Chapter 3 Geological Environment

3-1 Geology of Honduras (Refer to Fig. 2)

The Republic of Honduras is located geologically at the intersection of two tectonic lines; one is the line trending E-W or NE-SW from south Mexico to West Indies through Guatemala and the other is NW-SE tectonic line running along Nicaragua - Costa Rica - Panama. In Guatemala, stratigraphical zonal arrangement is obvious, with the trend of E-W in the main part or NE-SW toward the eastern part, that the older formations are distributed in the south and Tertiary system is in the north.

The geology of the Republic of Honduras is composed of three tectonic blocks. The block of Sierra of Northern Central America extending to the territory of Guatemala where geological trends of NW-SE and E-W are entangled though in the east NE-SW trend is predominant toward the border of Nicaragua. Along the coast of the Pacific Ocean, there is a Quaternary volcanic region extending NW-SE, forming the second tectonic block of Pacific Volcanic Chain. The third tectonic block, Volcanic Range and Plateau, occupies the area between the first and the second tectonic blocks, where mainly Tertiary volcanic rocks are distributed. Tectonic Unit in Sierra of Northern Central America is composed of Paleozoic metamorphic rocks, Mesozoic sedimentary rocks and igneous rocks intruding them.

3-1-1 Paleozoic Group

The basement of the land of the Republic of Honduras is Paleozoic metamorphic rocks. The Paleozoic Formation are mainly consist of metamorphic rocks, comprising sericite schist, bedded graphite schist, quartzite etc., which are grouped into two formations. Peten Formation in the upper part is composed of meta-sedimentary rocks with insertions of metavolcanics of various grade of metamorphism, and the Cacaguapa Formation in the lower part

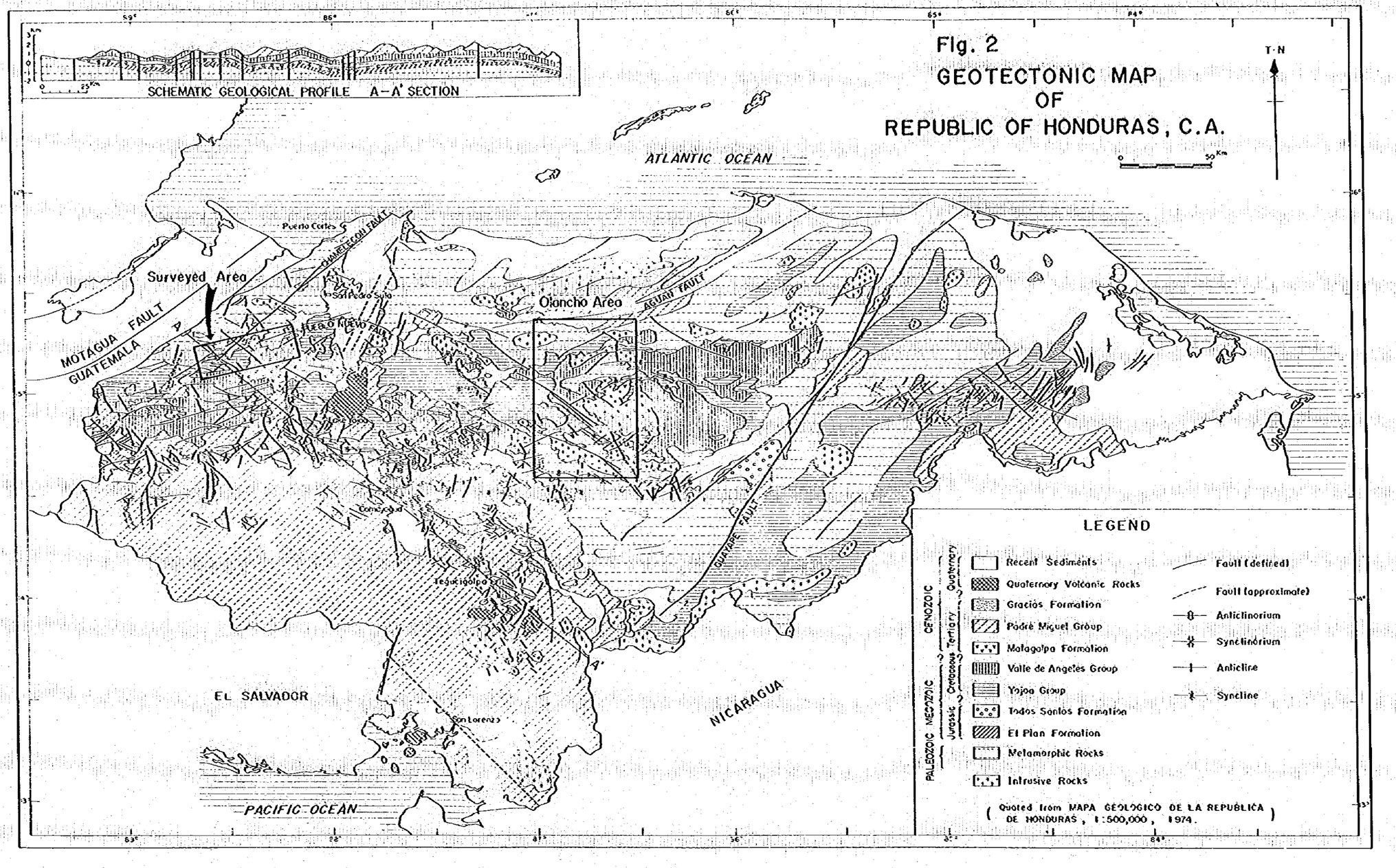


Fig. 2
GEOTECTONIC MAP
OF
REPUBLIC OF HONDURAS, C.A.
T-N
0 50 Km
SCHEMATIC GEOLOGICAL PROFILE A–A' SECTION
ATLANTIC OCEAN
Puerto Cortés
CHAMELECON FAULT
Surveyed Area
San Pedro Sula
Olancho Area
AGUAN FAULT
MOTAGUA FAULT
GUATEMALA
Tegucigalpa
GUAYAPE FAULT
EL SALVADOR
NICARAGUA
San Lorenzo
PACIFIC OCEAN
LEGEND
CENOZOIC
PALEOZOIC MESOZOIC
Quaternary
Tertiary
Cretaceous
Jurassic
Recent Sediments
Quaternary Volcanic Rocks
Gracios Formation
Padre Miguel Group
Matagalpa Formation
Valle de Angeles Group
Yojoa Group
Todos Santos Formation
El Plan Formation
Metamorphic Rocks
Intrusive Rocks
Fault (defined)
Fault (approximate)
Anticlinorium
Synclinorium
Anticline
Syncline
(Quoted from MAPA GEOLOGICO DE LA REPUBLICA DE HONDURAS, 1:500,000, 1974.)

is of mylonitized granite, chlorite schist, sericite schist, marble, phyllite and gneisses.

William et al (1969) stated that the geological basement of the Republic of Honduras consists of Paleozoic mica schists, phyllites and quartzites, associated with meta-volcanic rocks and ultramafic rocks in the northern part, and that the plutonic rocks in the central Honduras is thought to be at the stage of Laramide, with older ones in the northern side, showing general trend of the ages of Plutonic rocks older toward the north.

Irving (1957) described that the metamorphic rocks distributed in the Republic of Honduras are said to be pre-Permian, though metamorphic grades are variable locally, which probably ranged a long period of time for metamorphism, since it runs from pre-Cambrian to late Paleozoic at the youngest.

The Paleozoic formations develop east-west in the northern part of the country, extended in E-W direction from the border of Guatemala, and they are continuous mostly to Cretaceous Yojoa Group, partly to Valle de Angeles Formation and to Tertiary Matagalpa Formation. Paleozoic Group has been intruded by plutonic rocks of Cretaceous or Tertiary age. The Paleozoic formations occupy main part of the north and east Honduras and is also distributed sporadically in mozaic pattern in the south and the lowland occupied by Tertiary volcanic rocks. Around Comayagua in the southern part of the survey area, Paleozoic formations are seen surrounded by Jurassic formation, Cretaceous Yojoa Group and Valle de Angeles Formation.

3-1-2 Mesozoic Group

A) Triassic System

The beds of Triassic system called El Plan Formation comprise dark grey slate and shale, with siltstone and insertions of fine to medium grained sandstones. Medium to coarse grained poorly bedded sandstone has thin layers of bedded mudstones. Lenses of conglomerate with pebbles and

cobbles as well as marl beds are occasionally included. In the lower part there is shale bed with plant fossils. The distribution of this Triassic System is limited in small areas as near San Fernando along the border with Guatemala, at the southwestern margin of San Juan de Flores, and in the mining area of Rosario mine.

B) Jurassic System

The Jurassic system shows characteristically red color. It is called Todos Santos Formation, which is composed of alternation of conglomerate, quartz schist, mudstone, shale and volcanic rocks. Quartzite and conglomerate contains clastic fragments of metamorphic rocks. The formation does not cover broad area, but is distributed in the southeastern part of the survey area, in the Minas de Oro, in the Comayagua area and along the east-side of eastern Juticalpa, respectively neighbouring to the Paleozoic formations.

C) Lower Cretaceous System

Yojoa Group is divided into four formations of, in the order from the lower to the upper, Cantarranas, Ilama, Atima and Guare. They are composed, though two beds of red pyroclastic rocks are included, mainly of marine limestone members---well-bedded thick limestone, shale, calcareous shale, marl, dolomite, calcareous rock and calcareous conglomerate. The formation is in contact with Paleozoic formations along their south side, which extend east-west from Guatemala, bounded by the fault and is distributed widely in the area between Tertiary volcanic rocks and the Paleozoic Group. Also in the eastern part of the country, the formation is distributed widely after the Paleozoic formation with E-W or NE-SW trending. In the survey area, the formation is seen distributed in the central part and around the lake Yojoa.

D) Upper Cretaceous System

The lower part of the Valle de Angeles Formation consists of homogeneous red beds, composed of mudstone, shale, sandstone quartz-conglomerate and limestone, colored in various shades of red, yellow, grey or light brown. The thickness varies from thin layered shale to massive quartz conglomerate. The conglomerate contains fragments of schist, phyllite and quartzite. In the western part of this country, the formation develops east and west between Yojoa Group and Tertiary volcanic rocks, and in the eastern part between Yojoa Group and Paleozoic Group. The distribution of the formation is in the areas of Proteccion, San Jose de Colinas, San Centenario, Naranjito and Dolores. The boundary between this formation and Yojoa Group is usually with unconformity but occasionally by faults --- especially in the area extending north-south through Santa Barbara, the formation is bounded by N-S fault to Yojoa Group and Tertiary volcanic rocks. Esquias formation is contained in the upper part of the Valle de Angeles Formation. It is composed of bedded limestones, hard calcareous shale, fossil-bearing calcareous rock and marl, partly with insertions of shale, sandstone and limestone breccias. The formation is distributed only locally from Santa Barbara to the south of the lake Yojoa.

3-1-3 Tertiary Volcanic Rocks

A) Matagalpa Formation is mainly composed of Oligocene to Miocene basalt, andesite lava and their pyroclastic rocks, and distributed in the area of 50 km by 30 km around Trinidad to Ulua River in the east. Also scattered distributions are recognized around El Rosario and in the west of Tegucigalpa. The formation covers Valle de Angeles Formation and older formations.

B) Padre Miguel Formation is consitituted by volcanic rocks such as welded tuffs, pyroclastic rocks of rhyolite to andesite series, sedimentary rocks of materials of volcanic origin and lava flows of rhyolite, andesite

and basalt. The formation contains some beds hard to distinguish from Matagalpa Formation. Most of the southern part of the country is occupied by this formation. The distribution of this formation is seen extending north-south around Santa Barbara. The formation develops around Olanchica and in La Mosquitia in the eastern part of the country, and composes part of present mountain. Other than the above, there is Pliocene Gracias Formation as Tertiary Terrestrial sedimentary beds, composed of accumulations in graben and partly shallow marine sediments as brown shale, sandstone and conglomerate. Other than those seen extending north and south near Santa Barbara, the formation is distributed around Gracias in N-S trend, and also several distributions in the easternmost of the country are recorded.

