Thesis by Druecker
ON The Bladen Volcanic
Series

THE GEOLOGY OF THE BLADEN VOLCANIC SERIES, SOUTHERN MAYA MOUNTAINS, BELIZE, CENTRAL AMERICA

By

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A Thesis submitted to the Faculty and Board of Trustees of the Colorado School of Mines in partial fulfillment of the requirements for the degree of Master of Science (Geology).

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ABSTRACT

The Bladen Volcanic Series is located along the southern boundary fault of the Maya Mountain uplift in south-central Belize, Central America. This uplifted horst block has an overall internal structure of a synclinorium plunging 10 degrees toward the west-southwest.

The Bladen Volcanic Series is a complex folded and faulted sequence of Pennsylvanian volcanic rocks. The volcanic units are, from oldest to youngest, latite flows and flow breccias, laharic breccias and tuff breccias, quartz latite ash-flow tuffs and rhyolite to latite flows, air-fall tuffs, latite to quartz latite ash-flow tuffs, air-fall tuffs and tuffaceous sandstones, and dacite flows and ash-flow tuffs. Minor subvolcanic intrusions occur as dikes and sills.

The Santa Rosa Group is a thick sequence of sedimentary rocks deposited during the Permian in a subsiding trough or basin. This sequence lies above, and is unconformable with the Bladen Volcanic Series. The lower section is composed of basal conglomerates and sandstones and the upper section of carbonaceous shales with thin carbonate beds.

The onlapped Cretaceous carbonates are in angular unconformity above the folded and faulted rocks of the Bladen Volcanic Series and Santa Rosa Group.

Quaternary sediments of the study area are mostly coastal plain alluvium and stream gravels and sands.

During the Permo-Triassic orogeny, Paleozoic sedimentary and igneous rocks were folded and metamorphosed and later intruded by plutons within the Maya trough. Tectonite fabrics were imposed during and after the Permo-Triassic orogeny. Major faulting occurred in the Jurassic in response to rifting of the American and African plates.

The volcanic rocks are intensely sericitized due to both post-emplacement alteration and low-grade regional metamorphism.

Analysis of stream sediment samples showed low values for most trace elements other than barium in the study area.

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The Bladen Branch of the Monkey River looking northwest toward the southern Maya Mountains.

INTRODUCTION AND ACKNOWLEDGMENTS

The Bladen Volcanic Series of the southern Maya Mountains was studied as a thesis project for a degree of Master of Science in Geology at the Colorado School of Mines.

The thesis work included mapping the geology of the southern Maya Mountains on a reconnaissance basis at a scale of 1:50,000 (Plate I). A detailed geologic map of the East Bladen-Trio area with a scale of 1:12,500 was also prepared during thesis field work (Plate II). Field mapping included detailed stratigraphic work, the style and intensity of metamorphism, and observations of mineralization and alteration. Samples were collected for petrographic and geochemical analysis. The field work was accomplished during the spring and summer of 1976 and the laboratory work in the fall of 1976.

The Mineral Resources Division of the Anschutz Corp., Denver, Colorado, financially supported the field and laboratory work as part of their exploration program in Belize, Central America. I would like to thank Dr. D. A. Andrews-Jones for the support and information made available to me during this study.

The suggestions and support of my thesis chairman, Dr. R. C. Epis and members, J. J. Finney, S. B. Romberger and D. A. Andrews-Jones, in the field and laboratory are greatly appreciated.

I wish also to thank Kenneth E. Hugh for his guidance in the field and initiating me to jungle geology.

Special thanks goes to my workers, Arnaldo Sanchez, Antonio Puk and Gustavo Puk, whose hard work and rice and beans kept me on the go.

LOCATION AND GEOGRAPHY

Belize, formerly British Honduras, is located along the eastern coast of Central America. It is bordered to the north by Mexico and to the south and west by Guatemala. The study area is located in south central Belize and is the southern range of the Maya Mountains (Figure 1).

The study area is unsurveyed, but form line maps compiled from air photo coverage give a locally accurate representation of relative elevations. The area can be found on 15' quadrangle sheets 34, 35 and 38 of Defense Survey, Ministry of Defense, United Kingdom series E755, edition I-GSGS.

Access to the southern Maya Mountains is by means of the southern highway, an all weather dirt road connecting Stann Creek Town to Punta Gorda. The Bladen base camp is five miles northwest of the southern highway on a dry season dirt road. Access into the study area is by means of stream and bush traverses. The number of days spent on a traverse were limited by the water supply of the area and amount of supplies that could be backpacked. The average traverse lasted around eight days, although 23 days were spent on one traverse along the Trio branch of the Monkey River.

Topography in the area is extremely rugged with relief in many drainages of 2000 feet or more. In the central section

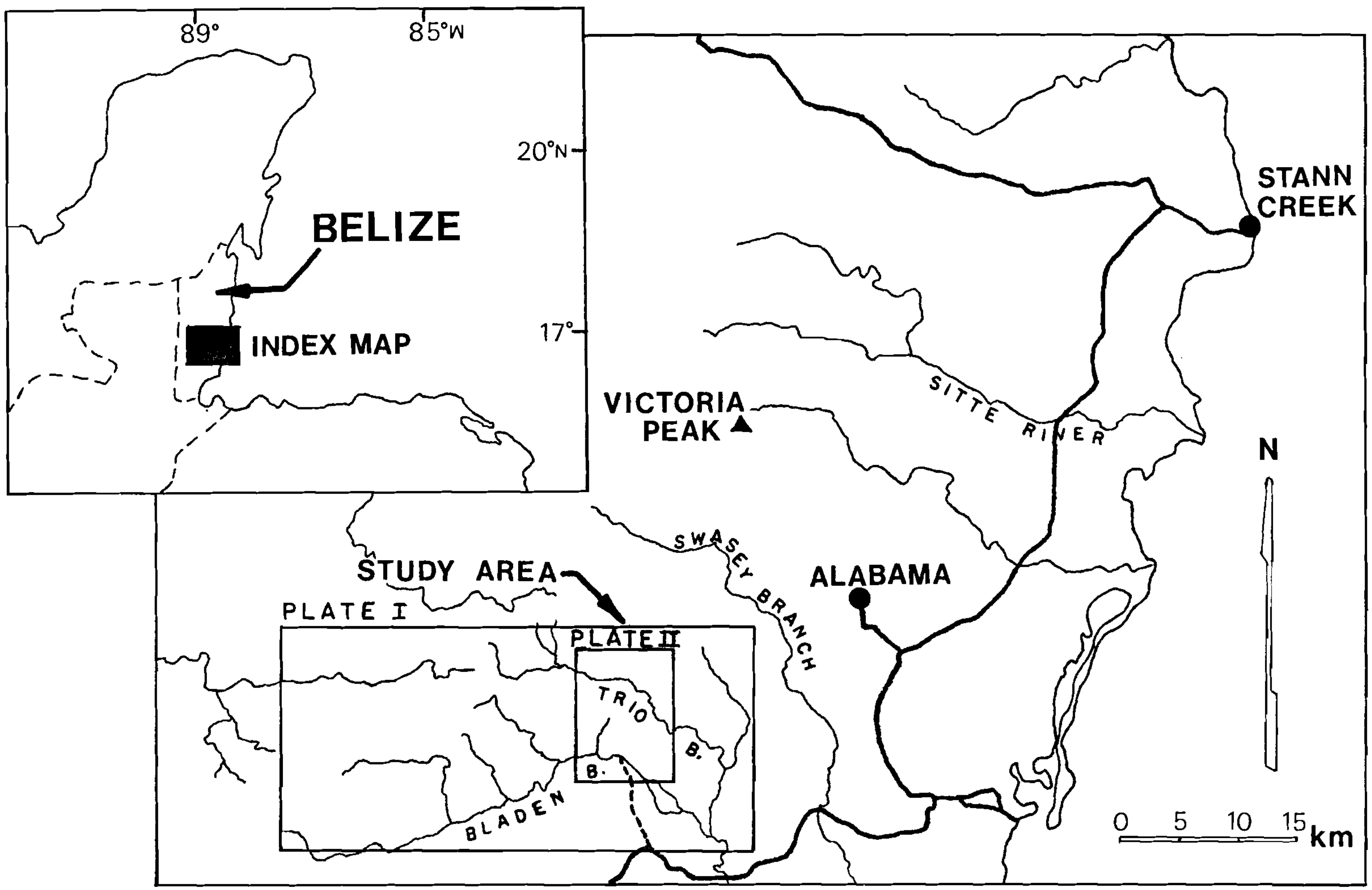

Figure 1 - Index map showing location of study area

of the area, steep canyons and vegetation limited access into smaller drainages.

The climate is tropical being 17° north of the equator. The area is covered by dense, lush jungle, particularly along the stream valleys.

The dry season usually begins in December and lasts until May or June. During the wet season the area is easily hit by hurricanes as evidenced by blow-down areas in the jungle.

PREVIOUS WORK

Observations on the geology of the southern Maya Mountains were first carried out by Sapper (1899), who recorded as one unit the metamorphic and fossiliferous Paleozoic sediments. He also recognized granite intrusives in the northern Maya Mountains and a quartz porphyry in the Bladen area.

Ower (1928) also recognized the equivalence of the metamorphic and fossiliferous sediments, and compiled the first geologic map of British Honduras. He also combined the Bladen porphyry with the granites as acid intrusions, but further observed that the southern porphyry probably embraced sills, dikes, flows and ash beds.

Dixon (1950-55) mapped the area in somewhat greater detail, and divided the Paleozoic sediments with an unconformity. He believed that during this hiatus the granites were intruded and eroded.

In 1971, Bateson and Hall reported that field and structural evidence supported Sapper and Ower in the recognition of the continuity of the Paleozoic sediments. They suggested that the sequence be renamed the Santa Rosa Group, and the porphyry, which was mapped as a complex volcanic pile, be called the Bladen Volcanic Member. The granites that intruded the Paleozoic rocks were considered by

Bateson (1972) to be Triassic in age based on radiometric data. Volcanism was placed during the late Paleozoic (Carboniferous?) by stratigraphic and paleontologic evidence (Hall & Bateson, 1972). This agrees with the radiometric age of 300 million years (Hurley et al, 1968) for three Rb:Sr whole-rock analyses of the volanics. Bateson and Hall (1975) published a report on the Maya Mountains and a geologic map of a scale of 1:130,000 that included the study area.

GEOLOGIC SETTING

The Bladen Volcanic Series is located along the southern boundary fault of the Maya Mountain uplift in south-central Belize. The Maya Mountains are an uplifted horst block of Paleozoic rocks. This block has an overall internal structure of a synclinorium closing eastward and plunging about 10 degrees toward the west-southwest (Bateson, 1972).

Figure 2 is a generalized geologic map of Belize. It shows the Maya Mountain uplift surrounded by onlapping Cretaceous carbonates and Quaternary coastal sediments. The Maya Mountains are bounded on the north and south by normal faults.

The Santa Rosa Group is a sequence of tightly folded, steeply dipping Permo-Pennsylvanian sedimentary rocks that have undergone low grade regional metamorphism. They comprise most of the Maya Mountains and consist of a lower arenaceous section with local basal conglomerates and an upper argillaceous section which includes thin crinoidal carbonate beds.

The igneous rocks of the Maya Mountains have long been a controversial subject with regards to both their origins and ages. The intrusive rocks which noticeably rim the peripheral limbs of the synclinorium are now thought to represent multiple intrusive episodes of igneous activity from the Devonian to the Triassic (Bateson, 1972 and Shipley, 1978).

