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Stratigraphy of Belize, North of the 17th Parallel

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Abstract

The stratigraphy of Belize, north of the 17th parallel, consists of (1) a thick section of deformed and metamorphosed Carboniferous-Permian sedimentary and volcanic strata in the Maya Mountains, (2) a moderately thick section of Mesozoic strata, mostly carbonates, which are found in the subsurface and in outcrop near the Maya Mountains and along major faults, and (3) a relatively thin section of Paleocene-Pleistocene carbonates, which comprise most of the coastal plain of northern Belize. All of the stratigraphic units of Belize are informal and most lack true type sections and proper descriptions. This paper attempts to discuss and synthesize what is known of the stratigraphy of this region.

Introduction

"If the world had any ends, British Honduras would certainly be one of them."
—Aldous Huxley, *Beyond the Mexique Bay* (1934)

Belize, formerly British Honduras, is no longer considered by most visitors to be at the "end of the world." However, from the perspective of modern stratigraphy, the former British colony is still at or near the "end of the world" when it comes to formal, stratigraphic nomenclature and accurate geologic mapping. Belize has a thick coastal plain stratigraphic section composed of exposed and subsurface Mesozoic and Cenozoic strata, which are underlain by deformed and metamorphosed Paleozoic strata and intrusive igneous rocks (Table 1). Since preparation of the relatively extensive stratigraphic study of Giovanni Flores (1952a), which was written for the Bahamas Exploration Company, Ltd., no detailed analysis of all stratigraphic units has been conducted in the northern area of Belize. Flores (1952a) described all stratigraphic units in Belize as informal and they remain so today.

In 1986, a provisional geological map of Belize (1:250,000) was produced for the Petroleum Office of the Ministry of Natural Resources (Cornec, 1985; 1986: Fig. 1). Like the Flores' report, this mapping effort did not include any formalized stratigraphy either. The Ministry does not publish materials such as a stratigraphic guide and does not act as a clearinghouse for stratigraphic nomenclature. Therefore, Belize has no formal stratigraphy (i.e., formal stratigraphy in the usual sense of that term as per NACSN (1983) or Salvador (1994)). There are no properly designated type localities (or stratotypes *sensu* Salvador, 1994) for any of the informal stratigraphic units (although Flores (1952a) and later Bryson (1975) suggested some type sections or mention some type localities (*sensu* Salvador, 1994) for some of the units that they discuss.

Our experience in Belize, working in the interior of the country north of the 17th parallel, has been that the provisional geological map has serious deficiencies and that stratigraphic nomenclature can be confusing. For these reasons, we are presenting here a discussion of the main stratigraphic units of northern Belize, with a description of each, their provisional type sections or type localities (if possible), and pertinent references. This paper is not intended to establish formal nomenclature, but rather to help in the larger effort to more fully describe northern Belize Coastal Plain stratigraphy. This paper includes a detailed description of Cretaceous-Tertiary boundary stratigraphy, which is not present in any previous stratigraphic synthesis for the area.

There are numerous locations of sections and wells mentioned in this paper. Therefore, we have included Figure 2, which is a reference guide to all the specific sites mentioned in this report.

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Table 1. Stratigraphy of Belize, north of the 17th parallel. Sources are cited in the text. More details of the type section and type locality location are provided in the text.

Lithostratigraphic unit (age assignment)	Lithologic description (unit thickness)	Type section (TS) or type locality (TL) per Cornec (C), Flores (F), Bryson (B), or Ocampo (O)
"alluvium and reef deposits" (Pleistocene – Holocene)	River sand and gravel; reef corals and sediments; variable thickness	none
Orange Walk group (Miocene-Pleistocene)	light-colored, fine and fossiliferous limestones and marls (~ 35 to 100 feet or ~ 11 to 30 m thick)	For TS, see Table 3.
Red Bank group (Oligocene-Miocene)	clays, sands, and gypsum-bearing facies (~ 65 to 75 feet or ~ 20 to 23 m thick)	TL = Red Bank[1] on the middle Belize River (F)
Iguana Creek formation (Oligocene)	conglomerate as being composed of limestone, dolostone, and chert pebbles (~100 feet or 30 m thick)	TS = Iguana Creek Bank on the Belize River, between El Cayo and Roaring Creek (F)
Doubloon Bank formation (Middle Eocene)	cream to buff, yellow to orange, dense, hard fine limestones with some marls and chert (~ 350 to 500 feet or ~ 107 to 152 m thick)	TL = middle course of Freshwater Creek (F)
El Cayo group (Paleocene-Lower Eocene)	mainly light buff to white cream and white limestones with some dark chert (over 2,600 feet (792 m) thick	TL = vicinity of El Cayo[2] (F)
Albion formation (Cretaceous-Tertiary boundary)	brown spheroid-bearing clay overlain by grey carbonate breccia (~ 40 to 50 feet or ~ 12 to 15 m thick)	TS = Albion quarry on Albion Island (O)
Barton Creek formation (Upper Cretaceous)	gray and tan limestone or dolostone with interbedded shales and evaporites (~1,600 to over 2,100 feet or ~ 488 m to over 640 m thick)	TS = headwaters of Barton Creek (F)
Yalbac formation Lower-Middle Cretaceous)	interbedded limestones, dolostones, anhydrites, and shales (~ 300 to 500 feet thick, but thickens to over 3,200 feet; ~91 to 152 m, but thickens to over 975 m)	none
Hill Bank formation (Lower Cretaceous)	porous, tan to light gray limestones and dolostones, slightly anhydritic (~ 150 to 1000 feet or ~ 46 to 305 m thick)	none
Margaret Creek formation (Jurassic)	sandstones, sandy clays, sandy dolomite, and a few conglomerate beds (~ 40 to over 400 feet or ~ 12 to over 122 m thick)	TS = Margaret Creek[3] (F)
Cockscomb granite (LowerTriassic)	alkalic to dioritic granite	TL = Hummingbird and Mullins rivers and at Cockscomb-Sapote[4] (C)
Santa Rosa group (Upper Carboniferous-Middle Permian)	(1) coarse conglomerates, sandstones, and quartzites; (2) argillites; (3) crinoidal limestones; and (4) volcanic rocks of the "Bladen volcanic member" (over 9,900 feet (3017 m) thick)	TL Maya member = Hummingbird Highway (B); TL Bladen member[5] = southern side of Maya Mountains (B); TL Macal member[6] = Southern Highway (B)
Mountain Pine Ridge granite (Silurian-Devonian)	granite of various compositions	TL = Mountain Pine Ridge (B)

[1]Red Bank is a defunct town that was located approximately 2.8 miles (4.5 km) northwest of Roaring Creek at the apex of a sharp bend in the Belize River.

