

OVERVIEW OF THE PETROLEUM GEOCHEMISTRY OF TRINIDAD AND TOBAGO

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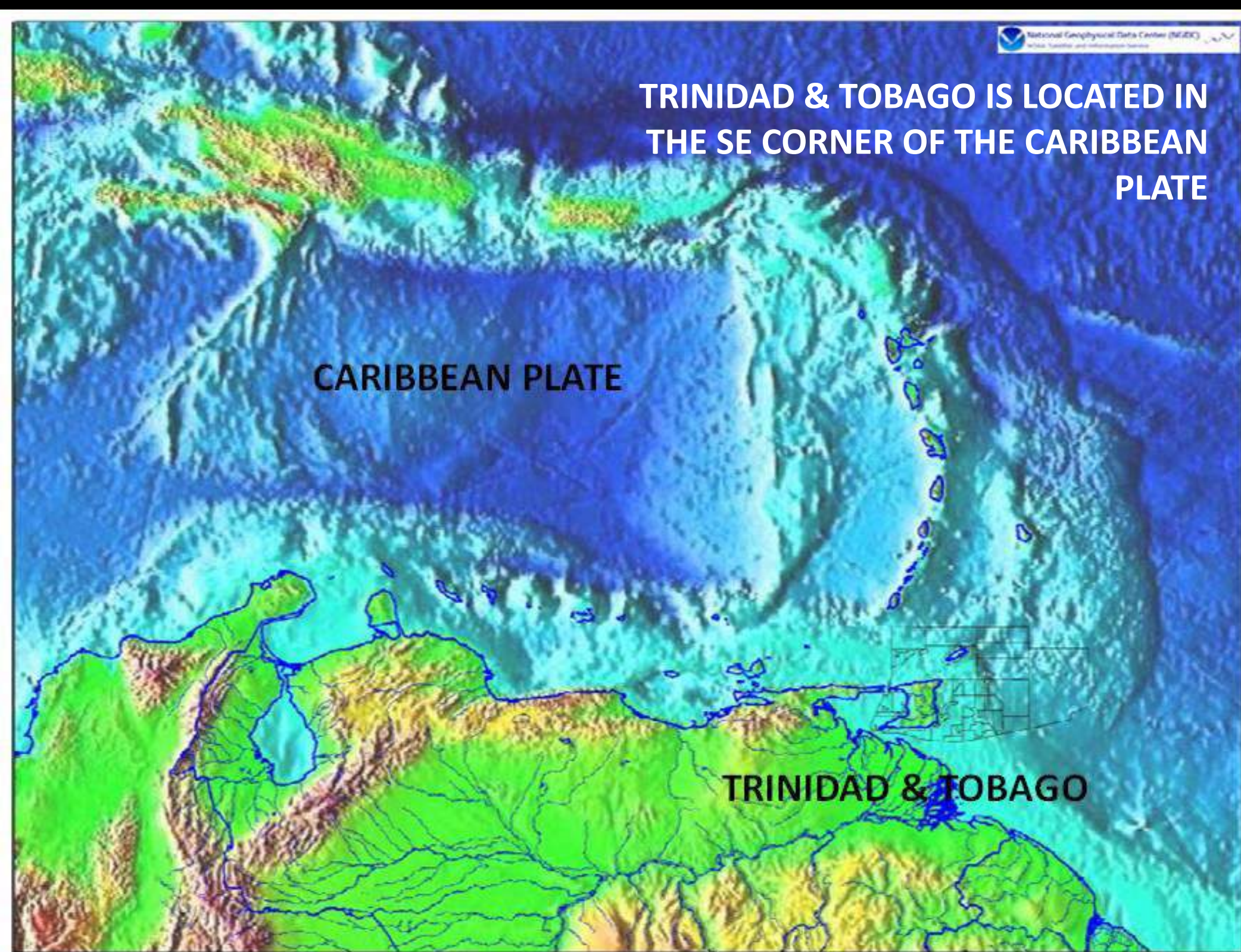
PETROLEUM SYSTEMS IN TRINIDAD AND TOBAGO

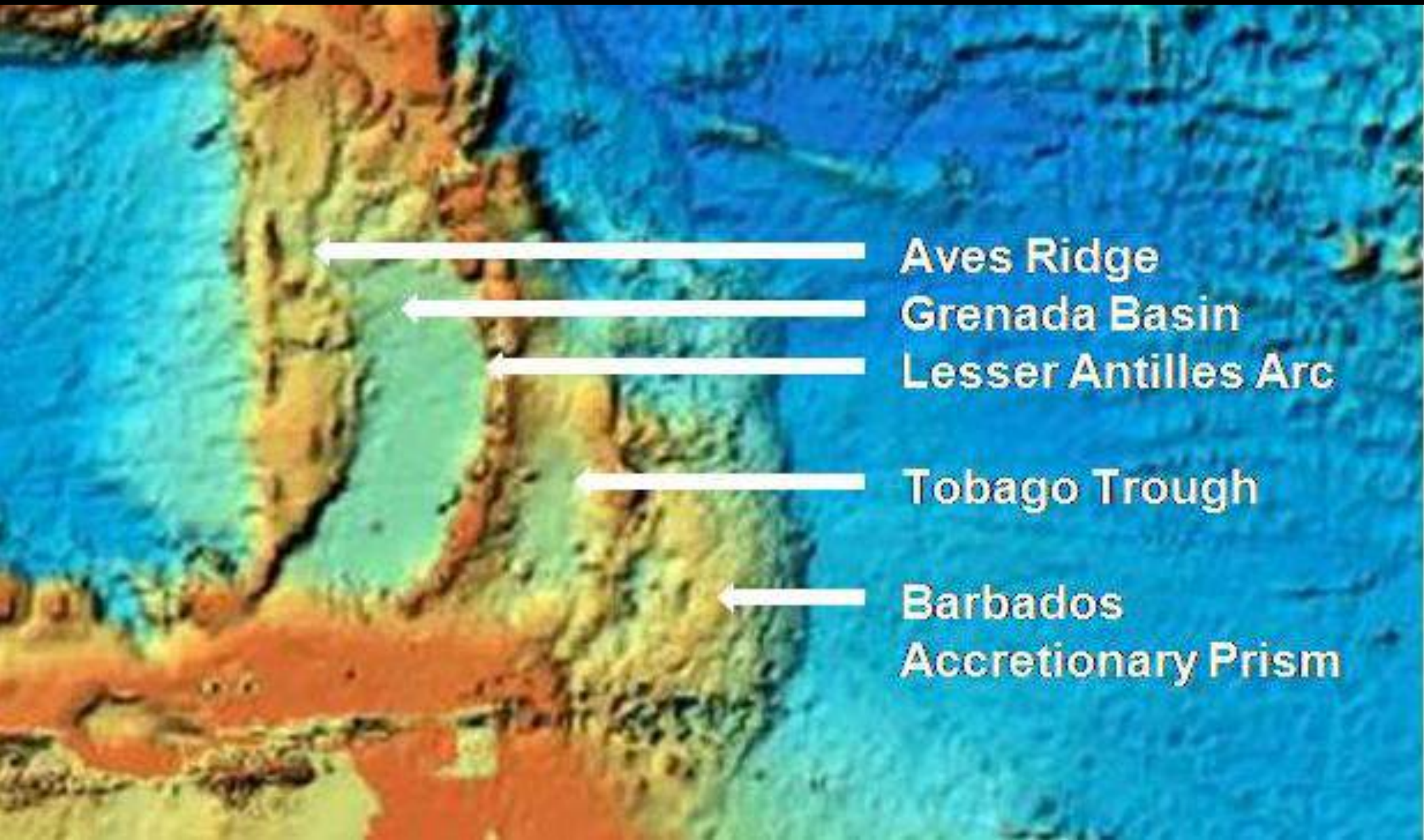
FUTURE POTENTIAL

**TRINIDAD & TOBAGO IS LOCATED IN
THE SE CORNER OF THE CARIBBEAN
PLATE**

CARIBBEAN PLATE

TRINIDAD & TOBAGO





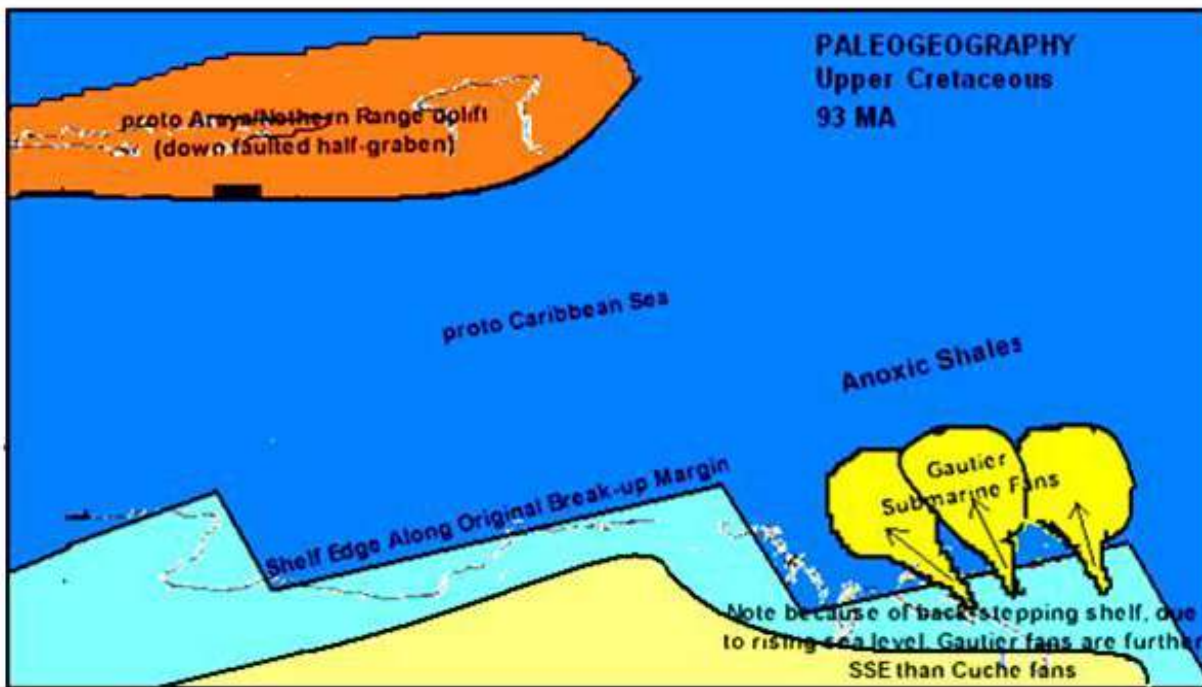
MAP SHOWING THE TECTONIC ELEMENTS OF THE SE CARIBBEAN AREA

FIRST A WORD ABOUT OUR PLATE TECTONIC HISTORY...AND ITS EFFECTS ON OUR PETROLEUM SYSTEMS

We have been found that a seven stage evolutionary model for the Trinidad area best fits all of the data, as follows:

