The American Association of Petroleum Geologists Bulletin
V. 58, No. 2 (February 1974), P. 176-188, 5 Figs.

Stratigraphy, Sedimentology, and Paleoenvironment of Esquias Formation of Honduras[1]

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Abstract The Esquias Formation of central Honduras is a thick sequence of carbonate rocks conformable within the upper part of the Valle de Angeles Group. The usage of the term "Esquias" in stratigraphic literature on Central America has been ambiguous and confusing. Some workers even have doubted that the Esquias exists. Recent studies in and near the type area of Esquias, Honduras, have clarified the nature, age, and stratigraphic relation of the Esquias Formation and constitute a basis of formal redefinition.

The Upper Cretaceous Valle de Angeles Group is dominantly a succession of red, mixed terrigenous and marine strata that conformably overlie carbonate rocks of the Lower Cretaceous Yojoa Group. These red strata are about 3,000 m thick and are distributed widely throughout Honduras. The only named formation within the Valle de Angeles Group is the Esquias Formation, which essentially divides the Group into upper and lower redbed sequences. At its type locality the Esquias Formation is a 470-m thick sequence of calcilutite, marlstone, and calcarenite. Lithically it is similar to, although somewhat more argillaceous than, limestones of the Yojoa Group exposed in the same area. Collections of molluscan and echinoid faunas indicate that the Esquias Formation is probably Cenomanian in age.

Interpretations of stratigraphic relation, petrology, biofabric, and faunal assemblage suggest that the Esquias was deposited under shallow, nearshore marine conditions, probably within lagoons and marine embayments that encroached across a complex paleogeographic surface. The region simultaneously was being subjected to early phases of Laramide orogenesis. The Esquias Formation seems to be an enigmatic synorogenic transgressive-marine sequence, and thus reflects the Mesozoic tectonic evolution of northern Central America.

even seems to be widespread with significant thickness over much of central Honduras. Quadrangle mapping programs in central Honduras during 1971–72 have enabled the writers to study the type area of the Esquias. Here we shall redefine formally the Esquias Formation and describe its stratigraphy and sedimentology. In conclusion, we hope to show how paleoecologic and paleogeographic interpretations of the Esquias relate to the tectonic evolution of Middle America.

Regional Setting

The village of Esquias is 80 km north of Tegucigalpa in the central highlands of Honduras (Fig. 1). At an elevation of about 1,000 m it has a mild semitropical climate. However, the six-month rainy season that pervades all of Central America results in alternations of profuse vegetative growth and profound weathering of feldspathic bedrock. Quartzitic and calcareous strata are far more resistant to erosion than the more common argillaceous and arkosic strata in

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Introduction

The Esquias Formation was introduced informally to Central American stratigraphy by Charles Weaver (Williams and McBirney, 1969, p. 20) more than a half-century ago and applied

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This work was supported by a grant from an anonymous private foundation. We wish gratefully to acknowledge the assistance and advice of many people who have contributed to various aspects of these studies. However, we fully accept responsibility for any errors in fact or reasoning contained herein. We

to a dominantly carbonate sequence of presumed Late Cretaceous age. Since its introduction, it has been employed widely and differently by Central American geologists and, like many terms introduced prior to the Code of Stratigraphic Nomenclature (Am. Comm. on Strat. Nomenclature, 1961), its meaning has undergone an evolutionary loss of identity. This evolution progressed to the point where some workers not only denied the significance of the Esquias, but even doubted its existence.

The Esquias Formation does indeed exist, and

particularly thank Reniery Elvir of the Direccion General de Minas e Hidrocarburos, Juan José Guevara of the Instituto Geografico Nacional, both representing the Republic of Honduras, and Rodney Saubers of the Inter-American Geodetic Survey, for their cooperation and logistic support. Fossil identifications were kindly afforded by Nicholas Hotton III, Earl Kauffman, and Norman Sohl of the U.S. National Museum, John Ostrom of Yale University, and Keith Young of the University of Texas. Robert Fakundiny, Richard Finch, Veron Garton, and Kenneth Hugh all contributed stimulating discussion and advice relevant to the Esquias problem. We are particularly appreciative of the excellent field assistance of James Cullen, Bruce Simonson, and Charles Smith from Wesleyan University.

which they occur. Consequently, the Esquias region is characterized by forested and rugged terrain of only moderate relief.

Until 1967 the geology of Honduras was certainly the least studied and poorest known of all the Central American republics. Since then, the Mesozoic stratigraphy has been studied in detail (Mills *et al.*, 1967), the Tertiary volcanic history has been shown to be quite complex (Williams and McBirney, 1969; Dupre, 1970), and a comprehensive program of quadrangle mapping has been initiated by the Honduran government with the cooperation of various American universities (Everett, 1970; Fakundiny, 1970; Dupre, 1970; Atwood, 1972; Finch, 1972; and King, 1972). Current studies by Horne are concerned with clarifying the nature of the Honduran basement complex.

Honduras occupies the eastern extension of Schuchert's (1935) Nuclear Central America, a region with a geologic signature that reflects tectonic relations to the North American continent (Dengo and Bohnenberger, 1969). However, Molnar and Sykes (1969) clearly demonstrated that, together with southern Guatemala and northern Nicaragua, Honduras is a dislocated appendage of Nuclear Central America at the trailing western corner of the actively migrating Caribbean plate. This crustal fragment seems to have been separated from the rest of North America along the Polochic-Motagua-Chamelecon fault zones in southern Guatemala and northwestern Honduras (Dengo, 1969). If this is valid, attempts to reconstruct the pre-Tertiary history of Nuclear Central America must consider the complex paleogeographic restoration of the Honduran fragment to its proper position on North America (*e.g.*, Malfait and Dinkelman, 1972).

The present paper is concerned with the late Mesozoic history of the Honduran fragment. Guzmán and de Cserna (1963) recognized elements of a Mesozoic orthogeosyncline extending southward along the eastern side of Mexico; they defined it as part of the Mexican geotectonic cycle. Dengo and Bohnenberger (1969) extended this same tectonic framework across Nuclear Central America and correlated its orogenic culmination in Late Cretaceous–early Tertiary time with the Laramide orogeny of North America. The Sierras of northern Central America (Eardley, 1951, p. 587) are a series of parallel ranges of tightly folded Mesozoic strata, cut by plutons and cored by metamorphic basement, that extend generally east-west through Guatemala and Honduras; they seem to be the structural-stratigraphic counterpart of the Rocky Mountains.

