Journal of Petroleum Geology, 10(2), pp. 125-134, 1987

THE ORINOCO OIL BELT, VENEZUELA

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The Orinoco Oil Belt of Venezuela is a very extensive, non-discrete, crude-oil producing area located along the southern third of the Maturin (Eastern Venezuela) basin, north of the Orinoco River and the Guayana Shield. It extends due westwards from Puerto Ordaz for 460km; the main producing areas, defined on the basis of productivity and magnitude of crude oil in-place, cover 13,600 sq. km. There are no significant surface indications of petroleum anywhere in the Belt. The first well drilled was La Canoa-1 *in 1936, initiating a stage of exploration which ended in 1967 with publication of a preliminary evaluation of the potential reserves; the Ministry of Energy and Mines, then of Mines and Hydrocarbons, and the State oil company* Corporación Venezolana del Petróleo *(CVP) completed a second stage of exploration in 1977; Petróleos de Venezuela and its operating companies then drilled 669 wells in five years (1979-83) totalling 643,000 m with 5.5 MM** m of logs, and shot 15,000 km of seismic lines at a cost of $US 615 MM, an effort conservatively estimated as having taken 2,500 man-years. The main producing areas are, from east to west, Cerro Negro, Pao, Hamaca, San Diego, Zuata, and Machete. Petroleum characterisation in the Belt is based on the study and analysis of 288 samples. Viscosity (dynamic) of the crude oils at reservoir conditions ranges from 2,000 to 7,000 mPa.s (cp)†. Production rates average 25 cu.m/d (160 b/d), increasing fourfold after steam stimulation. At the end of 1985, production was 13,000 cu.m/d (80,000 b/d)†, from the Cerro Negro and Hamaca main producing areas. Operating costs are similar to those in other heavy-crude oilfields in the basin. The volume of crude oil in-place is estimated to be 187.8 B cu. m (1,181 B brls), which makes the Orinoco Oil Belt the largest crude oil accumulation in the world. Proved reserves are 4.161 B cu. m (26.170 B brls), and unproved reserves 14.822 B cu. m (93.230 B brls). Investigative activities are underway, particularly in the Cerro Negro and San Diego producing areas.*

In subsequent papers of this thematic survey, A. Isea presents a geological synthesis of the Orinoco Oil Belt; G.Don Kiser discusses the exploration results of the Machete area; A. Santos and L. Frontado describes the reservoir geology of the Cerro Negro steam-injection area; and A. Vega and I. de Rojas summarise exploration results from the Zuata area.

INTRODUCTION

The Orinoco Oil Belt emerged as an extraordinary, albeit rather poorly-known, oil province during the 7th World Petroleum Congress (Galavis and Verlarde, 1967). The dimensions of the key reservoir parameters seemed at the time somewhat outlandish, as they indicated a staggering volume of hydrocarbons in the subsurface reservoirs, both in-place and suitable for potential future recovery. Prior to then, the Belt had been known for its occurences of bituminous substances with no apparent significance — as perhaps an oddity or a geological quirk.

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** *MM: million (10^6); B: billion (10^9).*

† *millipascal-seconds (centipoise). b/d: barrels per day.*

The "tar belt" of the late 1960s became the Oil Belt of the early 1970s, coinciding with a comprehensive review of Venezuela's rôle as a traditional substantial exporter of crude oil and products; with the rapid technological advances in the production, handling and processing of very-heavy crude oils; with increases in production; and with sharp increases in the price of petroleum.

LOCATION

A number of extensive, non-discrete crude-oil producing areas along the southern third of the Maturin (Eastern Venezuela) basin, north of the Orinoco River and the Pre-Cambrian Guayana Shield, form the Orinoco Oil Belt. The Belt extends westward in the meridian of Puerto Ordaz, the centre of a large metallurgical complex at the confluence of the Orinoco and Caroní Rivers for 460 km to Calabozo; it is of variable north-south extent, being up to 40 km wide. The main producing areas, defined on the basis of productivity and magnitude of crude oil in-place, cover 13,600 sq. km.

Access to any location in the Belt is easy, as there exist towns and settlements throughout the area, and a good year-round road system. A major industrial infrastructure has already been constructed and is in operation; there exist deepwater terminal facilities in the Orinoco River, as well as a large-diameter pipeline network which will allow eventual exports via ports in the Caribbean.

There are no significant surface indications of petroleum anywhere in the Belt.

PROGRESS OF EXPLORATION

The first discoveries in the Maturin (Eastern Venezuela) Basin — the *Guanoco* field in 1913, *Quiriquire* in 1928, and *Orocual* and *Pedernales* in 1933 (Martinez, 1969) — were located in the northern third of the basin, along a belt of Cretaceous and Tertiary outcrops. Geophysical surveys were completed in the deep, central parts of the basin, with a few seismic lines extending southwards.

