

# New oil discoveries in the Ceuta area, SE Lake Maracaibo, Venezuela

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**Abstract:** The Ceuta area forms the southeast extension of a major oil accumulation in the Maracaibo Basin, at present Venezuela's main oil producing area. The Ceuta Field, with current reserves of 600 MMBbls of light to medium gravity oil, is a major wrench fault structure, producing from Miocene and Eocene sandstones. Several major transcurrent faults are recognized in the Maracaibo Basin, each defining major producing oil fields like the Ceuta Field. These structures, roughly parallel to each other, are oriented in a North-South direction.

The principal plays in the Maracaibo Basin consist of Miocene and Eocene sandstones and, at greater depths, fractured Cretaceous carbonate reservoirs and fractured basement, all charged from the rich marine La Luna source rocks of Upper Cretaceous age.

The discovery of the Ceuta Field was the result of an intensive drilling campaign executed in the 1970s, based on conventional seismic techniques. At that time the exploration of the area was oriented towards the main North-South trending structures. The new exploration, undertaken during the last four years, was based on the structural modelling of the area in terms of the known transcurrent faulting. This allowed the recognition, in areas between the major trends, of three new types of traps related to different styles of faulting, such as normal, compressive and antithetic transcurrent.

The successful drilling of these structures has led to the discovery of an additional 1100 MMBbls of oil outside the existing Ceuta Field, confirmed by an intensive drilling appraisal campaign.

Today's total proven oil reserves of Venezuela are 58 000 MMBbls. At present, over 80% of Venezuela's total daily crude production, as well as the major share of light oil, still comes from the classic petroleum province of the Maracaibo Basin. Although this prolific basin has been producing since 1882, its remaining 9250 MMBbls of light to medium oil reserves still constitute over half of the current light to medium oil reserves of Venezuela.

Apart from the fact that to date major parts of the 50 000 km<sup>2</sup> Maracaibo Basin have still been relatively little explored, it is most interesting to note that substantial amounts of new oil reserves have been discovered during the last few years in recently defined new traps within the classic producing areas (Fig. 1). It must be stressed that part of this success was only possible thanks to the application of new seismic techniques that allowed the integration of land and lake data, in addition to the benefits of an overall increased seismic resolution.

The present paper focuses on the southeasterly extension of a main producing area in the Lake Maracaibo, the Ceuta Field, where in the 1980s substantial new oil reserves have been found. A recent intensive appraisal campaign indicates that the recoverable reserves of these new discoveries are in the range of 1100 MMBbls of light oil, adding to the 650 MMBbls

located in the existing fields of the area. Total expectations of currently defined prospects add another 500 MMBbls.

Apart from a brief description of the geological evolution, plate tectonic setting and hydrocarbon habitat, this paper concentrates on the structural model and trap types found in this area. On the basis of present reserves and appraisal results as compared to trapping possibilities, the paper gives a brief outlook of future exploration. Finally, the potential reasons for a continuing rate of success are highlighted.

## Geological evolution and plate tectonic setting of the Lake Maracaibo Basin

Paleozoic sediments which have mostly been metamorphosed during a Silurian-Devonian orogeny constitute the economic basement of the Maracaibo Basin (Fig. 2). During the Jurassic-Early Cretaceous, a series of NNE-SSW oriented grabens developed, probably as a result of the regional tectonic events related to the opening of the Central Atlantic (see James 1990). These grabens were filled with red beds and fluvial deposits (La Quinta and Rio Negro Formations).

The subsequent Cretaceous transgression across the newly formed continental margins and gradual subsidence led to the build-up of an



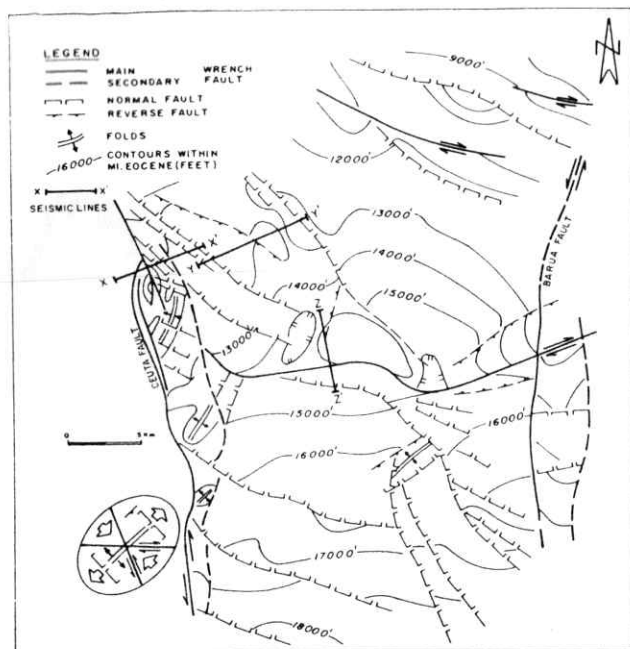


Fig. 4. Tectonic setting of the Ceuta area.

with gravities decreasing towards the upper part of the Eocene section.

