbed basaltic flow and tuffaceous black shale. Leakage is to be expected only at the jointed lava flow, however that outcrop is recognized only near damsite during the field trip.

The slope of reservoir area is composed of strongly weathered rock or very thick residual soil, so that slope is not so stable and silty sedimentation after impounding may be considered.

Proposed quarry site for rockfill material is located at 2 km north from damsite and north side of national road route one which is underlain by Parmisan diorite. Sand and gravel is to be used for filter materials and aggregate is located at 1-2 km downstream of damsite. Earth materials can be supplied by residual soil of tuff breccia 1-2 km upstream of damsite.

LEGEND OF GEOLOGIC MAP

SEDIMENTARY ROCKS

Quaternary deposits

- River deposits (R), Terrace deposits (T)

Clastic deposits

- Sandstone (SS)
- Claystone (CS), Mudstone (MS)
- Siltstone (SLT)
- Conglomerate (Cg)
- Graywacke (GW), Wacke (Wa)
- Shale (Sh)

Pyroclastic sediment

- Tuff (Tf), Lapilli tuff (Lt)
  Tuff breccia (Tb), Agglomerate (Ag)

Chemical or Organic sediment

- Limestone (LS), Dolomite (Dl)
  Coral Limestone (CLS)

IGNEOUS ROCKS

Extrusive rocks

- Andesite (An)
- Basalt (Ba)
- Dacite (Da)
- Volcanics (VL)

Intrusive rocks

- Granite (Gr), Diorite (Di)
  Gabbro (Gb)
- Quartz-diorite (Qd), Granodiorite (Gd)
  Diorite-quartz (Dq), Tonalite (To)
- Ultramafic or Ultrabasic rocks (UC)
  Peridotite (Pt)

METAMORPHIC ROCKS

- Meta sediments (Ms), Schist (Sc)
- Meta volcanics (Mv)
  (Mostly spilites and basalts)
- Basement complex (Bc)
  (Pre-Jurassic)

GEOLOGIC STRUCTURE

- Geologic contact
- Thrust fault
- Fault, showing relative movement
- Normal fault, Hachures on down thrown side
- Inferred fault or lineament
- Syncline axis
- Anticline axis
- Strike and dip of beds
- Strike and dip of fault

SCHEME LAYOUT AND CONSTRUCTION MATERIALS

- Dam site
- Powerhouse
- Water way
- Intake weir
- Intake weir from tributary
- Powerhouse
- Proposed quarry site
- Proposed borrow area for sand and gravel
- Proposed borrow area for earth material

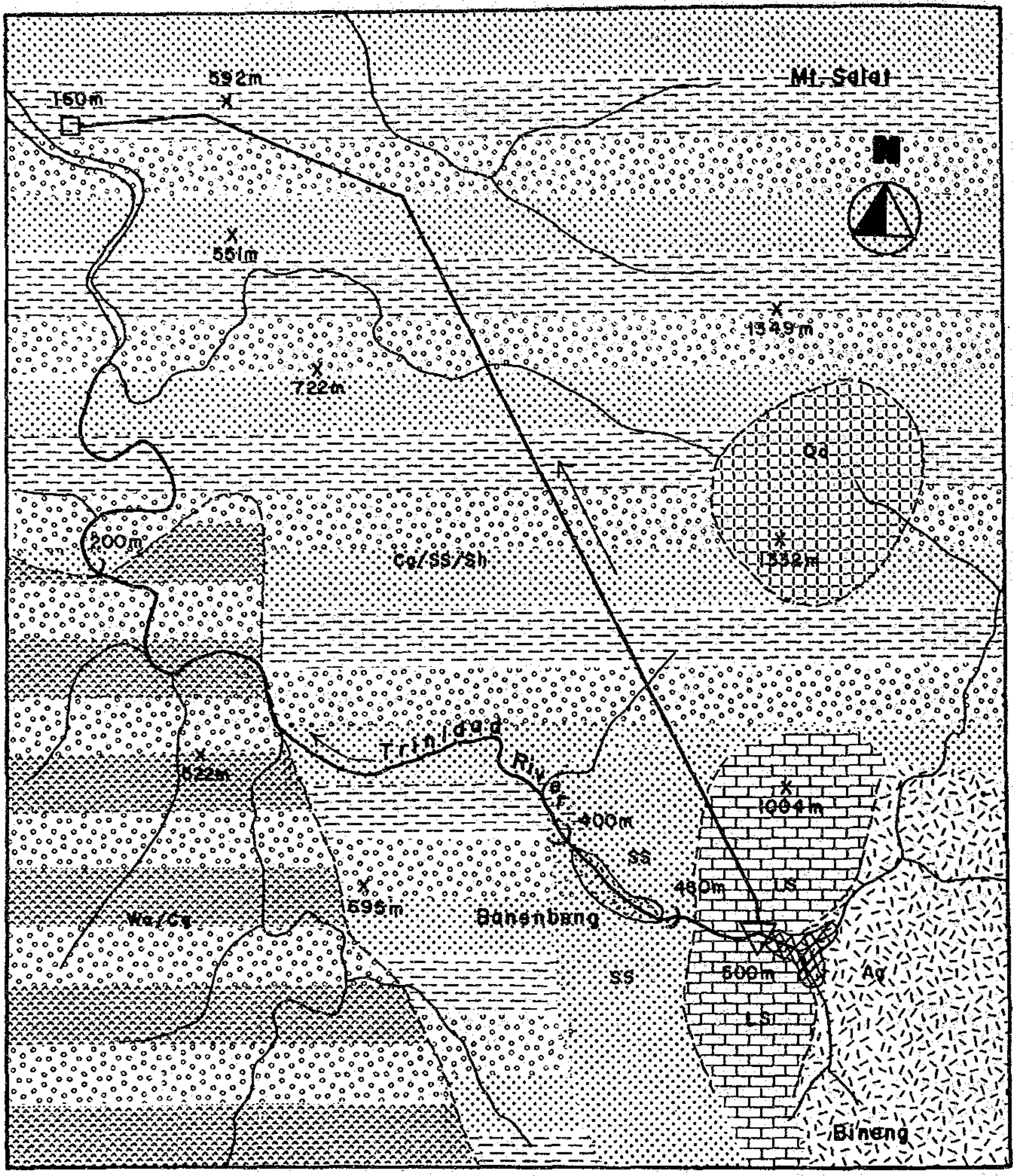


Fig. GEOLOGIC MAP OF NAGUILIAN SCHEME

SCALE
0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Bengued Province in scale of 1:250,000 (BMG Nov. 1974)

