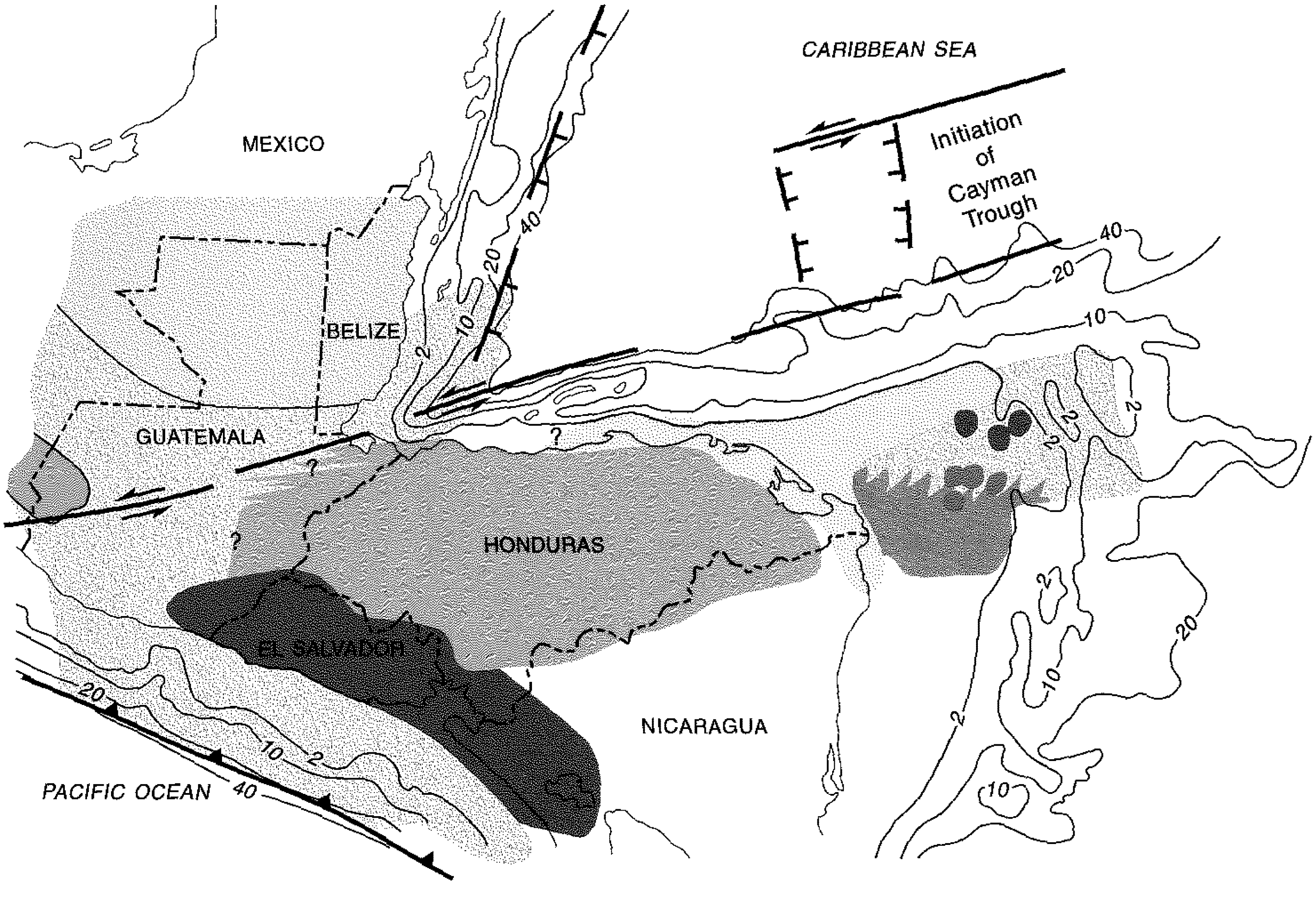
Final Report

GEOLOGY OF MOSQUITIA AND TELA BASINS, HONDURAS

by Luis A. Sánchez-Barreda



Bureau of Economic Geology

Noel Tyler, Director

The University of Texas at Austin • Austin, Texas 78713-8924

March 1999

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prepared for JGI, Inc.
under agreement no. UTA98-0427

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EXECUTIVE SUMMARY

Although the Mosquitia and Tela Basins are two of the better explored sedimentary basins of Honduras, they are still underexplored compared with other basins in the general region. The Tela Basin is composed of three en echelon, narrow depocenters, resulting from extensional tectonics that initiated in the Oligocene. These depocenters were filled primarily by turbidite sedimentation that exceeds some 4,000 m in thickness. The Mosquitia Basin is separated from the Tela Basin by a major regional, down-to-the-north, strike-slip fault. More than 75 percent of the basin lies in eastern Honduras, and the rest in Nicaragua. The basin's main depocenter is located near the Honduran-Nicaraguan border and is filled with some 9,000 m of Upper Cretaceous and Tertiary sediments. Both the structural and stratigraphic framework of these two basins is intimately related to evolution of the Chortis block as the block moved from its original position attached to southwestern Mexico to its present location as part of the Caribbean plate.

The Mosquitia Basin consists of three tectonic elements—the onshore Mosquitia Basin, the Mosquitia Platform, and the offshore Mosquitia Basin. Paleozoic strata are poorly understood in this region, but investigators have suggested that these rocks were affected by at least three episodes of deformation. The Chortis block was displaced into the present-day Caribbean during the Mesozoic, and displacement was followed by a suturing event as the Maya and Chortis blocks collided. This collision produced a regional compressional event, imparting a northwest structural grain and affecting both the onshore and offshore portions of the basin.

During the Cenozoic, the Chortis block was rotated, sheared, and stretched owing to movement of the Cocos, North American, and Caribbean plates. The northern limits of the Mosquitia Basin were defined by the Swan Island Transform fault, which was active from the Oligocene to the Miocene and later during the Pliocene and Pleistocene. Onshore, strike-slip fault systems developed and today are represented by the conspicuous drainage patterns of rivers in the area.

Rotation of the Chortis block caused a reversal of the direction of motion along faults, creating a series of small extensional basins. Similar features have been mapped in the offshore from seismic profiles, indicating that the offshore area underwent the same events and stresses as its onshore counterpart.

To improve present understanding of the structural framework of the Tela and Mosquitia Basins, this study recommends reprocessing of key seismic profiles, mapping of regional horizons and sequence stratigraphic analyses, along with "postmortem" evaluation of drilled wells. Efforts along these avenues will foster an enhanced understanding of each basin's petroleum system.

PURPOSE AND SCOPE OF WORK

The purpose of this project is to develop an improved understanding of the tectonic framework and depositional systems present in the Mosquitia and Tela Basins of Honduras. Although our efforts are primarily focused on the Mosquitia Basin, because it has undergone more intense investigation, this report also describes the evolution of the Tela Basin to the extent possible using available data.

A review of published information on Honduran geology was conducted. As part of that effort, a search of electronic data bases was used to develop a bibliography of published geologic literature inclusive of theses and dissertations (app.). All relevant articles and reports were read, synthesized, and incorporated as appropriate to the study.

For the Mosquitia Basin, maps of surface geology, depth to basement, base of the Tertiary, and known hydrocarbon shows were compiled. Several stratigraphic cross sections were constructed to illustrate lithologic relationships and preliminary interpretations of depositional systems. Two structural cross sections were developed to illustrate salient structural features of the basin.

Because of the constraints of the data, in terms of both availability and quality, one of the primary recommendations of this report is to implement additional studies to identify data needs to meet long-term goals of the Japex Geological Institute (JGI) and the Honduran government.

INTRODUCTION

The Mosquitia and Tela Basin are the two better explored sedimentary basins of Honduras.

The Mosquitia Basin is located in eastern Honduras and Nicaragua. In Honduras, the Mosquitia Basin has been divided into three elements (fig. 1): the onshore Mosquitia Basin, the Mosquitia Platform, and the offshore Mosquitia Basin.

The Mosquitia Basin proper covers approximately 155,280 km^2. More than 75 percent of the basin lies in Honduras, and the rest in Nicaragua. There have been 13 exploratory wells drilled offshore and 3 on land; however, commercial reserves were not found in Honduras, nor by the 26 wells drilled in the Nicaraguan portion of the basin.

Depths of the wells in the Honduran Mosquitia Basin range from 1,971 m (6,467 ft) to 4,263 m (13,986 ft), with an average depth of 2,952 m (9,685 ft). Most of these wells terminate in Tertiary, but nine of the wells bottomed in Mesozoic rocks that included Upper Cretaceous red beds and volcanics and Lower Cretaceous carbonates (see stratigraphic cross sections).

The basin's main depocenter is located on a regional structural high commonly referred as the Nicaragua rise (fig. 2). The rise extends from the coastlines of Honduras and Nicaragua northeastward to near the island of Jamaica.

The northern boundary of the Mosquitia Platform is defined by a down-to-the-north fault separating the upthrown platform from the Tela Basin (fig. 2). This regional fault bifurcates to the southeast and forms the regional left-lateral strike-slip Guayape fault system recognized onshore.

The Mosquitia Basin and Platform contain both Cretaceous and Tertiary carbonates and clastic rocks. Sediment intervals in the main depocenter near the Nicaraguan border are defined by seismic reflection profiles in excess of 9,000 m (fig. 3, pls. 1 and 2).

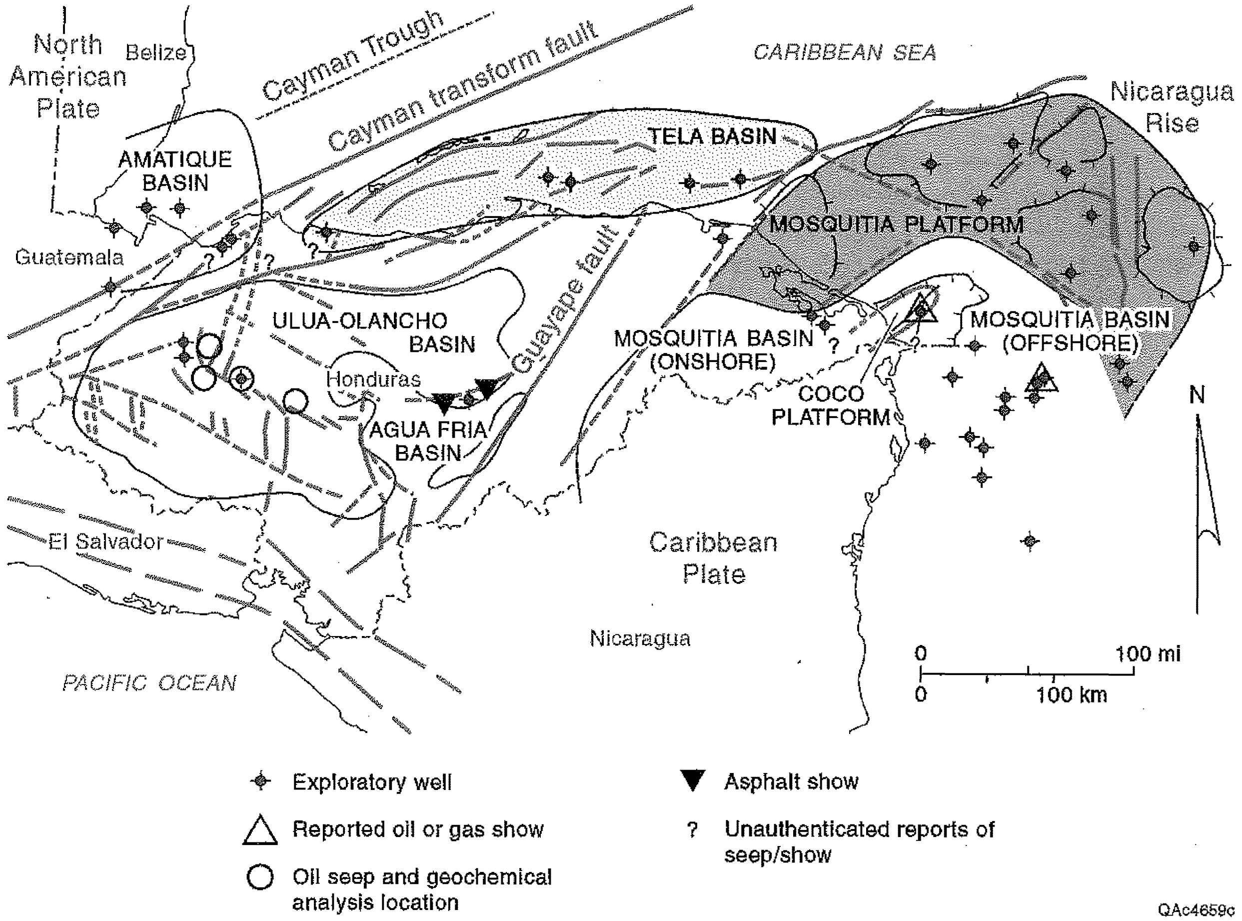

Figure 1. Map of locations of main sedimentary basins in Honduras showing well sites and principal tectonic elements: Cayman transform fault, Cayman trough, Caribbean plate, North American plate, Nicaragua rise, and Guayape fault.