The most important reservoir units are Miocene and Middle Eocene regressive sandstones. The Miocene sandstones have the best reservoir properties and the Bachaquero Member of the Lagunillas Formation, consisting of thick channel sands, is the best producer.

The Eocene shows considerable thickness variations across the Ceuta area (Figs 5–7). Most of the deeper parts of the fully developed Eocene sequence have not yet been penetrated by any wells. Where drilled, the deep interval consisted of a mainly transgressive sequence with relatively thin sandstone reservoirs (Misoa C). The thickest sands occur within the overlying, predominantly regressive Misoa B sequence, in particular the lower Misoa B beds, a distributary mouth bar complex.

The overlying holomarine Pauji Formation

contains transgressive sands at its base, which are the producing reservoir in the Barua field to the east.

#### Structural model and new discoveries

The recent exploratory campaign was based on the structural modelling of the area in terms of the known transcurrent faulting. The presence of wrenching has been previously demonstrated in other areas of the Lake Maracaibo (Krause 1971), but this is the first formal effort to interpret observed structures in function of a global model (Fig. 4). Fault geometries and deformational patterns in the Ceuta area appear to fit experimentally derived structural models (Naylor *et al.* 1986), and indicate a NW–SE oriented compressional stress field in accordance with the regionally observed field.

After exploration had drilled the most pro-

minent high relief structures along the main left lateral wrench fault systems, the search went on for some subtle structural features. These structural elements and the hydrocarbon traps associated with them, as well as the traditionally explored high relief structures linked to the main left lateral strike slip faults are briefly described below.

#### Structural framework

In the Maracaibo Basin the Eocene section thickens markedly to the northeast of a NW–SE trending hinge-line that runs roughly through the area of study (Van Veen 1972). For example, the area east of the Ceuta Fault contains 7000 ft more of Eocene section than the area to the west. Low-angle (30–40°) basement faulting along this flexure zone produced overburden deformation indicative of varying ratios of dip-to-strike-slip (Naylor *et al.* 1986).

The deformational history of the Ceuta area is therefore seen to have comprised at least three major phases.

- (1) An early Eocene extensional or divergent wrenching phase that resulted in syndepositional faulting and sediment thickness variations.

- (2) A late Eocene compressional or convergent wrench phase that produced the flower structure uplift of the Ceuta High. The northern part of the Maracaibo Basin was uplifted at this time (Zambrano *et al.* 1971) and a regional unconformity developed at the top of the Eocene section.

- (3) A Mio-Pliocene phase of transpression along the Bocono and Perija faults, resulting in the rise of the Merida Andes and the Perija Mountains, caused further inversion along the northern part of the Ceuta High trend so that local unconformities truncate major structures at La Puerta Formation level.

#### Left lateral strike slip

In the Ceuta area, two principal N–S oriented left lateral strike slip zones are present: the first is associated with the Ceuta High described below, the second delimits the Barua Field to the east.

The Ceuta High (Fig. 5) is bounded to the west by a duplex left lateral strike slip zone. The eastern boundary consists of parallel adjustment wrench faults.

The underlying basement fault appears to be

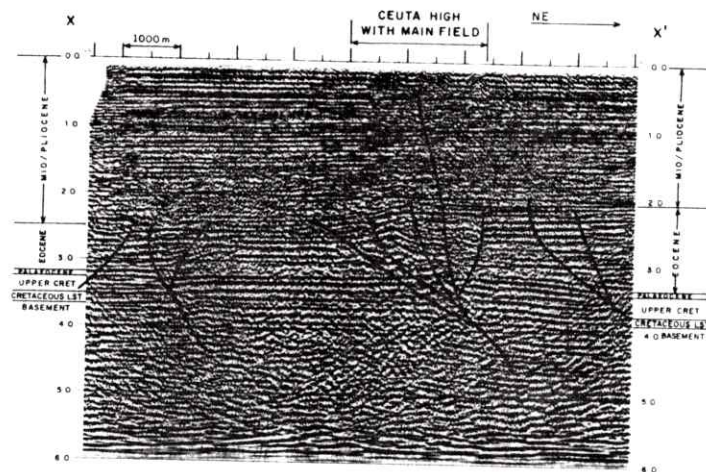


Fig. 5. E–W seismic line (XX' in Fig. 4) across Ceuta High with main field which contains oil accumulations both at Miocene (close Eocene unconformity) and at Middle Eocene levels. Note late Tertiary inversion of the Ceuta High.

a 45° reverse fault, but further south the same fault shows a normal throw at basement level. It thus behaves as a 'scissor' fault. Overburden deformation suggests strike-slip and dip-slip displacements to have been about equal. Two NE-SW oriented en echelon folds and a narrow shear - fault bounded pop-up anticline with extremely steep flanks (Fig. 5) constitute the traditional Ceuta High which is cut by four NW-SE oriented extensional faults.

