A geological / geoscience overview of the hydrocarbon exploration potential of Belize, Central America

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ABSTRACT

A review of the exploration history of Belize has led to the recognition of its possible untapped potential. Since the onset of oil exploration in Belize began in 1938, a total of only forty-seven wells have been drilled on the mainland and offshore. Well results indicate the presence of oil reservoir but as yet in sub-commercial quantities. Commercial quantities of oil, however, have been discovered within the stratigraphically equivalent Peten basin in the neighbouring countries of Mexico and Guatemala. Northern Belize is considered to be one of the most prospective areas of Belize. Thirty wells have been drilled in northern Belize, most recently in the early 1990's. A number of undrilled anomalous structures and possible play types have been identified. With the onset of new technologies, a more in-depth look at the prospectivity of Belize, particularly northern Belize, may be warranted.

INTRODUCTION

This overview of the geology and geophysics of northern Belize was initially undertaken to become familiar with the surficial geology in and around several Mayan ruin sites in northern Belize namely Ma'ax Na and Chan Chich (Figure 1).

To understand where the Mayans built their impressive pyramidal structures and plazas, and the materials they used, required the examination of the regional geological setting and lithological information. Several geophysical surveys conducted by the University of Calgary at these sites over the past several years have provided good images of the near surface confirming the existence of caves, a looter's trench, and other important archaeological features. This research however, has also uncovered a virtually unexplored area of considerable oil potential. Thirty wells have been drilled in the Corozal basin over the last seventy years of petroleum exploration history with encouraging results, namely several live oil shows but as yet non-commercial oil production. The intent of this paper is to summarize the information and findings of several sources, and those presented by the Geology and Petroleum Office - Ministry of Science and Technology and Transportation of the Government of Belize.

REGIONAL AND STRATIGRAPHIC SETTING

Belize is located in northeastern Central America and is bounded by Mexico, Guatemala, and the Caribbean Sea. It has an areal extent of 22,700 square kilometres and is the only Central American country with no Pacific coastline. According to Morrice (1993), "From an explorationist's viewpoint, Belize is exciting because of its placement on the rim of the prolific Southern Gulf of Mexico basin, containing most of the major Mexican oil production. Belize offers access to the same stratigraphic sequences of source, reservoir and seal facies."

TECTONICS

The evolution of Belize's tectonic history began with the super-continent Pangaea and its subsequent break up into the continents of North and South America over eighty million years ago. The associated rifting along fracture zones within what would become the Gulf of Mexico, and periods of juxtaposition between the North American and South American plates resulted in the Yucatan area being bounded by a series of faults. Continental drift of the North American plate precipitated the formation of new oceanic crust in an area adjacent to Belize, forming the Caribbean plate (Figure 2).

Continued tectonic activity led to the eastward movement of the Caribbean plate which deformed the Central American region and is responsible for the dominant and structurally controlled features of Belize today: the Maya Mountains, the offshore atolls and the coral barrier reefs (Geology and Petroleum Office, 1995).

THE STRATIGRAPHY AND PALEOGEOGRAPHY OF THE COROZAL BASIN

The Belize mainland can be subdivided into three geological provinces: Northern Belize, Southern Belize and South-Central Belize. The Corozal Basin of Northern Belize is an extension of the Yucatan platform and is stratigraphically part of the North Peten Basin of Guatemala. Southern Belize contains the Belize basin and the Maya Mountains are part of the South-Central Belize geological province (Figure 3). This report will focus on Northern Belize and the Corozal Basin.

The Corozal basin is comprised of a thick sequence of non-clastic sediments deposited during a 50 million-year history of tectonic uplift, erosion, faulting and transgressions. It is characterized by a predominantly marine carbonate sequence (Figure 4).

From a geomorphic perspective, the Corozal basin, is comprised of three distinct units: a coastal plain with swamps and flood plains of Quaternary age, a central plain with gentle topography and lakes created by subterranean karsting, and overlain with a cover of Lower and Upper Tertiary carbonates and clays, and a western expanse of hills ranging from 100 to 250 metres in elevation, with rivers and flood plains. Upper Cretaceous and Lower Tertiary carbonate rocks make up the surficial expression of this latter region. The most striking feature of the rivers north of the Maya Mountains is their remarkably straight courses (Dixon, 1956). Faults and fractures appear to dominate the drainage patterns throughout this region.

"Northern Belize contains a series of WNW-ESE trending anticlinal structures that plunge to the northwest, and may be of interest to petroleum exploration" (Geology and Petroleum Office, 1995). These structures are confined to the western area of Belize and are part of the Peten basin of Guatemala in which commercial quantities of petroleum have been discovered in the Reforma, Campeche and North Peten areas. The trending pattern of these structures has been postulated to be associated with the uplift of the Maya Mountains in the early Tertiary (Figure 5).

Figure 6 represents a geological cross-section through part of the Corozal basin and is a fair representation of the stratigraphy of the Mayan ruin sites of Max'an and Chan Chich. The geologic sequence and paleogeography of the Blue Creek 1 well, which represents the northern limit of the cross-section is outlined below arranged from the oldest to youngest deposits:

Santa Rosa Group

The creation of a geosynclinal trough due to tectonic activity led to the deposition of the Paleozoic sediments and metasediments of the Santa Rosa group which essentially form the basement rocks in the Yucatan Platform, Corozal Basin, Guatemala and southeastern Mexico. The Blue Creek 1 well was drilled to a depth of 3200 metres and encountered Paleozoic shale with minor greywackes, but other wells in the Corozal Basin have penetrated carbonates, with metamorphosed slates, phyllites and schist within the Santa Rosa group.

Hillbank Formation

Following a period of uplift, erosion and faulting, a major transgression occurred in Early Cretaceous flooding the Corozal Basin in its entirety. The Maya Mountains provided high topographic relief, and northern and southern boundary faults set limits of sediment deposition. Within the Corozal Basin, the Belmopan-Shipstern subsurface ridge split the basin into two geologic environments resulting in the creation of a hypersaline lagoonal basin in the west and a shallow marine sea to the east. The Hillbank formation consisting of clayey dark tan microcrystalline calcareous dolomite with interbedded sand and shale was deposited during this period.

Yalbac Formation

The Yalbac formation represents a period of sequential deposition of carbonates and anhydrites in the evaporitic basin of northwestern Belize. A thickness of over 2250 metres was encountered while drilling the Blue Creek 1 well.

Barton Creek Group

A stable marine environment in the Late Cretaceous period led to the deposition of over 200 metres of limestone and dolomitic limestone and marls. The Barton Creek Formation refers to the entire sequence above the Yalbac Formation.

In Early Eocene, a significant tectonic event resulted in thrust faulting, folding and uplift in the basin and shelf environments. During Miocene, a major transgression submerged most of the Corozal basin and reefal structures were created alongside areas of high relief. Lagoonal sedimentation consisted of limestone with boundstone/grainstone to wackestone textures. Subsequent regression of the seawater and the uplift of the mainland during Pleistocene times have led to Belize's present day geographical framework.