[2]El Cayo is the former name for San Ignacio, a town near the Guatemalan border. Ower's 1928(a) map marks this town as "Cayo" and some modern maps list Cayo in parentheses below the name San Ignacio. There is no "El Cayo" on any historical maps that we have seen, thus we assume that Cayo is the same as El Cayo.

[3]On modern maps, this creek is called St. Margaret's Creek. It drains north from a mountain

[4]Hummingbird River is not marked on modern maps, but Mullins River is marked. Neither Cockscomb nor Sapote are extant towns. Cockscomb is a mountain ridge (range) in southern Belize and a low area on the seaward side of that ridge is called Cockscomb bains. Sapote falls is on Swasey Branch in southern Belize, < 0.6 miles (1 km) upstream (north) of the junction with Sapete Creek. Swasey Branch is one of the creeks draining Cockscomb basin on the seaward side of Cockscomb ridge.

[5]Bladen is the name of a branch (creek) draining seaward from the Maya Mountains in southern Belize.

[6]Macal is the name of a river draining northward from the Maya Mountains toward San Ignacio.

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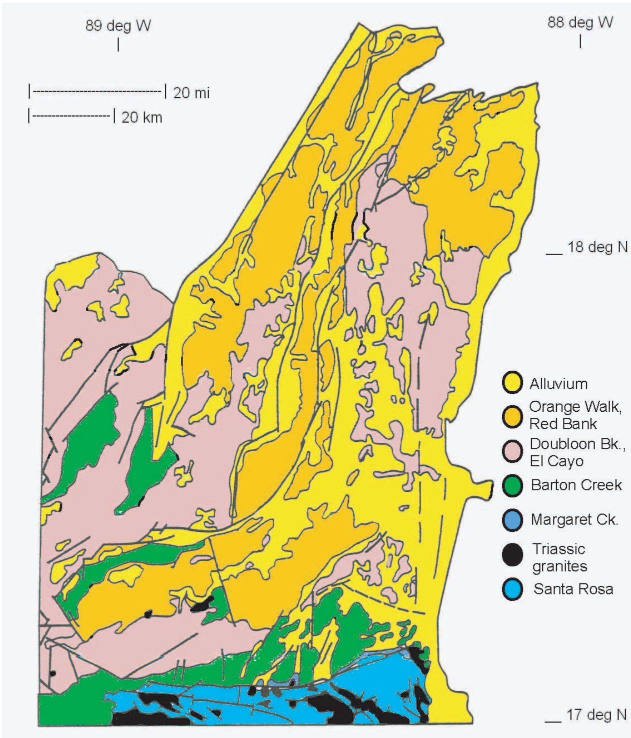

Figure 1. Geological map of Belize, north of the 17th parallel. After Cornec (1986).

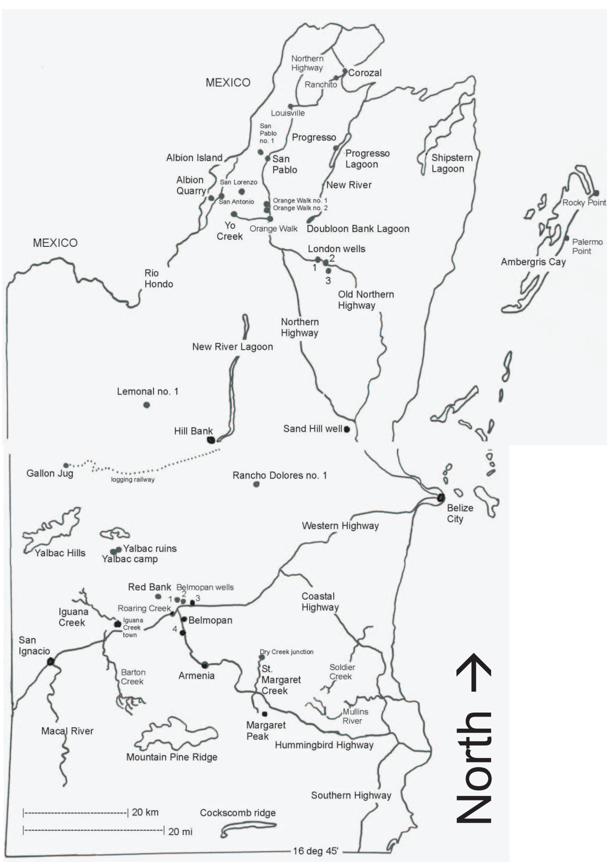

Figure 2. Location map for type sections, type localities, key outcrops, wells, towns, creeks, rivers, highways, and other reference points mentioned in this report, which occur north of 16° 45'.

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Stratigraphy

"British Honduras may be briefly described as a peneplain of Upper Carboniferous slates, surrounded by a thick, dense (section) of limestones."

—Leslie H. Ower, *The silica lines of British Honduras* (1928a)

Ower's (1928a) rather simplistic view of an ancient peneplain overlain by limestones is not quite accurate, but is a starting point in understanding stratigraphy in northern Belize. The stratigraphy of northern Belize encompasses folded and eroded Paleozoic strata and volcanic and intrusive rocks, which form the ancient core of the Maya Mountains, and overlying Mesozoic and Cenozoic strata of the northern carbonate terrain and carbonate-dominated coastal plain (Flores, 1952a). Except for strongly folded Paleozoic rocks of the Maya Mountains, most strata in Belize are relatively gently inclined. However, several large fault-bounded blocks in northern Belize strongly affect the surface and subsurface distribution and thickness of coastal plain stratigraphic units (James and Ginsberg, 1979; Donnelly et al., 1990). For example, King et al. (2003) noted that the stratigraphic succession and thickness of units seemed to vary according to fault-bounded geography.

Paleozoic System of Belize

The Paleozoic is represented by some intrusive igneous rocks and a sequence of sedimentary and meta-sedimentary stratigraphic units, all situated in the Maya Mountains of Belize (Bryson, 1975).

Intrusive igneous rocks, which have Silurian-Devonian Rb/Sr ages, form the basement granitic complex in the Maya Mountains of Belize (Bryson, 1975). The Mountain Pine Ridge granite, which Bryson (1975) notes as consisting of various compositions of granite owing to "several episodes of intrusion," underlies the Santa Rosa group. Bryson (1975) regards the Mountain Pine Ridge granite as approximately the age-equivalent of the Rabinal Granite of Guatemala and the Chaucus Gneiss of México. In addition to the granites, Cornec (1985) notes some granitic cataclastic rocks of unknown age cropping out near Mountain Pine Ridge in the Maya Mountains.