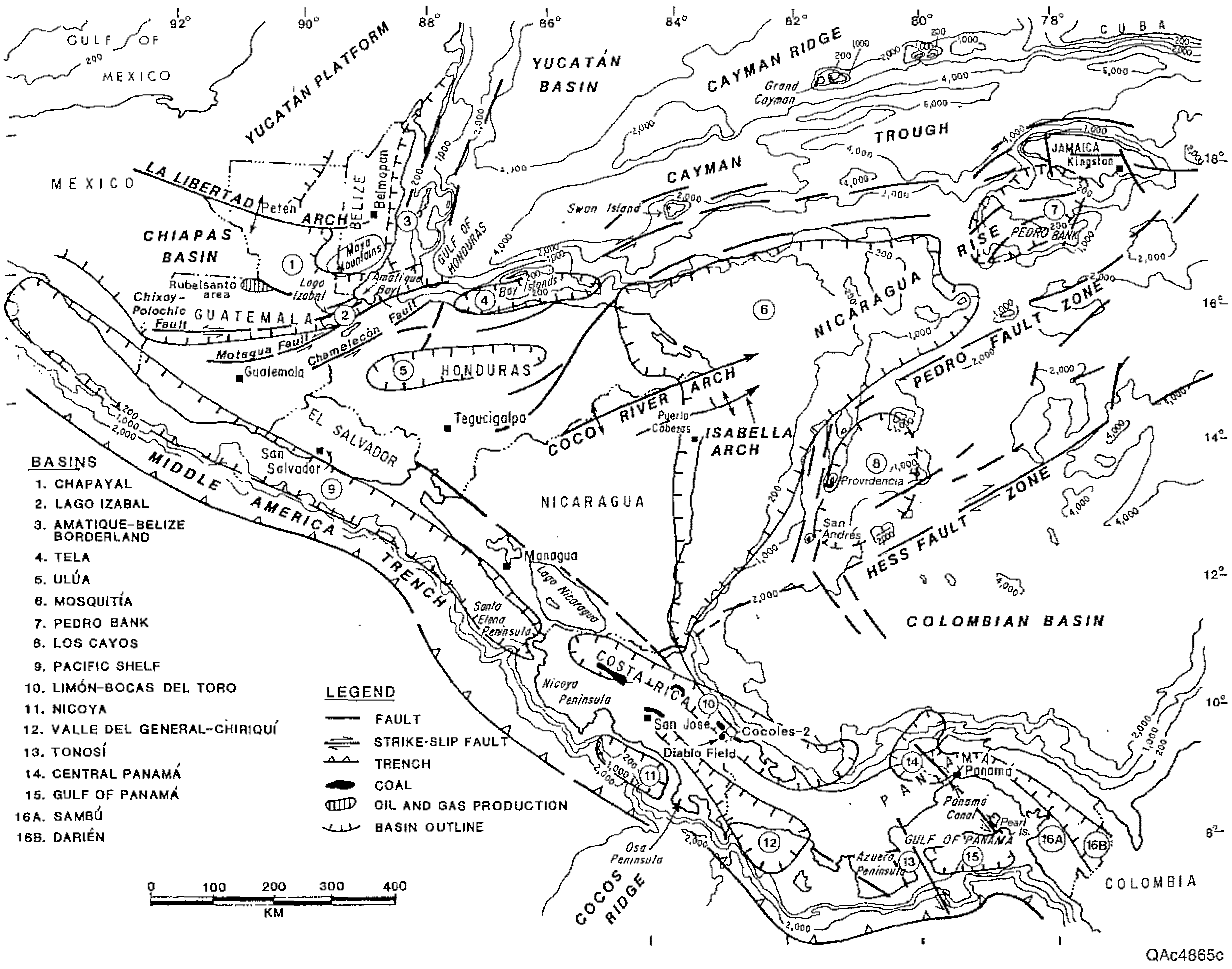

Figure 2. Major structural elements of Central America (from Morris and others, 1990).

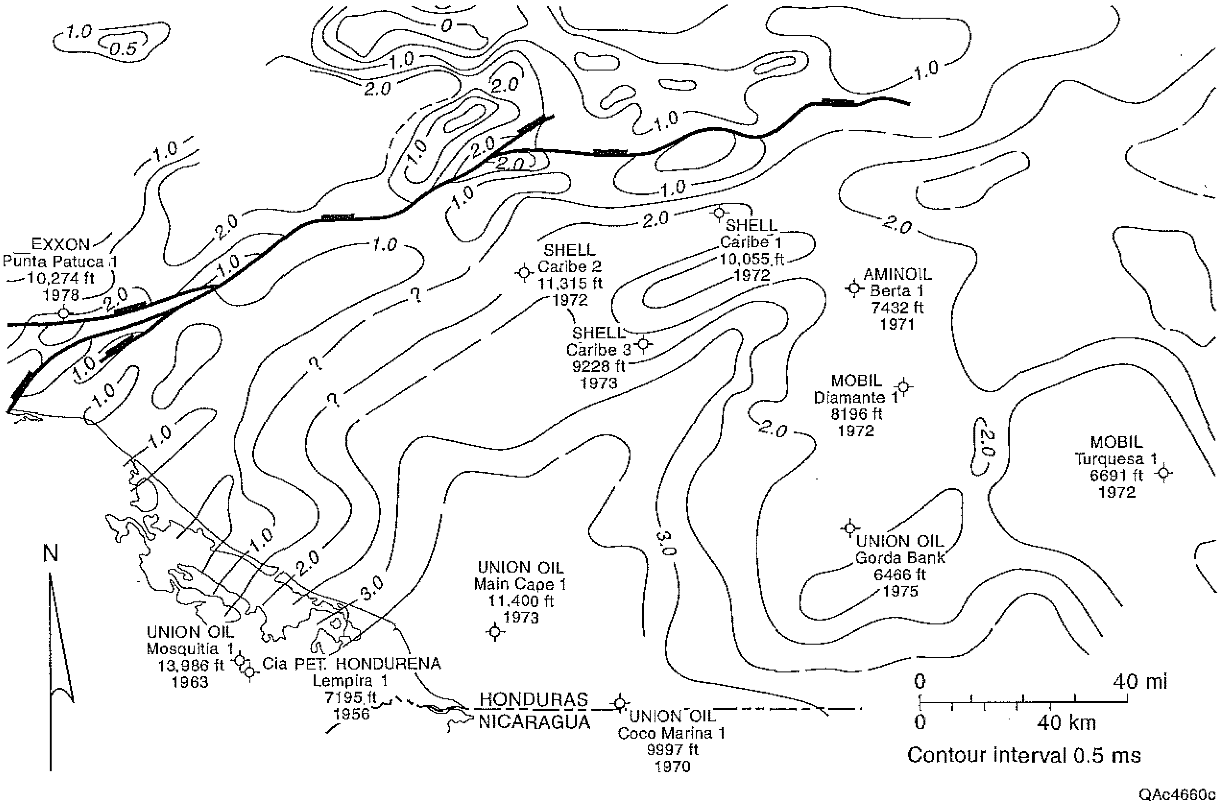

Figure 3. Seismic two-way traveltime thickness of post-Cretaceous sediments in the offshore portion of the Mosquitia Basin.

The Tela Basin (fig. 1) covers an area of some 20,000 km^2 between the shoreline and the shelf edge. The basin is composed of three narrow, en echelon depocenters produced by extensional tectonics that originated during the Oligocene. These depocenters were filled predominately by Neogene clastic sediments (primarily turbidites) with thicknesses exceeding 4,000 m. The depositional axes of these depocenters trend northeast to southwest and parallel the direction of movement along the North American–Caribbean plate boundary (fig. 2).

Onshore extension of the Tela Basin is located in the northern reaches of the Sula Valley and along the coastal plain between the towns of Tela and La Ceiba. This part of the basin is composed of a sequence of Mesozoic rocks downdropped into a northeast-trending Cenozoic graben, which in turn was filled by unknown thicknesses of Tertiary and Quaternary sediments.

Only five exploration wells were drilled in the Tela Basin, and no commercial hydrocarbons have been encountered.

STRATIGRAPHY

The earliest recognized work in Honduran geology is that credited to Carpenter (1954), who studied the San Juan de Flores quadrangle, and reconnaissance work by Roberts and Irving (1957), although Central American stratigraphy was previously described by Karl Sapper (1899; 1905). A comprehensive regional study of Honduras was presented by Mills and others (1967). Wilson (1974) published an interpretation of Honduran stratigraphy, which differed considerably from earlier studies, particularly that of Mills and others, regarding the stratigraphic positions of formations. In general, Wilson's offering was better documented with paleontologic time control; however, his nomenclature was never widely accepted.

Several quadrangle maps and reports were prepared by The University of Texas, Wesleyan University, and Peace Corps geologists working in western and northwestern portions of Honduras from the early 1970's to the 1980's. The Japanese Metal Mining Agency undertook detailed mapping of a limited area on the Chamelecon River in northwest Honduras and also did some reconnaissance work in the Olancho area (Southernwood, 1986).

Mills and others' (1967) stratigraphic column was revised by Finch (1981) and Ritchie and Finch (1985). A version of their column for Honduras in general, modified by Southernwood (1986), is utilized in this report, and additional formations relevant to the Mosquitia Basin and described by Rogers (1995a) are noted in the text.

Pre-Mesozoic

Basement and Paleozoic Rocks

Honduran metamorphic basement consists of low- to medium-grade metamorphic rocks of volcanic, calcareous, and pelitic origins, which were originally considered Precambrian (Roberts and Irving, 1957) but more recently have been designated Paleozoic in age (Horne and others, 1974). Basement was first termed the Palacaguina Formation in Nicaragua, and later Dengo (1965) extended its use throughout northern Central America. However, local Honduran geologists have utilized a different terminology. Graphite and sericite schists near San Juancito were termed the Peten Formation by Carpenter (1954), whereas basement in the Comayagua Mountains was called the Cacaguapa Schist (Fakundiny, 1970). Horne and others (1974) also referred to metasedimentary basement in central Honduras as the Cacaguapa (fig. 4).

Fakundiny (1970) described the Cacaguapa Schist as a unit composed of phyllite, schist, marble, and quartzite (pl. 3). Horne and others (1974) correlated the Cacaguapa on a regional scale to low-grade phyllites, mica schists, and marbles possibly belonging to the Permo-Carboniferous Santa Rosa Group and Las Ovejas Group, which are exposed in Guatemala between the Motagua and Jocotán faults.

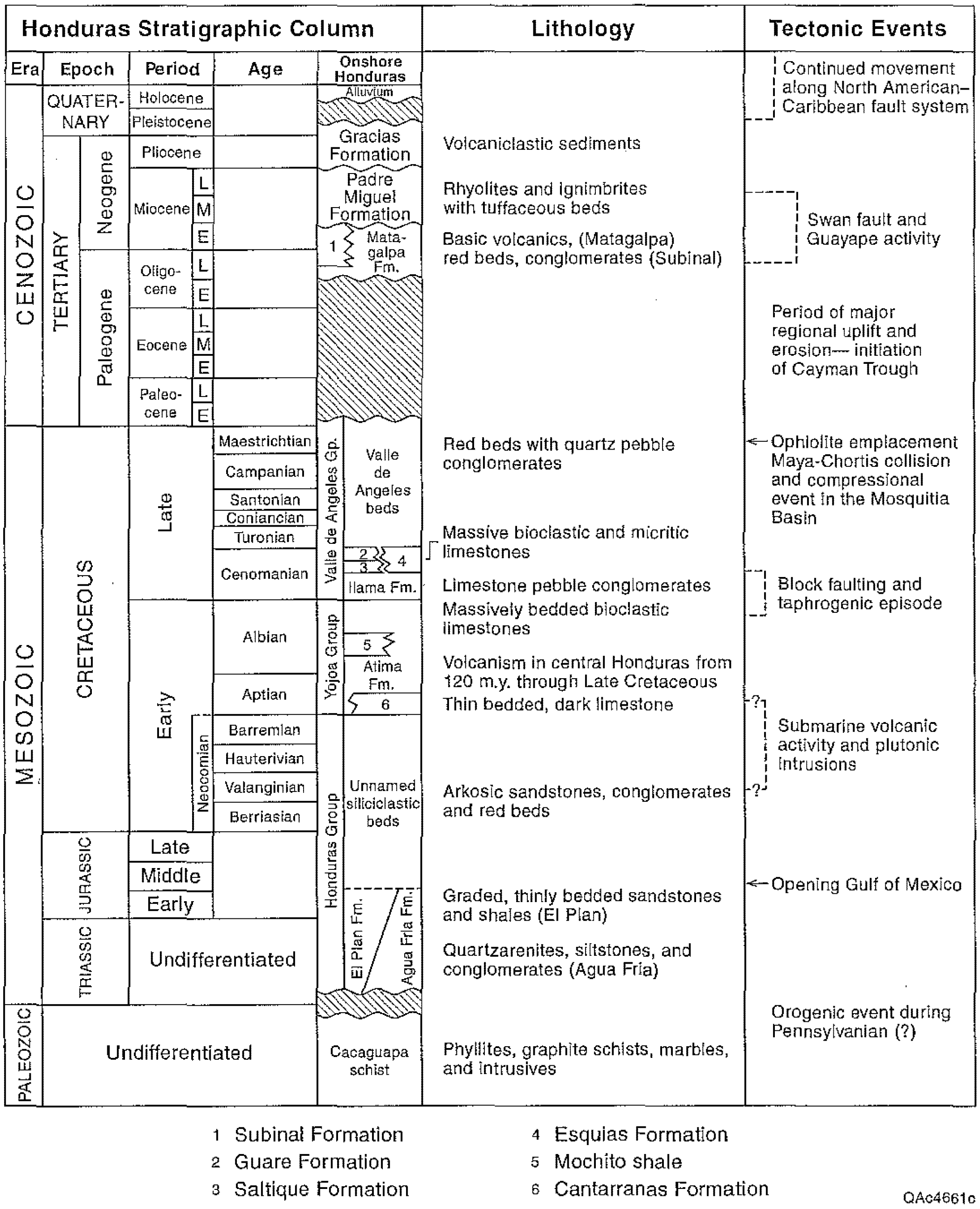

Figure 4. Honduran stratigraphic column with lithologic descriptions and tectonic events (adapted from Southernwood, 1986).