Late Eocene-Oligocene uplift resulted in severe erosion, removing the Pauji Formation over much of the high and cutting progressively deeper westwards into the Missoa Formation. Deposition in Miocene times was largely controlled by intermittent folding and syndimentary faulting. Miocene stratigraphy and reservoir development is therefore complicated by changes in thickness and lithofacies due to on-laps and off-laps onto the rising anticlines. This results in the pinch-out of some units onto the highs, and thicker lower Miocene units in the lows. The eastern boundary fault was inactive during Miocene times. However, reverse movements along the western boundary fault have resulted in the thickest Miocene development in the downthrown block to the west of the N-S trending boundary fault. This indicates inversion during middle Miocene-Pliocene

times. Overpressures in this area might be caused by this process.

Most faults do not reach the younger horizons. Faults with several hundred feet of throw at the Missoa Formation level may still be sealing in the Lower Miocene units, but by top Bachaquero (upper Miocene) level the vertical displacement may amount to only a few tens of feet, thus becoming unimportant for trapping.

#### Right lateral strike-slip

The largest right lateral (antithetic) strike-slip fault in the Ceuta area appears to be a 30-45° northward hading normal basement fault (Fig. 6). The fault had a very important dip-slip component and was active during early Eocene time as indicated by a greatly increased Eocene thickness on the downthrown side of the fault. This Palaeogene sub-basin is thought to be a branch of the Trujillo Flysch trough, which is known to the northeast of the study area and corresponds to the foredeep that formed in the front of the Caribbean ranges (Gonzalez de Juana *et al.* 1980). The Trujillo Formation is a shaly sequence including basinal turbidites, but locally coarse elastic aprons may have developed along the subaerially exposed scarp of the active fault. These characteristics had been

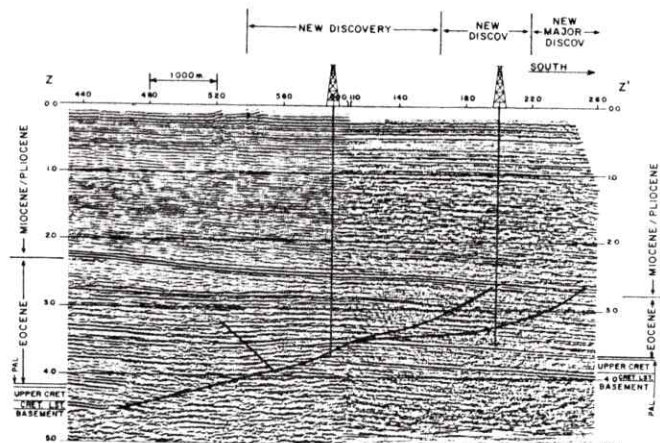


Fig. 6. N-S seismic line across three recently discovered accumulations. Objective level intra-Eocene (ZZ' in Fig. 4). Note right-lateral strike-slip fault with huge normal vertical throw and Riedel-type secondary fault.

partly recognized in earlier seismic interpretations of the area (Araujo 1986), and were confirmed by recent drilling.

On Fig. 4, the fault trace shows two linear segments with a N-S accident offset that may result from dextral offset. The lateral offset and rotation have created a local pull-apart low. The difference in attitude of the associated Riedel-type faults (normal in the west, reverse in the east) is probably related to differences in the strike-slip to dip-slip ratio: along the western segment of the fault, the amounts of strike-slip and dip-slip are probably similar, while in the east the strike-slip is much more important, leading to true Riedel shears. Recent drilling had confirmed that these Riedel shears give rise to structurally high oil-bearing fault blocks (Figs 4 & 6).

It is interesting to note that in the west, the extensive flank behind this fault is largely undisturbed, while in the east it shows considerable faulting.

The above described fault system cuts across the regional monocline that rises northwards from the foredeep adjacent to the Merida Andes, and so forms a trap for migrating hydrocarbons. The recent discoveries suggest that this is a giant trap, containing volumes greater than those of the traditional Ceuta and Barua fields. This fault, with its north hading plane, truncates the monocline of the southern Moracaibo Basin and therefore provides an ideal trap for oil migrating northwards from the Andean foredeep. The newly discovered oil, exceeding the amount found in the main fields, suggests the presence of a giant hydrocarbon trap.

#### Folds and reverse faults

Compressional features perpendicular to the main stress field can be mapped by seismic techniques. These are in essence SW-NE oriented folds, generally bounded by reverse faults. These features form important structural trapping elements, as shown by the drilling of the largest one found in the area, with potential reserves in excess of 100 MMBbls (Fig. 6, Shot Point 600).