GEOPHYSICS

Although Belize has a history of oil exploration since the 1930's, from a geophysical point of view, a large part of the area is generally unexplored. Oil companies such as Gulf, Anschutz, Chevron, Placid Oil, Petro Belize and American Eagle have drilled a total of 30 wells in the Corozal Basin from 1956 to 1994, and results have established the presence of oil but as yet in uneconomic quantities. With the onset of new technologies such as 3D seismic, computer workstations, improved instrumentation and seismic processing software, it may be possible to take a fresh look at the hydrocarbon prospectivity of northern Belize.

GRAVITY

The Corozal Basin contains a number of Bouger anomalies as noted in Figure 7. Gravity lows in the north, trend NW-SE and may signify the continuation of the Peten Basin embayment or a low-density granitic pluton. Two anomolously high gravity readings are evident in the central part of the Corozal Basin and trend in a north-south orientation. The southwestern part of the basin consists of low gravity values suggesting a gradational thickening of the regional sedimentary sequence to the northwest.

Figure 8 is the residual gravity anomaly of the Corozal Basin. The presence of high frequency anomalies may in fact infer the configuration of the basement. The linear alignment of anomalies suggests a NW-SE trending fault.

Two major sub-basins within the Corozal Basin are present due in part to the existence of this fault known as the Hillbank Fault. The Sand Hill sub-basin is part of the Yucatan platform while the Hillbank sub-basin represents the eastern expression of the Peten basin. Structures on the SW side of the fault would be potential targets for petroleum exploration (Geology and Petroleum Office, 1995).

MAGNETICS

Although the magnetic anomaly map of the Yucatan Peninsula does not include coverage over Belize, it does confirm the existence of a magnetic low in the northwestern part of Belize, which corresponds to the extension of the Peten Basin of Guatemala. This possible embayment was also postulated from gravity lows. The presence of the NW-SE trending Hillbank Fault was also confirmed on the magnetic anomaly map.

In 1974, an aeromagnetic survey to magnetic basement was conducted in Belize, covering a total of approximately 14,000 square kilometres. The aeromagnetic map highlights areas of high and low magnetic anomalies (Figure 9).

In the Corozal Basin of northern Belize, anomalies trend in a NW-SE orientation with values increasing toward the eastern region, and toward the Maya Mountains. These anomalies appear to reflect lithological variations in the basement composition and are not structurally related (Geology and Petroleum Office, 1995). Estimates of the depth of the magnetic basement range from almost zero in the vicinity of the Mayan Mountains to over 5500 metres in the northwest region of the Corozal Basin.

SEISMIC

Various oil companies have acquired nearly 10,000 kilometres of 2D seismic lines in Belize over the last several decades (Figure 10). The data quality of the seismic lines has varied from poor to good (Figure 11). According to Rao (1983), "The majority of wells drilled within the Corozal basin have been delineated on the basis of gravity data or poor seismic data. So it is possible that wells were not located on the highest part of the structures." It is believed that poor seismic recordings are caused by near surface karst structures that are prevalent in the area. These cave-like voids result in seismic interference, which leads to poor signal-to-noise and the lack of continuity of events. Recent ground-penetrating radar surveys have easily detected such features and may provide a means of establishing a better layout of seismic lines at a negligible cost.

Figure 12a shows the location of an eight-kilometre 2D seismic line (Figure 12b), shot by Vaalco Energy Inc. in the western part of the Corozal Basin. The section confirms the presence of a major thrusted fault block of Paleozoic age, similar to the structural configuration of the North Peten Basin of Guatemala in which commercial oil production has been established. Subtle draping of the Yalbac formation overlies the structure, followed by a flat, uninterrupted layering of Cretaceous age sediments. A potential well location has been identified penetrating the central portion of this feature (Geology and Petroleum Office, 1995).

PLAY TYPES

Two possible play types in the Corozal Basin are structural closures bounded by faults and pinchouts (Figure 13). The play concepts as presented indicate normal faulting downthrown to the south-east, creating potential trapping mechanisms for the northwest dipping Mesozoic sediments. Exploration companies have mapped approximately twenty faulted anticlinal structures in this basin (Geology and Petroleum Office, 1995).

The two most likely formations with reservoir/seal potential are considered to be the Yalbac and Hillbank formations. Both formations have notable oil shows. Drilling to deeper Paleozoic rock however is another potential target. In Central America, the Paleozoic and Pre-Cambrian formations have been rather neglected owing to the greater importance of the younger oil producing formations (Dixon, 1956).

CONCLUSIONS

A review of the geology and geophysics of northern Belize has uncovered some interesting undrilled geological structures. The government of Belize is committed to encouraging the participation of foreign investment in hydrocarbon exploration. Belize's stability, democratic government, and investment incentives with respect to the petroleum sector make it an attractive place to invest in. At this point, it is premature to comment on the quality of the plays outlined in this report as more work is warranted in integrating the geological and geophysical data. Near-surface geophysical methods such as ground-penetrating radar could provide a mean of determining karst topography and allow for the acquisition of better quality seismic data. New technologies such as three-dimensional seismic acquisition could better image the subsurface and aid in quantifying the risk of potential exploration targets.

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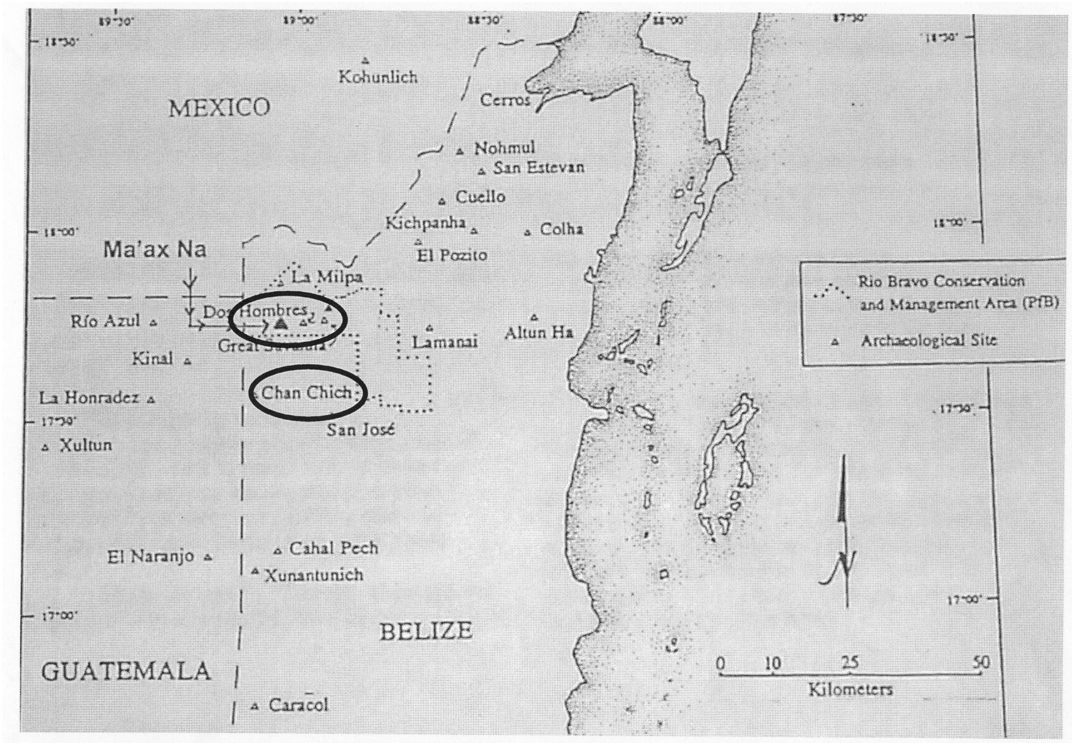

FIG. 1. Map of Mayan sites in northern Belize.