Mesozoic

Triassic to Middle Cretaceous

Honduras Group

The Honduras Group includes El Plan Formation, Agua Fria Formation, and the unnamed siliciclastic beds. This designation was proposed for Honduras by Ritchie and Finch (1985) for all clastic strata overlying metamorphic basement and underlying the Cretaceous Yojoa Group (fig. 4).

In the Mosquitia Basin along the Patuca and Wampu Rivers, Rogers (1995a) described the Jurassic-Cretaceous Honduras Group containing weakly metamorphosed, dark- (fresh exposure) to light-gray, pink and tan phyllites, tan to gray quartzites with minor black graphitic schist, and gray slate with quartz veins increasing in frequency and size northward along the Wampu River. These rocks form the rugged northeast-trending highlands of the northern Mosquitia Basin (pl. 3).

El Plan Formation

Unconformably overlying the Cacaguapa Schist is a thick sequence of alternating dark-gray shales and thinly bedded gray sandstones described by Carpenter (1954) as El Plan Formation (fig. 4). Silts and shales in the formation are nonmarine and tuffaceous with abundant plant debris. The type section for the formation is located at the town of El Plan outside of San Juancito, where a thickness of some 914 m was reported by Carpenter (1954) and Mills and others (1967). The El Plan Formation was considered to be Triassic or Triassic-Jurassic in age by Newberry (1888) and Knowlton (1918) on the basis of plant fossils and to be Upper Triassic by Wilson (1974) on the basis of plant impressions. In the offshore, reservoir potential for the formation is low, and its potential as a gas source rock is considered only speculative at best (Shell Oil Company, personal communication, 1998).

Agua Fria Formation

The Agua Fria Formation at its type section near Danli is composed of alternating quartz, pebble conglomerates; fine-grained, clean quartzarenites; siltstones; and gray to green, fossiliferous shales (Southernwood, 1986) and, on the basis of paleontologic evidence, is considered time equivalent to El Plan Formation (Ritchie and Finch (1985). The lateral extent of the unit is not well known, although Ritchie and Finch (1985) identified outcrops to the south near Nicaragua and to the northwest near Catacamas; however, east of the Guayape fault zone, the Agua Fria Formation was not well developed.

Rogers (1995a) correlated weakly metamorphosed metasedimentary rocks in the Mosquitia Basin along the Patuca and Wampu Rivers to Jurassic Agua Fria Formation east of the Guayape fault on the basis of what he considered a similarity in composition and style of deformation. Rogers (1995a) observed no fossils in the unit but assumed it is Jurassic. These strata were observed unconformably overlain by red beds (Valle de Angeles Group) and are only locally faulted. The red beds show no indication of metamorphic effects. Rogers (1995a) also observed the metasediments unconformably overlain by Tertiary Tabacón beds and below mafic volcanic flows along tributaries of the Wampu River.

Unnamed Siliciclastic Beds

Mills and others (1967) found early Mesozoic clastic sequences consisting of predominantly homogeneous, thinly bedded shales and sandstones throughout Honduras (fig. 4). Some of the uppermost beds are more calcareous, and the beds contain mollusk fragments and locally plant remains. This upper Honduras Group unit in the Comayagua–La Libertad and Minas de Oro area is more massively bedded and contains coarse quartz pebble and lithic fragment conglomerates (Fakundiny and Everett, 1970; Atwood, 1972; Southernwood, 1986). Simonson (1977) encountered nonred siliciclastics underlying the Cretaceous Yojoa Group in El Porvenir quadrangle; he termed these rocks "unnamed siliciclastic beds."

Neocomian sediments in Honduras (Mills and others, 1967) are assigned to red beds of the Todos Santos Formation; however, Wilson (1974) viewed this time interval as a period of nondeposition in Honduras. Finch (1981) suggested that red clastic intervals present on the Chortis block south of the Motagua-Polochic fault zone should not be termed Todos Santos Formation because paleomagnetic data from Gose and Swartz (1977) indicate that "classic" red beds of the Todos Santos in Chiapas, Mexico, and western Guatemala were deposited on a different tectonic plate and in a different magnetic environment from those of Honduras. Lithologies similar to those of the Early Jurassic Todos Santos Formation appear to be widely distributed on the Chortis block (Southernwood, 1986) and are thought to result primarily from local erosion (Weyl, 1980).

In the offshore Caribe No. 1 well, Shell Oil Company (personal communication, 1998) identified Neocomian-age sediments at depths of 2,399 to 3,065 m (7,870 to 10,055 ft) on the basis of a succession of nannofossil species. Lithologically, the interval consists of indurated tuffs, derived from mafic sources, with thin interbeds of calcareous tuffaceous shales that contain abundant pelagic microfossils. The abundant radiolarians and nannofossils in the calcareous streaks are indicative of deep-marine deposition.

Early Cretaceous

Yojoa Group

The Aptian to Albian Yojoa Group is composed of the Cantarranas Formation, the Atima Formation, and an informal unit, the Mochito shale (Finch, 1981). Carbonates of the Yojoa Group are absent north of the Patuca River in the Mosquitia Basin (Rogers, 1995a) (pl. 3).

Cantarranas Formation

The Cantarranas Formation consists of alternating beds of massive limestones and calcareous shales that in some areas conformably overlie siliciclastic beds and range in thickness from 30 m

(98 ft) to 190 m (623 ft) (Southernwood, 1986). Mills and others (1967) described oysters, echinoids, miliolids, and pelecypods in the formation. Two facies have been described in the formation: (1) a lower massive limestone that is overlain by (2) thinly bedded calcareous shale and siltstone beds. The Cantarranas Formation was originally described as an Early Cretaceous formation by Carpenter (1954). Mills and others (1967) considered the unit to be the oldest subdivision of the Yojoa Group. Southernwood (1986) reported that use of the term Cantarranas Formation fell into disfavor because some workers were unable to identify the unit in the field (Finch, 1981; Emmet, 1983).

Atima Formation

The Atima Formation is composed of dark- to medium-gray, thickly bedded micrites with a few sparry calcite, biomicritic beds and some shale partings (fig. 4). Mills and others (1967) dated the limestone as latest Barremian through late Albian. The Atima limestones are highly resistant to erosion and form the karstic highlands of the Colón Mountains south of the Patuca River. In the Mosquitia Basin, a limestone unit was correlated to the Atima Formation (Albian-Aptian) of Central Honduras on the basis of its general lithology, thickness, and mapped stratigraphic relations (Rogers, 1995a). Thickness of the Atima Formation ranges from 50 m (164 ft) to 1,210 m (3,970 ft) (Southernwood, 1986). In the Mosquitia Basin area, the Atima's lower contact is not exposed, although its upper contact, in the Sutawala Valley, appears conformable with thinly bedded sandstones and shales of the Krausirpi beds (Rogers, 1995a). Fossils found in the Atima include rudists, oysters, pelecypods, gastropods, foraminifera, echinoids, ostracodes, sponge spicules, miliolids, and algae.

In the Mosquitia Basin, epikarst development in the Atima Formation was found immediately below Valle de Angeles red beds along the Quebrada Kahkatingni south of Cerro Wampu (Rogers, 1995a). An upward shoaling during Albian to lowermost Cenomanian time is indicated for the limestone's deposition (IBI, 1985). Deposition of Atima limestone apparently continued in eastern

Honduras following cessation of its deposition in central Honduras (Rogers, 1995a). The massive shallow-water limestones of the Atima Formation (Mills and others, 1967) or the Pito Solo limestones (Wilson, 1974) appear to interfinger with deep-water carbonates of the Lajas Formation and Talanga Limestone (Wilson, 1973).

In the Honduran offshore wells (Caribe Nos. 1 through 3), the Aptian-Albian section consists of deep-water shales and pyroclastics. A shallow-water, muddy, nonporous limestone, some 30 to 50 m (100 to 150 ft) thick, occurs in the Caribe No. 1 well, but this interval has been interpreted as part of a large block from a nearby bank area that slumped into a deep-marine environment (Shell Oil Company, personal communication, 1998). In outcrop in Honduras, banks of shallow carbonate deposition appear to be separated by areas of deeper water limestones of a generally nonreservoir facies. Bank carbonates of the Atima type could serve as a potential reservoir. A Recent analog might be the shallow Pedro Bank, west of Jamaica, that is separated from other shallow areas by water depths of more than 300 m (1,000 ft). If a shallow-water carbonate slump block is indeed present in Caribe No. 1 well, the banks, if present in the subsurface, cannot be identified on the seismic data. An unconformity or disconformity is present in the Caribe No. 1 well at the top of this interval of deep-marine, planktonic-rich deposits.

Mochito Shale

This term is an informal designation for a green shale bed that divides the Atima Formation into upper and lower limestone units in the area of Santa Barbara–Lake Yojoa (Finch, 1981). The Aptian-age Mochito shale thickens and shows evidence of oxidation northward of El Mocho mine area; in the mine proper, the shale is 115 m (377 ft) thick (Southernwood, 1986).

Late Cretaceous

Krausirpi Beds

Rogers (1995a) described the Krausirpi beds as light-gray to tan shales and gray, thinly planar bedded, arkosic, lithic arenites and graywackes that are locally calcareous. The rocks weather to a red-brown orange. A limestone breccia occurs near the contact with the underlying Atima limestone. Additionally, the Krausirpi beds contain thin limestone beds and a minor, lithic pebble conglomerate. The clastic beds exhibit upward-fining sequences and rare wood fragments. Rogers (1995a) noted that the calcareous rocks are generally finer grained, and one limestone bed was found to contain algal stromatolites. During low flow, the Krausirpi beds are exposed along the Patuca River; they are also found in strike valleys of the Colón Mountains. The unit conformably overlies the Atima limestone in the Sutawala Valley and is unconformably overlain by the Valle de Angeles red beds at Krausirpi. IBI (1985) reported that the Krausirpi beds contain upper Albian to lower Cenomanian marine fossils. Rogers (1995a) suggested that the change from marine carbonate to marine clastic deposition, coupled with terrestrial carbonaceous material positioned unconformably below terrestrial red beds, indicates a marine regression and that the Krausirpi beds may be prodeltaic. Krausirpi beds were found to thin and disappear southwestward along the Patuca River, suggesting a margin for the marine depositional basin (Yojoa Group) during the Late Cretaceous–early Tertiary (Rogers, 1995a).

Valle de Angeles Group

The Cenomanian to Maestrichtian Valle de Angeles Group is dominantly a thick sequence of clastic red beds with some limestones at its base (fig. 4). It is composed of the Ilama Formation, Esquias Formation, Jaitique Formation, Guare Member, and upper Valle de Angeles red beds. Finch (1981) concluded from paleomagnetic and stratigraphic evidence that at least two separate, unconformable sequences of red beds are present within the group. Limestone clast conglomerates of the Valle de Angeles Group were found by Rogers (1995a) to occur only south of and distal to the exposed Honduras Group highlands.

Changes in depositional environments in the offshore are recorded in the Caribe No. 1 well where the abrupt transition from underlying deep-water deposition into red sandy shales and conglomerates indicates major uplift, regression, and development of a land area in the Mosquitia Basin. The section grades upward through a tuff layer into green shales and thin limestones and finally into massive limestones at depths of 1,375 to 1,120 m (4,400 to 3,590 ft) in the well. Between 1,340 and 1,375 m (4,300 and 4,400 ft), a high-energy packstone is present, but the remainder of the carbonate section is a low-energy mudstone. A similar section is found in the Caribe No. 3 well, but rocks of this age and similar deep-water deposition are missing from the Caribe No. 2 well. Cenomanian-age sediments in Honduras as described by Wilson (1974) are very similar to the section found in the Caribe No. 1 well. Onshore, the underlying continental sequence is the Ilama or Plancitos Formation, and the overlying limestones are the Cantarranas and Esquias Formations. A shallow-water carbonate thickness of 150 to 304 m (500 to 1,000 ft) is consistently seen for this time period (Shell Oil Company, personal communication, 1998). Rogers (1995a) noted that the Yojoa and Valles de Angeles Groups appear to be younger stratigraphically (10 to 15 m.y.) in the Mosquitia Basin area than in Central Honduras, which indicates a progressively younger depositional basin eastward.

Ilama Formation

The post-Albian Ilama Formation is composed dominantly of limestone clasts eroded from the Atima Formation with lesser amounts of quartz, red sandstone, and volcaniclasts (fig. 4). The conglomerate is generally clast supported with a calcareous, red, fine- to coarse-grained matrix (Southernwood, 1986).

Lower Valle de Angeles Beds

Finch (1981) and Southernwood (1986) recognized this lower sequence as red, coarse-grained sediments with quartz-pebble conglomerates and interbedded dark-green sandstones. Finch (1981) found the contact between the upper and lower red beds to be gradational to possibly unconformable. Rogers (1995a) described the lower contact of the Valle de Angeles red beds as unconformable with the underlying Honduras Group and Krausirpi Formation. In the area southeast of Cerro Wampu along Quebrada Kahkatingni, he also described red beds unconformably resting upon epikarst developed on the Atima limestone. This sequence indicates that subaerial exposure of the Atima Formation occurred before red-bed deposition. Thickness of the lower red beds was estimated by Atwood (1972) to be 2,000 m (6,562 ft); Atwood also made the only fossil discovery for the red beds—a Late Cretaceous *Hadrosaur* bone.

