TECTONICS AND PETROLEUM POTENTIAL OF BELIZE

BY

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Abstract

Belize falls in the southern edge of the North American Plate.Three structural units could be discerned - the Belize Basin in the south which is contiguous with the South Peten Basin, the Central Maya Block comprising Paleozoic metasediments and granites, and the Corozal Basin in the north which is the southern continuation of the Yucatan Platform and the eastern continuation of the North Peten Basin. The Belize Basin is structurally complex with folded sediments and thrusts.The Corozal Basin however is characterised by normal faults some of which appear to have strike slip movements.

The regional tectonic framework is one of ancestral basins and rifts known to have formed in Pennsylvanian - Triassic interval. From Jurassic to Mid-Cretaceous the area was surrounded by extensive carbonate shelves, later obliterated at places by Tertiary clastic wedges of deltaic origin. Source rocks appear to be Jurassic to Middle Cretaceous whereas accumulations are likely to be in Middle Cretaceous.

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INTRODUCTION

Tectonically Belize forms part of the North American plate and is an extension of the Peten Basin of Mexico and Guatemala and Yucatan platform of Mexico. The boundary between the North American plate and the Caribbean plate is the Motagua-Polochic Fault system and the Swan Fracture Zone in the offshore. This runs very close to the southern extremity of Belize. The northern Belize is named the Corozal Basin which has a sedimentary thickness of over 10,000 ft and is characterised mostly by carbonates and evaporites. The Maya Block comprises Paleozoic metasediments and igneous (Granites and Rhyolites) intrusives. Further south are the exposed Cretaceous and Tertiary sediments. These constitute a folded belt and the sedimentary area is named the Belize Basin (Rao, 1982) which has a thickness of over 16,000 ft predominantly of siliciclastics and limestones. The sedimentary facies, structural style and the tectonic frame work are favourable for the generation, migration and accumulation of petroleum in commercial quantities. The purpose of this paper is to review the geology of Belize including the latest data generated by the Office of Geology and Petroleum, Belmopan and to highlight the oil and gas prospects.

ROCK STRATIGRAPHY

Contributions to the stratigraphy of this region include those of Ower (1928), Flores (1952), Dixon (1956), Vinson (1962), Richards (1963), Wilson (1974), Clemons et al (1974), Dengo (1975), Bateson and Hall (1977), Bishop (1980), Peterson (1983), Nair and Cornec (1986), Nair (1987) and others.

The oldest rocks exposed in Belize are the Maya Mountains. These are referred to as Santa Rosa Group and believed to be geosynclinal deposits formed during Pennsylvanian to Permian time. It is not however certain that similar Paleozoic rocks reported from Guatemala, Mexico and western part of the United States were deposited in a single geosynclinal area or in several separate basins. The Santa Rosa Group is intruded by granites of Permian - Triassic age.

Post Triassic sedimentary record of Belize shows somewhat significant differences between the Corozal and Belize Basins, possibly due to the differences in the evolution of these two basins. The salient points of the lithostratigraphy of these two basins are summarised in Fig. I.

BIOSTRATIGRAPHY

Mega and micro fauna from Belize were reported by earlier workers including Flores (1952), Dixon (1956) and Bateson and Hall (1977). In addition a few oil companies exploring for petroleum in Belize carried out micro faunal and floral studies both from exposed as well as subsurface sections.

In an attempt to understand paleogeography, paleoecology and depositional history of the sedimentary basins in Belize, foraminiferal biostratigraphic work was initiated by the Office of Geology and Petroleum, Belmopan in 1985. As a result of this a preliminary biostratigraphic zonation has been established for Belize using both planktic and benthic foraminifera. This includes four assemblage zones for Cretaceous and fifteen assemblage and range zones for Tertiary intervals (Ramanathan 1985a,b). These zones together with the major unconformities recognised in Mesozoic and Cenozoic time and the significant transgressive and regressive cycles inferred for a few well sections are given in Fig. 2.