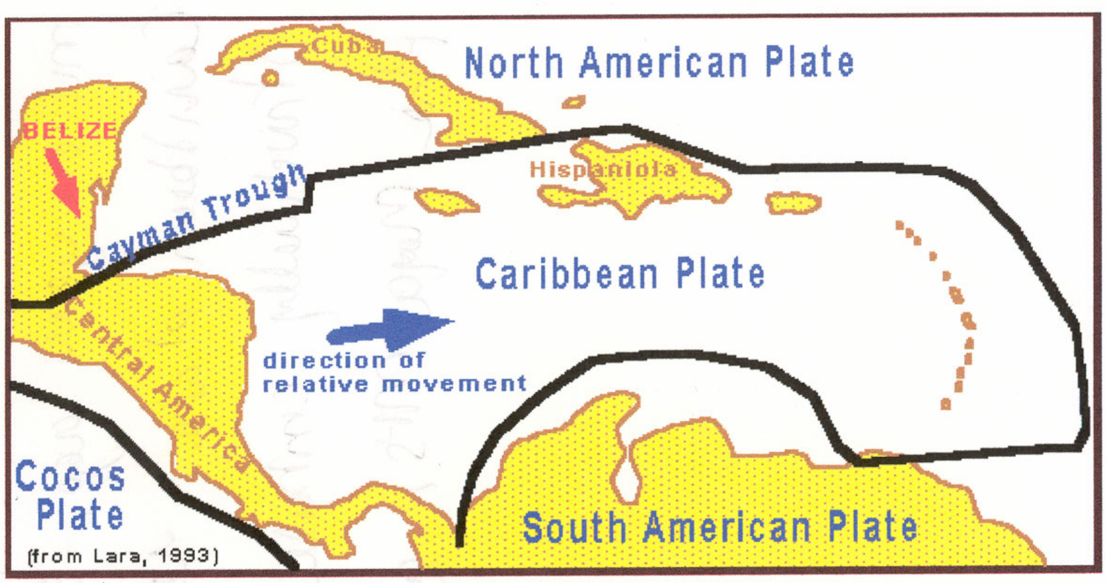

FIG. 2. Tectonic plates of the Caribbean (Geology of Belize and Ambergris Caye, 2002).

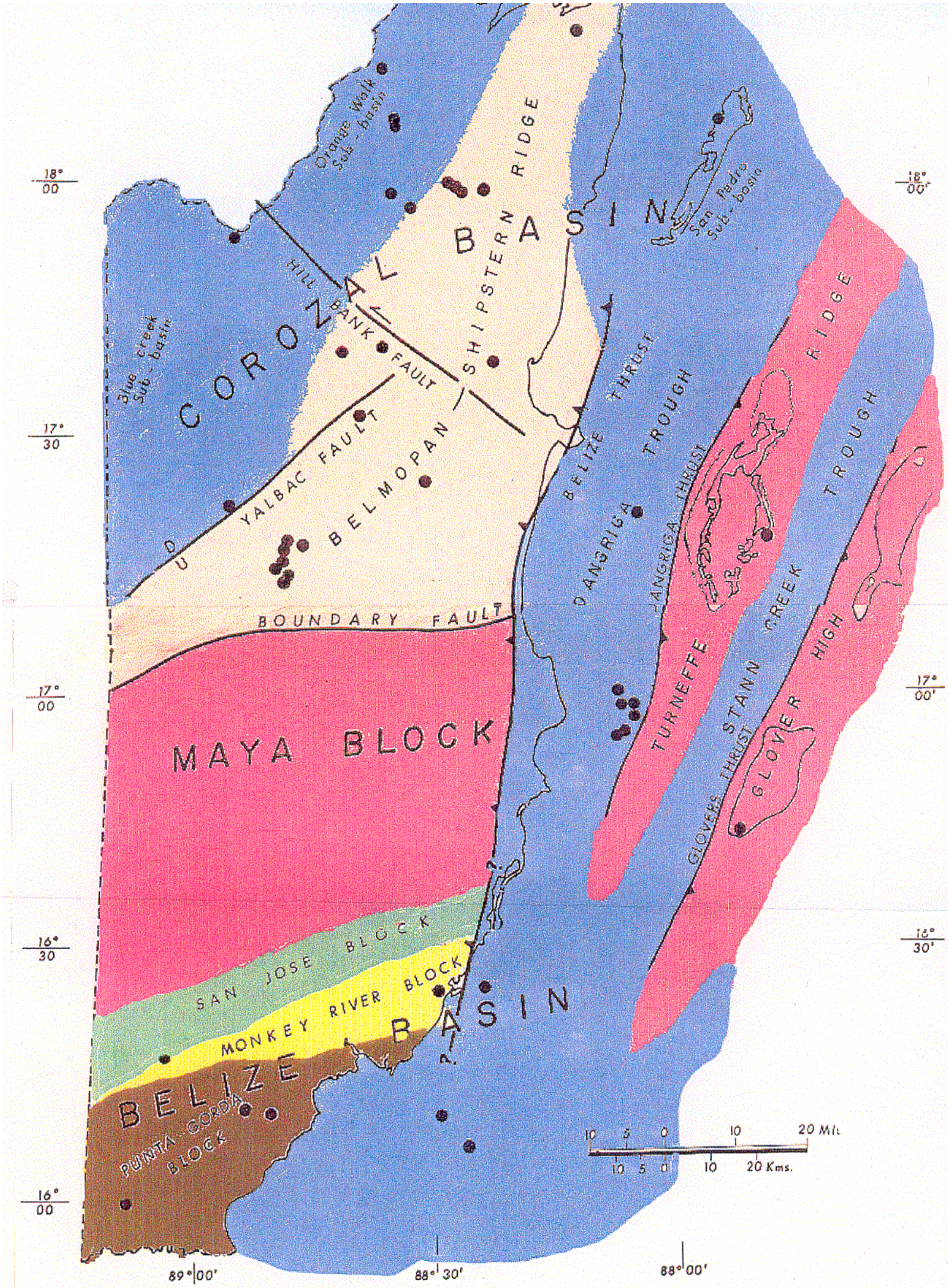

FIG. 3. Tectonic map of Belize (Geology and Petroleum Office, 1995). Wells shown as black dots.

