TALARA: A NEW LOOK AT AN OLD PETROLEUM BASIN

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OVERVIEW

Ideas developed during the early geologic exploration of the Talara basin persisted right up into the 1970s. New concepts based on more recent data are still being developed and not yet widely known, so this presentation is in the nature of a much-needed update. The application of seismic stratigraphic techniques to modern 2-D seismic records has helped to define the vertical and lateral limits of the Talara basin, as well as the structure and stratigraphy of the offshore part of the basin. Zonations using foraminifera and palynomorphs have enabled biostratigraphers to provide a geologic-time framework that has been used to clarify the geologic history of the basin.

Most of the published literature on the Talara basin predates the development of plate tectonics, which has made such a profound change in our view of the geology of Peru's continental margin.
Recent geophysical surveys have provided important data—especially the marine seismic data, whose interpretation has shed new light on attractive potential plays, including turbidite channel fill, stratigraphic onlap and offlap, and seismic amplitude anomalies.

BASIN SIZE, LIMITS, AND AGE

Both areally and vertically, the Talara basin is bigger than formerly believed. It is not limited to rocks of Eocene age. Northern, western, and southern limits were previously left undescribed. The old idea was that the basin was small—perhaps 2,000 sq. km. in area, at least half of that onshore. The offshore limits were unknown, and of little interest. Thus when Belco Petroleum Corp. began the first sustained offshore development, it kept operations within the 100-meter isobath as their working economic limit.

Iddings and Olson (1927) estimated that the basin (onshore only) had a width of just 16 miles (26 km) but they did calculate that the total sedimentary section could reach 25,000 ft. By 1951 Travis had increased the estimated thickness of the total post-Paleozoic section (i.e., the maximum basin depth) to 30,000 ft., including the Cretaceous. To that could be added the 4,600 ft. of Paleozoic strata measured by Newell, et al.

Until recently neither onshore nor offshore limits of the basin were defined. The northern limit was considered to be somewhere around Máncora (Fig. 1), with the southern limit close to the Río Chira. The seaward limit was informally considered to be the edge of the continental shelf, at about 200 m water depth.. The total east-west extent was thus about 30 km, while the north-south dimension was close to 90 km. By 1970 the estimated basin dimensions had increased to an average 50 km wide by 150 km from north to south, or about 7,500 sq. km. in area.

For decades the focus of attention for exploration and oilfield development was limited to Eocene rocks; not much interest was given to older strata. The total sedimentary thickness was considered to be what was penetrated by deeper onshore wells In a 1958 article Youngquist stated that "Tertiary sediments here total some 15,000 feet, and all are Eocene in age." That article, published 41 years ago, is still among the most recent regional papers in English.

Today, we recognize that sedimentary strata are present over an offshore area of some 15,000 sq. km.—about four times the size of the onshore part of the basin, with over half of it in water depths greater than 100 meters. M. Martínez (1970) measured a section of Paleozoic strata totaling 5,278 m in the Amotape Mountains, comprising four formations that range in age from Devonian to Permian. G. Gonzáles (1976) estimated that the total thickness of Talara basin sediments could exceed 16,000 m.

We now know that offshore the Talara basin extends north under the Banco Peru, and probably has its NW boundary at the Dolores Megashear. Furthermore, long E-W lines of modern seismic data confirm that sedimentary strata extend westward to the axis of the Perú-Chile Trench and beyond. Talara basin strata likewise extend southward all the way to the limits of the Pimentel and Sechura-Salaverry basins.

The full N-S extent could thus be as much as 300 km; an E-W extent of some 70 km would imply an area in excess of 20,000 sq. km, or close to 10 times as great as the very earliest estimates (Fig. 2).

Now we also recognize that the primarily Eocene basin was superimposed on a regional Mesozoic basin, which in turn was underlain by an even larger Paleozoic basin. The ***vertical*** dimension of the Talara basin (including pre-Tertiary sediments) may be require an equally great increase over early estimates. For example, seismic data suggest that the Peru Bank could have a sedimentary section of as much as 16,000 m. The maximum thickness of pre-Tertiary sediments is not known, but Well 3995, onshore in Lote XII, had 2,400 m of Cretaceous strata (Fig. 3).

REGIONAL STRUCTURE

Once characterized as a "taphrogenic [extensional] basin" of early Tertiary age, the Talara basin was considered unique among Perú's continental-margin basins as the only one that was ***not*** a typical forearc basin.