Detailed studies of the Ceuta High indicate that small-scale folds will generally show syndimentary growth, and will occur in an en echelon mode, with their axes offset by NW-SE normal faults. This setting will produce a complex distribution of the fluids in the reservoirs, and therefore the recognition and delineation of these folds will be a key factor in the appraisal and development of the area.

The present day seismic coverage is not adequate to map these features in detail, and therefore only the largest ones are shown on the maps. Extensive 3D coverage is at present underway.

For the same reasons, it is not possible to determine the true nature of other features such as the NNW-SSE oriented faults south of ZZ' in Fig. 4. It is possible that they belong to a left-lateral strike-slip system.

#### Stress - relief normal faults

The preferentially NW-SE oriented normal faults (see Fig. 7) show considerable variation in the amount of throw: some have throws in excess of 1000 ft. Potential hydrocarbon traps of considerable size exist both on the downthrown as well as the upthrown side of major normal faults, if adequate NW closure can be mapped. Such closure may be provided by SW-NE oriented synclines, by a roughly N-S oriented left-lateral strike-slip fault, or occasionally even by a favorable change in the strike of the major fault. The chance for this kind of up-dip closure clearly improves in the vicinity of a left-lateral strike-slip system, where such secondary structural elements are more likely to occur.

The extensional down-to-the-basin faults, with a W to NW direction, are very difficult to differentiate in this area from the antithetic wrench faults because of their similar orientations. Furthermore, it is very likely that these normal faults were overtaken by the later compressional phases, and therefore will show deformational features very similar to other right lateral wrench faults.

#### Reserves

The traditional Ceuta Field carries ultimate recoverable reserves of 600 MMBbls of light oil, of which 340 MMBbls are contained in Miocene reservoirs, and around 260 MMBbls are found in the Eocene.

As shown in Fig. 8, the reserves discovered within the last few years actually exceed those previously found in the high relief structures. To date, the newly discovered reserves are all within the Eocene, where folding and faulting is more pronounced than in the overlying section. The oil in place of these new discoveries is estimated to 3065 MMBbls (Dec 1987), with recoverable reserves of 1100 MMBbls, according to the results of the recent intensive appraisal campaign.

Development plans are underway, in order to raise over a period of five years, the production

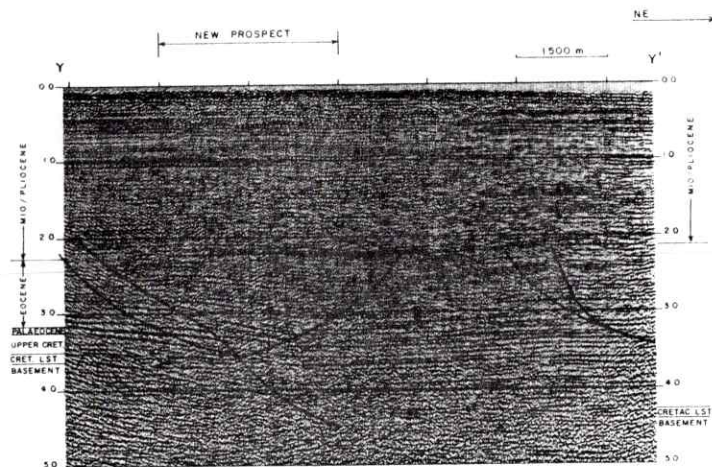


Fig. 7. E-W Seismic line across prospect on down-thrown side of major normal fault (YY' in Fig. 4).

potential of the area from 80 000 BBIs/D to a total of 200 000 BBIs/D.

Currently defined prospects (Fig. 9) have an additional total expectation of approximately 500 MMBBIs of light oil. With a considerable exploration effort ongoing, this figure has a good chance to increase, though much depends on the effectiveness of some of the untested trap types further discussed in a later section.

## Appraisal results

### First discoveries

The discovery well, VLG-3693 (1X in Fig. 10), a 3 km outstep east of the Ceuta Field, was drilled in 1981. The initial production in the Lower B sands (Misoa Fm) was 3164 BBIs/D, with a GOR of 1223 CF/B. In 1982, the exploratory well VLG-3707X (2X in Fig. 10) was drilled, and tested 4500 BBIs/D. In both cases, the oil was light, with gravities around 36 °API.

Further to the east, the exploratory well TOM-1X (3X in Fig. 10), located on land, was drilled in 1985. The well discovered oil in Upper and Lower B sands, with an initial production of 2000 BBIs/D.

To the west of the Ceuta Field boundary fault, a thick interval of Eocene sediments is missing, and the C sands turn out to be the most

productive reservoirs. The first well drilled in this area produced an average of 3000 BBIs/D during five years and has accumulated more than 5 MMBBIs of oil. An appraisal well drilled 4 km to the south tested 3000 BBIs/D.