The Esquias region is within the southern ranges of the Sierras of northern Central America, and in most respects it reflects a history rather typical of these ranges. It occupies a struc-

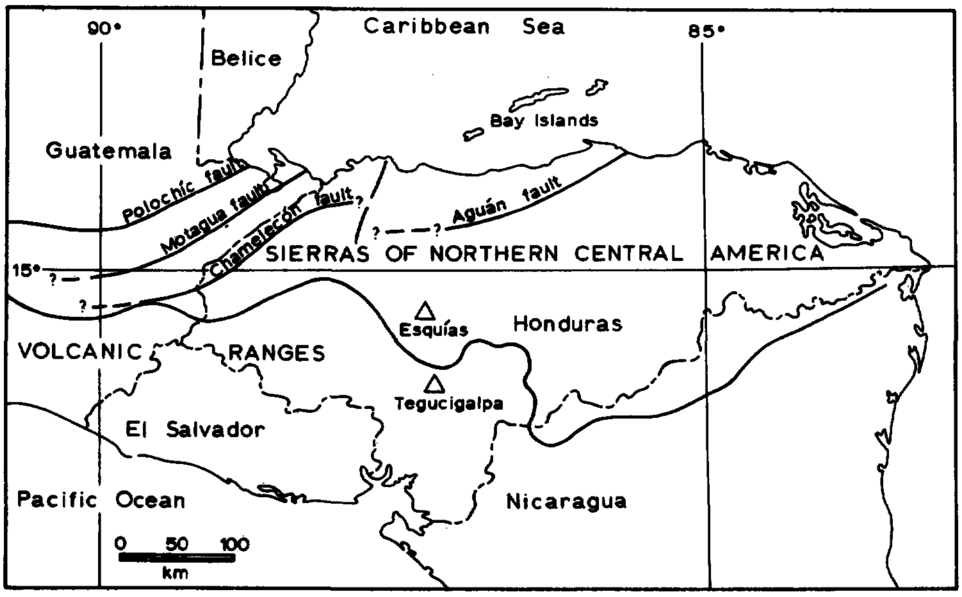

FIG. 1—Index map of eastern Nuclear Central America, with tectonic provinces and major faults.

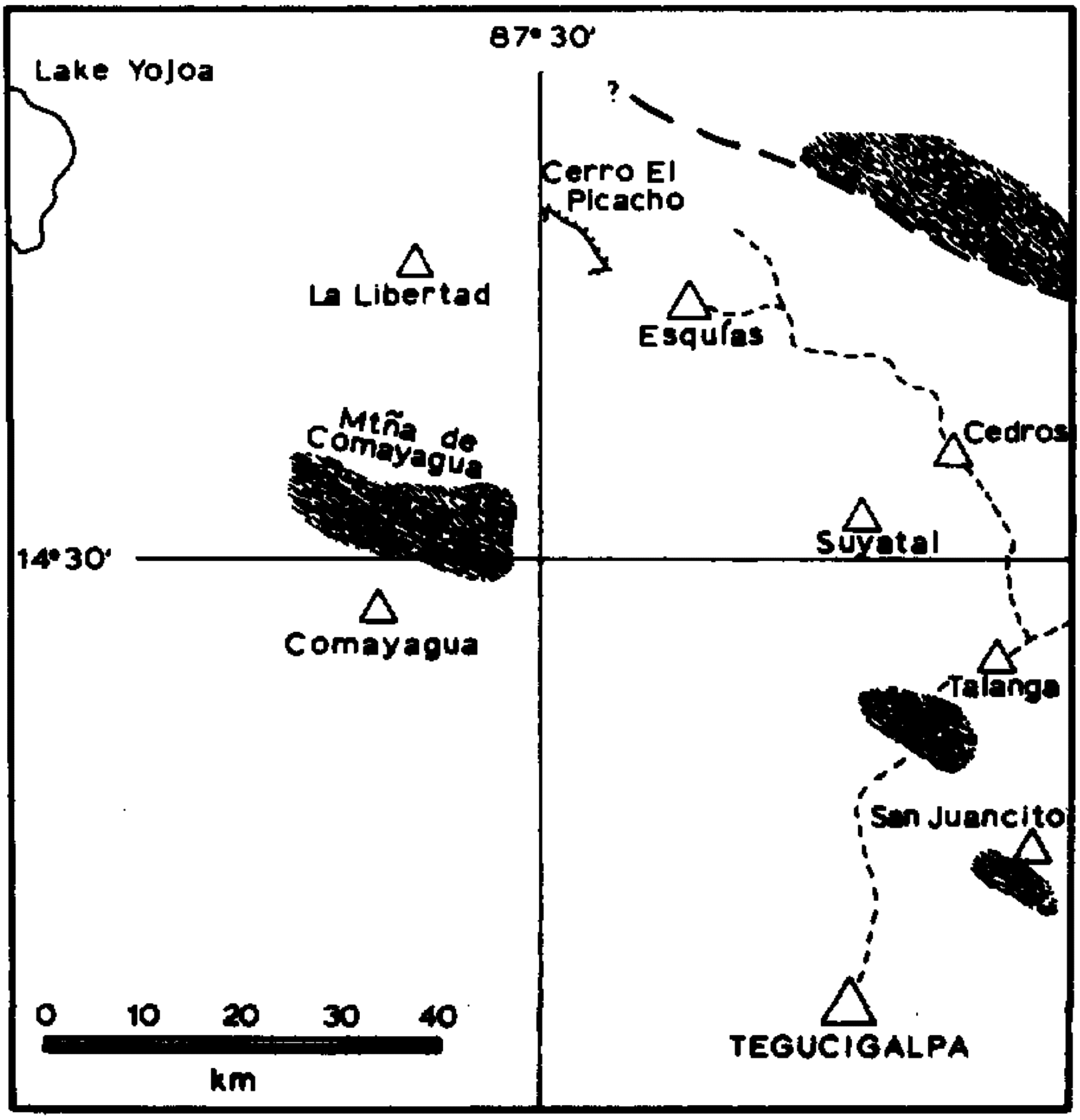

FIG. 2—Location map of central Honduras showing major basement highlands (stipple).

tural saddle of dominantly Mesozoic strata lodged between the basement-cored Montana de Comayagua structural belt (Everett, 1970; Fakundiny, 1970) on the south and a major mountain front of upfaulted basement rocks on the northeast (Fig. 2). The region is cut by Late Cretaceous–early Tertiary granite plutons (Horne *et al.*, in press), and contemporaneous sedimentary strata are dominated by thick sequences of feldspathic molasse. Both of these tectonic elements were considered typical of the anatexitic-through-taphrogenic phases of the Mexican geotectonic cycle in Mexico (Guzmán and de Cserna, 1963) and northern Central America (Dengo and Bohnenberger, 1969). However, the carbonate rocks of the Esquias Formation stand out as enigmatic and paradoxical exceptions to this classic tectonic synthesis.

ESQUIAS PROBLEMS

Because the history of nomenclatural usage in Central American stratigraphy is both involved and confusing, particularly with regard to the Esquias Formation, it is advisable to review briefly the evolution of a few stratigraphic terms that have a bearing on the discussion at hand.