Drilling in the Belt commenced in 1935. Very little attention was given to the completion of a new-field wildcat, *La Canoa No. 1*, 155 km SSW of Maturin and 40 km NNW of Ciudad Bolivar, the Orinoco River and the outcropping edge of the Guayana shield. Liddle (1946) reported the well as abandoned by Standard Oil (Venezuela) at a total depth of 1,176 m (3,855ft), after testing 6 cu.m/d (40 b/d) of 1,022 kg/cu.m (7° API gr.) oil "in tar sands in a thin detrital conglomerate zone at contact of sediments with basement". The giant *Temblador* field was discovered nine months later, 150 km NE of *La Canoa-1*; Standard Oil (Venezuela) completed 210 km of refraction lines north of Zuata in 1937, the first documented geophysical survey in the Belt (Vega and Rojas, 1987).

During the next three decades, only 58 wells were drilled in the area designated as the "tar belt" by the concessionaires, no more than one control point per 1,000 sq. km. Most of these wells were abandoned without testing, although the lowermost sands of the Middle Miocene Oficina formation were impregnated with unmarketable, very viscous and heavy crude oil in more than 50 of the wells. The *Morichal* field was discovered in October 1958, north of the Cerro Negro area, producing typical "Belt" crude from the lowermost sands, together with "Oficina-type" crudes from the top section. Renz *et al.* (1958) discussed the "tar problem" in a report on the habitat of petroleum in the Maturin basin.

During 1964, an operating company approached the Venezuelan state oil company CVP (Corporación Venezolana del Petróleo) with a proposal to start the experimental work needed for a feasibility study of the commercial development of the huge volume of hydrocarbons in-place (Martinez, 1966).

The CVP Board decided to assign the task of preparing a regional study of the area to the geologist Hugo Velarde, together with José Antonio Galavis, a geologist at the Hydrocarbons Office of the Ministry of Mines and Hydrocarbons, now Energy and Mines (Velarde, 1985).

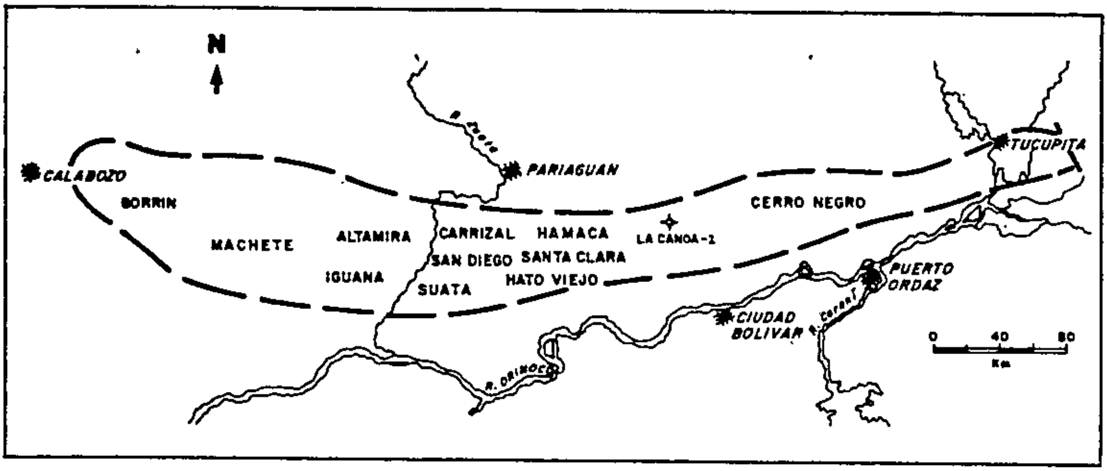

Fig. 1. The Orinoco Oil Belt, as in Galavis and Verlarde (1967).

Work started in April, 1965 and was completed in February, 1966. Based on the scout-well data available and geological and geophysical records in the Ministry files, the report covered an area of 32,000 sq km (600 km east-west, and some 50 km north-south) east of Calabozo, west of Tucupita and south of the producing fields, and included a preliminary evaluation of the potential resources.

The Galavis and Velarde report was presented in April 1966 to the 1st Technical Workshop of CVP in Caracas, to the 7th World Petroleum Congress in Mexico City (1967), and to the 4th Venezuelan Geogical Congress in Caracas, 1969 (Velarde, 1985; Galavis and Velarde, 1967; Galavis and Velarde, 1971). Among the conclusions were: that the deposits of very-heavy crude oil, designated at the time as "non-conventional", are found in unconsolidated, medium- to coarse-grained sands of the Oficina, Merecure and La Pascua formations; that the monocline dips 2-4° to the north; that the hydrocarbons accumulated in shallow, brackish-water sands in a marine environment, as the stable platform subsided slowly; that structural deformation is minor; that the density of the crude oils is less than 1,000 kg/cu. m; that the sulphur content is 4%, and vanadium and nickel concentrations are significant; that the net thickness of the oil-sands can be as high as 85 m at the the west end of the Belt, and 100 m at the east end; and that the oil saturation varies between 30% and 90% with an average (later proved to be rather low) of 60%.