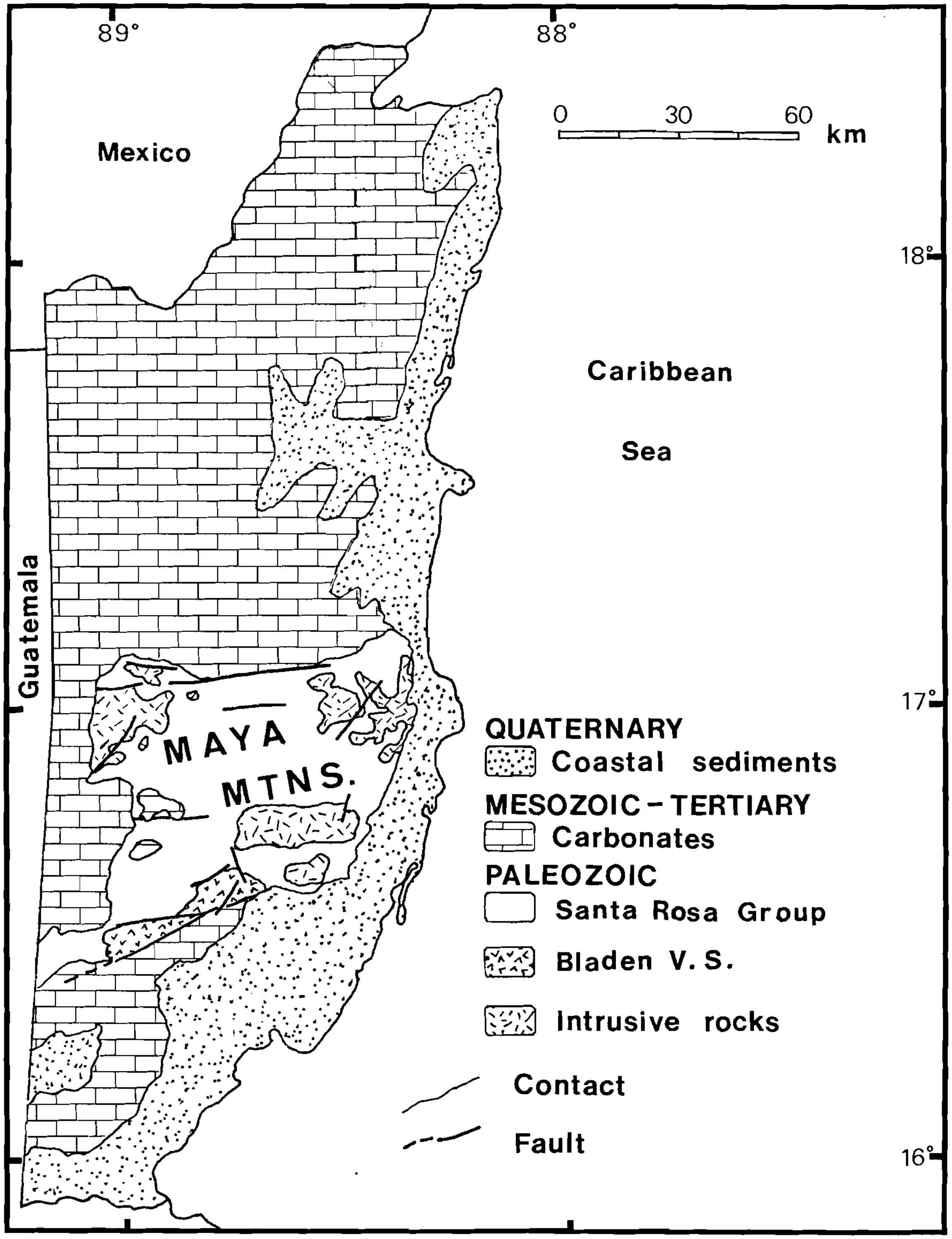

Figure 2 – Generalized geologic map of Belize, C. A.
(modified from Bateson and Hall, 1975)

Extrusive rocks occur mainly in the southern Maya Mountains although subvolcanic rocks and welded tuffs have been observed along the northern limb of the synclinorium (Shipley, 1978). Detailed mapping of the volcanic rocks in the study area has shown that these extrusives are not a member of the Santa Rosa Group. These volcanics consist of a complex folded and faulted sequence of flows, breccias, ash-flow tuffs and volcanic sediments probably underlain by a Middle to Early Paleozoic basement complex. Figure 3 shows a contour map of the top of the volcanic rocks. The contours parallel the general structure of the north dipping limb of the synclinorium and coincide with exposures of the volcanics. Basement contours for the Maya Mountains delineate this plunging synclinorium and also agree with exposures for most of the igneous rocks.

Stratigraphically above and unconformable with the Bladen Volcanic Series is the Santa Rosa Group. A sequence of basal conglomerates and medium-grained sandstones occur in the lower section of the group. This grades into a thick sequence of siltstones and shales that are moderately phyllitic and occur with thin, discontinuous beds of crinoidal limestones and dolomites.

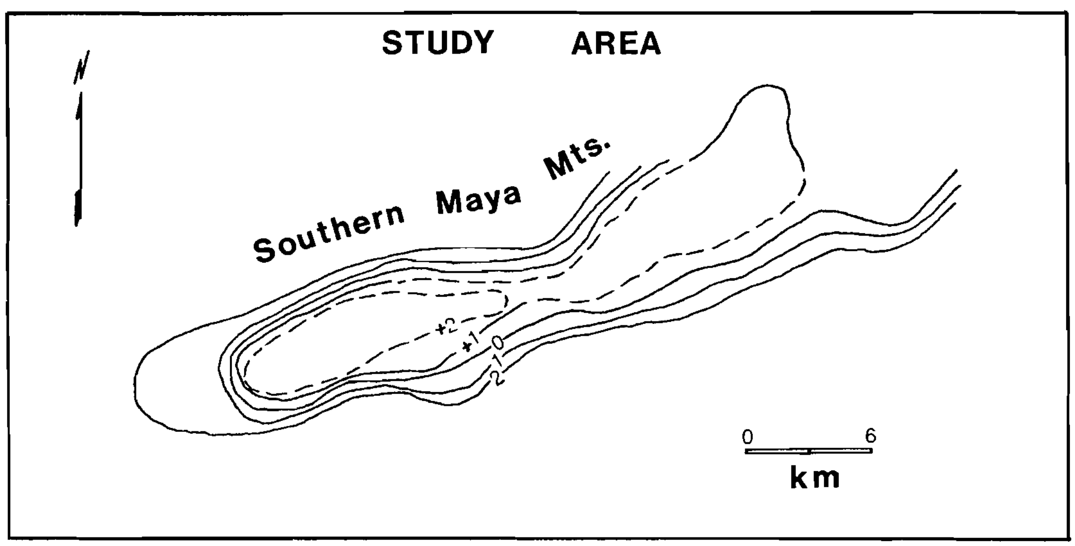

Figure 3 - Contour map of the depth to relative basement (volcanics) as interpreted from a high resolution aeromagnetic survey of Belize. Contour interval = 1000 feet, (modified from Deguen et al, 1975). Datum is sea level.

BLADEN VOLCANIC SERIES

The Bladen Volcanic Series is a sequence of volcanic thickness of the Bladen Volcanic Series in the study area is probably around 5000 to 6000 feet. A late-Paleozoic age has been assigned to these volcanics based on their stratigraphic position below the Permo-Carboniferous sediments of the Santa Rosa Group. Previous investigators (Hurley, et al, 1968) suggested an age of 300 million years (Middle Pennsylvanian) based on three Rb:Sr whole-rock analyses of volcanic rocks from the area.

The sequence in the East Bladen-Trio area consists of lava flows, flow breccias, ash-flow tuffs, air-fall tuffs and tuffaceous sedimentary rocks, and laharic and tuff breccias, with compositions ranging from rhyolitic to dacitic. Minor sub-volcanic intrusions (IPvd) of acid to intermediate composition occur as dikes and sills in the western portion of the study area. Two complete sections in the volcanic rocks were measured during field work, one along the Trio Branch of the Monkey River and another between the Bladen and Trio Branches near the western boundary of the area. These sections correspond closely to the two cross-sections through the East Bladen-Trio area (Plates II and III).

The volcanic rocks are grouped into units and are, from oldest to youngest: latite flows and flow breccias ($\mathbb{P}vf_1$); laharic breccias and tuff-breccias ($\mathbb{P}vt_1$); quartz latite ash-flow tuffs and rhyolite to latite flows ($\mathbb{P}vf_2$); air-fall tuffs ($\mathbb{P}vt_2$); latite to quartz latite ash-flow tuffs ($\mathbb{P}vf_3$); air-fall tuffs and tuffaceous sandstones ($\mathbb{P}vt_3$); and dacite flows and ash-flow tuffs ($\mathbb{P}vf_4$) intercalated with $\mathbb{P}vt_3$ (Plates II and III).

Latite Flows and Flow Breccias

The oldest unit in the study area is a series of dark gray-green to reddish black, propylitized, biotite latite flows and flow breccias ($\mathbb{P}vf_1$) with a total exposed thickness of 500 feet. The individual flow units are between 100 and 200 feet thick. The flow breccias consist of subangular blocks ranging from 5 centimeters to 0.5 meter in diameter, in a matrix of the same composition (Figure 4). Flow banding is common in the flow units and in some of the autobrecciated flow fragments.

In thin section the rocks are porphyritic-aphanitic to porphyritic-glassy, biotite latites (Figure 5). Phenocrysts comprise about 20-30% of the rock and are set in a devitrified groundmass of feldspar microlites and iron oxides. The phenocrysts are 50% sanidine, 40% plagioclase, 10% biotite altered to chlorite, 8% magnetite and less than 1% quartz.

Figure 4 - Latite flow breccia ($\mathbb{P}vf_1$) along the Trio Branch. B = subangular breccia fragments with distinct flow banding. Matrix is of the same composition. Pen is 15 cm long.

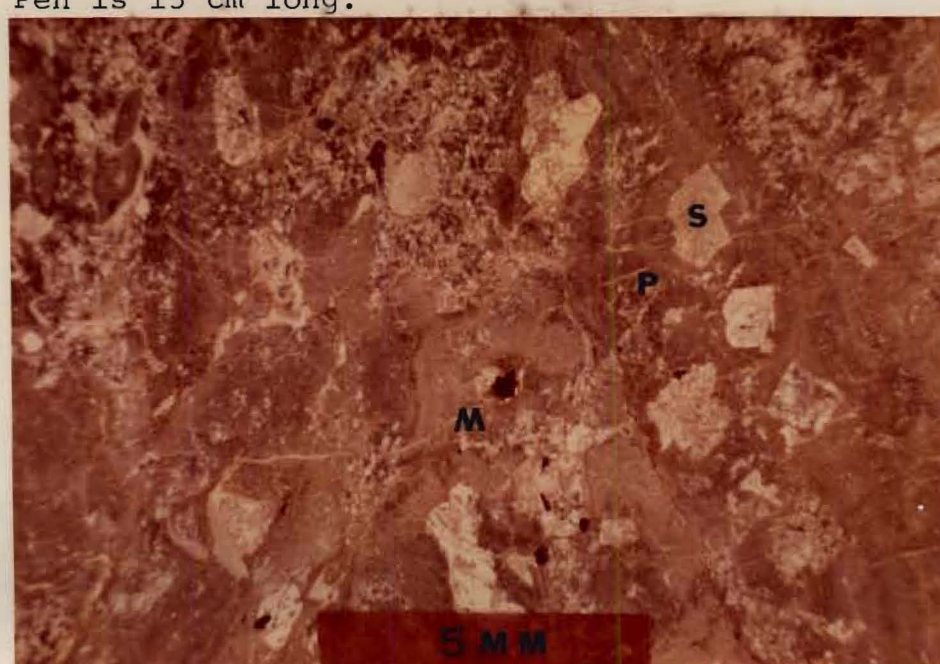

Figure 5 - Photomicrograph of latite flow, crossed polars, S = Sanidine, P = plagioclase, M - magnetite altered to iron oxide. Ground mass is sericitized and composed mainly of devitrified glass showing perlitic cracks.

The sanidine crystals are zoned and the plagioclase is oligoclase. Biotite is absent in some of the units which may contain from <1 to 3% zircon and apatite. Perlitic cracks in the original glassy matrix have been preserved by selective sericitization and iron oxide staining along the conchoidal fractures. Moderate alteration of the plagioclase to calcite and sanidine to sericite is common.

Outcrops of the latite flows and flow breccias are best seen along the creeks and rivers near the Southern Boundary fault system (Plate II) in the southern part of the study area. Contacts between the different flow units are poorly preserved. The unit as a whole varies little in thickness throughout the study area.

Laharic Breccias and Tuff-Breccias

Overlying the latite flows and flow breccias is a series of intercalated gray-black laharic breccias and tuff breccias (Pvt_1). This unit was not deposited over the entire study area and is absent along traverse lines in the western portion (Plate II). The unit thins toward the west with some pinching out of tuff breccia units observed along the Trio Branch. The maximum thickness of the unit in the study area is 600 feet. The laharic breccias consist of angular to subangular breccia blocks ranging in size from 2 cm to 1 meter in diameter (Figure 6). The blocks are fragments of the underlying latite flows

Figure 6 - Laharic breccia ($\mathbb{P}vt_1$) from Trio Branch showing rolled and unsorted, angular breccia fragments of flow banded latite ($\mathbb{P}vf_1$). Matrix is devitrified gray ash. Scale is 15 cm.

and flow breccias and exhibit rolled features in the light-gray, porous ash. Broken crystals and lapilli were observed in small quantities in some units. The laharic breccias are poorly-sorted, poorly-indurated units measuring 100 to 300 feet in thickness.

The tuff-breccias consist of accidental lithic fragments of argillized latite flows and black consolidated ash in a matrix of gray, crystal-rich ash. Lithic fragments comprise over 30% of the tuff. The tuff breccias are interbedded with the laharic breccias and range in thickness from 20-75 feet. The crystals are broken and consist of altered plagioclase and sanidine. Little or no compaction of these units was observed in the field.

Quartz Latite Ash-Flow Tuffs and Rhyolite to Latite Flows

The next unit in the sequence consists of a series of quartz latite ash-flow tuffs and rhyolite to latite flows ($\mathbb{P}vf_2$). The lower section of the unit is a quartz latite crystal-lithic ash-flow tuff measuring 300 feet in thickness. It is a multiple flow, compound cooling unit with at least two separate densely welded zones each about 25 feet thick (Figure 7). Above this ash-flow is an eruptive sequence of rhyolite to latite flows and another quartz latite ash-flow tuff. The flows were only observed in the western portion of the study area where they measure 25 to 100 feet in thickness.