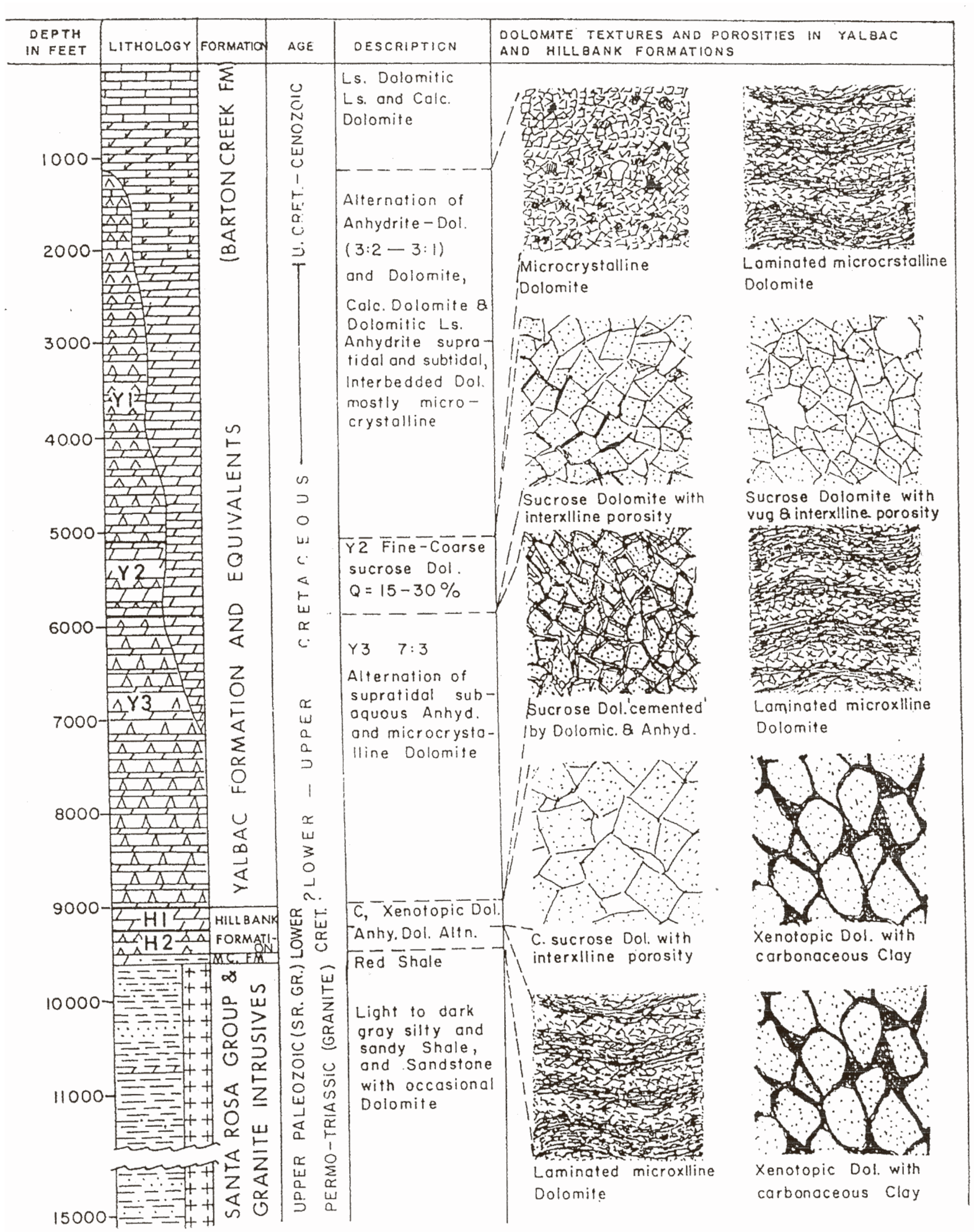

FIG. 4. The stratigraphic column of the Corozal Basin (Geology and Petroleum Office, 1995).

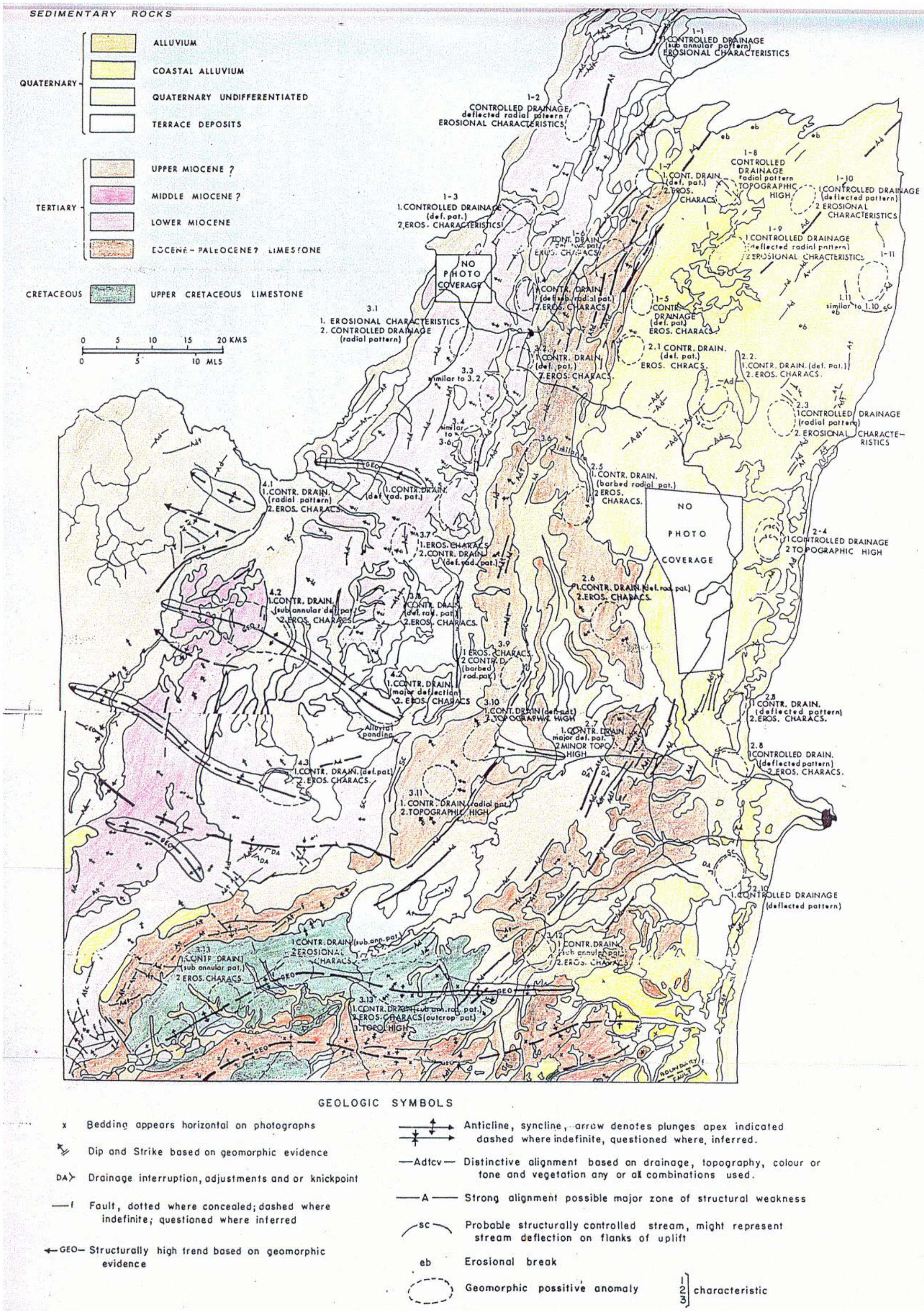

FIG. 5. Geomorphic map of northern Belize (Geology and Petroleum Office, 1995).