- PRE-RIFT, SYN-RIFT and DRIFT (Late Jurassic-mid Cretaceous)**
- PASSIVE MARGIN (Mid -Late Cretaceous)**
- NORTH SOUTH COMPRESSION (Late Cretaceous-Eocene)**
- RETURN TO PASSIVE MARGIN (Eocene-Oligocene)**
- SEQUENTIAL OBLIQUE COLLISION (Late Oligocene-mid Miocene)**
- WRENCH PHASE (Late Miocene-Recent)**
- CONTINENTAL EMBANKMENT (Pliocene-Present)**

- **PASSIVE MARGIN (Mid -Late Cretaceous)**
 - High Sea Level...Source Rock Formation
 - Submarine Fans sourced from the south



Basin floor fans formed at low stands of sea level
During middle to upper Cretaceous rising sea level allowed widespread anoxic conditions, with the formation of rich marine source rocks

Anoxic Shales

BFF

BFF

BFF

Recent & Syn-rift Sediments

DRIFT PHASE

SSE

BACKSTEPPING SHELF

Shelf's stones and shales

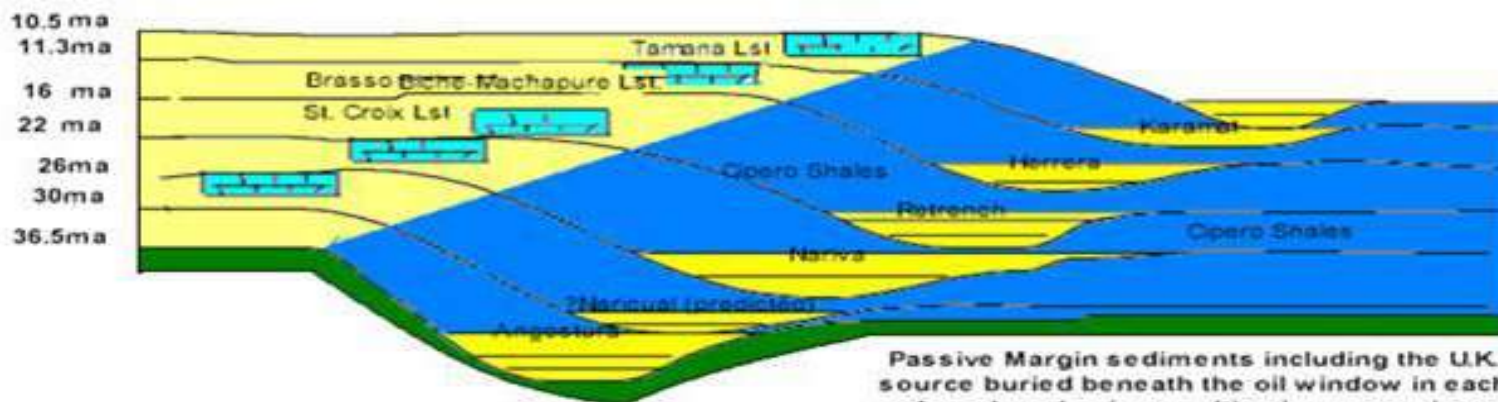
75 MA
92 MA
98 MA
115 MA

- **SEQUENTIAL OBLIQUE COLLISION (Late Oligocene-mid Miocene)**
 - **Foredeep Basin**
 - **Active Margin turbidites**
 - **Source Rock Maturation**
 - **Foreland Uplift**
 - **Source for turbidities**
 - **Foreland Fold and Thrust Belt**
 - **Overthrusting**
 - **Asymmetric Anticlines**
 - **First Phase HC Accumulations**

NNW

SSE

SEQUENTIAL OBLIQUE COLLISION PHASE



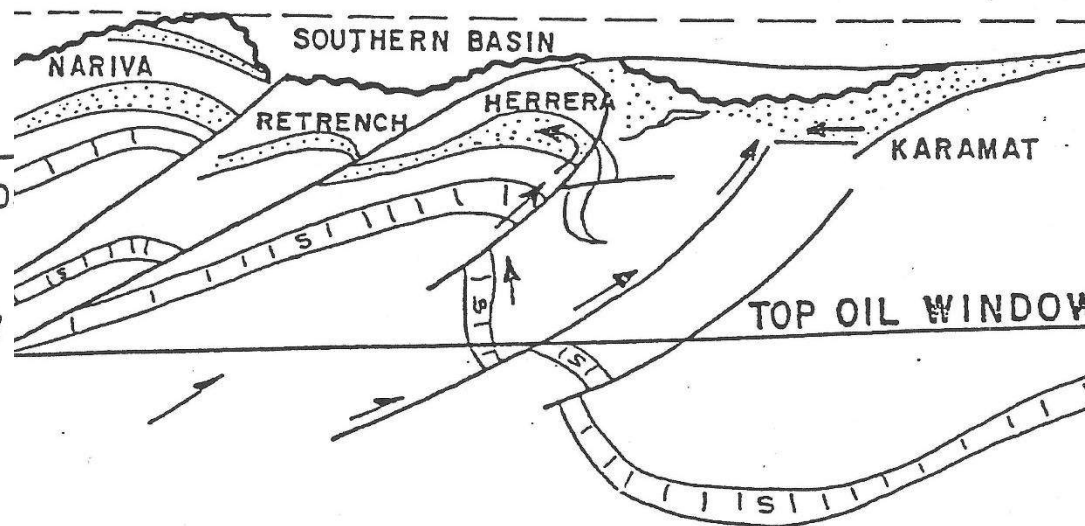
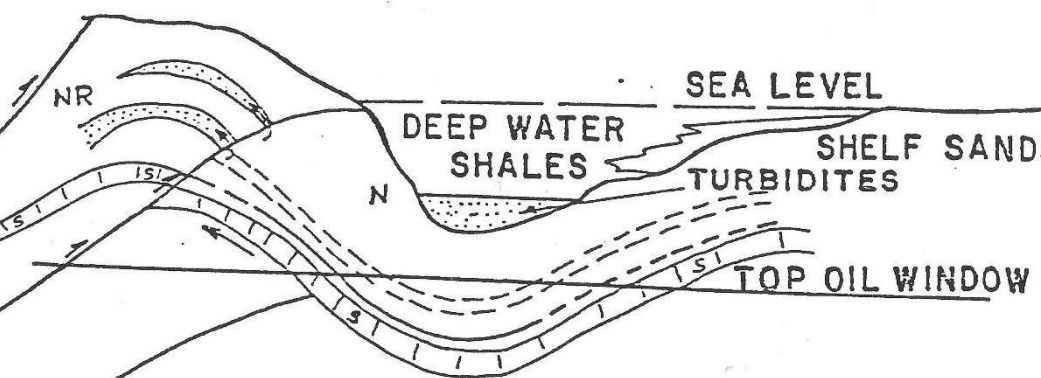
Fore Deep Basins
with ponded active margin
turbidites and submarine fans
migrating to the SSE during the
Sequential Oblique Collision

Passive Margin sediments including the U.K.
source buried beneath the oil window in each
fore deep basin, resulting in successive
elongated kitchens trending ENEWSW

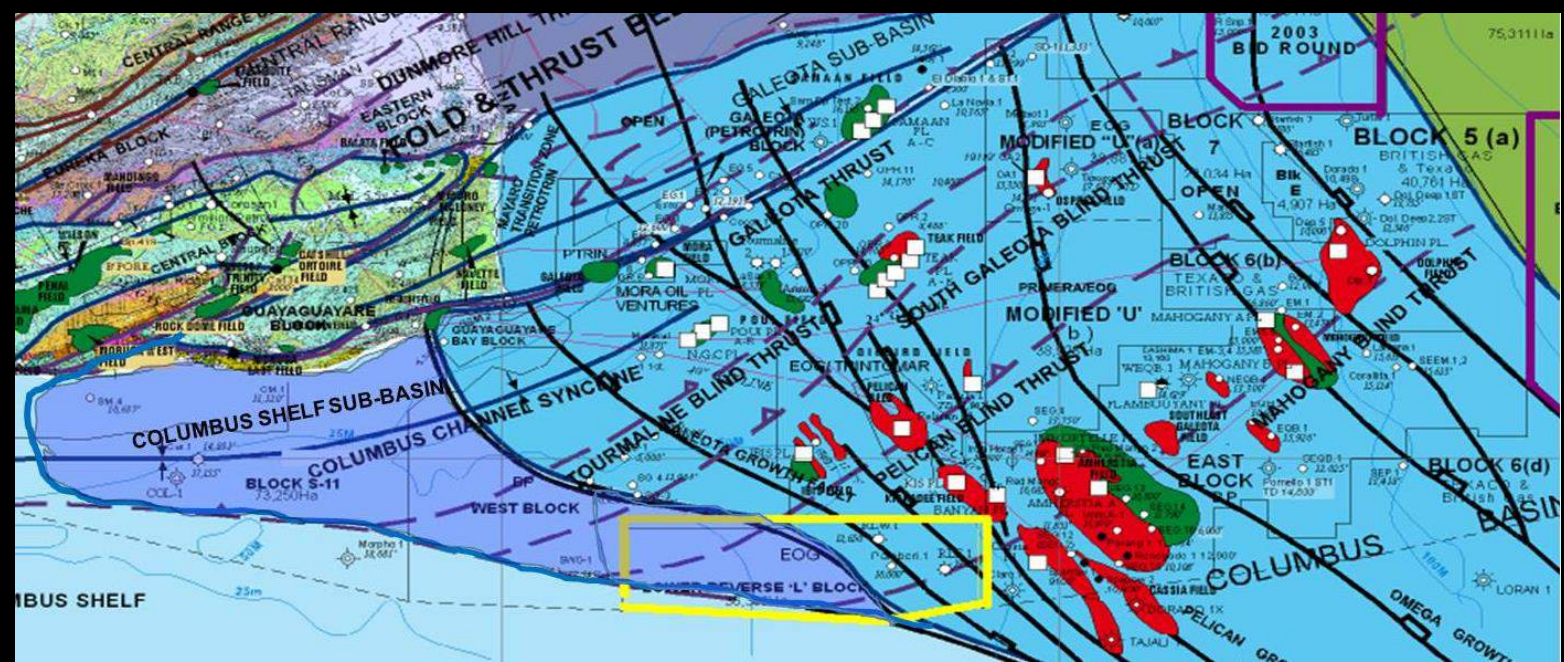
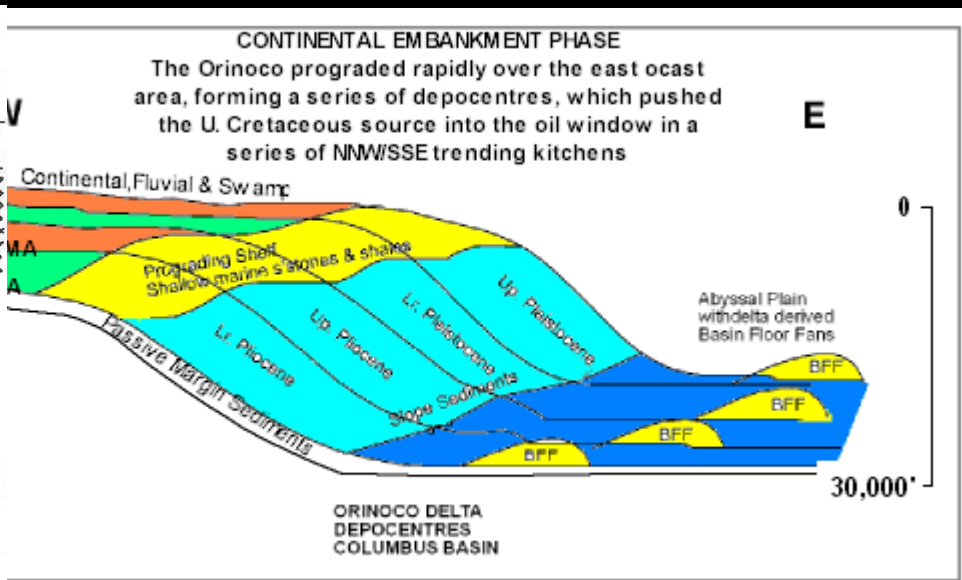
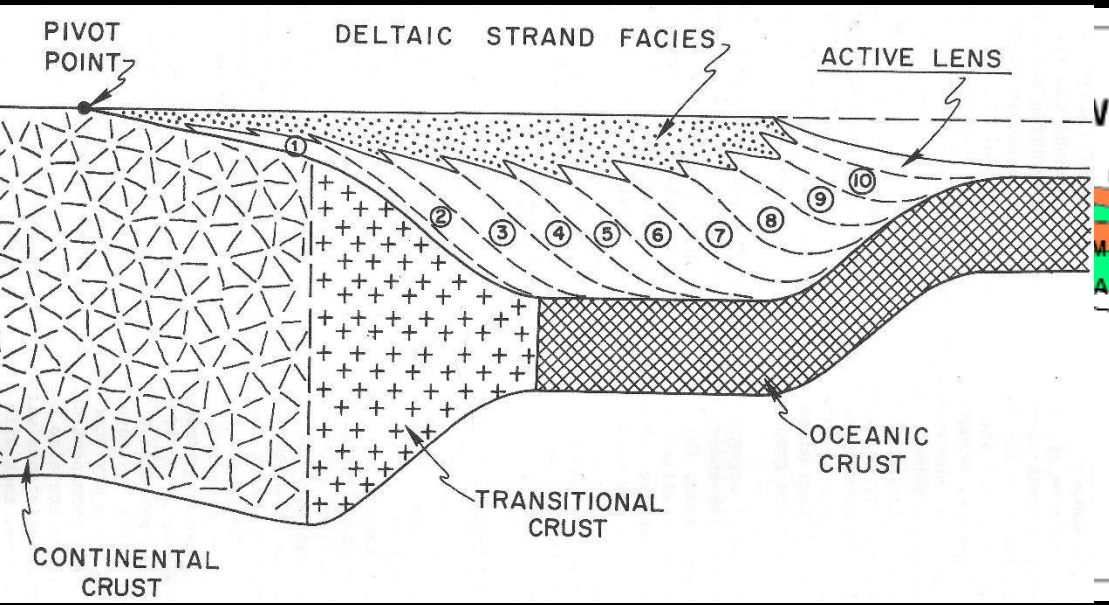
Turbidites form during low stands of sea
level and limestones form during high
stands