Figure 7 - Columnar jointing in a quartz latite ash-flow tuff ($\mathbb{P}vf_2$) looking west in a north-south creek along the western boundary of the study area. Columns on the right are 20 cm x 3 meters.

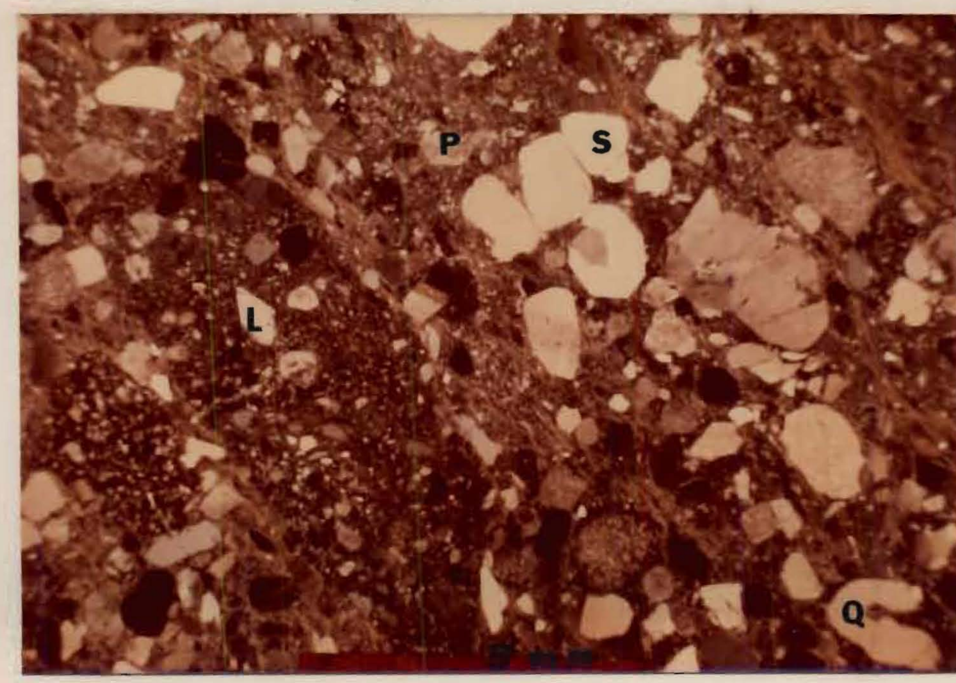

Figure 8 - Photomicrograph of a moderately welded zone showing compaction layering in a quartz latite ash-flow tuff, crossed polars. Q = quartz, S = sanidine, P = plagioclase, L = lithic fragments of welded crystal ash-flow tuff. Matrix is devitrified glass.

In thin section the ash-flow tuff in the lower part of the unit shows variation in crystal and lithic percentages between different eruptive units. The crystals comprise between 25 to 40% of the rock and consist of sanidine 40%, plagioclase 30%, and quartz 30%. Lithics, which are mainly fragments of underlying ash-flows and crystal tuffs, show pronounced flattening in the welded zones (Figure 8). The matrix consists of partly devitrified glass shards and ash that have been moderately sericitized. Compaction features are well developed in the ash-flow tuffs.

The flows in the western part of the study area are porphyritic-aphanitic lavas of rhyolitic, trachytic and latitic composition. A trachyte flow measuring 40 feet in thickness (Figure 9) was observed to consist of turbid, pink microclinized sanidine phenocrysts in a partly recrystallized trachytic groundmass. The sanidine was converted to microcline by thermal re-equilibration during regional metamorphism. A rhyolite flow, 60 feet in thickness, shows distinct glomeroporphyritic texture with large (3-5 mm) phenocrysts of embayed quartz.

Air-Fall Tuffs

Air-fall tuffs ($\mathbb{P}vt_2$) are composed of broken crystal fragments of sanidine, plagioclase, and minor quartz in a light gray ash matrix. Many of the tuffs are rich in both

Figure 9 - Hand sample of trachyte porphyry (ℙvf_2) from North Creek. Phenocrysts of sanidine = S show flow alignment in a trachytic groundmass of sanidine laths, iron ore and cryptofelsite. Minor biotite is also present.

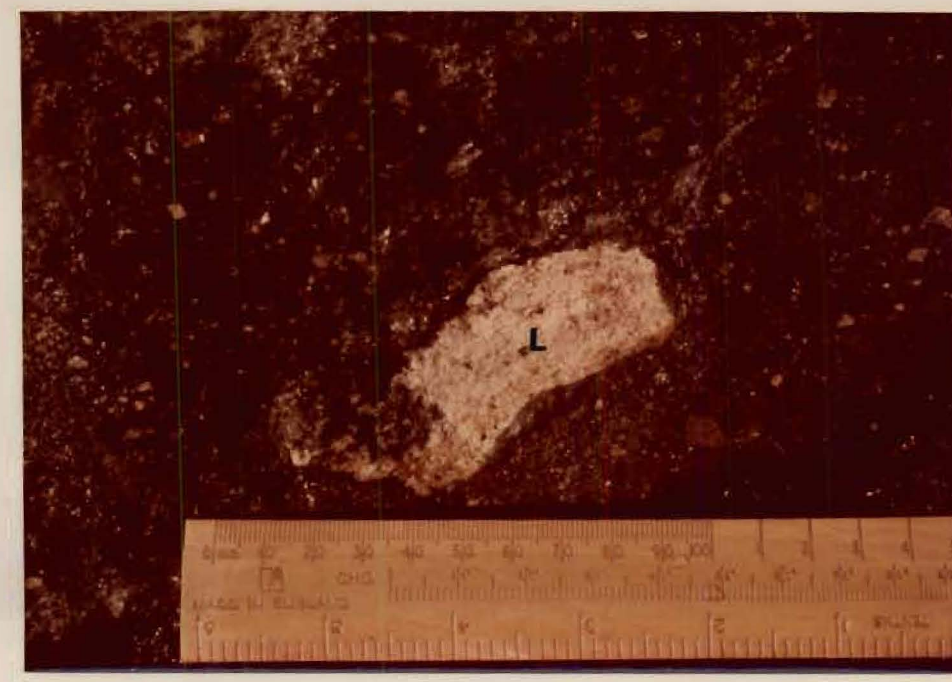

Figure 10 - Hand specimen of a crystal-lithic air-fall tuff (ℙvt_2) from the Trio Branch. Large lithic fragments = L of altered porphyry. Matrix is accidental crystal fragments and volcanic ash and lapilli. Scale in mm and inches.

crystals and lithics (Figure 10). The lithic fragments are derived predominantly from older pyroclastic and flow rocks. Some of the tuffs are interbedded and show distinct layers of alternating crystal-rich and crystal-poor tuff. The unit varies in total thickness between 500 and 600 feet. In the few exposures observed, this unit is moderately indurated and uncompacted and because of its soft, porous nature, it is poorly exposed throughout the study area.

Latite to Quartz Latite Ash-Flow Tuffs

Overlying the air-fall tuffs is a 550-foot thick sequence of latite and quartz latite ash-flow tuffs ($\mathbb{P}vf_3$). The ash-flows are mainly simple cooling units that are rich in both crystals and lithic fragments. The crystal-lithic ash-flow tuffs show some compaction layering. Near major faults the principal planar structure is tectonic flattening and stretching of lithic fragments of quartzite (Figure 11). A densely welded vitrophyre was observed in a latitic crystal-lithic ash-flow tuff along the Trio Branch (Plate II and III) but was not located in any of the other traverses to the west.

In thin section the ash-flow tuffs are moderately welded and strongly compacted, light gray, crystal-lithic, biotite quartz latite to latite ash-flow tuffs (Figure 12). The crystals comprise 20-30% of the rock and are approximately 40% plagioclase, 50% sanidine and 10% biotite. The plagioclase is zoned sodic andesine with more calcic cores. The

Figure 11 - Hand sample of a moderately welded crystal-lithic ash-flow tuff from Trio Branch. Lithic fragment (L) of quartzite showing strong tectonic flattening.

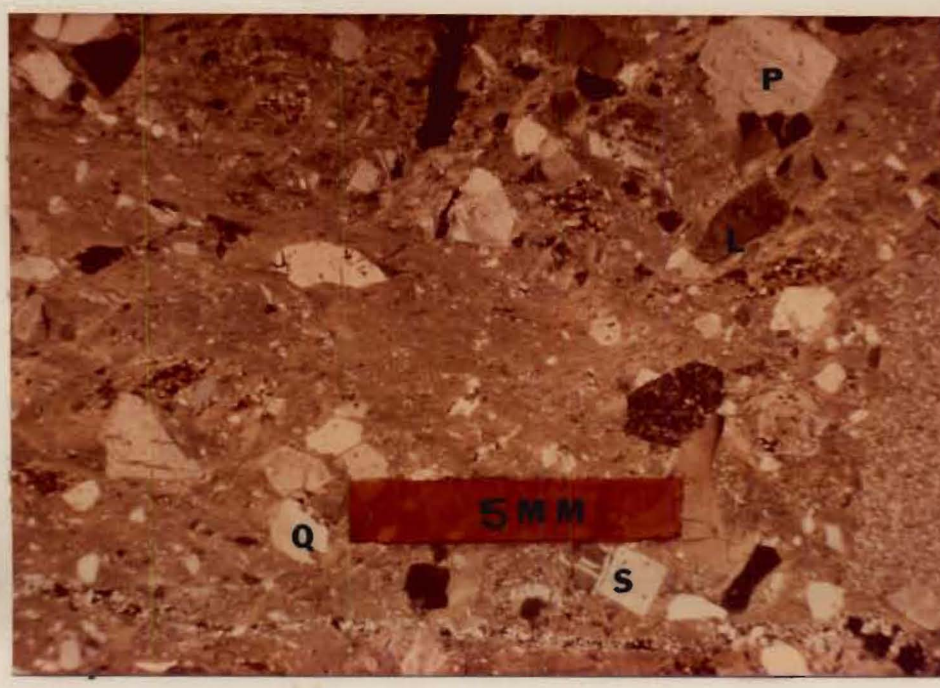

Figure 12 - Photomicrograph of hand sample in Figure 11, crossed polars. L = lithic fragments of quartzite, S = sanidine, P = plagioclase, Q = quartz. Groundmass shows tectonic layering that is intensified by sericitic alteration.

biotite occurs in clusters and most of the grains are altered to chlorite and iron oxide. Sericite has replaced much of the devitrified groundmass and enhances compaction textures in thin section (Figure 12). Accidental lithic fragments of quartzite, probably from the underlying metamorphic basement complex comprise about 10% of the rock. The presence of quartzite fragments and the absence of arkosic sandstone and shale fragments supports this older basement complex below the volcanics. The lithics range in size from 4 mm to 6 mm in the elongated dimension.

Outcrops of this unit occur mainly along the Trio Branch just before it bends to the west (Plate II). Exposures are good and contact relationships within the unit are easily observed.

Air-Fall Tuffs and Tuffaceous Sandstones

Above the ash-flow tuffs is a series of pyroclastics and tuffaceous sedimentary rocks ($\mathbb{P}vt_3$) intercalated with numerous dacitic eruptives. The air-fall tuffs are similar in texture and composition to the air-fall tuffs of $\mathbb{P}vt_2$ with the exception of fewer lithic fragments derived from the older volcanics. The tuffaceous sandstones (Figure 13) are a composite of pyroclastic lapilli and ash, and subangular to subrounded, medium grained arkosic sand. The thickness of this unit is extremely variable ranging from 50 to 500 feet. In

Figure 13 - Hand sample of tuffaceous sandstone (IPvt$_3$) from Trio Branch. L = lithic fragments of consolidated ash. Matrix is partly fine to medium-grained sand with abundant crystal fragments of quartz and K-feldspar.

the northeastern part of the study area at the Trio Branch's southern bend (Plate II) the Permian basal conglomerates of the Santa Rosa Group rest unconformably above this unit. The western section is much thicker and along creeks draining into the Trio Branch local unconformities were observed between the tuffs and underlying dacite extrusives; underclays and thin soil development were diagnostic.

Dacite Flows and Ash-Flow Tuffs

Intercalated with the air-fall tuffs and tuffaceous sandstones are medium to dark gray, biotite dacites and ash-flow tuffs. They range in total thickness from 100 to 400 feet. The flows are porphyritic-aphanitic and show moderate planar flow structure. Along the Trio Branch a 100-foot thick biotite dacite flow is the only member of this unit. In the northwest portion of the area the flows are thicker and more numerous with a 250-foot welded dacite ash-flow tuff exposed under the flows along the Trio Branch (Plate II and III).