GEOLOGIC HISTORY

The history of sedimentation in Belize dates back to Late Jurassic-Early Cretaceous, when the weathered peneplained surface of the Santa Rosa Group was faulted down locally. The deposits in these fault bound depressions were fault scree, conglomerate and red shale with occasional anhydrite. (Todos Santos Formation of Belize Basin and Margaret Creek Formation of Corozal Basin).

By the close of Early Cretaceous, there seems to have been extensive diastrophism removing much of the sedimentary cover except from fault bound depressions. The marine transgression that followed seems to be in Albian resulting in the deposition of carbonates in the Belize Basin (Coban Formation) and carbonates and anhydrites in the Corozal Basin (Hill Bank Formation). There seems to be a major unconformity representing non-deposition from Cenomanian to Early Campanian in the Belize Basin. However, such a major break in the depositional history is yet to be recognised in the Corozal Basin. Nevertheless, a major transgression in Late Campanian brought these two basins under marine influence. While Belize Basin experienced a deep marine turbidite facies (Toledo Formation) and a shallow marine carbonate facies (Campur Formation) the Corozal Basin continued to be under the influence of hypersaline lagoonal conditions in the western part supporting carbonates and anhydrites (Yalbac Formation) and normal marine conditions in the eastern part accomodating carbonates (Sand Hill Formation).

The major tectonic events witnessed in Belize and Corozal Basins were also responsible for the uplift of the Maya Mountains during Early Eocene. Extensive movements along preexisting fault trends took place during this time. Atleast some of these movements seem to have been strike slip in conformity with the tectonic style of the period in the region. Extensive development of chert possibly due to hydrothermal activity along some of these faults also took place in parts of Corozal Basin.

Except in fault bound depressions, there was again a major break in deposition from Middle Eocene to Early Miocene. Late Miocene witnessed a significant transgression resulting in the deposition of lagoonal shallow shelf and shelf edge carbonates in the Corozal Basin (Barton Creek Formation) and shelf edge reef carbonates interbedded with terrigenous clastics in the Belize Basin (Belize Formation)

STRUCTURE

Regional Considerations

Bouguer anomaly map of the Yucatan Peninsula highlights a regional gravity high in the northeastern part and a large low in the south-western part, the two apparently separated by a fault. This fault separates the Yucatan Platform from the Peten Basin. The magnetic map is not that clear but in the Yucatan Platform there is a coincidence of the gravity and magnetic lows which could indicate a sedimentary basin. The magnetic map, however, clearly brings out the extension of the Peten Basin into the Blue Creek area of Belize.

Structure of Belize

Aeromagnetic as well as geologic maps confirm the existence of three structural units, the Corozal Basin, the Maya Block and the Belize Basin. In a broad sense, the aeromagnetic map of Belize has two features - the northern Belize (Corozal Basin) with low frequency anomalies and the southern Belize (Maya Block and Belize Basin) with high frequency anomalies (Fig. 3).

The Corozal Basin is separated from the Maya Block by a boundary fault, known as Northern Boundary Fault expressed in all the maps - geological, geomorphic, aeromagnetic and gravity. The structure of Corozal Basin is interpreted based on isobath of "basement" prepared from well information, aeromagnetic, bouguer anomaly, geological and geomorphic maps (Fig. 4). The Corozal basin has two significant trends - (i) a large NE - SW ridge named Belmopan-Shipstern Ridge flanked in the East and West by sub-basins and (ii) a NW-SE fault that bisects the Corozal Basin into two parts - the northern half being the extension of the Yucatan Platform and the southern half the continuation of the Peten Basin. The Belmopan-Shipstern Ridge appears to be cut and displaced by this NW-SE tear fault. These faults divide the Corozal Basin into sub-basins and ridges (See Fig. 3).