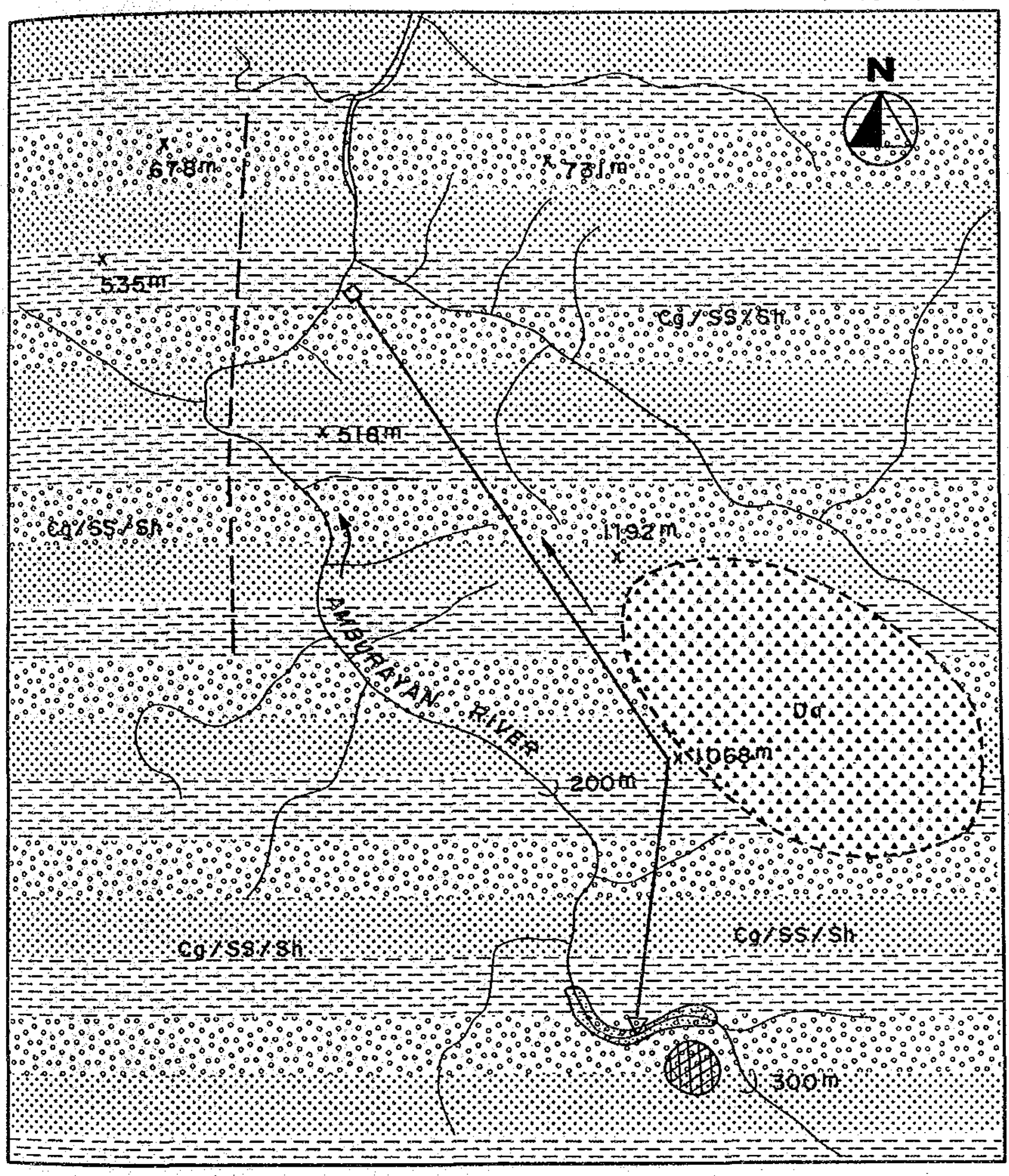


Fig. GEOLOGIC MAP OF LUYA SCHEME

S C A L E

0 1 2 3 4 5 Km

Geologic map is adapted from geological map of Bengued Province in scale of 1 : 250,000 (BMG Nov. 1974)

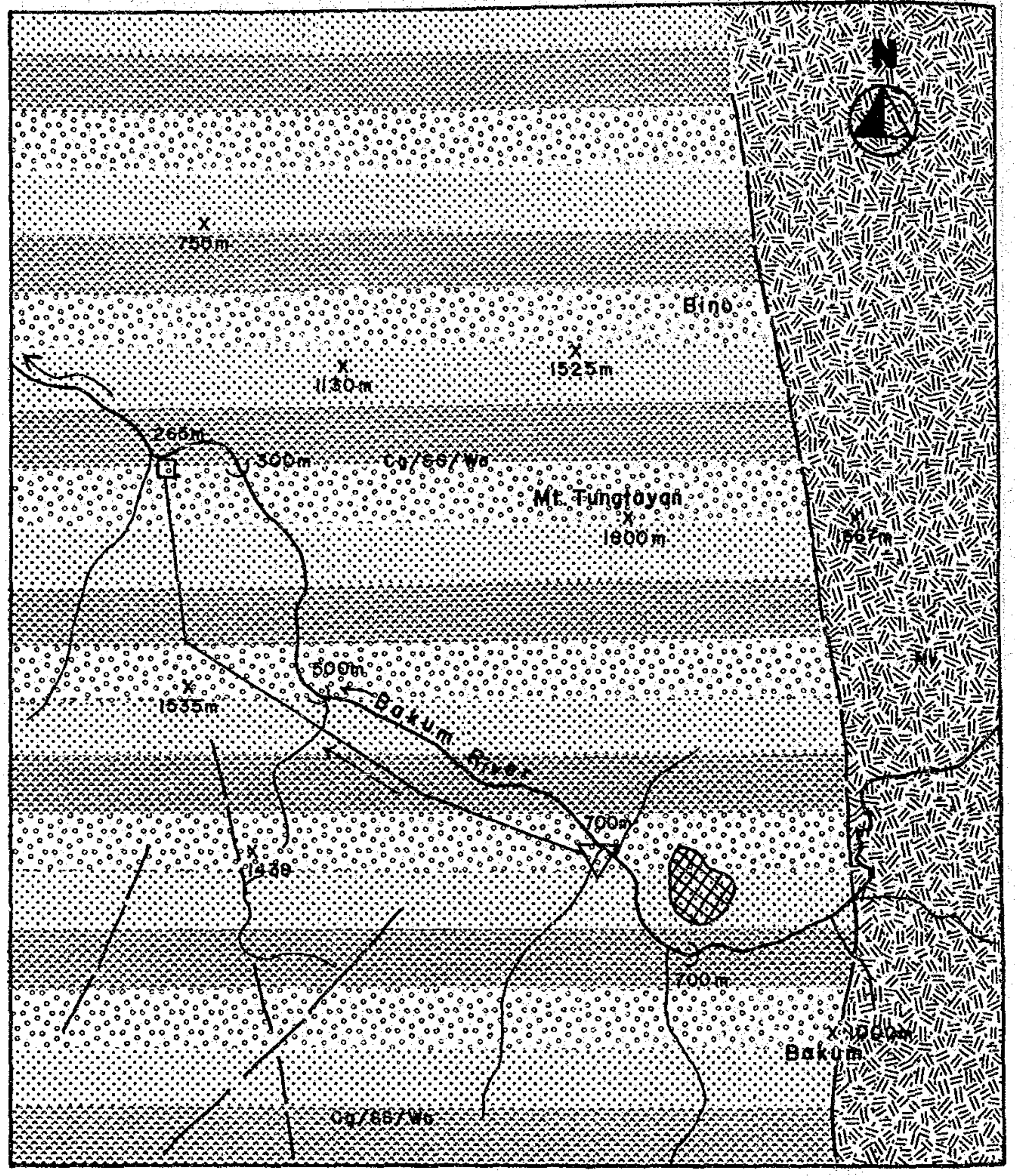


Fig. **GEOLOGIC MAP OF BAKUM SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Benguet Province in scale of 1:250,000 (B M G Nov. 1974)