In thin section the biotite dacite flow that occurs near the southern bend of the Trio Branch (Plate II) consists of zoned andesine (An_{35}) phenocrysts in a groundmass of sodic andesine laths, and altered biotite grains (Figure 14). Plagioclase phenocrysts represent about 25% of the rock and biotite about 5%. Microclinized sanidine is present in small amounts in some sections and an occasional corroded quartz crystal is

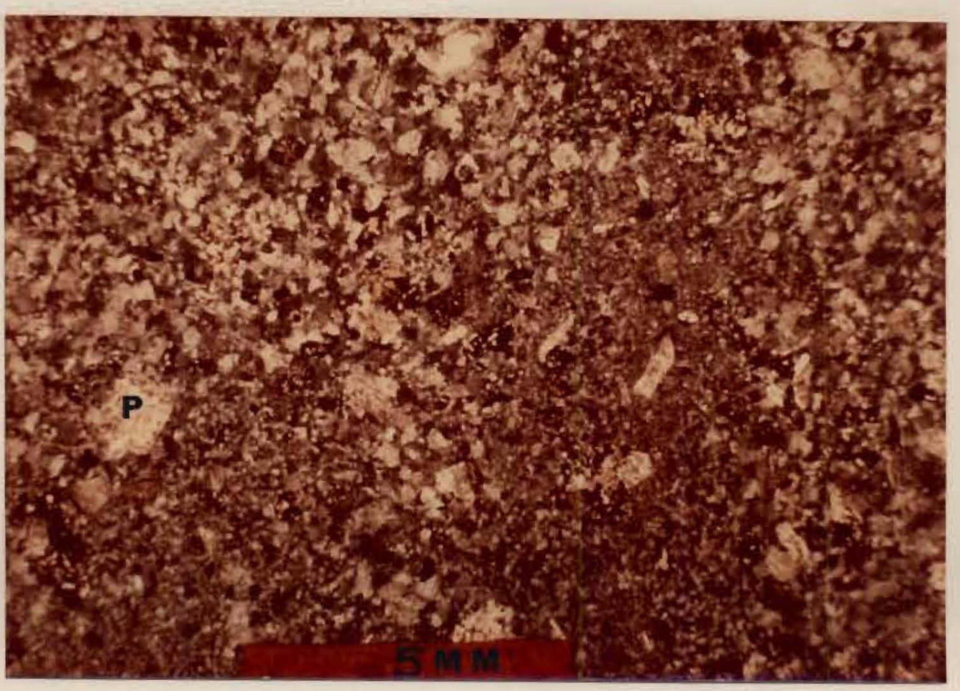

Figure 14 - Photomicrograph of a dacite porphyry (IPvf$_4$) from Trio Branch, crossed polars. P = plagioclase is andesine. Groundmass is composed of microlites of feldspar, quartz, biotite altered to chlorite and iron oxides.

not uncommon. Many of the sections show propylitization with the plagioclase altering to calcite, albite and epidote. Biotite alters to chlorite and iron oxide. A single section showed uralitization of a pyroxene phenocryst.

Acid to Intermediate Subvolcanic Intrusions

Intrusive rocks occur in the western portion of the study area and appear nearly contemporaneous with volcanism. The dikes and sills range between 20 and 100 feet in thickness. Where contacts are exposed, typical glassy margins are now devitrified. Forceful injection features are also common and wall rock plucking was observed in one exposure.

In thin section a rhyolite porphyry dike (Figure 15) with 20% phenocrysts consists of 40% partly corroded bipyramidal quartz, 50% thermal re-equilibrated sanidine and 10% sodic oligoclase. The groundmass is a sericitized cryptofelsite. Many of the phenocrysts show clustering giving a distinct glomeroporphyritic texture.

Outcrops are good but because of numerous shears and faults in the area exposures are discontinuous and erratic (Plates II and III).

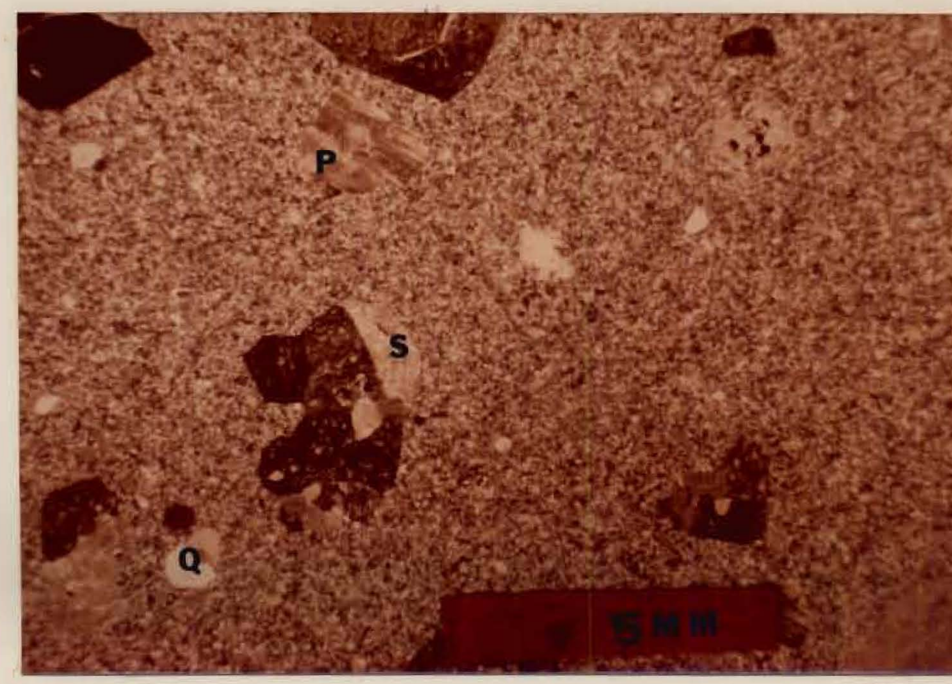

Figure 15 - Photomicrograph of a rhyolite porphyry dike (IPvd), crossed polars. S = sanidine, Q = quartz, P = plagioclase. The groundmass, partly altered to sericite, is a mixture of quartz, sanidine, and plagioclase with small amounts of magnetite. Zircon and apatite occur as rare accessories.

SANTA ROSA GROUP

The Santa Rosa Group is a thick sequence of predominantly marine sedimentary rocks deposited during the Permian in a subsiding trough or basin. This sequence lies above and unconformable with the Bladen Volcanic Series. The contact of the Santa Rosa Group with the underlying Bladen Volcanic Series is an erosional surface that truncates the upper units in the volcanics.The contact, which closely parallels the northern drainage of the Trio Branch (Plate II), is usually covered by recent stream alluvium. The lower section of the Santa Rosa Group is composed of an arenaceous facies consisting of basal conglomerates and sandstones ranging from 200 to 500 meters in thickness. The section grades into an upper section of carbonaceous shales and mudstones with local fossiliferous dolomites approximately 200 meters in thickness. The Santa Rosa Group is principally a transgressive episode starting with a basal conglomerate that was deposited on an eroding volcanic pile. Minor fluvial channels with graded bedding were observed on top the volcanics in the northwestern portion of the study area.

This sequence is best exposed in the northeast part of the study area. Along the northwest portion of the area numerous faults make contact relationships hard to follow. The sediments of the Santa Rosa Group in the downthrown side of the Sapote fault are not easily correlateable with those to the north, but they also appear to be part of the same transgressive sequence (Plates II and III).

Conglomerates and sandstones

The lower section of the Santa Rosa Group is an arenaceous facies composed of conglomerates and sandstones (Pss). This sequence represents an initial transgressive episode.

A series of lag conglomerates, 0.5-2 meters in thickness, are interbedded with coarse arkosic sandstones that show definite graded bedding. Units that show graded bedding are between one and three meters thick and fine upward from granules to medium sand. Figure 16 shows an outcrop of the basal conglomerate and graded beds. The basal conglomerates are silicified, sericitized sandy quartz pebble conglomerates. Sorting is moderate to poor with very slight orientation of pebbles and cobbles along bedding planes. The matrix, originally silt and clay, has been recrystallized to sericite and quartz. The composition of the clasts suggest a mixed terrain for the source rocks. The grains are rock fragments of quartzite, siltstone, tuffaceous sediments, tuffs and flow rocks from the erosion of the Bladen Volcanic Series. Polycrystalline fragments of undulose quartz, orthoclase and muscovite are common.

Figure 17 shows an outcrop of tabular cross-bedded arkosic sandstone that is stratigraphically overlain by intercalated

Figure 16 - Outcrop of the basal conglomerate of the Santa Rosa Group along the Trio Branch looking north.

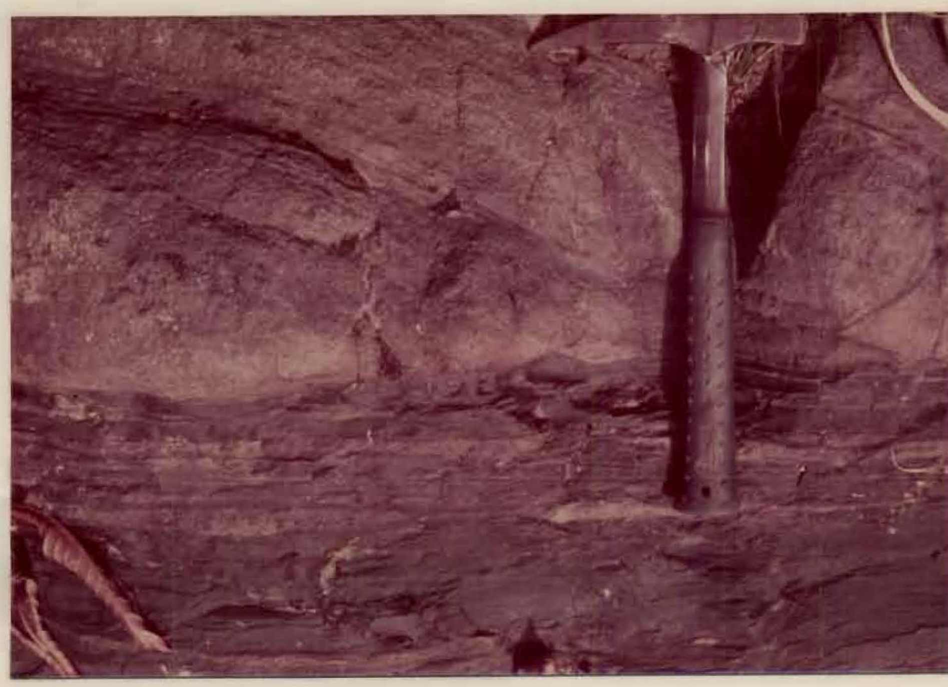

Figure 17 - Outcrop of cross-bedded sandstone and pinch-and-swell structure in intercalated sandstones and mudstones of the Santa Rosa Group.

medium sandstones and mudstones that exhibit pinch-and-swell structure. These are common genetic units within the lower section and occur above the conglomeratic zone. The sandstone is best described as a arkosic wacke due to the high feldspar and quartz content and numerous lithic fragments derived from the volcanics. The feldspar grains are usually orthoclase. Muscovite and undulose quartz are also common in thin section. The matrix is recrystallized to sericite and mosaic quartz with minor hematite stains.

The units of the lower section of the Santa Rosa Group are best exposed along the west bend of the Trio Branch where they dip steeply to the north. These units grade into mottled shales and siltstones, and finally into carbonaceous mudstones of the upper section.

Mudstones and shales

Mudstones and shales (Psm) are the dominant lithology of the Santa Rosa Group. Where the arenaceous units grade into the mudstones and shales, the units are silty claystones and mottled shales. They are well laminated and show distinct bedding that is commonly cross-cut by the major foliation direction produced during regional metamorphism. The mottled shales are carbonaceous and show sericite growth after the clays and feldspars. The mottling appears to be primary and due to bioturbation of the original shale layers.

Figure 18 is an outcrop of shales and mudstones of the upper section. The unit dips northward 65 degrees. The rocks are mildly phyllitic, but only in local areas. This is probably due to a higher clay content in certain layers of the section. Petrographic analysis of the shales reveals that the siltstones are composed of subrounded to subangular quartz and orthoclase grains in equal proportion. The clays are carbonaceous and in thin (0.25 mm) laminations. Small pyrite cubes were observed to be in layers within the clay laminations and were secondary in origin.

Carbonates

The carbonates (Psc) of the Santa Rosa Group are part of the upper section, but because of their resistant weathering habit are a decernible unit. Most of the carbonates are dolomites and a few have been silicified. The carbonates outcrop in the study area along the Bladen Branch of the Monkey River south of the boundary fault, and throughout much of the section in the north. Some of the carbonates show breccia development and slump features. The breccias appear to be of two types, solution breccias and slump breccias. Most of the carbonates are fossiliferous with crinoid stem fragments and an occasional fusulinids. Paleontologic evidence suggests that these carbonates are probably Early Permian (Hall & Bateson, 1972). The carbonates are generally dark gray to black and probably

Figure 18 - Outcrop of mudstones and shales of the Santa Rosa Group showing moderately steep dipping beds that are slightly phyllitic.

represent eroded and transported detritus from reefs that were deposited in death assemblages.

Figure 19 is a photomicrograph of a sandy carbonaceous crinoidal dolomite. Many of the crinoid stems are broken because of transportation from their growth environment. Secondary sparry calcite veins support a fracture filling episode probably during dolomitization.