Early Studies

Karl Sapper, the pioneering geologist of Central America, first described the stratigraphy of Honduras (1899, 1905, 1937). He defined the

Metapan sequence as the "lower Cretaceous marls, sandstones, shales, puddingstones, conglomerates, and limestones found in northwestern Salvador, southeastern Guatemala, and western Honduras" (Sapper, 1937, p. 101). Above the thick section of the Metapan (later used as a formation) Sapper recognized, but did not name, an "upper middle Cretaceous limestone" (p. 109).

Weaver called Sapper's unnamed upper limestone the "Esquias Formation." Although the "name was first used in 1919 by Charles Weaver in describing sediments close to the village of Esquias" (Williams and McBirney, 1969, p. 20), it was published for the first time in Schuchert's *Historical Geology of the Antillean-Caribbean Region* (1935, p. 354). According to Weaver (reported by Schuchert, 1935, p. 354) the Esquias consists of:

> . . . massive bluish gray limestone, varying in thickness from 20 feet to 500 feet. Interbedded with the limestones are conglomerates, brownish gray sandstones, calcareous sandstones, creamy brown calcareous shales and dark brown shales. How much of Cretaceous time is represented is not known. It has poorly preserved species of *Lima, Inoceramus* and unidentifiable gastropods.

Weaver said that the formation lies conformably on Lower Cretaceous shales of the Metapan Formation in Comayagua, which he described (*in* Schuchert, 1935, p. 355) as:

> . . . interbedded thin layers of dark-brown shale and medium-grained sandstone, together with thicker lay-

ers of buff to light-brown calcareous shale, and occasional layers of bluish-gray limestone.

Weaver (1942, p. 180) cited among other good exposures of the Metapan Formation a 2,000-ft thick limestone section near Esquias which contains echinoids, gastropods, and pelecypods. The age of some of these fossils was determined by Bohm and Loriol (Schuchert, 1935, p. 355) as Early Cretaceous. However, Weaver seems to have misused Sapper's original Metapan by including the Lower Cretaceous limestones of Honduras. According to Imlay (1944, p. 1116):

> The Metapan beds are overlain concordantly by a considerable thickness of gray, thin- to thick-bedded limestone, marly limestone, marl, conglomeratic limestone, and locally by beds containing chert concretions. From these beds at many places in Honduras and near Metapan in El Salvador were obtained middle Albian fossils, . . . Weaver presumably includes these late Lower Cretaceous limestones in the Metapan beds, but his usage does not correspond with that of Sapper . . .

Nevertheless, although his usage of the Metapan may have been incorrect, Weaver did identify

the Esquias as overlying these strata. As Imlay points out (1944, p. 1116), the Esquias

> . . . has been considered Upper Cretaceous solely on the basis of stratigraphic position, as the only listed fossils, *Lima* and *Inoceramus*, are not restricted to the Cretaceous.

Thus, it is clear that from the beginning the concept of two major limestone units within the Mesozoic System of Honduras was well established in the literature, although certainly not in the clearest terms.

Carpenter (1954) employed a new nomenclature for the succession in the San Juancito area of central Honduras. He followed Weaver's error by suggesting (1954, p. 27) that his newly defined Lower Cretaceous Cantarranas Formation, of dominantly carbonate rocks, may be equivalent in part to the Metapan. He introduced the Valle de Angeles Formation for the thick sequence of redbeds above the Cantarranas (Carpenter, 1954, p. 28), but did not recognize the Esquias. In 1957, Roberts and Irving applied the Esquias Formation to the upper part of the sequence of interbedded limestone, conglomerate, and shale that overlies the Metapan. They added, ambiguously, that a considerable thickness of limestone and shale may lie between the Metapan and Esquias (Roberts and Irving, 1957, p. 22).

Recent Studies

Mills *et al.* (1967) compiled the most recent and comprehensive treatment of the Mesozoic stratigraphy of Honduras. They gave a concise review of the historical development of the terms "Metapan" and "Esquias," showing how they had evolved into general terms applied to Lower Cretaceous and Upper Cretaceous strata respectively. They suggested that the Metapan was excessively vague for continued usage, and replaced the term with the Lower Cretaceous Yojoa Group of carbonate rocks and the overlying Valle de Angeles Group of redbeds (Mills *et al.*, 1967, p. 1720–1723). They retained the Esquias Formation, but because their newly defined Yojoa Group also includes massive bluish-gray limestone (the Atima), and because the Atima Formation was thought to be (p. 1722–1723)

> . . . equivalent to the massive, peak-forming limestone part of Weaver's Esquias Formation . . . the term 'Esquias' should be restricted to Upper Cretaceous–Eocene, brown, marly limestone and shale which overlie the lower part of the Valle de Angeles redbeds in certain places . . .
>
> Where deposited, the Esquias marly limestone beds divide the redbed group into a lower part which probably is Late Cretaceous in age and an upper part that is middle Tertiary in age.

Although Mills *et al.* (1967, p. 1750–1753) did not study the Esquias in its type area, they described a section of what they believed to be Esquias 20 km west near La Libertad, Comayagua. They also suggested that the Esquias Formation may be equivalent to part of Vinson's (1962) Peten Group in Guatemala (Mills *et al.*, p. 1775).

Williams and McBirney (1969, p. 20) also recognized the Esquias Formation, as used by Mills *et al.* (1967) and analyzed tuffaceous limestone samples from the La Libertad locality. They concluded that the Esquias was deposited during the early stages of volcanism in Honduras within shallow-marine embayments bordered by lowlands. They also suggested that the Esquias Formation, or at least part of it, is the equivalent to the Sepur Formation north of the Motagua Valley in Guatemala (Williams and McBirney, 1969, p. 21).

As a consequence of this rather confusing and sometimes ambiguous history of nomenclatural usage, recent students of Honduran stratigraphy have debated the presence of more than one major limestone unit in the Mesozoic sedimentary sequence. The debate was understandable. A Lower Cretaceous massive limestone unit had been well established by fossil evidence (Mills *et al.*, 1967); however, until January, 1971 (as explained later), definitive evidence for an upper limestone was lacking. The older and younger limestone units exposed in Honduras cannot be distinguished by lithic type, fabric, obvious fossils, weathering characteristics, thickness, or sequence. In addition, the upper limestone formation may have been deposited in local embayments, with the result that two limestone units may not be present in all areas. The existence of two major limestone units, indistinguishable by lithic criteria, obviates the simple criterion of stratigraphic position relative to limestone that some geologists in Honduras have used to distinguish between the lithically similar Valle de Angeles and Todos Santos clastic units. If two major limestone formations exist, a minimum of 3 units (all redbeds) underlie, separate, and overlie the limestones.

