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Update Geological and Geophysical Framework on the Pacific Onshore, Nicaraguan Sandino Basin.

Ministry of Energy & Mines /General Hydrocarbons Directorate
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ABSTRACT

The Sandino Basin is surrounded by the Rivas Isthmus, southwest of Managua between Lake Nicaragua to the east and the Pacific coast, over the landward flank of the Sandino Tectonic Basin. The main geographical aspects are a belt of volcanoes, part of the Central American Cordillera, which parallels the Pacific coast, and the deep offshore Middle American Trench. The Sandino Basin is a fore-arc basin which was developed over the subduction zone where the oceanic Cocos Tectonic Plate moves eastward and beneath the southwestern lip of the Continental Caribbean Plate. Geologically, Nicaragua rests on the southern part of the Chortis block, which originated at the western edge of the North American Plate prior to the Cenozoic. Subsequently, during the early Tertiary, it was jointed with the Caribbean Plate along a major strike-slip fault The Sandino Basin structure was established throughout the Cretaceous, covering over some 30,000 square kilometers, 5,000 of which are onshore. Up to 10,000 meters of sediment have accumulated in its depocenter.

The original structure has been altered by ongoing tectonic developments including subsidence, uplift, compression and extension, associated to relative movements of juxtaposed tectonic plates. Presently, the overall structure consists of a deep offshore marine basin to the west, progressing northwestward up a monocline, landward to a coastal anticlinal structure, which underlies the concession area, the Nicaraguan depression, represented by the lakes district and the interior anticline to the east. The large northwest-southeast trending anticlinal trends have been dissected by numerous cross-cutting, steeply dipping faults compartmentalizing the area and longitudinal faults which provide some topography to the otherwise monotonous monocline descending to the basin depths. The area of most interest for exploration is situated over the coastal anticline in a northwest-southeast trending band, parallel to the coast, and about 30 kilometers wide. Further east, these generally southwest-dipping Tertiary strata are overlain unconformably by flat-lying Quaternary volcanic.

Geological Framework of Main Formations Prospective to make Exploration and Found Hydrocarbons.

The main geological characteristic of the onshore Sandino Basin is the subdivision of three structural units. The southern part is described by deposits of the late Cretaceous Rivas Formation and the upper Paleocene to Eocene Brito Formation. These deposits are compartmentalized by numerous NW-SE striking normal faults creating Horst and Graben structures, which are further divided into smaller compartments by NE-SW striking transform faults. The middle unit is bounded to the North near the mouth of the El Carmen River by a NE-SW striking transform fault and to the South near the harbor of Huehuete, where the sediments of the Masachapa and Fraile formation continue to crop out offshore. This unit is characterized by the absence of structure-parallel striking normal faults. However, several structure-parallel anticlines are dominating the overall picture. The third unit consists mainly of deposits of Fraile formation and the mid Miocene Tamarindo volcanic debris and covers the area north of the El Carmen River to the border of Honduras. ***(Figure 1)***

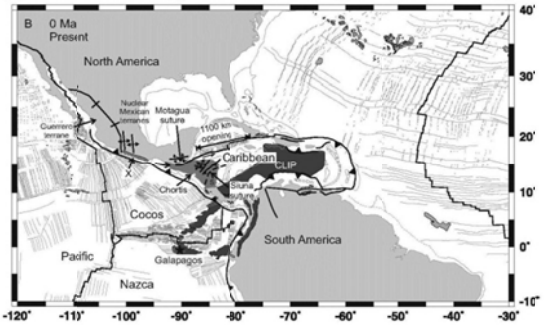

Fig. 1 Frame Tectonic of Nicaragua, (Figure from: Robert Douglas Rogers, B.S., M.S.)

The principal reservoir targets can be lie within the upper Paleocene to Eocene Brito Formation and the overlying Oligocene Masachapa Formation, which crops out along rivers and road cuts in the area around San Cayetano. The presence of several anticlines being potential traps, several oil seeps (San Cayetano, Oil Seeps), a thick sediment column with source rock and reservoir rock potential make this area a prime location. The Oligocene Masachapa formation rests with an angular unconformity on the Brito formation. The Masachapa is represented in the existing geological maps of Nicaragua by two members – the Lower San Rafael and the Upper San Cayetano. The overall thickness of the Masachapa formation is approximately 1,600 meters. The San Rafael Member consists of a sequence of tuffitic and limy shale, siltstone and thin sandstone layers deposited in a marine slope environment and relatively deep water conditions. The formation is conformably overlain by the Oligocene-Miocene San Cayetano member, represented by coarse-ning-upward detritus. The San Rafael member contains potential source rock. The overlying San Cayetano reservoirs generally consist of coarser clastic debris. Interbedded and interlaminated shales provide regional and local seals. ***(Figure 2)***.