LATE MIOCENE REEFS

COLUMBUS SHELF



CONTINENTAL EMBANKMENT ...DELTA IN OPEN OCEAN (Pliocene-Present)



IDENTIFICATIONS OF SOURCE

FIRST IDENTIFICATION by Persad et al. (1980)

Naparima Hill and Gautier Formations found to be a rich oil prone mature source and to correlate with many produced oils

OIL SOURCE CORRELATION CONFIRMED by Talukdar et al. 1989 and 1995

SUBSEQUENT CONFIRMATIONS made by MANY AUTHORS

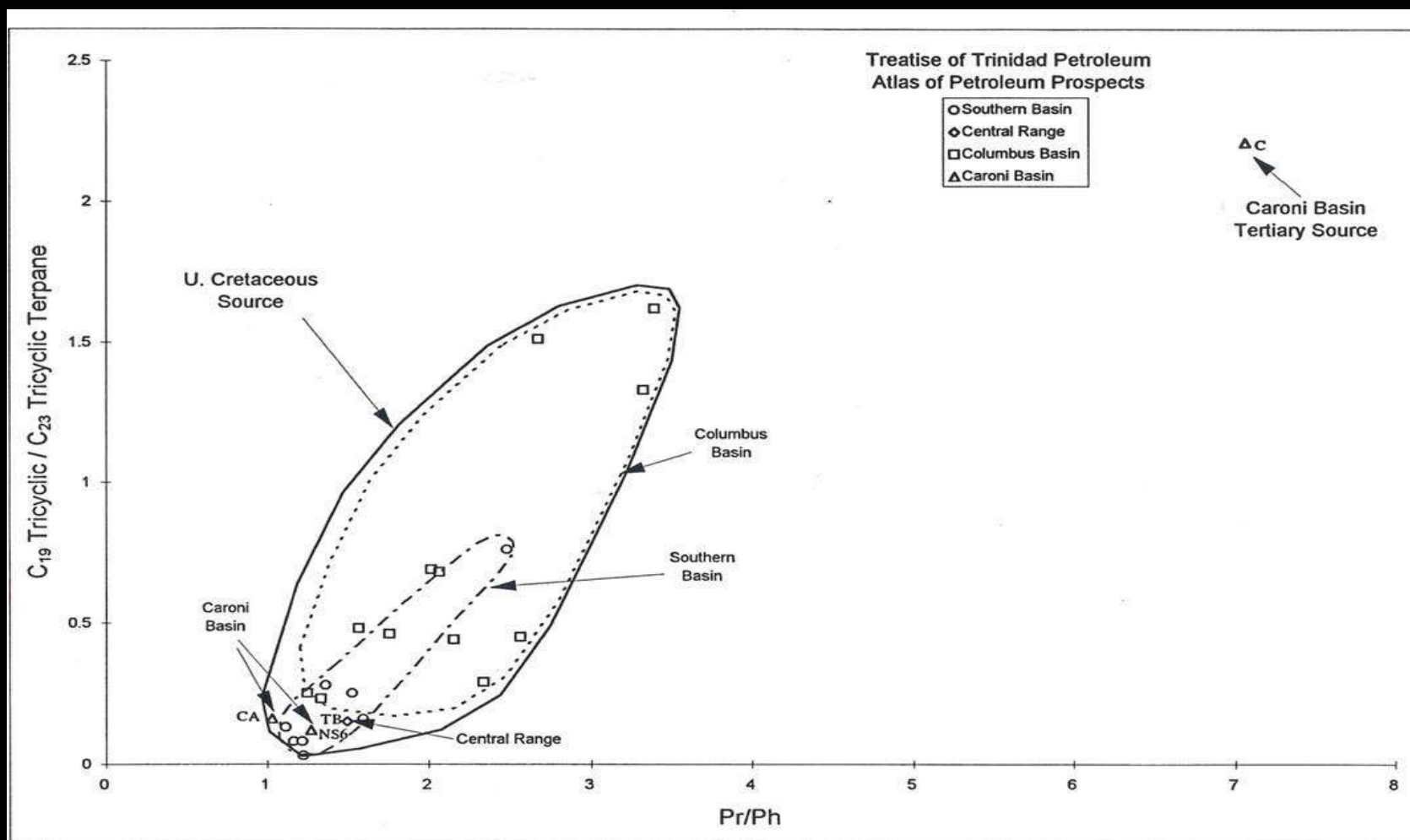
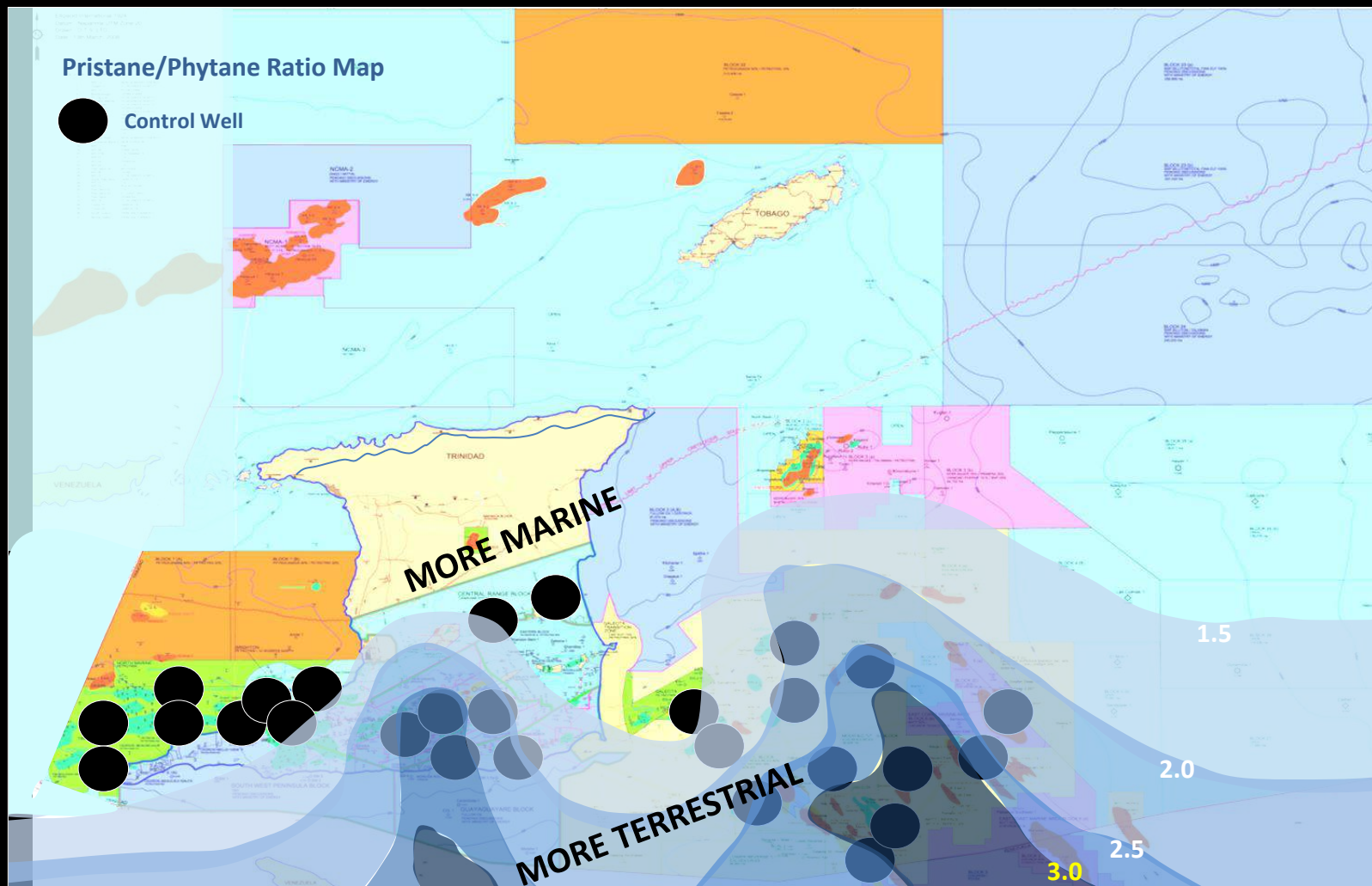


FIGURE 38 - Variations of C₁₉ Tricyclic Terpene/C₂₃ Tricyclic Terpene ratio vs. Pr/Ph ratio

SOURCE TYPES

Kerogen quality of these oil-prone source rocks varies considerably from type II to mixed type II/III.