Sedimentary structures found in the lower Valle de Angeles consist of small- and large-scale crossbedding, ripple marks, graded bedding, and mud cracks. In the Mosquitia Basin, the strata exhibit planar bedding, lack basal scour marks, contain matrix-supported clasts, and possess few channels and crossbeds, features Rogers (1995a) suggested indicate deposition by high-viscosity and hyperconcentrated fluid flows. He thought deposition occurred as a series of debris flows on a tropical alluvial fan with only a minor contribution from fluvial systems.

Southernwood (1986) ascribed the lower Valle de Angeles beds to a late Albian to Cenomanian age on the basis of ages of limestone units that define the beds' upper boundary. Rogers (1995a) identified mafic volcanic flows that occur at the upper contact separating the Valle de Angeles red beds from the younger Tabacón beds. He suggested that the red beds' age is constrained by lower Cenomanian limestone clasts, derived from the Atima Formation and found within the conglomerates, and ages of the mafic volcanic flows that have been dated between 80.7 ± 4.3 and 70.4 ± 4.3 Ma (Weiland and others, 1993).

Mafic Volcanic Rocks

In the Mosquitia Basin area, Rogers (1995a) described dark-gray, green, and reddish basalt and andesitic flows containing plagioclase phenocrysts in a biotite-rich groundmass; flow banding, scoria, and autobrecciated flows were also observed. The mafic flows contain calcite- and zeolite-filled cavities. Extensive flows are found in low-relief areas north of the Wampu River and between the Pao and Ner Rivers; isolated flows also occur within the Valle de Angeles red beds. Weiland and others (1993) obtained ages of 80.7 ± 4.3 to 70.4 ± 4.3 Ma from whole rock and plagioclase dating of the flows. Rogers (1995a) noted that mafic flows separate the Tabacón beds and the Valle de Angeles red beds on the Crique Malawas and that mafic flows unconformably overlie the Honduras Group north of the Mosquitia area.

Esquias Formation

In the Minas de Oro quadrangle, the Esquias Formation is composed of massive limestones and divides the Valle de Angeles into upper and lower red-bed units (fig. 4). The formation consists primarily of calcilutites, marly beds, and fossiliferous calcarenites (Horne and others, 1974) with some minor thin sandstones and shales and evidence of laminated bedding and biohermal structures (Finch, 1972). Fossils present in the Esquias Formation include ostracodes, miliolids, orbitolinids, pelecypods, echinoid fragments, clams, and gastropods (Southernwood, 1986).

Jaitique Formation

The Jaitique Formation was defined by Finch (1981) as the limestone unit that separates the upper and lower Valle de Angeles red beds in the Santa Barbara–Lake Yojoa area. The Jaitique is divided into two members. The unnamed lower member is a thick-bedded, gray limestone of variable total thickness that is micritic and fossiliferous and contains biohermal structures. The unit contains rudists, pelecypods, gastropods, echinoid fragments, and numerous foraminifera. Finch (1981) reported that Shell Oil Company paleontologists assigned a Cenomanian age to the limestone and that the unit is less than 200 m (656 ft) thick. Southernwood (1986) in her correlation chart showed the Jaitique as time equivalent to the Esquias Formation on the basis of the tentative correlation by Horne and others (1974).

Guare Member

Finch (1981) and Southernwood (1986) reported a dark-gray to black, microcrystalline, pelagic limestone interbedded with black shales present above the Jaitique Formation. The shale is reported to have a petroliferous odor and to be finely laminated and generally unfossiliferous (Southernwood, 1986). At the type locality of the Guare Formation, oil seeps from the petroliferous limestones. The Guare limestone is overlain by a gypsum-bearing shale unit. Finch (1981) reported that the gypsum-shale unit appears to have conformable lower and upper contacts. The gypsum is laminated or is found as dirty gray lenses in the shale.

Upper Valle de Angeles Beds

In general the upper Valle de Angeles beds in Honduras are finer grained than the lower red beds of the Honduras Group. The strata are locally gypsiferous and contain large amounts (as much as 60 percent) of volcanic detritus (Fakundiny and Everett, 1976). Everett (1970) reported that the upper Valle de Angeles beds conformably overlie the Cenomanian limestone units but are separated by an angular unconformity from the overlying Matagalpa volcanics.

In the Mosquitia Basin, contact of the Valle de Angeles beds with the overlying Tabacón beds is gradational because the red beds gradually coarsen upward. Mafic flows separate the upper Valle de Angeles red beds on the Crique Malawas from the overlying Tertiary Tabacón Formation. This upper red-bed unit contains tabular or lenticular beds, ripple marks, mud cracks, and both small- and large-scale crossbedding.

Finch (1972) considered the unit to be Cenomanian to Eocene in age, but Southernwood (1986) found no data to support a Tertiary age and, therefore, assumed a latest Cretaceous age. Offshore in the Caribe No. 1 well (fig. 5), there is a 25-m (75-ft) interval of sandy, green shale with plant debris that was dated through palynology as Turonian (Shell Oil Company, personal communication, 1998). In Honduras, the upper Cenomanian-Turonian section contains pelagic limestones of La Mision–Guare Formations. The post-Turonian section of the Upper Cretaceous is missing in the Caribe Nos. 1 through 3 wells. The absence of this portion of the section is probably due to an unconformity. Post-Turonian sediments may, however, be present in some portions of the basin. Their reservoir potential is considered doubtful. Sediments of this age are either absent in the onshore of Honduras or present in the red beds of the Valle de Angeles Group. Valle de Angeles beds and basal transitional Tabacón red beds were considered by Rogers (1995a), on the basis of limited paleocurrent data, to have a northern provenance.

Tertiary

Tabacón Beds

These Tertiary-age beds were described by Rogers (1995a) in the Mosquitia Basin area as maroon to green, cobble- to boulder-sized, subangular to angular breccias and conglomerates composed of quartzite, volcanic rock, quartz, and minor red sandstone clasts. Angular clasts of the conglomerates are supported in a fissile mud matrix with only a minor sand component represented. The beds occur flanking the Honduras Group highlands on the southwest and appearing as rugged ridge formers northwest of the Honduras Group highlands (Rogers, 1995a). Exposures along the Quebrada Tabacón exhibit planar bedding.

Rogers (1995a) reported a gradational contact between the Tabacón and the underlying upper Valle de Angeles red beds with some minor fluvial crossbedding present in the transition zone. Along tributaries of the Wampu River, the Tabacón unconformably overlies mafic volcanics and the Honduras Group. Rogers (1995a) considered the beds to be Tertiary because of (1) their stratigraphic position with respect to underlying Late Cretaceous volcanics and (2) the nature of volcanic clasts comprising the Tabacón conglomerates. Rogers (1995a) suggested that angularity of material comprising the Tabacón conglomerates suggests high-viscosity debris flows that were rich in fines and whose provenance was a nearby fault-bounded uplift. The Tabacón beds are possibly a local unit of the Valle de Angeles Group and cannot be correlated to other Honduran units (Rogers, 1995a). Evidence of tectonic activity is demonstrated by the presence of mafic volcanic rock. Additionally, the Tabacón unit represents, according to Rogers (1995a), a possibly local, Late Cretaceous to early Tertiary episode of basin fill. The limestone boulder breccia and mafic volcanic rocks found along the Coco River between Tilba and Awasbila south of the Colón Mountains may be correlated genetically to the Tabacón beds found north of the same mountains and define the southern margin of the Late Cretaceous–early Tertiary depositional basin (Rogers, 1995a).

Matagalpa Formation

McBirney and Williams (1965) correlated andesitic and basaltic rocks unconformably overlying the Valle de Angeles Group in Honduras to the Matagalpa Formation of north-central Nicaragua (fig. 4). Southernwood (1986) reported thicknesses for individual flows as some 20 m. These mafic volcanics are dark gray and fine grained and contain some petrified wood, suggesting that they were extruded (Atwood, 1972). Finch (1972) noted that the flows lack pyroclastic ejecta and vesicular structures, indicating that the flows were erupted quietly and with minimal gaseous explosions.

Widespread Cenozoic volcanism in northern Central America is considered by Sutter (1977) to have occurred at 30 m.y. with ages of Matagalpa mafics reported as 30 to 10 m.y. He thought the time of volcanism overlapped with Subinal deposition because Matagalpa volcanics are found interbedded with the Subinal Formation. Emmet (1983) suggested an age as old as the Paleocene for the Matagalpa, although an Oligocene age is more widely accepted.

Subinal Formation

The Subinal Formation in the Motagua Valley is described by Hirschmann (1963) as a poorly sorted but well-stratified series of red and green conglomerates, sandstones, arkoses, siltstones, and shales that were reported from two incomplete sections as 754 m (2,470 ft) and 898 m (2,920 ft) in thickness, respectively (fig. 4). The conglomerates, which exhibit angularity and poor sorting, compose as much as one-fourth of the section and are found with a red clay, calcite, and silica matrix. Hirschmann (1963) recognized quartzite, vein quartz, serpentine, red siltstone, and sandstone as contributing to the three main types of clasts, although red shale, mafic and felsic rock, limestone, marble, granite, diorite, schist, and Fe-rich minerals are also present.

Southernwood (1986) noted that in the type section, volcanics are present throughout and tuffaceous beds, lavas, and particularly andesitic flows are important components elsewhere. Burkart and others (1973) found the proportion of volcanics to increase up section in the areas of southeastern Guatemala, such as Quezaltepeque, Esquipulas, Jocotán, and Chiquimula. This trend was also encountered in western Honduras by Williams and McBirney (1969).

Age control for the Subinal Formation is weak because it unconformably overlies a variety of rocks and is in turn unconformably overlain by Tertiary basaltic units (Hirschmann, 1963). Hirschmann (1963) placed the lower age limit at post-Cenomanian, on the basis of the presence of fossils of this age extracted from some of the limestone clasts. He assigned the upper boundary of the Subinal Formation to the pre-Pliocene because a younger series of red beds, containing Miocene- to Pliocene-age foraminifera, were found overlying the unit (Hirschmann, 1963). Interbedded tuffs and volcanic flows within the upper Subinal Formation have been dated by Sutter (1977) using K-Ar methods as latest Oligocene (25 to 30 m.y.). Southernwood (1986) assigned an age range of Oligocene to Miocene, owing to the fact that Sutter gave no specific sampling sites.

Padre Miguel Group

A series of ignimbrites, tuffs, lahars, volcanic arenites, claystones, and interbedded polymictic conglomerates unconformably overlie the Matagalpa Formation volcanics (fig. 4). Williams and McBirney (1969) described ignimbrites covering a vast area of Central America, which includes most of southern Honduras. Atwood (1972) mentioned fine-grained welded tuffs that contain phenocrysts of plagioclase, sanidine, biotite, and quartz, and Emmet (1983) reported crystal-rich, ashy, nonwelded tuffs in the Agalteca area. Dupre (1970) and Curran (1980) also described the highly complex and variable lithology of the Padre Miguel Group. The tuffaceous sediments were either deposited from air falls or were water laid (Fakundiny, 1970; Finch, 1972) and contain sedimentary structures such as current scour marks, thin to massive bedding, and crossbedding. Total thickness of the Padre Miguel Group in the Comayagua quadrangle is estimated by Everett (1970) to range from 400 to 1,200 m (120 to 400 ft). Finch (1972) found some silicified wood fragments in the section. K-Ar dating of the ignimbrites yielded ages ranging from 14 to 19 m.y. (Emmet, 1983).

Gracias Formation

Unconformably overlying the Padre Miguel Group is a unit consisting of sand, silt, and clay with a few conglomeratic beds (fig. 4). The Gracias Formation is locally exposed in western Honduras and ranges from 200 to 300 m (656 to 984 ft) in thickness (Williams and McBirney, 1969). The Padre Miguel Group was the source of material for the Gracias Formation. Williams and McBirney (1969) reported that the formation is largely composed of rhyolite, rhyodacite pumice, vitric ash, quartz, feldspar, and minor biotite fragments. The Gracias Formation is considered to be Pliocene in age on the basis of the presence of horse bones and an indeterminate *Cervid* (Olson and McGrew (1941).

Quaternary

Alluvium

Unconsolidated silt, sand, and gravel compose much of the thick, river valley fill for such major Honduran fluvial systems as the Aguan and Ulua Rivers, along with areas adjacent to the confluence of the Patuca and Sutawala Rivers and along the Wampu River and other rivers and streams in the Mosquitia Basin.

Plutonic Igneous Rocks

Plutonic igneous rocks in Honduras have been divided into (1) pre-Laramide and (2) Laramide and younger (Williams and McBirney, 1969). The older, pre-Laramide, or Paleozoic, plutons are characterized by sheared gneisses, cataclastic textures, and interlayering with basement schists. They are distributed in the north, on the old road from Yoro to El Negrito, and in southern Honduras, around Catacamas-Juticalpa (Southernwood, 1986).

The Cretaceous and younger plutons are granodioritic, tonalitic, or dioritic, true granites being rare. Appearance of these younger plutons is also deceptive, as they may also be sheared and mylonitized; radiometric dating provides the only definitive age. The plutons are found from the Nicaraguan border northward through Honduras to the Caribbean and are especially concentrated in northern Honduras near the coastal cities of Trujillo, Tela, and Mezapa (Southernwood, 1986). Exposures are commonly restricted to river beds or isolated boulder fields, thus limiting the ability to discern an individual pluton's areal extent (Southernwood, 1986).