The first fossil evidence that established the presence of an upper limestone was found by Bruce M. Simonson 9 km southwest of the village of Esquias. The femur of an ornithopod of probable Cretaceous age (identified by John Ostrom of Yale University was found bedded in a thin, blue-gray clay layer interbedded in red

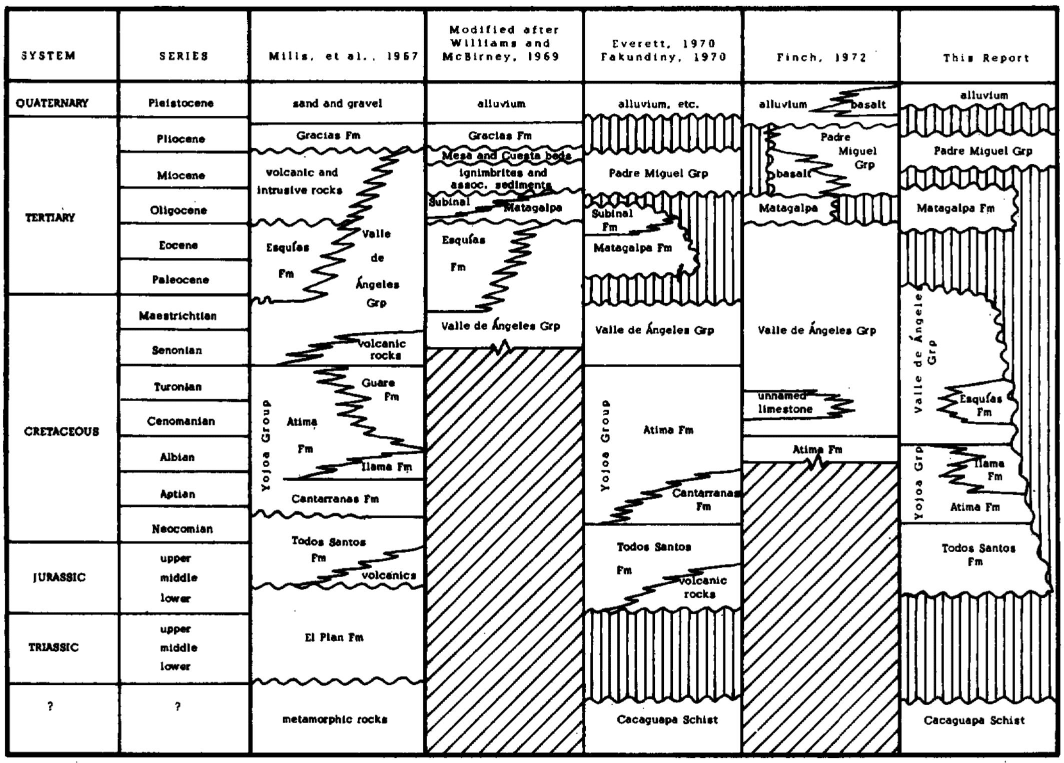

FIG. 3—Correlation chart of Honduran stratigraphy currently employed by various workers.

siltstone and sandstone strata directly (within 10 m) underlying conformable marls and thin-bedded fossiliferous limestone of a major limestone unit (the Esquias Formation). Subsequent field mapping clearly showed the presence of two major limestone units separated by about 2,000 m of variegated clastic strata. Two major limestone units now are recognized and mapped by almost all students of Honduran geology, including geologists from the United Nations minerals project (D. Elliott, personal commun., May 1971), the Peace Corps (A. King), and the University of Texas (R. Finch, personal commun., December 1971; R. Fakundiny, personal commun., March 1972).

The primary intent of this paper is to redefine specifically and formally the Esquias Formation, and to document its age and its relation to other units. A redefinition requires justification, and in the case of the Esquias Formation past usage reflects the confusion arising from its inadequate original definition.

STRATIGRAPHY—SEDIMENTOLOGY

Figure 3 briefly summarizes current usage of stratigraphic nomenclature in Honduras. A continuous stratigraphic section from the lower part of the Todos Santos Formation, through the entire Yojoa and Valle de Angeles groups, to the Matagalpa Formation is moderately well exposed in the Esquias area by the breaching of a major east-west anticline-syncline couplet between La Libertad and Minas de Oro. The Esquias Formation occupies the westward-plunging core of the syncline just west of the village of Esquias.

Valle de Angeles Group

Carpenter (1954) applied the name "Valle de Angeles Formation" to the 3,300-m-thick sequence of mixed red clastic rocks exposed near the village of that name about 20 km northeast of Tegucigalpa. Because it overlies the Cretaceous Cantarranas Formation, he believed the Valle de Angeles was Upper Cretaceous or lower Tertiary and suggested that it was a continental intermontane deposit (Carpenter, 1954, p. 28). The name was raised to group status by Mills *et al.* (1967), and its definition was broadened to include all sedimentary units overlying the

Lower Cretaceous Yojoa Group and underlying Tertiary volcanic units. The only formation designated was the Esquias, which divides the Valle de Angeles Group into upper and lower redbed sequences. The upper redbed sequence was tentatively correlated (Mills *et al.*, 1967, see Fig. 3, p. 1719) with the Subinal Formation of Guatemala (Hirschmann, 1963). In accordance with the ideas of de Cserna (1960), Mills *et al.* (p. 1775) interpreted the Valle de Angeles as a postorogenic molasse deposit.

Williams and McBirney (1969) discussed the Valle de Angeles Group at length, and generally agreed with Mills and his colleagues. A notable exception was with regard to the Subinal, which was believed to be considerably younger than the Valle de Angeles, and equivalent to the Matagalpa volcanic sequence (Williams and McBirney, 1969, p. 17). Because the Valle de Angeles Group is widely distributed, is characterized by even bedding and good sorting, and contains thinly interbedded limestones with marine molluscan faunas, they concluded that it was deposited under dominantly deltaic and marginal marine conditions.

The present writers consider the Valle de Angeles Group to be essentially as described by Mills *et al.* (1967), and modified by Williams and McBirney (1969). Names have not been proposed for the redbed sequences that are separated by the Esquias Formation. The informal designation "lower Valle de Angeles redbeds" refers to the red clastic rocks with intercalated thin limestones that overlie the Yojoa Group and underlie the Esquias Formation. Similarly, "upper Valle de Angeles redbeds" refers to the variegated clastic strata which conformably succeed the Esquias and unconformably underlie the Matagalpa Formation of andesitic volcanics and associated redbeds. Where the Esquias is not present, or where there are insufficient criteria for dividing the redbeds, the sequence is merely referred to as "Valle de Angeles redbeds." An unnamed Cenomanian limestone unit mapped in western Honduras (Finch, 1972) may be a second major limestone within the Valle de Angeles Group, or may be in part equivalent to the Esquias Formation.