Regarding sedimentary and meta-sedimentary rocks, Cornec (1985) refers to these units as parts of the Santa Rosa group, which he says consists of four "facies." These facies are: (1) coarse conglomerates, sandstones, and quartzites; (2) argillites; (3) crinoidal limestones (that may be equivalent to the Chocal Formation of Guatemala); and (4) volcanic rocks of the "Bladen volcanic member" (Bateson and Hall, 1971), which consist of rhyolitic and andesitic lavas, pyroclastic tuffs and breccias, and volcanic argillites (all of which interfinger with previously noted sediments). The ages of these units were regarded by Flores (1952a) as Carboniferous and Permian, based upon megafossil evidence (Flores, 1952a, cites previous work on Santa Rosa fusulinids and crinoids by Sapper (1899) and Ower (1928b)). Work by Bateson and Hall (1977) narrow the Santa Rosa group's age to Late Carboniferous-Middle Permian.

Bryson (1975) subdivides the Santa Rosa group, which was named for the similar-appearing group of that name in Guatemala (Bateson and Hall, 1971), into three units that he refers to as "members." The subdivision is more clearly delineated, according to Bryson (1975), on the southern side of the Maya Mountains where the middle (Bladen) volcanic member separates an upper (Maya) member from a lower (Macal) member. The Maya "member" (Dixon, 1955) is composed of greywacke, shale, quartzite, slate, phyllite, schist, and gneiss. A potential Maya member type locality mentioned by Bryson (1975) is "along the Hummingbird Highway in the northern part of the Maya Mountains." The Macal "member" consists of a lower part containing a basal conglomerate followed upward by "grit and sandstone with shale interbedded" (Dixon, 1955) and, ultimately, an upper part composed mainly of carbonaceous and calcareous shale and "flaggy" sandstone. A crinoidal limestone, ~ 50 to 100 feet (~ 15 to 30 m) thick, occurs within this upper shale unit. Potential type localities discussed by Bryson (1975) include outcrops on the Southern Highway "between Medina Bank and Deep River" and outcrops "on Swasey Branch." Cross-sectional diagrams in Bryson (1975) indicate that the Santa Rosa group is ~ 4,000 feet (~ 1,219 m) thick, however, Dixon (1955) reports the thickness of the Macal "member" alone may be ~ 9,900 feet thick (~ 3,018 m), of which as much as ~ 3,500 feet (~ 1,067 m) may be the lower sandstone part of the Macal.

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Mesozoic System of Belize

Triassic rocks

There are two areas of Mesozoic granitic intrusion in the Maya Mountains, ranging in composition from alkalic to dioritic granite (Cornec, 1985). According to Cornec (1985), these granites crop out on the Hummingbird and Mullins rivers and at Cockscomb-Sapote. Bryson (1975) refers to all these granite intrusive bodies as the Cockscomb granite. Potassium-argon age determination shows these rock bodies to be Early Triassic (Andrews-Jones, 1981). Bryson (1975) notes that there are granites in deep wells drilled near Orange Walk, but it is not known if these granites are the Cockscomb, the older Mountain Pine Ridge granite, or some other unnamed granite.

Jurassic strata

Lying directly upon basement in northern Belize is the Jurassic Margaret Creek formation (~ 40 to over 400 feet (~ 12 to 122 m) thick), which Flores (1952a) says is comprised of sandstones, sandy clays, sandy dolomite, and a few conglomerate beds. The rock type is more specifically an arkose with silica cement that is partially replaced by iron oxide or partially dissolved. Flores (1952a) says that an informal type section is "on the northern bank of Margaret Creek, where (Margaret Creek) joins the Upper Dry Creek." At this place, the Margaret Creek formation is said to be ~ 130 feet (~ 40 m) thick. Flores (1952a) says that the outcrops of the Margaret Creek are "rather scanty" and occur only beneath the Upper Cretaceous section "along the northern edge of the Maya Mountains." Cornec (1985) noted that the Margaret Creek is "well exposed" in the areas of Silver Creek, Margaret Creek, and Soldier Creek in northern Belize.

The Margaret Creek shows good evidence of being a fluvial unit (i.e., cross-bedding and an arkosic composition), which grades eastward into more marine facies containing rare mollusks. Flores (1952a) cites one outcrop rich in organic matter, including lignitic and pyritic wood fragments, which support this contention. The Margaret Creek grades laterally to the east into light-green silty clays suggestive of a marine environment. The unit vertically grades into overlying carbonates of the Lower Cretaceous Hill Bank formation (Cuche and Glaus, 1967). The lateral equivalent of the Margaret Creek formation in the Belize basin of southern Belize is the Todos Santos formation (a.k.a., San Ricardo formation; Bryson, 1975), which is known mainly from the subsurface (Bryson, 1975; Cornec, 1985).

Cretaceous strata

In the rugged foothills of the Maya Mountains (i.e., the northern carbonate terrain), where tower karst is common, the contact between the Margaret Creek and the overlying Upper Cretaceous Barton Creek formation crops out. This contact, which Flores (1952a) calls conformable, must be in fact *dis*-conformable, because Cornec (1985), who had the advantage of working with considerably more subsurface material than did Flores, describes two stratigraphic units *between* the Margaret Creek and the Barton Creek. They are the Lower Cretaceous Hill Bank formation and the Yalbac formation.

Cornec's Hill Bank formation (a.k.a. "Hillbank formation," Bryson, 1975) consists of ~ 150 to 1000 foot-thick, porous, tan to light gray limestones and dolostones that are slightly anhydritic in some places (Bryson, 1975). Bryson (1975) notes that the Hill Bank may be laterally equivalent to part of the San Ricardo Formation of Guatemala (Vinson, 1962) and the lowermost Coban Formation of Guatemala and southern Belize (Vinson, 1962). Bryson (1975) says that the Hill Bank "probably onlaps" the Todos Santos formation on the southern side of the Maya Mountains. Bryson (1975) notes that the Hill Bank "was not observed on outcrop." Thus, we are left to infer that the formation was probably discovered by drilling, perhaps near the town of Hill Bank, located on the shore of New River Lagoon in northern Belize. The Hill Bank appears to be a shallow shelf carbonate unit that developed across the area prior to subsidence of the Chipas-Peten basin of northern Guatemala.

The Yalbac formation, which grades vertically from the upper Hill Bank, consists of interbedded limestones, dolostones, anhydrites, and shales (Bryson, 1975). According to Bryson (1975), the Yalbac represents sedimentation on the eastern margin of the Chipas-Peten basin, which began subsiding during Early to Middle Cretaceous. The Yalbac is ~ 300 to 500 feet (~ 91 to 152 m) thick in part of northern

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Belize, but abruptly thickens to over 3,200 feet (~ 975 m) in wells north of 17^{o} 30' N latitude (Table 2). The Yalbac is probably equivalent to the upper part of the Coban Formation and the lower beds of the Campur Formation of Guatemala (Vinson, 1962). Like the Hill Bank, the Yalbac was "not observed" in outcrop by Bryson (1975), who is the first author we know of to mention these two units. It is possible that the name derives from the Yalbac Hills of northern Belize, which are situated about 9.3 miles (15 km) northwest of Belmopan (but there is also in that area, Yalbac camp, Yalbac Creek, and a Mayan ruins named Yalbac). Perhaps a well drilled in that area encountered the first notable Yalbac section, but we found no records of such a well at the Geology and Petroleum Office in Belmopan.