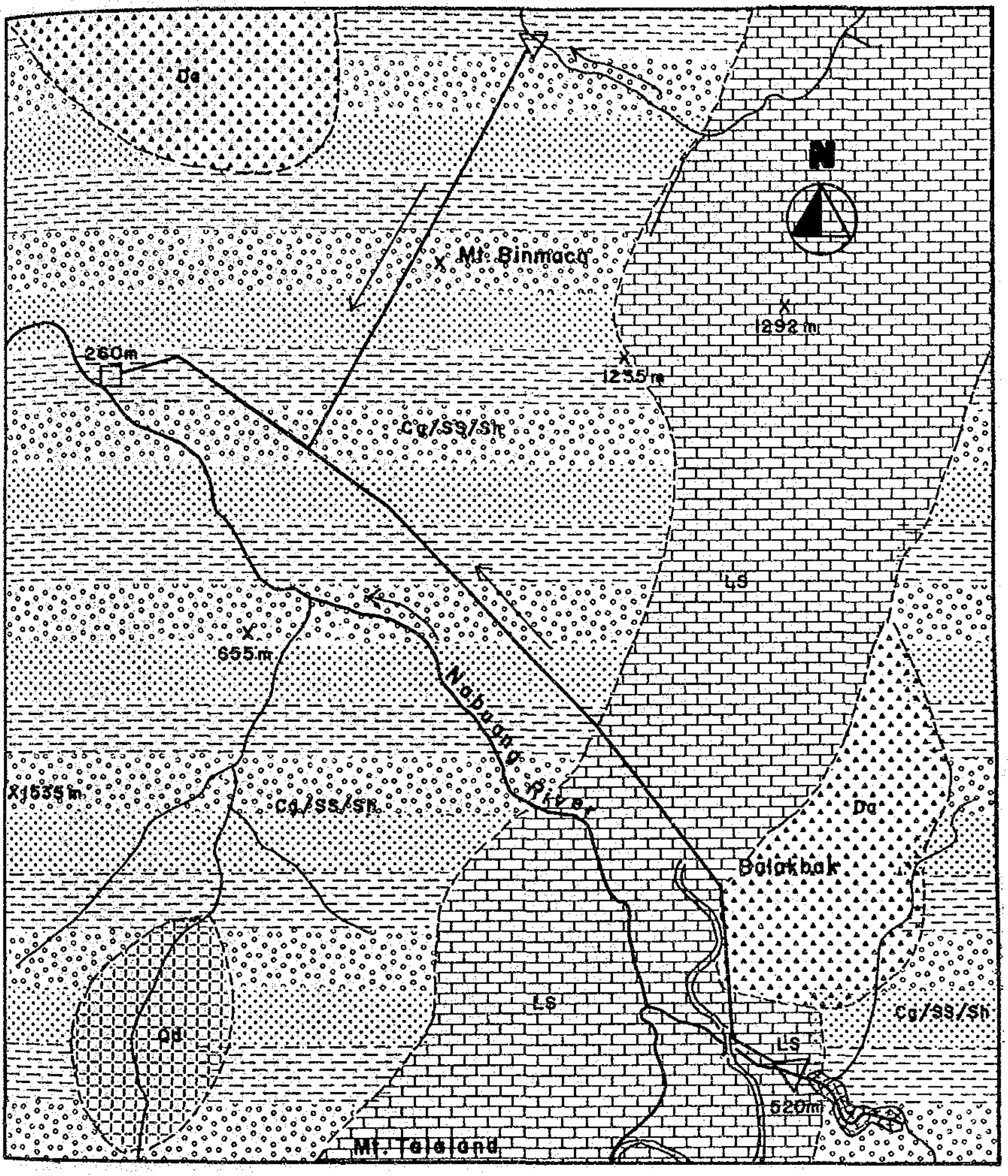


Fig. **GEOLOGIC MAP OF AMBURAYAN SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Benguet Province in scale 1:250,000 (B M G Nov. 1974)

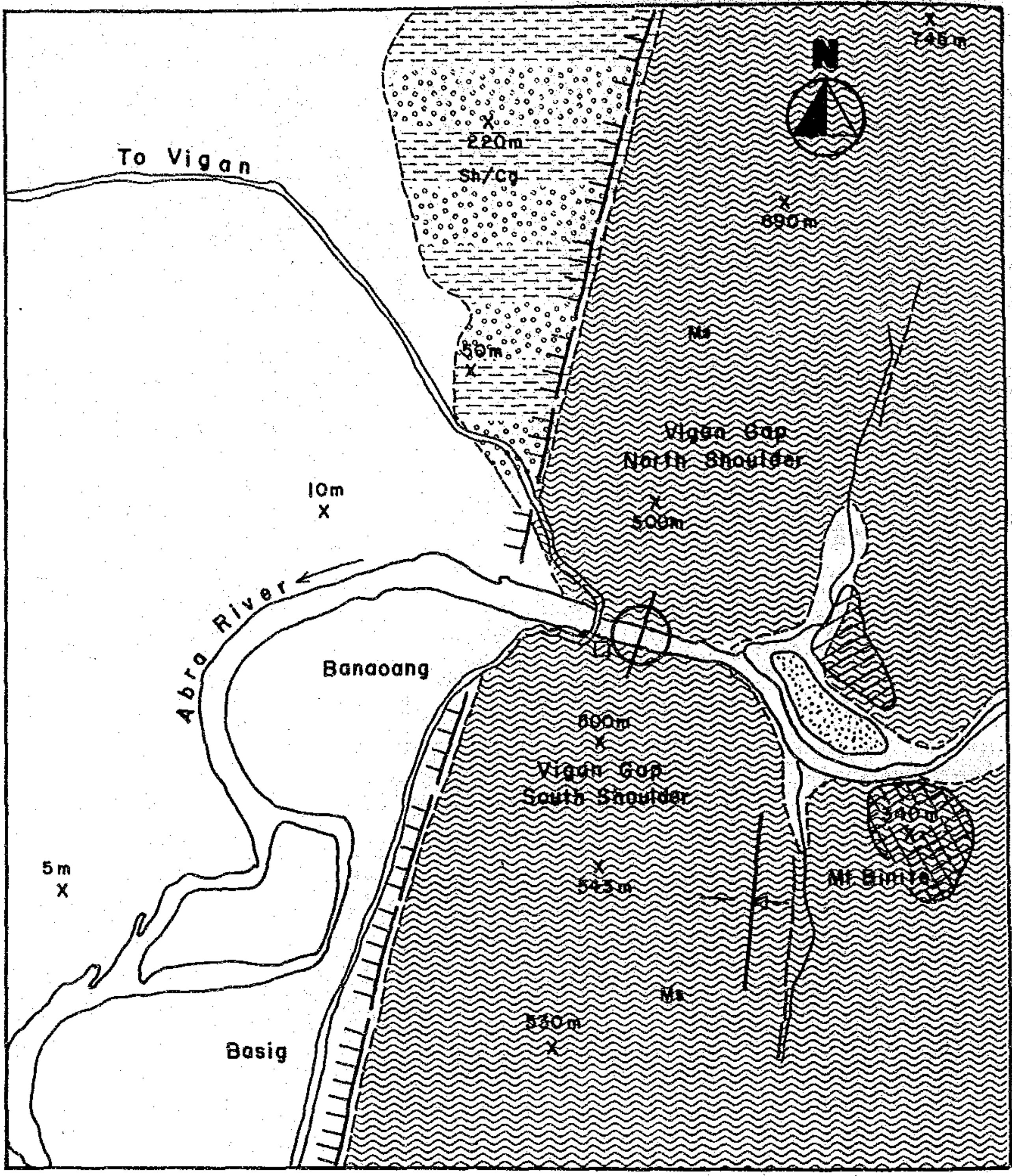


Fig. GEOLOGIC MAP OF BANAOANG SCHEME

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of the Philippines scale of 1:1,000,000 (BMG 1962)