Galavis and Velarde designated four principal areas of petroleum concentration; from east to west these are: Gorrin-Machete; Altamira-Zuata-Iguana; Santa Clara-Hamaca; and Cerro Negro (Fig. 1).

In 1968, M. Stephenson completed another compilation of geological data on the Belt for the Ministry of Mines and Hydrocarbons. This report also proposed alternatives for the development of the deposits, and included an assessment of prospects by the geologist Santiago Aguerrevere (Gutiérrez, 1978). The Ministry signed an agreement in May, 1968 with IVIC (The Venezuelan Institute for Scientific Research) to proceed with laboratory and field work on the Orinoco Belt hydrocarbons, and CVP started drilling stratigraphic wells in December, 1968, in the La Canoa area (Martinez, 1972), concurrently with the shooting of the first thousand km of seismic lines. The programme was expanded progressively over a period of five years; an Office for the Belt was formed within the Ministry. Stratigraphic drilling resumed with a 14-well project in 1973, later expanded to 36 wells; the First Forum on the Belt — exploration, processing and future development — was held in April, 1973, in Ciudad Bolivar.

. It was thus shown that the sedimentary section was thicker, and that the prospective areas extended further to the south, closer to the Shield, than had previously been expected. An agreement was signed in 1974, between FONINVES (Foundation for Development of Manpower in the Petroleum Industry — attached to the Ministry of Mines and Hydrocarbons) and Amoco, part owner and operating company of the *Morichal* field, for the completion and prolonged testing of *Cogollar-1X (SE-1)* in the Cerro Negro area, and *Pao-1X (SE-13)*, in the newly-discovered producing area nearer to the Orinoco River. Due to mechanical problems, the field operation was turned over to CVP; the well tested more than 10 cu. m/d on the pump over two months (at the end of 1971); the density of the crude oil averaged 1,010 kg/cu. m and its viscosity was 4,500 mPa.s (centipoises), thus demonstrating the true character of the hydrocarbons in the Orinoco Oil Belt. An airborne magnetometer survey covering 23,600 sq. km, completed during April 1976, indicated the existence of a thick pre-Cretaceous sedimentary section in the Carrizal area (Hato Viejo and Carrizal formations) and a prominent Basement "high" in the Altamira area (Gutiérrez, 1978).

The Office for the Belt (Director, Dr. Francisco J. Gutiérrez) drilled, during the last stages of work, ten stratigraphic wells and completed eight locations for the steam-injection project in the Cerro Negro area. The *Carrizal-2X* well found the top of Basement 2,000 m lower than estimated; at least five other wells penetrated a few metres into predominantly granitic Pre-Cambrian rocks (Gutiérrez, 1978). A thorough evaluation of well completion, production, transportation and processing methods was completed, as well as comprehensive environmental and social studies. Key (1977) presented to the Fifth Venezuelan Geological Congress a new stratigraphic nomenclature for the Oficina Formation and its four divisions — in ascending order, the Morichal, Yabo, Jobo and Pilón members; "Unit I" of the final evaluation report of Petróleos de Venezuela (1983) is the Morichal member of the Oficina Formation; "Unit II" is the Yabo member; and "Unit III", the undifferentiated Jobo and Pilón members. "Unit IV" and "Unit V" are equivalent to the Freites Formation.

The Federal Executive assigned the Orinoco Oil Belt to the holding company of the national petroleum industry, Petróleos de Venezuela, in December 1977, for exploration and development planning. An evaluation area of 54,000 sq. km was delineated and, in September 1978, each of the four operating subsidiaries of Petróleos was assigned a region. From west to east, the Machete area to Corpoven; the Zuata Area to Maraven; the Hamaca Area to Meneven* and the Cerro Negro Area to Lagoven (Figs. 2 and 3).

The evaluation of the Belt was completed by Petróleos in five years, with the drilling of 669 wells totalling 643,000 m, 5.5 MM m of well logs, 4,500 m of cores (recovery: 73%), 595 reservoir tests, 15,000 km of *Vibroseis* seismic lines, and a 54,000 sq. km airborne magnetometer survey. The total exploration cost was $(US) 615 MM (Petróleos de Venezuela, 1983). The effort carried out by Petróleos is enormous, conservatively measured by the Author as 2,500 man/years.