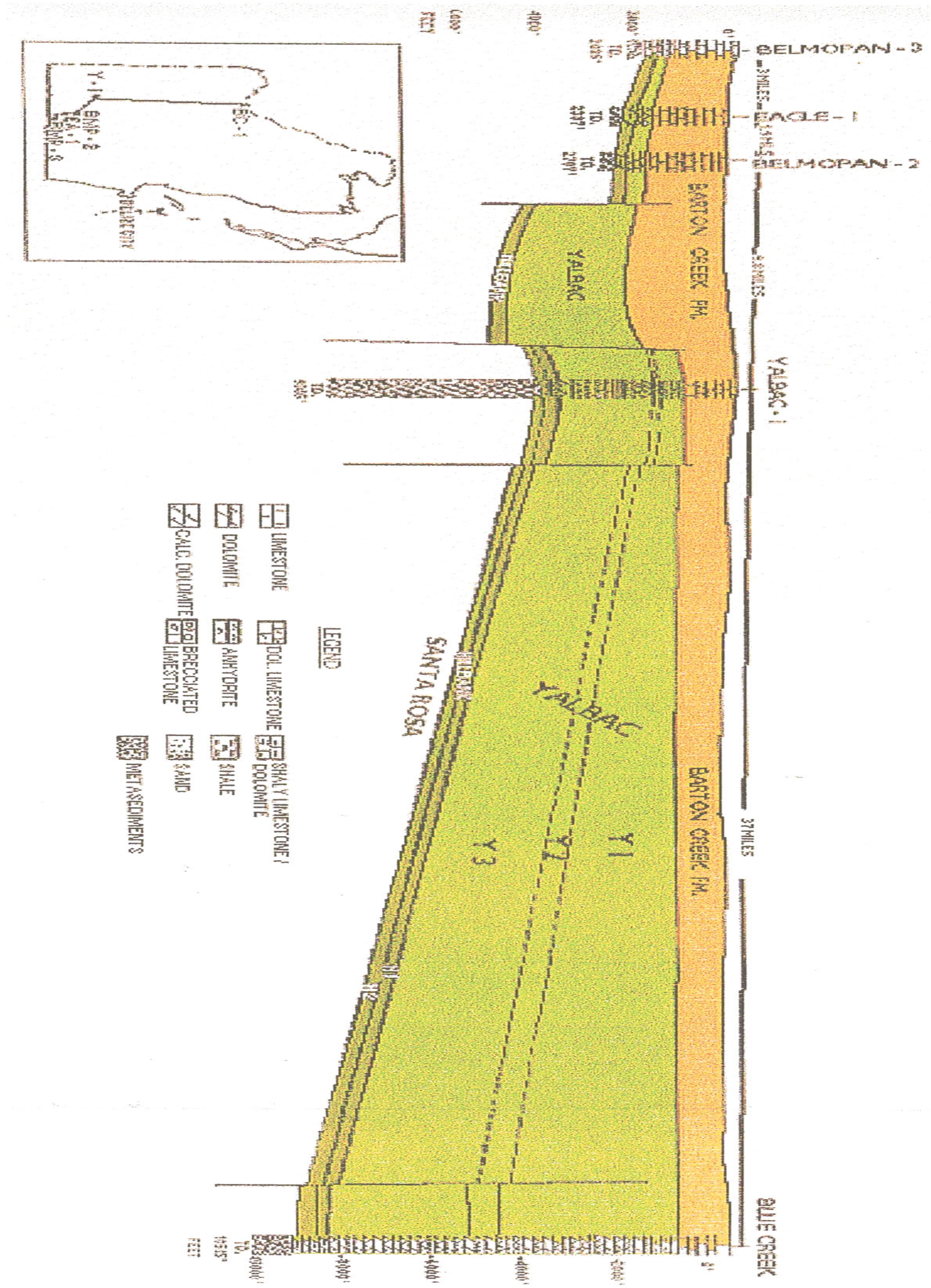

FIG 6. Geological cross-section of northwestern Belize (Geology and Petroleum Office, 1995).