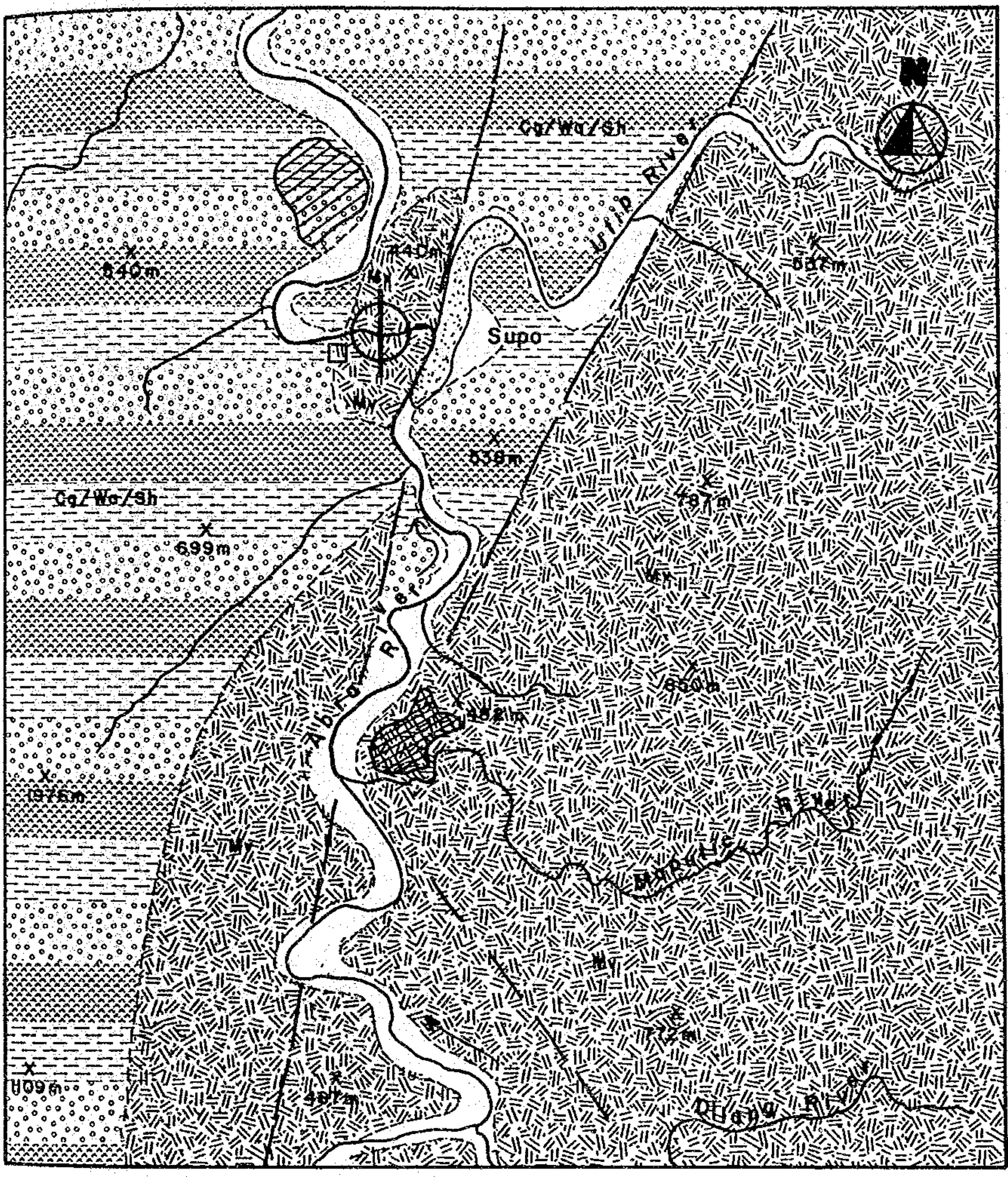
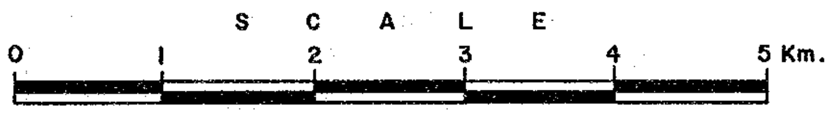


Fig. **GEOLOGIC MAP OF SUPO SCHEME**



Geologic map is adapted from geological map of Ilocos Sur Province in scale of 1:250,000 (BMG July 1981)

I-22-0-6

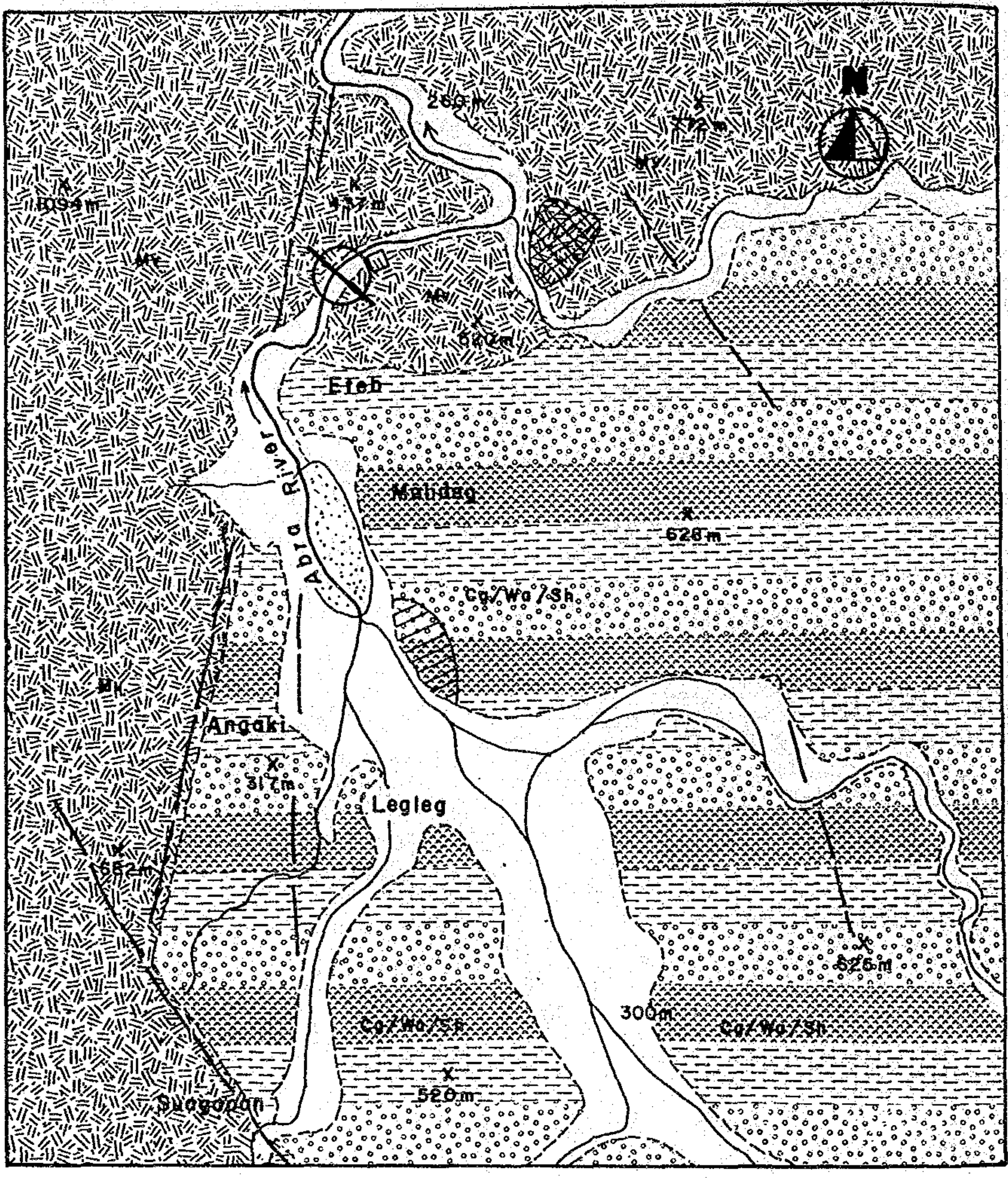


Fig. GEOLOGIC MAP OF ETEB SCHEME

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Ilocos Sur Province in scale of 1:250,000 (BMG July 1981)