3-1-4 Quaternary Volcanic Rocks

As Quaternary volcanic rocks, there are sheets and lava flows of basalt, andesite (olivine-bearing) and their pyroclastics. The distribution is fairly limited, as in the south end of the graben structure in the north of the lake Yojoa, scatteringly in near Amapala in the Fonseca Bay.

Quaternary Sediments

Terrace deposits, talus deposits and other sediments, composed of pebbles, sands, clay etc., are widely distributed in the lowland of Caribbean Sea side and in the vicinity of Amapala of the Pacific Ocean side. Other than the above, extensive deposits of sands and pebbles are seen along Ulua River, in the downstream of Chamelecon River, in the downstream of Choluteca River, in the downstream of Palla Aguan River and near Juticalpa.

3-1-5 Geological Structure

There are two largest tectonic lines controlling the geology of this country, trending NE-SW separated with interval of 300 km east and west. The fault line in the west is called Motagua Fault, running about 20 km off the border in Guatemala almost parallel to the borderline.

The Motagua Fault is the most important tectonic line giving influence to the geological structure of the Caribbean Islands in the north-east of the Republic of Honduras. Chamelecon fault, running about 20 km off the border to the Honduras side, parallel to the border line, is a branch from Motagua Fault. It extends into the survey area, where many other faults disturb the continuation and make it hard to trace the fault line on the surface.

The other main tectonic line, located in the east, is called Guayape fault, which runs along the Paulaya River, and the Guayape River which is the upstream of the Patuca River and also along the gorge of the Guayambre River. The strike of this fault is NE-SW. As is the case with Motagua fault, it is by the drag of this fault dislocating the westside toward southwest that the folding axes of E-W trending strata are bent northeastward. That is, the area between these two parallel faults trending NE-SW, the general trend and the distributional rearrangement of stratas show wavy curve along which the western wing goes southwestward and the eastern part runs northeasterly. The extreme jutting point to the north of the curve corresponds nearly to San Pedro Sula. The survey area occupies bending part in its southwest, but, reflecting the change of its strike of the Motagua fault to the west, general trend of the formations in the southwest part of the survey area is turned to E-W.

General geological constitution of the Republic of Honduras can be said as this; Paleozoic formations composed principally of metamorphic rocks are distributed in the north zone, Mesozoic formations mainly of limestone, sandstone and shale are in the central zone and Tertiary formations of pyroclastic rocks are southerly at the Pacific Ocean side. The survey area is situated in the north to central zone in the west part of the Republic of Honduras, and consequently Paleozoic metamorphic rock are

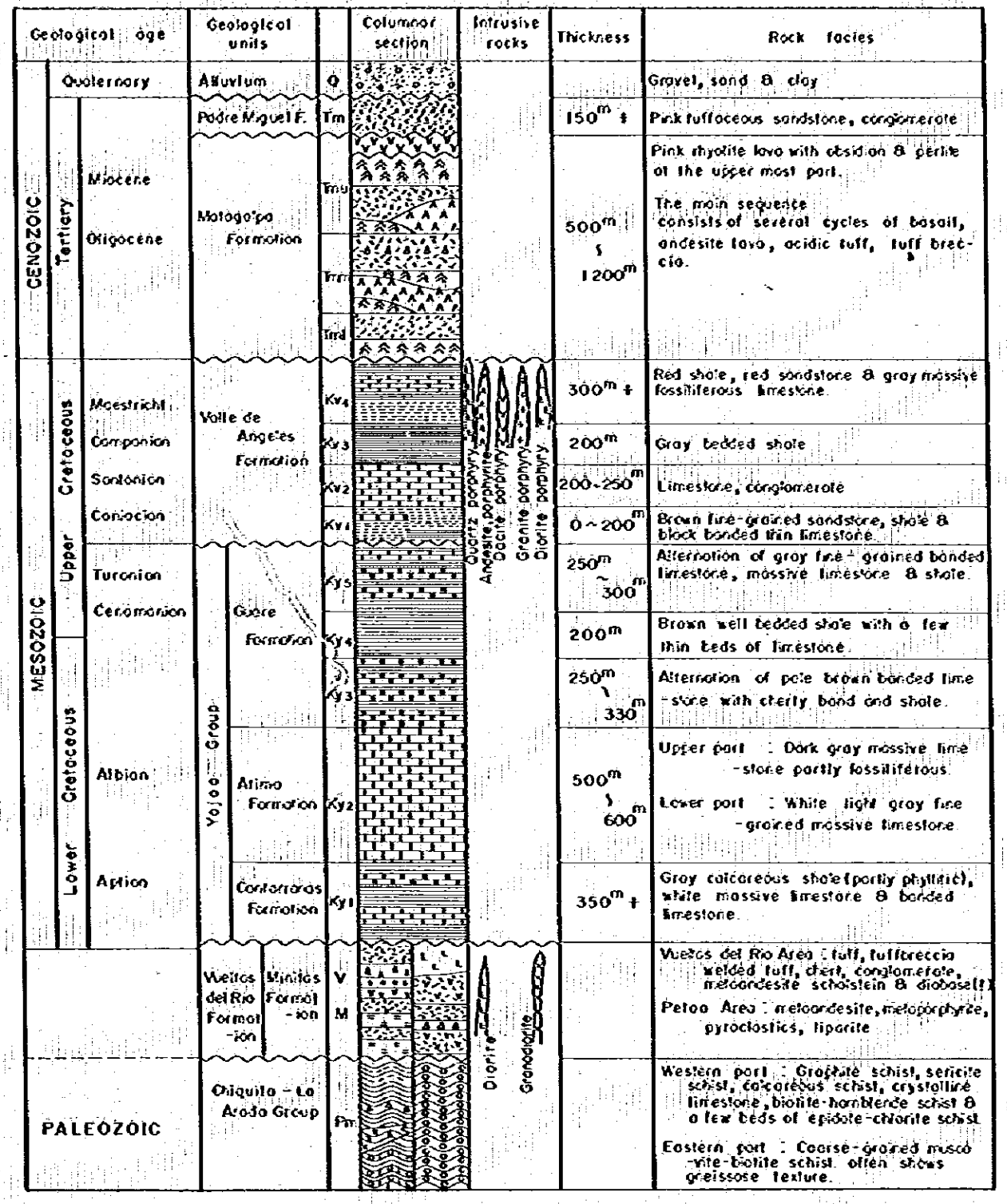
in contact with Mesozoic formations bounded by faults. The south-eastern part of the area is covered with Tertiary pyroclastic rocks locally distributed only in this area. As the fault or tectonic lines found in the country other than Motagua, Chamelecon and Guayape faults trending NE-SW, those of NW-SE system are paired with the above Fault, developing as well as E-W and N-S faults. The boundary fault, Pueblo Nuevo Fault, between Paleozoic metamorphic rocks and Mesozoic formations is one of the E-W trending faults. The N-S trending faults have a role to form graben structure represented by Comayagua basin or Yojoa lake.

3-2 Outline of Geology (Refer to Fig. 3, PL. I-1, I-2, I-3)

The survey area belongs to a structural block called Sierra of Northern Central America and is composed of Paleozoic sedimentary rocks, Mesozoic sedimentary rocks and volcanic rocks intruding them except for the estern half and the southern part where Tertiary volcanic rocks prevail.

The geology of the survey area has been studied by Roberts and Irving (1957), Mills, Hugh, Peray & Swolfs (1967) and Williams, Birney & Aoki (1969), added by UN (1974). The names of the formations or beddings in the survey area in this report are named mostly after Mills et al. (1967) or in some cases temporarily after the village names where certain rocks are recognized outcropping typically. Weather condition and thick vegetation leaving very poor exposures on the surface, in addition to deep weathering, it is quite hard to identify textural features of rocks and to confirm relations of the respective formations. The survey area corresponds to Area II and a part of Area III of the stratigraphical blocks by Mills et al. (1967), and it can be said roughly that Paleozoic Group is distributed in the north of Chamelecon River while Mesozoic Cretaceous formations are in the south. From north to south, the stratigraphical succession is in the order of their

Fig. 3 SCHEMATIC GEOLOGICAL COLUMN OF THE SURVEYED AREA



ages from Paleozoic formations. In the eastern part of the survey area, Tertiary volcanic rocks are distributed. The Paleozoic formations are composed of crystalline schists originated from pelitic or partly psamitic sedimentary rock, those of basic volcanic rock origin and also those of limestone origin.

The area where crystalline schists are distributed is divided into three areas according to rock facies; the western area in the west of la Flecha, the central area near San Francisco del Valle and the eastern area to the east of the above. This formation is named Chiquila-La Arade Formation in this report temporarily, after the name of the village where the formation is distributed typically.

The western area is underlain mainly by sericite-graphite schist rich in graphite, and sericite schist, with subordinate crystalline limestone and chlorite schist containing inserted lenses of amphibolitic mica-hornblende schists. They form repetition of anticline and syncline, with partial complicated drag-foldings, of the axes of ENE-WSW and E-W, which shows, as a whole, the structure occupying north wing of an anticlinorium. The central area is thought to be a transitional zone, composed of mica schist and partly gneissose schists with less amount of limestone layers. Complicated foldings are repeated with axes of east and west. In the eastern area, metamorphic degree is thought to be higher than that of the western area, as this comprises mainly two-mica schists and migmatite bearing quartz lenses, which includes gneissose parts. They form synclinal structure of the axes of E-W or WNW-ESE. In each area, near the contact with Mesozoic formation, E-W trend with south dip predominates in the Paleozoic formations, notably fractured. Weathering has brought topography of gentle undulations except for the area occupied by limestones. The distribution of Mesozoic formations also forms a succession in the order of their age from north to south, as

follows; Vueltas del Rio Formation and Minitas Formation, Cantarranas Formation, Atima Formation, Guare Formation and, to their south, Valle de Angeles Formation.

Vueltas del Rio Formation is composed of metamorphosed volcanic rocks and pyroclastic rock include partly with phyllite insertions and diabase, distributed in the Vueltas del Rio area. The formation is contacted with another Formation by fault, and it comprises shallow-water sediments of meta-volcanics, it is differ with El Plan Formation, so it is correlated the underterminated stage, though separated from other formations with faults.

Minitas Formation is distributed in the Minitas area, and consist of meta-pyroclastics as well as Vueltas del Rio Formation, and so correlate with Vueltas del Rio Formation. Cantarranas Formation is constituted with calcareous shale, massive limestone and banded limestone, and its distribution is near Zapotal, from the east of Chumbagua to Potrerrillos. Alternations of quartzite and black shale found in a small area about 3 km southeast of La Arada is correlated to this formation by the rock facies.

In the south of the area where above formations are distributed, sedimentary rocks mainly of limestones develop in east and west. They are correlated to Yojoa Group based on the evidences of fossils and rock facies, and divided into four blocks as the Atima Formation, lower, middle and upper part of Guare Formation distributed in this succession from north to south. In detail, Atima Formation is composed of fine-grained massive limestones and dark grey massive limestones, with certain thickness. The lower part of Guare Formation comprises pale greenish brown bedded limestones with thin chert and shale layers. The middle part of Guare Formation is composed of brown bedded shales with thin layers of limestone and the upper part of Guare Formation comprises marine sediments composed of fine-grained bedded limestone, massive limestone and shale. The thickness of each part of Guare

Formation is about 200 to 600 meters. The beds distributed east and west in the south of the area occupied by this formation are correlated to Valle de Angeles Formation (Upper Cretaceous), as they are composed, from lower part to upper, of shallow-water sediments, characteristically colored in red, of alternation of brown fine-grained sandstone and shale, limestone-conglomerate, grey bedded shale, red shale and sandstone bed with occasional limestone. The thickness is about 200 meters and their sedimentation is conformable. The Paleozoic and the Mesozoic formations are bounded by a overthrust (Pueblo Nuevo Fault) trending east and west, along which Vueltas del Rio Formation, Cantarranas Formation, Atima Formation, lower Guare Formation and partly crystalline schists are intruded by intermediate to basic dykes of diabase, andesite, dolerite and by plutonic or hypabyssal intermediate to acidic dykes and stocks of diorite and quartz-diorite porphyries etc. They have affected contact metamorphism and fracturation the wall rocks.