The Upper Cretaceous source becomes more marine in a NNW direction as evidenced by the Pristane/Phytane ratio



MINOR TERTIARY SOURCE: ORGANIC FACIES AND THERMAL MATURITY

Many of the Tertiary formations in Trinidad, ranging in age from Palaeocene to Pliocene (inland and offshore), contain abundant shales that have been evaluated for petroleum source potential Persad et al., 1980; Leonard 1983; Rodriguez, 1988; Talukdar, Dow and Persad, 1989

All work showed they contain essentially gas-prone kerogen and are generally immature.

**The Brasso shales were however found to be an oil source in the Gulf of Paria, the only Tertiary source rock recognized...
Very minor production to date**

OIL ALTERATIONS

**SEVERAL STUDIES BY TALUKDAR, PERSAD and/or DOW
STARTING IN 1989 AND CONTINUING RECOGNISED THAT MOST
TRINIDAD OILS ARE ALTERED AND THAT THERE ARE MAINLY TWO
TYPES OF ALTERATION**

BIODEGRADATION

and

EVAPORATIVE FRACTIONATION

**THEY FURTHER RECOGNIZED THAT THERE MAY MULTIPLE PHASES OF
ALTERATION**

BIODEGRADATION

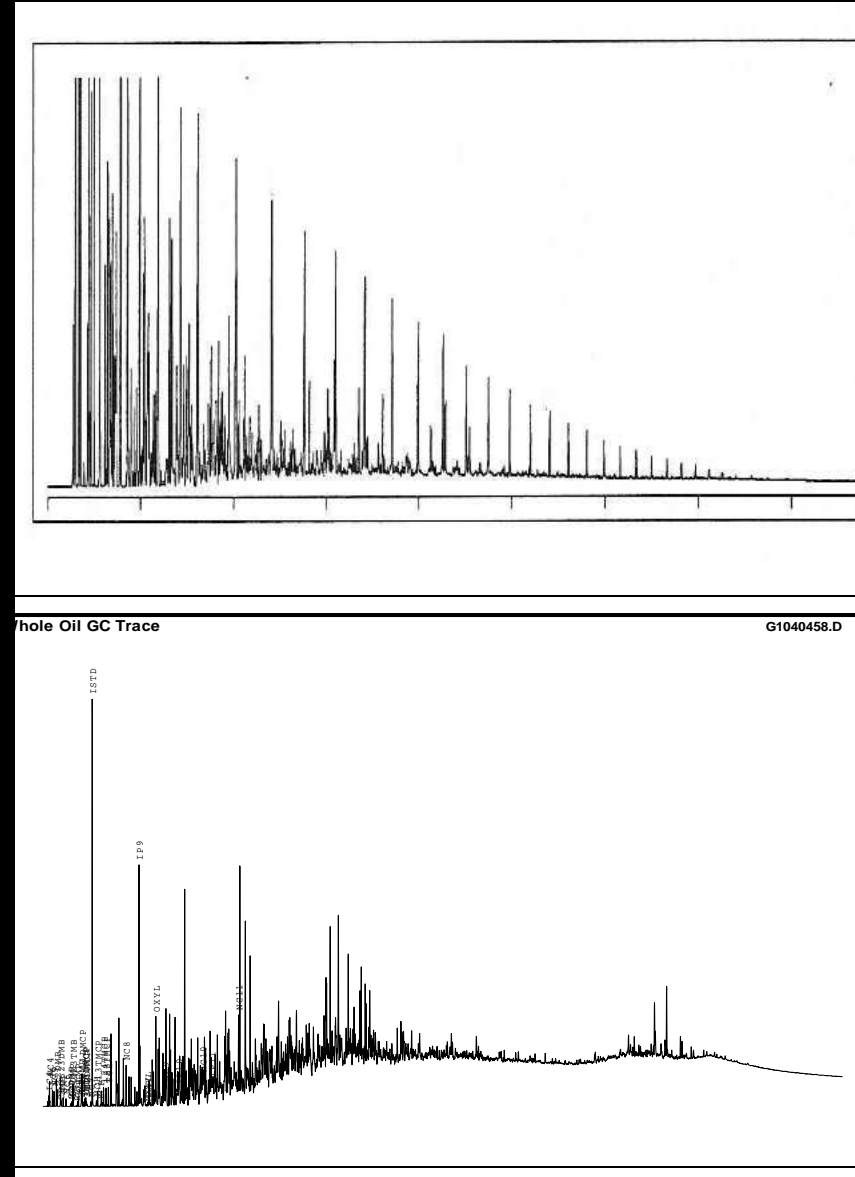
LONG KNOWN AND EASILY RECOGNISED

IT RESULTS IN:

Decrease in API Gravity, GOR and light hydrocarbons content

Increase in viscosity and sulphur content

**It is caused by oils coming into contact with
meteoric water carrying aerobic microbes**



DESCRIPTION OF TYPES OF OIL ALTERATIONS

EVAPORATIVE FRACTIONATION

A "residual" oil shows loss of light hydrocarbons and a reduced API gravity compared to the original oil and is waxier.

The other petroleum fraction that has left the oil pool and migrated above is a condensate (known as evaporative condensate) and has a much higher API gravity.

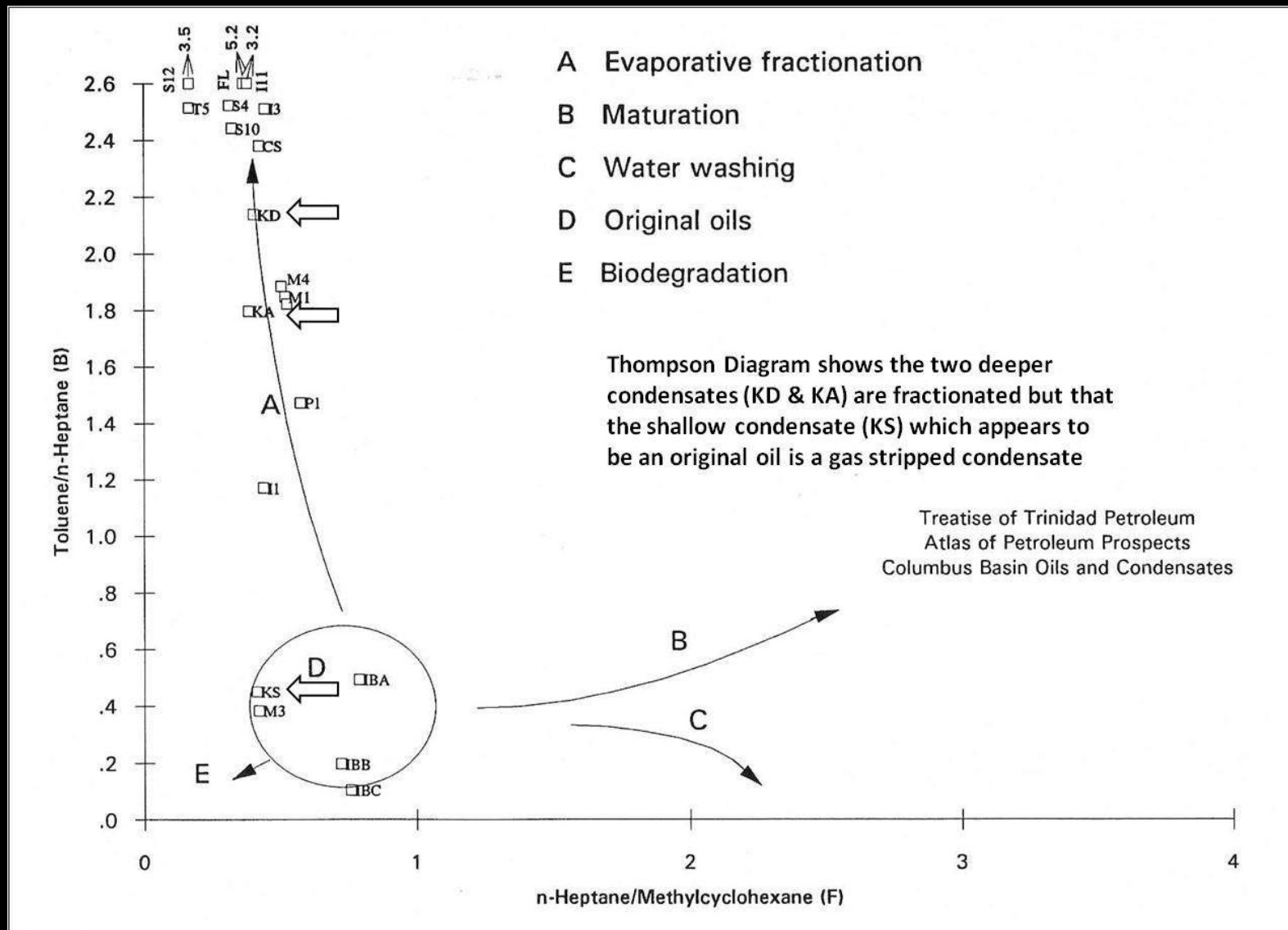
This condensate will have two characteristics.

First, contrary to thermal condensates, it will have the same range of thermal maturity as the "residual" oil or any original oil from the same source in the area that escaped the introduction of gas and resulting fractionation.

Secondly, contrary to the complementary "residual" oil, it will be enriched in light hydrocarbons. It will appear like an unaltered original condensate.