### Appraisal results

Since well 2X, eleven new wells have been drilled and completed, with a cumulative oil production of 14 MMBBIs at the end of May 1987. Based on production and pressure data, seismic reinterpretations and geological well data (Figs 11 & 11a), the following reservoir definition was established:

**Lower B sands.** This is the main producing interval in the area to the southeast of the Ceuta Field, where fault closure exists to the north, east and west. The OWC is as yet unknown. Thicknesses of this interval are in the range of 800 feet in average, slightly increasing in a northeasterly direction (Figs 11 & 11a).

The reservoir is heterogeneous. Several sealing shales can be recognized that separate sands with as yet unknown directional permeability. Well data suggest the presence of coalescing channel sand bodies with widths of 1800 feet (Fig. 12). However, pressure data indicate the presence of three main reservoirs within the Lower B sands, separated by inter-

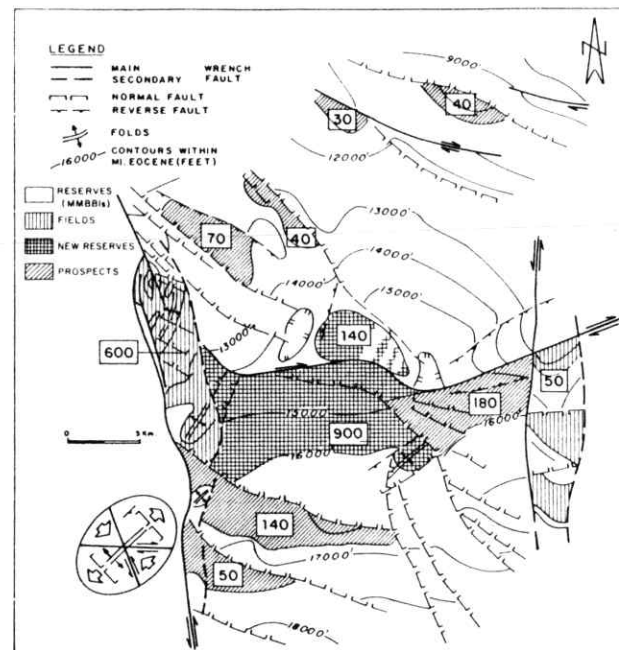


Fig. 8. Reserves in the Ceuta area.

bedded shales and correlatable over a distance of 8 km. Pressure differences between these separate reservoirs are as large as 1000 psi. Thus, the Lower B interval appears to correspond to a multilayered reservoir model.

**Upper C sands.** The interval has been in production only to the west of the Ceuta Field, where the structure is a south-dipping gentle monocline cut by NE-SW trending normal faults which may constitute the main trapping mechanism for the accumulation. Logs define the reservoir units as thin individual sands, 15 to 30 ft thick. No OWC has been detected so far.

Depth of burial is probably an important factor for the porosity and permeability of this interval. To the east of the field, subsidence has been greater than to the west. This is reflected in the poor production of most of the wells that tested the Upper C level in the eastern area, where porosities vary between 9 and 11%.

### Future exploration

Given the southerly regional dip, the most promising trapping opportunities are offered by the roughly W-E oriented right-lateral strike-slip faults. An extensive drilling campaign is planned for the future to explore the flank behind the eastern part of the main right lateral fault (Fig. 8). Right lateral strike slip faults also appear to occur in the NE area of Ceuta, which to date has been little explored and is at present poorly covered by seismic.

Further, untested potential hydrocarbon traps are also formed by the NW-SE oriented normal faults which provide up-dip closure against the regional southerly dip. As mentioned earlier, such closure is most likely to be present close to a left-lateral strike-slip system. Another important factor determining the effectiveness of this type of trap is the amount of throw along these normal faults. Although large throws are

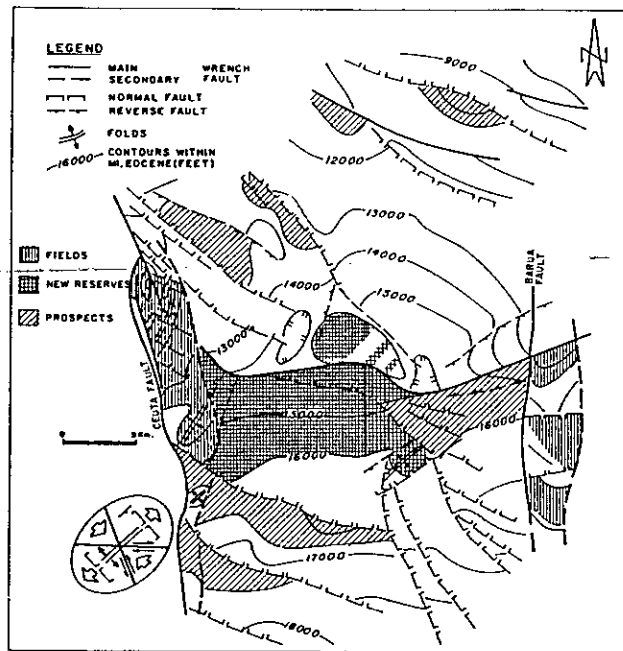


Fig. 9. New discoveries and prospects in the Cueta area.

obviously preferable, faults with as little as 200–300 ft might be sealing. The first of these types of traps against normal faults will be tested later this year.