Description—The reddish variegated clastic rocks of the Valle de Angeles Group have been described extensively in the literature (Carpenter, 1954, p. 28; Mills *et al.*, 1967, p. 1722 ff.; Williams and McBirney, 1969, p. 17–19; Everett, 1970, p. 33–40; Fakundiny, 1970, p. 81–89; Atwood, 1972, p. 32–49; Finch, 1972, p. 38–66). The lower Valle de Angeles redbed sequence in the Esquias area is about 2,000 m thick. It consistently overlies the carbonate rocks of the Yojoa Group with complete conformity, and in some places the lower contact appears gradational. These strata consist of an assortment of varicolored terrigenous clastic rocks. Oligomictic conglomerates of fine, well-sorted and rounded quartz pebbles in brownish arkosic matrix dominate exposures, but probably comprise only about a quarter of the section. Buff to red, submature, feldspathic sandstones and subgraywackes are as well represented as the conglomerate. Both the rudites and the arenites commonly are planar stratified, but trough cross stratification is also common. Deep red to maroon or, less commonly, green siltstones and claystones are less resistant, but volumetrically as significant as all the more coarse-textured strata. Limestone-pebble conglomerate is common in the lower part of the section. Scattered, thin-bedded marly limestone and calcareous shales are common in the upper part, but have been reported at various stratigraphic levels throughout the Valle de Angeles in western Honduras (Williams and McBirney, 1969; Douglas Elliott, personal commun., April 1971; Finch, 1972). Two stratigraphic trends have been noted in the lower Valle de Angeles redbeds within the area: (1) a general increase in red color up-section, and (2) an overall fining-upwards in mean grain size.

The upper Valle de Angeles redbed sequence in the Esquias area is relatively thin. No more than 100 m of clastic strata have been found to overlie the Esquias Formation conformably. These strata consist of buff to red, fine-grained clastics, dominantly siltstones and claystones. Other sequences of red clastics directly overlie the Esquias with marked unconformity, but these are thought to be sedimentary facies of the Tertiary Matagalpa Formation, perhaps equivalent to the Subinal Formation of Guatemala. In some exposures, the upper Valle de Angeles redbeds are overlain with marked unconformity by andesitic Matagalpa volcanic rocks. In other exposures the Esquias, or even the lower Valle de Angeles redbeds, is overlain unconformably by the Matagalpa or by the younger Padre Miguel Group of Miocene ignimbrites.

The age of the Valle de Angeles Group is limited by the well-established Aptian-Albian age of the underlying Yojoa Group (Mills *et al.*, 1967), and by the early Tertiary andesitic volcanics of the Matagalpa (Williams and McBirney, 1969; Horne *et al.*, in press). Finch (1972, p. 56) collected a Cenomanian assem-

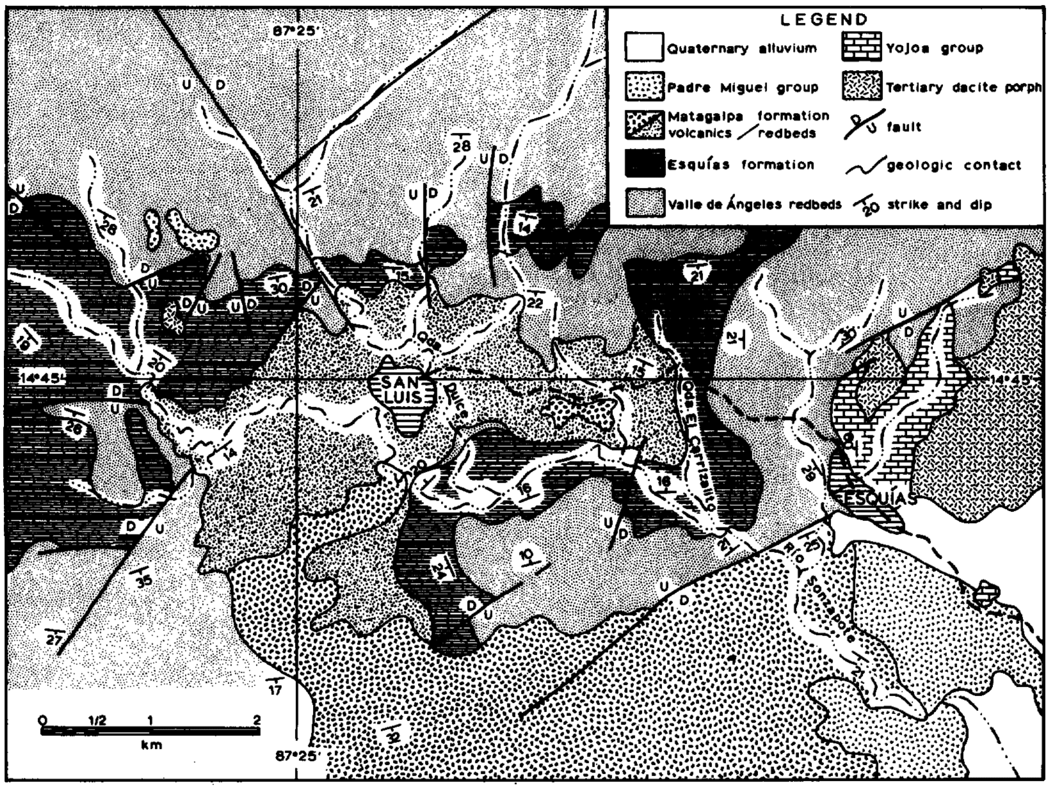

FIG. 4—Geologic sketch map of Esquias area, central Honduras; simplified after Atwood (1972).

blage of fossils from an unnamed limestone within the Valle de Angeles in western Honduras. Fauna collected from the Esquias Formation suggests a medial Cretaceous age, as discussed in a subsequent section.

Esquias Formation

The Esquias Formation is the thick section of dominantly carbonate rocks conformably within the upper part of the Valle de Angeles Group exposed just west of the village of Esquias, Departamento de Comayagua, Honduras. It is an unfortunate coincidence that limestones of the Lower Cretaceous Yojoa Group also crop out directly north and east of Esquias village. These are probably the limestones that Weaver (1942, p. 180) referred to as Metapan, and their proximity to the type area of the Esquias no doubt contributed to the confusion regarding the relevance of the Esquias Formation.

The type section of the Esquias Formation (Fig. 4) is exposed in the channel of Rio Sonzapote between the villages of Esquias and San Luis; easy access to the section is afforded from either village. The lower contact is defined as the base of the lowermost thin-bedded limestone overlying the variegated sandstones and shales of the lower Valle de Angeles redbed sequence near the confluence of Quebrada El Carrizalito and Rio Sonzapote, about 1 km west-southwest of Esquias center. The upper contact is defined as the top of the uppermost thin-bedded limestone conformably underlying the variegated shales and sandstones of the upper Valle de Angeles redbed sequence in Quebrada Dulce, approximately 0.8 km south-southeast of San Luis center. The Esquias Formation at this type section is 470 m thick.