According to Bryson (1975), there is a clearly defined unconformity between the Yalbac and overlying Barton Creek formations in Belize. Cornec (1985) comments that the "limit of anhydrite" in wells occurs "somewhere between Caves Branch and Belmopan." The anhydrite-bearing interval in the upper Yalbac is 360 feet (~ 110 m) thick in the Anschutz Lemonal no. 1 well, 127 ft thick in the Anchutz Orange Walk no. 1 well, but only 20 feet (~ 6 m) thick in Anschutz Rancho Delores no.1 well (see Table 2 for locations of wells).

Records of two drilled wells, Anschutz Belmopan no. 1 and Lemonal no. 1 (for locations, see Table 2), make note of a petroleum-bearing zone within the Yalbac called the "Roaring Creek oil zone," which is located ~ 80 feet (~ 24 m) above the base of the Yalbac. The Roaring Creek oil zone is in total ~ 114 feet (~ 35 m) thick in Anschutz Belmopan no. 1, of which a separate "lower Roaring Creek zone" comprises the basal ~ 66 feet (~ 20 m) of this interval. Coring descriptions from the upper and lower parts of this "oil zone" indicate that it is a fractured, anhydritic dolostone.

The Barton Creek formation, which is ~ 1,600 to over 2,100 feet (~ 488 to over 640 m) thick at the northern edge of the Maya Mountains (Flores, 1952a), is mainly a gray and tan limestone or dolostone with interbedded shales and evaporites (Bryson, 1975; Cornec, 1985). The Barton Creek crops out on the northern flank of the Maya Mountains and along some fault scarps north of the Maya Mountains (Bryson, 1975; Cornec, 1986; Ocampo et al., 1996). Flores (1952a) does not mention a type section or type locality, but says that the name derives from "almost complete exposures which were measured in the headwaters of Barton Creek." The Barton Creek weathers deeply and is prone to karst development and, in some places, the Barton Creek is known to have cavernous porosity. Further, the rock may be recrystallized during weathering so that a very coarse calcitic texture develops locally (Bryson, 1975). A bright red soil develops on weathered Barton Creek. Bryson (1975) and Cornec (1985) note that the Barton Creek may be inaccurately mapped in some places and that some of the Hill Bank and Yalbac may have been mapped as Barton Creek by Flores (1952a) and Cornec (1986).

The Barton Creek contains Maastrichtian and Campanian fossils, which clearly establish this unit as the youngest Cretaceous formation in Belize (Bryson, 1975). Key age-indicative fossils from the upper Barton Creek include *Carcineretes planetarius* Vega and a nerineid gastropod with infolding wall structures (Vega et al., 1997; Pope et al., 1999). Recent work on the Barton Creek in Mexico just north of the Belize border has identified a new species of the gastropod *Aporrhais*, also of probable Maastrichtian age (Vega et al., 2001). As noted by Ocampo et al. (1996), a late Maastrichtian (~ 66.5 m.y.) age of uppermost Barton Creek is supported by $^{87}Sr/^{86}Sr$ ratios ranging from 0.70786 to 0.70796.

At Albion quarry on Albion Island (near San Antonio in the Corozal District), ~ 137 feet (~ 42 m) of Barton Creek is exposed (Ocampo et al., 1996; Fig. 3). The Barton Creek is composed of thick-bedded and thin-bedded, medium crystalline, pale gray dolostones, which have been extensively recrystallized. The Barton Creek displays comminuted shells, rounded grains, collapse breccias, and fining upward sequences with fine laminations at the top (Ocampo et al., 1996; Pope et al., 1999). All of these are features that suggest deposition in shallow water of a carbonate platform (Ocampo et al., 1996).

Cretaceous-Tertiary boundary interval

It is perhaps one of the most telling facts about the inadequacy of Belize mapping stratigraphy that no author of any report on general stratigraphy of this nation has ever noted the complex of unusual stratigraphic units present at the Cretaceous-Tertiary boundary. This is particularly remarkable considering the fact that this boundary interval is as much as 49 feet (15 m) thick in some places and is an economically important resource (i.e., the breccias are mined for road-building materials in several small and one large quarry).

Table 2. Table of key wells in northern Belize. Data from reports on file at Petroleum and Geology Office, Unity Boulevard, Belmopan, Belize. Where thickness is noted with a +, the thickness is greater than that number because the well spudded in this formation or bottomed in this formation.

Company / well / spud date	Latitude / longitude	Thickness of key units
Anschutz Overseas Corporation San Pablo no. 1 18 April 1975	18deg 13' 40" / 88deg 35' 09"	Orange Walk = 270 ft/ 82 m (+) Red Bank = 360 ft/110 m Barton Creek = 2,000 ft/610 m Yalbac = 825 ft/251 m (+)
Petro-Belize Roaring Creek no. 2 26 May 1983	17deg 15" 00" / 88deg 47' 30"	Barton Creek = 1,600 ft/488 m Yalbac = 424 ft/129 m Hill Bank = 202 ft/62 m Margaret Creek = 64 ft/20 m Paleozoic = 271 ft/83 m (+)
Petro-Belize Belmopan no. 4 6 September 1983	17deg 16' 48.56" / 88deg 46' 56.20"	Barton Creek = 1,777 ft/542 m (+) Yalbac = 468 ft/143 m Hill Bank =231 ft/70 m Margaret Creek = 52 ft/16 m Paleozoic = 74 ft/23 m (+)
Anschutz Overseas Corporation Belmopan no. 2 14 May 1973	17deg 16' 48" / 88deg 47' 08"	Barton Creek = 1,870 ft/570 m (+) Yalbac = 453 ft/138 m Hill Bank = 177 ft54 m Margaret creek = 120 ft/37 m Macal = 97 ft/30 m (+)
Anschutz Overseas Corporation Belmopan no. 3 5 March 1975	17deg 13' 22" / 88deg 46' 37"	Barton Creek = 1,497 ft/456 m Yalbac = 239 ft/73 m Hill Bank = 171 ft/52 m Margaret Creek = 100 ft/30 m (+)
Anschutz Overseas Corporation Belmopan no. 1 23 February 1972	17deg 17 ' 2x" / 88deg 44' 48"	Barton Creek = 1,861 ft/567 m (+) Yalbac = 433 ft/132 m Hill Bank = 156 ft48 m Margaret Creek = 310 ft/94 m (+)
Anschutz Overseas Corporation Lemonal no. 1 26 May 1972	17deg 40' 20" / 88deg 35' 08"	Doubloon Bank = 150 ft/46 m (+) Barton Creek = 1,770 ft/539 m Yalbac = 3,210 ft/978 m Hill Bank = 395 ft/120 m Margaret Creek = 105 ft/32 m Macal = 45 ft/14 m (+)