In the eastern part of the survey area, volcanic rocks are widely distributed covering the above formations. The volcanic rocks are divided into lower, middle and upper parts, thickness of which is over 500 meters respectively, and are correlated to Tertiary Matagalpa Formation. They are composed of basalt, andesite, their pyroclastics, acidic tuffs and rhyolite, and they occupy main part of the eastern mountainous land. At the southwest corner of the survey area, a group of sedimentary beds is found in a small area, which is composed of tuffaceous sandstone and conglomerate. This is correlated to Padre Miguel Formation by rock facies and stratigraphical succession.

3-2-1 Paleozoic Formation

The distribution of Paleozoic formations is ; in the western area, in the north side of a line linking villages of La Libertad ----- Chamelecon;

in the central area, in the northern side of a line 3 km south of Chumbagua and San Marcos; and in the eastern area in the northern side of a line typing La Arada and about 2 km south of San Francisco del Valles.

The rocks of Paleozoic formations are classified as follows, for efficient mapping and considering frequency of appearance.

A) Sericite schists (sericite schist, sericite-chlorite schist, sandy schist).

B) Graphite schists

C) Biotite-muscovite schists (biotite-muscovite schist, gneissose schist, migmatite).

Apart from the above, as some lenticle beds limestones (recrystallized limestone, calcareous schist) and biotite-hornblende-quartz schists (of the amphibolitic composition) have been classified too.

A) Sericite Schists

The sericite schists generally contain chlorite. Between green chlorite schist and reddish-brown sericite schist there are several stages of rocks of the intermediate composition.

They are abundantly distributed in the whole central to western area. Schistosity due to the alignment of micas develops very well. Banding texture is occasionally seen with grains of quartz and micas separated layer by layer. Usually there are insertions of lenticular white or transparent segregation quartz bed or thin layers of limestone-calcareous schist (thickness 1 to 10 cm, occasionally over 1 meter, with extension of several meters to several deci-meters). Quartzose schist is distributed in the north of Chiquila, but the amount is limited. Partly it is contained in graphite schists. Mineral composition is quartz, feldspar and small amount of sericite with epidote, biotite and calcite. It shows pale greyish brown in color, with poor foliation, but cleavage of 5 to 10 cm interval develop

well. It is thought to have originated from fine-grained sandstone.

B) Graphite Schists

Graphite schists are distributed mainly in the northwestern part of the western area. The boundary between graphite schist and sericite schist is gradual and the transitional zone is composed of lenticular interfingering of the two schists, increasing the quantity of graphite schists toward the west. This schist include sericite schist and sandy schist and are thought to be a product under such sedimentary environment as to accumulate turbidite, absorbing carbonaceous matters. Microscopically the schist contains lenses of magnetite and hematite in addition to quartz, graphite and sericite.

C) Biotite-Muscovite Schists

Biotite-muscovite schists, are distributed in the east of San Francisco del Valles.

Pale green two-mica schist contains quartz, partly as lenticular quartz. The rock is locally composed of migmatite and is argillized to form coarse-grained white minerals around the Pueblo Nuevo Fault in the southern periphery. Under microscope, quartz, plagioclase potash feldspar, mica and biotite are the main constituent minerals. Biotite is often chloritized and sometimes granular or gneissose textures are observed. It is characteristic that limestone insertions are found in less amount. Where lenses of rather basic part containing abundant fine-grained micas, of the thickness about a meter, are included in this rock, foliation continues by-passing the lenses. Usually quartz grains are 4 to 5 mm in diameter and biotite is brownish, 2 to 3 mm. In the easternmost part, aboundant quartz is contained and gneissose texture develops well.

By the study of the chemical composition on the rock collected in the north of La Arada, the origin of this rock is thought to be pelitic rock or greywacke. The age of this rock determined by K-Ar method is 222

± 8 m.y., which corresponds to Permian period.

D) Biotite-Hornblende-Quartz Schists

Lenses of epidote-chlorite schist in pelitic schists, distributed in the north of Sula, in the north of El Rosario and in the south of San Antonio, and biotite-hornblende-quartz schist of the chemical composition of amphibolite distributed in a zone around the area of El Rosario --- San Antonio --- Chiquila, are included in this category. Microscopically, the former is composed of chlorite, epidote and quartz, showing pale green schistose texture, and the latter is white or green coarse-grained rock having poor foliation, with the main constituent minerals of green hornblende, biotite and feldspar. As they are deformed as is the case with pelitic schists seen around, the original rock is thought to be basic sheets intruded concordantly into the bedding before metamorphism.

E) Limestones

Two types are recognized; one is massive and poorly foliated medium to fine-grained crystalline limestone and the other is well-foliated calcareous schist. They are metamorphosed rocks of lenticular or bedded limestones included in pelitic schists. The degree of resistance against weathering is as high as to form ridges or steep cliffs. They are found as lenses or layers in pelitic schists in the western area. In the central area they are recognized only locally as thin lenticular layers, while no limestone is seen in the eastern area. The thickness is usually several ten meters and rarely over 200 meters except for swells formed with foldings. Though there is an unusual case in which strike extension traced by outcrops is over 6 km, they from lenticular mass and disappear in several hundred meters. Pelitic schist is grey black and well-foliated with dark colored band composed mainly of graphite, sericite and chlorite, alternated with white band of calcite and less amount of quartz, forming "Partings" of

interval of several centimeters. Crystalline limestone is white or milky white in color, composed of fine-grained calcite, and occurs locally as marble. Poorly foliated but partings of a few to 20 centimeters interval develop well. Graphite is observed sitting along foliations under microscope.

F) Relation to Other Formations

The Paleozoic rocks are in contact with Mesozoic formations by fault. Acidic porphyritic dyke more than 5 meters wide is seen to have intruded the sericite schist at Loma del Mico. By the UN report (1974), mica schist forms alternation with aplite around Loma del Mico and with garnet rich rock near La Libertad. The schists are in contact with tuff of Matagalpa Formation horizontally at the south of San Marcos, and along the Agua Suela road in the east, and also they are found to be covered horizontally with grey tuffs bearing obsidian.

3-2-2 Formation of unknown age

A) Vueltas del Rio Formation

This formation is exposed mainly in the Vueltas del Rio sector, as well as in a belt extending east and west with the width of 1 to 2.5 km in N-S, from Vueltas del Rio sector to Laguna Seca sector. The Vueltas del Rio Formation is composed mainly of basic to acidic andesitic or liparitic pyroclastic rocks with occasional insertions of shale, conglomerate and other volcanic rocks. They have been metamorphosed and schistosity develops well, with fine drag-foldings. Due to heavy alteration by silicification, sericitization and argillization, it is extremely difficult to determine lithologically their original rocks on the surface. Therefore, emphasis has been laid to subdivide this formation as precisely as possible to confirm the structure and the stratigraphy of this formation.

Although, in the last year's survey, fine grained rocks like tuff

with well-developed schistosity in this formation was taken as phyllite while tuff breccia was treated as conglomerate and sandstone, it has been confirmed in this year's survey that the Vueltas del Rio Formation is composed of the sedimentary rocks such as volcanic rocks and pyroclastic rocks after classifying the rocks of the formation into metamorphosed tuff, tuff breccia, in addition to welded tuff, metamorphosed tuff containing quartzite layers, metamorphosed andesite, conglomerate, shale and schalstein. These beds have been intruded by the dykes of diabase, quartz porphyry, dacite porphyry and andesite and in the southern part they are in contact with the shallow water sediments of the Cantarranas Formation and the Atima limestone beds with unconformity or faults.

In the Laguna Seca sector, the distribution of the Vueltas del Rio Formation is small, and the development of schistosity as well as the alteration is rather weak. In the southern part, metamorphosed andesites and metamorphosed andesitic pyroclastic rocks are distributed and in the area further to the south there is the covering of the Atima limestone beds. These metamorphosed andesitic rocks are similar to the members of the Minitas Formation which forms the basement in the Minitas Sector, and therefore it is expected that the chronological relation of the Vueltas del Rio Formation to the Minitas Formation will be ascertained taking the metamorphosed andesites to be key beds.

The Vueltas del Rio Formation is viewing from the facts that it is composed of the sediments derived mainly from volcanic activities and that the development of schistosity is noted, it is thought that they would have been the products of the volcanic activity after the sedimentation of the crystalline schists, prior to the formation of the El Plan Formation, and therefore it would be thought that the period of the sedimentation and the metamorphism would have been around the Permian Period, but further study

will be necessary for the chronological correlation of the formation.

B) Minitas Formation

The Minitas Formation is distributed as the basement over the area including the Minitas sector and the Pueblo Nuevo sector, and is composed of the metamorphosed andesites and their pyroclastic rocks with occasional dioritic porphyrite. In the Minitas sector, the formation is seen intruded extensively by granodiorite, while in the Pueblo Nuevo area liparite is observed to have intruded the formation.

They are overlain by the Atima limestone beds.

The metamorphosed andesite is dark in color, showing porphyritic texture with the phenocrysts of feldspar and chloritized mafic minerals, and the andesites as well as their pyroclastic rocks are partly altered by epidotization, calcitization and argillization in addition to the regional metamorphism and the mylonitization such as chloritization.

Remarkable variation of the lithofacies is characteristic, from fine grained porphyritic facies to coarse grained dioritic facies. The granodiorite is distributed in irregular shape dominantly in the northern side of the Minitas sector, and is seen to have intruded the aforesaid andesite as dykes. As their forms are complicated and no reaction rim has been observed along the margin, the period of the intrusion is thought to have been not later than the formation of the metamorphosed andesites.

C) Formation of unknown age

This formation is distributed in a small area of 1 km by 500 m in the east of Barbarita, at about 3 km to the south of La Arada in the eastern area. This formation consists of quartzite and alternation of quartzite and shale.

Quartzite is composed of creamy white quartz grains of 2-3 mm and contains bandings of hematite-quartz. Shale is reddish brown, partly black.

The trend of this formation is northwest with dip of 40° to the northeast. The formation is surrounded by diorite but their geological relation is not obvious as the outcropping is not sufficient. The southern periphery of this formation covered horizontally with Matagalpa Formation. Based on the chemical composition of the rocks of this formation, it is obviously different from Yojoa Group limestones. The actual relation to Yojoa Group is not certain because of poor outcropping, and therefore no key has been found yet to determine the age. Considering from rock facies, it might be correlated to Cantarranas Formation.

3-2-3 Mesozoic Group

A) Cantarranas Formation of Yojoa Group (Y-1 Formation)

Distribution; The formation is distributed in an area of 1 km^2 in the south of El Zapotal, from the east of Chumbagua to the north of Potrerillos and also in a small area of 200 m by 300 m in the south of San Marcos.

Lithology; The formation comprises mainly alternation of grey thin limestone layers and light grey phyllitic shale, partly including sandstone and in the lower part, it contains milky white massive limestone. Total thickness is over 350 meters. In the area of Chumbagua-Potrerillos, lower part of this formation is composed of milky white massive limestone or light grey fine-grained bedded limestones partly while middle part consists of fine-grained banded slaty calcareous shale and banded limestones of pale greenish brown to greyish grey in color. Upper part is composed of alternation of calcareous black shale and fine-grained bedded pale greenish brown sandstone, or of alternation of thin calcareous shale and banded limestone, though shale excesses in amount. Locally, in the north of Potrerillos, milky white massive limestone predominates.

Structure; The most prevailing structural trend is ENE-WSW or E-W with

north dip.

Relation to other formation; This formation is in contact with Vueltas del Rio Formation and crystalline schists by fault, and also it is bounded to Atima Formation distributed in the south by fault or by the interposition of igneous rock. An outcrop is found near Potrerillos in which the formation is covered with tuffs of the lower part of Matagalpa Formation. The formation is seen intruded by quartz-diorite porphyry near Zapotal.

Correlation; This formation is correlated to Cantarranas Formation defined by Carpenter, on the basis of the rock facies, scare macroscopic fossils and the fact that it is in apparent contact with Atima Formation of Yojoa Group though fault separates this formation from others.