The Belmopan-Shipstern Ridge in the southern part of the Corozal Basin is thrust over the offshore along the Dangriga Trough. This thrust which is NE-SW continues southwards, whereas it dies further north. The northern part of the Corozal Basin (as a part of the Yucatan platform) appears to have experienced only epeirogenic movements. The western part of the Belmopan-Shipstern Ridge has normal faults hading east and the beds dip in the westerly direction into the Orange Walk sub-basin. (The structural style that could be expected here are closures againsts faults.) The Belmopan-Shipstern Ridge has a Saddle in the northern part and gravity, magnetic and seismic data suggest the presence of an extra sedimentary section, perhaps a Jurassic basin underlying the Cretaceous. Southwest of the Hill Bank Fault, the Yalbac Fault brings the Shipstern - Belmopan Ridge against the Blue Creek sub-basin, (which is the eastern extension of the North Peten Basin.) The dips on the western flank of the ridge are slightly steeper. Fault closures against Yalbac Fault and Hill Bank Fault are the structural styles expected.

The Belize Basin is essentially a folded and faulted belt. In the offshore, the southern part appears to be a "platform" as indicated by the low frequency magnetic anomalies and by a large gravity high. The Belize Basin constitutes several structural units - the San Jose Block, the Monkey River Block, the Punta Gorda Block etc. (See Fig. 3). Further northwards in the offshore there are sets of deep sub-basins and ridges. The Maya Block evidently gets cut off by N-S Fault and juxtaposed with a deep basin - the Dangriga Trough with a sedimentary thickness of more than 16,000 ft. These ridges and troughs are very likely the continuation of the Cuban Folded Belt. Reverse faults appear to be common - atleast in two wells there is repetition of section.

Unlike the eastern part of the Corozal Basin, the Belize Basin and offshore form part of a tectonic setting where the dominant mechanism is strike slip faulting. Sub-basins and ridges in this basin are formed due to such a mechanism. Structures where entrapment takes place could be fault closures or pinchouts on the margins juxtaposing these with probable source rocks in the deeper parts of the basin.

PETROLEUM GEOLOGY

Temperature Gradient Map

A temperature gradient map (Fig. 5) suggests that the gradients increase towards the Maya Mountains. The higher gradient in the north near Belmopan could be related to the boundary fault and in the east (offshore) and south to a system of tear faults. The structures that fall in this wide region of higher geothermal gradients are worth exploring.

Oil Occurrences

Oil occurrences in the Reforma-Campeche-Guatemala area range from Albian to Paleocene. In Corozal Basin oil shows are in Yalbac Formation (Cenomanian - Turonian), whereas in the Belize Basin they are in the Albian part of the Coban Formation.

Oil Seeps

There are atleast three surface oil seeps in the Corozal Basin, near Warree Bight, Buena Vista and Roaring Creek (Fig. 6). Others reported are near Bullet Tree Falls and Sibun River. In the Belize Basin, there are atleast one seep near Temash and three reported seeps near Punta Gorda (Fig. 6).

Oil Shows

Almost all the wells in the western part of the Corozal Basin (west of Belmopan - Shipstern Ridge) had live oil shows from the Yalbac section. Of the seventeen wells drilled in the Belize Basin eight had live oil shows from the Coban section.

Source Rock

The Tertiary, the Upper Cretaceous and the Lower Cretaceous rocks encountered in the wells of Corozal Basin have thin black shales which are organic rich. These rocks would thicken basinward and organic matter could be rich in the depocenter. This could be especially so in the case of Middle Cretaceous (Turonian) whose equivalent is the Eagle Ford shale of East Texas (Brown and Ruth, 1985). If this is the case, and if proper traps are identified and drilled there could be prolific production.

The oil in S.E. Mexico is supposed to be sourced from the Jurassic-Lower Cretaceous marine shales (Viniegra, 1971, Bishop, 1980, Meyerhoff, 1980, Santiago et. al 1984, Peterson, 1983) which could be the marine equivalent of the Todos Santos Formation. This formation has been penetrated in two wells, Spanish Lookout and Seal Caye. The environment in which it was deposited (in Seal Caye) was continental to begin with and changed to marginal marine passing upward into normal marine shelf and probably pelagic. This formation is correlatable with the Todos Santos Formation of Western Guatemala and Lecho Rojos and San Ricardo Formations of Southern Mexico.