Company / well / spud date	Latitude / longitude	Thickness of key units
Anschutz Overseas Corporation London no. 1 4 August 1972	17deg 59' 34.5" / 88deg 26' 48.5"	Doubloon Bank = 796 ft/242 m (+) Barton Creek = 1,426 ft/435 m (+)
Anschutz Overseas Corporation London no. 2 28 June 1973	17deg 59' 10" / 88deg 26' 18"	Doubloon Bank = 535 ft/163 m (+) Barton Creek = 2,030 ft/619 m Yalbac = 2,443 ft/745 m (+)
Anschutz Overseas Corporation London no. 3 28 October 1973	17deg 59' 03" / 88deg 26' 04"	Doubloon Bank = 1,550ft/472m(+) Barton Creek = 2,822 ft/860 m Yalbac = 1,663 ft/507 m Hill Bank = 481 ft/147 m Margaret Creek = 38 ft/12 m unknown granite = 3 ft/1 m(+)
Anschutz Overseas Corporation Orange Walk no. 1 18 October 1972	18deg 07' 28" / 88deg 34' 01"	Red Bank = 94 ft/29 m (+) Doubloon Bank = 1,446/441 m ft Barton Creek = 1,665 ft/507 m Yalbac = 4,155 ft/1,266 m Hill Bank = 535 ft/163 m Margaret Creek = 32 ft/10 m unknown granite = 43 ft/13 m (+)
Anschutz Overseas Corporation Orange Walk no. 2 23 November 1974	18deg 07' 08" / 88deg 33' 48"	Yalbac = 1,404 ft/428 m (+) no report above or below Yalbac
Anschutz Overseas Corporation Rancho Dolores no. 1 13 April 1972	17deg 32' 12" / 88deg 37' 43"	Barton Creek = 1,560 ft/475 m (+) Yalbac = 2,690 ft/820 m Hill Bank = 290 ft/88 m Margaret Creek = 150 ft/46 m(+)
British Honduras Gulf Oil Co. Sand Hill 5 May 1958	not given / not given (16 miles (27 km) northwest of Belize City)	no report above Hill Bank Hill Bank = 380 ft/116 m (+) Margaret Creek = 20 ft/6 m Macal = 242 ft/74 m (+)

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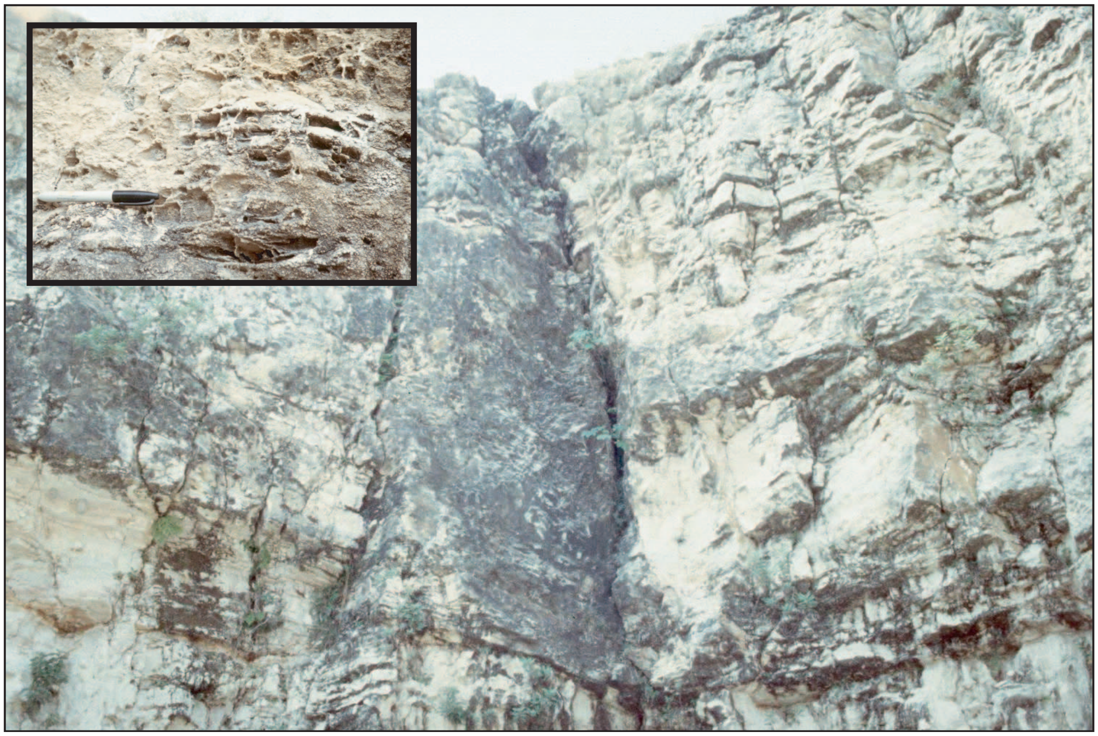

Figure 3. Typical Barton Creek outcrop on Albion Island, Belize. Exposure is ~ 66 feet (~ 20 m) high. Inset: karstic weathering on the face of the outcrop (pen for scale).

In Flores' view, the Barton Creek upper contact is "unconformable" with lower Eocene limestones lying directly on top of Barton Creek (Flores, 1952a). He cites an outcrop showing an unconformable contact with lower Eocene limestones "in the vicinity of Waika Creek on the Hill Bank-Gallon Jug logging railway." Since Flores' time, the unquestioned view of stratigraphers working in Belize has been that the Cretaceous-Tertiary contact is a regional unconformity.

There is, however, a significant Cretaceous-Tertiary boundary interval in Belize, which has been recently studied in detail by several workers (Ocampo et al., 1996; Fouke et al., 1998; Pope et al., 1999; Pope and Ocampo, 2000; King and Petruny, 2003). Ocampo et al. (1996) named the boundary interval's stratigraphic unit the "Albion Formation," a ~ 14-m thick breccia unit with a ~ 1-m thick basal spheroid and clay bearing bed that crops out and is mined at Albion Quarry on Albion Island (near San Antonio in the Corozal District of Belize). Subsequent work has shown that the Albion formation on Albion Island also crops out in adjacent area of Quintana Roo, Mexico, where it is overlain by Tertiary limestones of the El Cayo group (Smit, 1999; Pope et al., 2000; King et al., 2002).