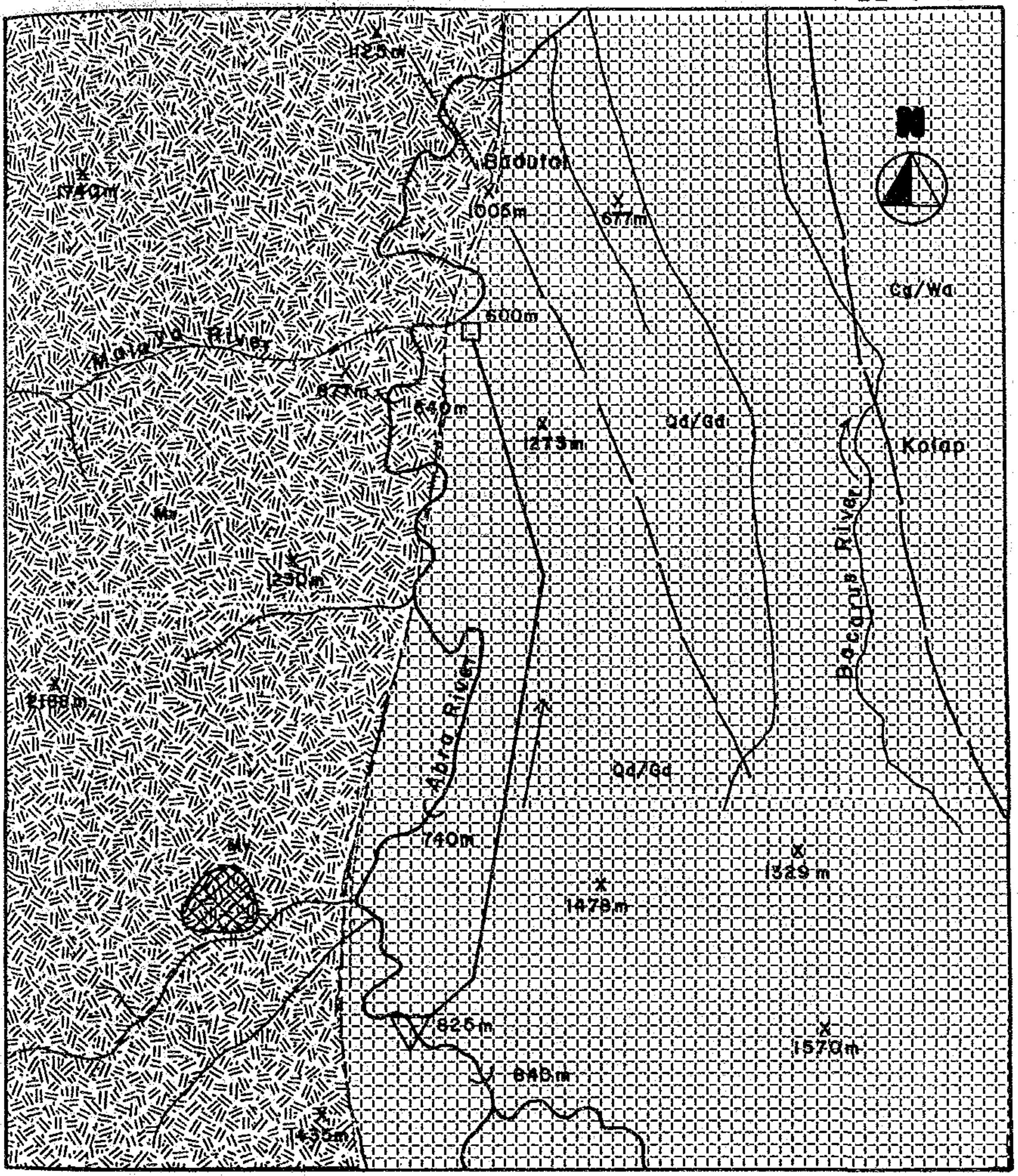


Fig. GEOLOGIC MAP OF ABRA SCHEME

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Benguet Province in scale of 1:250,000 (BMG Nov. 1974)

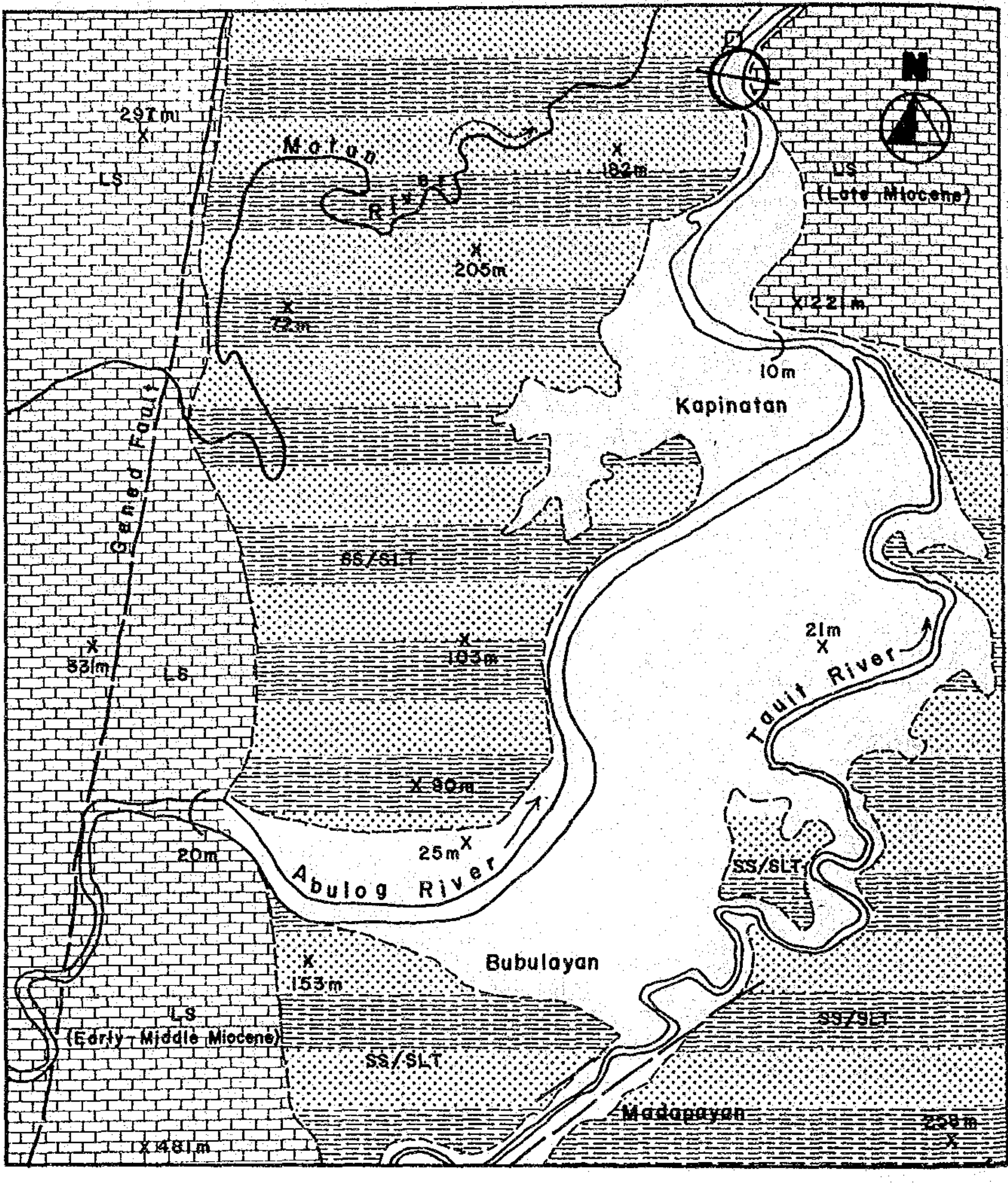


Fig. **GEOLOGIC MAP OF SISIRITAN SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Gened damsite and reservoir area in scale of 1:60,000 (NPC-NEWJEC Aug.1979)