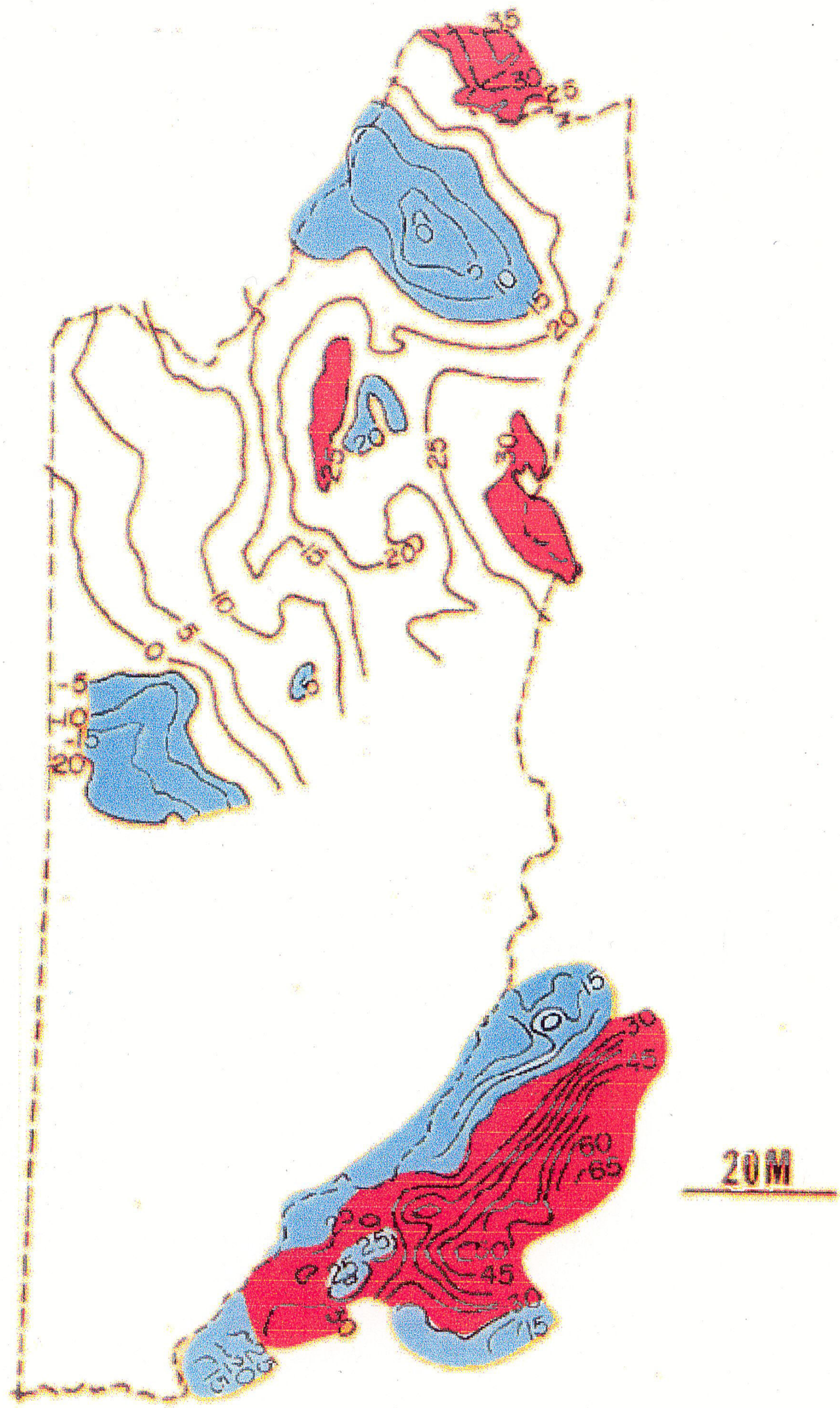

FIG. 7. Bouger anomaly map of Belize (Geology and Petroleum Office, 1995).

Belize.

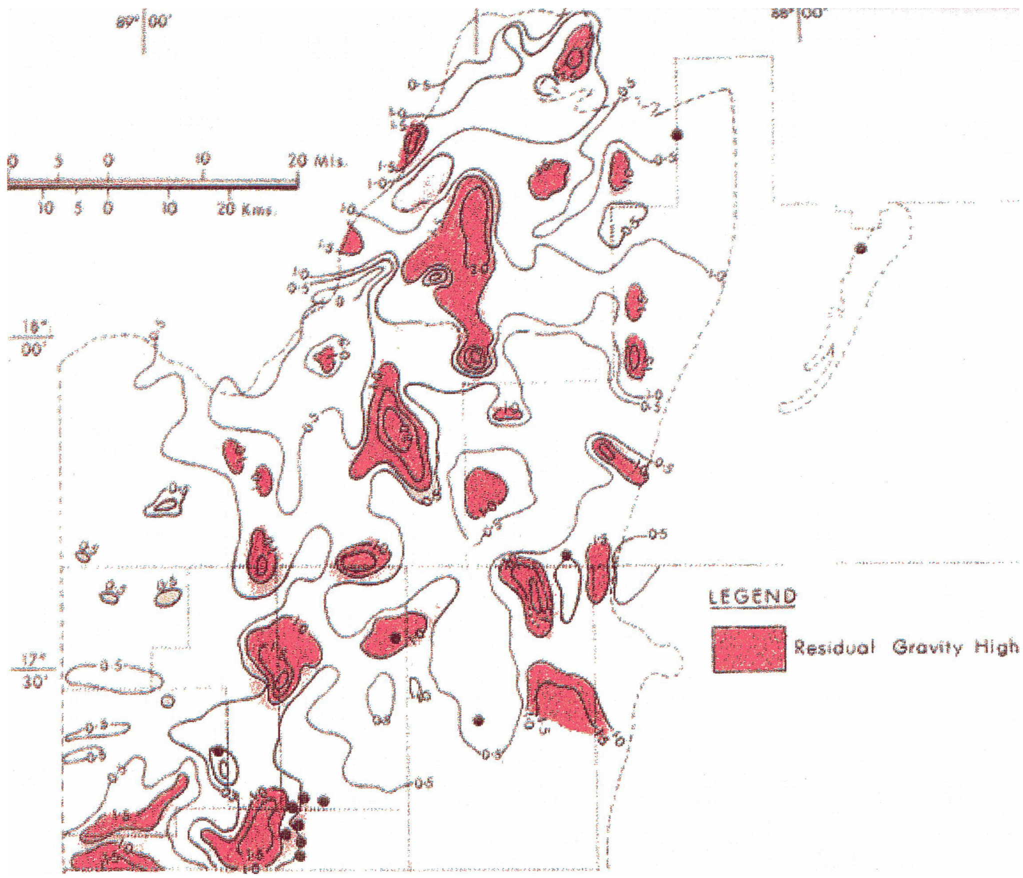

FIG. 8. Residual gravity anomaly map of the Corozal Basin (Geology and Petroleum Office, 1995).

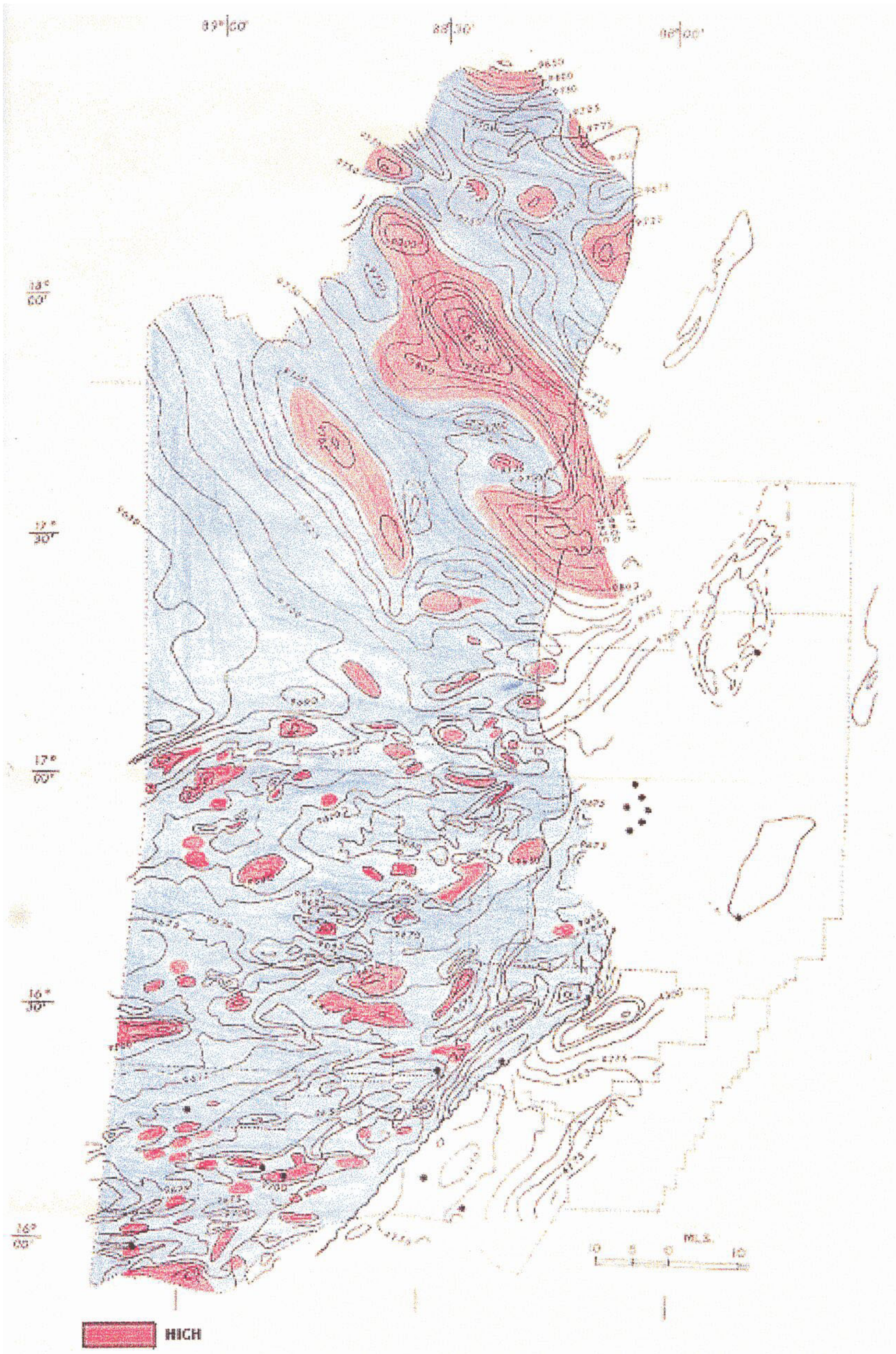

FIG. 9. Aeromagnetic map of Belize (Geology and Petroleum Office, 1995).