B) Atima Formation of Yojoa Group (Y-2 Formation)

Distribution; This formation is distributed in the area of 16 km (E-W) by 2 to 4 km (N-S) in La Zona -- Agua Helada -- La Cueva -- Rio Blanco in the western part, in the area of 15 km (E-W) by 3 to 10 km (N-S) in El Guanacaste -- Cerro Tabuletas -- Cerro del Ojo de Agua -- Cerro Calichal in the central area, and also in the area of 14 km (E-W) and 8 to 4 km (N-S) from the south of San Francisco del Valles to La Arada in the eastern area. The thickness of this formation is about 500 m in the western area, about 600 m in the central area and over 300 m in the eastern area, where the estimation of thickness is hard as the formation is separated into three blocks by diorites.

Lithology; The formation is composed mainly of grey massive fine-grained limestones. Bedding is rarely recognized, but occasionally rather thick strata of about 2 meters are found and also grey massive chert bed amounted to 10 meters thick is found contained in the formation at a place about 1 km north of El Guanacaste in the western part.

Calcite veins are abundant partly. In the upper part there are occasional dark grey massive fossiliferous beds, which are through to belong to transitional zone to upper Y-3 Formation. Clastic sediments are rare. In the north of Monte Largo, pale brown fine to medium-grained altered sandstone of the thickness of about 10 meters is recognized. Also at around Piletas 4 km east of Chumbagua, two outcrops including thin layers of grey fine-grained sandstone and shale are recognized.

Fossils; By Turrilitaceae Ammonite and stromatoporellina sp. (T-191) collected in limestones at Piletas north of Potrerillos, the age of the formation is determined to be lower Cretaceous, and also by Orbitolina texana found in brownish grey pelitic limestone at Petoa (S224A, S224B), the epoch of the formation is confirmed to be early Albian. The formation is correlated to Atima Formation defined by Mills et al. (1970) by the comparison of the fossils at location 126 and 127 in the eastern part of Trinidad stated by Mills et al. in the western Chamelecon area.

Relation to underlain and overlain formations; The boundary to the crystalline schists, Vueltas del Rio Formation and Cantarranas Formation located north of this formation is fault, but upper Guare Formation is found in several locations to be bounded conformably to this formation. By andesite, diorite and quartz-diorite porphyry, the formation is intruded. Andesite is found to have intruded as sheets in the formation at the south of Laguna Seca. In the eastern part, this formation is separated into three blocks by diorites extending east-west. Around the contact zone, alteration is recognized at several places to form light yellowish grey to white part, with remarkable hardening of the rocks including medium to coarse grained recrystallization partly

with abundant calcite veins. Through the higher resistance to weathering, this formation has contributed to form topographic features of steep hills and sharp cliffs.

Structure; Repetition of gentle syncline and anticline with axes of east-west is notable, with the general succession of the bedding to go upper, southerly. Though rare in the central part, intrusion of igneous rocks are seen extending mainly east and west in the western part. In the eastern part, the intrusion of diorites stretching east and west makes the E-W anticlinorium structure more complicated. Trends of faults are ENE-SWS and NW-SE.

C) Lower Guare Formation (Y-3 Formation)

Alternation of bedded limestone and quartzite forms this formation, which composes Guare Group with Middle Guare Formation composed mainly of shale and Upper Guare Formation of alternation of bedded limestone and shale.

Distribution; The formation is distributed in an area of about 3 km (N-S) by 13 km (E-W) around Las Flores --- La Virtua Alegrias --- El Guanacaste, at the western end of the survey area. Also in the central part, it is found in an area of about 2 to 3 km (N-S) by 12 km (E-W) on a limestone plateau north of San Isidro. The thickness is approximately 300 m in the west and 350 m in the central part.

Lithology; The lower part is alternation of pale greenish brown limestone and dark-colored quartzitic rock, which is composed of banding 1 to 5 cm thickness. The upper part is also alternation of bedded limestone and small amount of shale (with some dark quartzite). In the north of Montana El Limon, a block is seen in which brown sandstone and shale are prevailing.

Fossils; The followings are found in the reddish brown limestone in the west of Montana El Limon; Pollen of Pinus Podocarpus, Quereus,

Cardnoideae, Tricolpopollenites, Insporturopollenites and concentricyses in brackish-water sediments. Spore of Osmundaceae, Monolete Spore and Trilete Spore. There are no microfossils suggesting Cretaceous age among them, but from the above fossils the period of the lowermost Tertiary is indicated. Abundant foraminifera are observed under microscope in a calcareous siltstone located in the south of El Cacao, While there is no megafossils there. Mills et al. (1970) determined the age of this formation to be Albian to Cenomanian by the fossils (Location 39, 40) in limestone 4 km west of San Isidro. This formation is correlated to Lower Guare Formation.

Relation to other formations; The formation is comformable with Atima Formation and Middle Guare Formation --- especially, sudden change is observed from banded limestone to shale rich formation at the northwest of Ruidosa. There are some places where the formation is seen bounded by fault to the upper formations. The formation is observed to be in contact with the Middle Guare Formation conformably at the south of Lagunitas. Andesite is seen to have intruded into this formation as sheets of E-W trend with south dip over 10 meters thick. The andesite sheets are also found in the north of Mata de Platano.

Structure; Extending east and west, the formation is notable by the repetition of syncline and anticline with axes of east-west. At Chiqueros, this formation is bounded to Upper Guare Formation by fault, resulting in the fact that both formations are approximately at the same level across a valley, and also at the northeast of Ruidosa, this formation is seen dislocated horizontally about 100 meters to left-hand side along the fault. Remarkable brecciation is observed in the eastside of this dislocation, with sudden change of the stratigraphical trending.

D) Middle Guare Formation (Y-4 Formation)

Distribution; The formation is distributed in an area of about 2 to 0.5 km (N-S) by 10 km (E-W) near hill-tops around Cerro Copa del Higo -- La Ruidosa -- La Laguna and in an area of a little less than 1 km (N-S) by 4 km (E-W) of extension of east-west around Lagunitas -- El Cacao. Also it is found in a small area west of La Union. The thickness is usually 200 m but locally reaches 250 m.

Lithology; The formation comprises brown bedded shale and thin layers of limestone. Shale is dark, fine-grained and calcareous, with thin bedding. Left as relict from erosion on the limestone plateau, shale on the surface appears yellow to pale brown and fragile, due to weathering. Limestone lying between is dark grey, fine-grained and well-bedded with the thickness under 10 cm.

Fossils; No particular fossiliferous zone has been found.

Relation to other formations; Actual relation to upper formation has not been confirmed, though the relation is thought to be conformable.

Structure; Synclines are found locally with the axes of east-west. The fault of east-west trend bounding this formation to the northern Y-3 Formation is an inferred fault along a zone where topographic feature change sharply.

E) Upper Guare Formation (Y-5 Formation)

Distribution; The formation is distributed in a wide area of 3 km (N-S) by 19 km (E-W) around Chiqueros -- La Union -- La Golondrina, in the west and in the south of Cerro Copa del Higo. Also in a small area in and around Terremoto it develops.

Lithology; The formation consists of banded limestone, massive limestone and shale. The lower part is mainly dark banded limestone, with minor black to grey fine-grained massive limestone, containing occasional

dark quartzitic beds. Shale is rarely inserted. The upper part is composed mainly of grey to dark banded limestone often with shale insertions, containing occasional massive limestones and thin layers of black quartzite 1 to 5 cm thick. The thickness reaches 250 to 300 meters.

Fossils; Grey microcrystalline limestone (T211) at the south of La Union contains Actaeonella cf. syriaca and Stromatoporellina sp., being of the age of Cenomanian to Turonian. Also, in light grey microcrystalline limestone, at the southeast of La Laguna, Actaeonella syriaca Conredo and formainiferas are found to reveal it to be Cenomanian to Turonian. The formation is correlated to Guare Group defined by Mills et al. (1967) on the basis of the fossils.

Structure; Repetition of gentle syncline and anticline is notable, with axes of east-west. Faults of ESE-WNW and NE-SW are inferred according to topographic particularities. Along the NE-SW fault, horizontal dislocation of about 500 meters is seen at the south of Chiquero.

Relation to other formations; At several places, the formation is overlain conformably by limestone-conglomerate of Valle de Angeles Formation. This formation is in direct contact with sandstone of the lower of Valle de Angeles Formation, in the westside, while, in the east, both formations are bounded by unconformity on the wing of the anticline of this formation.

F) Valle de Angeles Formation

The formation is divided into four members according to rock facies.

V1; Alternation of brown fine-grained sandstone and shale, containing occasional thin layers of limestone.

V2; Limestone-conglomerate

V3; Grey bedded shales

V4; Red shale and sandstone beds, grey fossilliferous massive limestone.

(1) V1 Member

The member is distributed in an area of 1 km (N-S) by 7 km (E-W) around La Reina in the west, and also in an area from the south of La Union to El Colirio through Santa Elena. The member is composed of alternation of light brown fine-grained sandstone, light brown shale and thin banded black limestone, but sandstone predominates. In the eastern part, only sandstone is distributed, though thickness is rather small, while in the western part amount of shale increases in the lower part and thin limestone-conglomerates are contained in the upper part of the member. Pollens of Pinus, Betula and Monolete Spore are found in yellowish brown shale about 1 km north of Cerro Ocote, and the age of the member is placed tentatively to the lowermost of Tertiary rather than Cretaceous. Wavy undulation is seen extending east and west. Transitional zone to V2 member is observed in the western part where limestone-conglomerates are contained.

(2) V2 Member

The distribution of this member is in an area of a little less than 1 km (N-S) by 20 km (E-W) around Cerro Las Corres -- Cerro Ocote -- north of La Union -- Nisperales, and in an area of about 2 km (N-S) by 12 km (E-W) around south of La Union -- Santa Elena -- Los Terreros. The member is also found in a small area between El Terremoto and Oscula valley. Thickness is variable but reaches 250 meters.

Lithologically the member consists of limestone-conglomerates. In the northern part, sizes of pebbles and cobbles are from sand-size to 30 cm, well-sorted to form respective horizons according to the sizes. Matrix is reddish brown calcareous sand, and subangular pebbles and cobbles contained are slightly elongated and are composed mainly of limestone with

minor calcareous sandstone. In La Reina area, subangular black limestone, sandy limestone and black cherts of various sizes up to 40 cm are seen cemented in brownish sands. Sorting is only occasional. In Chiquerros area, pebbles and cobbles are of grey to whitish limestone locally with minor sandy limestone and black siliceous rock, sizes of which are up to 20 cm. Near the end of Rio Blanco Fault, this member appears to show slight wavy structure, though not brecciated. In the eastern part, tuff beds of Matagalpa Formation overlie this member.

(3) V3 Member

Along the south of the zone where V2 Member develops, this member is distributed in an area of about 23 km in east and west with width of a little less than 1 km, from Zambrano in the west to Caracol through El Miguelito and La Pimienta. Constituent rocks are fine-grained siltstone or shale in weathered light brown color in the west and light brown to grey shale in the east. They are well-bedded and not calcareous. The thickness reaches 200 meters. At the west of El Malcotal, shale of the lower part of the member is covered with tuffs of Matagalpa Formation. Exposure of rocks is very poor in the area where this member is distributed.

(4) V4 Member

This member is exposed in a zone in the southwestern part of the survey area. Thickness is over 300 meters. The member is composed of red shale, red sandstone (medium to coarse-grained) with occasional thin layers of limestone-conglomerate (thickness of several ten meters, extension up to 2 km) and limestone (grey massive, distributed in Cerro Negro area and in the southwestern part of the survey area). Limestone is dominant in the lower part while sandstone and shale are main constituents in the upper part. This member is overlain by tuff beds of Matagalpa Formation and Padre Miguel Formation with unconformity.

3-2-4 Tertiary System

Matagalpa Formation is divided into three parts, lower, middle and upper, by the distribution and rock facies.

A) Lower Matagalpa Formation

This is pyroclastic rocks distributed in the land below 700 m above sea level. The distribution is in San Marcos area, in El Tablon area in the eastern part and around San Isidro in the western part. Around San Isidro, form lower horizon to upper, the succession is tuffaceous sandstone and conglomerate -- tuffaceous sandstone --- rhyolitic tuff --- basalt.

Tuffaceous conglomerate; Locally distributed in the south and north of San Isidro, this is composed of pebbles of sandstone, shale and occasional limestone. As a whole, it appears pale brown and matrix is sandstone and tuff, with poor sorting. Attitude is horizontal or north dip.