Today's hydrocarbon systems model of the Talara basin recognizes that this area has had a long history of sedimentation, from the mid-Paleozoic through a complex evolution during the Cretaceous and Tertiary, reflecting the area's location near the "leading edge" of a continental plate. The plate-tectonic configuration is characterized by a very narrow shelf off Negritos. The Paleozoic uplifts are not at the eastern edge of these northern coastal basins (Sechura, Talara, and Tumbes), as formerly believed; rather, the Paleozoic highs form a discontinuous ***mid-basin*** chain that may be the onshore extension of the the "Outer Ridge" that has been mapped from marine seismic (Fig. 4).

LOCAL (INTRABASIN) STRUCTURE

The old picture of the Talara basin was dominated by normal faulting that occurred during two periods of extensional tectonics. When low-angle gravitational slide faults were recognized through the paleontologic identification of repeated strata, they were considered to be younger, cutting both sets of normal faults.

Today the Talara basin is placed near the junction of two megashears, reflecting a complex structural setting that includes transcurrent (wrench) faulting as well as both high-angle and low-angle faults of varying ages. Peralta (1968) identified four phases of tectonic activity. Strong compression with tight, complex folding appears limited to Paleozoic strata. Cretaceous tectonic activity was characterized by more gentle folding, reflected (for example) in prominent anticlines and syclines in the Cretaceous of the Lancones basin.

The last uplift of the Amotape Mountains is relatively recent, most probably early Paleocene (Danian). Cretaceous strata in the Lancones Synclinorium indicate that the Cretaceous was present regionally, but was eroded off the high areas when the Amotape Mountains were uplifted. Intense normal faulting is primarily late Paleogene to early Neogene, diminishing in intensity in later Tertiary time. In mid-Eocene and later time, both penecontemporaneous slumping and low-angle gravity slide faulting occurred (slide faulting is particularly common in the Neogene beds of the Tumbes sub-basin). In some cases the slide "sheets" are bounded laterally by strike-slip (transcurrent) faults.

Periods of faulting show up in the Paleozoic, Cretaceous, Paleocene, and Mid- to Upper Eocene. Some low-angle gravity sliding may be contemporaneous with later normal faulting. It is now recognized that the highly oil-productive Lobitos and Negritos highs are ***not*** Paleozoic uplifts—although the Eocene is thinner, there is a thick Cretaceous section here. Thus, these uplifts reflect Tertiary activity (Fig. 5).

BIOSTRATIGRAPHY

The old conceptual framework based on paleontology of the onshore Talara basin was extremely sketchy. There was no basis available for developing a regional picture, during either the Mesozoic or the Cenozoic; most of the conceptualizing was local. The unrecognized effects of (1) repetition by gravity slide faulting and (2) abrupt lateral changes due to intense normal faulting made it dificult to fit the paleontologic evidence into a coherent framework.

In biostratigraphy the main breakthrough has been the new chronologic framework developed primarily on the basis of the refined zonations by planktonic foraminifera, assisted by palynomorphs, and (more recently) nannofossils. Detailed biostratigraphy based on analysis of planktonic and palynological species has aided sequence stratigraphic analysis, which has been carried offshore into undrilled areas using modern seismic sections. Major facies changes have been confirmed in both Tertiary and Cretaceous strata.

PHYSICAL STRATIGRAPHY

Earlier there were two contrasting concepts of the stratigraphy: (1) the drilled section and outcrop section were thought to reflect a very complex situation with rapid facies changes over short distances; (2) other investigators postulated essentially no facies changes except over very long distances. The lateral variations over relatively short distances were attributed to faulting

Data from outcrops south and east of the Amotapes, including those sampled in the Pazul basin, demonstrate that the so-called Lancones basin is really just the eastern part of the Talara basin, with the Tertiary section removed. The Lancones and Talara areas became separated in post-Redondo time (Fig. 6).

Ideas about rates of deposition have changed substantially. Some early workers believed there were few facies changes, with very slow, gradual deposition in this basin. Other early workers, particularly some British geologists, considered that each local area had a distinct depositional regime, meriting different formation names for the sedimentary units. Later, some geologists proposed very rapid deposition ("dumping and slumping") to account for strata that are now recognized as turbidite deposits.