TECTONIC HISTORY

Early history of the Mosquitia Basin is related to evolution of the Chortis block. Principal difficulties associated with any reconstruction of the Chortis block's history derive from the paucity of reliable evidence as to its pre-Mesozoic paleogeographic position. It currently is widely accepted in the scientific community that the Chortis block was tectonically transported to its present position. Various models have attempted to restore the block to its stratigraphic basement position adjacent to southwestern Mexico (Dengo, 1985).

Pre-Mesozoic

The oldest known component of the Chortis block includes a meta-igneous complex that is considered late Precambrian to early Paleozoic in age (pl. 3). These rocks are unconformably overlain by early to middle Paleozoic terrigenous strata, which were regionally metamorphosed and intruded by an intermediate composition batholith during a major orogenic episode that occurred probably in the Pennsylvanian (Donnelly and others, 1990).

During the late Paleozoic, a marine sequence was deposited over the older basement, covering the entire Chortis block. This younger sequence was, in turn, regionally metamorphosed to a greenschist facies and later exposed to prolonged periods of subaerial erosion (Donnelly and others, 1990).

Mesozoic

The Chortis block at the beginning of the Mesozoic was a denuded, moderate-relief, emergent area. Deposition of the Honduras Group sequences began in the Middle Jurassic and was characterized by thick, extensive coastal plain sequences, fluvial channel sands, floodplain sediments, and occasional marine transgressions. No major tectonic activity occurred, enabling a gradual evolution from terrigenous to mixed land to ultimately general marine conditions.

From the Early to middle Cretaceous, the Chortis block, including the Mosquitia Basin, was inundated by the Yojoa sea with its characteristic shallow-water carbonate deposition. The oldest sediments described in the Caribe No. 1 well consist of Neocomian lithic tuffs and pelagic oozes (fig. 5). Scattered submarine volcanic activity and plutonic intrusions occasionally interrupted the calm marine conditions. This situation supports the contention that a subduction zone existed west of the Chortis block as it moved eastward on collision with the Maya block.

Wilson (1974) described a period of widespread shallow-water deposition of carbonate banks (Yojoa Group) separated by deeper water troughs during the Aptian and early Albian (fig. 6). These troughs were the initial result of block-faulting produced by a taphrogenic episode during the late Albian to early Cenomanian (fig. 7). Uplifted horsts contributed coarse detritus to the developing basins. Alluvial fans, piedmont plains, lagoons, and shallow-marine environments contributed to molasse deposits represented in the stratigraphic column by the Valle de Angeles red beds.

The late Cenomanian was characterized by a drastic change in paleogeography (fig. 8). The sediment record indicates development of shallow-marine environments, carbonate platforms, and emergent land. This period of renewed marine transgression was accompanied by minor volcanic activity (Donnelly and others, 1990).

Late Cretaceous history of the Chortis block is obscured by an incomplete stratigraphic column possibly resulting from a major regional uplift (fig. 9). Subsidence continued to the west, initiating the deposition of deep-water, pelagic limestones. Before and during collision of the Chortis and Maya blocks, ophiolitic sequences were emplaced along Guatemala's Motagua Valley. Upper Valle de Angeles red beds, considered by Finch (1972) to be Cenomanian to Eocene in age and by Southernwood (1986) to be latest Cretaceous, indicate by their presence a period of relative tectonic quiescence. Tropical, alluvial fans, floodplains, and lacustrine and deltaic environments flanked remnant basement highlands in the southwest.

Widespread plutonic activity, accompanied by extensive brittle deformation, signaled termination of the Mesozoic Era for the Chortis block. A marked angular unconformity between upper Valle de Angeles beds and mid-Tertiary sequences has been interpreted both from outcrop studies and subsurface seismic data. This major event appears to be time equivalent to major deformation associated with the Laramide Orogeny of North America. Although age and

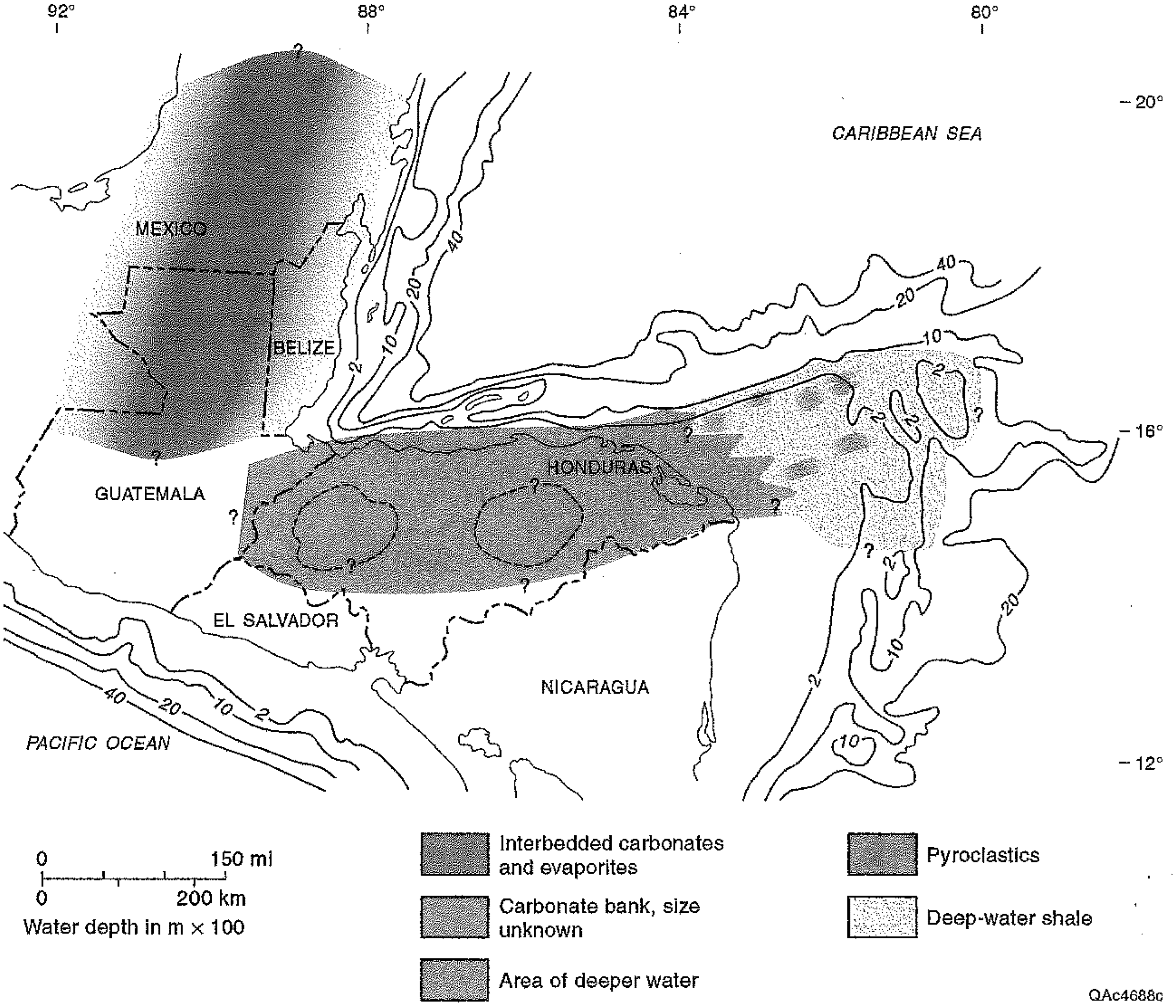

Figure 6. Paleogeographic map of northern Central America during the Aptian to Albian.

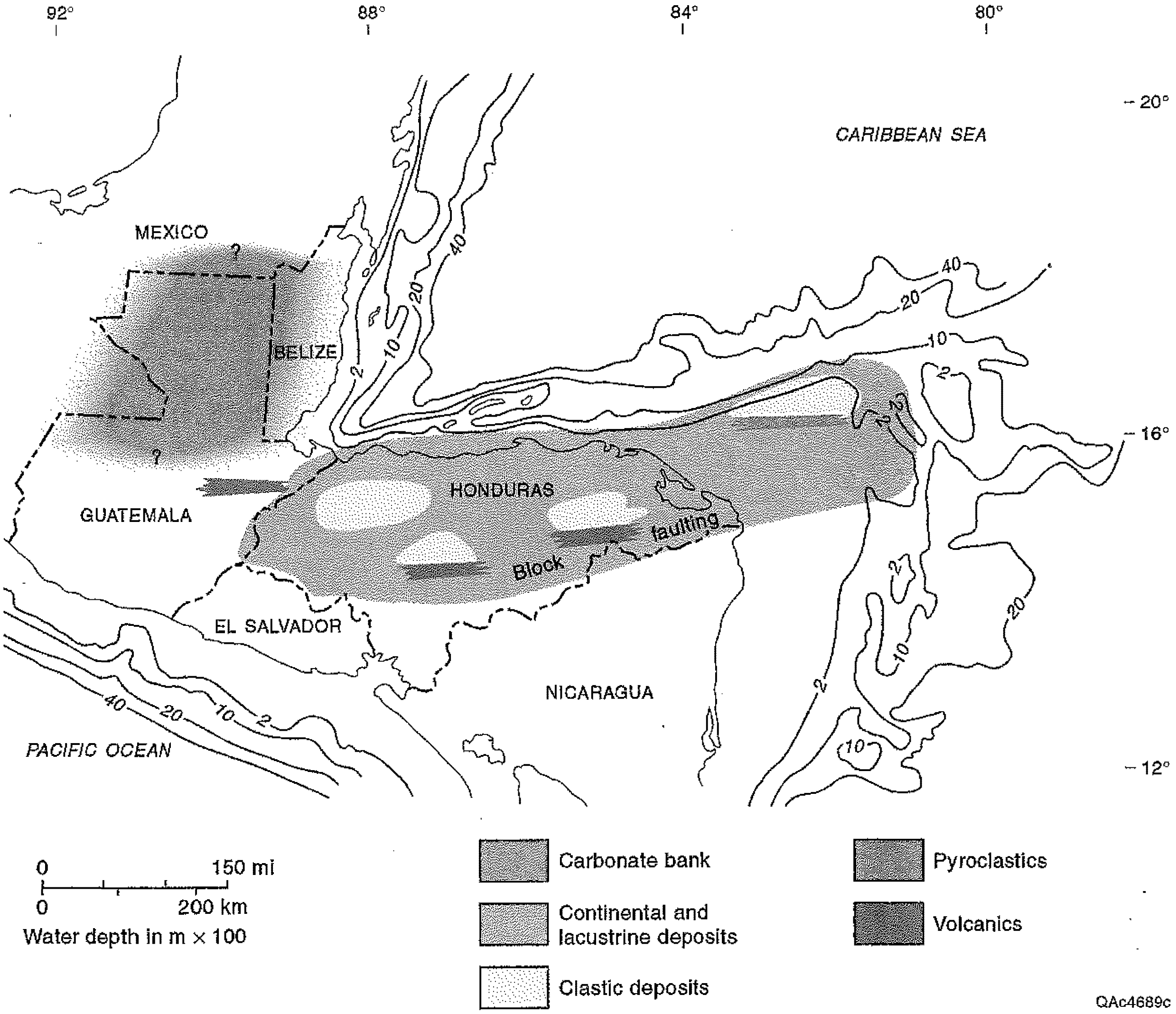

Figure 7. Paleogeographic map of northern Central America during early to middle Cenomanian.