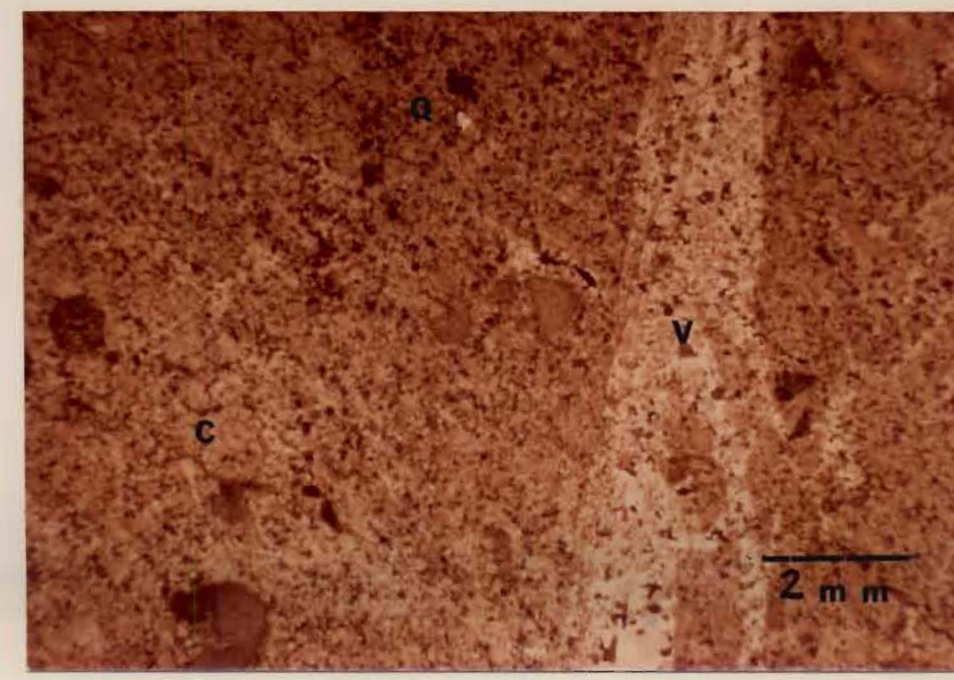

Figure 19 - Photomicrograph of crinoidal dolomite in the Santa Rosa Group. Note crinoid buttons (C) and quartz sand grain (Q). V = sparry calcite vein.

CRETACEOUS CARBONATES

The angular unconformity between the folded and faulted rocks of the Bladen Volcanic Series and the Santa Rosa Group and the onlapped Cretaceous carbonates (Kc) represents a time gap. This contact occurs in the southern portion of the study area where the Cretaceous limestones are faulted against the Paleozoic rocks (Plate II). Near the Southern Boundary fault the limestones are folded in large gently dipping drag folds. On the upthrown side of the Southern Boundary fault in the southwest part of the study area the angular unconformity between the Cretaceous limestone and the Paleozoic rocks is readily observed in the field.

In the study area the major carbonate is the Cretaceous limestones of the Campur Formation (Bateson, 1972 and Ramos, 1975). These limestones are mostly massive, light gray to tan, sublithographic to medium crystalline. They are occasionally brecciated due to solution and karst development. Filled recent sinkholes were observed in the field along the southern border of the study area. There are locally interbedded calcareous shales and ash layers within the limestones, particularly near breccia zones. Only minor dolomitization of the limestone was observed throughout the study area. Some of the lime mudstones are fossiliferous, but the fossils are only fragmental and consist mostly of brachiopod shells.

The thickness of the limestones on the upthrown side of the Southern Boundary fault is several hundred feet. Total thickness of carbonates on the downthrown side of the fault is not known.

QUATERNARY SEDIMENTS

The Quaternary sediments (Qs) of the study area are mostly coastal plain alluvium and colluvium with minor stream sands and gravels. The sediments occur in the southeastern portion of the thesis area. The coastal sediments are mostly silts and sands with sporadic conglomerate lenses of colluvium that were reworked during a transgressive sequence or sequences. River gravels and sands do not occur in the southern Maya Mountains except in local areas of sand bars and partly eroded terraces. This absence is due to the juvenile topography of the area. River sediments do occur where the streams leave the mountains and enter the coastal plain. Large river banks are formed as the streams meander toward the sea through the coastal plain. The sorting of these bars and river bed loads is usually poor, with boulders and silt intermixed. This is because of the sporadic flooding of these drainages during the rainy season. Compositionally, the sediments are mostly composed of Paleozoic volcanics and Cretaceous limestones with occasional Santa Rosa fragments. Where the Bladen Branch drains through the Cretaceous carbonates, travertine may coat the bed load sediments and bank deposits. This usually occurs during the dry season when many of the streams are subterranean and cause ground water pools to form. During field mapping several poorly preserved small terraces were found along the Trio drainage. The highest occurred about 800 feet above the valley floor, and one, and possibly two, between 200 and 300 feet above present stream level. All the terraces resemble gravel bars and bank deposits along the present river course and were probably deposited during Tertiary.

STRUCTURE AND METAMORPHISM

This section is divided into four parts: Regional tectonics, Regional metamorphism and folding, Dynamic metamorphism and transposition foliation, and Faulting.

The regional tectonics will be concerned with the present structural and tectonic setting of nuclear Central America. The other sections will deal with this structural and tectonic framework as it applies to the southern Maya Mountains and in particular, the study area.

Regional Tectonics

The regional tectonics of nuclear Central America has long been a subject of controversy among both geologists and geophysicists. Exceptions to many proposed tectonic models continually plague Caribbean investigators. Yet, it is these exceptions that often provide the clues that help unravel the Caribbean's tectonic history. The Maya Mountains of Belize is one of these anomalous areas. This Paleozoic window is situated near the mid-axis of the western extension of the Bartlett Trough (Figure 20). The block is isolated from the major trend of exposed Paleozoic rocks which lie in a concave northward arc extending from southern Mexico to eastern Honduras. Some investigators (Banks, 1975 and Ramos, 1975) believe the

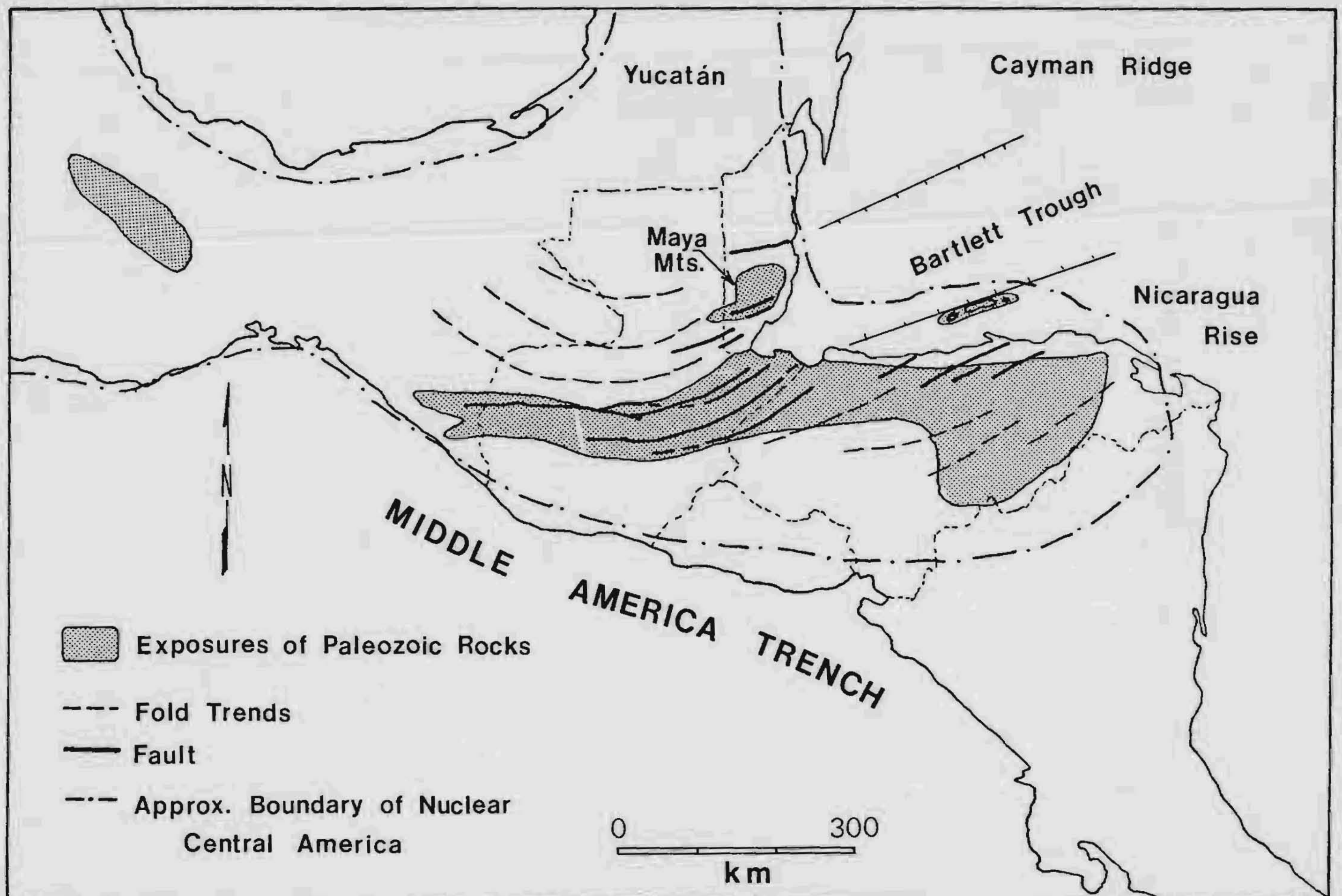

Figure 20-Structure and tectonic map of nuclear Central America. (modified from Kesler, 1971)

Nicaragua Rise is the seaward extension of this arcuate basement high. The major post-Paleozoic fold trends and faults run approximately parallel to this belt (Figure 20).

The Maya Mountains lie along the extension of a synclinal fold axis and associated arcuate faults (boundary faults). Middle to Early Paleozoics, composed of metamorphic and igneous rocks, underlie or are exposed within the Maya Mountains as they are throughout all of nuclear Central America (Kesler, 1971 and Bank, 1975).

Regional Metamorphism and Folding

The rocks of the Bladen Volcanic Series and the Santa Rosa Group have undergone low-grade regional metamorphism of the lower greenschist facies. This regional metamorphism and folding occurred during the Permo-Triassic orogeny and is associated with later plutonic intrusions within the Maya trough. The younger Cretaceous carbonates and the later plutonic intrusives are unaffected by this regional metamorphism and folding.

Numerous mineralogical and textural changes have occurred in the Paleozoic rocks of the Maya Mountains because of this regional metamorphism. All the rocks in the study area exhibit an abundance of sericite with a preferred orientation. This preferred orientation produces a slaty cleavage in the thick sequence of shales and mudstones of the Santa Rosa Group and in the air-fall tuffs, tuff-breccias and tuffaceous sediments of the Bladen Volcanic Series. Occasionally fracture cleavage is exhibited in the sandstones and conglomerates of the Santa Rosa Group and in the ash-flow tuffs, flows and flow breccias of the Bladen Volcanic series. Throughout most of the study area both slaty and fracture cleavage is at an angle to the bedding of the volcanic and sedimentary rocks, it is also more or less parallel to the axial planes of the isoclinal folds (Plates II and III).

Figure 21 is a contour diagram of foliations in the Paleozoic rocks of the study area. The foliations are plotted as poles in the lower hemisphere. The diagram shows a strong perferred foliation with a strike of approximately east-west and a vertical dip. The strike, using contours of 10% and higher, ranges from N65E through E-W to N80W. The dip of this slaty cleavage is symmetrical about the vertical deviating 10 degrees to the north or south.

Other predominant mineralogical changes are the thermal re-equilibration of sanidine to microcline, and the presence of chlorite and iron oxides. Some sanidine crystals have altered to microcline, albite, sericite, clay and chlorite making it extremely difficult to identify the original composition of the rock.