Tuffaceous sandstone; Pale brown to light grey, medium to coarse-grained, this rock contains biotite fragments and lumps of tuff.

Tuff; Colored white, pale grey or pale brown, this rock contains irregular quartz and tabular fragments of feldspar, with occasional biotite fragments, and has acidic composition. Around San Isidro, it is altered by montmorillonitization. Rolling stones of obsidian and perlite are recognized near Cerro del Naranjo. In Oscula valley lenticular mass of white to pink rhyolite is recognized extending 10 to 20 meters. Occasionally, pumice is contained.

Basalt; Distribution of the basalt is in the northeastern part of San Luis. This basalt is brownish black olivine-bearing rock, intruding as sheets. In the south of San Marcos, the succession from lower part to upper is as follows:

Basalt; Thickness is over 100 meters. Distributed extending north and south

1 km east of Quebraditas village and in Los Vaditos, this basalt is dark grey to black fine-grained hard rock of porphyritic texture bearing plagioclase, olivine, magnetite and fine pyroxene with crypt-crystalline part. Gaseous vesicles are aboundant partially.

Andesite; Thickness is about 100 meters, thining out in the marginal zone. The andesite is dark green, brown or reddish purple, hard and porphyritic rock with autobrecciation structure. Phenocrysts are up to 2 mm and are composed of plagioclase, hypersthene, olivine, pyroxene and a little amount of alkalic feldspar.

Tuffs; Thickness is about 300 meters. This tuffs are composed of andesitic breccia, lapilli tuff and acidic tuff. Breccias are andesitic round cobbles or subangular cobbles, altered by chloritization and sericiti-zation. Acidic tuff is porous rock with pumices of while to pale color. In San Marcos area, the rock is rather rhyolitic with abundant pumice, but in not generally welded, except for local welded tuff which has welding structure of pumice and ash and is composed of quartz, feldspar, hornblende and apatite.

The tuff lying directly on the limestone at the east of Cerro Mapache contains aboundant pumices of 10 cm by 5 cm, without bearing any accidental breccia. It contains, apart from pumices, biotite and dark grey material with acidic volcanic ash. Andesitic tuff in the eastern part is medium to coarse-grained yellowish brown sandy rock, poor in pumices and contains lapilli of andesite or basalt of sizes under 1 cm. Generally, in the eastern part, pumice tuff is dominant. Pumice is very porous and of various sizes. Grains of feldspar are recognized microscopically. Matrix is composed of volcanic ash crushed pumices.

B) Middle Matagalpa Formation

This formation is distributed in the highland between 700 m and 1,200m above sea level from the depths of Nanchapa valley to around Quebradita village in the southeastern part of the survey area.

In the western part, the succession from the lowest is as follows;

Basalt lava; Thickness is 100 meters. Dark green, bearing phenocrysts of olivine and pyroxene.

Andesite lava; Thickness is 50 to 180 meters. Brownish due to abundant hematite. Phenocrysts of plagioclase and pyroxene, especially of hypersthene are contained.

Andesitic pyroclastic rocks; Thickness 50 to 100 meters.

Basalt lava; Thickness is 50 meters.

Andesite; Thickness is 50 meters.

Acidic tuff; Thickness is 200 to 250 meters. Not welded.

Bedding is fairly clear. At Tontorar this tuff is well bedded and dips about 10° to the north.

In the eastern part, the succession from the lower part to upper is as follows;

Andesite; Thickness is 120 meters. Lava flow, reddish purple and porous. Pale color to brownish porphyritic rock with phenocrysts of plagioclase, hypersthene and pyroxene.

Pyroclastic rocks; Thickness is 20 meters. Contain breccias of andesite and basalt of sizes up to 30 cm. Grey to pale brown tuff, bearing round quartz 3 mm in diameter.

Andesite; Lava flow. Thickness is 100 meters. Particulars are same as above-mentioned but for the fact that this andesite bears hornblende, plagioclase, quartz and tridymite, and is chloritized.

Lapilli tuff; Thickness is 30 meters, grey to pale brown.

Basalt lava flow; Thickness is 200 meters. Dark grey, porous, bearing magnetite.

Acidic tuff; Thickness is 100 to 200 meters. Pale color. Pumices are like flat-oval pea. Medium to coarse-grained volcanic ash with hornblende and fragments of pumice, quartz and calcite grains. Bedding is clear in the north of Robledar at the southeast corner of the survey area. Missing beds are there among the above-described in this Middle Matagalpa Formation due to the variation of the thickness.

C) Upper Matagalpa Formation

The Upper Matagalpa Formation is distributed in the highland of about 1,200 meters or more above sea level, mainly around Cueva del Tigre and Cerro Cuchilla Alta at the southeast end of the survey area. Cerro Cantiles in the southeastern part is the highest peak in the survey area, of 1,731 meters above sea level. The succession from the lower part to the upper is as follows:

Basalt; Thickness is 100 meters, dark or dark grey in color, bearing phenocrysts of olivine and pyroxene.

Tuff; Thickness is 150 to 220 meters. Acidic yellowish brown sandy part predominates. Pumices are not abundant. Contains granules of andesite and basalt, of sizes of 0.5 to several millimeters.

Basalt; Thickness is 130 meters. Contains phenocrysts of olivine and pyroxene.

Rhyolite; Scatteringly distributed in the eastern part of the survey area; that is, around Las Flores and Platanillo in the west, around Cerro El Caracol, Santa Rosita and Cerro de Las Pilas in the middle and around 1.5 km south of Escaretos and Cerro Cuchilla Alta in the east. The thickness is 100 to 150 meters but reaches 300 meters locally. It has remarkable flow structure. Vitric, partly perlitic texture

is notable. It is fine compact rock, bearing phenocrysts of quartz and feldspar, with various colors pinkish brown to pale green and white. Partly it contains layers of tuff breccia about 10 meters thick, and up to an area of 3 km by 3 km is occupied by this rock.

This rhyolite is locally seen in direct contact with lower Matagalpa Formation, but there is no place where Lower Matagalpa Formation is bounded directly to Upper Matagalpa Formation, other than the above.

D) Padre Miguel Formation

Distribution; This formation is distributed in an area of 6 km (E-S) by 2 km (N-S) in a plain of Palma Real at the southwestern end of the survey area.

Lithology; This formation is composed of conglomerate containing volcanic materials, tuffaceous sandstone, tuff breccia and partly conglomerate of andesitic rocks. Rocks are consolidated rather hard and the thickness is up to several ten meters.

Structure; Owing to landslip or landslide, the trends of this formation are put out of order, but gentle northward dipping is seen generally, and the formation overlies the Valle de Angeles Formation with unconformity.

Correlation; The formation is younger than Valle de Angeles Formation. As this formation contains abundant breccias of volcanic origin, source of which is thought to be Matagalpa Formation, this is correlated to Padre Miguel Formation, considering the time gap of the accumulation of this formation and that of Matagalpa Formation.

3-2-5 Quaternary System

There is no Quaternary volcano in this survey area. A plan stretching north and south with the width of 3 to 5 km through Macuelizo and El Ciruelo narrows gradually in the south toward Rio Blanco. Also there is

another plain in Quimistan area, though rather narrower, extending north and south. Considering large scale plains develop around Valle de Naco in the east and along Ulua River, too, it is certain that there must have been a movement at the end of Tertiary Period to form tectonic lines of north and south. Along the Chamelecon River, there are river terraces of the thickness of 2 to 10 meters. They are composed of sediments carried by river flow; reddish brown to brown or grey clay, sand and pebbles mixed with sediments of apparent volcanic ash.

3-2-6 Igneous Rocks

Apart from volcanic rocks belonging to Matagalpa Formation, intrusions of plutonic rocks as diorites and of igneous rocks as andesites are seen around Chamelecon area and around Petoa area, in the survey area. Their distribution is mostly along the contact zone of the Paleozoic crystalline schists and rocks of Yojoa Group. Details are described hereunder in respective area.

A) Chamelecon Area

Diabase; Mainly Vueltas del Rio Formation in the northeastern part is intruded by diabase as several sheets. Diabase is pale green to green in color with fine hollocrystalline or porphyritic hollocrystalline texture. Width is several deci-meters, and trends are generally east-west.

It shows the rock is in the range of quartz diorite according to the classification of plutonic rocks by the result of norm calculation. The age of this rock determined by K-Ar method is 86.3 $\pm$ 3.7 m.y., which indicates early Tertiary or late Cretaceous period. It might reveal the igneous activity to have been in late Cretaceous period.

Andesite; In El Manguito area, andesite lies 50 to 300 meters in width, extending east and west. Also it is distributed with the width of

150 meters. Yojoa Group limestone formations, distributed in area of 17 km (E-S) by about 1 km (N-S) from La Zona in the west to La Cueva in the east through El Pital and El limon and beyond Rio Blanco to Cerro los Taburetas, contains andesite as a group of dykes intruded in the Group. As it is difficult to confirm boundary of respective dyke due to poor exposure on the surface, they are shown as "its distribution area" on the geological map. The andesite is usually weathered to appear brown in color, having fine porphyritic texture, and is composed of a rock with phenocrysts of pyroxene and feldspar and of dark colored rock with those of hornblende and plagioclase.

Quartz-diorite porphyry; As small intrusive bodies, the quartz diorite porphyry occurs intruding Vueltas del Rio Formation as well as Contarranas Formation near Zapotal in the western part and Atima Formation. It has white, medium to fine-grained porphyritic texture, with main constituent minerals of hornblende, pyroxene, quartz and plagioclase, and is silicified intensely in general.

Diorite; The diorite is distributed as stocks intruding limestone and andesites of Atima Formation, usually extending east and west with the width of several hundred meters, in the north of Agua Helada, in the east of El Manguito and around Monte Largo. It is composed mainly of hornblende, pyroxene, plagioclase and partially quartz.

In the mica schists located in the south of Sula, intrusions of andesite and diorite are observed.

B) Central

In plains at Cementerio in the northwest of San Marcos, whitish grey granodiorite is distributed as an apparent relict hill. This rock is hollocrystalline with main constituent minerals of muscovite, alkali-feldspar, plagioclase and quartz. The relation to surrounding mica schists has not

been confirmed in this area, but in the exposures along the national highway at the northwest of San Marcos outside the survey area and also granodioritic rocks are observed as dykes intruding mica schists. Also, the rock is seen as intrusive bodies of greyish white coarse-grained rock, along the boundary between mica schists and Cantarranas limestones 2 km northwest of Potrerillos as well as in the limestone 2 km west of Potrerillos.

C) Petoa Area

The Minitas Formation is mainly composed of me metamorphosed pyroclastics such as fine to medium grained meta-andesite and meta-tuff breccia, and intruded by following volcanic rocks.

Grandodiorite; Around the Minitas, this rock body distributed the complicated forms, and is coarse grain, holocrystalline, without reaction rim. In the spherical zone, this rock body takes the many dyke form, partly develope a foliation.

Liparite; It is distributed the northernpart of Pueblo Nuevo. It is hard compact rock, and is intruded by dyke of the end of Cretaceous period.

We guess that these igneous rocks are thought to be of little chronological difference from the meta-andesite. Granite porphyry and granodiorite porphyry; In the Minitas Valley, and at Macutalo, these rocks distributed as dyke rock as shown NW-SE direction, and suffered by intense silicification. It is thought that these rocks are related to the mineralization of replacement type in this area.

Andesite; Located at the west of Petoa, the andesite is seen intruding limestone beds but intruded by diorite. Other than this, narrow dykes of andesite and quartz porphyry, several meters in width, are observed intruding limestone and diorites.

By chemical analysis of the rock sample of amygdaroidal porphyry produced in the northern part of Pueblo Nuevo, this value shows by

normative classification as the area between diorite-gabbro.