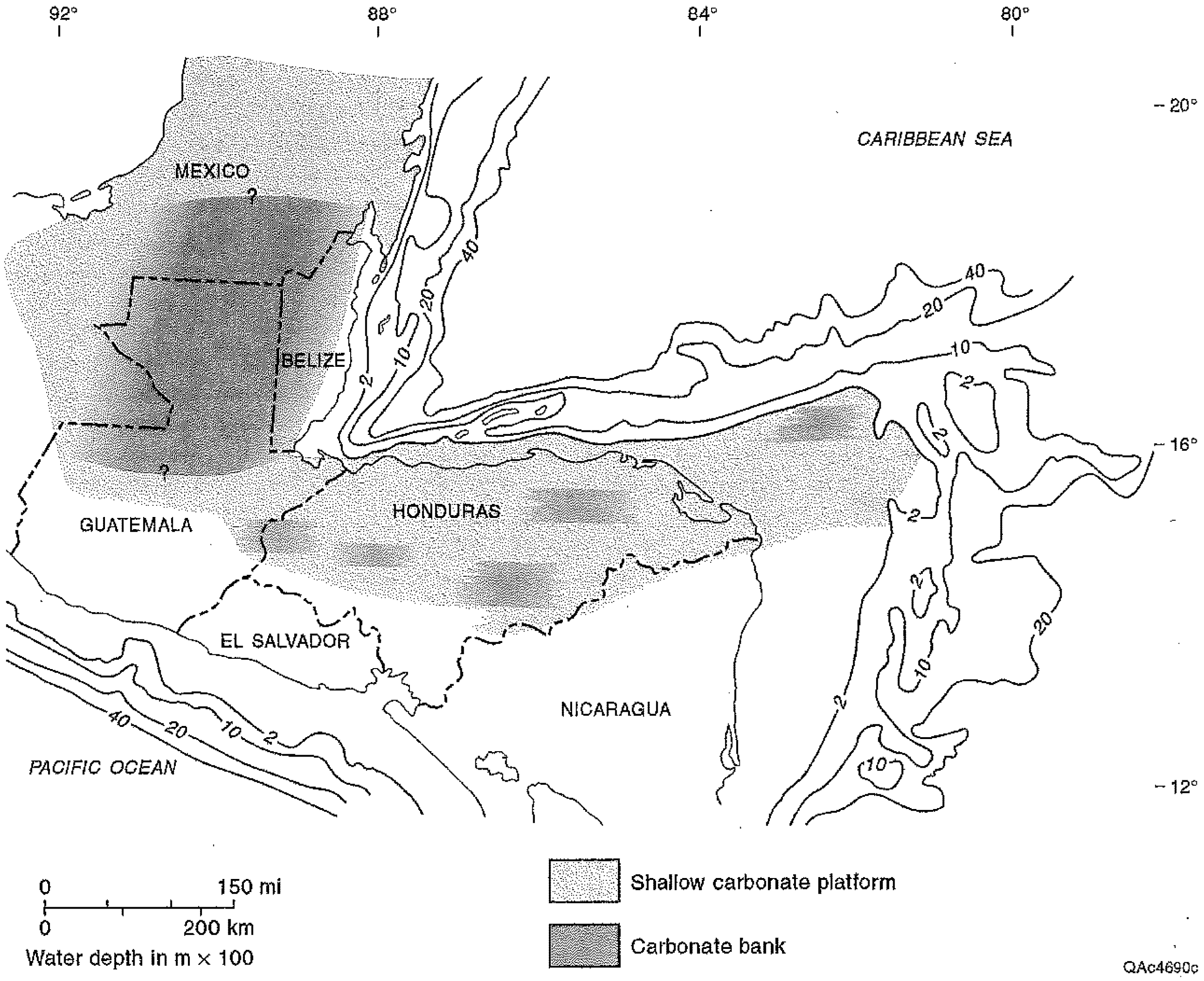

Figure 8. Paleogeographic map of northern Central America during late Cenomanian.

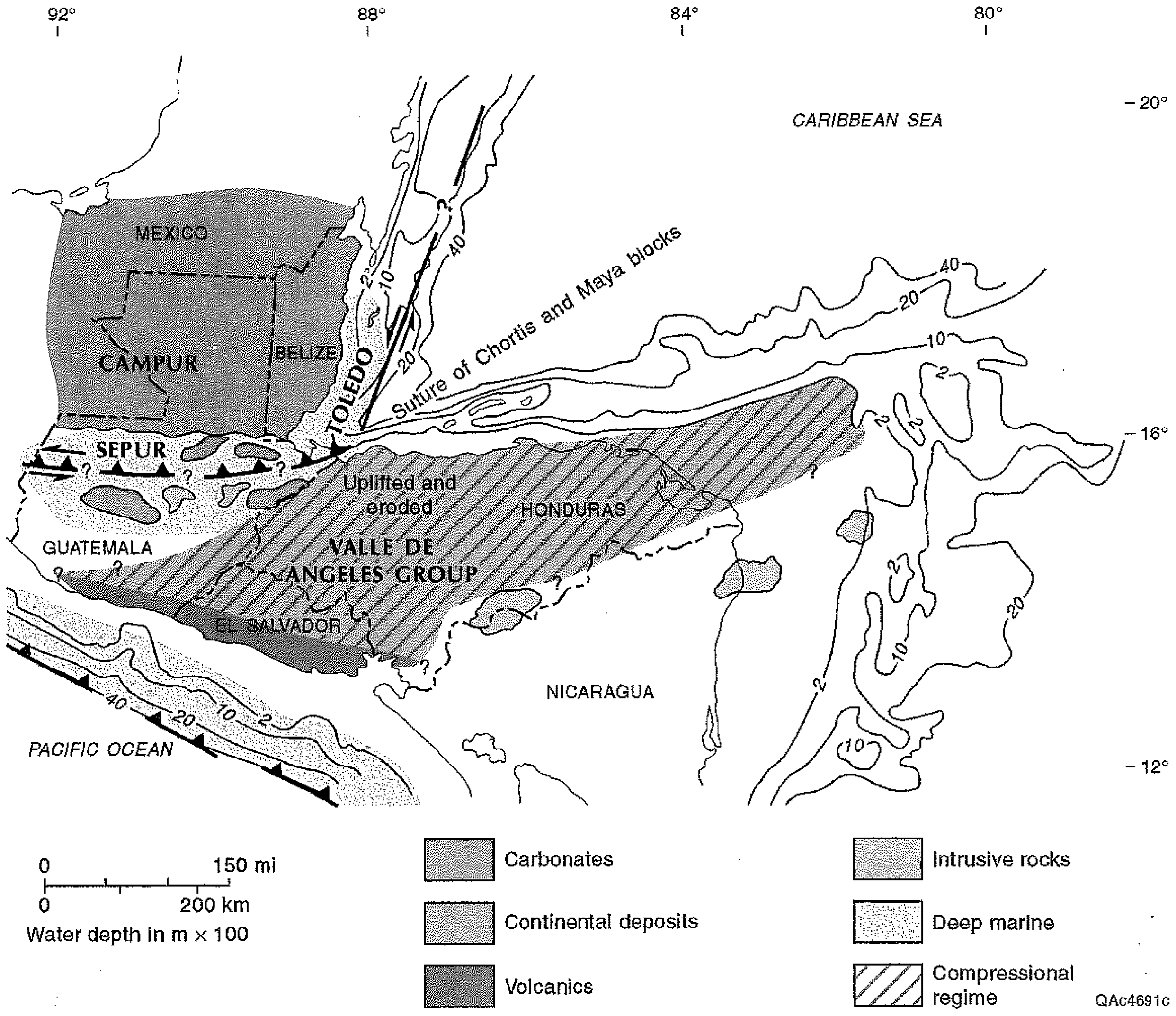

Figure 9. Paleogeographic map of northern Central America during the Turonian and Maestrichtian.

deformational styles are similar, the tectonic setting for Central and North Americas was clearly different.

Recent geologic mapping by Rogers (1995b) in eastern Honduras has revealed for the first time that the poorly understood Colón Mountains actually form a prominent northeast-trending fold and thrust belt some 30 km wide by 150 km long. Field reconnaissance efforts indicated southeast-dipping beds and large northwest-verging reverse faults, which place the Lower Cretaceous Atima limestones over Upper Cretaceous–early Tertiary (?) upper Valle de Angeles red beds.

Additional evidence of a compressional event was reported 185 km to the northeast near Awaus, where True Oil Company drilled the Awaus No. 1 well near the coastline and penetrated 7,000 ft of Jurassic Honduras Group shale before encountering much younger Valle de Angeles Group sandstones (Rogers, 1995b). This report documents the first instance in the region of such a thick interval of Jurassic shale having been penetrated by drilling.

Structural cross sections such as plates 4 and 5 and figure 10 indicate the extension of this compressional event for at least 150 to 200 km (95 to 125 mi) in the offshore direction. In the Caribe No. 2 well, the Aptian-Neocomian sequence overlies Aptian-Albian strata. Pollen determinations were questionable, but results from dipmeter logs indicate that at this same depth, a dramatic change in dip occurred (Shell Oil Company, personal communication, 1998). A seismic profile near the Caribe No. 3 well additionally illustrates a Mesozoic section affected by compressional and thrust features. Further detailed interpretations, however, are required to determine dip and fault directions (pls. 4 and 5).

Cenozoic

During the Late Cretaceous to early Tertiary, tectonic activity in the Honduran region involved collision and resultant suturing of the Maya and Chortis blocks. The Cenozoic history of eastern Honduras was subsequently dominated by interactions of the Caribbean, North American, and Cocos plates. Left-lateral transform motion between the North American and Caribbean plates created an expansive zone of strike-slip displacements along the Motagua-Polochic fault zone and its extension into the offshore, known as the Swan Island Transform (fig. 11).

Peaks in deformational intensity occurred during the latest Cretaceous and again during the early Eocene (Holcombe and others, 1990). Uplift and erosion, which locally exposed intrusive bodies and Paleozoic basement rocks, were prevalent throughout the early Tertiary. Paleocene and lower Eocene deposits are noticeably absent except in structural troughs and offshore portions of the Mosquitia Basin (figs. 5, 10, 11, and 12).

A regional transgression reflected in a shift of marine sediments toward the northern edge of the basin (fig. 11) occurred from the middle to late Eocene. A widespread emergence and development of an onshore regional unconformity signaled the end of the Eocene. In the north, the Cayman trough fracture zone was initiated in the late Eocene.

From the Oligocene to the Miocene, a marine transgression inundated the Eocene surface (figs. 5 and 13), with shallow-water limestones covering most of the present-day offshore portion of the Mosquitia Basin. Concurrently, the Coco River, originating along the Honduras and Nicaragua border, developed a delta from west to east. Northern limits of the Mosquitia Basin were delineated by the Swan Island Transform fault, which was an active strike-slip margin from the late Oligocene to early Miocene. This boundary was inactive for the remainder of the Miocene, with only vertical movements recorded along the onshore fault zones and accompanied by subsidence of the Honduran margins (Pinet, 1975).

Carbonate deposition continued into the Miocene, as marine sedimentation covered over the thick clastic wedge of the Coco River Delta (figs. 10 and 14). This extensive transgression continued until most structural highs were covered. Deposition was characterized by accumulations of deep-water marls and limestones along the eastern flank of the carbonate platform. Eastward in the Tela Basin (fig. 13), the Castaña No. 1 well and the Castilla No. 1 well, located northeast of the town of Trujillo, contained 1,200 m (3,940 ft) of Miocene clastic rock overlying the Cretaceous (Pinet, 1975).

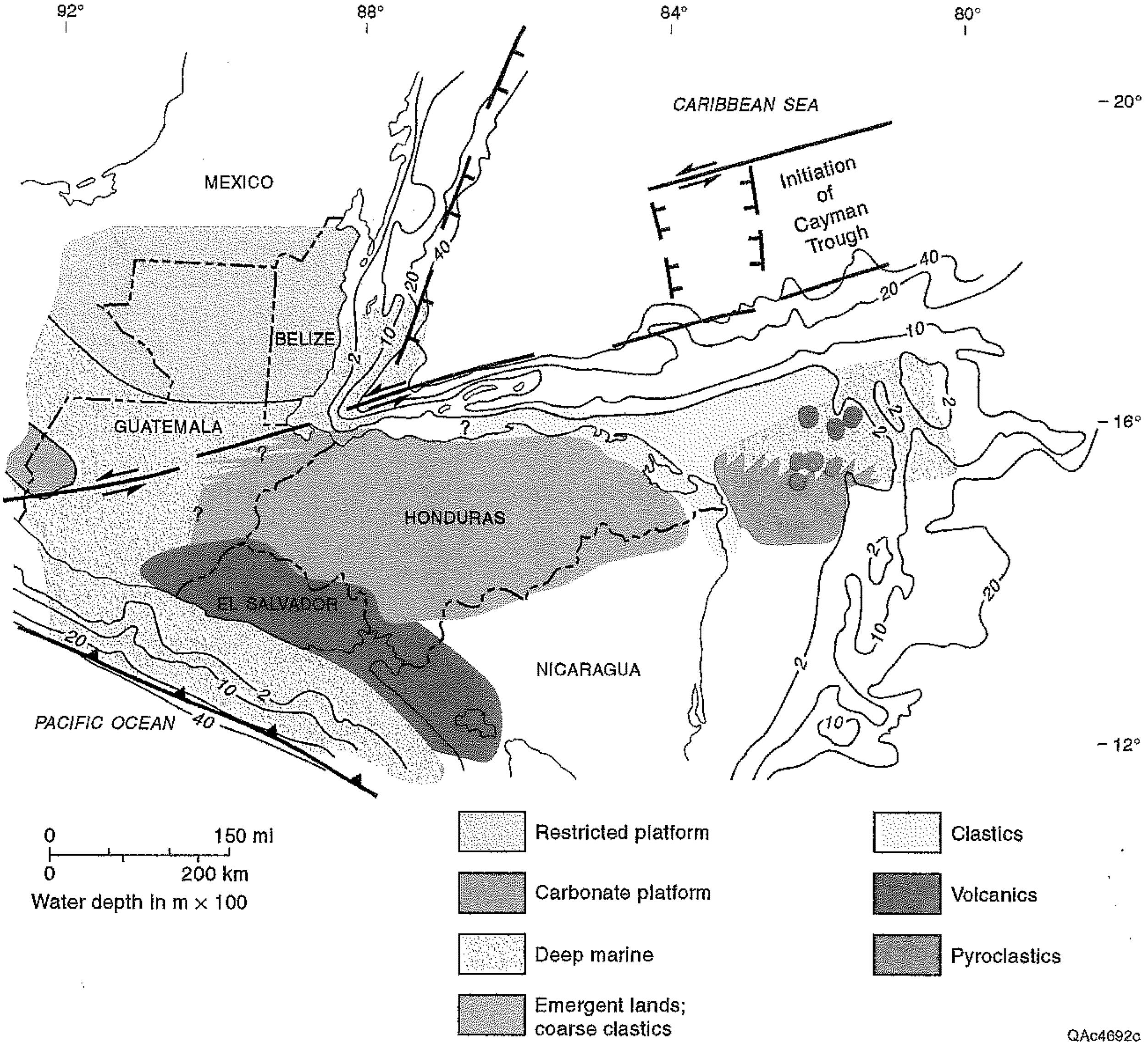

Figure 11. Paleogeographic map of northern Central America during the Eocene.