Reverse-fault bounded folds are another potential type of trap, of which new seismic investigations are likely still to find more. A possible zone of interest is the NNW–SSE oriented normal faults, which might form part of a left-lateral strike-slip system as mentioned earlier. Furthermore, lateral velocity changes appear locally to increase the amount of seismic closure, in particular across areas with rapid thickness variations, such as the zone of wedging of the marine Pauji Formation or the Eocene sub-basin north of the main right-lateral wrench fault.

Finally, there also exists the possibility of some stratigraphic trapping, especially on the downthrown side of major faults, where coarse

clastic aprons and thick sand development may shale out further away from the faults. It should also be noted that the oldest section of the Eocene has not yet been penetrated by the drill, as the few deep wells drilled in the area have all been positioned on local highs with an incomplete stratigraphic sequence.

In summary, given the seismic and well data at hand indicate that the probability of discovering between 500 MMBbls to 1000 MMBbls of mainly light oil within the next five years in the Cueta area is high.

### Conclusions

In the Cueta area, the presence of the main ingredients necessary for oil accumulation has been demonstrated: the source rock occurs as the prolific La Luna organic-rich limestone, currently in an advanced stage of the oil window

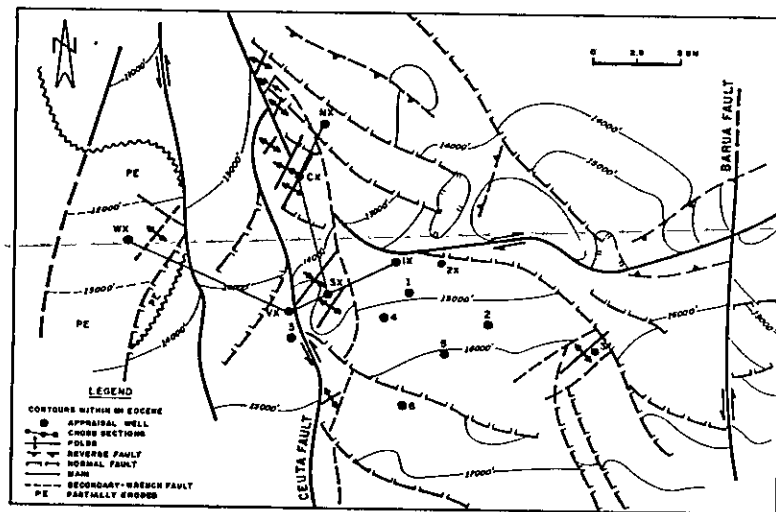


Fig. 10. Cueta area appraisal program.

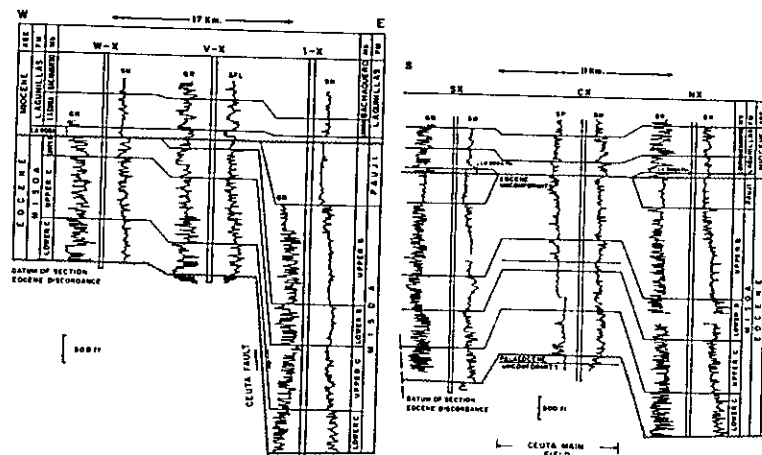


Fig. 11. Well log correlation across Cueta area: (a) W-E, (b) N-S.

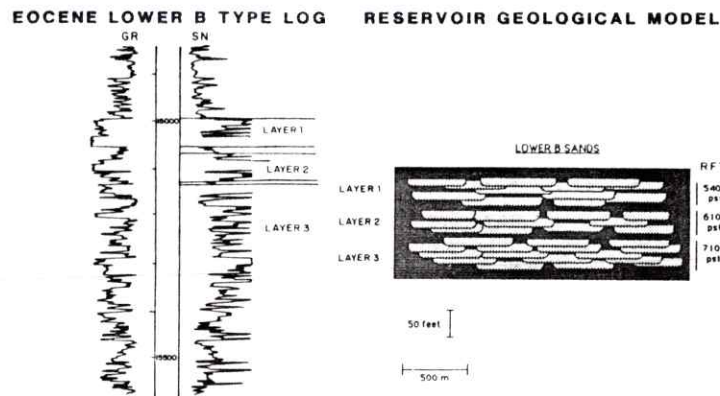


Fig. 12. Cueta field reservoir model.

over much of the Ceuta area. Maturity was reached only relatively recently, after the Plio-Pleistocene formation of the Andean foredeep in front of the rising Andes. This same foredeep is responsible for the development of a very broad monoclinical flank which provides an extensive oil source drainage area.