Other reference sections of the Esquias are exposed in the general area. The entire formation crops out in the northeast-facing escarpment of Cerro El Picacho, about 12 km northwest of Esquias, but access is afforded only by mule trail and a steep climb. A more accessible section is exposed in the hills near the village of Suyatal, about 30 km south-southeast of Esquias; access is by trail west from the Talanga-Cedros road (Fig. 2). Mills *et al.* (1967, p. 1750–1753)

referred to a section of limestone, marlstone, and shale exposed 5 km south of La Libertad, on the road to Comayagua, as a possible reference section of the Esquias Formation. This section is approximately 20 km due west of the type locality, and the writers have not mapped the continuity of Esquias strata into the La Libertad area. However, we have visited Mills' reference section south of La Libertad, and on the basis of both stratigraphic position and petrology we concur in assuming a correlation between the areas.

Description—Details from the measured section of the Esquias at its type locality in Rio Sonzapote are given in Figure 5. In general, the Esquias Formation is similar in appearance to the Atima and Cantarranas Formations of the

Yojoa Group, as described by Mills *et al.* (1967). This similarity is undoubtedly the basis for much of the skepticism that prevailed regarding the existence of the Esquias. However, careful examination shows that the Esquias is somewhat more argillaceous than the Yojoa; marlstone is much less prevalent in the latter.

Three different types of carbonate rock dominate the Esquias section. The order of prevalence is as follows.

1. Calcilutite: brownish-gray to light-brown marly wackestone of bioclasts, generally fragmental molluscan and echinoid debris, but also entire sparite-filled shells of bivalves, gastropods, and ostracods; occasionally intraclastic, with some pelletal beds; allochems are poorly sorted and float in massive to burrow-mottled micrite with sparse bird's-eye structures, medium- to thick-bedded in 0.5–2.0-m units.

2. Marlstone: brownish-gray argillaceous micrite with few suspended bioclasts; generally silty or sandy with quartz grains; minor burrow mottling in thinly bedded 3–10-cm units.

3. Calcarenite: medium- to bluish-gray packstone of well-sorted bioclasts variably within sparite or micrite matrix, locally mixed; bioclasts commonly foraminiferal; internally stratified into medium to thick beds (0.5–3.0 m).

At the type locality the calcarenites are concentrated in the upper 25 percent of the section. Immediately beneath the calcarenite sequence is a well-bedded interval of finely ripple-laminated and algal-matted dolomitic micrite with abundant bird's-eye structures. The more common calcilutites and marlstones are distributed alternately throughout the section, and are punctuated liberally by thin interbeds of gray calcareous shale.

Age and correlations—As previously noted, the Esquias Formation is commonly fossiliferous but generally contains only unidentifiable molluscan debris. Good mulluscan and echinoid fossils were collected from the Esquias by King near the village of Cedros, about 30 km south-southeast of the type section. Specific identifications by Keith Young, at the University of Texas, suggest that the fauna is probably Cenomanian, certainly medial Cretaceous (see faunal list in Appendix). Somewhat poorer collections of similar material from the type section are being studied at the U.S. National Museum.

According to Schuchert (1935, p. 354), Weaver's original fossil collection from the Esquias contained only species of *Lima* and *Inoceramus* that are not age-definitive. Its presumed Late Cretaceous age was purely conjectural, in that it overlies dated Lower Cretaceous strata. Mills *et al.* (1967) reported two faunas from the Esquias section exposed south of La Libertad: (1) Locality 65 contained a possible Eocene fauna (p. 1780); and (2) Locality 158 contained a middle Albian to Late Cretaceous fauna (p. 1784).

The maximum age limit for the Esquias Formation postdates the well-established (Mills *et al.*, 1967) Albian age of the Atima Formation; about 2,000 m of undated Valle de Angeles red clastic strata were deposited on the Atima prior to Esquias deposition. The minimum age limit is controlled by the overlying early Tertiary (Eocene-Oligocene) volcanics of the Matagalpa Formation (Williams and McBirney, 1969); a major angular unconformity separates the Matagalpa and Esquias Formations, and indicates considerable hiatus. Thus, the Esquias Formation may range from medial Cretaceous to early Tertiary. However, faunal evidence suggests an early Late Cretaceous age (? Cenomanian). Finch (1972) has reported similar limestones of Cenomanian age from an area just south of Lake Yojoa, about 70 km west of Esquias.

Paleoenvironment

Admittedly, our stratigraphic-sedimentologic data from the Valle de Angeles Group are somewhat limited. We have studied the strata in detail only over a relatively small area in central Honduras; we do not have regional data on lithosomes controlled with respect to time. Therefore, we are not able to restore lithotopes, show facies relations, or reconstruct an accurate paleogeographic scene of deposition.

However, our localized data on sequence, lithologies, and faunas do warrant preliminary interpretations of environmental conditions. In addition, during reconnaissance studies, we have observed many of the same characteristics in these strata throughout central Honduras. Here we shall inventory the characteristics of these strata that are suggestive of sedimentary condi-