In the eastern onshore area, the thin Tertiary sequence does not imply that the Paleozoic must be near the surface; rather, there is a very thick section of Cretaceous. The same is true around the Negritos Uplift, where the Basal Salina crops out. Most recently, offshore data from Peña Negra show thick Cretaceous as well.

The area of the present basin must have undergone relatively frequent periods of uplift and erosion: there are three major unconformities in the Cretaceous and four in the Paleogene. Nevertheless, those erosional intervals obviously did not lead to the destruction of the basin's rich concentration of hydrocarbons. Within the Eocene there are four megasequences: Basal Salina to Pale Greda; Rio Bravo-Pariñas-Chacra-Echino; Talara shale to Pozo shale; and Chira-Verdún-Mirador-Cone Hill (Fig. 7). Nearshore facies are prominent, with turbidite and deltaic equivalents. The source direction varies; Chira-Verdún sediments may have had a southerly to southwesterly source area. The Salina and Mogollón apparently had sediment sources to the north, NW, and NE. The Chacra and Pariñas had sources to the east, as did the Helico turbidites.
The foregoing conditions are all conducive to hydrocarbon deposits.

RESERVOIR ROCKS, SOURCE ROCKS, AND SEALS

Early workers in the area considered that good reservoirs were restricted to Upper Eocene units such as the Verdún sandstone. Later the concept was extended to the Lower Eocene Pariñas, Salina (Manta), and Basal Salina sands. Both source rocks and seals were believed to be scattered throughout the Eocene. Because the basin's productivity was already well established, the organic geochemistry of the basin was not considered.

Today the Cretaceous Muerto and Redondo formations are known to be strong candidates for commercial-quality source rocks. Of the Paleocene and Lower Eocene candidates, the best are the deep-water shales of the Negritos, Pale Greda, and Chacra formations, and the Talara shale's Lobitos member (Rica faunal zone). Among the possible Upper Eocene candidates we have the Chira and Cone Hill shales, which could also be petroleum sources.

Reservoir-quality rocks are present in units of widely differing ages, from Late Paleozoic to Late Eocene—principally the Basal Salina, Mogollón, Pariñas, and Cabo Blanco sandstones. Additionally, some of the best reservoirs are turbidite sands, which should include the Helico and the Talara sandstone. The basal conglomerate of the Talara group, called the Terebratula, is productive, gives way laterally and vertically to highly calcareous shales and even limestone.
Even the Pennsylvanian Amotape formation can be a commercial reservoir in areas where it is highly fractured (quartzite facies), and where it is capped by Redondo shale.

Sealing strata, principally deep marine shales and claystones, are present throughout the section.

HYDROCARBON MIGRATION & ENTRAPMENT

For many decades petroleum migration was treated as a theoretical rather than a practical concern, since the presence of multiple highly productive reservoir units was already obvious. The few geologists who focused on how and when hydrocarbons moved from source to reservoir assumed a single phase of very short-range migration into the reservoirs, with no subsequent re-migration. Normal faults were of course recognized as effective barriers, provided the displacement was sufficient to put reservoir sand against sealing shale.

Today we have recognized that there were probably several periods of hydrocarbon migration (Fig. 8), which would help account for (1) the presence of oil and gas in rocks of all ages, from Late Paleozoic to Late Eocene; (2) the presence of both HCT (paraffinic) and LCT (naphthenic) oils; and (3) the highly complex distribution of gas, oil, and water in multiple-sand reservoirs like the Salina of the Portachuelo field. In Portachuelo detailed pressure- and fluid-distribution studies demonstrated that the original accumulation most probably formed by lateral migration into multiple sands on a simple anticlinal structure. This relatively straightforward fluid distribution was enormously complicated by mid-Eocene extensional faulting, which flattened the Salina anticline until it was unrecognizable. This hydrocarbon system model seems to fit other Talara basin pools, as well. But in all cases, the model has to be constructed on the basis of the specific local stratigraphic system as it relates to the local structural configuration.

We now consider that oil in Cretaceous formations—mainly the Maastrichtian Mesa sands—could be found a long way from outcrops or pre-unconformity subscrops, that is to say, offshore. The Ancha conglomerate is a less attractive potential reservoir in the Cretaceous because of (1) its red shale matrix derived from a continental environment of deposition, and (2) its restricted areal distribution.