EVAPORATIVE FRACTIONATION

In the Thompson diagram, the oils with evaporative fractionation show fractionation of the C7s compared to the original oils



EVAPORATIVE FRACTIONATION is recognized in the whole oil GC by the loss of light or low molecular weight hydrocarbons together with or accompanied by evaporative fractionation of the C7s"

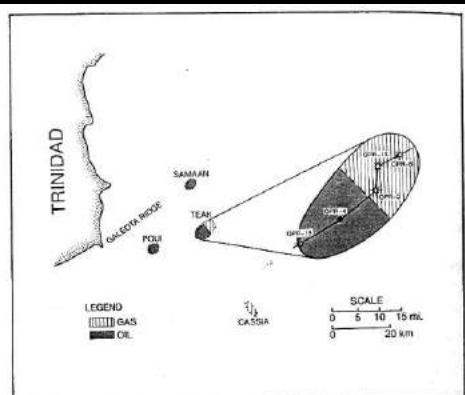


Figure 1: Location map for Teak, Poui, and Samaan fields, offshore Trinidad.

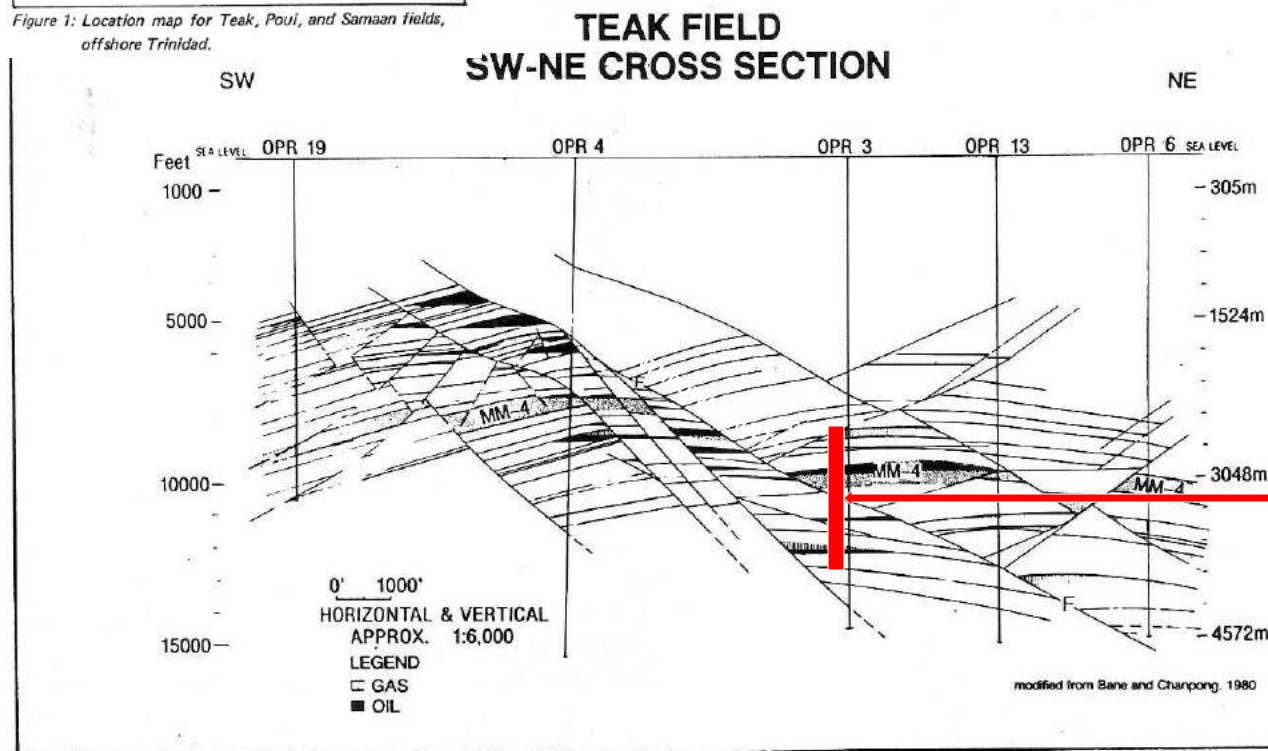


Figure 2: SW to NE cross section of Teak field, see Figure 1 for well locations.

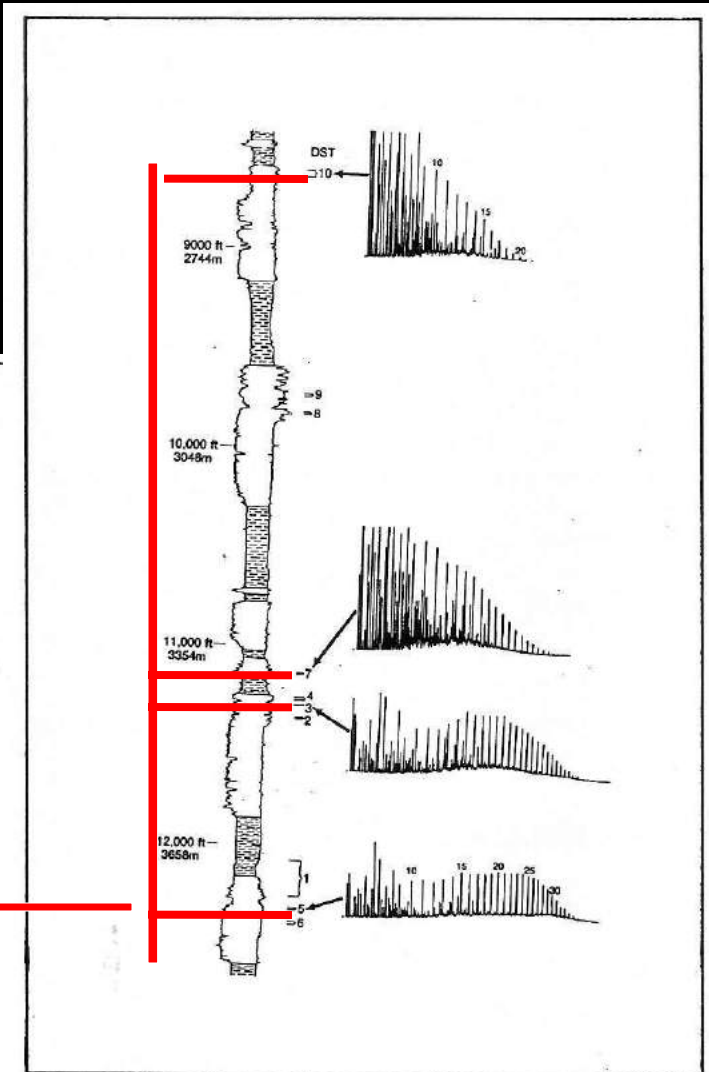


Figure 4: Molecular distribution of selected oils from OPR - 3 well, see Figure 1 for well location.

CONCEPT OF PETROLEUM SYSTEMS

**SEVERAL STUDIES BY TALUKDAR, PERSAD ET AL
STARTING IN 1995 AND CONTINUING HAVE RECOGNISED AND
DESCRIBED ELEVEN PETROLEUM SYSTEMS**

**The concept of petroleum systems is discussed briefly next and
then we list the systems identified by Persad and Talukdar et al
and provide a brief description of the most prolific**

PETROLEUM SYSTEMS

The Concept of Petroleum Systems

According to Magoon and Dow (1994) "a petroleum system encompasses a pod of active source rock and all related oil and gas and includes all the essential elements and processes that are needed for oil and gas accumulations to exist".

These essential elements of a petroleum system are the source, reservoir, seal and overburden...migration pathway. The processes are the timing of trap formation, generation, migration and accumulation of petroleum. Traps must have been formed at the correct time, i.e. prior to migration. This is defined in the petroleum systems approach as the critical moment.

Definition and Description of Petroleum System

The petroleum system's name combines the name(s) of the reservoir rock(s) and the source rock or rocks with the level of certainty:

e.g. The Gautier/Naparima Hill-Cruse/Forest/M L'Enfer (!) System

The name includes first the source, followed by the reservoir, but separated by a hyphen.

In each case the formations are given with the oldest first.

LISTING OF THE PETROLEUM SYSTEMS

The eleven petroleum systems that have been identified by Talukdar et al are listed in the next slide on a basin by basin basis
Each with its designation as known, hypothetical and/or speculative as the case may be

The systems in yellow account for 99.99% of the oil produced to date and all share a common source, i.e. the Upper Cretaceous Naparima Hill and Gautier Formations.