EXTENT OF THE BELT

Nomenclature has always been somewhat arbitrary in the oil industry. Over the years, various geographic names in the Orinoco Oil Belt region have been used, at times inconsistently, to refer to a successful completion; a concession; an area assigned to a subsidiary of Petróleos for evaluation purposes; or a producing area, i.e. *Machete*, *Zuata* and *Hamaca*. Other names, such as *Gorrin*, lost permanency because exploration did not result in immediate commercial discoveries. Names such as *Altamira* or *Iguana*, areas of past representation, became later wholly or in part integrated with particular areas. Terms such as *Carrizal* were lost, as the operating company chose to use localized terminology, and others such as *Guanipa* were introduced for commercial purposes. By contrast, new names, such as *Pao* and *San Diego* have emerged†.

* *Meneven merged with Corpoven in June, 1986.*

† *See footnote, page 130.*

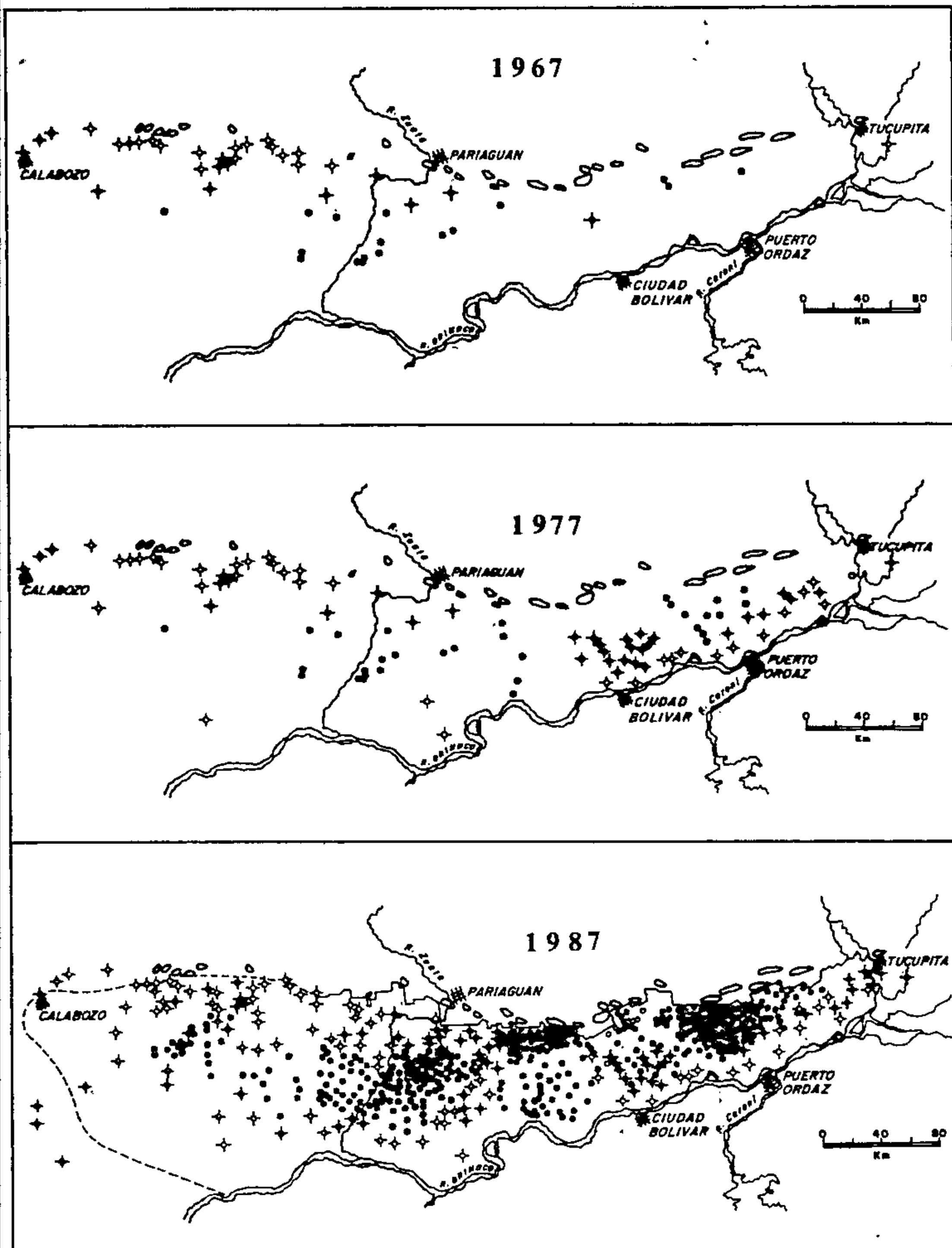

Fig. 2. The progress of exploration drilling in the Orinoco Oil Belt, 1967-1987.