The Albion formation is the only formation in Belize with a properly established type section, which was appointed by Ocampo et al. (1996) as the quarry exposures on Albion Island. The Albion formation would be a formal unit if it were recognized by the Geology and Petroleum Office, but as noted at the outset of this paper, there is no mechanism for establishing formal nomenclature in Belize.

The Albion formation at the type section (Fig. 4) is subdivided into a basal spheroid and clay-bearing bed (or "spheroid bed;" Pope et al., 1999) containing mm- and cm-sized carbonate accretionary lapilli, which rests directly upon the Barton Creek formation. This basal spheroid unit has been interpreted as vapor-plume deposits from the Chicxulub impact event in adjacent México (Ocampo et al., 1996; Pope et al., 1999). Above the basal spheroid bed is a ~ 14-m thick interval of crudely bedded impact breccia (the "diamictite bed" of Pope et al., 1999), which has been interpreted as ejecta-curtain deposits that were either directly emplaced or flowed into place upon collapse of the ejecta curtain from Chicxulub impact crater (Ocampo et al., 1996; Pope et al., 1999; King and Petruny, 2003).

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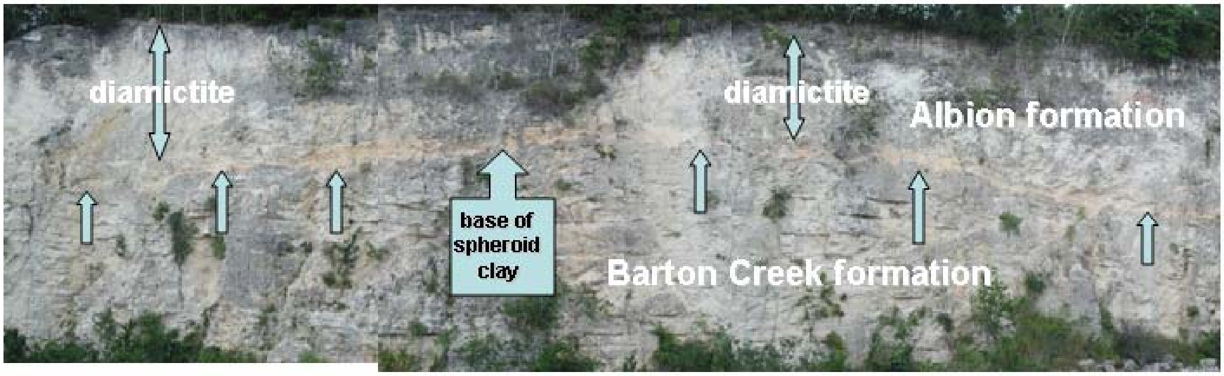

Figure 4. Typical Albion formation outcrop at the proposed type locality of Ocampo et al. (1996) on Albion Island, Belize. West wall, Albion Quarry. Exposure is ~ 98 feet (~ 30 m) high. Dots mark top and bottom of basal spheroid and clay bed.

Other Cretaceous-Tertiary boundary deposits occur in northern Belize. These deposits can be viewed as either laterally equivalent facies of a potentially more diverse Albion formation (Ocampo et al., 2000) or as separate unnamed laterally equivalent units of the Albion. On the Hummingbird Highway at Armenia, a ~ 12-m thick section of Cretaceous-Tertiary boundary deposits rests on top of highly weathered Barton Creek formation (Ocampo et al., 2002; Fig. 5). This section consists of a ~ 16 foot (5 m) thick, basal spheroid bed (finely divided carbonate containing embedded accretionary lapilli of carbonate), which has been interpreted as Chicxulub vapor plume deposits (Ocampo et al., 2002) and an overlying, ~ 7-m conglomeratic layer composed of rounded, pitted, polished pebbles. These pebbles, called Pook's pebbles by their discoverers, Pope and Ocampo (2000), are interpreted to be Chicxulub carbonate ejecta, which were rounded and polished in flight through the Chicxulub vapor plume and pitted by impacts during flight. Beyond the Armenia section, in the karstic carbonate terrain of the foothills of the Maya Mountains, Pook's pebble deposits have been found as discontinuous deposits. These deposits occur mainly as admixtures with clayey karst-filling sediments (Pope and Ocampo, 2000; Ocampo et al., 2002). In northern Belize, near Progresso on Progresso Lagoon, a ~ 16 foot (5 m) thick section of grain-supported conglomerates consisting of Pook's pebbles and rounded chert pebbles also crops out (Fig. 6).

Cenozoic System of Belize

Cenozoic strata of Belize are separated into two unconformity-bounded packages, one above a regional unconformity and the other below. Strata *below* the regional unconformity span Paleocene to Middle Eocene (Flores, 1952a, b). These Paleocene-Lower Eocene strata are limestones and dolostones of the El Cayo group (> 2,600 feet (> 792 m) thick; Flores, 1952a). Middle Eocene strata are cherty limestones of the Doubloon Bank formation (~ 350-500 feet (~ 107 to 152 m) thick; Flores, 1952a). Strata *above* the regional unconformity span Oligocene through Pleistocene. The problematic Iguana Creek formation is said to be strictly Oligocene based upon stratigraphic position and reworked Eocene fossils, whereas the overlying Red Bank and Orange Walk groups span collectively Oligocene through Pleistocene (Flores, 1952a).

Lower unconformity-bounded package

The El Cayo group consists of carbonates, mainly limestones, which formed on the Belize coastal plain north of the Maya Mountains. Most facies in the El Cayo have back-reef or lagoonal affinities (Bryson, 1975), but reefal facies and evaporites also occur (Flores, 1952a, b). El Cayo limestones are distinctively colored "light buff to white cream and white" (Flores, 1952a) and are quite dense and "evenly grained (and) sublithographic … commonly showing a conchoidal fracture" (Flores, 1952a). Rare, small nodules of black or very dark chert occur in the El Cayo (Flores, 1952a). Flores (1952a) does

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not discuss a type section or type locality for the El Cayo, but mentions that "more than 2,600 feet (792 m) were measured in the vicinity of El Cayo." El Cayo or Cayo is the former name for the town of San Ignacio in western Belize, near the Guatemalan border (inferred from town name shown on geological map in Ower, 1928a). "Reefoid" El Cayo limestone is said to occur "east of Gallon Jug" (Flores, 1952a). Flores (1952b) presents lists of mega- and micro-fossils suggestive of Paleocene-Lower Eocene affinity.

Figure 5. Armenia section of the Albion formation (or its lateral equivalent), on the Hummingbird Highway in central Belize. Exposure is ~ 26 feet (~ 8 m) high. Albion formation spheroid bed (white unit) overlies a dark red weathered surface of the Barton Creek. Spheroid bed is overlain by Pook's pebble conglomerate..