In the Eocene, the widespread Salina group is highly productive because it includes good potential sources (Negritos shale and San Cristóbal shale) which, along with the overlying Pale Greda, can also act as seals. The Chacra shale may similarly have acted as both source and seal for the prolific Pariñas sandstone; but even where the Chacra is absent (Talara shale lying on Pariñas), the Pariñas can be productive. This is readily explained by downward migration from the Quemada or Rica zones of the Talara Group, or possible upward migration from the Pale Greda.

UNDEVELOPED POTENTIAL

During the 1960s and 1970s no significant undeveloped potential was believed to exist in the Talara basin—particularly onshore, after more than a century of locally intense exploitation (in some pools the average well spacing is now less than 4 ha [10 acres]). Because natural gas was essentially uneconomic (for lack of a market), its future potential was not even studied. Even after locally prolific production was found in Amotape quartzites in the Portachuelo, Leones, and Laguna pools , the Paleozoic was not considered a primary commercial target.

Similarly, the Cretaceous has never been the object of ongoing systematic exploration. However, since the 1970s good production was found in older Tertiary units (Basal Salina and Mogollón) in a number of onshore and offshore localities.

Our current conception is that major potential must exist offshore in the Talara basin—particularly in water depths greater than 350 ft., which is shallow by today's standards ("deep water" is now taken to mean greater than 3,000 meters depth). Future commercial reservoirs may range in age from Paleozoic to uppermost Eocene (and younger strata, if present). Abundance of source rocks, never a concern in the onshore part of the basin, should be even less a problem in a seaward direction. The natural gas potential of the entire basin, onshore as well as offshore, is only now beginning to be evaluated. The southern onshore and offshore areas look particularly promising for gas.

Specifically, there is high potential for gas in the Lagunitos area, and also east of the main oil trend from Portachuelo all the way to Máncora, and stratigraphically from the Paleozoic to the younger Tertiary reservoirs. Another zone of high potential involves the productive sands below 4500 ft. beneath all the areas where intensive waterflooding was carried out under contract with Occidental. Finally, offshore the entire sedimentary section has potential, particularly beyond 120 m water depth.