The four evaluation areas assigned by Petróleos to its operating subsidiaries are clearly distinguishable; Petróleos de Venezuela (1983) divided the Belt into first and second order accumulations. North of the limit drawn for the Cerro Negro evaluation area, the Belt continues uninterruptedly northwards past its arbitrary boundary into traditional oilfield areas, such as *Morichal* and *Jobo*. Contrary to original expectations, the area east of Cerro Negro proved to be of little importance; the easternmost well in the belt, *Los Indios No. 1*, was abandoned at 1,309 m TD (4,288 ft) in 1939, with no oil shows (Liddle, 1946).

It is proposed in this paper to designate six main producing areas in the Orinoco Oil Belt defined on the basis of the magnitude of crude oil in-place and productivity (Fig. 3). The rectangular *Cerro Negro* main producing area covers 250,000 ha., of which the western end is within the limits of the evaluation area assigned to Meneven. The *Pao* main producing area, 230,000 ha. in area, is located some 50 km west of the Cerro Negro area, and west of the unattractive La Canoa area. The *Hamaca* main producing area, immediately to the north of the Pao area, includes the "Guanipa" development project for the eventual production of 15,000 cu. m/d (100,000 b/d).

The *San Diego* main producing area, corresponding to the "Priority Area" of Maraven (Vega and Rojas, 1987), covers 250,000 ha., including the Santa Clara area; it is west of the Hato Viejo high, and south of the area designated Zuata Norte by Maraven, or more properly, Carrizal.

West of San Diego is the *Zuata* main producing area, covering 207,000 ha, of which half is in the Corpoven evaluation area: the Altamira and part of the Iguana areas have now been incorporated into the Zuata area. The *Machete* main producing area, at the western end of the belt, is separated from Zuata both by the Monasterio arch, and also on the basis of crude oil characterisation*. The large Gorrin area to the west of the Machete area is of considerable prospective interest (Kiser, 1971, 1987).

CRUDE OIL RESERVES

Galavis and Velarde (1967) estimated that the volume of hydrocarbons *in situ* in the Orinoco Oil Belt was 110 B cu. m (692 B brl) assuming basic parameters of half the volume of net oil-sand, a porosity of 12 to 38% (average 25%), a crude oil saturation of 30 to 90% (average 60%), and a shrinkage factor of 0.96; they also estimated in-place volumes of 21.1 B cu. m (132.5 B brls) for the Machete-Gorrin area; 41.1 B cu. m (258.6 B brl) for the Altamira-Iguana-Suata area; 12.7 B cu. m (80.0 B brl) in the Hamaca-Santa Clara-Hato Viejo area; and 17.6 B cu. m (110.9 B brl) in the Cerro Negro area. Thus, the volume of hydrocarbons in-place in the four main producing areas of the Belt amounted to 92.5 B cu. m (582 B brl), or 84% of the total hydrocarbons *in situ*. Galavis and Velarde (1967) used the terms petroleum, bituminous oil, heavy crude oil and non-conventional oil indiscriminately to characterise the hydrocarbons; they indicated that the density was always greater than 986 kg/cu. m (12°API), with a general average of 1,002 kg/cu. m (9.9° API); density distribution was irregular, although higher density values were usually found towards the south.

† *(p. 128) It is also inevitable that original names were subjected to phonetic adaptation, misspelling, sudden changes and other linguistic phenomena.* Zuata *(Suata) is one example,* Cogollal *(Cogollar) another;* Las Iguanas *lost both its article and its plurality;* El Machete *only lost its article; and so on.*

* *The* San Diego, Zuata *and* Machete *main producing areas correspond in some degree to the schematic division of Galavis and Velarde (1967) into a South Zone and a SW Zone along the Altamira "high"; actually, the dividing line is the Hato Viejo fault, which runs perhaps by coincidence along the present course of the Zuata River. The same boundary was used by Petróleos de Venezuela (1983) for division of the Belt into Eastern and Western Provinces.*