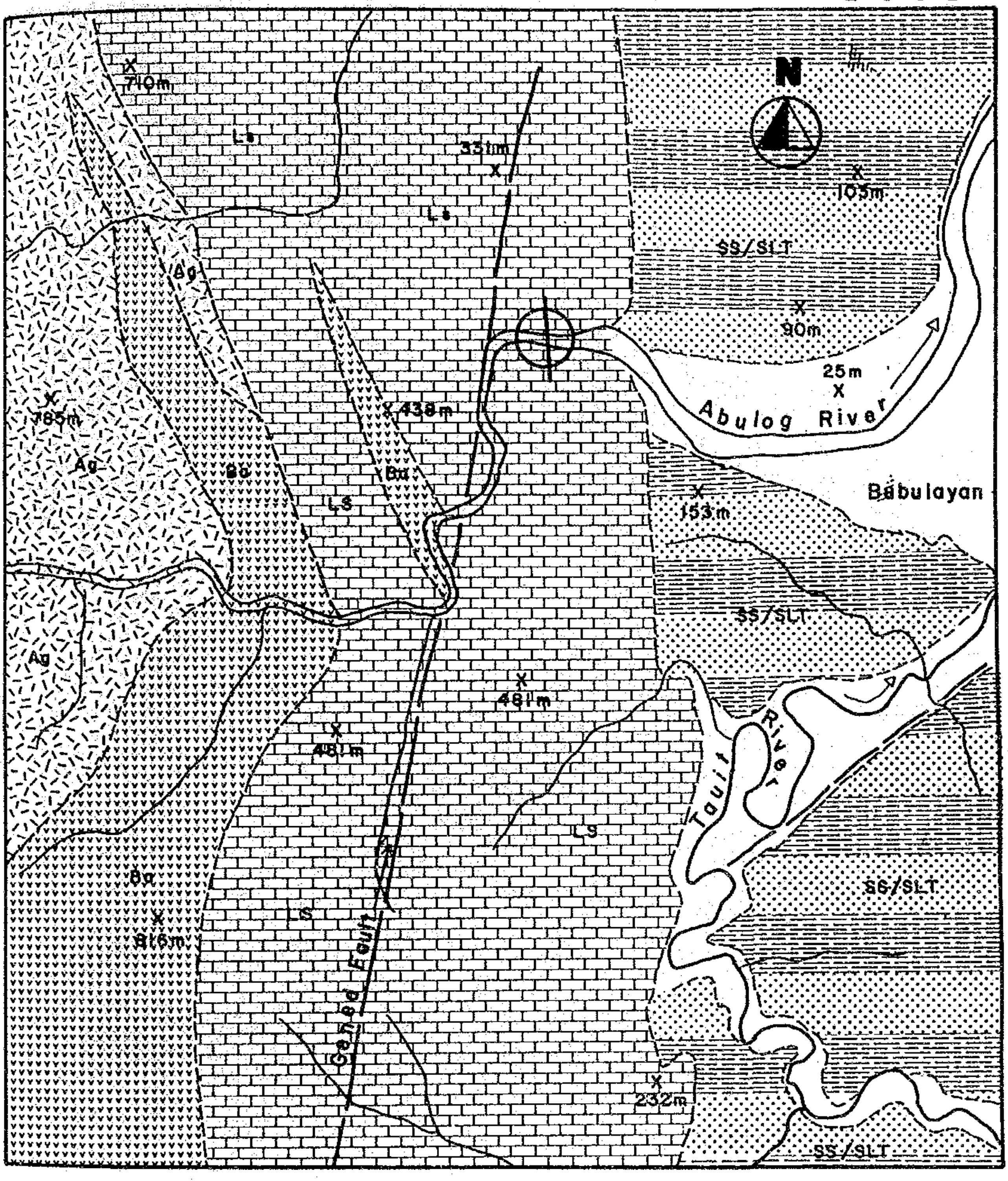


Fig. **GEOLOGIC MAP OF BUBULAYAN SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Gened damsite and reservoir area in scale of 1:60,000 (NPC – NEWJEC Aug. 1979)

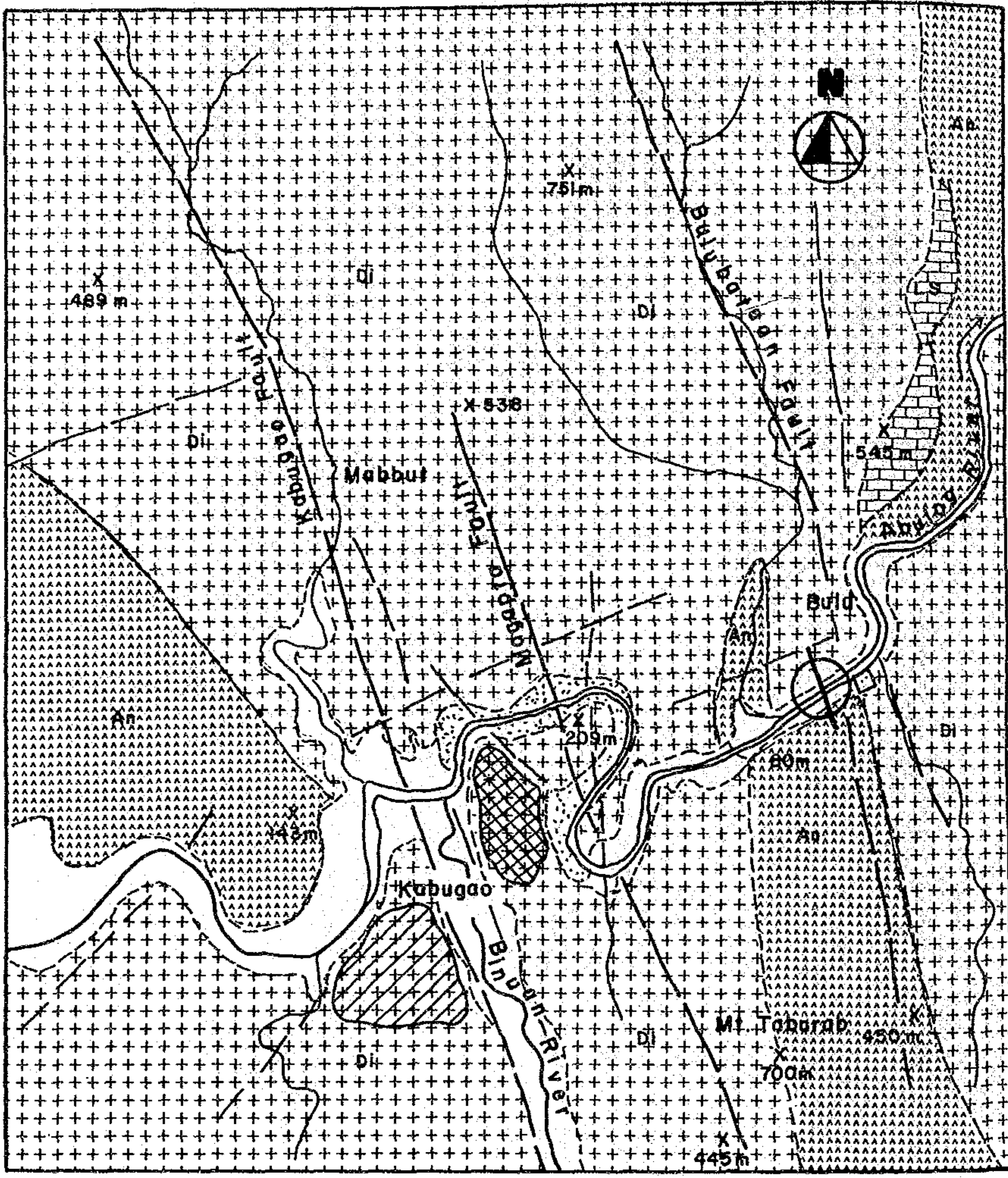


Fig. **GEOLOGIC MAP OF BULU SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Gened damsite and reservoir area in scale of 1 : 60,000 (NPC - NEWJEC Aug. 1978)

