ALVAREZ - CASTRO JOSE, Ceinpet -Cupet, Cuba, RAFAEL SOCORRO, Digicupet - Cupet, Cuba, SOFIA LOPEZ, Digicupet - Cupet, Cuba, GUSTAVO ECHEVARRIA, Ceinpet -Cupet, Cuba, JOSÉ O. LÓPEZ, Ceinpet -Cupet, Cuba, RAMON CRUZ, Ceinpet -Cupet, Cuba, SILVIA VALLADARES, Ceinpet -Cupet, Cuba, MARITZA RODRIGUEZ, Ceinpet -Cupet, Cuba, ROLANDO GARCIA, Ceinpet -Cupet, Cuba, JOSE L. PROL Digicupet - Cupet, Cuba, & GUILLERMO MIRO, ISPJAE, Cuba.

Integrate Methods used for Exploration Evaluation in North Cuban Thrust Belt. Case: Northern Heavy Oil Trend.

The main objective and purpose of the Cuban National Oil Industry is to increase oil reserves and the discovering new oil fields in the near future.

Cuban proved Petroleum System is related to the Northern Oil Province, mainly in the Cuban Thrust Belt where the main oil fields, such as Varadero, Boca de Jaruco, and Puerto Escondido, are located. Our team studied the methodology to improve the results in this complex type of traps and define the leads and prospects to be developed in the future, proposing the priority of development.

In conditions of over-thrust carbonate rocks, it is very difficult to use only the seismic method because the image obtained is unclear. Usually we only can observe clear the envelope of the Paleocene-Lower Eocene unconformity.

We applied a methodology based on integrated studies to reduce the exploration risk establishing the structural style, reservoirs, seals, the traps, the leads and prospects, the charge of the prospects and the migration paths.

To define the structural style we use the interpretation of various methods as follows:
Stratigraphic information gave us the possibility of understanding the very complicated tectonic style that is composed by several thrust sheets of different rocks forming duplexes type of traps. The first one is associated to the last stage of Cuban Orogeny (Middle Eocene age) and is composed of carbonates rocks from Upper Jurassic to Lower Cretaceous named as Veloz Group of Placetas Belt; this one is covered by sediments of Paleocene – Lower Eocene age. The second one is associated to the middle stage of the Cuban Orogeny (at the end of Maestrichtian age) and is composed of carbonates rocks intercalated with cherts and shales of Middle Cretaceous and covered by sediments of Maestrichtian age. The third sheet is associated to the beginning of the Cuban Orogeny (at the end of Campanian – Early Maestrichtian age) and it is a melange composed of reworked ophiolites and tuffaceous rocks of Lower – Middle Cretaceous. This section appears in wells at the first part of the stratigraphic column bellow the post- orogenic sediments (Middle-Upper Eocene to Recent). The stratigraphic column is shown in the Figure 1 represented by the Boca the Jaruco Oil Field, which was the first discovered oil field on the Veloz Group; it also produces from other sections (Figure1).

Geomorphology, satellites image, gravity and magnetic fields contributed to the knowledge of the regional tectonic style. There are two main fault systems: one is composed of reverse faults with NW – SE direction; the second one is composed of strike-slip faults that cut the first system with NNE – SSW direction. Gravity shows a minimum in the Northen Cuban Oil Province (NCOP) associated to the development of carbonates rocks that have less density than the dolomites developed to the north and the Zaza Terrane (volcanics and dense ophiolites, peridotites and basalts).

Using the reinterpretation of 2D seismic lines, we defined the leads and prospects based on a geological model and the traps established by the authors (Figures 2 & 3).