SOUTHERN BASIN

The Gautier/Naparima Hill-Cruse/Forest/M L'Enfer (!) System

COLUMBUS BASIN

The Gautier/Naparima Hill-Lower Cruse/Gros Morne/Mayaro (!) System

FOLD AND THRUST BELT

The Gautier/Naparima Hill-Cipero (!) System

The Gautier/Naparima Hill-Angostura (.) System

The Gautier/Naparima Hill-Cuche/Gautier/Naparima Hill (.) Petroleum System

The Gautier/Naparima Hill-Naparima Hill (.) Petroleum System

The Gautier/Naparima Hill-Pointe a Pierre/San Fernando () System

CARONI BASIN/GULF OF PARIA PULL APART BASIN

The Gautier/Naparima Hill-Manzanilla/Springvale/Talparo (!) System

The Cipero-Brasso/Manzanilla (!) Petroleum System

**CARUPANO BASIN (CARACOLITO SUB-BASIN and the PARIA SUB-BASIN)
and THE EAST TOBAGO HALF-GRABEN**

The Cretaceous-Neogene () Petroleum System

SOUTHERN BASIN

The Gautier/Naparima Hill-Cruse/Forest/M L'Enfer (!) System

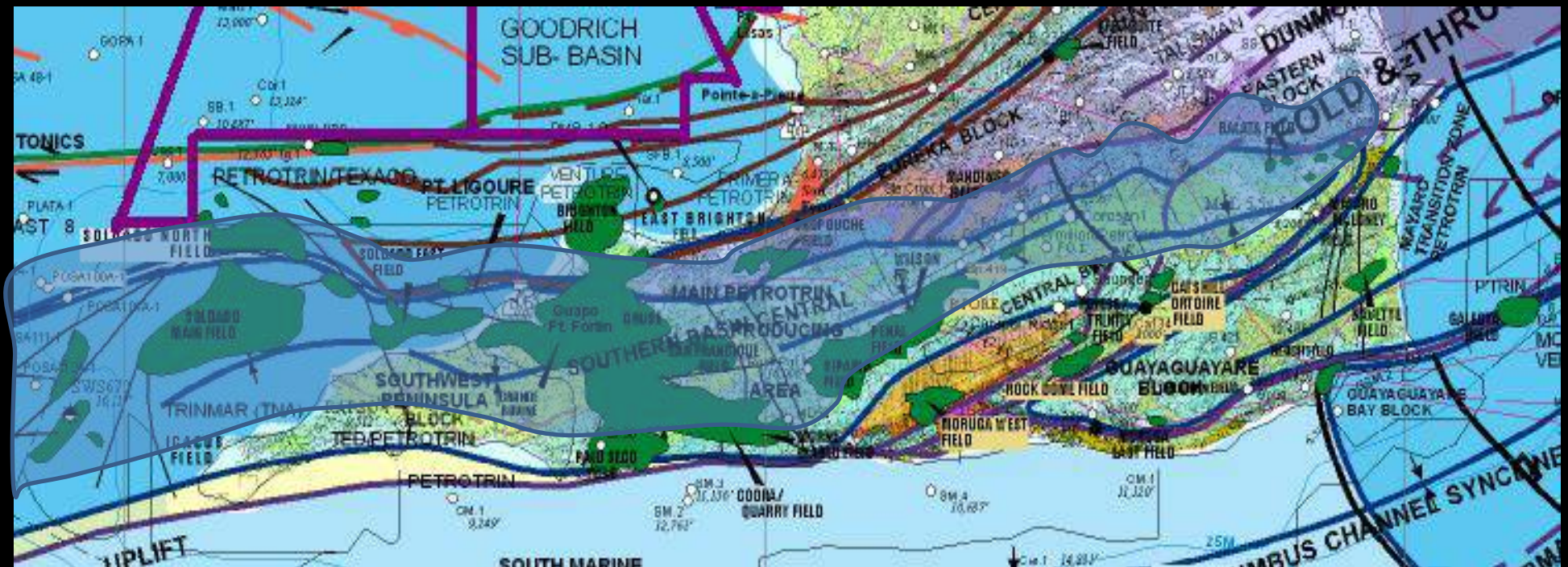
GEOGRAPHIC EXTENT

This system is known to exist in the Southern Basin onshore and in its extension offshore in the Gulf of Paria. It lies within the piggy back Southern Basin, which is subdivided into the western Erin Syncline, which lies west of the Los Bajos Fault, and extends westward into the Gulf of Paria, a central portion known as the Siparia Syncline and an eastern portion termed the Ortoire Syncline.

OIL PRODUCTION

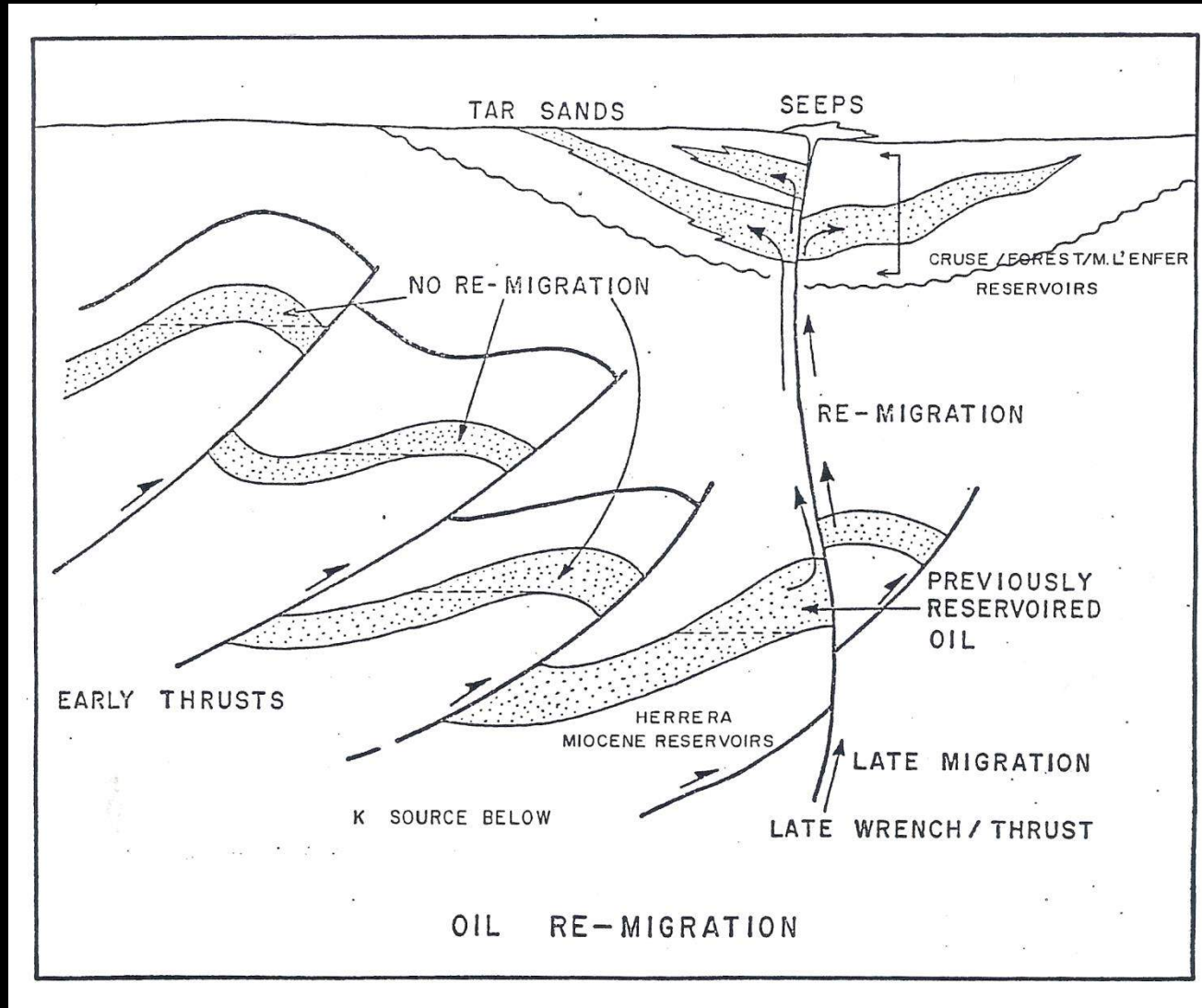
It is the largest known contributor to oil production in the country having produced an estimated 1,900 million barrels of oil to the end of 2010.

OOIP in these reservoirs/fields is estimated to be over eleven billion barrels



SOUTHERN BASIN

The Gautier/Naparima Hill-Cruse/Forest/M L'Enfer (!) System



The oil has re-migrated from deeper (most likely Herrera) reservoirs into the shallower Pliocene reservoirs (Talukdar et al 1989)

COLUMBUS BASIN

Gautier/Naparima Hill – Lower Cruse/Gros Morne/Mayaro (!) System

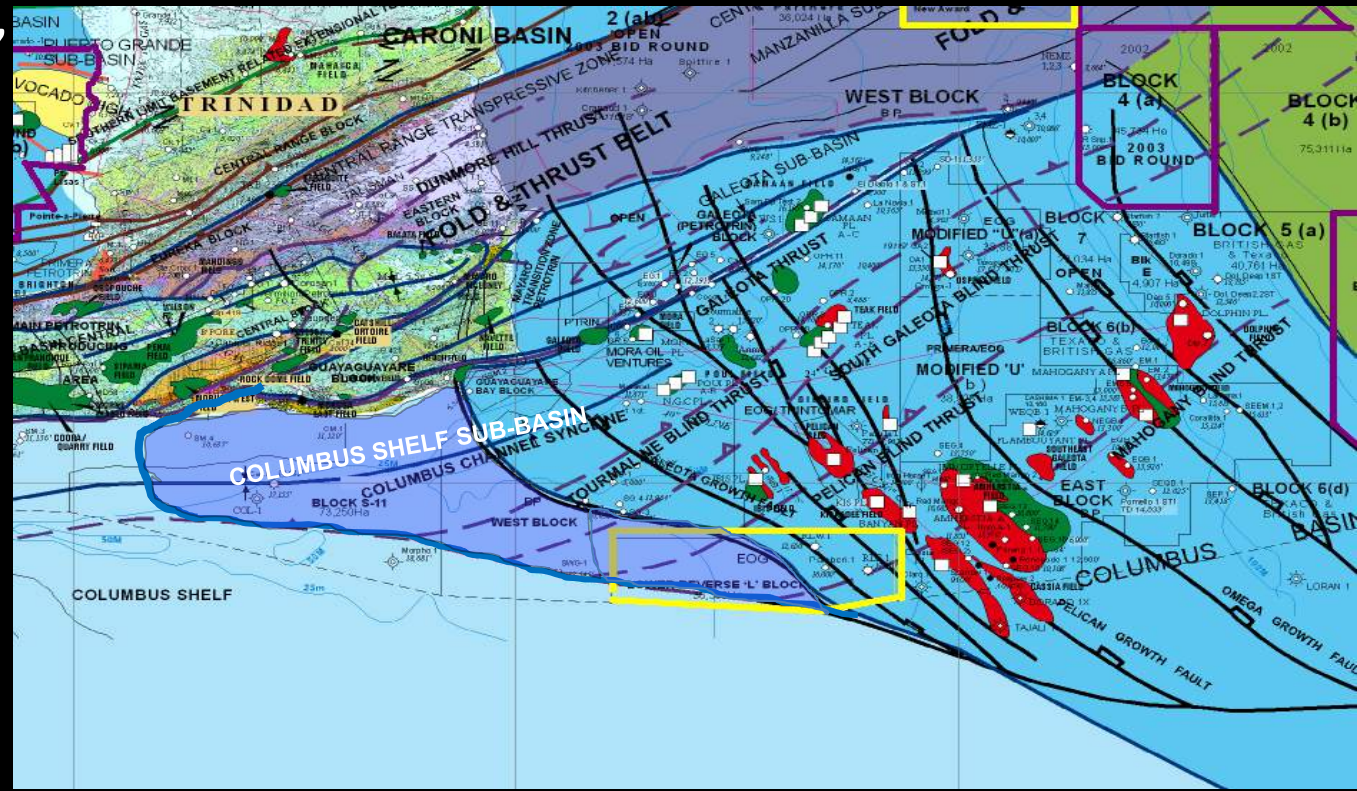
GEOGRAPHIC EXTENT

found mainly offshore the south and southern part of the east coast of Trinidad. A western onshore portion, lies to the south-east of the eastern part of the Southern Basin, and east of the Guayaguayare sub-basin. It extends as far north as the Darien Ridge and includes the Galeota Sub-basin. Its southern boundary extends beyond the territorial waters into Venezuela. Its eastern boundary is perhaps best defined as the eastern limit of the growth fault province of the Orinoco delta

PETROLEUM ACCUMULATIONS

This basin contains some of the largest petroleum accumulations known in the Trinidad area to date. There are oil fields, as well as gas/condensate fields with thinner oil legs below.

The fields have produced over one billion barrels of oil and ten TCF of gas to date



FOLD AND THRUST BELT

Within the fold and thrust belt area number of petroleum systems grouped together, because of the similarity of their origin and development.

They all have the Naparima Hill and Gautier formations as their source. They are all caught up in the down-warping of the successive foredeep basins, which created a succession of elongate kitchens which caused the maturation of the source rocks.

The migration and trapping of the oil and gas in the mid to lower Tertiary reservoirs represents the first phase of oil accumulations within all of these petroleum systems.