Within this setting, the Eocene deltaic Misao Formation provides ample reservoir capacity. The regional stress pattern of compression along a NW-SE axis generated both folding and faulting that cut across the broad regional monocline, thereby forming a variety of trapping possibilities.

The key to the continuing success is the recognition of the structural features which, according to the model, may control the accumulation. The ability to discover these ever more subtle traps, will depend not only on the seismic data quality, but also on the careful calibration with all existing well information (VSP, well shoots). Depth conversion becomes critical, and seismic stratigraphy a necessary complementary tool.

Finally, continuing success will largely depend on the capacity of the interpreter to produce an imaginative search for further trapping possibilities, both structural and stratigraphic.

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- Exploration in the Oriente Basin was initiated in 1921 although it was not until 1937 that the first well was drilled by Shell (Tschopp 1953). In 1964, the Texaco/Gulf group acquired a large concession following the discovery of their Orito Field in the Putumayo Basin of Colombia. The first oil field was subsequently discovered in the Oriente by this consortium at Lago Agrio in 1967. An active phase of exploration followed with operators including Anglo-Ecuadorian Oilfields, Amoco, Sun and Cayman. By 1975 the only remaining concessions were held by Cayman (subsequently taken over by City Investing Co.) and the prolifically successful Texaco concession (in which the Ecuadorian State oil company CEPE had assumed an interest). Texaco has discovered over ten oilfields including Sacha, Shushufindi, Auca, Cononaco and Bermejo (Canfield et al. 1982b). CEPE assumed control of all open acreage and by 1985 had discovered five significant oilfields including the giant Libertador Field (Lozada et al. 1985, Almeida 1986).
- In 1985 Ecuador introduced a new scheme of service contracts and since then have offered acreage throughout the Central and Southern Oriente (Rosania 1985, Anon 1987). Concessions have been acquired by ten consortia with commitments to drill over 35 wildcats by 1992. Significant discoveries have already been made by BP and Conoco and these are under appraisal.

## Tectonic setting

The Oriente Basin occupies an area of approximately 100 000 km<sup>2</sup> and comprises only a small part of the Sub-Andean system of foreland basins, which extends over 6400 km from Venezuela to Argentina (Urien & Zambrano 1985). All of these basins developed during Tertiary times between the Pre-Cambrian

## Aspects of the petroleum geology of the Oriente Basin, Ecuador

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**Abstract:** The Oriente Basin of Ecuador is one of the most productive of the South American Sub-Andean Basins. Cumulative production of oil to the end of 1986 was over one billion barrels, and current production stands at approximately 300 000 barrels per day. At least 20 oil fields have been discovered to date, including five giant fields, and exploration is currently in the early stages of a new and already successful phase in which ten new operators are scheduled to drill over 40 wells between 1985 and 1992.

The Oriente Basin contains a sedimentary fill of Palaeozoic to Recent age. Major commercial interest is confined to the Cretaceous depositional cycle and all of the significant production comes from fluvio-deltaic and marine sandstones of the Hollin and Napo Formations. Most of the productive structures are low-relief, north-south orientated, anticlines of two distinct types: foot wall anticlines associated with normal faults, (Type 1) or hanging wall anticlines associated with reverse faults, (Type 2). Evidence points to the importance of pre-Miocene structural growth, comprising either early-mid Cretaceous rejuvenation of pre-Cretaceous 'basement' faults in the case of Type-1 structures and 'Early Andean' (latest Cretaceous to Oligocene) compression in the case of Type-2 structures. Few commercial discoveries have been made associated with 'Late Andean' (Miocene-Pliocene) compressional structures, essentially because these structures appear to post-date the main phase of primary oil generation and migration.

The origin of the oils is problematical because the potential source rocks, the marine claystones and limestones of the Cretaceous Napo Formation, are generally immature or marginally mature within the confines of the present-day Oriente Basin. Oil analyses indicate a single family of oils. Available evidence, combined from structural and geochemical data, supports a major phase of Early Andean age oil generation and migration.

There is a considerable variation of oil type from 37° API paraffinic oils with a GOR of 250-300 to altered 10° API oils. Marked variations exist not only between oilfields but also between reservoirs in the same well. The observed trends can in most cases be accounted for systematically in terms of: early primary oil generation, migration and entrapment; and subsequent structural evolution locally involving the processes of biodegradation, water washing and/or flushing, and oil remigration.