3-3 Geological Structure

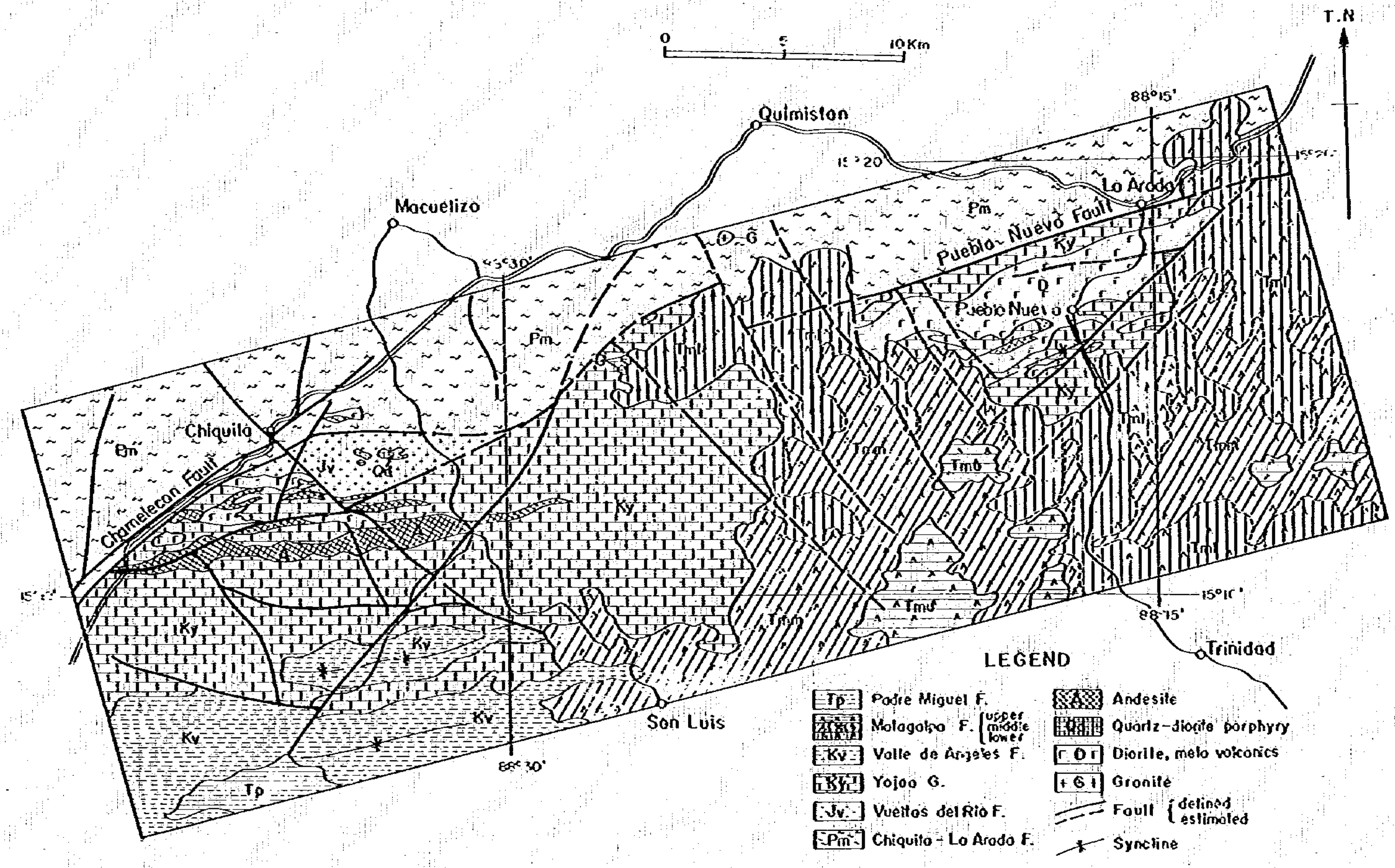
3-3-1 Outline of the Structure. (Refer to Fig. 5)

Paleozoic schists are distributed in the north side and Mesozoic sediments are in the south side of the survey area, extending east and west. From north to south, Yojoa Cantarranas Formation, Yojoa Atima Formation, Yojoa Guare Formation and Valle de Angeles Formation are distributed in the order of their age from the oldest. They are folded--- especially drag-folds with partially complicated anticline and syncline develop well in the Paleozoic mica schists, which, as a whole, has general trend of east and west, waving in syncline and anticline of NNE-SSW axes. Axes extending east and west are common in Paleozoic formations, in Yojoa Group and in Valle de Angeles Formation, as well as in the whole survey area.

Distribution of diorite and andesite is confined in a narrow zone extending east and west along the boundary between the Paleozoic formations and Yojoa Group. Though very rare in the north side of the boundary, they are distributed, concentrating to Chamelecon area and Petoa area, in the width of 3 to 6 km along the southern side of the boundary. Tertiary volcanic rocks of Matagalpa Formation develop in southeastern part of the survey area, and their prevailing trends are N-S or NNW-SSW. Upper horizons are in the south and in the east while lower part is distributed in the north, quite contrary to the case of Valle de Angeles Formation.

The most conspicuous tectonic line in this survey area is Pueblo Nuevo Fault, which bounds the Paleozoic formations from the Mesozoic sediments. The fault is a major overthrust, extending out of the survey area with strikes of E-W but for local trend of NE-SW, and it has formed particular topographic features. The second major line is NE-SW fault extending

Fig.5 IDEALIZED MAP OF GEOLOGICAL STRUCTURE OF THE SURVEYED AREA



through El Guanacaste and Chumbagua, which is also well expressed on the topography. This fault is parallel to the Pueblo Nuevo Fault south of Chiquila, and is thought to have formed "opening" in east and west. Other E-W faults parallel to the Pueblo Nuevo Fault are found in Yojoa Group but they are not clearly traced as located in limestone area.

Several NE-SW faults are observed in the south of Petoa, and also NW-SE faults are seen in Chamelecon area. There is none which cuts Matagalpa Formation. Considering the distribution of Matagalpa Formation near San Marcos, that it is located in a narrow zone about 5 km wide along the NNW-SSE tectonic line in Yojoa Group and that it spreads out at the north of Pueblo Nuevo Fault, and also viewing that igneous rocks are poor in the Yojoa Group lying in the central part of the survey area, respective estern, central and southern part of Yojoa Group are composed of somewhat different rocks and structures one another.

Valle de Angeles Formation is distributed in the southwestern part of the survey area and it is not observed in the eastern part. This might be because Matagalpa Formation covers the eastern part or because the sedimentation of the formation was poor in the east. The eastern part is underlain by Paleozoic highly metamorphosed members formed at the depth. Also, Yojoa Group is represented by Atima Formation, not by the upper formations, in the eastern part. Accordingly, it can be said that the northeastern part is occupied by the oldest formation followed by the younger formations distributed southward in the order of their age, and that the part where stress has been concentrated most intensely is along the border between the Paleozoic formations and the Meszoic sediments. The structure becomes gentler southerly from the border.

3-3-2 Foldings and Faults

A) Foldings in the Paleozoic Formations

The trend of folding axes in schists is N40°-60°E with the plunge of 15° to 40° to northeast. Wave-length of the foldings is 1.5 to 2.5 km, but there are few axes showing distinct extension and as a whole, the strike of beddings keeps itself to be almost east-west with the dip to the north. In spite of the repetition of foldings, generally the upper horizon appears northerly. In Sula area, folding axes are almost east-west, and in the south of Sula, Pueblo Nuevo Fault runs also in E-W, parallel to the trend of E-W axes of the foldings. It is thought that the fault has been formed in relation to the main trend of the foldings in the period of sedimentation from Paleozoic formations to Yojoa Group. The fact that clear repetition of beds are not seen against many folding axes, is thought to be due to their position at the northside of the anticlinorium as a whole and, also due to their ruffle-like foldings. WNW-ESE anticline axis is seen, in an outcrop along the national highway, in the schists located at the north of Petoa area. Part of the beds is absorbed in the Pueblo Nuevo Fault, indicating that folding axis varies further from general trend of E-W in the eastern part.

B) Foldings and Faults in the Mesozoic Sediments

The trend of folding axes in the Yojoa Group is dominantly east-west both in the eastern part and in the western part. Partial ENE-WSW trend is occasionally observed in the eastern part, showing disturbance by the intrusion of igneous rocks. But as the area is essentially underlain by the calcareous rocks poorly bedded and flexous, so the observation has not been successful so as to be able to analyse the variation of folding axes in detail. By the same reason, faults and fissures are not well observed, but for those only located at the boundary of Cantarranas Formation with Atima Formation. In Valle de Angeles Formation, foldings are seen rarely and no notable faults and fissures are found.

C) Foldings and Faults in Matagalpa Formation

No notable folding structure is seen in Matagalpa Formation. Also, noteworthy fault has not been observed probably because of the existence of aboundant tuffs. The Matagalpa Formation is divided into three parts; lower, middle and upper. The lower Matagalpa Formation is most broadly distributed, and it shows a sedimentation along its flowing direction; that is why the inclination of strata is toward the west in the westside, toward NNW near San Marcos area and northward in the east side. Rhyolite contained in the upper Matagalpa Formation is distributed scatteringly in ENE-WSW or toward SSE and usually forms a hill-top of up to 250 meter in thickness. The distribution corresponds to the area where Metagalpa Formation develops rather thick.

3-3-3 Relation to Igneous Rocks

Igneous rocks except for Matagalpa Formation are distributed as described above, in a zone about 6 km wide along the southern side of the Pueblo Nuevo Fault, concentrating in Chamelecon area and in Petoa area. A little is found in the central part of the survey area. In Chamelecon area, there are diabase, andesite, diorite and quartz-diorite porphyry, all extending mainly east and west, with the width of several deci-meters to 1 km. Their dippings have not been confirmed in many cases. In Petoa area, meta-andesite, liparite, granodiorite and andesite are distributed in a main trend of E-W with minor tendency of NW-SE. Their intrusion is seen in an area of widespread limestones located in the footwall-side of Pueblo Nuevo overthrust. It is considered that the concentration of stress by the fault activity offered a favorable condition for the intrusion of the igneous rocks in the southern side of this fault.

3-4 Geological History and Igneous Activity

3-4-1 Paleozoic Era

The oldest formation in the survey area is what is called Paleozoic Group distributed in the north of Chamelecon River. The Group contains gneissose schists, crystalline schists and marble, showing various metamorphic grades in different localities. The Group is thought to contain formations accumulated in wide ranges of period. Roberts and Irving (1957) stated that the Group contains Pre-Cambrian rocks partially and that the youngest comes down to later Permian series containing fossils. In the survey area, the Group is in contact with Cretaceous limestones bordered by fault.

Viewing that the Group is metamorphosed and lithology of the Group is quite different from that of Cretaceous formations, the Group is thought to be pre-Cretaceous. The metamorphic rocks are similar lithologically to those underneath the Cretaceous Metapan Formation located in the eastern part of the Republic of Honduras. Levy (1970) described that the absolute isotopic age is 142 $\pm$ 6 m.y., obtained by K-Ar method on sericite contained in a pegmatite dyke intruding the metamorphic rocks found between Quimistan and El Ciruelo. By the above facts, it is certain that the age of the system is pre-Cretaceous. Viewing from the fact that the metamorphic rocks in the survey area have little variation of lithology except for differences of metamorphic grades, it is thought that the metamorphic members do not contain the sediments of such a wide range of period.

The age of mica schist collected at the north of La Arada determined by K-Ar method is 222 $\pm$ 8 m.y., which is confirming to correspond to Permian period.

3-4-2 Mesozoic Era

Hills et al. (1967) divided the Mesozoic Group into following (1) to (5) from the lowest upwards.

(1) Thin black shales ----- El Plan Formation.

(2) Red formations with some thin layers of limestone ----- Todos Santos Formation.

(3) Thick limestone group ----- Yojoa Group.

(4) Red pyroclastic rocks (partly containing effusive volcanic rocks) ----- Valle de Angeles Formation.

(5) Brown marly shale and limestone ----- Esquias Formation

Yojoa Group, mentioned as above (3), is classified as follows:

A) The oldest, thin layers of dark limestone and shale ----- Cantarranas Formation, to be of Neocomian to early Albian age.

B) Massive limestone, forming steep cliffs, generally, dark grey to black, fine compact and brecciated in many places.

----- Atima Formation, to be of Albian age.

C) Then layers of black shale and limestones with partial limestone-conglomerates ----- Guare Formation, to be of late Aptian to late Cretaceous.

D) Limestone-conglomerate ----- Ilama Formation

The rocks found in the survey area are placed to correspond to the above formations according to the geological features mentioned hereunder.