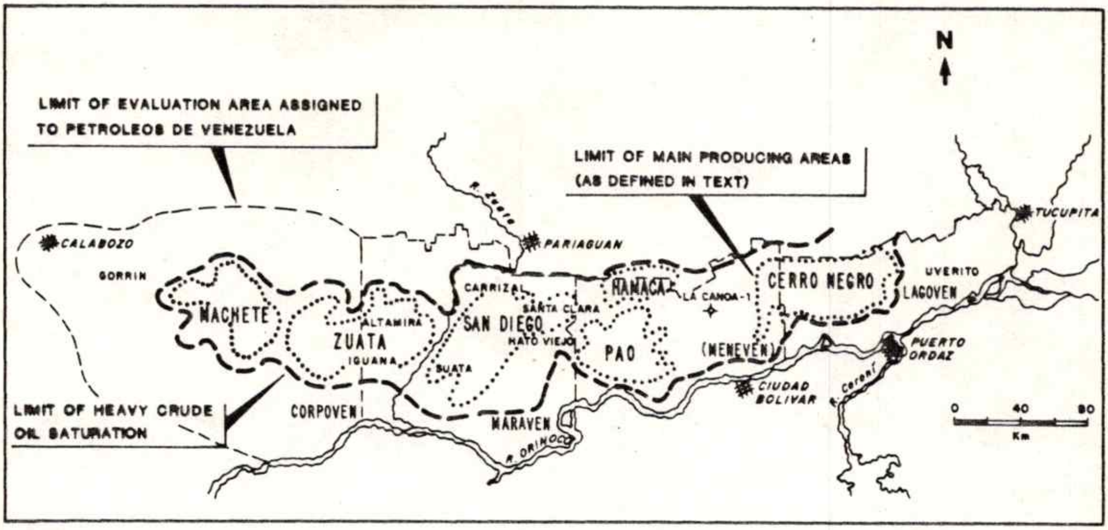

Fig. 3. Crude oil saturation and main producing areas in the Orinoco Oil Belt.

In order to classify the petroleum and systematise the petroleum reserves of the Orinoco Belt, the directives of the Study Group Report of the World Petroleum Congresses (Martinez *et al.*, 1983 and 1987) are followed here, since these provide a broad framework of definitions that attempt to standardise world-wide usage. It should be noted that even though the volumes indicated in this paper as "proved reserves" have not been approved by the Ministry of Energy and Mines as required by law, they represent the recovery by primary conventional production methods, as evaluated by the technical groups of Petróleos de Venezuela that worked on the Orinoco Oil Belt from 1979 to 1983.

Petroleum characterisation in the Belt is based on the study and analysis of 288 samples by Petróleos de Venezuela. Hydrocarbons in the belt are crude oils, because their dynamic viscosities at original reservoir temperatures and atmospheric pressure, on a gas-free basis, range from 2,000 to 7,000 mPa.s(cP). The density of most of the crude oils in the Belt is in the heavy and extra-heavy ranges*.

The volume of oil in-place in the Orinoco Belt is estimated to be 187.8 B cu. m (1,181 B brl), which makes it the largest crude oil accumulation in the world. As of year-end 1986, proved reserves in the Belt are 4.161 B cu. m (26.17 B brl) and unproved reserves 14.822 B cu. m (93.230 B brl). Proved reserves were computed for a drainage area of 200 ha for duly-tested sands more than 15-m thick; the area is increased to 300 ha. if the crude-oil bearing sands are more than 92-m in thickness, but reduced by half if oil sands are less than 15-m thick.

* *Definitions applicable are as follows:-*

Hydrocarbons *are chemical compounds consisting wholly of hydrogen and carbon;* Petroleum *is a naturally occurring mixture, predominantly of hydrocarbons;* Crude Oil *is the portion of petroleum that has a viscosity of less than or equal to 10,000 mPa.s at original reservoir temperature and atmospheric pressure, on a gas-free basis. Crude oil with a density greater than 1,000 kg/cu. m should be classified* extra-heavy; *an acceptable range for* heavy *crude oils is 1,000-920 kg/cu. m (Martinez et al., 1983 and 1987). Millipascal-seconds (mPa.s) is an SI-derived unit for dynamic viscosity, of dimension gram per centimeter per second; it is identical to the centipoise (cP), a CGS-unit of measurement of general usage in the oil industry; the centistoke (cSt) is the CGS unit for kinematic viscosity (square centimeter per second). The term* non-conventional *as applied to crude oils is now used only infrequently.*

Unproved reserves are the volumes of crude oil adjacent to proved reserves, outside the drainage areas, located with a sufficient degree of certainty to suggest the likelihood of their existence if proved reservoirs continue without interruption*.

Crude oils in the Belt are highly mobile, notwithstanding high densities (low °API), which is explained by the viscosities at reservoir conditions. Average temperatures in the reservoirs vary between 50°C at 800 m, and 60°C at 1,100 m. Average oil saturation in the Cerro Negro main producing area is 85%, in San Diego 80%, and in Machete 71%. These conditions, plus the fact that the reservoirs can be produced with conventional field technology, will undoubtedly have significant implications on final recovery; compaction may allow extraction of up to 8% of the crude oil in-place, on the basis of uniaxial compressibility analyses of cores taken in the main areas.