If local basins developed during strike slip movements in Lower Cretaceous and Paleocene, chances of development of richer shales with oil prone - type Kerogen would be present. In fact anomalously high heat flows are observed in Dangriga well, and thick sediments reaching oil window are present as for instance in Palmetto Caye well offshore. Other factors which are speculative are maturity, adequate organic matter, local migration, existence of migration fairways (depositional, tectonic) and trapping within margins of depocentres.

Reservoir and Cap Rocks

In Corozal Basin, the Yalbac Formation which comprises alternations of dolomite and anhydrite is the natural combination of reservoir and cap rock. The underlying Hill Bank Formation is also a dolomite section with anhydrite intervals. In the Belmopan area the shale content of the dolomite varies from 5 to 20% and permeability of 10 milli darcies, with a few intervals going upto 130 milli darcies. The Yalbac Formation however has porosities up to 15% and permeabilities upto 3 millidarcies, a few exceptions however are 50 milli darcies. Core analysis data show low permeabilities at high porosities, which suggests that effective porosities could be increased by formation stimulation. Fracture porosity seems to be present near fault zones.

In Belize Basin, the best reservoir rock appears to be Upper Coban. In one of the wells (Coco Plum-I) a high porosity of 45% and permeability of 37 darcies are reported in one case. One view is that the tallus that is buried in the shale (Punta Gorda Formation is an example) could be a good exploration target. Structures over such basinal margins where such tallus is deposited or "stratigraphic traps" are the areas to look for. Exploration for pure stratigraphic traps is expensive and elusive and so any seismic anomaly located on basin margins is worth drilling. Location of basin margins is possible, provided a high quality seismic exists supported by aeromagnetic data. Numerous structures are already mapped by seismic and if from regional considerations cap rock is identified such areas would be worth testing.

TYPE OF PLAYS EXPECTED

Corozal Basin

In Corozal Basin the major structural feature is the Shipstern Ridge which nearly limits the anhydrites. The western flank of this ridge is characterised by normal faults hading eastwards. Closures developing against these faults are the plays to be tested. The seismic lines bring out some of the fault closures. Other closures expected are the ones against Yalbac Fault and Hill Bank Fault.

Belize Basin (onland and offshore)

Numerous anticlinal closures are mapped by seismic in the offshore, and geologically mapped onshore. Although seismic quality is good it is not clear how many of these structures continue downwards (antiforms?) and whether some of these are cut off by thrust faults. The prospects of these however are very good especially if sub-thrust blocks of these structures are tested.