List of Figures

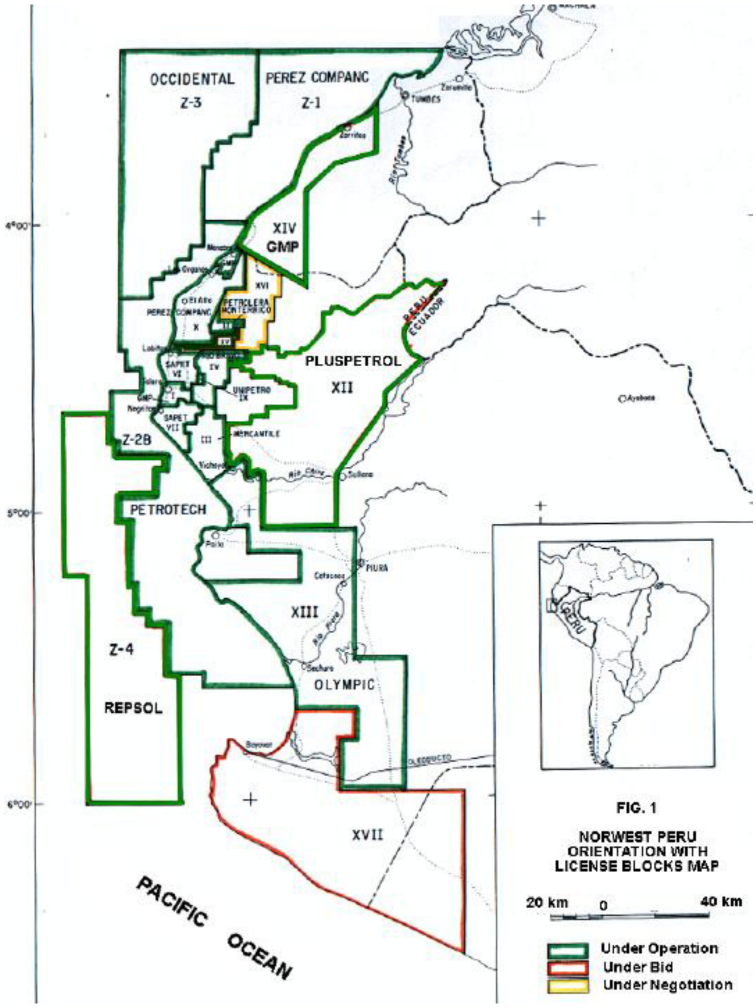


FIG. 1
NORWEST PERU ORIENTATION WITH