The petroleum systems we described within the fold and thrust belt are:

The Gautier/Naparima Hill-Cipero (!) System

The Gautier/Naparima Hill-Angostura (.) System

The Gautier/Naparima Hill-Cuche/Gautier/Naparima Hill (.) Petroleum System

The Gautier/Naparima Hill-Naparima Hill (.) Petroleum System

The Gautier/Naparima Hill-Pointe a Pierre/San Fernando () System

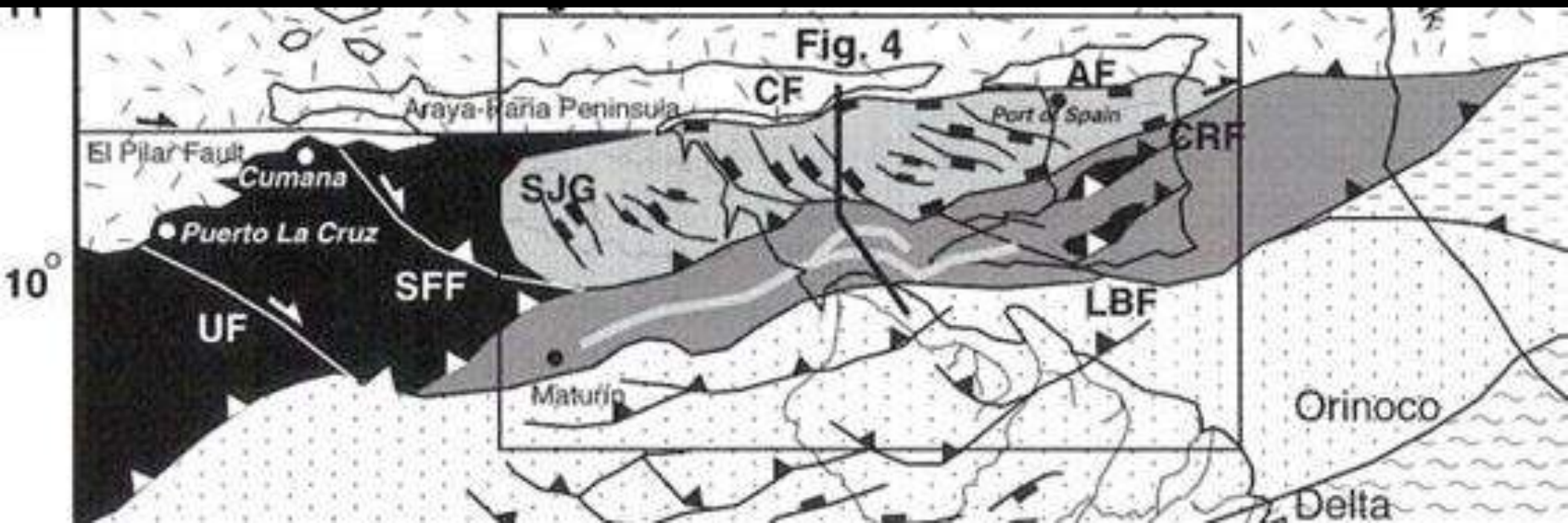
Those in **yellow** account for all of the oil produced within the Fold and Thrust Belt to date

FOLD AND THRUST BELT

GEOGRAPHIC EXTENT

It underlies the entire Caroni Basin, onshore and offshore, where the GOPPA obscures its features. It is partly exposed in the Central Range Uplift, which is a local transpressive zone related to the east-west wrench movement.

To the south, it is overlain in part by the piggy back Southern Basin, but outcrops locally in uplifts like the Rock Dome and Singuineau uplifts. It extends north-eastwards into the eastern offshore of Trinidad and westwards into the western Gulf of Paria and into eastern Venezuela.



FOLD AND THRUST BELT

The Gautier/Naparima Hill-Cipero (!) System

GEOGRAPHIC EXTENT

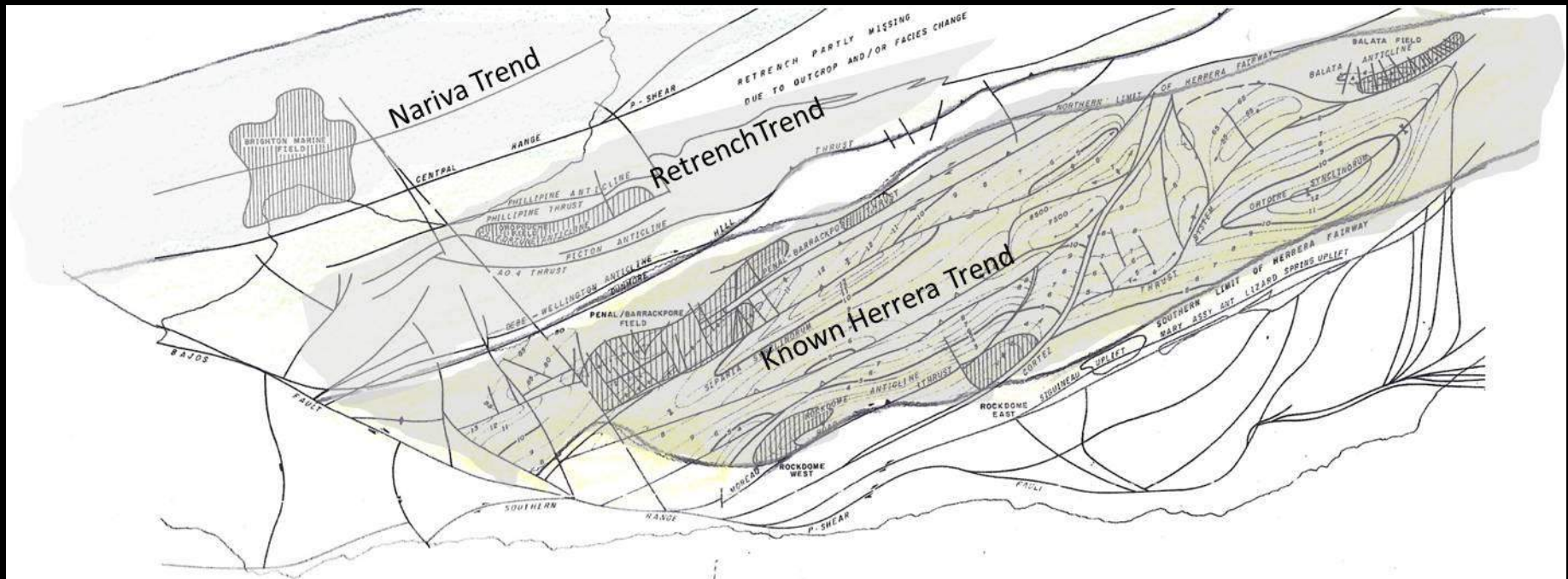
Known to exist onshore southern Trinidad, south of the Central Range and westward into the Gulf of Paria.

The reservoirs extend in three major fairways all trending north-east/south-west to ENE-WSW. They are from north to south, the Nariva fairway, the Retrench fairway and the Herrera Fairway.

The latter can be sub-divided into Cipero and Karamat Herrera fairways.

PRODUCTION

Fields found have to date produced over 250 million barrels of oil.



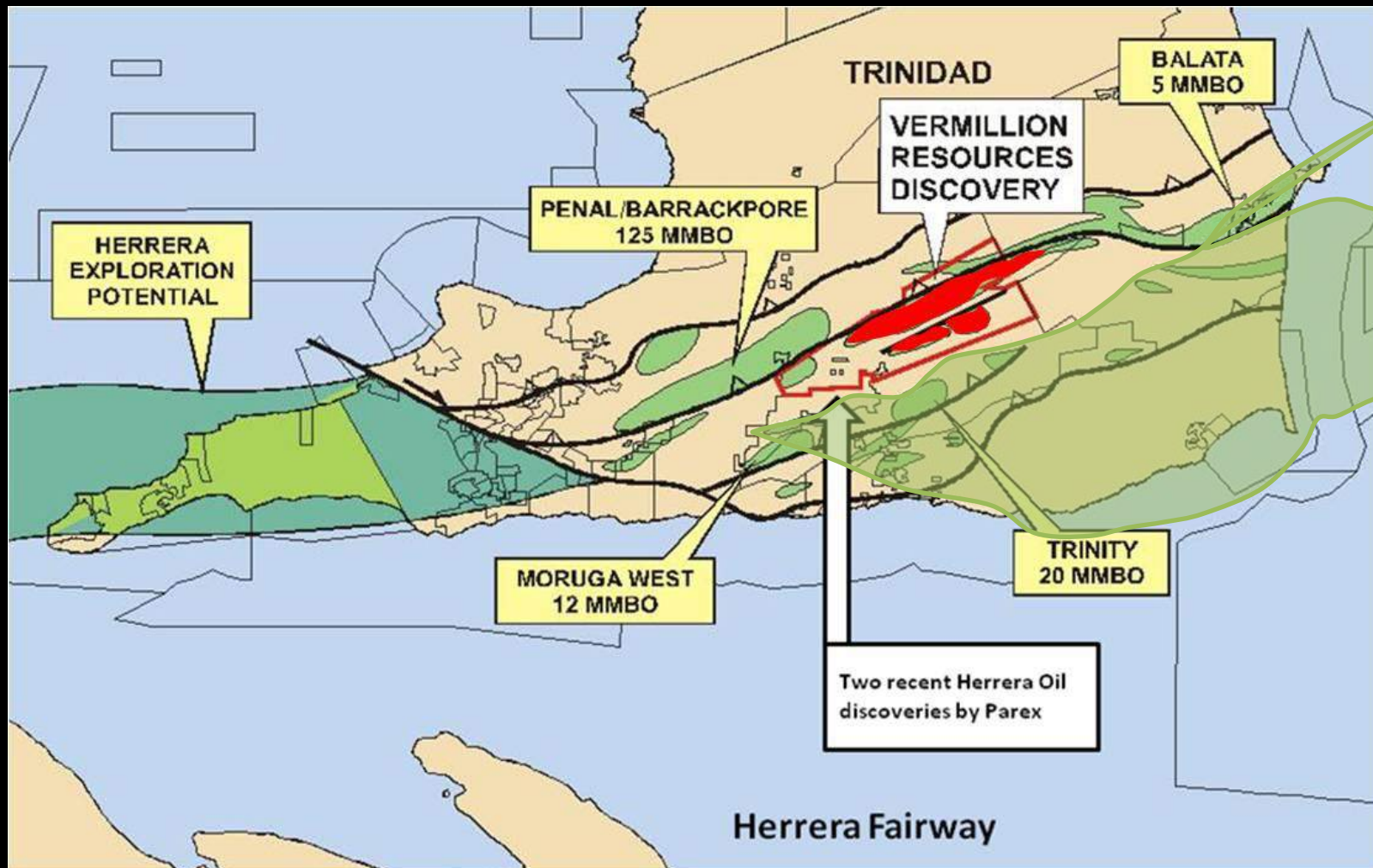
FOLD AND THRUST BELT

The Gautier/Naparima Hill-Cipero (!) System

GEOGRAPHIC EXTENT continued

Potential extensions of these trends have been postulated by this author who has suggested that they could contain significant accumulations of hydrocarbons.