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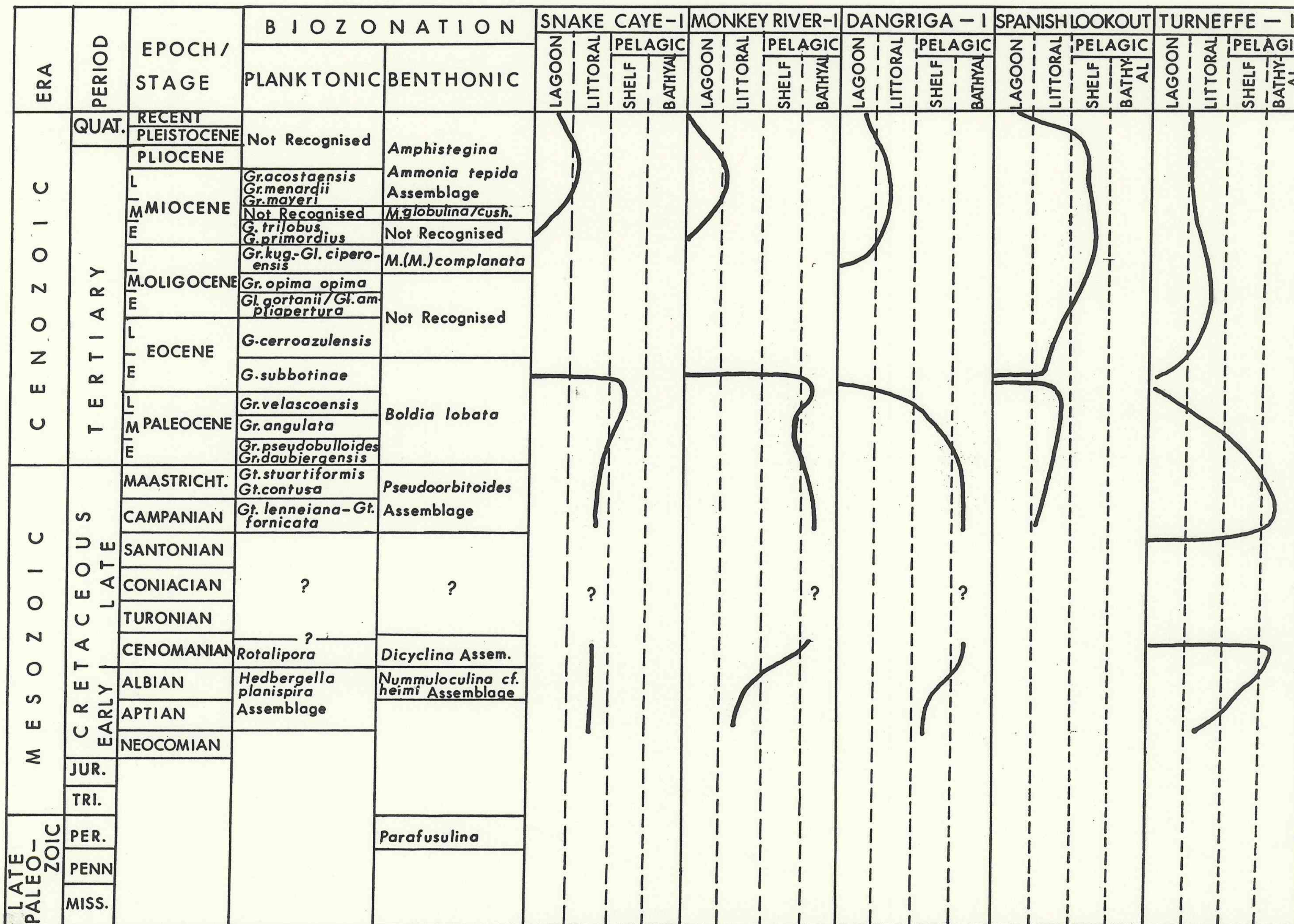
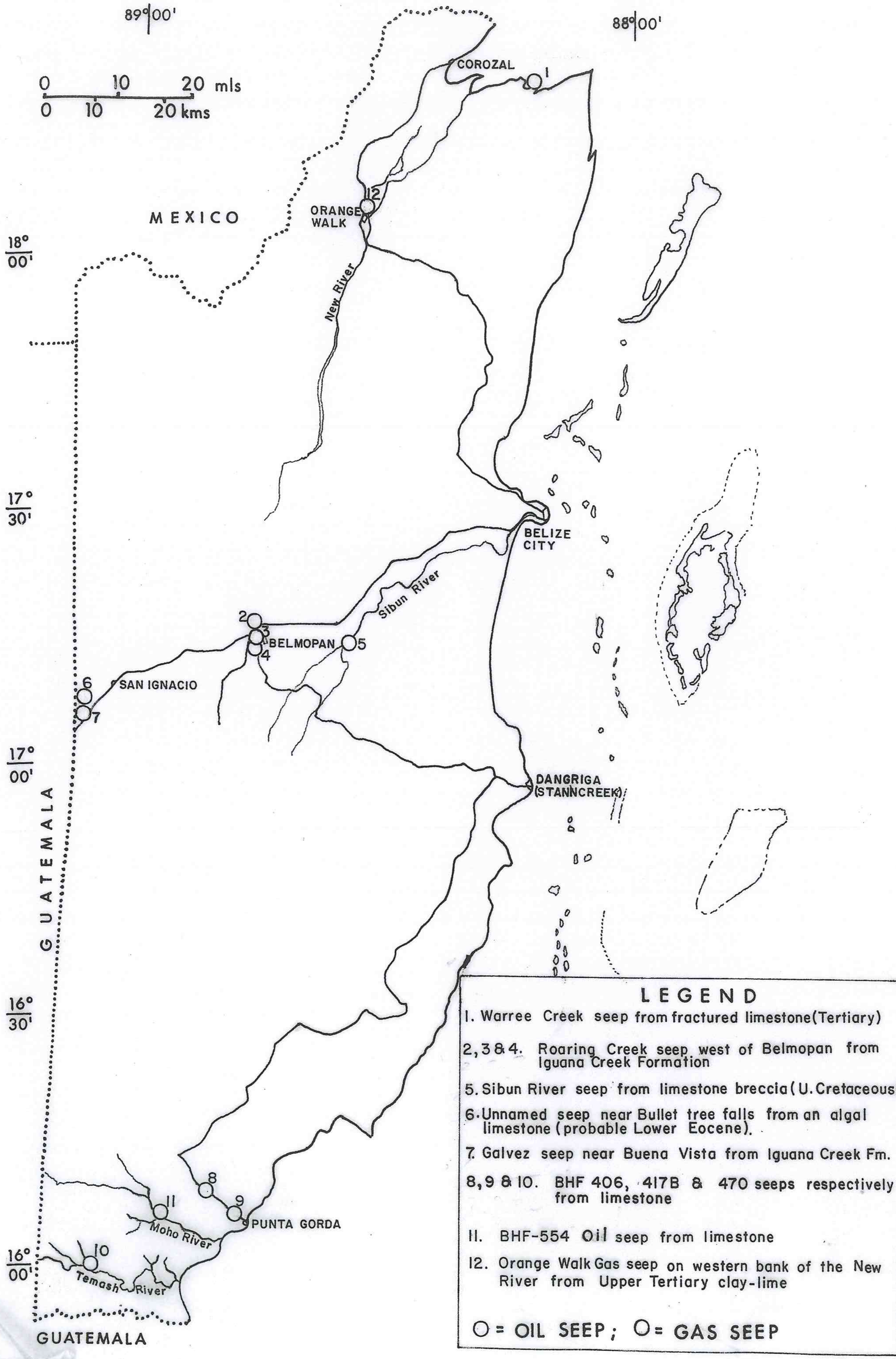