LICENSE BLOCKS MAP

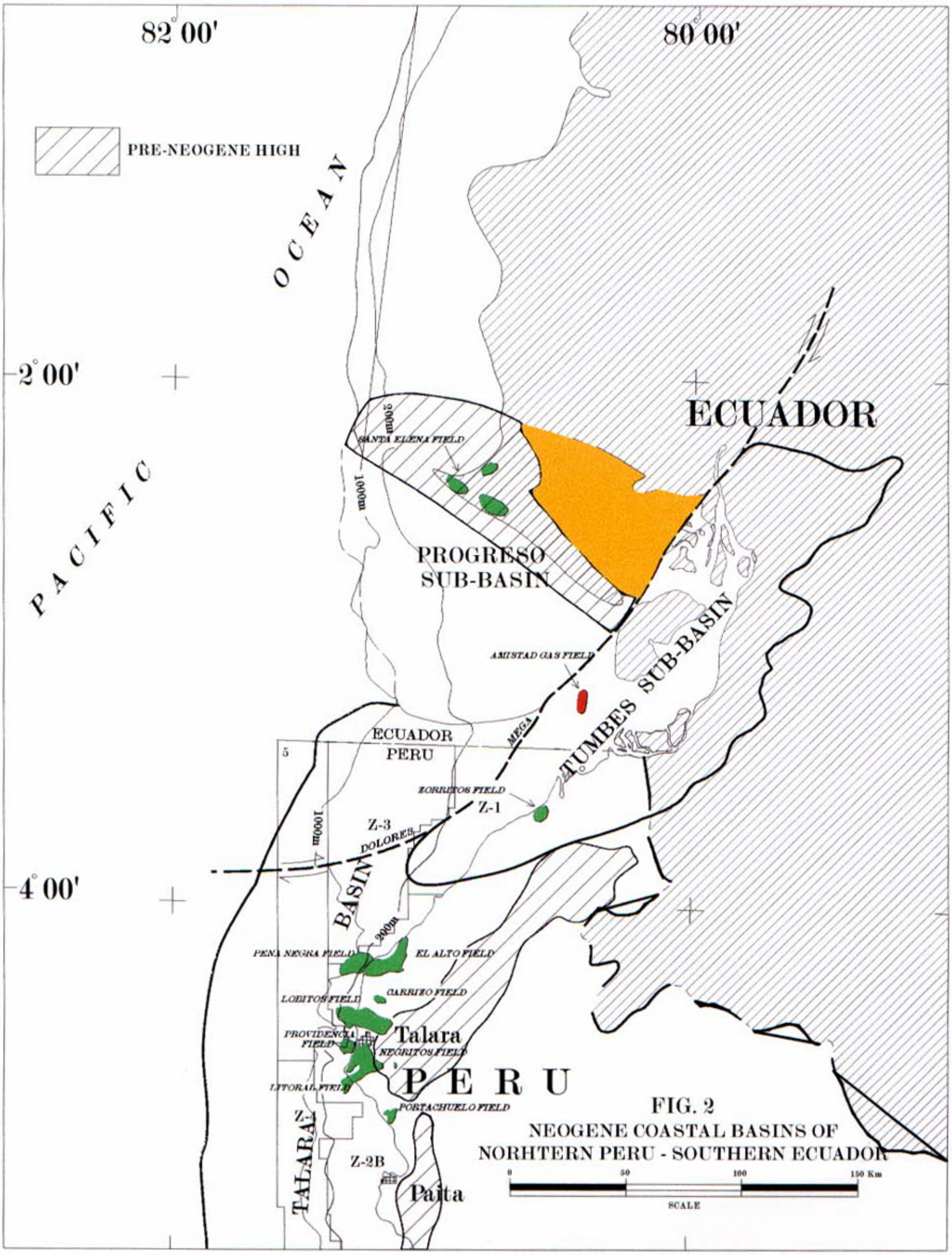
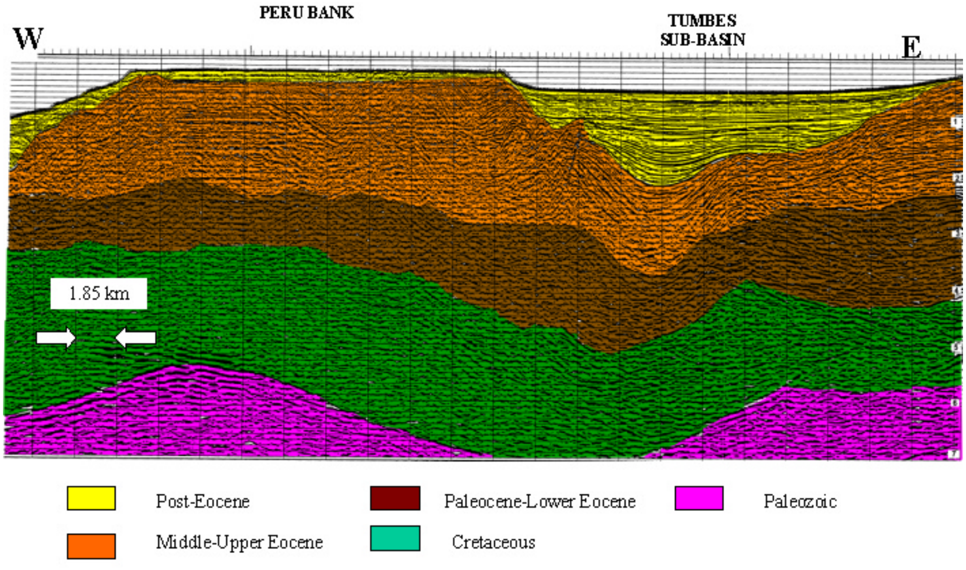