Figure 22 shows a contour diagram of lower hemisphere plotted joint poles. The major joint orientation is between

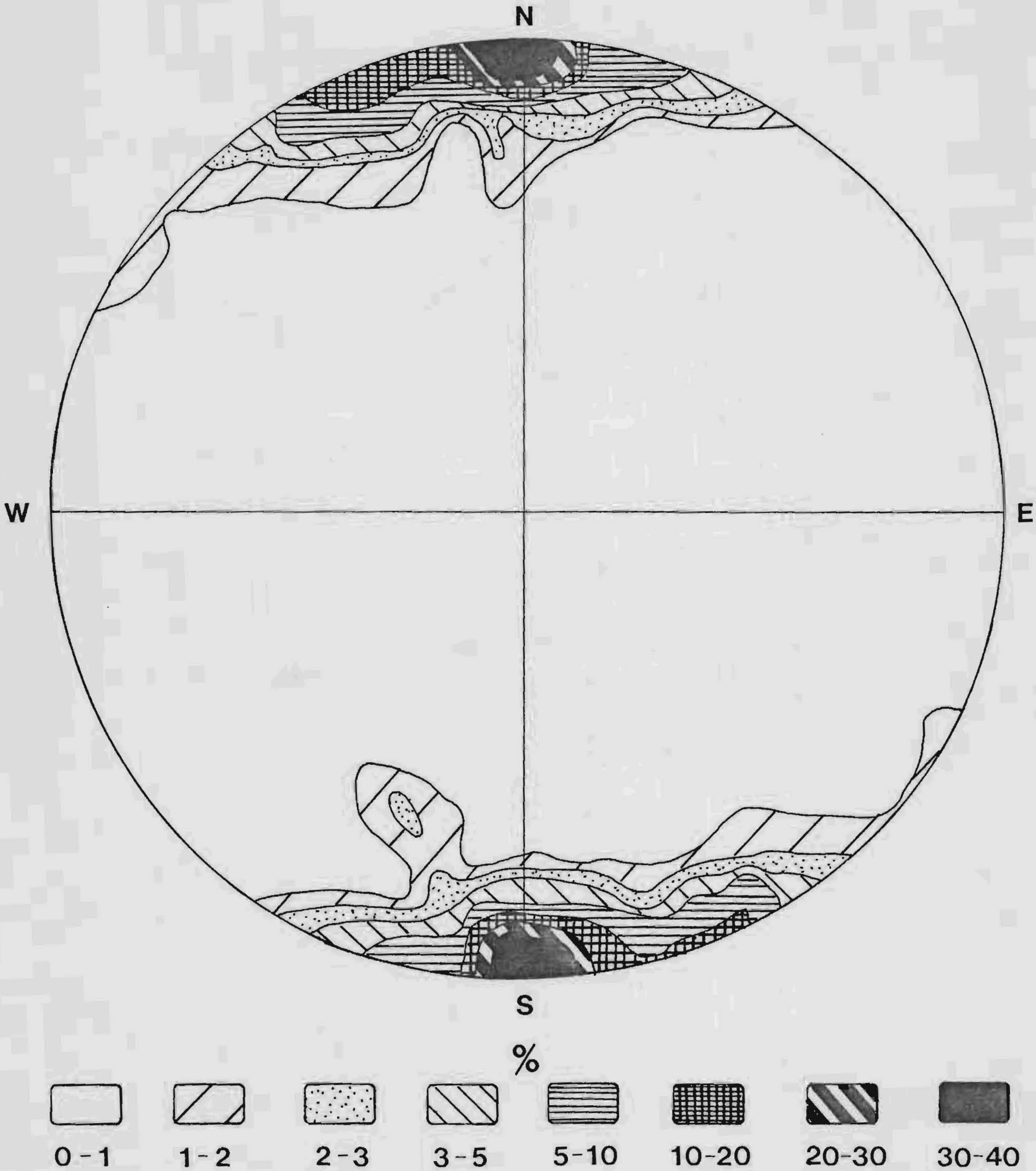

Figure 21-Contour diagram of 98 foliations in Bladen volcanics. Plotted as poles in the lower hemisphere.

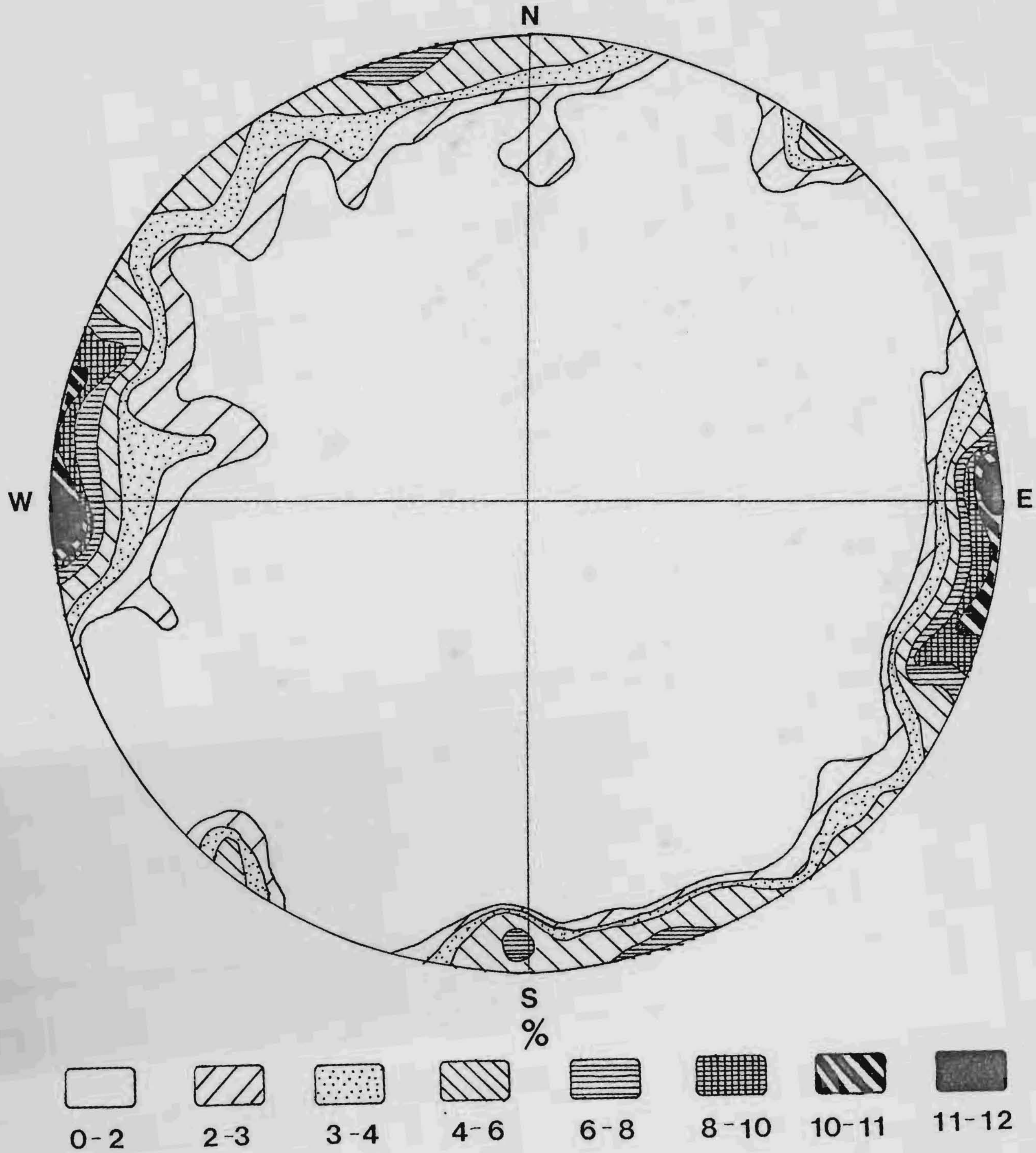

Figure 22-Contour diagram of 114 joint poles in Bladen volcanics.

N5W and N25E with a vertical dip. These joints correspond to cross joints that are more or less perpendicular to the foliation or slaty cleavage. The joints tend to be very regular with respect to the strong foliation direction. These cross joints are associated with quartz-filled gash fractures throughout the Bladen Volcanic Series. A minor joint orientation closely parallels the major foliation direction and is consistent with other closely spaced fractures that are aligned with the slaty cleavage. The 4-6% contours may possibly show a conjugate joint set at 30 degrees and symmetrical to the foliation.

Isoclinal folding of the Bladen Volcanic Series and the Santa Rosa Group produced fold axes trending near east-west (Plate II). Throughout most of the Maya Mountains the majority of the bedding planes dip steeply, and are therefore probably tightly folded. In the study area the folding is much more open and dips of 45° or less are not uncommon (Bateson & Hall, 1977 and this study). The explanation for these gently dipping folds is not known, but could be related to its proximity to Southern Boundary fault. The isoclinal folding probably caused slippage along the axial planes of the folds during the Permo-Triassic orogeny and during later faulting.

Dynamic Metamorphism and Transposition Foliation

Field observations of dynamic metamorphism in the study area suggests that tectonite fabrics were imposed during the Permo-Triassic orogeny and during the later faulting. The dynamic metamorphism was probably a result of large stresses built up along axial planes of folds during the Permo-Triassic orogeny and subsequent movement of these planes during faulting. Renewed faulting occurred after the Triassic in response to early rifting and uplift.

Transposition foliation was the best field criteria for determining the dynamic fabric of outcrops. Transposition foliation is when attenuated fold limbs are replaced by glide surfaces that are parallel to a secondary foliation (Turner and Weiss, 1963). This is illustrated in Figure 23 where the original bedding surface (S_1) has undergone transposition of the lithologic layers into a foliation (S_2) which is the regional metamorphic foliation. The figure shows moderate transposition, but in highly transposed units the original bedding (S_1) can be completely obliterated by the foliation (S_2). Figure 24 is a photomicrograph showing strong transposition foliation. The crystal fragments are displaced along microshears and numerous quartz veinlets have filled the fractures and shears. Other dynamic structural changes include crystal fragments of the tuff showing dynamic abrasion, stretching and the development of an intense foliation best seen by the alignment of sericite.

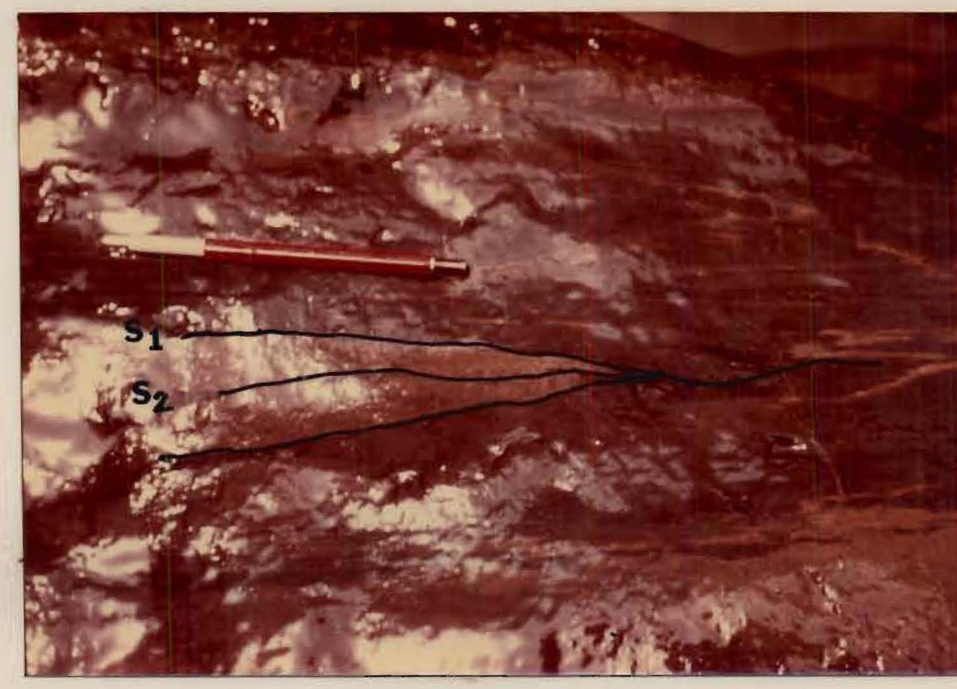

Figure 23 - Transposition of bedding S_1 into a foliation S_2. Pencil is 15 cm.

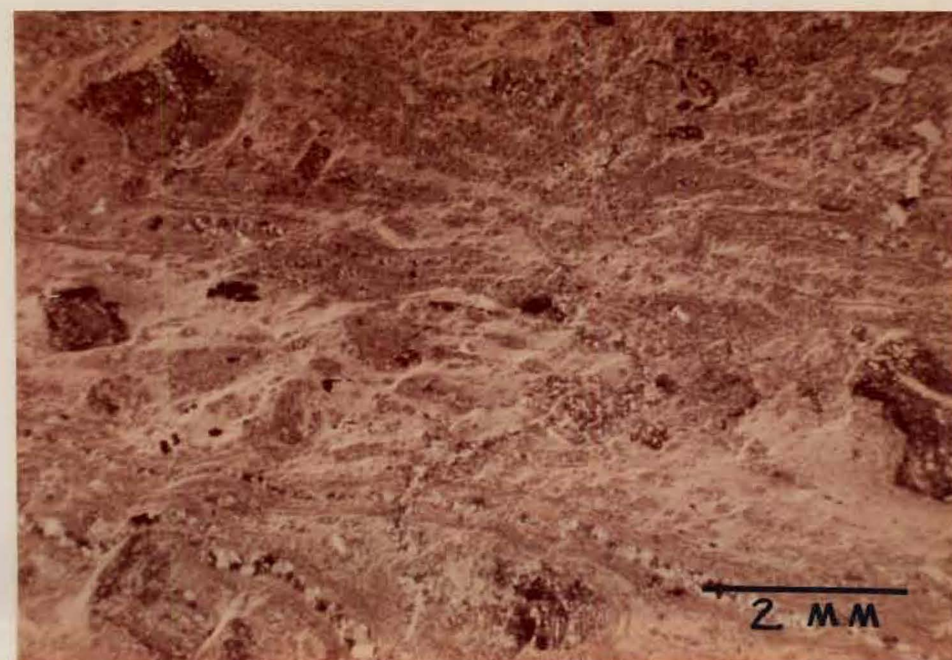

Figure 24 - Photomicrograph showing strong shearing and sericite development due to dynamic metamorphism in an ash-flow tuff.