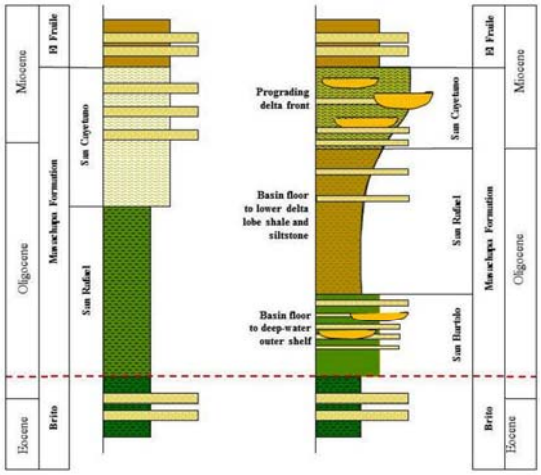

Fig. 2 the results of the reconnaissance work in June-2004 suggest that the Masachapa formation consists of three units: (a) San Bartolo – deep water depositional environment, (b) San Rafael – lower delta front / upper slope, and (c) San Cayetano - upper delta front with deposition of distributary channels.

Masachapa Formation. Lower San Rafael Unit

The depositional conditions of the sediments in the newly defined Lower San Bartolo unit of the Masachapa formation are quite distinct based on characteristic sedimentological attributes of the sediments. Although the base is not well exposed in any outcrop of the study area there is evidence that the sequence develops gradually out of the Brito formation. It consists of thin-bedded (1-3 inches) fine to medium grained sandstones alternating with silt and shale. Toward the top of the unit the sandstones become gradually thicker (6-12 inches). ***(Photo 1).***

Photo 1. Thin-bedded heterolithic sequence in the basal part of the Middle San Rafael unit. Each layer is characterized by considerable lateral continuity.

The trace fossil Zoophycos was discovered at this level of the Masachapa Formation. The best exposure of this trace fossil was found approximately 100' downstream from the oil seeps in the Citalapa River near San Cayetano. It consists of a helically coiled spreite, in which chevron-shaped lamellae occur in cross-section as an internal structure. The ichnofossil Zoophycos has been created by a deposit feeder on the sea floor in an oxygen-poor depositional environment either in the outer shelf region or on the basin floor. ***(Photo 2).***

Photo 2. Zoophycos borrows indicate deposition of Masachapa sediments in deep water between basin floor and upper slope to outer shelf.

The sediments of the middle San Rafael unit consist mainly of shale and fine-silt, which have gray-greenish color on fresh rock surfaces. Thin silt and fine-grained sand layers of 1 to 2 inches are randomly intercalated. No fossil remains have been found in this middle Masachapa unit including evidence of trace fossils indicating a deep sea depositional environment. The shale of this unit is deeply weathered with a leather-brown color and forms generally a thick blanket of disintegrated material on the plateaus and valley floors.

Upper San Cayetano Unit

The Masachapa gradually coarsens upward indicating the progradation of a delta fan lobe characterized by thick distributary channels and delta front facies association. The transition from the deeper water Masachapa sediments to the shallow water deltaic sediments has not been evaluated in depth during the field reconnaissance work. The best outcrop with deltaic sedimentation was visited in the north of the working area near the farm of Salamina and in the river El Carmen. Potential reservoir sands in this upper Masachapa unit and also the overlying Fraile formation in form of porous and thick developed distributaries will be subject of a future studies.