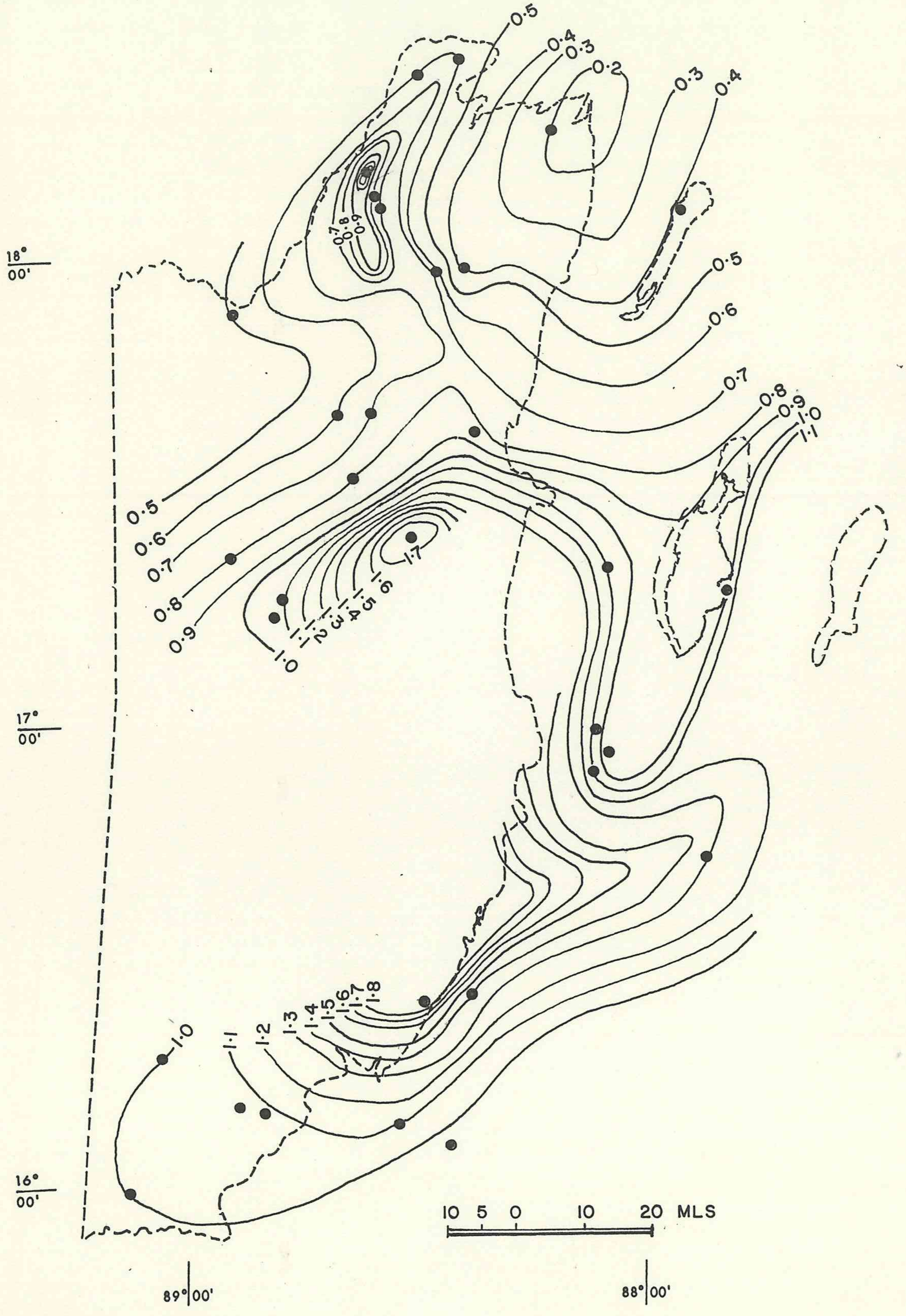