1) Unknown age Formation

The Formation outcrop in the Vueltas del Rio Sector and Minitas Sector, are composed of volcanics, pyroclastics and black shale of thin layers, and suffered by metamorphism.

By this reason these formations differ with the El Plan Formation, which no accompanies any igneous activity, stated by Mills et al. (1967), and the K-Ar dating age of the granodiorite in the Minitas Formation are determined to be Premian.

Therefore the Formation has correlated prior to the end of Paleozoic age.

Also, the beds found in the southeast of La Arada in the eastern part of the survey area are only locally distributed and have no direct contact with other formations. As they are composed of quartzite and shale, lithologically they are thought to be a part of Cantarranas Formation rather than of Todos Santos Formation. However, further study would be necessary for the determination of the period of the formation of these beds.

2) Yojoa Group

Cantarranas Formation; Distributed in Zapotal area and in Potrerillos area, the beds are situated at the footwall side of massive limestone though bounded with fault to render stratigraphical succession uncertain. No fossils have been found but they are correlated to Yojoa Group as the lithology is quite corresponding to that described by Mills. The banded limestone and shale belonging to Guare Formation have phyllitic character easy to be distinguished from the above.

Atima Formation; The lithological particulars are same as described by Mills, corresponding to Area II of the geological division by Mills. By fossils collected in the formation by Mills and through this survey, the age of the formation has been determined to be lower Cretaceous. The fossils collected in the massive limestone in Petoa area indicate early Albian, corresponding to the Atima Formation.

Guare Formation; Characteristic lithology of banded limestone and shale corresponds to the one described and displayed on the geological map by Mills. The fossils collected in the formation through this survey are all indicating Cenomanian or Cenomanian-Turonian, which agrees with the result of the age determination by Mills.

Ilama Formation; Large part of limestone-conglomerate is contained in the Valle de Angeles Formation and hence this formation is not employed in this report.

Valle de Angeles Formation; According to the classification by Mills, this formation is applied to red pyroclastic rocks lying on the thick limestone group. The beds represented by brown marly limestone and shale covering the lower red beds are correlated to be Esquias Formation. Where this formation exists, Valle de Angeles Formation is divided into two parts, lower and upper. The lower part is correlated to lower Cretaceous and the upper part is thought to correspond to Tertiary --- to Subinal Formation named in Guatemala. By Howel et al. (1967), this formation is taken as non-volcanic sediments of upper Cretaceous to Eocene. Howel et al. and UN report are emphasizing limestones in the formation, which is different from Mills' description, but summing up the whole above-mentioned, it is concluded that the Valle de Angeles Formation is composed of red pyroclastics, limestone-conglomerate to limestone as lithologic facies. This is quite agreeable with the geological classification in the present survey area.

3-4-3 Igneous Rocks

Igneous rocks are distributed in E-W trend in an area of 15 km (E-W) by 5 km (N-S) in the Yojoa Group and in the Vueltas del Rio Formation, along the contact zone between the mica schists and the Yojoa Group. Vueltas del Rio Formation is intruded by diabase and dacite porphyry, andesite, and Cantarranas Formation is intruded by diorite and quartz-diorite porphyry. Atima Formation is intruded by diabase, andesite, diorite and quartz-diorite porphyry, and Guare Formation is intruded by andesite and diorite. The order of the intrusion of these rocks is from the oldest, diabase --- andesite --- dacite porphyry --- diorite, although the mutual relation of these rocks is not completely observed, leaving some uncertain factors. The only igneous rock found in the central part of the survey area is mica granite intruding Cantarranas Formation.

In the eastern part of the survey area there are distributed of liparite and granodiorite, which are found to have intruded the basement rock such as metamorphosed andesite, volcanic pyroclastic rocks. They are subjected to remarkable alteration. But the chronological result of this granodiorite shows the age of 224 + 17 m.y., and that the age of the rock is correlated the same as that of the meta-andesite. The dyke of granite porphyry, quartz porphyry and andesite intruded ofthese rocks and Yojoa limestones, and on some part are associated with mineralization, and it is thought that their ages would be later Creataceous.

The factors are; the chronological distribution is limited to the schists, Cantarranas Formation, Atima Formation and the lower Atima Formation; the location is confined to a certain zone extending east and west along the boundary between the schists and the Yojoa Group; the areas where respective igneous rocks are distributed are duplicated or adjoined; and they are lithologically quite different from igneous rocks of Matagalpa Formation.

From the fact that little igneous materials is found in the Valle de Angeles Formation, the period of the intrusion is taken to be immediately after the sedimentation of Valle de Angeles Formation, in this report.

3-4-4 Summary of Geological History

The sedimentary rocks, in the northern part of the survey area, as pelitic sediments, basic igneous rocks and calcareous sediments, were metamorphosed to form various schists by regional metamorphism, which might have lasted in fairly long period, as gneisses were formed in the east and violent movement to form foldings might have been with the formation of schists at the end of Paleozoic era. Sediments mainly of great amount of limestones were precipitating in the period of Jurassic to Cretaceous age in Mesozoic era. But at the end of Paleozoic era or prior to the Jurassic, in the Vueltas del Rio and Minitas Sectors are distributed the meta-volcanics,

pyroclastics that suffered by strong alteration. So we cannot identify the stratigraphy of each formations. But they are distributed the formation that subjected to the metamorphism after the volcanic activity.

Foldings with east-west axes and the Pueblo Nuevo Fault were formed after the sedimentation of Yojoa Group composed of Cantarranas Formation, Atima Formation and Cuare Formation. After the sedimentation of neritic Valle de Angeles Formation mainly of non-calcareous sediments, there occurred a folding and faulting movement. It promoted overthrusting of the Pueblo Nuevo Fault and introduced intrusion of igneous rocks such as andesites followed by quartz porphyry, granite porphyry which were associated with mineralization. The movement was violent with intrusion of dykes and development of faults and fissures.

In the period from Oligocene to Miocene, volcanic activity of tuffs, basalt, andesite, and rhyolite occurred extensively. The activity includes roughly 3 cycles of variation of chemical composition of the volcanic rocks, finalized by the activity of rhyolite.

Erosion and block movements were there to form approximately present topographical features, and subsequently sands and pebbles of Padre Miguel Formation were sedimented in small areas in the southeastern part of the survey area. In Quaternary period, by the difference of resistance of respective bed or tectonic lines, erosion and weathering have formed Quimistan plain and Chamelecon River as a part of present topography.

3-5 Ore Deposits and Indications

3-5-1 Distribution (Refer to Fig. 4)

Levy (1970) stated as follows; In the Central America, Laramide orogenic movement occurred in late Cretaceous to Tertiary period. After sedimentation and deformation of Valle de Angeles Formation, major metallic ore

deposits were formed by mineralization associated with the igneous activity. The mineralization at El Mochito (silver, lead and zinc), at El Rosario (gold, silver) and at Agalteca (iron) was at this period. Also, there are epithermal gold-silver veins in andesitic lava as the mineralization related directly to Pliocene volcanic activity.

The survey area belongs to Northern Cordillera block, which contains various types of ore deposits as silver-lead-zinc type, gold-copper-lead-zinc type and gold-silver type, extending easterly from Guatemala.

Ore deposits and indications ever reported and confirmed by the present survey in this survey area are shown in Table 6-7.

A) Mineralization in Paleozoic Group

Indication of gold and manganese with quartz veins in epidote-chlorite schist, and weathered outcrop of mineralization in mica schist are observed.

B) Mineralization in Vueltas del Rio Formation

Copper-gold deposits of veinlets and dissemination are seen in intensely altered part along the contact zone between meta-andesitic tuff and tuff-breccia.

C) Contact metasomatic deposits along the boundary of granite porphyry and Yojoa Group limestone beds. Iron-copper-lead-zinc-gold-silver ore deposits associated with skarn minerals as garnet and actinolite, at Macutalo and at Minitas etc., in Petoa area.

D) Ore veins in Granodiorites

Copper-lead-zinc-gold veins contained in quartz porphyry, granite porphyry and so on.

E) Veins in sedimentary rock of calcareous beds

Copper-lead-zinc-gold-silver veins in limestones in Pueblo Nuevo area.

F) Gold deposits of Residual and Secondary enrichment

In the Vueltas del Rio Formation, gold zone include the old workings and quartz veins.

G) Placer deposits

Placer gold has been reported to have been mined along Chiguila River.

There are some secondary enrichment deposits among the above except for G. Special notes on the distribution of the above-mentioned mineralizations are given below.

A) There is no notable indication found in Guare Formation at the top of Yojoa Group, in Valle de Angeles Formation and in Matagulpa Formation.

B) Most of the mineralized places are confined in the area with igneous rocks as diorites and andesites.

C) Mineralizations are found predominantly in the sedimentary rocks of upper part of Paleozoic to lower Cretaceous period as Vueltas del Rio, Minitas, Cantarranas and Atima Formation.

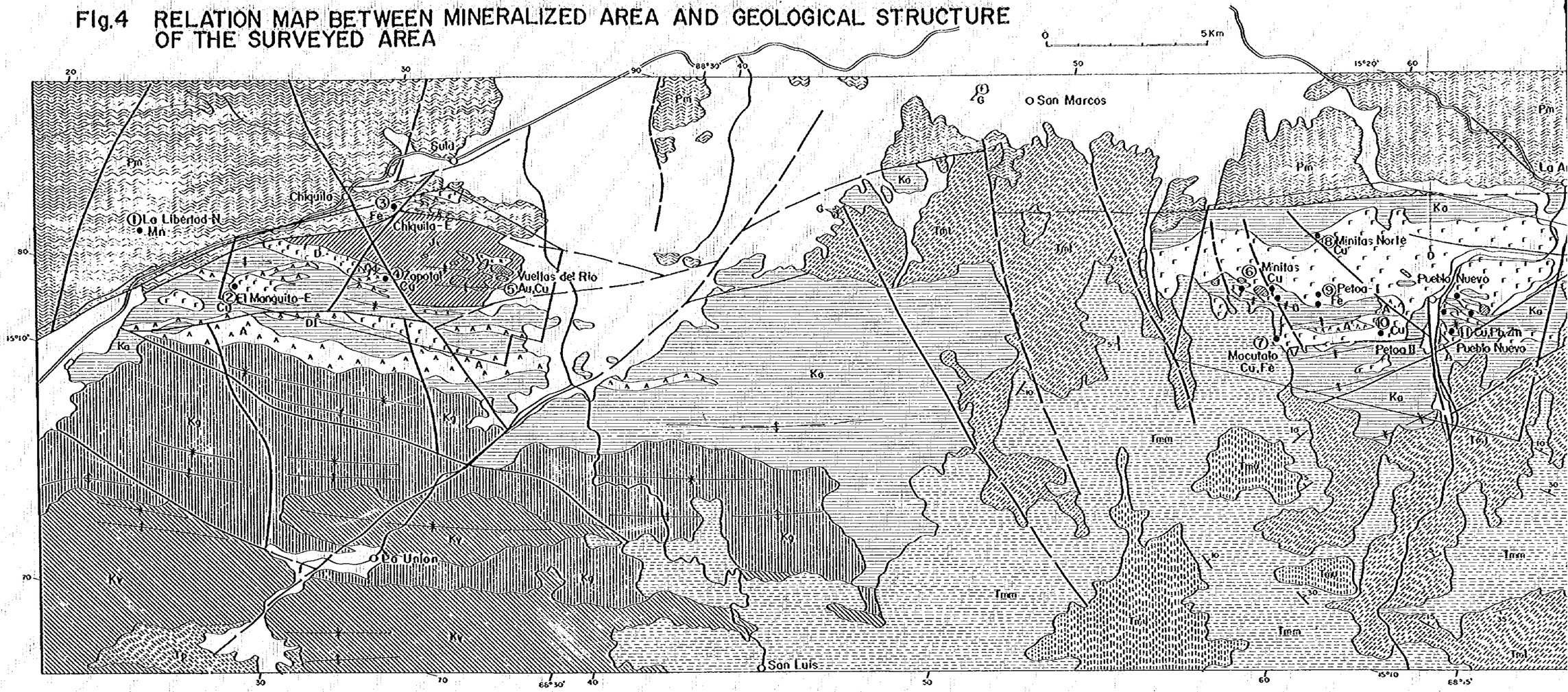
D) Mineralizations are mostly concentrated in a zone with abundant faults and fissures along the south side of Pueblo Nuevo Fault. Indications of mineralization in the schists of Palezoic system are also found in the vicinity of the Pueblo Nuevo Fault.