The Hamaca main producing area has been developed on the basis of the Guanipa project; crude oil is produced into existing facilities of the *Oficina* group of fields; production since 1983 is 8,000 cu. m/d (50,000 b/d). There are two experimental production blocks in Cerro Negro, with a total of 143 wells and all the surface facilities required, including flow stations with combined daily capacity of 5,000 cu. m/d (30,000 b/d). Operating costs in the Belt are similar to those of other heavy crude-oil fields in the basin.

Table 1 shows the crude oil in-place and reserves of the Orinoco Oil Belt by evaluation areas. Table 2 shows the estimated crude oil in-place and reserves of the main producing areas, as defined in this paper. Table 3 (page 134) shows general reservoir production parameters pertaining to the main producing areas to the Belt.

Nearly 600 stratigraphic intervals have been tested cold on the pump, producing an overall average of 20 cu. m/d (125 b/d); after steam injection, stabilised production increased fourfold on average.

Natural Bitumen

In the Orinoco Oil Belt, as could be expected, there are occurrences of natural bitumen. Characterisation has been on the basis of (dynamic) viscosity of more than 10,000 mPa.s at original reservoir temperature and atmospheric pressure; the density of the bitumen can be as high as 1,043 kg/cu. m (4°API).

Natural Gas

There are some natural gas-bearing sands in the San Diego main producing area, but these are more important in the Machete and Gorrin areas; in the Machete main producing area, natural gas appears not to be associated with the extra-heavy crude oil but rather as if it has been injected into the sands after emplacement of the crude oil. The volume of natural gas in-place in the Machete area might be in the order of 60 B cu. m, perhaps more than in the San Diego area.† Rates of 100,000 cu. m/d (3.8 MM cu. ft/d) dry gas was obtained in some production tests; however, in general, the natural gas-crude oil ratio in the Belt is in the range of 4-6 cu. m/cu. m (80-100 cu. ft/brl).

* Proved reserves *are those estimated volumes of discovered crude oil, which at a specific date, analyses of geological and engineering data demonstrate with reasonable certainty to be recoverable in the future from known reservoirs under the economic and operational conditions at that date;* unproved reserves *refer to the estimated discovered volumes of petroleum, at a specific date, which analyses of geological and engineering data indicate might be economically recoverable, with a sufficient degree of certainty to suggest the likelihood of their existence, and can be given as a single intermediate figure into which all uncertainties have been incorporated;* crude oil in-place *is the total volume estimated originally to exist in naturally-occurring reservoirs (Martinez* et al., *1983 and 1987). Petròleos and operating companies have had to follow the classification and nomenclature system defined in 1966 by the Ministry of Mines and Hydrocarbons (now Energy and Mines) which explains the difference between crude oil in-place and reserves; as shown in Appendix II of Martinez* et al., *1983 and 1987, unproved reserves are designated in Venezuela as "semi-proved" and "not proved" reserves.*

† *The existence of a natural gas seep has been reported but not documented near the Iguana River, near the village of Hervidero, south of the western end of the Zuata main producing area. Also, a number of seismic shot-holes blew-out gas while drilling, and flowed for 3-4 weeks.*

Table 1. Crude oil in-place and reserves by evaluation areas.

Evaluation area	*Crude oil in-place* B cu. m *(B brl)*	*Proved plus unproved reserves* B cu. m *(B brl)*
Cerro Negro	34 *(213)*	4 *(24)*
Hamaca	34 *(214)*	4 *(24)*
Zuata	79 *(499)*	8 *(49)*
Machete	41 *(255)*	4 *(23)*
Totals	188 *(1,181)*	19 *(119)*

Source: Petròleos de Venezuela

Table 2. Estimation of crude oil in-place in the main producing areas.

Main producing area	*Crude oil in-place B cu. m (B brl)*	*Proved and unproved reserves* B cu. m *(B brl)*
Cerro Negro	37 *(234)*	4 *(27)*
Pao	24 *(154)*	3 *(19)*
Hamaca	5 *(33)*	– *(3)*
San Diego	41 *(255)*	5 *(31)*
Zuata	45 *(283)*	4 *(24)*
Machete	18 *(110)*	2 *(10)*

Source: Data derived by Author from Petròleos de Venezuela (1983).

Coal

Petrophysical studies indicate the occurrence of very thin beds of coal in the Freites and Chaguaramas formations throughout the Belt, down to around 500 m, but it seems they are of no commercial value.

Fresh water

Evaluation of fresh water resources down to 140 m show very good aquifers to be present throughout the Belt evaluation areas.