FIG. 2. BIOSTRATIGRAPHY



89°00'
88°00'
0 10 20 mls
0 10 20 kms
COROZAL
MEXICO
ORANGE WALK
New River
18° 00'
17° 30'
BELIZE CITY
Sibun River
BELMOPAN
SAN IGNACIO
17° 00'
DANGRIGA (STANNCREEK)
GUATEMALA
16° 30'
PUNTA GORDA
Moho River
16° 00'
Temash River
GUATEMALA
1
2
3
4
5
6
7
8
9
10
11
12
LEGEND
1. Warree Creek seep from fractured limestone (Tertiary)
2, 3 & 4. Roaring Creek seep west of Belmopan from Iguana Creek Formation
5. Sibun River seep from limestone breccia (U. Cretaceous)
6. Unnamed seep near Bullet tree falls from an algal limestone (probable Lower Eocene).
7. Galvez seep near Buena Vista from Iguana Creek Fm.
8, 9 & 10. BHF 406, 417B & 470 seeps respectively from limestone
11. BHF-554 Oil seep from limestone
12. Orange Walk Gas seep on western bank of the New River from Upper Tertiary clay-lime
O = OIL SEEP; O = GAS SEEP



LEGEND

● CONTROL POINTS (WELLS)

CONTOURS IN °F

HIGH

LOW

FIG. 5 TEMPERATURE GRADIENT MAP OF BELIZE

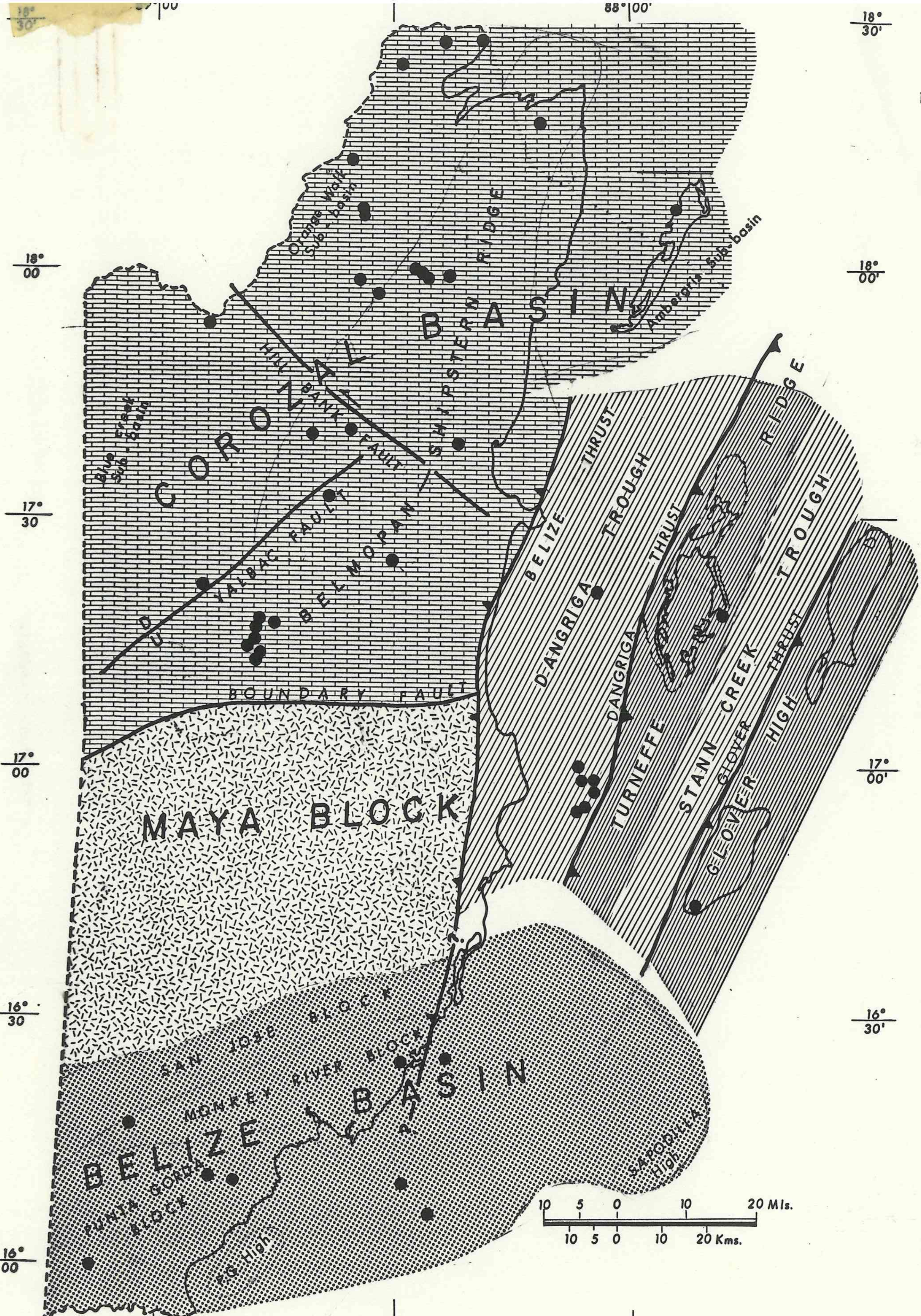


FIG. 3. TECTONIC MAP OF BELIZE

Smallest letters not less than 120 & others proportionately larger.