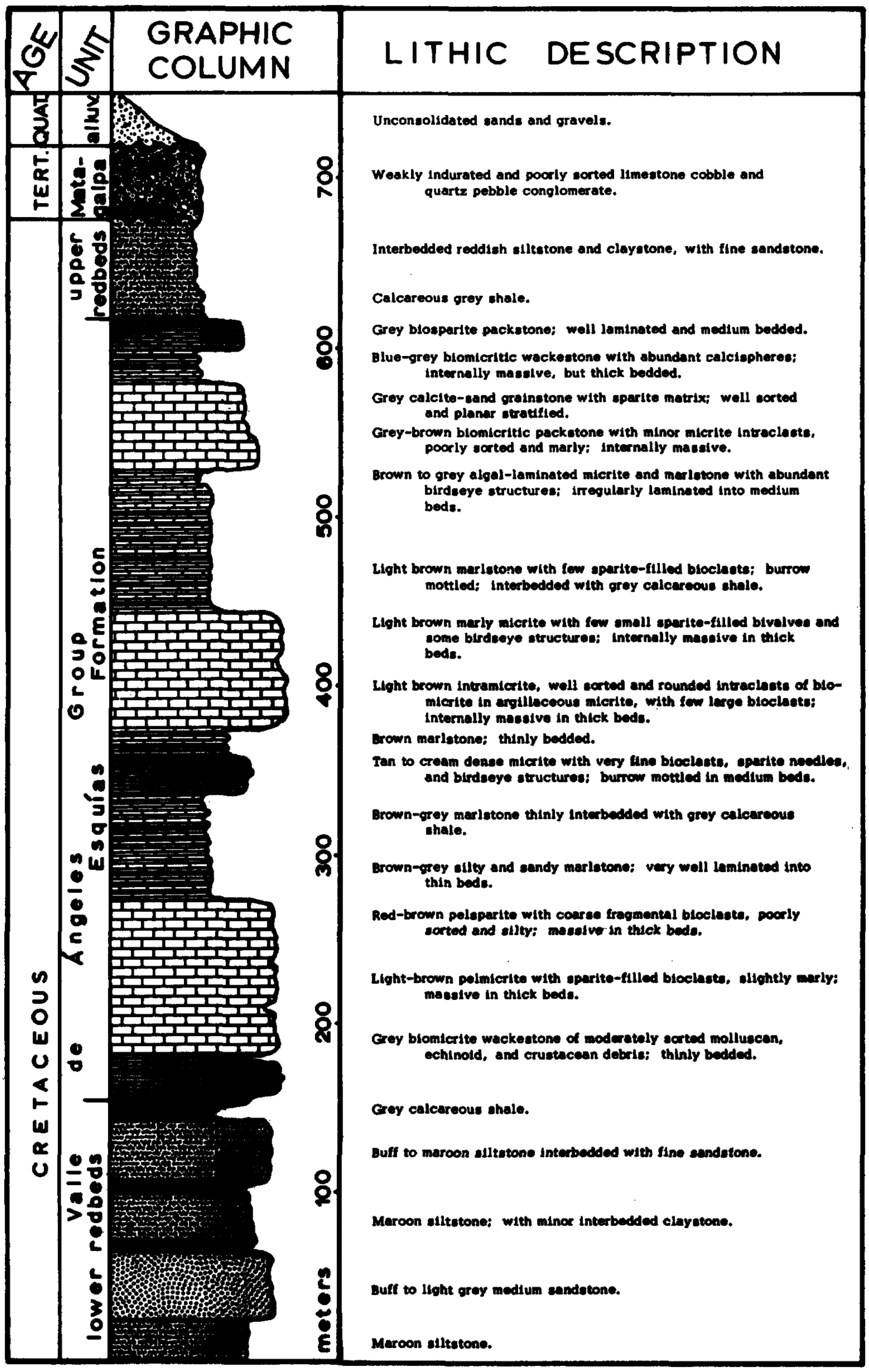

FIG. 5—Columnar section of Esquias Formation, as measured at type locality between Esquias and San Luis.

tions, and we shall attempt to synthesize a paleoenvironment that bears on the tectonic evolution of Nuclear Central America.

Valle de Angeles Redbeds

The variegated terrigenous clastic rocks that compose the Valle de Angeles redbeds are of mixed compositions and textures. Distinctive limestone-pebble conglomerates are common in the lowest part of the succession and indicate sedimentary cannibalization of the underlying Yojoa Group. The vast predominance of moderately rounded and well-sorted quartz pebbles within most other conglomerates immediately suggests environmental maturity. In addition, the much more common and areally extensive mudstones suggest quiescence and stability. Nevertheless, the arkosic matrix of the conglomerates and the abundance of both physically and chemically immature sandstones belie these facile interpretations; they are suggestive of rapid burial and proximal sources. Interdigitation of these lithologies indicates that quartz pebbles may have been derived locally from a complex source and rapidly buried within a flood of finer and less stable material.

The reddish colors that dominate the Valle de Angeles clastic strata suggest subaerial exposure. Most of the mudstones are notably deficient in organic material, and invertebrate fossils are not known from the clastic strata. The presence of dinosaur remains certainly substantiates an interpretation of terrestrial conditions. However, thin green and gray claystones are present locally within the dominantly red succession, and suggest possible lacustrine or paludal conditions. Moreover, thin intervals of calcareous shale, marlstone, and calcilutite with sparse molluscan faunas are present in the upper part of the lower

Valle de Angeles redbed succession, and these suggest marine transitions to the Esquias carbonate rocks.

Distinctive primary sedimentary structures are not common within the Valle de Angeles redbeds. The rudites are coarsely and poorly stratified, and seem to persist over broad areas; small-scale cut and fill structures are found at the base of some units. The arenites generally are planar stratified with only minor trough cross stratification. Some lutites bear ripple-drift laminations but more commonly are monotonously well stratified. Internal fining-up sequences have been noted occasionally within 2–5-m packages of strata. Because of poor exposure, lateral relations between lithosomes are not obvious. Vertical sequence, however, does show a gross fining-up tendency within the entire 2,000-m lower section of the redbeds.

The full suite of sedimentary characteristics enumerated is strongly suggestive of fluvial deposition on a gently sloping plain, perhaps evolving from a braided to meandering drainage regime as gradients were reduced (see Allen, 1965, or Selley, 1970, for discussions). This plain must have bordered a nearby marine setting that slowly transgressed the accreting surface. It also must have flanked low-lying source lands that provided the abundance of unstable debris that was deposited. Hence, the environment was probably a piedmont alluvial plain.

Low-grade metasedimentary rocks are exposed in uplifted ranges both northeast and southwest of the subject area. These rocks consist of feldspathic sericite schists and phyllites, peppered with a profusion of blebs, knots, and pods of vein quartz; very locally they are capped with thin plates of Yojoa Group carbonate rocks. These basement terranes may have been uplifted in the medial Cretaceous, been stripped largely of their Yojoa cover to produce the limestone-pebble conglomerates common in the lowest part of the Valle de Angeles, and constituted a single provenance for the entire clastic sequence.

Esquias Carbonate Rocks

The stratigraphic position of the Esquias Formation clearly indicates depositional relation with the probable piedmont conditions that produced the Valle de Angeles terrigenous sequence. The nature of the transition between the two environments, either in space or time, is difficult to establish without greater areal and temporal control. The upper part of the lower red-bed sequence does, however, show marine transitions. The fauna contained within the Esquias is of shallow-marine affinities, but some assemblages may have been tolerant of brackish-transitional conditions. Relatively high concentrations of fine terrigenous material suggest fluvial contamination of offshore carbonate banks. Thus, it is not immediately clear whether the Esquias was deposited in an open-shelf environment, or within restricted marine embayments.

Sedimentary textures and internal structures indicate a considerable range in physical conditions of deposition for the Esquias. In addition, consideration of biofabric elements reveals the existence of several microfacies. Algal-laminated calcilutites with bird's-eyes suggest quiet supratidal to intertidal conditions. Well-sorted and winnowed skeletal calcarenites with sheetwash stratification suggest deposition in a surf

zone. Marly and burrow mottled calcilutites with entire sparite-filled bioclasts suggest quiet and turbid lagoons. Pelletal calcisiltites that are partly winnowed and stratified into massive beds suggest well-circulated sublittoral conditions. Massive calcilutites bearing calcispheres and planktonic foraminifers suggest deeper and quieter waters with open-marine connections. Many of these microfacies are very similar to those described from the Golden Lane trend of medial Cretaceous limestones in eastern Mexico (see Griffith *et al.*, 1969, or Coogan *et al.*, 1972, for comparisons). However, no reef subfacies has been recognized within the Esquias Formation; rudistids are both uncommon and isolated.