Brito Formation

The sedimentology and facies characteristics of the Paleocene to Oligocene Brito Formation are of particular interest for hydrocarbon exploration and development in Nicaragua due to its excellent source and reservoir rock characteristics. The Brito Formation outcrops parallel to the Pacific coast from the Costa Rica border to the town of San Rafael Del Sur. The formation is underlying the sediments of the Masachapa Formation for most part of the area. The sediments are interpreted as deposits of basin floor shale and basin floor fan lobes. The sediments are interpreted as deposits of basin floor shale and basin floor fan lobes. To study the sediments of the Brito sediments with regard to depositional environment and facies development an outcrop was visited on the north side of San Juan del Sur.

Analog models of this type of depositional environment recommend the Brito formation to be an excellent exploration target. More detailed outcrop and seismic work will be required to better understand the depositional system including the location of the distributary feeder system and basin floor fans. Porosities of about 30 percent were reported from the Brito sandstones, which makes them more than just attractive exploration targets.

Geological Analysis of Percussion Sidewall Samples Las Mesas No.1.

This result of thin section analysis (TS) and X-Ray diffraction analysis (XRD) performed on twenty-one (21) percussion sidewall core samples from the Las Mesas No. 1 Well, San Rafael Del Sur Field, Nicaragua. The objectives of this study was to determine as much as is possible about the mineralogy, pore-filling constituents, pore types, diagenetic features and sample damage caused by the percussion sidewall coring process for the percussion sidewall samples. Of this 21 samples analyzed, nine samples are argillaceous sandstones, slightly argillaceous sandstones and sandstones with average grains sizes ranging from 0.20 to 0.70 mm (upper very fine- to upper coarse grained). Six samples are silty claystones, some of which contain significant sand, as laminate or in burrows. Five samples are foraminiferal silty calcareous claystones. The sample from 7941.0 feet is a lime wackestone. All lithologic names are based on the original rock texture at the time of deposition (*before diagenetic alteration*).

Geological Analysis of Percussion Sidewall Samples San Bartolo Rodriguez Cano No. 1.

This result of thin section analysis (TS) and X-Ray diffraction analysis (XRD) performed on eight (8) rotary sidewall core samples, and on seventeen (17) percussion sidewall core samples from the San Bartolo

Rodriguez Cano No. 1 Well, San Rafael Del Sur Field, Nicaragua. Scanning electron microscopy (SEM) was originally scheduled on all twenty five samples, but close examination of each sample under the SEM indicated that none of the original texture was preserved in the percussion sidewall samples. The objectives of this study are to determine as much as is possible about the mineralogy, pore-filling constituents, pore types, diagenetic features and sample damage caused by the percussion sidewall coring process for the percussion sidewall samples. Thirteen samples are sandstones to slightly argillaceous sandstones, with average grains sizes ranging from 0.08 to 0.42 mm (upper very fine- to upper medium-grained). Five samples are argillaceous sandstones and three samples are silty calcareous claystones. The sample from 6736.0 feet is a silty claystone and the sample from 6828.0 feet in an argillaceous siltstone. The most unusual samples are a sandy grainstone from 8167.0 feet and an igneous rock from 7764.0 feet. All lithologic names are based on the original rock texture at the time of deposition (*before diagenetic alteration*).

San Bartolo and Maderas Negras Testing

The well San Bartolo – 1, was drilled and tested in 2007, the geological formation reached was Brito and Masachapa Formation, oil indications was observed in the logs, in Brito Formation eleven DST were made, hydrocarbon recovered by reverse flow, none flow to surface, also acid stimulations, swabbing test were made without records, Masachapa Formation was not tested.

Characteristics of Brito & Masachapa sandstone reservoir.

All three Norwood wells had significant oil, condensate and gas shows along much of the well bores. 40 API analyses for oil. Brito sandstones typically 8-20% porosity, 10-50md permeability. Masachapa sands are 15-30% porosity. Turbidite sands contain abundant illite/smectite and chlorite. Very sensitive to fresh water and HCl acid. Reservoirs appear to be normally pressured (from limited DST data and fluid levels during swabbing.
Rocks appear to be locally fractured from FMI images and cores. Faults create abundant loss circulation events. Breakdown pressures 1800-3000 psi.

Oil and Formation Water Analyses from San Bartolo-1.