FIG. 2
NEOGENE COASTAL BASINS OF
NORHTERN PERU - SOUTHERN ECUADOR

Fig. 3 - TUMBES SUB-BASIN AND PERU BANK



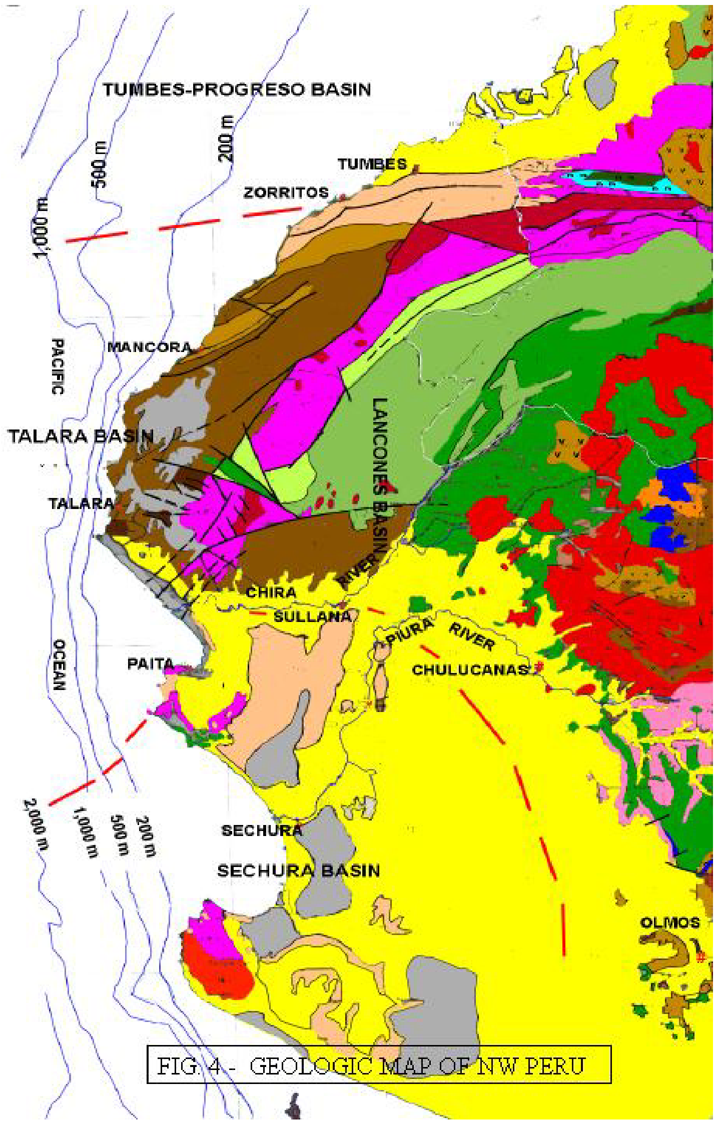
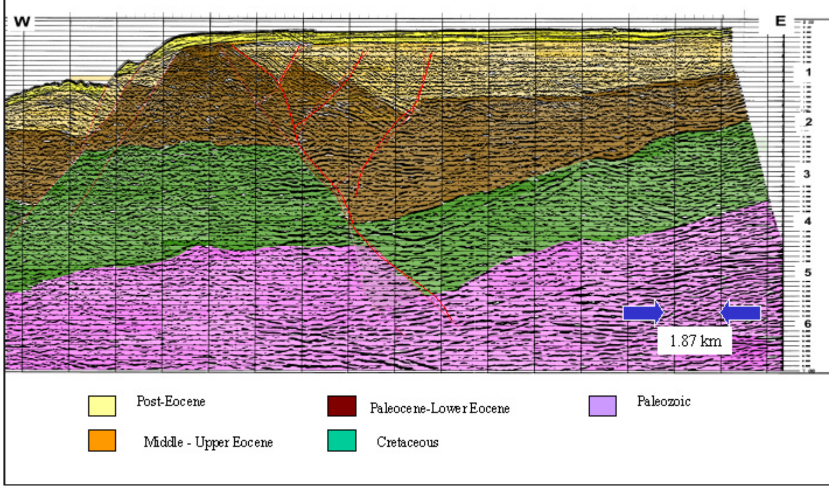