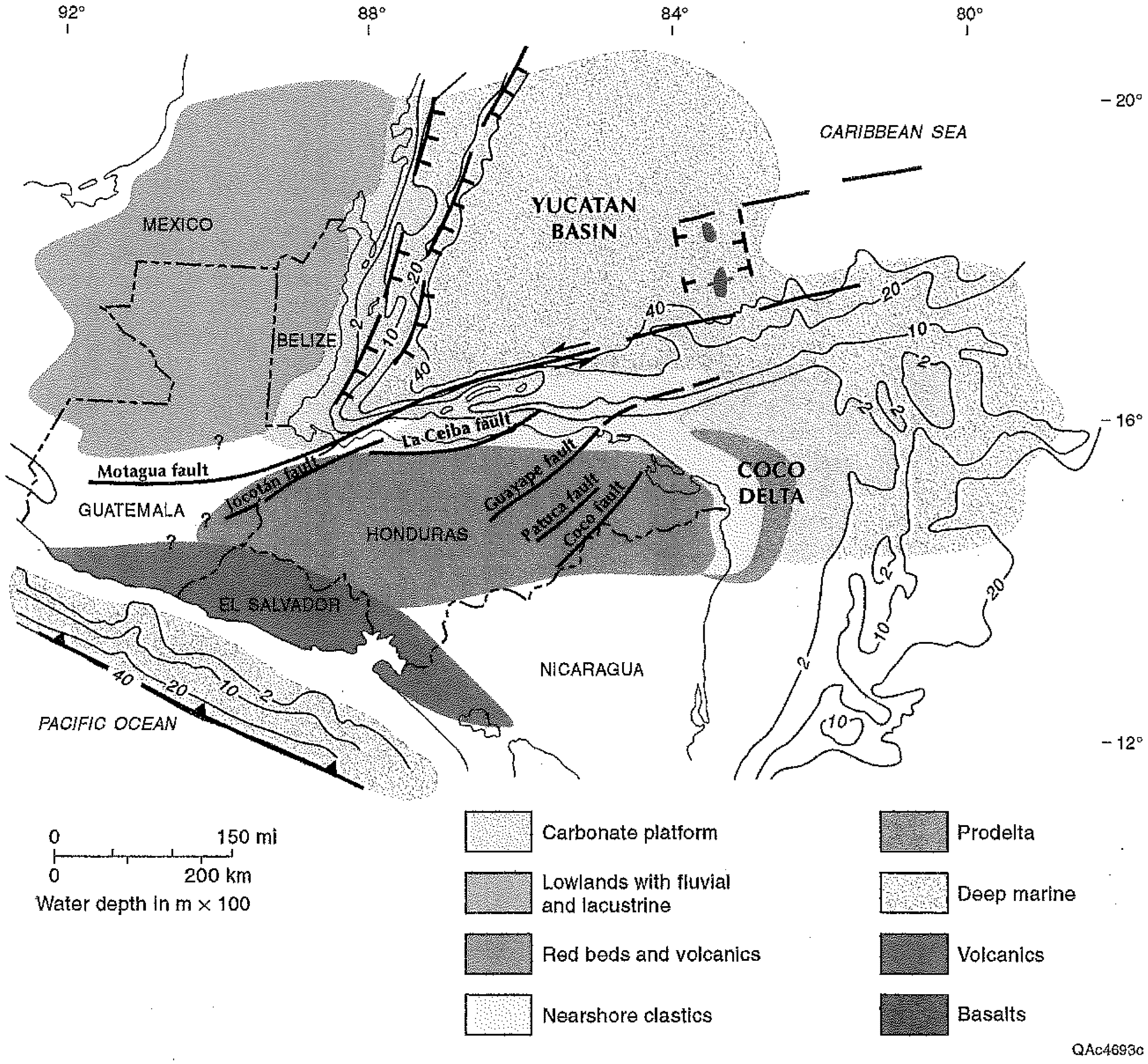

Figure 13. Paleogeographic map of northern Central America from early to middle Miocene.

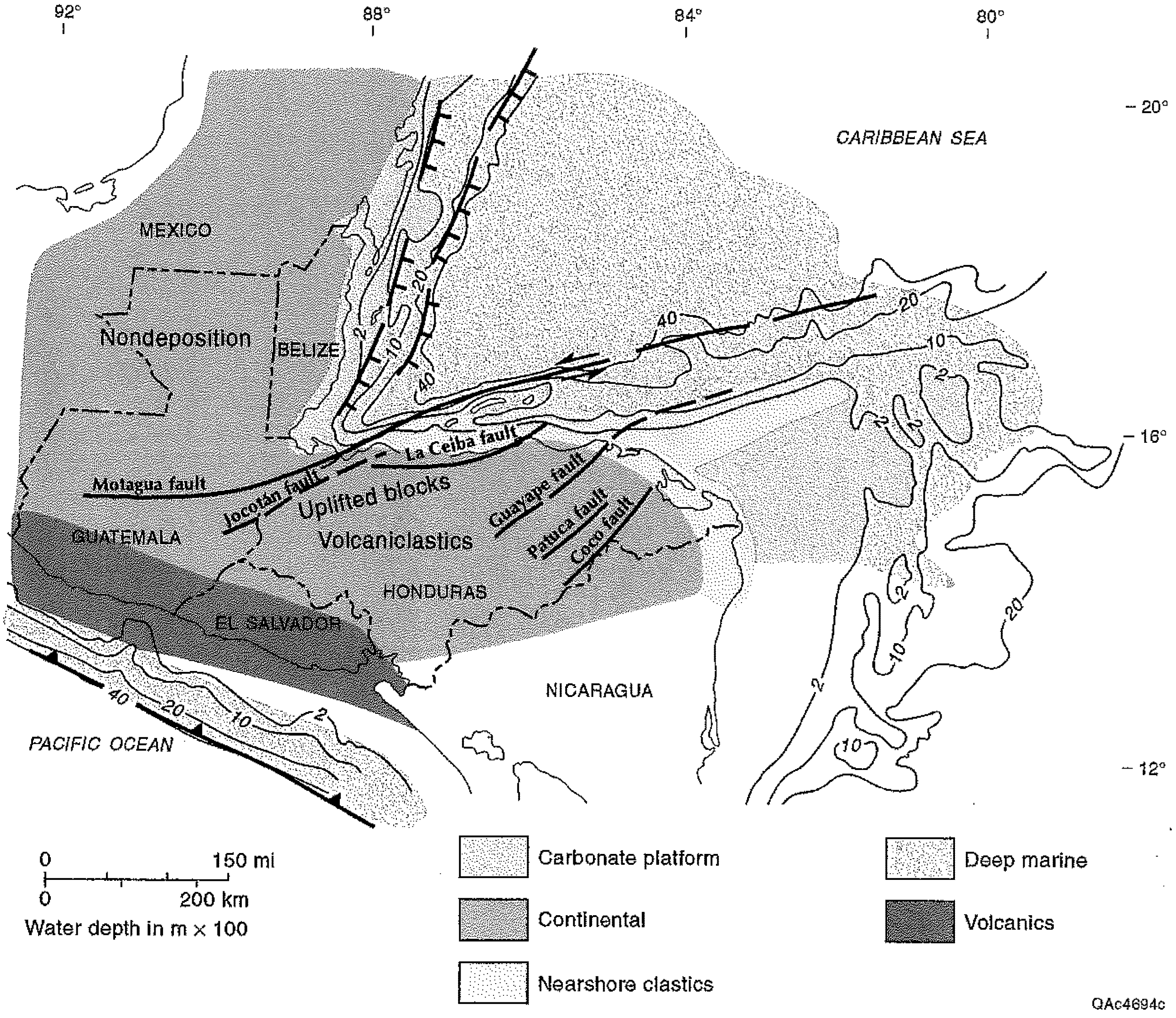

Figure 14. Paleogeographic map of northern Central America from middle to late Miocene.

According to Manton (1987), a post-Miocene faulting event is reflected in the flow alignment of present-day Honduran rivers. Flow direction is controlled by two groups of fractures—one trending northeast and the other trending northwest (fig. 15). A line separating these two drainage areas strikes N21°W and passes approximately 20 km (12 mi) west of the island of Utila. Drainages that developed in western Honduras on Miocene volcanic terrain were apparently controlled by post-Miocene surface fractures, which in turn were reactivated along an older system of strike-slip faults (Manton, 1987).

In Eastern Honduras, drainage patterns of most major rivers also imply fault control due to the conspicuous alignment of their courses. Finch and Ritchie (1991) reported that the Guayape fault system is the longest continuous structural feature in eastern Honduras. A complex zone of faults, as much as 25 km (15 mi) wide and trending N30°–35°E for 290 km (180 mi), was found on a series of seismic surveys to continue into the offshore (fig. 16).

Again river alignments in eastern Honduras and western Nicaragua suggest the presence of fault systems, whereas offsets of major streams and mesoscopic slip indicators suggest left-lateral displacement of the Guayape fault. Modern-day topographic lows along the fault systems are indicative of right-lateral displacement. According to Finch and Ritchie (1991), the Guayape fault system exhibits a two-stage history. The first stage, which involved sinistral slip, resulted in more than 50 km (31 mi) of displacement and was followed by a dextral-slip phase that produced much smaller displacements. The age of the motion's inception is unknown, but it is probably coeval with Oligocene-Miocene movement of the Chortis block along the North American plate's boundary faults.

Oblique convergence of the Cocos plate with the Chortis block along the Middle American trench in the Quaternary produced a series of volcanoes along Central America's Pacific margin (Carr, 1984) and crustal extension within the Chortis block, accompanied by internal block rotation (fig. 17). Strike-slip faulting resumed from the Pliocene to Pleistocene, creating horsts along the northern coast of Honduras and turbidite-filled basins in the offshore Tela Basin, similar in nature to the California borderland basins. No Pliocene sediments were deposited in the southern portion

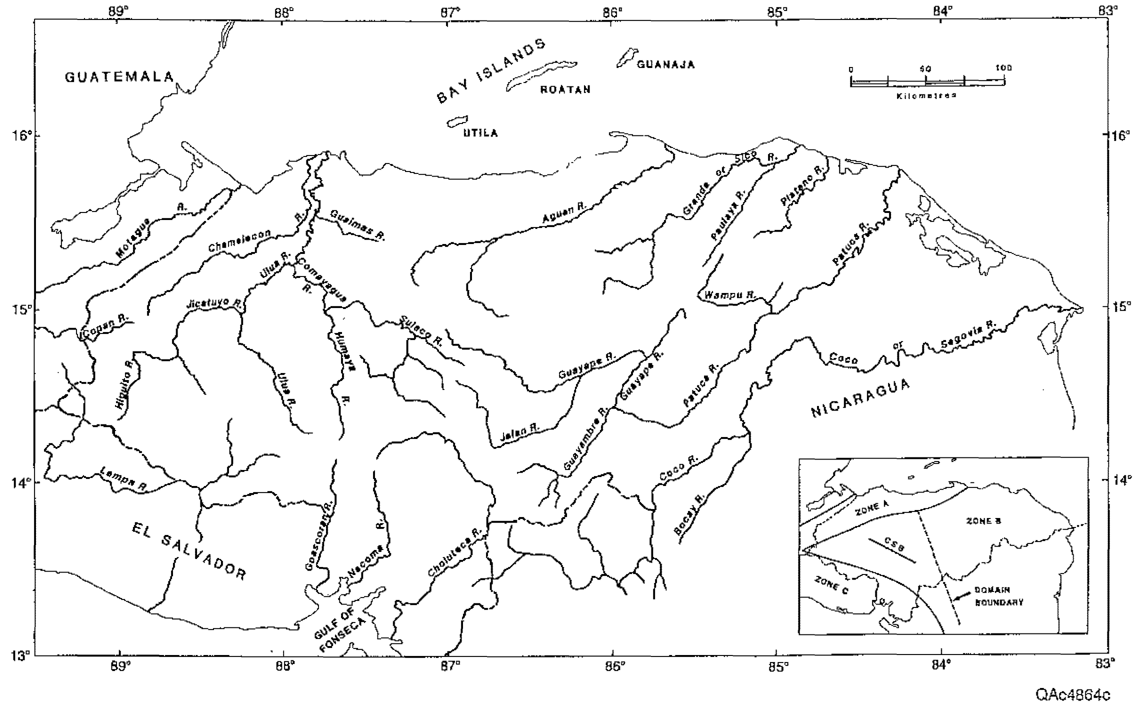

Figure 15. Present-day drainage map of Honduras, indicating the directions of fractures that control the northeast-to-northwest flow of rivers (from Manton, 1987).