Oil analysis from 2008 swab of San Bartolo 5915-5950' is light sweet crude of 39.3API, density of 830 kg/m3, high in C5-C7, <0.05% total sulphur, <10mg/kg mercapgtans. Formation water analyses from San Bartolo are contaminated with completion brine but indicate relatively fresh water with 15,000-45,000ppm NaCl. 2007, testing analyses from Baseline Resolution of crudes from Las Mesas, and San Bartolo DST6 and DST7 show APIs of 33.3, 32.1 and 34.7 respectively. Biomarker analysis from Baseline Resolution shows crudes are low mature, derived from Tertiary marine fluviodeltaic shales. Likely upper Rivas and Brito formations.

Conclusions

- The Sandino basin structure developed during the Cretaceous, extending over some 30,000 square kilometers, 5,000 of which are onshore. Up to 10,000 meters of sediment have accumulated in its depocenter.

- The oldest sediments in the Sandino Basin are distal on-lapping turbidite and pelagic limestone deposits, which rest on the underlying basement complex. They are of Cretaceous and Paleocene age and assigned to the Rivas and overlying Brito formations.

- San Bartolo and Las Mesas Gutierrez Mendez 1 indicate a depositional system composed of sandstones, siltstone, and shales also occasionally carbonate and carbonate cements are present. Petrophysical analysis shows good pay in both wells ranging from 193.8 to 270 feet with porosity between 11.2 to 11.3% and permeability of 12 and 11 mD. The DST data were not conclusive due to formation damage. Both wells gave formation water production from a good permeable reservoir

- Two mayor fault lines divide the reconnaissance area in the vicinity of town San Cayetano into three structure domains: (a) NNW-SSE striking horst structure bound in the SW and NE by normal faults, (b) syncline to the east of horst structure and (c) monocline of Masachapa sequences dipping toward the center of the Sandino basin with 12 degrees without further fault perturbation.

- Turbiditic lower slope to basin floor fan channel complexes in the Masachapa formation outcrop on top of the horst and are concentrated in the Citalapa River north of San Cayetano. The channels are filled with porous fine- to medium grained sands. Paleo-current data suggest that the sediments were transported from the NE to the SW – normal to the present-day structure. Along the NE –SW axis on the north side of San Cayetano exist the greatest potential for

exploration wells in this area due to the presence of considerable reservoir-type rock.

- The oil and gas reservoirs in the Masachapa and Brito formations are geologically complicated and difficult to drill. Sandstone reservoir was deposited in a deep water turbidites environment. The sand porosity can produce high flow of hydrocarbon such as the channels and crevasse splay sands.
- Channel sand resevoirs are normally pressured, causing the not flowing of oil and naturally requires artificial lift. The sand unit from Paleocene to Lower Eocene indicated fresh formation water.
- The horst structure has several reported oil seeps but only thin Masachapa thickness above the Brito formation. The possibility finding hydrocarbon at Brito level is probably good. The monocline to the southwest has reservoir potential in stratigraphic horizons, the Masachapa and the underlying Brito formation. Drilling in front of the westerly fault increases the change to penetrate several reservoir levels.

- The ichnofossil Zoophycos has been created by a deposit feeder on the sea floor in an oxygen-poor depositional environment either in the outer shelf region or on the basin floor.

- The Lower San Bartolo Unit It consists of thin-bedded (1-3 inches) fine- to medium grained sandstones alternating with silt and shale. The sediments of the middle San Rafael unit consist mainly of shale and fine-silt, which have gray-greenish color on fresh rock surfaces. Thin silt and fine-grained sand layers of 1 to 2 inches are randomly intercalated. No fossil remains have been found in this middle Masachapa unit including evidence of trace fossils indicating a deep sea depositional environment.

- The Masachapa Formation gradually coarsens upward indicating the progradation of a delta fan lobe characterized by thick distributary channels and delta front facies association. The transition from the deeper water Masachapa sediments to the shallow water deltaic sediments has not been evaluated in depth.

- The geological analysis of percussion sidewall from San Bartolo – 1 and Las Mesas – 1 show that the petrology of the samples in both wells are dominated by: argillaceous sandstones, slightly argillaceous sandstones, silty calcareous claystones and sandstones with average grains sizes ranging from 0.20 to 0.70 mm.

- The new geophysical data acquire by GRANT GEOPHYSICAL (INTL) Inc. consisted of 31 lines of fire of which 28 are distributed in parallel in SW-NE direction and 3 SE-NW directions as mooring lines for a total programmed to 430 km.

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