According to the above, it is possible that the mineralization is at least at the period the end of Paleozoic or after the sedimentation of Cretaceous sediments and before deposition of Tertiary volcanic rocks.

3-5-2 Mineral Indications confirmed by this survey (Refer to Table 6-7, 6-8, 6-9)

By the detailed geological survey accompanying with trench, and diamond drillings, the mineral indications have discovered in the Vueltas del Rio and Minitas areas. These are mainly the vein type with gold, copper, lead, and zinc, and the contact replacement type accompanied with same metals. And especially in the Vueltas del Rio sector are confirmed the autochchonous residual gold ore deposit in the secondary enrichment zone.

Fig.4 RELATION MAP BETWEEN MINERALIZED AREA AND GEOLOGICAL STRUCTURE OF THE SURVEYED AREA



Cenozoic
- Quaternary
  - Recent Sediments
- Tertiary
  - Tp Padre Miguel F
  - Tmv Matagalpa F. upper
  - Tmm Matagalpa F. middle
  - Tml Matagalpa F. lower

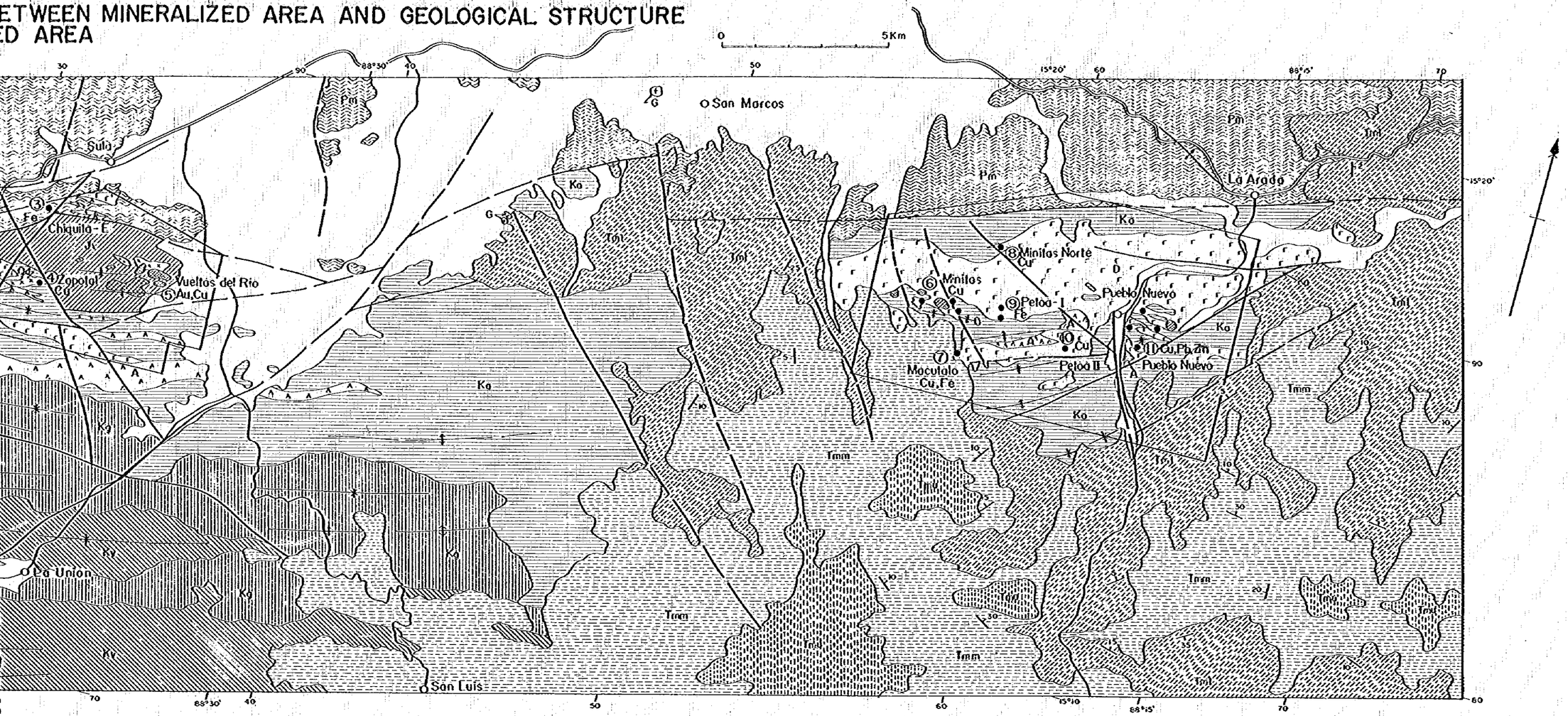
Mesozoic
- Cretaceous
  - Kv Valle de Angeles F.
  - Kg Guare F.
  - Ka Alima F. & Cantarranas F.
- Jurassic
  - Vueltas del Rio F.
  - Chiquila - Lo Arada F.

Paleozoic

Intrusive rocks
- Granite
- Diorite, Melo volcanics
- Andesite
- Dolerite
- Quartz-diorite porphyry

- Bedding
- Fault defined estimated
- Anticline , Syncline
- Ore deposits, Mineral showings
- Area of Semi-detailed Survey

ETWEEN MINERALIZED AREA AND GEOLOGICAL STRUCTURE
ED AREA



- Quaternary
  - Recent Sediments
- Tertiary
  - Padre Miguel F
  - Matagalpa F. upper
  - Matagalpa F. middle
  - Matagalpa F. lower
- Mesozoic
  - Cretaceous
    - Valle de Angeles F.
    - Guare F.
    - Alima F. & Cantarranas F.
  - Jurassic
    - Vueltos del Rio F.
    - Chiquila - La Arada F.
- Paleozoic
- Intrusive rocks
  - Granite
  - Diorite, Meta volcanics
  - Andesite
  - Dolerite
  - Quartz-diorite porphyry
- Bedding
- Fault (defined, estimated)
- Anticline, Syncline
- Ore deposits, Mineral showings
- Area of Semi-detailed Survey

Table 6—8 List of Mineral Indication in the Surveyed Area

No.	Surveyed sector	Name	Location E	Location N	Kind of ore	Host rock	Related igneous rock	Mode of occurrence	Scale of mineralization	Amount of unit ore body	Unit ore body: Length	Unit ore body: Width	Unit ore body: Direction	Ore mineral	Grade of ore	Sample No.	Remarks
1	Vueltas del Rio	Vueltas del Rio	333.5	1682.5	Au,Cu	Vol r.		diss & vlt	1200m x 300m	5 ~ 10m	50-400m	2-100m	E-W	Au,ccp,py	Au 1g/t ↓ by UNDP		Ore reserves by UNDP,1972 Probable Possible Au 7.5×10^6t (1.3 g/t) 10×10^6t (0.95 g/t)
2	Vueltas del Rio	DDH No. 53-1	334.80	1682.65	Cu	pyro		vein		1	(Core length) (2m)	10cm		ccp,py	Cu 1.28%	No. 1096	depth 96~98m
3	Vueltas del Rio	DDH No. 53-2	334.07	1681.98	Au	pyro		vlt		1	(2m)	5~10cm		Au	Au 44 g/t	No.2006	depth 6~8m
		"	"	"	Au,Ag,Cu	"		"		1	(1m)	5cm		Au,ccp,py	Au 97g/t,Ag 80g/t Cu 5.94%	No.2173	depth 173~174m
4	Vueltas del Rio	DDH No. 53-3	333.20	1681.90	Au,Zn	pyro		vlt		1	(2m)			Au,sp,py	Au 3.34g/t, Zn 1.85%	No.3046	depth 46~48m
		"	"	"	Cu	"		diss & vlt		1	(22m)			ccp,py	Cu 0.122%	No.3101~ No.3124	depth 104~ 126m
		"	"	"	Au,Zn	"		vein		1	(4m)			Au,sp,gn	Au 1.3g/t, Zn 1.78%	No.3146~ No. 3148	depth 146~ 150m
5	Vueltas del Rio	DDH No. 53-4	333.20	1682.53	Au,Cu,Zn	pyro		diss		1	(2m)			Au,ccp,sp	Au 0.76g/t, Cu 0.15%, Zn 1.84%	No. 4090	depth 90~92m
		"	"	"	Cu	pyro		vein		1	(2m)			ccp	Cu 1.59%	No. 4108	depth 108~ 110m
6	Minitas	Qda.Minitas	358.10	1687.10	Cu,Zn	ls	gp	vein	5m x 1.75m	1	5m	1.75m	N45W	az,mala,chry	Cu 4.28%,Zn 0.77%	MS22,MS23	Outcrop
7	Minitas	DDH No. 53-7	357.40	1687.93	Cu,Zn	ls	gp	contact	500m x 90m	1	(120m)		N45W	ccp,mala,py	Cu 0.35%	No. 7068	depth 68~70m
		"	"	"	"	"	"	"		"				"	Cu 0.09%,Zn 0.68%	No. 7080	depth 80~82m
		"	"	"	"	"	"	"		"				"	Cu 0.68%	No. 7086	depth 86~88m
		"	"	"	"	"	"	"		"				"	Cu 1.21%	No. 7090	depth 90~92m
8	Minitas	Macutalo	358.00	1686.53	Cu,Fe	ls	gp	contact	120m x 30m	1	10~30m		E-W	ccp,py,mala mg,Au	Cu 0.99%	MS28~MS33	old pit
9	Minitas	Petoa I	358.95	1687.85	Fe	ls		vein	10m x 2m	2	5m	1m	N45W	mg,mala	Cu 0.44%	MS 27	old pit
10	Pueblo Nuevo	Santa Ines	363.60	1688.82	Cu	ls		vein	150m x 2m	1	150m	2m	flat	ccp,mala,az	Cu 1.99%,Zn 0.5%	PN7~PN10	old pit
11	Pueblo Nuevo	Santo Domingo	364.30	1688.75	Cu,Pb,Zn	lip		vein	50m x 6m	1	50m	6m	N40E	az,mala,ccp gn,sp,py	Cu 0.31%,Pb 1.57% Zn 2.04%	PN 5	old pit
12	Pueblo Nuevo	Esperanza	362.60	1688.53	Cu	ls		vein	5m x 1m	1	5m	1m	flat	mala,az			old pit

Host rock
ls..limestone
pyro.. pyroclastics
lip.. liparite
vol r..volcanic rock

Related igneous rock
gp..granite-porphyry

Mode of occurrence
diss..dissemination
vlt..veinlet

Ore mineral
Au...gold
az...azurite
ccp..chalcopyrite
chry..chrysocolla
gn..galena
mg..magnetite
mala..malachite
sp..sphalerite
py..pyrite

Table 6—9 List of Mineral Indication by Drilled Core in the Vueltas del Rio Sector

1000 PPM ≧ Cu, Pb, Zn
1 g/t ≧ Au

Boring No.	Depth		Width m	Elements Analysis			
	From m	To m		Cu %	Pb %	Zn %	Au g/t
54-1	14.0	20.0	6.0	0.826	–	–	–
	248.0	250.0	2.0	0.250	–	–	–
54-2	2.0	8.0	6.0	–	–	–	1.54
	28.0	32.0	4.0	0.324	–	–	–
54-3	36.0	50.0	14.0	0.048	–	0.83	–
	58.0	78.0	20.0	–	–	0.43	–
	176.0	178.0	2.0	0.228	–	–	–
54-4	0.0	36.0	36.0	–	–	0.318	3.24(10m–12m)
	62.0	80.0	18.0	–	–	0.321	–
	94.0	102.0	8.0	–	–	0.495	–
	109.0	110.0	1.0	0.628	–	0.052	–
	189.0	189.1	0.1	1.0~2.0	–	–	–
54-6	0.0	14.0	14.0	–	–	0.237	–
	14.0	30.0	16.0	–	–	0.277	–
54-7	170.0	176.0	6.0	–	–	0.278	–
54-8	240.0	242.0	2.0	0.510	–	–	–