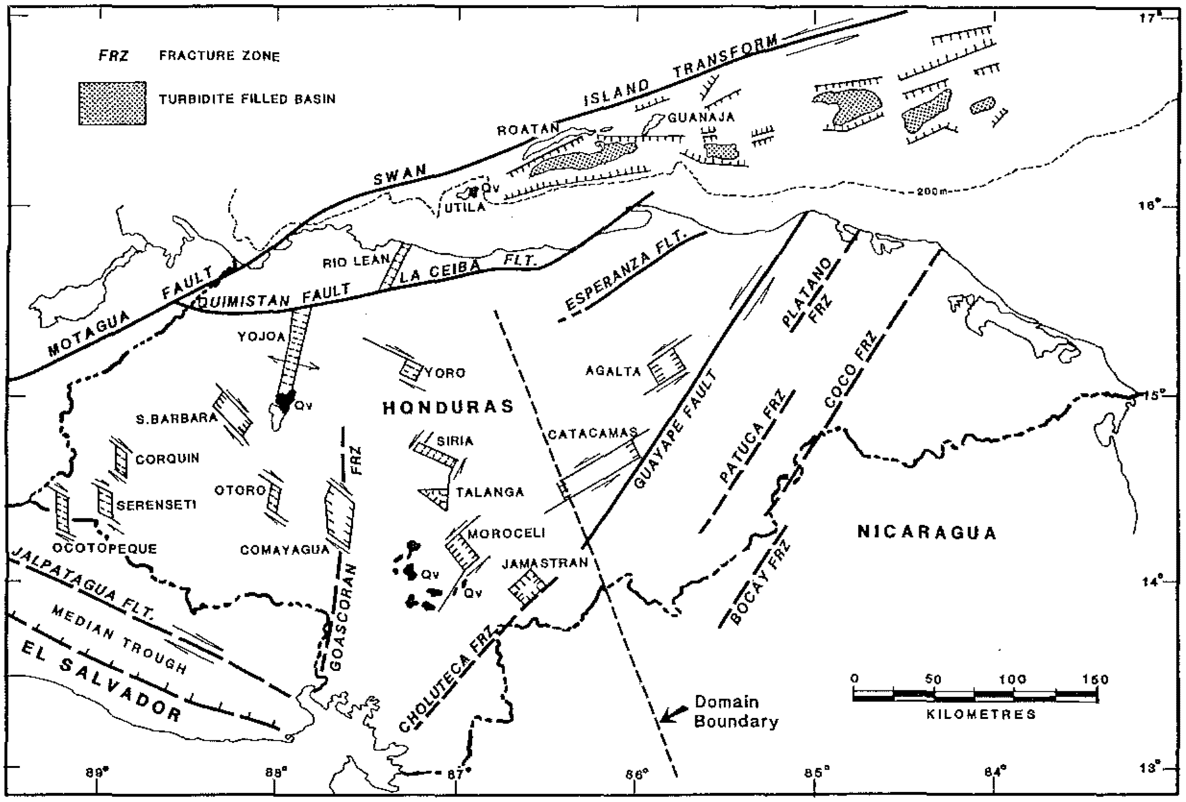

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Figure 17. Tectonic map of Honduras, indicating the principal Neogene strata (from Manton, 1987).

of the Tela Basin (fig. 18). Marls reported from the northern offshore area of Honduras indicate the presence of deeper marine environments that gradually shoaled upward from the Pleistocene to the Recent as broad carbonate platforms developed (fig. 18).

HYDROCARBON INDICATIONS

Hydrocarbon indications are present in outcrop in Honduras in association with Cretaceous-age rocks. Oil seeps have been reported at the type locality for the upper Cenomanian to Turonian Guare Formation limestones.

Figure 19 indicates locations of hydrocarbon shows reported for exploration wells drilled in the Mosquitia Basin through 1980. Oil stains and live oil shows were only reported for wells drilled near the Nicaraguan territorial waters and at outcrops 180 mi to the west. More recent information is required to update the map in figure 19.

CONCLUSIONS AND RECOMMENDATIONS

The major structural elements that delineate the Honduran basins are presented in figure 16. The Tela and Mosquitia Basins encompass the back-arc region of Honduras and are bounded to the north by the Swan Island Transform fault. This significant fault defines the present-day North Amercian–Caribbean plate boundary. To the south, the Mosquitia Basin extends into western Nicaragua, outside the study area, where its southern limit is represented by a major fracture zone.

The Tela Basin consists primarily of a series of east-to-west-trending depocenters that developed during the Neogene. The basin was the product of transtensional and compressional stresses along the southern flank of the Swan Island Transform fault. Sediments deposited in the Tela Basin range from Miocene to Recent in age and consist primarily of deep-water clastic and trubidite deposits unconformably overlying the Cretaceous.

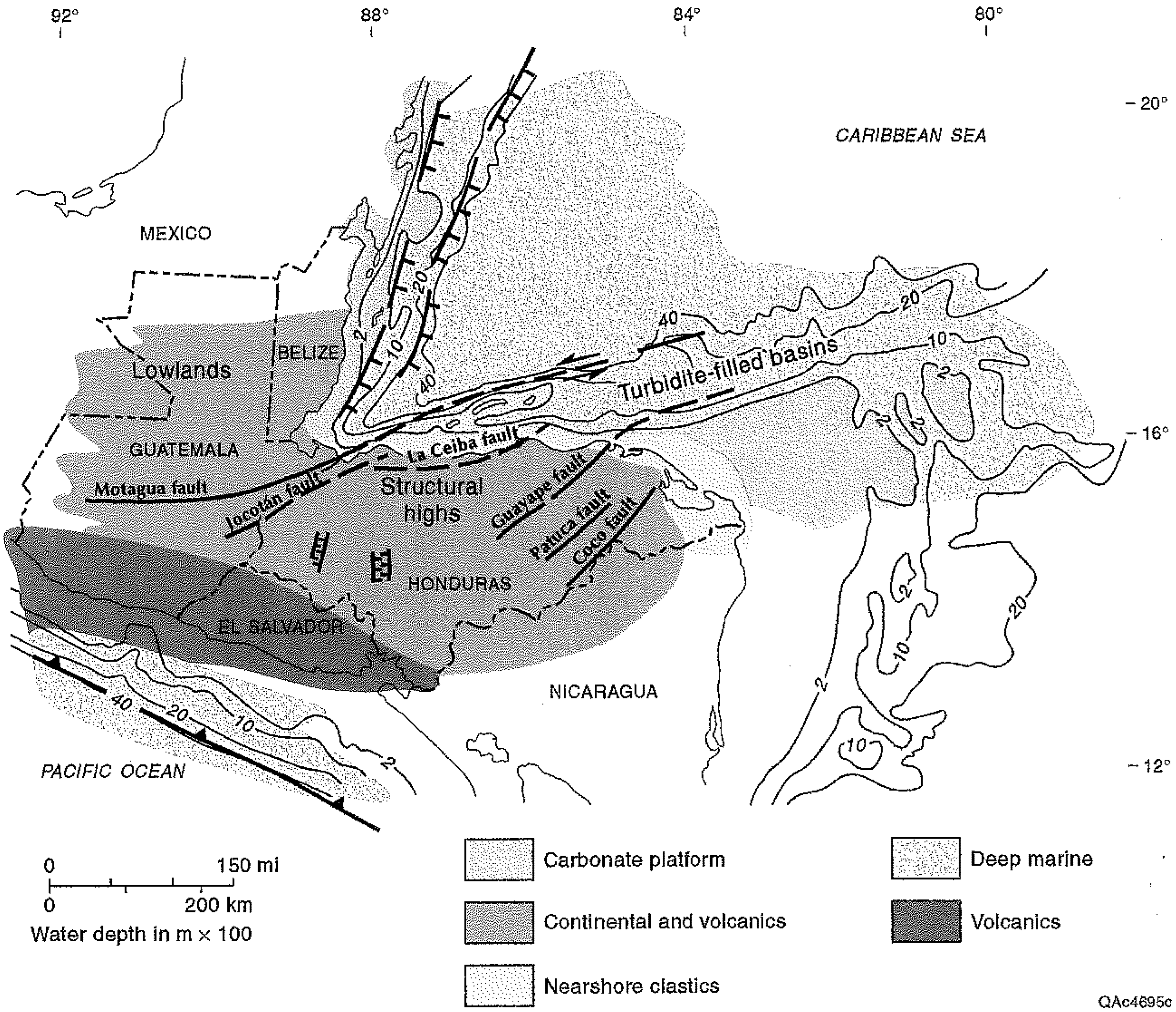

Figure 18. Paleogeographic map of northern Central America during the Plio-Pleistocene.

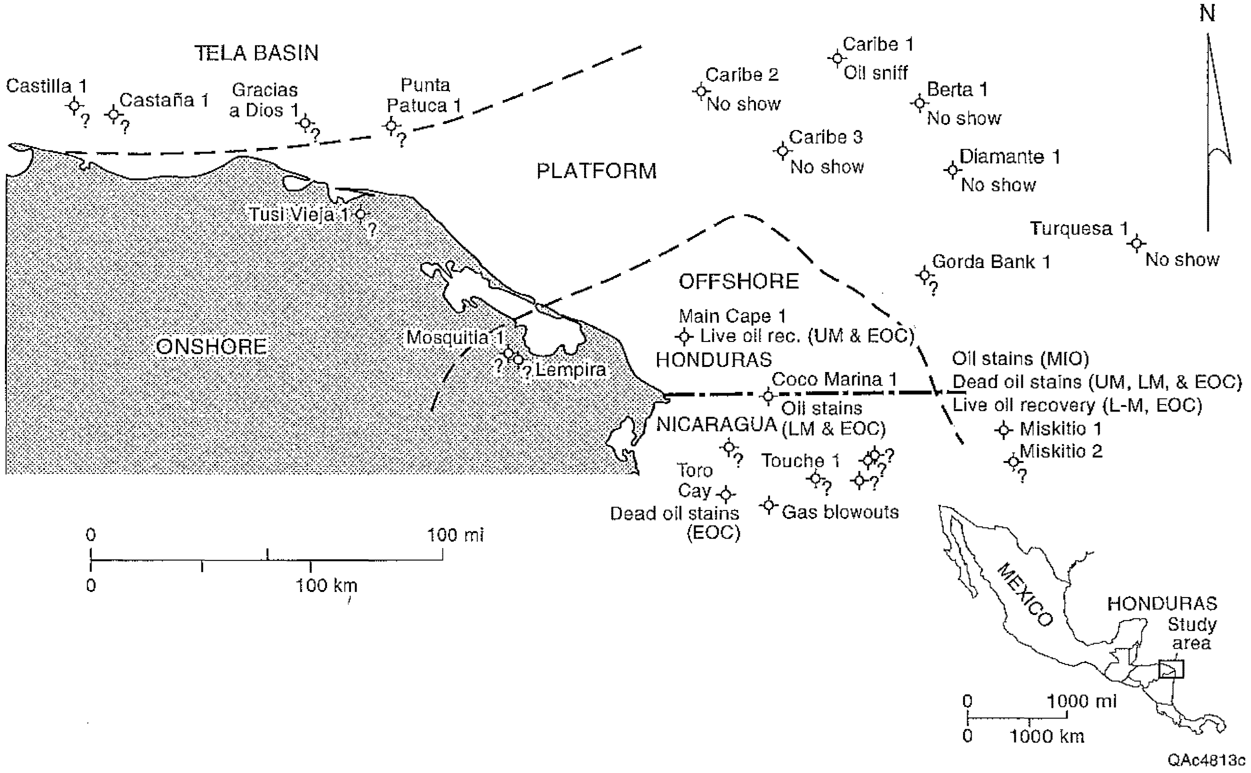

Figure 19. Location map of hydrocarbon indications.

Tectonic elements and structural framework of the Mosquitia Basin are intimately related to the evolution of the Chortis block. Pre-Mesozoic structures have not been described within this basin. Metamorphic basement rocks are encountered outside of the basin's boundaries and exhibit at least three episodes of Paleozoic deformation.

Compressional folding and faulting are the dominant structural features affecting all of the Mosquitia Basin's Mesozoic units. This structural style is recorded not only in the onshore element of the basin, for instance, in the Colón Mountains, but also in the exploratory offshore wells.

This compressional event, which could have occurred at the end of the Mesozoic or as early as the early Tertiary, has been interpreted as the result of collision or closure between the Chortis and Maya blocks. Onshore structural grain trends are to the northeast with a strong northwest compressional component. Offshore trends are difficult to ascertain until better processing and interpretation of seismic data are possible.

During the Cenozoic, the Chortis block underwent rotation, shearing, and extensional stresses that resulted from its tectonic position between two very active plate boundaries—the Middle American trench and the Motagua-Polochic fault system. The onshore portion of the Mosquitia Basin is cut by a series of strike-slip faults, trending to the northeast, which are commonly associated with right-lateral, strike-slip extensional basins. Some of the regional faults have a history of reversing their motion—a tendency possibly caused by subsequent rotation of their associated block.

Structural trends indicate an extension of regional strike-slip fault systems into the offshore Mosquitia Basin. Detailed mapping from reflection seismic profiles by various oil companies determined that intensive faulting occurred above the base of the Tertiary section (pl. 6). From examination of the limited seismic profiles available for this study, such faulting does not appear to be controlled by the underlying strata but is more likely related to sediments affected by shear motions during periods of active movement.

Younger sediment-filled extensional features (that is, features younger than the faults produced by shear motions) have been seismically mapped with a northwest trend. Similar features also trending northwestward have been more extensively mapped by a variety of authors for the onshore portion of the Mosquitia Basin. Examination of their mapped interpretations indicates that these extensional, grabenlike features were related to rotation of the strike-slip faults and that the three principal tectonic elements of the Mosquitia Basin—the onshore Mosquitia Basin, the Mosquitia Platform, and the offshore Mosquitia Basin—have reacted throughout geologic time as a single unit.

Recommendations for further effort in the Mosquitia and Tela Basins would involve the following tasks:

- Reprocess key seismic profiles to delineate and map Mesozoic structural trends in the offshore.
- Incorporate exploration data from the Nicaraguan portion of the basin.
- Conduct detailed sequence-stratigraphic analysis combining outcrop, well, and seismic data.
- Perform a detailed "postmortem" analysis for each well drilled in the Mosquitia and Tela Basins.

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