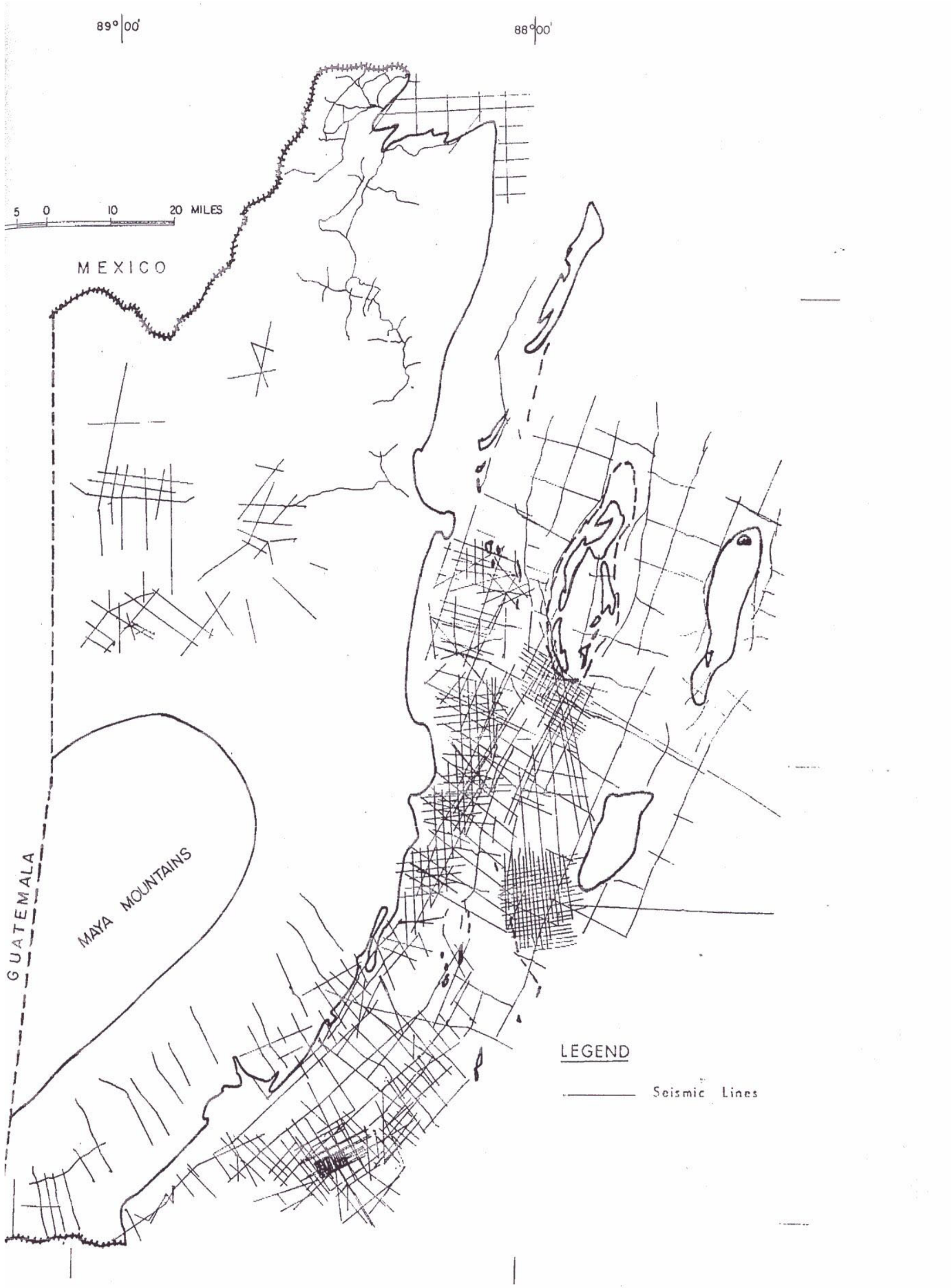

FIG. 10. Seismic base map of Belize (Geology and Petroleum Office, 1995).

FIG. 11. Seismic data quality (Geology and Petroleum Office, 1995).

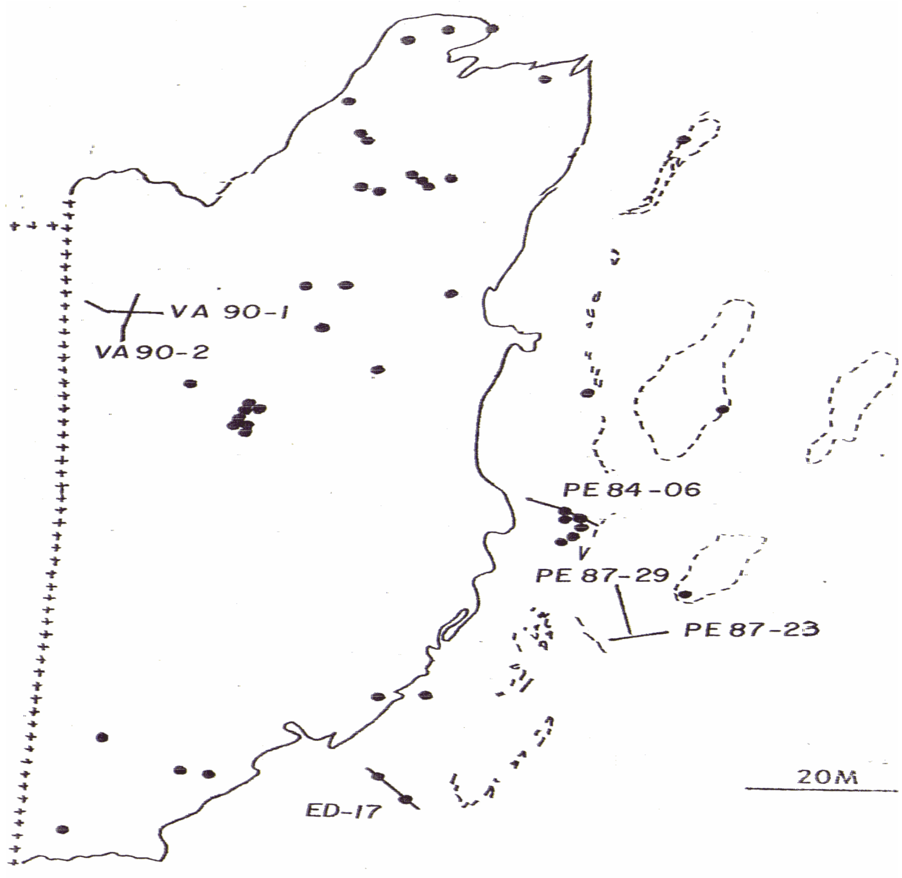

FIG. 12a. Location of seismic line VA 90-2 (Geology and Petroleum Office, 1995).