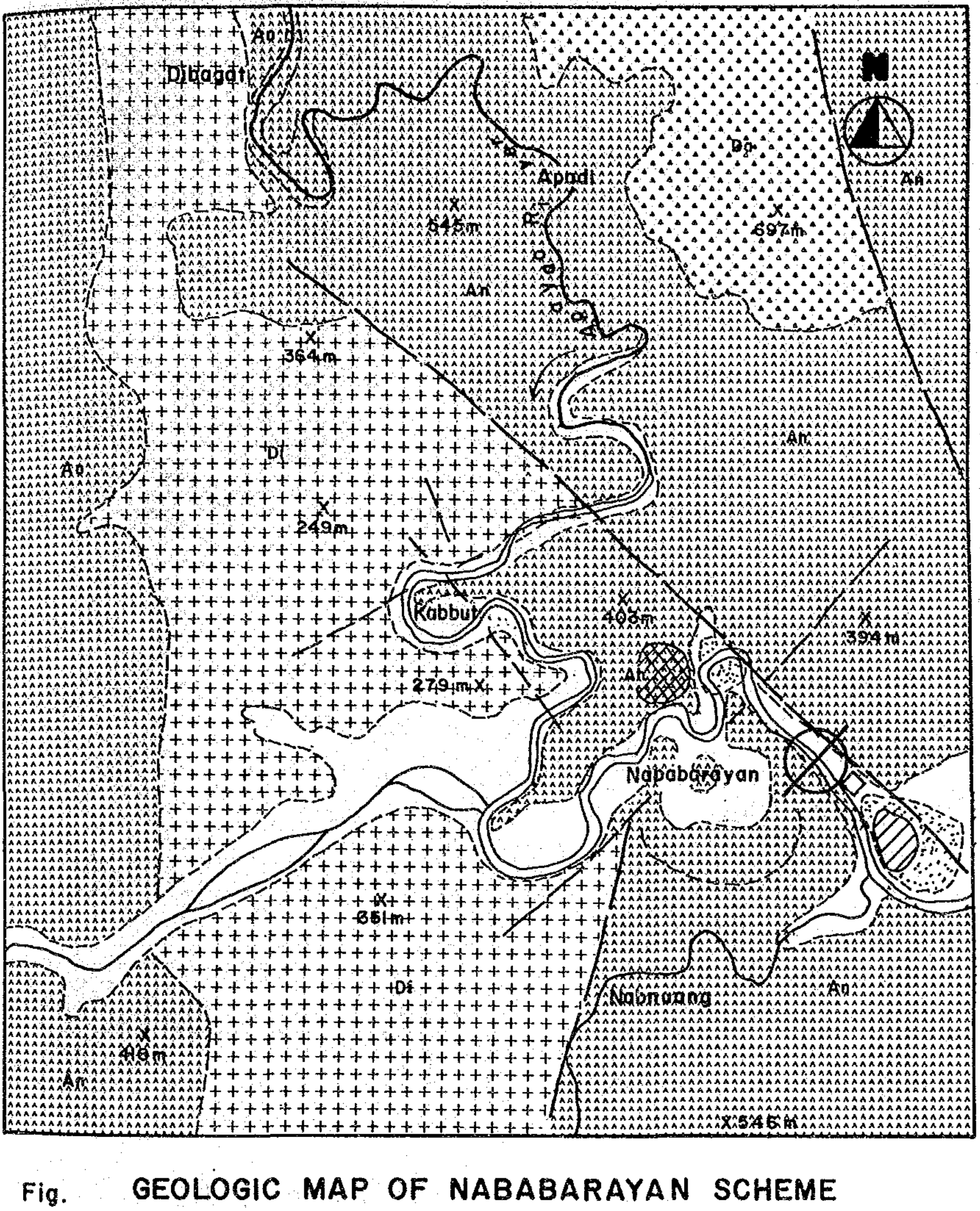


Fig. GEOLOGIC MAP OF NABABARAYAN SCHEME

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from North-Western Luzon geological map in scale of 1:250,000 (JICA-MMJA 1981)

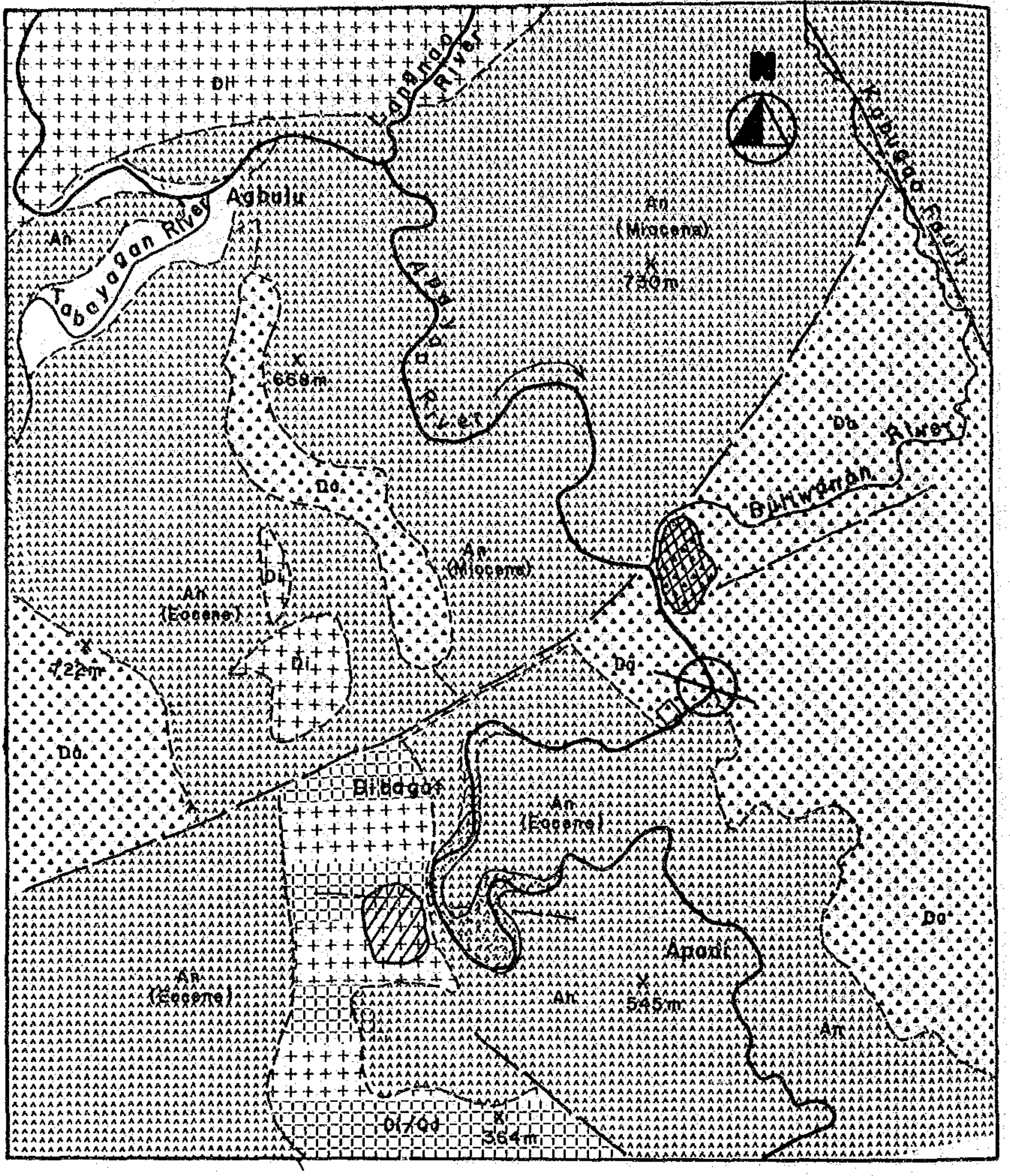


Fig. **GEOLOGIC MAP OF DIBAGAT SCHEME**

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from North-Western Luzon geological map in scale of 1:250,000 (JICA-MMJA 1981)