The study of reservoirs and seals concerning the leads and prospects was done. The main reservoir rocks are the carbonates of the Veloz Group (Upper Jurassic – Barremian). The secondary porosity present is due to diagenetic processes, mainly fracturing and deep karst, which exhibit average values of porosity of 13 - 18 % and permeability in order of Darcys. The most relevant effect of secondary porosity in the oil production is the type of fracturing that is developed in three stages: the first one is related to the early diagenesis (pre-orogenic period) where the fractures are chaotic and sealed by calcite; the second stage is related to the middle diagenesis (orogenic period) where the fractures are parallel to the bedding and are filled by bitumen and oil and the third stage is related to the late diagenesis (post-orogenic period) where the fractures are chaotic due to the intense brecciation and are filled by bitumen and oil (Figure 4); The two last stages are the response of the oil production. We introduce the study of types of porosity in different part of the structure, analyzing the compaction effect (Figure 5) and used it in order to select the cut off (2500 – 3000m depending of part of area) in order to select the quality of reservoir into each lead and prospect previously determined by other methods. We classified the reservoirs in different categories considering the porosity cut off and finally obtained the classification of the reservoirs as very good, good, bad, and very bad and mapped it on the studied area. The same for the seal was done obtaining the quality of the seal.

To define the source rocks, the migration paths and the charge of the prospects previously defined, more than 200 geochemical analyses were done and compared with other analysis previously done. The results were that the source rocks are the same carbonates and intercalated shales of the Veloz Group that exhibit very good values of TOC up to 14 % and good S1 and S2 values. Oil window is found at 4, 000 m. depth. The Veloz Group due to the stacking of different thrust sheets is present at more than 6 km depth; this is the cause why those rocks are able to expulse oil type IIS, and the kitchen area is very huge. It was demonstrated that migration occurs in a short distance and each sheet is able to charge its trap. The oil trapped is heavy and extra heavy about 11- 13^{o} API and up to 6 % of sulphur. Using different softwares we model the basin and the extension of the kitchen; further the reserves were also calculated. These reserves were recalculated using the pattern analyses comparing it with the reserves in known oil fields. We calculated more than 18 x 10^{3} million of barrels *in situ*.

The play type with its mainly properties that is called Veloz Play was determined. Such properties are resumed in the Table 1.

The Northern Heavy Oil Trend (NHOT) is not an isolated phenomenon because it has a relationship to the Cuban Orogeny; similar trends can be discovered in other parts of the Northen Cuban Oil Province.

New 14 leads and 10 probable charged prospects have been identified and defined in the Northern Heavy Oil Trend (Figure 6). Those prospects are located offshore, 1 – 3 kms from the sea shore, and the most economic method used for exploring and the evaluation of the oild fields is the horizontal drilling. In recent horizontal wells the oil production is in between 1,500 – 4,000 barrells / day per well. The horizontal drilling is the success response of the above mentioned researches and also because the wells were drilled towards the major fractures and karstified part of the reservoir.

Five of these 10 prospects were developed and four are new oil fields which are increasing the oil production in several times.

CONCLUSIONS

1) The applied methodology allowed to increase successfuly the oil exploration being responsible for definition of 14 leads and 10 prospects in the Northern Heavy Oil Trend.
2) Those prospects improved Cuban oil reserves in several times because they exhibit high density of oil in place and reserves.
3) Five prospects were explored, four of them discovered oil. The Cuban oil production increased several times due to horizontal drilling of the new wells which is the most economic method used for that purpose in those oild fields.
4) There are more prospects prepared for exploration. It is possible to increase the oil production in the near future finding oil fields as Varadero with 1×10^3 millions barrels of oil in situ.

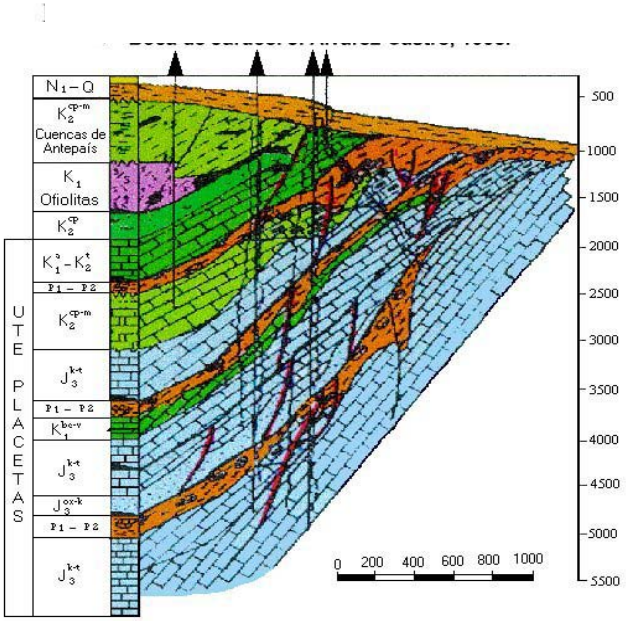

Fig. 1 Geological section of Boca de Jaruco Oil Field Representing the Stratigraphic Column of NHOT