CONCLUSION

The Orinoco Oil Belt is the largest deposit of heavy and extra-heavy crude oil in the world. As at year-end 1986, the volumes of proved and unproved reserves were 18.980 B cu. m (119.4 B brl) i.e. 10.1% of the crude oil in-place; a doubling of the extraction by means of multiple projects of improved recovery, particularly steam injection, would considerably increase the future potential recovery. Crude oils in the Belt are highly mobile. The cost of producing and marketing Belt crudes compares favourably with that from the many heavy and extra-heavy accumulations in Venezuela and elsewhere in the world. At the end of 1986, production of crude oil from the Orinoco Oil Belt was 13,000 cu. m/d (80,000 brl/d). During 1986, Lagoven started commercialisation of an emulsion with Belt hydrocarbons, for direct burning in electricity generation plants.

Activities continue, particularly those of an investigative nature; thus Intevep, the research institute of Petróleos, spent nearly half its budget by itself or jointly with European and USA institutes on experimental work directly related to the exploitation, processing and transport of Orinoco crude oils. Lagoven's Jobo experimental pilot programme actually consists of several pilot plants with a refining capacity of 6 cu. m/d (250 b/d), including the basic unit for pre-heating the feedstock.

Table 3. General reservoir and production characteristics.

Main producing area	*Density of crude oil* kg/cu. m (°API)	*Net oil sand* m (ft)	*Average depth* m (ft)	*Cold production* cu. m/d (b/d)	*Production following steam injection* cu. m/d (b/d)
Cerro Negro	979/1,020 *(7°-13°)*	70 *(230)*	810 *(2,670)*	30 *(180)*	60 *(390)*
San Diego	985/1,015 *(8°-11°)*	50 *(150)*	790 *(2,600)*	20-110 *(140-700)*	160 *(1,000)*
Pao	993/1,015 *(8°-11°)*	60 *(200)*	670 *(2,200)*	10 *(60)*	100 *(600)*
Machete	986/1,050 *(3°-12°)*	40 *(150)*	1,110 *(3,630)*	10 *(50)*	30 *(210)*

Source: Petróleos de Venezuela (1983)

REFERENCES

FIORILLO, G., 1984. Exploration and evaluation of the Orinoco Oil Belt. AAPG and Unitar/UNDP Inf. Centre, Res. Conf., Santa Maria CA (Nov. 84).

GALAVIS, J.A. and VELARDE, H., 1967. Geological study and preliminary evaluation of potential reserves of heavy-oil of the Orinoco tar belt, Eastern Venezuelan basin. *Proc. 7th. World Petrol. Cong.*, **1**, 229-234.

GALAVIS, J.A. and VELARDE, H., 1971. Estudio geológico y de evaluación preliminar de reservas potenciales de petróleo pesado en la Faja Bituminosa del Orinoco — Cuenca Oriental de Venezuela. *Proc., IV Venezuelan Geol. Cong.*, **IV**, 2527-2537.

GUTIERREZ, F.J., 1978. Síntesis de lo realizado en materia de estudios e investigación por la Oficina de la Faja Petrolífera del Orinoco hasta Diciembre de 1977. Dir. Gen. Hid., Energia y Minas.

KEY, C.E., 1977. La Formación Officina en el Campo Jobo. *Proc., V Venezuelan Geol. Cong.*, **IV**, 1599-1615.

KISER, G.D., 1971. Futuras provincias petroliferas de Venezuela. *Proc., IV Venezuelan Geol. Cong.*, **I**, 467-482.

_________, 1987. Exploration results, Machete area, Orinoco Oil Belt, Venezuela. *Journ. Petrol. Gèol.*, **10**, (2) 149-162.

LIDDLE, R.A., 1946. The geology of Venezuela and Trinidad. Ithaca, N.Y.

MARTINEZ, A.R., 1966. Our gift, our oil. Dordrecht, Netherlands.

_________, 1969. Chronology of Venezuelan oil. (1985. Cronologia del Petróleo Venezolano. 4th ed.). London, Caracas.

_______ *et al.*, 1983. Classification and nomenclature systems for petroleum and petroleum reserves. Study group report, *11th World Petrol. Cong.*, **II**, 323-343.

_______ *et al.*, 1987. Classification and nomenclature systems for petroleum and petroleum reserves. Study Group Report, *12th World Petrol Cong.*

PETRÓLEOS DE VENEZUELA, 1983. Evaluación exploratoria de la Faja Petrolífera del Orinoco. **1**, FIORILLO, G., (Coord.), Petróleos de Venezuela.

RENZ, H.H., *et al.*, 1958. The Eastern Venezuelan basin. *In:* "Habitat of Oil", AAPG, pp. 551-600.

VEGA, A. and ROJAS, I. de, 1987. Exploration and evaluation of the Zuata area, Orinoco Oil Belt, Venezuela. *Journ. Petrol. Geol.*, **10** (2) 163-176.

VELARDE, H., 1985 Memoria anecdótica de la Faja. (Pers. comm.).