The incompetent units such as the volcanic sediments and ash-fall tuffs were most readily transposed. The lava flows and ignimbrites, particularly the welded zones, showed brittle fracturing in response to the dynamic metamorphism.

Occasionally, near major faults in very incompetent units such as ashes and air-fall tuffs, dynamic metamorphism caused glide planes to extend several tens of meters into other units. Within these units tightly appressed fold hinges and S-curves were observed (Figures 25 and 26). In some cases the glide surfaces were very apparent and could be traced in outcrop for several meters. Other units have glide planes that have been obliterated by alteration and weathering of the unit.

Faulting

The present horst structure of the Maya Mountains appears to have been initiated at least by Middle Cretaceous time. The Maya Mountain block has been subjected to periodic relative uplift until the mid-Tertiary (Bateson and Hall, 1977). This faulting was of a basin and range style with normal block faulting. This block faulting modified the overall structure of the Maya trough into a shallow, west-southwest plunging synclinorium.

The Sapote and Southern Boundary faults are high angle normal faults located in the southern part of the study area (Plates II and III). The Southern Boundary fault has upthrown

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The Sapote and Southern Boundary faults are high angle normal faults located in the southern part of the study area (Plates II and III). The Southern Boundary fault has upthrown associated with alteration of the lavas and tuffs. The quartz stringers are tenths of a millimeter in width and are associated with sulfide mineralization in the volcanics.

Pyrite is ubiquitous throughout the southern Maya Mountains. It is in the form of small (0.25-2 mm) crystals that are related to hydrothermal alteration or ground water activity. These pyrite cubes are largest and densest in the tuffs and sediments that originally contained good permeability.

The only observed shows of sulfide mineralization were observed during a traverse up Richardson Creek. The host rock is a highly sheared and silicified ash-flow tuff of a quartz latite composition. The sample taken for analysis showed visible sulfides of arsenopyrite and possibly minute amounts of a silver sulfide. The trace element geochemistry of rock sample 18342-3074 (Appendix B) shows the rock to contain 3000 ppm arsenic, 70 ppm vanadium and 1 ppm silver. The sample also contained 1500 ppm barium which occurs as barite and is a gangue mineral along with the extensive quartz webbing. High barium values occur in samples 18316-3094, 18342-3074 and 18400-3106 although only the above showed anomalous metal values.

Two of the samples that were analyzed by emission spectrography (Appendix B) showed anomalous strontium values. Both these samples (18400-3106 and 18402-3099) were highly calcareous with calcium greater than 20% and high manganese

(500 ppm). These limestones and calcareous sediments were highly organic rich, crinoidal lime-mudstone breccias that locally were dolomitized and recrystallized.

MAJOR ELEMENT GEOCHEMISTRY

Analyses of the major elements of selected rocks of the Bladen Volcanic Series are shown in Table 1. This table shows the lavas of the Bladen area to be mostly potassium-rich rhyolites in chemical composition. Sample number 18336-3134 is chemically closer to a quartz latite, and 18376-3178 is a dacite because of the 61% SiO_2 and 3.5% CaO. The dacite also contains over 5% total iron and less than 3% K_2O. Both sample 18326-3159 and 18338-3184 are more trachytic with total alkalis equal or greater than 11%.

The potassic rhyolites have high K_2O percentages (about 7%) and strong calcium depletions, averaging about 0.067 CaO%. The average ratio of K_2O/Na_2O is 2.9, again showing the high potassium versus sodium values. Total iron percentages on the average are less than 2% and MgO around 0.5%. The dacite has a K_2O/Na_2O ratio of about one, and a total iron content of greater than 4.5%.

The majority of the Bladen lavas show pervasive metamorphic sericite which may account for many of the high K_2O percentages. Calcium may be released during the weathering of calcite and clays that were plagioclase before metamorphism and alteration. The low iron and magesium can be attributed to the rarity of ferromagnesium minerals in the lavas.

Table 1. Major element analyses of selected rock samples of the Bladen volcanics. Sample locations shown on Plate IV.

Sample No.	SiO_2%	Al_2O_3%	K_2O%	Na_2O%	CaO%	FeO%	Fe_2O_3%	MgO%	Ba(ppm)
18336-3134	67.6	15.5	6.5	1.0	.095	1.5	1.1	1.7	650
18339-3155B	73.2	11.9	6.5	3.2	.067	.22	.94	.21	200
18326-3159	67.2	14.7	7.7	3.1	.049	.92	.70	.26	200
18329-3159A	70.3	15.5	7.0	3.1	.064	.63	1.4	.64	150
18333-3153A	65.5	12.3	6.9	1.0	.042	.28	1.2	.70	550
18338-3184	67.8	15.1	7.2	4.4	.080	.83	2.1	.31	300
18338-3185	73.6	11.1	7.0	.46	.054	.28	1.0	.61	1500
18376-3178	61.0	14.2	2.8	2.6	3.5	3.9	.71	1.9	800
MPR-8-1	69.7	13.8	6.6	2.7	.081	1.3	1.0	.17	--

All analyses done by Skyline Labs, Inc. using Atomic Absorption

-- analysis not done

MPR-8-1 is a sample from the Mountain Pine Ridge Area

STREAM SEDIMENT GEOCHEMISTRY

During thesis field work in Belize an extensive reconnaissance geochemical sampling program was carried out for mineral exploration. Forty stream sediment samples were collected in the southern Maya Mountains which were later analyzed by Skyline Labs, Inc., Denver, Colorado (Appendix B). The analyses, in general, show low values for most metals with the exception of occasional anomalous zinc, lead and tungsten values. Except for the tungsten, these anomalous values show few or no trends.

Tungsten (Table 2) appears to be highly mobile in the neutral to alkaline waters running through the southern Maya Mountains. It shows a distinct trend along the northwest boundary of the Bladen Volcanic Series. This area is associated with numerous faults and shear zones that could have acted as conduits for mineralizing fluids. Table 2 shows four samples at or above the 2nd standard deviation, which is considered to be the threshold of anomalous values. Of special note is sample number 3104-18388 with a tungsten value of 16 ppm and a barium value of 1050 ppm.

Geochemical anomalies in the Bladen Volcanics were generally moderate with only a few strong anomalous regions (Figure 28). Barium and tungsten showed some anomalous values

Table 2. Geochemical analysis for tungsten (W) from 42 stream sediment samples in the Bladen volcanics. Sample locations shown on Plate IV.

Sample Mean = 6.52 ppm

Standard Deviation = 3.24 ppm

Sample No.	Data(ppm)	Data-1st s.d.
3136-18411	13	3.2
3144-18377	12	2.2
3135-18412	15	5.2
3144-18380	13	3.2
3104-18388	16	6.2
3079-18335	10	0.2
3049-18279	12	2.2

2nd Standard Deviation = 6.47 ppm

Sample No.	Data(ppm)	Data-2nd s.d.
3136-18411	13	0.0
3135-18412	15	2.0
3144-18380	13	0.0
3104-18388	16	3.0

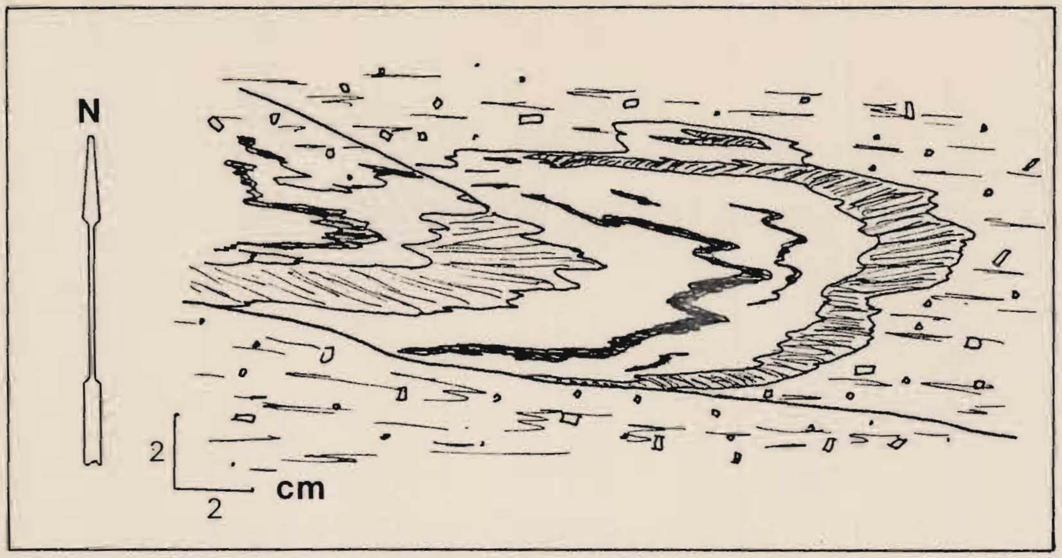

Figure 25 - Sketch of glide plane and fold in transposed layers of crystal-lithic tuff.

Figure 26 - Survival of a tightly appressed fold hinge of ash in a crystal-lithic tuff. Scale is 15 cm.

the Paleozoic rocks to the north several thousand feet. The Sapote fault is a scissors fault with the upthrown block to the north in the study area. In the western extent of the Sapote fault, the downthrown block is to the north.

Other faulting within the study area is very complex. This includes shears and axial plane faults that produced dynamic metamorphism of the units during the Permo-Triassic.

Cretaceous and Tertiary carbonates show tilting and deformation along the southern boundary fault. Faulting may also have occurred during the Quaternary, based on observations of tilted coastal sediments and elevated terraces along the Trio Branch of the Monkey River. The juvenile topography of the southern Maya Mountains, with its narrow gorges and steep sided canyons, also gives evidence for recent uplift.

Minor faulting occurred throughout the study area and usually offset both units and any older structures. These faults are post-Paleozoic in age because of their cross-cutting relationships with the surrounding structures.

Quaternary faulting is indicated by the presence of elevated terraces along the Trio Branch and truncation of coastal plain alluvium along the eastern part of the Southern Boundary fault.

MINERALIZATION AND ALTERATION

The Bladen Volcanic Series is sericitized and silicified throughout much of the exposed areas. Sericite development is related to the regional metamorphic episode and to some extent the dynamic shearing. The lava flows show relatively minor sericitization of their matrix and moderate feldspar destruction to sericite and clays. In contrast, the tuffs are highly sericitized in both the matrix and crystal fragments.

Silicification of the volcanic pile is related to hydothermal activity during the Triassic intrusive episode and possibly contemporaneous with dynamic metamorphism. At least two episodes of quartz veining are recognizable in the field. The first type of quartz veins are associated with massive, non-mineralized quartz. These veins occur as fillings in gash fractures and other tensional fractures that are discordant with the major foliation (Figure 27). Some veins are intimately associated with shear zones and micro-fractures that in places offset the veins and veinlets by a few centimeters. These veins are pervasive throughout the southern Maya Mountains. Another type of quartz veining is recognized in the field by its very local distribution within the volcanic pile. These are bluish, clear quartz veinlets and webbing

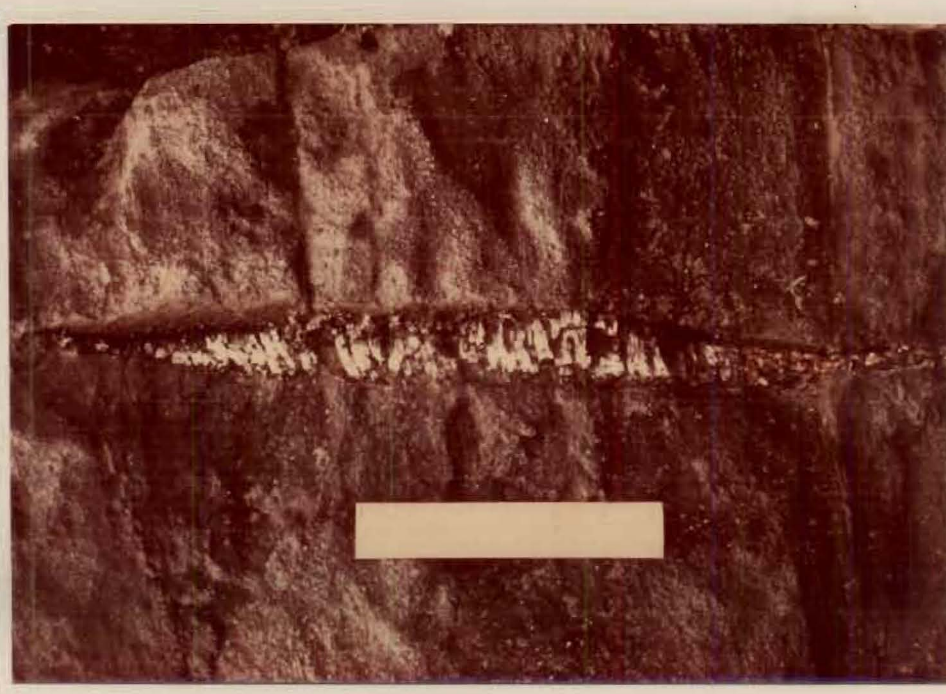

Figure 27 - Quartz filled gash fracture in ash-flow tuff.
Scale is 15 cm.