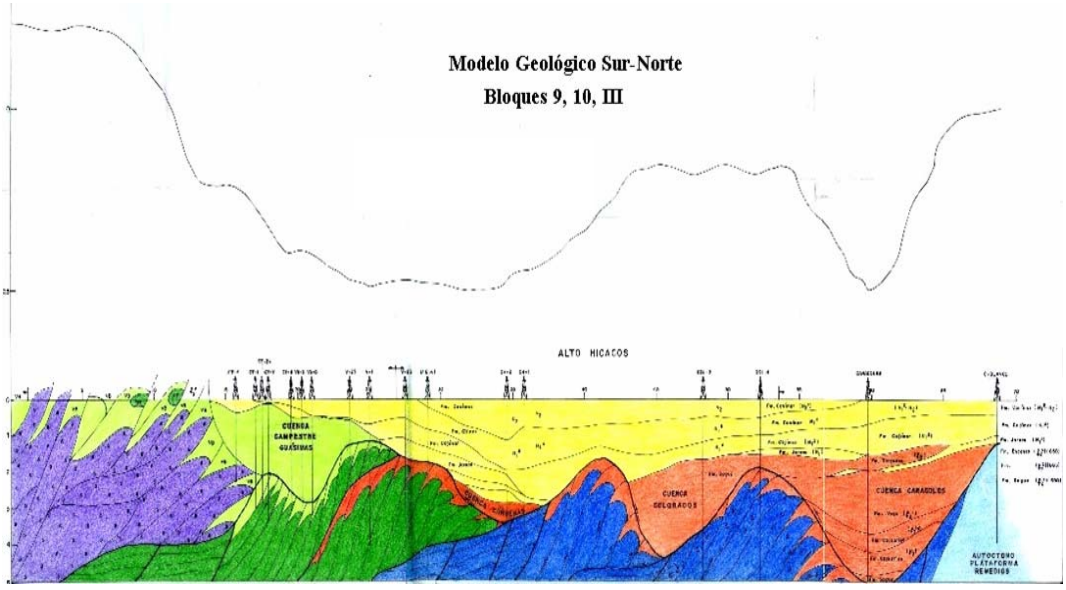

Figure 2. Geological model proving the tectonic style in the NCOP

VELOZ GROUP

MID. CRETACEOUS SEDIMENTS

OPHIOLITES & VOLCANICS

K2 SEDIMENTS

PALEOGENE SEDIMENTS

MID EOCENE – RECENT SEDIMENTS

THRUSTED BELT

DUPLEX

THRUSTED SHEETS

SUB TYPE	AREA (km²)	NET pay zone (m)	EXAMPLES (OIL FIELDS)
JURASSIC-NEOCOMIAN SHEETS (Veloz Group)	9	240	B. JARUCO YUMURI PTO. ESC.
MIDDLE CRETACEOUS SHEETS	3	80	B. JARUCO V. SUR GUASIMAS CANTEL
ANTIFORM	30	520	VARADERO

Figure 3: Type of Traps present in NCOP and in NHOT.

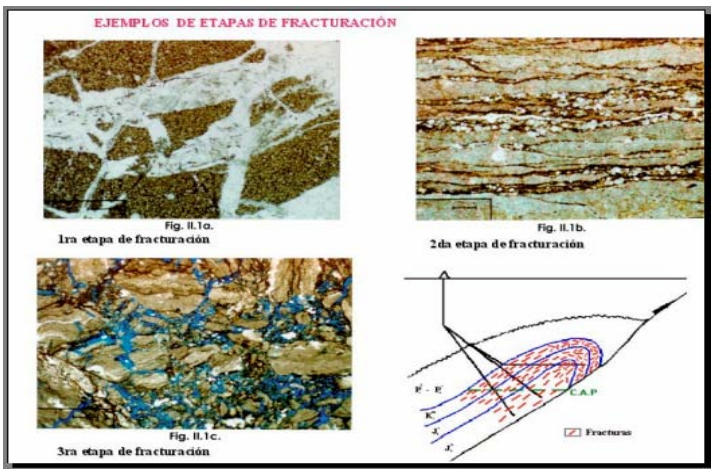

Figure 4: Stages of fracturing and its relationship with the oil production.