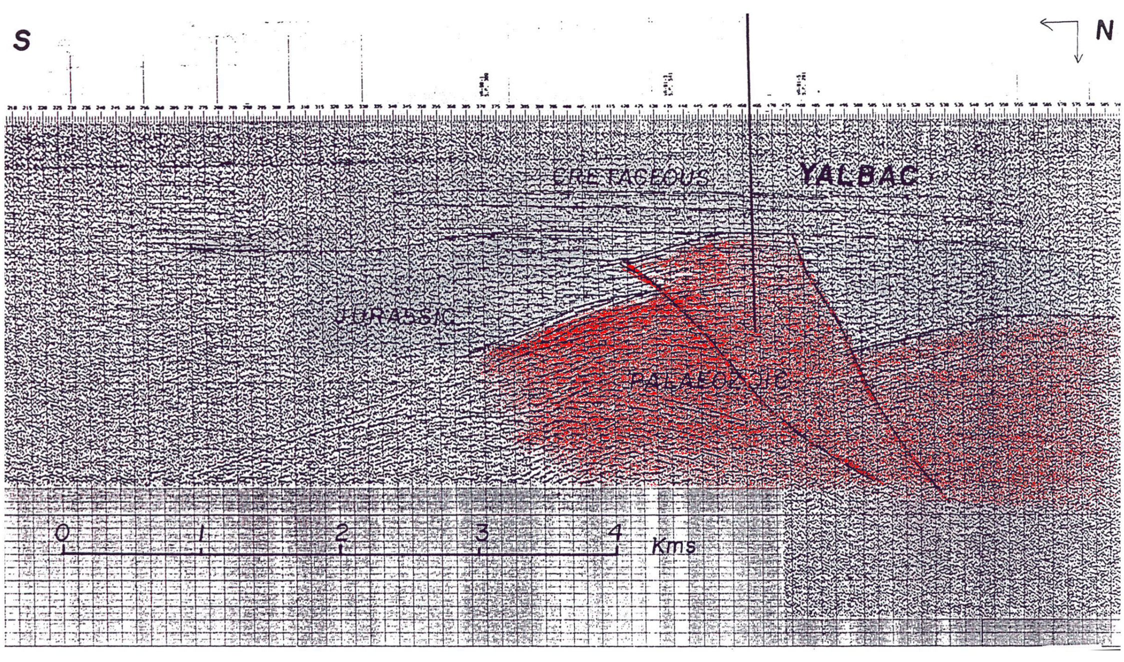

FIG.12b. Seismic line VA 90-2 (Geology and Petroleum Office, 1995).

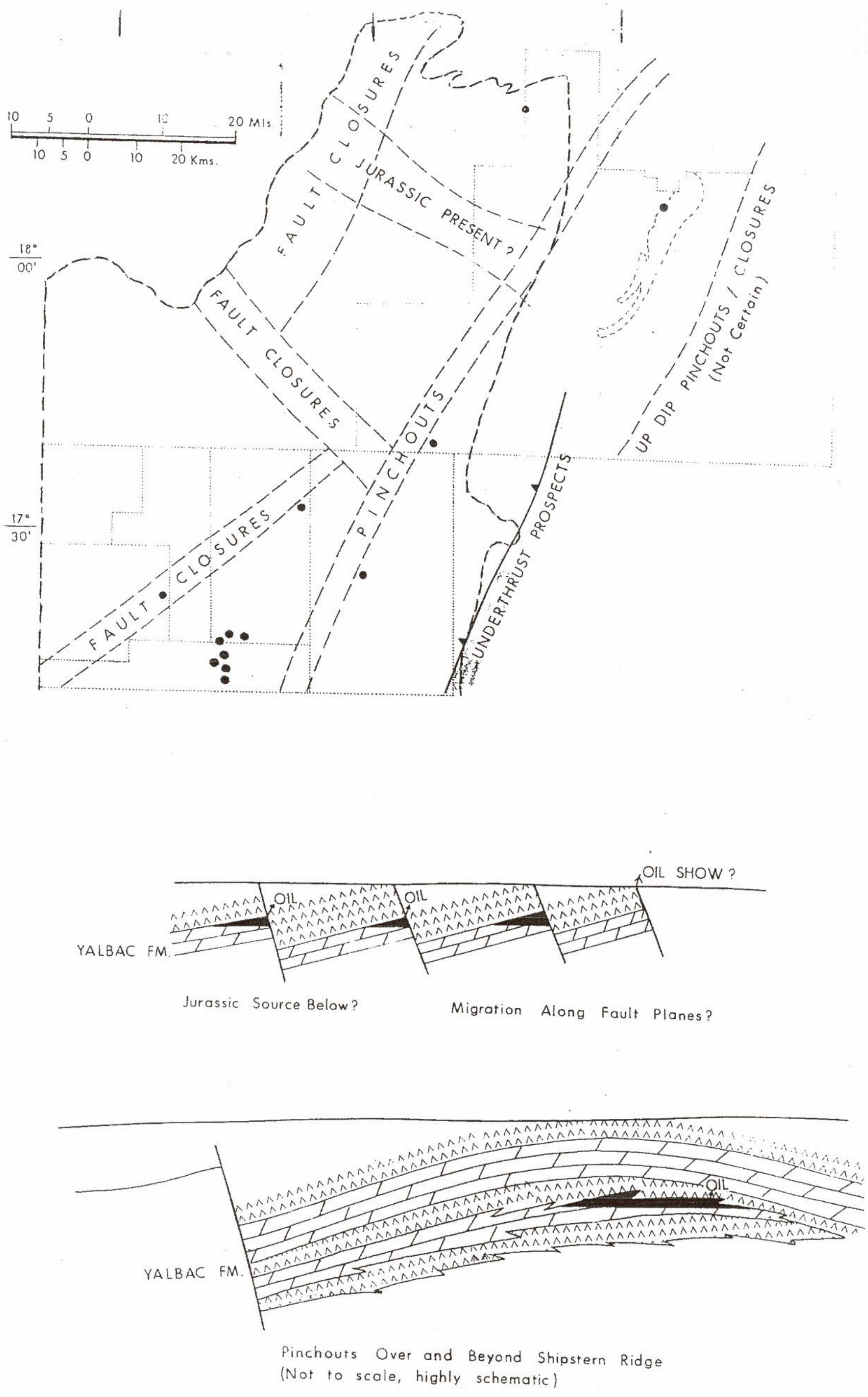

FIG. 13. Possible play concepts in northern Belize (Geology and Petroleum Office, 1995).