From BROOKS, J. (ed.), 1990. *Classic Petroleum Provinces*, Geological Society Special Publication No 50, pp 89-117.

## EOCENE LOWER B TYPE LOG RESERVOIR GEOLOGICAL MODEL

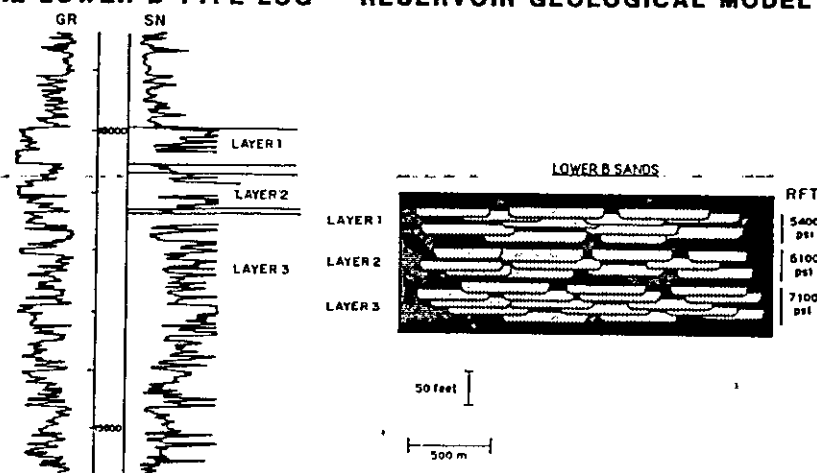


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- Abstract: The Oriente Basin of Ecuador is one of the most productive of the American Sub-Andean Basins. Cumulative production of oil to the end of 1986 is one billion barrels, and current production stands at approximately 300,000 bbl/day. At least 20 oil fields have been discovered to date, including five giant fields. Exploration is currently in the early stages of a new and already successful phase: ten new operators are scheduled to drill over 40 wells between 1985 and 1992.
- The Oriente Basin contains a sedimentary fill of Palaeozoic to Recent age. Commercial interest is confined to the Cretaceous depositional cycle and all significant production comes from fluvio-deltaic and marine sandstones of the Napo Formations. Most of the productive structures are low-relief, north-oriented, anticlines of two distinct types: foot wall anticlines associated with faults, (Type 1) or hanging wall anticlines associated with reverse faults, (Type 2). Evidence points to the importance of pre-Miocene structural growth, comprising early-mid Cretaceous rejuvenation of pre-Cretaceous 'basement' faults in the Type-1 structures and 'Early Andean' (latest Cretaceous to Oligocene) compressional case of Type-2 structures. Few commercial discoveries have been made associated with 'Late Andean' (Miocene-Pliocene) compressional structures, essentially because structures appear to post-date the main phase of primary oil generation and migration.
- The origin of the oils is problematical because the potential source rocks, the claystones and limestones of the Cretaceous Napo Formation, are generally immature within the confines of the present-day Oriente Basin. Oil geochemical data, supports a major phase of Early Andean age oil generation.
- There is a considerable variation of oil type from 37° API paraffinic oils with a 250-300 to altered 10° API oils. Marked variations exist not only between oil fields but also between reservoirs in the same well. The observed trends can in most cases be accounted for systematically in terms of: early primary oil generation, migration, entrapment; and subsequent structural evolution locally involving the processes of degradation, water washing and/or flushing, and oil remigration.
- Exploration in the Oriente Basin was initiated in 1921 although it was not until 1937 that the first well was drilled by Shell (Tschopp 1953). In 1964, the Texaco/Gulf group acquired a large concession following the discovery of their Orito Field in the Putumayo Basin of Colombia. The first oil field was subsequently discovered in the Oriente by this consortium at Lago Agrio in 1967. An active phase of exploration followed with operators including Anglo-Ecuadorian Oilfields, Amoco, Sun and Cayman. By 1975 the only remaining concessions were held by Cayman (subsequently taken over by City Investing Co.) and the prolifically successful Texaco concession (in which the Ecuadorian State oil company CEPE had assumed an interest). Texaco has discovered over ten oil fields including Sacha, Shushufindi, Auca, Cononaco and Bermejo (Canfield et al. 1982b). CEPE assumed control of all open acreage and by 1985 had discovered five significant oilfields including the giant Libertador (Almeida 1986).
- In 1985 Ecuador introduced service contracts and since then the acreage throughout the Central Oriente (Rosania 1985, Anderson 1985) has been acquired with commitments to drill over 100 wells by 1992. Significant discoveries have been made by BP and Conoco and appraisal.
- Tectonic setting**
- The Oriente Basin occupies an area of approximately 100,000 km<sup>2</sup> and comprises part of the Sub-Andean system of basins, which extends over Venezuela to Argentina (Uribe 1985). All of these basins date from Tertiary times between the

## Aspects of the petroleum geology of the Oriente Basin

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