Figure 6. Exposure on Progresso Lagoon showing mainly grain-supported conglomerate. Inset: Pook's pebbles and chert pebbles (hammer for scale). Exposure is ~ 16 feet (~ 5 m) high.

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The Doubloon Bank formation consists of limestone that is "cream to buff, yellow to orange, dense, hard, almost lithographic in texture, showing a slight marly content" and conformably overlies the El Cayo (Flores, 1952a). In places, large, dark-centered chert nodules characterize the formation. Flores (1952a) notes that foraminifera (e.g., Miliolids and *Globigerina*, plus age-indicative species, *Coskinolina floridana* and *Dictyoconus cookei*) are "in general well preserved and relatively abundant." According to Flores (1952a), the Doubloon Bank, ~ 350-500 feet (~ 107 to 152 m) thick, forms poor exposures and covers a limited outcrop area "between the New River and Shipstern Lagoon fault lines." These fault lines are sub-parallel, northeast-striking faults apparently depicted on Flores' (1952a) map (now lost). Cornec (1986) shows only the New River fault on his map. Flores (1952a) mentions a potential type locality at Doubloon Bank Lagoon "… in the middle course of Freshwater Creek." Flores (1952b) presents a partial faunal list for the Doubloon Bank.

Upper unconformity-bounded package

The Iguana Creek formation (~ 100 feet (~ 30 m) thick) is a problematic, basal unit said to be resting upon the regional unconformity noted above (Flores, 1952a). Oligocene is the presumed age affinity for the Iguana Creek because of its stratigraphic position and because of reworked Eocene fossils (Flores, 1952a). Flores (1952a) describes the conglomerate as being composed of limestone, dolostone, and chert pebbles, which are up to 3 to 4 inches across and subrounded to subangular, except the chert, which tends to be angular. Flores (1952a) notes a possible type section at Iguana Creek Bank on the Belize River, between El Cayo (i.e., San Ignacio) and Roaring Creek. Unfortunately, we have not been able to locate this outcrop or any other Iguana Creek outcrop noted by Flores (1952a). Bryson (1975) and Cornec (1985) say almost nothing about the Iguana Creek, suggesting they could not find it either. On the 1986 geologic map of Belize (Cornec, 1986), the Iguana Creek is mapped as a stippled, surficial deposit near the Maya Mountains and in a small area near Belmopan. This is remarkable because these areas are *not* the limited, fault-related locations cited by Flores (1952a). The Iguana Creek, if it exists, may be the stratigraphic equivalent of the La Cumbre formation of southern Belize (see stratigraphic column in Sanchez-Barreda, 1990). However, the two formations are shown as being quite different in age within the correlation by Cornec (1985).

We have been concerned that perhaps the Cretaceous-Tertiary boundary interval, with its unusual breccias and conglomerates, could have been mistaken for the Iguana Creek formation, which was placed in the wrong stratigraphic position by earlier writers (e.g., Flores, 1952a; Cornec, 1985). Thus, at one point, we considered that perhaps the Cretaceous-Tertiary boundary interval (Albion Formation) and the Iguana Creek were the same unit. We now think that the Iguana Creek probably exists as a separate unit, but may be covered up due to limited outcrop and cannot be found at this time. We do not think that the Iguana Creek as depicted by Cornec (1986) is correctly mapped.

The Red Bank group (Oligocene-Miocene; Flores, 1952a), which consists of clays, sands, and gypsum-bearing facies, overlies either the problematic Iguana Creek formation and/or the regional unconformity noted above. The Red Bank covers a significant area of the northern coastal plain of Belize (Flores, 1952a; Cornec, 1986), yet little information is available about the unit thickness. Bryson (1975) includes cross-sectional diagrams showing Red Bank with thicknesses ranging from ~ 65 to 75 feet (~ 20 to 23 m). The Red Bank group has a type locality designated by Flores (1952a) "at Red Bank on the middle Belize River," however he notes that the Red Bank crops out along the Belize River near Red Bank as well. Red Bank is a defunct town not shown on modern maps, but it is shown on the geological map in Ower (1928a). Red Bank was located at the apex of a sharp bend in the Belize River, ~ 2.8 miles (4.5 km) northwest of Roaring Creek town. The Red Bank is a "red, grayish green and bluish, mottled yellow-brown or orange bentonitic clay admixed with fine to medium clear and frosted quartz sand, finely divided glass laths of volcanic origin, and rare nodules of lime" (Flores, 1952a). Nodular limestones typically display a fauna of pelecypods, gastropods, echinoid spines, and *Amphistegina*, whereas clays display rather abundant microfossils, such as *Rotalia beccari*, *Elphidium*, *Cibicides*, and some ostracode species. (Flores, 1952a). In some clays below gypsum layers, a fresh-water fauna comprised of fish scales and bones plus remains of *Chara*, a fresh-water algae are found (Flores, 1952a). Flores (1952a) notes that mapping Red Bank is aided by the fact that Red Bank marls support growth of "thicket vegetation," whereas Red Bank clays support growth of "pine-covered ridges."

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The Orange Walk group (~ 35 to 100 feet (~ 11 to 30 m) thick), which consists of mainly limestone and marl facies, conformably overlies the Red Bank group and crops out over wide areas in northern Belize (Flores, 1952a; Cornec, 1985). Key fossils in the Orange Walk are much like those in the Red Bank (Flores, 1952a), but in addition there are numerous pectin (*Chlamys* ?), large oysters (*Crassostrea* ?), and coral masses (*Montastrea* ?; King et al., 2003). Flores (1952a) subdivided the Orange Walk group into five, informal, laterally equivalent formations: (1) the Orange Walk (formation) *sensu stricto* (a coquinal limestone comprised of "marls, lime and sandy limes"); (2) the Louisville formation (or the "Louisville marls" comprised of "white, soft marly lime with sand grains"); (3) the San Lorenzo formation (or the "San Lorenzo limestone" comprised of "hard, sandy limestone"); (4) the Ambergris coral limestone (or the "Ambergris reef limestone" comprising "a more marine equivalent of the Orange Walk limestone *sensu stricto*"); and (5) the Corozal formation ("lagoonal lime with scanty gypsum flakes"). He listed a proposed type locality (really a type section, *sensu* Salvador, 1994) for each of his subdivisions (Table 3). In a schematic cross-section of northern Belize, Flores (1952a) shows the San Lorenzo as a facies within the Louisville, and the Orange Walk as a unit overlying the lower Louisville, but laterally equivalent to the upper Louisville. In the same cross-section, the Ambergris is laterally equivalent to the Orange Walk, with the Corozal forming an intermediate lateral facies equivalent to the Ambergris and Orange Walk, in the upper part of the section (see King et al., 2003).