Considering the controversy that exists regarding the deposition of the El Abra and associated limestones in the well-studied Golden Lane trend (see Coogan *et al.*, 1972, for discussions), we believe that it is inappropriate to base an ecologic interpretation of the Esquias on our limited data. Nevertheless, the role that Esquias deposition played in the developing Laramide orogenesis that pervaded Nuclear Central America is worthy of brief consideration.

Tectonic Environment

The contention that the Sierras of northern Central America are primarily Laramide structures was first elaborated by Sapper (1899, p. 73–80) and has been supported by essentially everyone who has worked in the region in this century. Dengo and Bohnenberger (1969, p. 212–214) cited various lines of evidence that support this thesis. Chief among them is the abundance of presumed Cretaceous-Tertiary plutons in the region; this has been confirmed for Honduras by recent work which indicates that plutonism probably occurred as various events over a long period of time (Horne *et al.*, in press). Another excellent piece of evidence that is not often cited is the marked angular unconformity between the Upper Cretaceous Esquias Formation and the Eocene-Oligocene Matagalpa Formation, classic evidence of orogeny since James Hutton recognized its significance in the 18th century.

Many have referred to a Mesozoic orthogeosyncline in northern Central America, and to its termination by clastic wedge deposits in the latest Cretaceous and early Tertiary. Mesozoic geosynclinal deposits indeed may exist in the western and northern parts of the region. However, we have not seen evidence of Mesozoic orthogeosynclinal evolution in Honduras, especially within the context of Stille (1941), Kay (1951), or Aubouin (1965), nor even of paralic troughs or the miogeoclines of Dietz and Holden

(1966). Rather, it seems to us that the Mesozoic stratigraphic record in Honduras is of marine transgression over a sialic platform, similar to the early Mesozoic record of the Rocky Mountains in North America. This development was interrupted in both regions by late Mesozoic orogenesis and consequent terrestrial clastic deposition.

Furthermore, we do not believe that the Valle de Angeles redbed sequence is truly an exogeosynclinal or successor-basin clastic wedge; it is not a wedge, but an irregularly distributed thick blanket. In addition, it seems not to be coarsely banked as fanglomerates against yoked highlands, nor does it overlie unconformably the Yojoa Group of marine carbonates. It probably was derived locally and internally from the presently situated metamorphic highlands as they gently and slowly rose in the medial Cretaceous, sympathetic with massive plutonic intrusion. Early Cretaceous plutonism has been documented in the immediate vicinity (Horne *et al.*, in press) and probably was the precursor to this positive isostatic adjustment. In this sense, the Valle de Angeles redbed sequence may be considered a synorogenic molasse.

The medial to Late Cretaceous marine transgression that deposited the Esquias carbonates is somewhat enigmatic within this tectonic framework. The Esquias Formation probably was deposited within lagoons and partly restricted marine embayments that encroached across a mellowing terrestrial physiography that was uplifted during the Early to medial Cretaceous. When considered in the context of continuing Laramide orogenesis, it seems unlikely that the transgression was the result of epeirogenic subsidence. Late Cretaceous marine deposits are not only widespread throughout the Caribbean region, but also over much of the North American craton. This vast transgression suggests worldwide eustatic changes. Readjustments of ocean-basin geometry through sea-floor spreading may have accounted for orogenic responses along plate margins and simultaneous eustatic transgressions of cratonic platforms, a tectonic response referred to as the "Antler or Haug effect" (Johnson, 1971, 1972). The spatial coincidence of these effects in northern Central America not only confuses the record, but again suggests that the region was not truly geosynclinal.

Conclusions

The Mesozoic evolution of northern Central America has been described in terms of the Mexican geotectonic cycle (Guzmán and de Cserna, 1963; Dengo and Bohnenberger, 1969). More recently, with the advent of a global theory of plate tectonics, it has been suggested that the concept of geotectonic cycles need not apply to many mountain systems (Coney, 1970). Indeed, its continued application may serve only to confuse proper understanding of the tectonic evolution of some orogenic belts.

We submit that the classic geotectonic cycle is not valid as an orogenic model for the Mesozoic evolution of Nuclear Central America. The region certainly was affected by Laramide orogenesis in the latest Cretaceous and early Tertiary, and in many regards its history is analogous with the development of the Laramide belt of North America. However, at least in Honduras, there is no evidence of a precursor geosynclinal trough, nor even of a postorogenic successor basin. The Laramide Sierras of Honduras seem to have formed as an ensialic mountain system, probably upon a microcraton or continental fragment that already may have been dislocated from its parent plate. The Esquias carbonates represent a paradoxical synorogenic marine deposit on this crustal fragment.

Mapping in the type area finally has clarified the sedimentary-tectonic significance of the Esquias Formation of central Honduras. As herein redefined, the Esquias is believed to correspond to the original usage by Weaver and to provide a useful rock unit in Central American stratigraphy. It appears to be widespread with continuity over much of central Honduras. The confusion that has arisen over its usage derives from equivocal faunal data and its similarity to the Yojoa limestones.

Appendix—Paleontology

Source: Schuchert, 1935, p. 354.
Location: unknown, near Esquias.
Stratigraphic unit: Esquias Formation.
Fauna: *Lima* sp.; *Inoceramus* sp.
Age: Late Cretaceous (?).
Paleontologist: Charles E. Weaver.

Source: Mills *et al.*, 1967, p. 1780, locality 65.
Location: just south of La Libertad.
Stratigraphic unit: dense limestone, Esquias Formation.
Fauna: *Mesalia* (?) sp.; *Globularia* (*Ampulella*) sp.; *Crassostrea* sp.
Age: probably early Tertiary (?).
Paleontologist: Wendell Woodring.
Source: Mills *et al.*, 1967, p. 1784, locality 158.
Location: just south of La Libertad.
Stratigraphic unit: marly limestone, Esquias Formation.
Fauna: *Cuneolina* sp.; *Nummoloculina* sp.
Age: middle Albian to Late Cretaceous.
Paleontologists: Bonet and Teller.

Source: collections by Allen P. King, 1972.
Location: Universal Mercator Grid 821-062 on Hoja 2759 I, approximately 9 km southwest of Cedros.
Stratigraphic unit: marlstone, Esquias Formation.
Fauna: *Tetragramma* sp.; *Heteraster* or *Toxaster* sp.; *Neithea* sp.; *Granocardium* sp.; *Cyprimeria* sp.; *Exogyra olisiponensis* Sharpe; *Crassostrea soleniscus* Meek.
Age: apparently middle Cretaceous.
Paleontologist: Keith Young.

Source: collection by Bruce M. Simonson, 1971.
Location: Universal Mercator Grid 508-266 on Hoja 2760 III, approximately 10 km southwest of Esquias.
Stratigraphic unit: claystone, lower redbed sequence, Valle de Angeles Group.
Fauna: femur of ornithopodian dinosaur.
Age: indeterminate.
Paleontologist: John H. Ostrom.

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