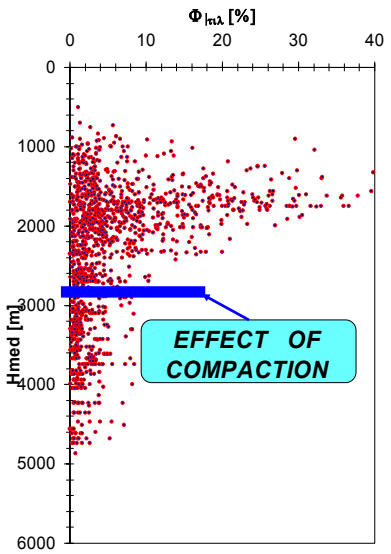

Figure 5: Compaction effect (ϕ vs depth) from core Analysis in wells drilled in NHOT.

Table 1: Main data of Veloz Play

Main play which oil production in NHOT is named Veloz Play.
Their main parameters are:

- **Area: 9 - 30 km²**
- **Net pay zone: 240 - 520 m.**
- **Average porosity: 13 - 18%**
- **Oil & gas Saturation: 70 - 85%**
- **Primary oil recovery factor: 7 - 12%.**
- **Oil density: 10 - 14°API**
- **Oil "in place": 800 - 3000 MMB.**
- **Average production per well: 1200 - 4000 barrels/day**

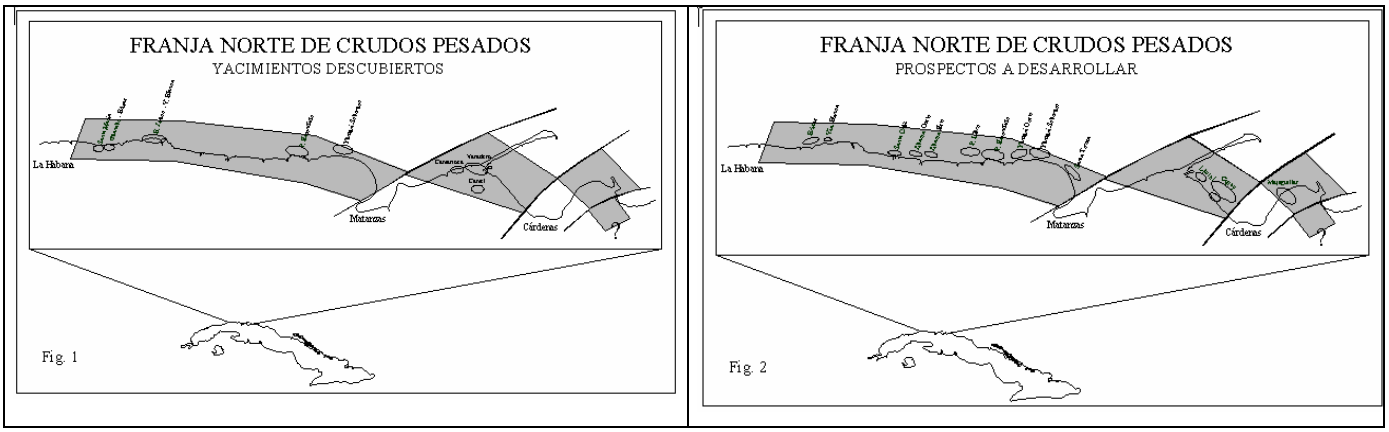

Figure 6: Oil fields discovery in NHOT (fig 1). Varadero & Boca de Jaruco were discovered before this Work.
Prospects prepared with this work. (fig 2)