Subsequent studies of the area's stratigraphy have treated the Orange Walk group as a single stratigraphic unit comprised of various unnamed facies rather than use the informal stratigraphic units proposed by Flores (1952a). Bryson (1975) described the Orange Walk group as follows: "The group grades upward from (its basal) unconformity through a sequence of sandy limestones, marls, coquina limestones, and coral limestones. In some areas near the present coast and on the barrier reefs and cays, (the Orange Walk) forms the base for the Pleistocene reef." Cornec (1985) also ignored the Orange Walk stratigraphy of Flores (1952a). Cornec (1985) graphically depicted the Orange Walk group as a random mixture of limestone, marl, shale, and sand without any specific vertical sequence of lithologies or internal facies relations. Cornec's associated map (1986) similarly treated the Orange Walk group as an undivided mapping unit.

Table 3. Table of informal stratigraphic units of Flores' report, their description, and the designated type section or type locality (from Flores, 1952a). Formations are listed in order from most landward (San Lorenzo) to most seaward (Ambergris), according to Flores' facies cross-sectional diagram (Flores, 1952a).

Formations within the Orange Walk group	Description of rock and key fossils	Type locality
San Lorenzo formation or San Lorenzo limestone	yellow-brown, hard, sandy limestone (up to 30% quartz sand) and calcareous sandstone; miliolids, *Rotalia*, small textularid foraminifera, mollusks	quarry about 0.5 miles (0.8 km) south of San Lorenzo on the road to Yo Creek
Louisville formation	white, soft, marly limestone; oysters, *Rotalia*, ostracods, *Chara*	road cuts in the vicinity of Louisville
Orange Walk formation sensu stricto	white to cream-colored, sandy limestone and coquinoid limestone (10 to 20% quartz sand); pecten, turritella, *Rotalia* and other foraminifera	in the town of Orange Walk, on the hill where Orange Walk hospital is situated
Corozal formation	Soft limestone and marl with gypsum flakes; gastropods and corals (patch reefs, King et al., 2003)	the shore at Corozal and vicinity
Ambergris coral limestone	coral reef limestone	about 3 mi (5 km) north-northeast of Palermo Point, east coast of Ambergris Cay; also at Reef Point on Ambergris Cay

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In a facies transect through the study area, spanning the region between San Pablo Town in the Orange Walk District to Ranchito in the Corozal District, King et al. (2003) observed a typical upper Orange Walk seaward facies transect spanning (1) barrier island facies (Fig. 7), (2) carbonate shelfal lagoon (including bryozoan and coral patch reefs), and ultimately (3) a coralline platform-margin buildup (or extensive distal patch reef) facies. These deposits probably formed during the last transgressive event that affected this portion of the Yucatán platform (the late Miocene-early Pliocene eustatic sea-level high; Haq et al., 1988) and the area has been exposed to erosion since that time (King et al., 2003).

Figure 7. Exceptionally good outcrop displaying the Orange Walk group's barrier island facies (King et al., 2003. This facies is approximately the same as Flores' unit named San Lorenzo formation. Exposure is ~ 15 feet (~ 4.5 m) high.

Pleistocene and Holocene of Belize

Flores' (1952a) "Ambergris reef limestone," which is the youngest of his subdivisions of the Orange Walk group, is said to crop out at Palermo Point and Rocky Point on Ambergris Cay. The lithology is "coral reef limestone" with encrusting algae. Flores (1952a) notes that in some areas near the present coast and on the barrier reefs and cays, the uppermost part of the Orange Walk "forms the base" of the most recent phase of reef development. Most modern research papers on Belize reefs refer to a generic "Pleistocene limestone" as the base of the modern reef (e.g., Mazullo et al., 1992; Burke et al., 1998; Gischler et al., 2000). Based on similarity of description, we suggest that this "Pleistocene limestone" is most likely the same as the Pleistocene "Ambergris reef limestone," which Flores (1952a) said were the older Pleistocene "coral reef and equivalent back-reef" deposits of the area. Gischler et al. (2000) showed that the age of these older, more basal Pleistocene reefal deposits is between ~ 125,000 and 130,000 years.

Holocene deposits, aside from those related to reef growth and other marine sedimentation, include soils, stream and river deposits, deltaic deposits, cave deposition, and lagoonal sedimentation in northern Belize. Flores (1952a) refers this collective unit as "Quaternary and Recent." Cornec (1986) treats these deposits as one broad unit of "alluvium - reef deposits" belonging to "Pleistocene-Holocene." There is considerable variability in soil types in Belize, but there is no systematic published soil stratigraphy.

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Conclusions and Recommendations

Most of Belize stratigraphy comes from the half-century old, hand-typed report of Giovanni Flores (1952a), who wrote that, despite the relative thoroughness of his work, much more needed to be done in Belize and that his units were only intended to be provisional and informal. Bryson (1975) added some additional information about stratigraphic units gleaned from subsurface reports that were newly available at that time. Cornec's (1985; 1986) synthesis was very brief and his map perhaps more schematic than detailed in northern Belize. Now that Flores' (1952a) map has been lost, there is no other map besides Cornec's. The passage of time has erased many of Flores' proposed type sections, type localities, and selected outcrops that he mentions.

Based upon our experiences in Belize, we think that Belize needs a system of standardized, formal stratigraphic nomenclature. This would be quite useful to "promote unambiguous communication" (NACSN, 1983) about rock bodies and strata in the country and to assist in the future construction of an accurate geological map of the country. The proper and effective use of the nation's natural resources would be greatly aided by formal stratigraphy and reliable geological mapping.

In order to establish formal stratigraphy in Belize, a comprehensive review of stratigraphy needs to be undertaken to assess the validity of names already assigned to units and to determine if new names are needed. Further, the ages of all units should be reassessed considering the fact that most specific age assignments within coastal plain Mesozoic and Cenozoic strata are based upon fossil identifications that are over a half-century old and that were never peer-reviewed. Lastly, a new comprehensive mapping program needs to be started so that a complete, accurate geological map of Belize can be produced in the near future.

The Geology and Petroleum Office, or some agency within the Ministry of Natural Resources, could act as a clearinghouse for coordinating efforts as noted above and act as a central location for approval of nomenclature and receipt of published reports as well as a repository for samples related to surficial type sections and subsurface type-section materials. There is a strong need for an on-site collection of index fossils and type specimens of fossils indigenous to Belize. As formal status requires a specific type of publication "within a recognized scientific medium" (NACSN, 1983; Salavdor, 1994), it would be helpful if the Ministry would provide such a medium or at least coordinate publication in such a way that formal nomenclature can be compiled for easy access. A Belize Stratigraphic Committee or Commission would be most helpful.

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