FIG. 4 - GEOLOGIC MAP OF NW PERU

Fig. 5 - SEISMIC SECTION ACROSS SOUTHERN TALARA BASIN (OFF NEGRITOS)



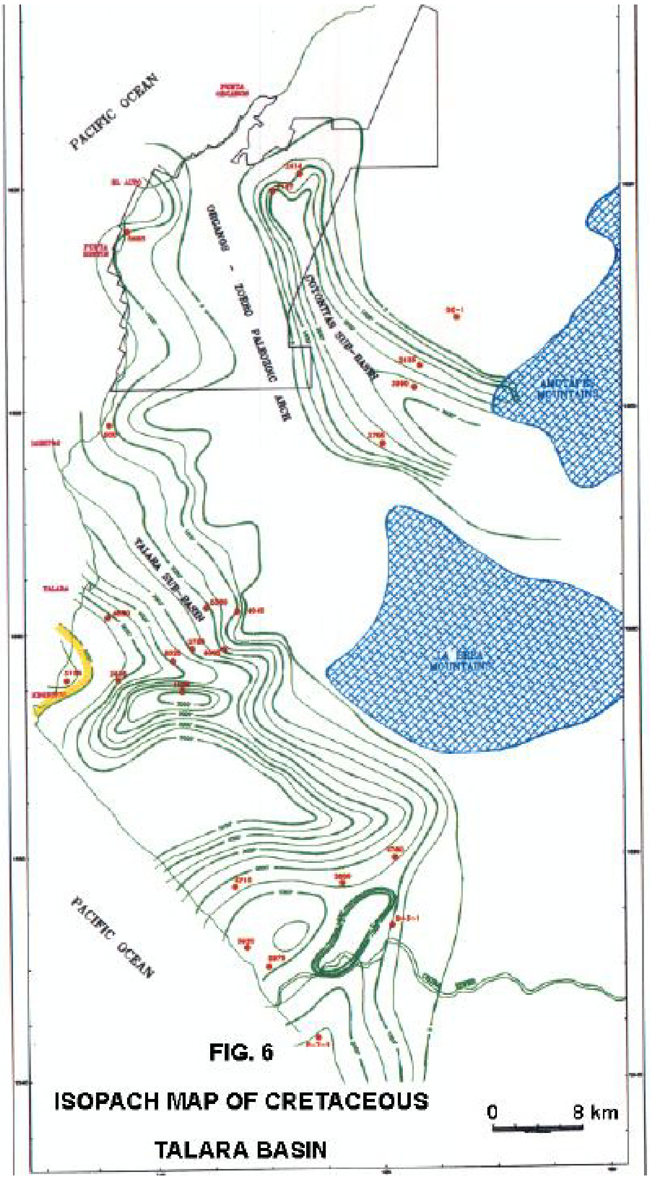


FIG. 6

ISOPACH MAP OF CRETACEOUS

TALARA BASIN

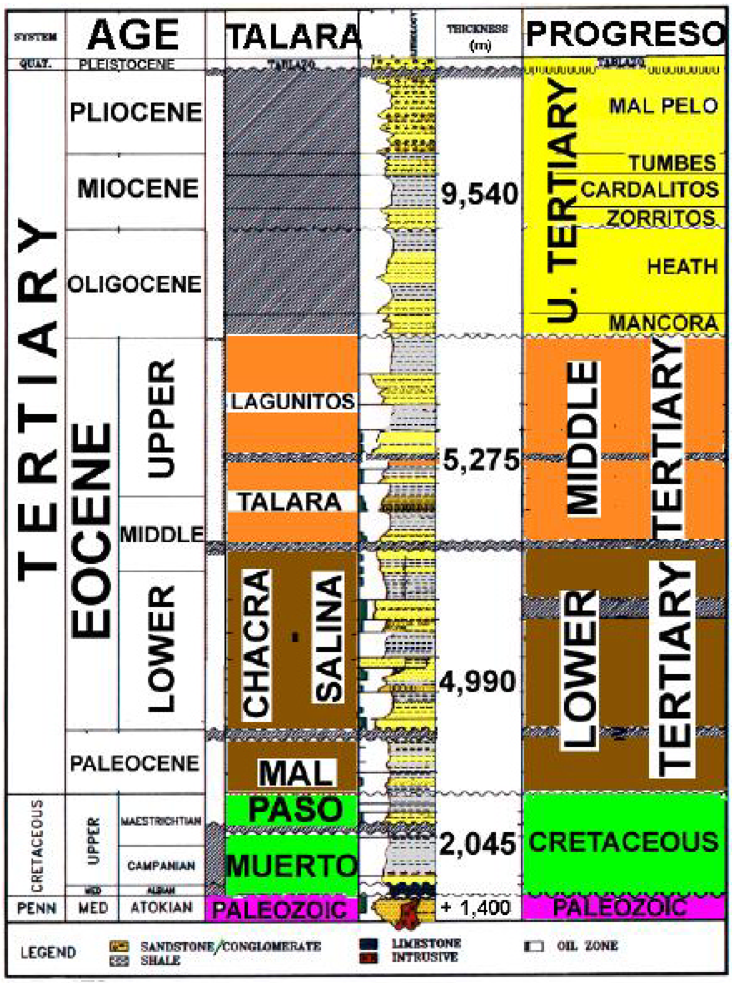


FIG. 7 - STRATIGRAPHIC COLUMN OF PROGRESO - TALARA BASINS

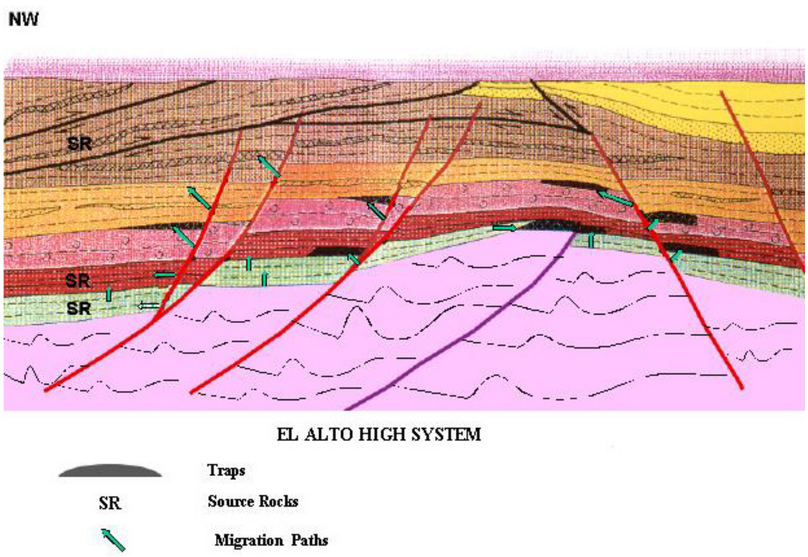


FIG. 8 Hydrocarbon systems model, El Alto area