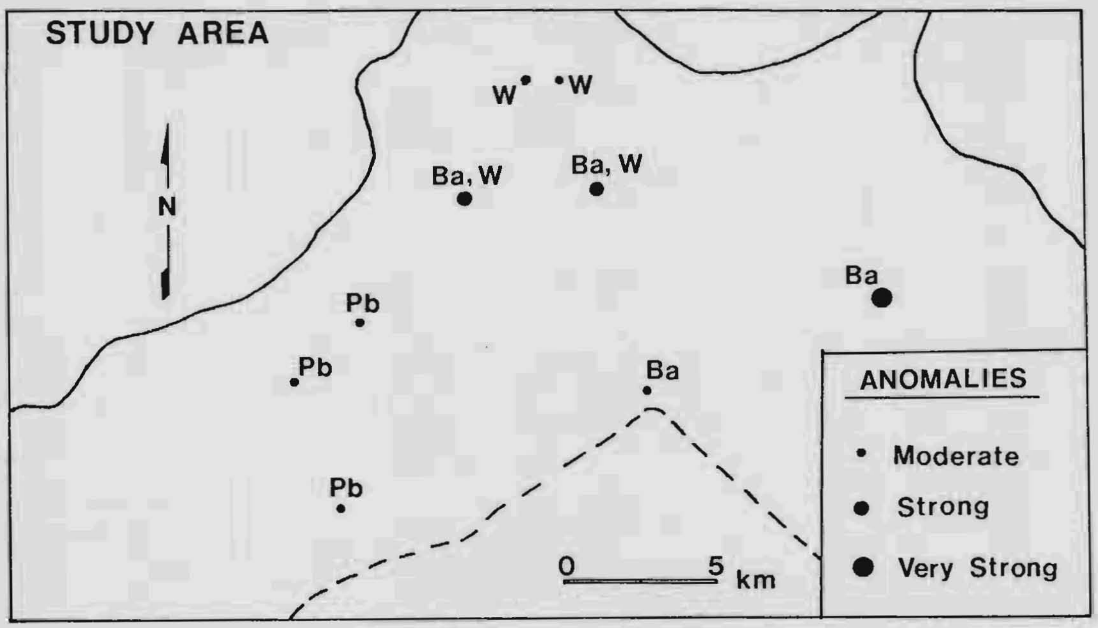

Figure 28 - Stream sediment geochemical anomalies in the southern Maya Mountains.

in the central and eastern portion of the study area. Lead gave some weak anomalies to the west.

As can be seen in Figure 28, barium is ubiquitous throughout much of the study area and due in part to barite and quartz flooding associated with hydrothermal alteration.

GEOLOGIC HISTORY

The Bladen Volcanic Series was erupted and emplaced during the Pennsylvanian time (300 million years) along with contemporaneous volcanism and plutonic activity in the northern Maya Mountains. Minor subvolcanic intrusions occurred during the late stages of volcanic activity.

In the study area volcanic activity is first represented by quartz latite to latite ash-flows and lava flows. These flow rocks were intercalated with air-fall pyroclastics and tuffaceous sediments. The end of the volcanic activity brought extrusion of dacitic lava flows and ash-flows. (Figure 29)

The volcanic pile was eroded and beginning in the early Permian, the Santa Rosa Group was deposited on the erosional surface as a transgressive episode.

During the Permo-Triassic orogeny the Paleozoic sequence was metamorphosed to the lower greenschist facies and isoclinally folded and uplifted.

In Cretaceous time carbonates were deposited in an onlapping sequence over the deformed Paleozoic rocks. (Figure 29)

Block faulting was initiated at least by Mid-Cretaceous and has produced the present structure of a shallow west-southwest dipping synclinorium. Faulting continued through Tertiary time and possibly as late as the Holocene.

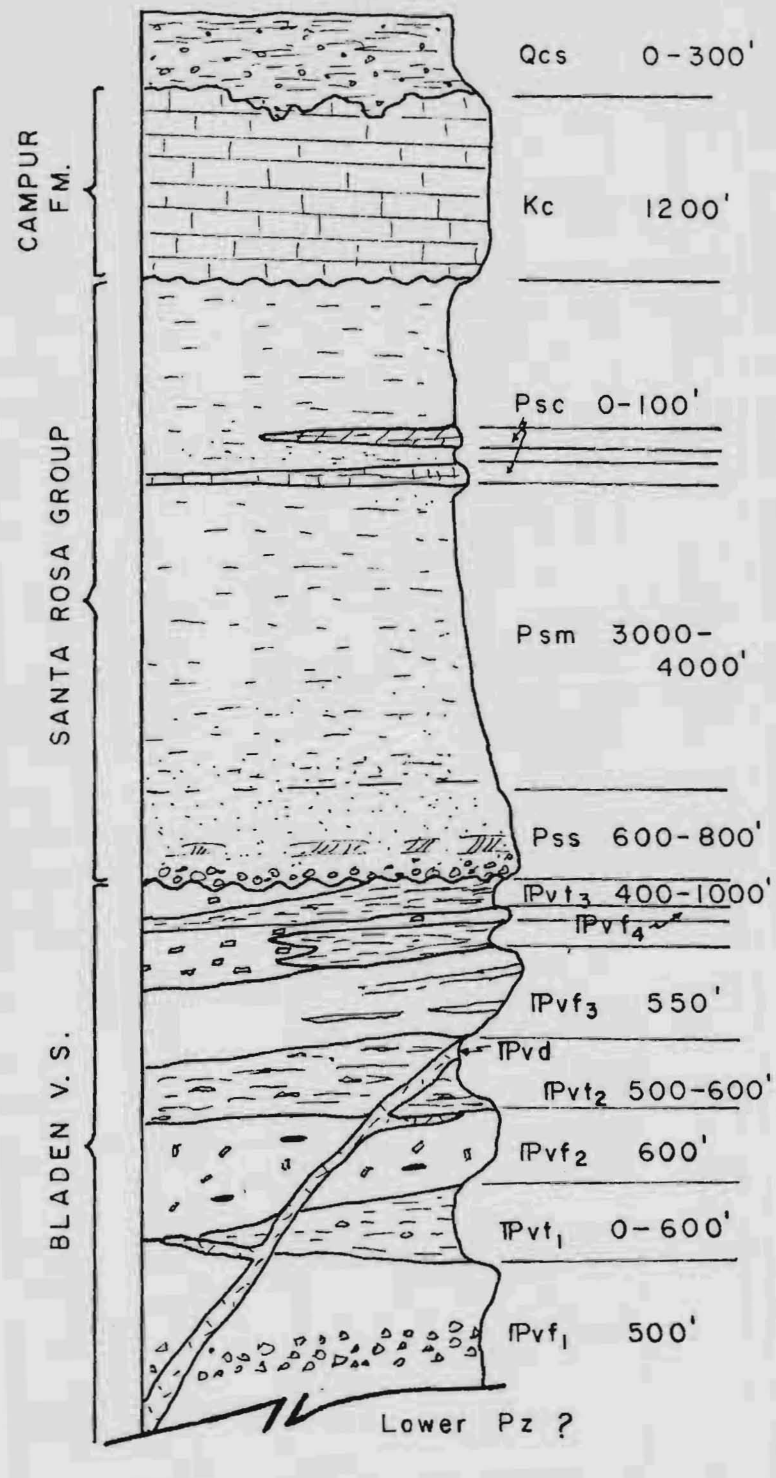

Figure 29 - Generalized stratigraphic column of the East Bladen-Trio area, southern Maya Mountains, Belize, Central America.

APPENDIX A

Trace Element Analyses

of Selected Rock Samples

Sample No.	Fe%	Ca%	Mg%	As	Ba	Be	Cu
18272-2961	1	.02	.2	-	30	2	-
18280-2955	1	.02	.15	-	15	10	2
18247-2944	.2	20	1.5	-	-	-	-
18316-3094	1.5	.15	.2	-	700	5	2
18317-3010	3	10	1.5	-	20	-	-
18333-3078	1.5	.05	.15	-	50	2	10
18333-3084	.3	.02	.03	-	150	-	-
18334-3085	1	.03	.1	-	100	2	3
18335-3080	5	.03	.5	-	50	5	2
18339-3078	1	.03	.5	-	15	3	-
18340-3078	2	.03	.2	-	200	5	-
18342-3074B	1.5	.02	.15	3000	1500	2	7
18342-3074A	3	.02	.2	-	300	5	-
18344-3072	2	.02	.2	-	300	5	-
18353-3062	1.5	.02	.07	-	70	2	10
18389-3101	.2	20	.15	-	-	-	-
18400-3106	2	.2	1	-	1000	7	5
18402-3099	1	20	2	-	5	-	-

\- Below limit of detection

Analysis by Skyline Labs, Inc.

Instrument - Jarrell-ash, 1.5 meter, D.C. Arc Emission Spectrograph.

Sample No.	La	Mn	Mo	Pb	Sr	Ti	V
18272-2961	20	10	-	10	-	150	-
18280-2955	30	-	-	50	-	200	10
18247-2944	20	200	-	-	50	50	10
18316-3094	100	20	-	30	-	500	10
18317-3010	20	700	-	10	-	2000	20
18333-3078	100	10	-	15	-	300	10
18333-3084	20	-	-	20	-	20	10
18334-3-85	70	-	-	100	-	300	10
18335-3080	100	100	-	70	-	1500	20
18339-3078	50	50	-	20	-	200	10
18340-3078	150	50	-	20	-	500	10
18342-3074B	70	10	5	50	50	3000	70
18342-3074A	100	15	-	50	-	2000	70
18344-3072	100	15	-	10	-	2000	70
18353-3062	50	-	-	10	-	1000	50
18389-3101	20	500	-	10	200	200	20
18400-3106	20	300	-	30	50	2000	70
18402-3099	-	500	-	10	1500	30	10

APPENDIX B

Trace Element Analyses

of Stream Sediment Samples

Sample No.	Cu	Pb	Zn	Au	Ag	W	Mo	Be	Ba
3258-18364	30	35	130	0	.4	6	2	6	300
3241-18352	25	15	90	.02	.4	6	0	5	500
3238-18350	15	30	65	0	.2	7	2	7	1500
3221-18338	20	25	85	0	.2	2	2	5	650
3191-18368	25	25	100	0	.2	6	2	5	650
3192-18307	15	45	85	0	.4	6	2	2	300
3175-18305	10	10	65	.06	.4	7	0	0	0
3170-18318	5	40	30	0	0	6	2	4	350
3163-18317	5	40	40	0	0	6	2	6	900
3159-18380	25	25	165	0	.2	9	2	5	450
3155-18397	25	25	110	0	.2	7	2	5	450
3144-18380	20	25	110	0	.2	13	2	4	450
3144-18377	5	60	60	0	0	12	2	9	1100
3141-18319	5	40	50	0	0	7	4	6	500
3136-18411	15	25	115	0	.2	13	2	5	550
3135-18412	15	35	80	0	.2	15	2	6	450
3134-18318	5	40	45	0	0	6	2	6	700
3123-18315	5	30	40	0	.2	8	2	4	200
3112-18305	5	30	65	0	.2	6	2	6	400
3112-18307	5	40	65	0	0	7	2	4	200
3104-18388	10	60	95	0	.2	16	2	7	1050

Analysis by Skyline Labs, Inc.

Method - Atomic Absorption

Sample No.	Cu	Pb	Zn	Au	Ag	W	Mo	Be	Ba
3103-18389	30	35	135	0	.2	6	2	5	450
3099-18403	20	15	75	0	.2	7	2	5	550
3099-18404	30	20	120	0	.4	4	2	5	500
3091-18294	15	50	80	0	.4	4	2	6	300
3079-18335	15	70	110	0	0	10	2	5	350
3078-18333	15	85	130	0	.2	9	2	5	500
3069-18277	10	30	65	0	.2	3	2	5	350
3067-18280	20	80	105	0	.4	5	2	7	600
3064-18353	15	40	90	0	.2	7	2	4	250
3049-18279	5	45	50	0	0	12	2	3	250
3045-18270	10	40	55	0	0	9	2	6	150
3043-18315	25	80	135	0	.4	5	2	6	550
3022-18259	20	50	100	0	.4	5	2	9	250
3017-18301	20	45	95	0	.2	3	2	6	700
2993-18252	10	40	55	0	0	4	0	8	50
2980-18239	10	45	70	0	0	4	0	8	350
2979-18237	25	30	85	0	0	5	0	3	450
2960-18241	20	30	80	0	0	5	0	6	500
2955-18280	10	55	85	0	0	8	0	9	650
2953-18238	15	30	85	0	0	6	0	5	550
2935-18225	20	20	90	0	0	5	0	5	500

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