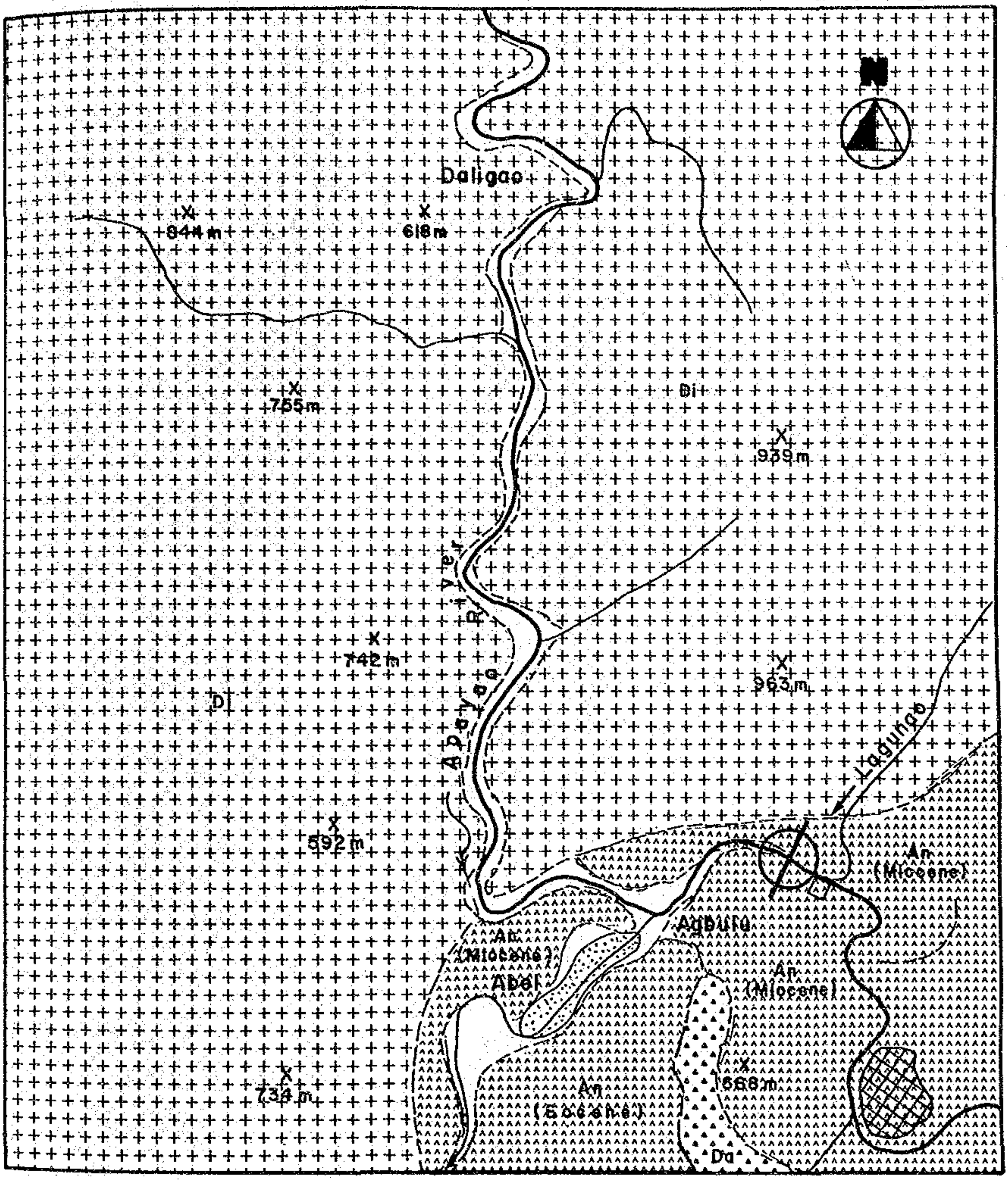


Fig. GEOLOGIC MAP OF AGBULU SCHEME

SCALE

0 1 2 3 4 5 Km.

Geologic map is adopted from geological map of Gened damsite site and reservoir area in scale of 1:60,000 (NPC-NEWJEC) and North-Western Luzon geological map in scale of 1:250,000 (JICA-MMAJ 1981)

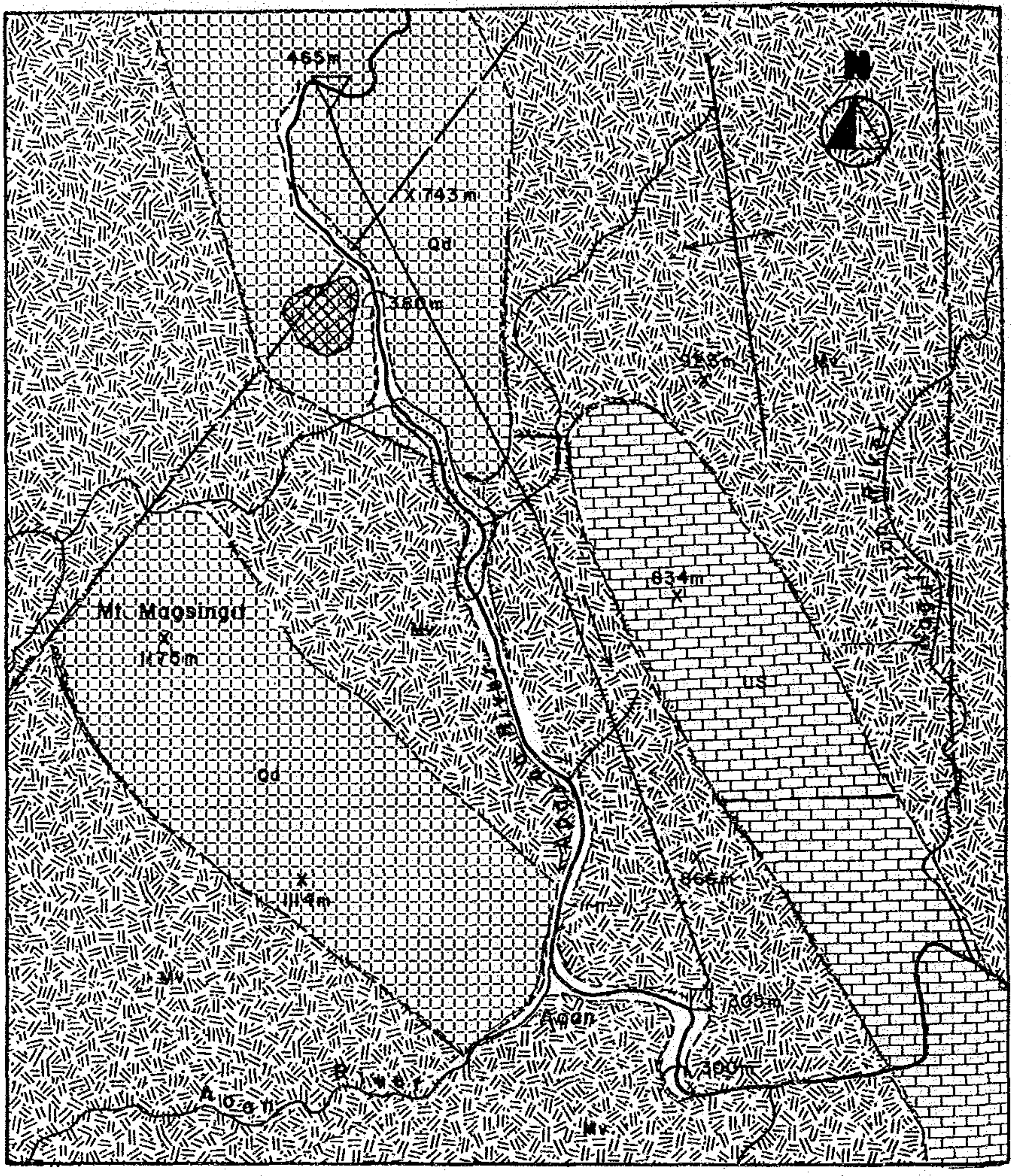


Fig. GEOLOGIC MAP OF APAYAO SCHEME

S C A L E

0 1 2 3 4 5 Km.

Geologic map is adapted from geological map of Kalinga—Apayao in scale of 1:250,000 (BMG 1974)