For example he has postulated a westward extension to the Herrera trend west of the Los Bajos Fault and into the western Gulf of Paria



FOLD AND THRUST BELT

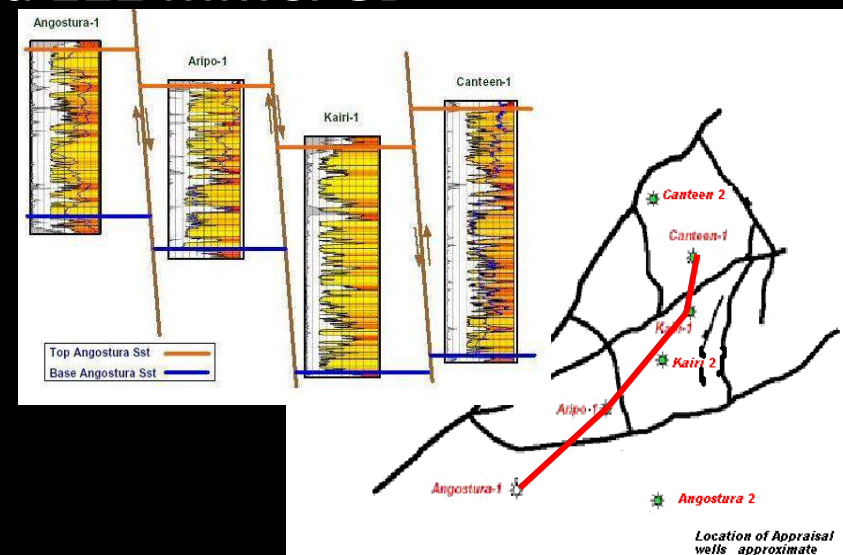
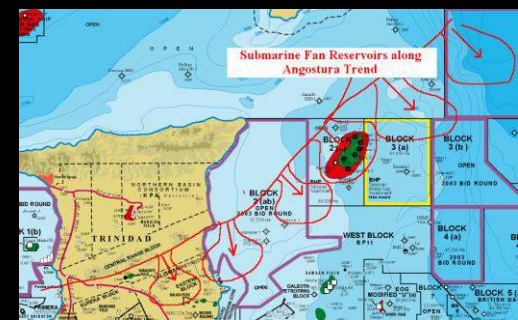
The Gautier/Naparima Hill-Angostura (.) System

GEOGRAPHIC EXTENT

Known to lie within the transpressive zone of the Central Range Uplift, in the eastern offshore of Trinidad, at least in Blocks 2 and 3. It may extend along trend to the south and to the southwest into the onshore of Trinidad. The Angostura sands, which are lower to middle Oligocene, may outcrop in the eastern Central Range, where it is known as the Pointe a Pierre. May be active margin turbidites, or derived from the passive margin.

PETROLEUM PRODUCTION

To March 2015 the Angostura Field has produced over 70 MM barrels oil and is currently producing 8,000 bopd and 222 MMCFGD



FOLD AND THRUST BELT

The Gautier/Naparima Hill-Cuche/Gautier/Naparima Hill (.) Petroleum System

GEOGRAPHIC EXTENT

A hypothetical petroleum system

Postulated to contain sub-marine fan reservoirs within the Caroni and Southern Basins and in the Eastern offshore in the Manzanilla sub-basin.

Not expected to be present in the Central Range where these formations outcrop.

Erlich and Keens-Dumas (2007) have discussed possible distribution of reservoirs and source rocks in the Cretaceous and their maps show the possible extent of this system.

PETROLEUM ACCUMULATIONS

To date the only known oil accumulations are non-commercial ME 15 and Rocky Palace 1

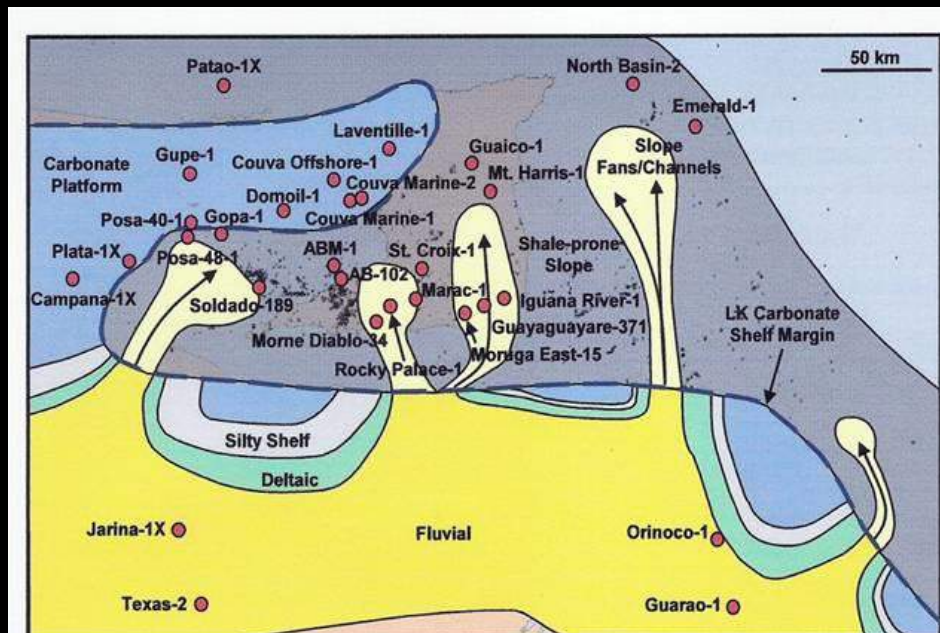


Figure 18. Albian palaeogeography, north-eastern Venezuela and Trinidad.

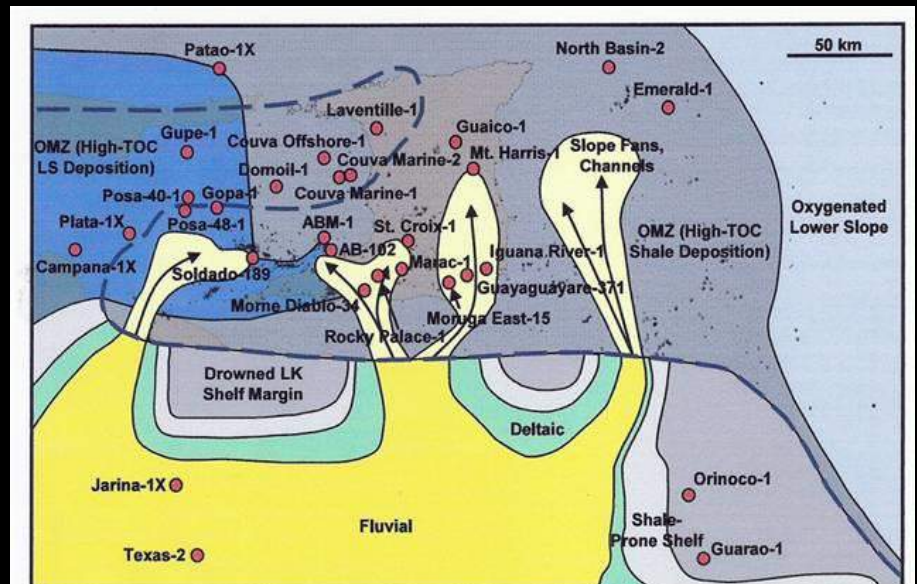


Figure 19. Cenomanian – Santonian palaeogeography, north-eastern Venezuela and Trinidad. Note that the Lower Cretaceous shelf margin was drowned concurrently with the Guayana-Suriname shelf margin at the end of the Albian.

FOLD AND THRUST BELT

The Gautier/Naparima Hill-Naparima Hill (.) Petroleum System

GEOGRAPHIC EXTENT

Fractured argillites expected to be found within the southern area of the Central Range transpressive zone onshore and its eastward and westward extensions offshore, as well as the entire Southern Basin and the Guayaguayare Sub-Basin. Portions missing because of uplift and erosion within the Central Range

PETROLEUM ACCUMULATIONS

No commercial accumulations found to date.

Sub-commercial amounts of light oil were produced in various wells in Guayaguayare area e.g.

Gu 263 70K 15.1 degrees API

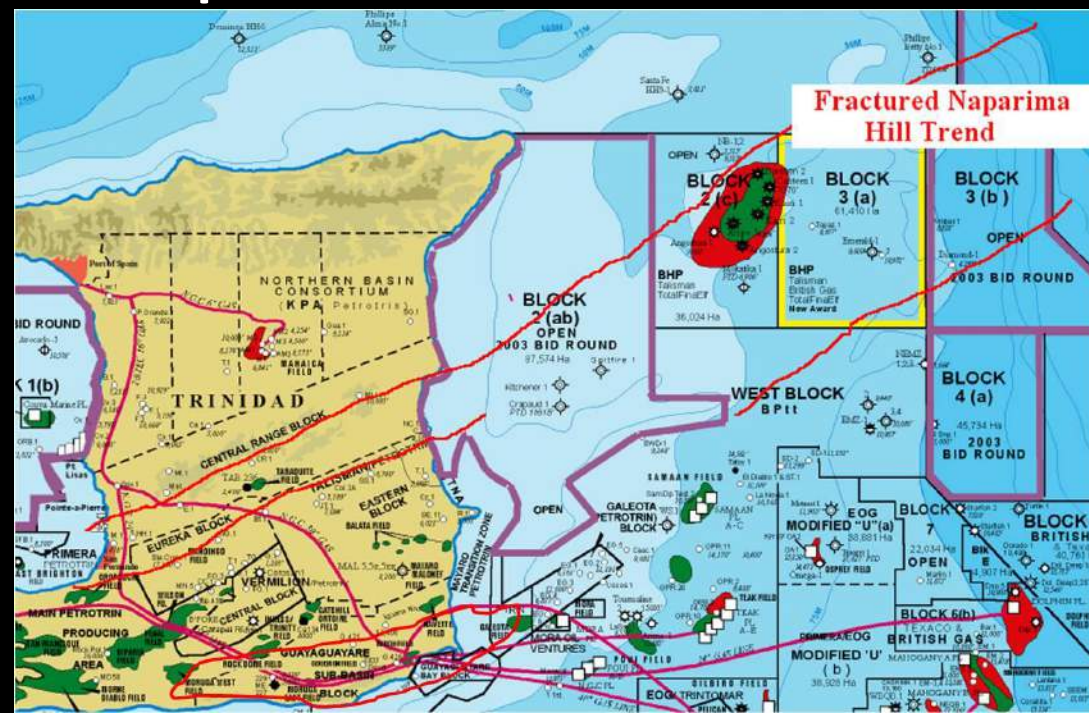
Heavy oil shows in Marabella 1

Minor gas in Esmeralda 1

Gas and condensate in Howler 1

POTENTIAL

Significant unconventional shale oil potential



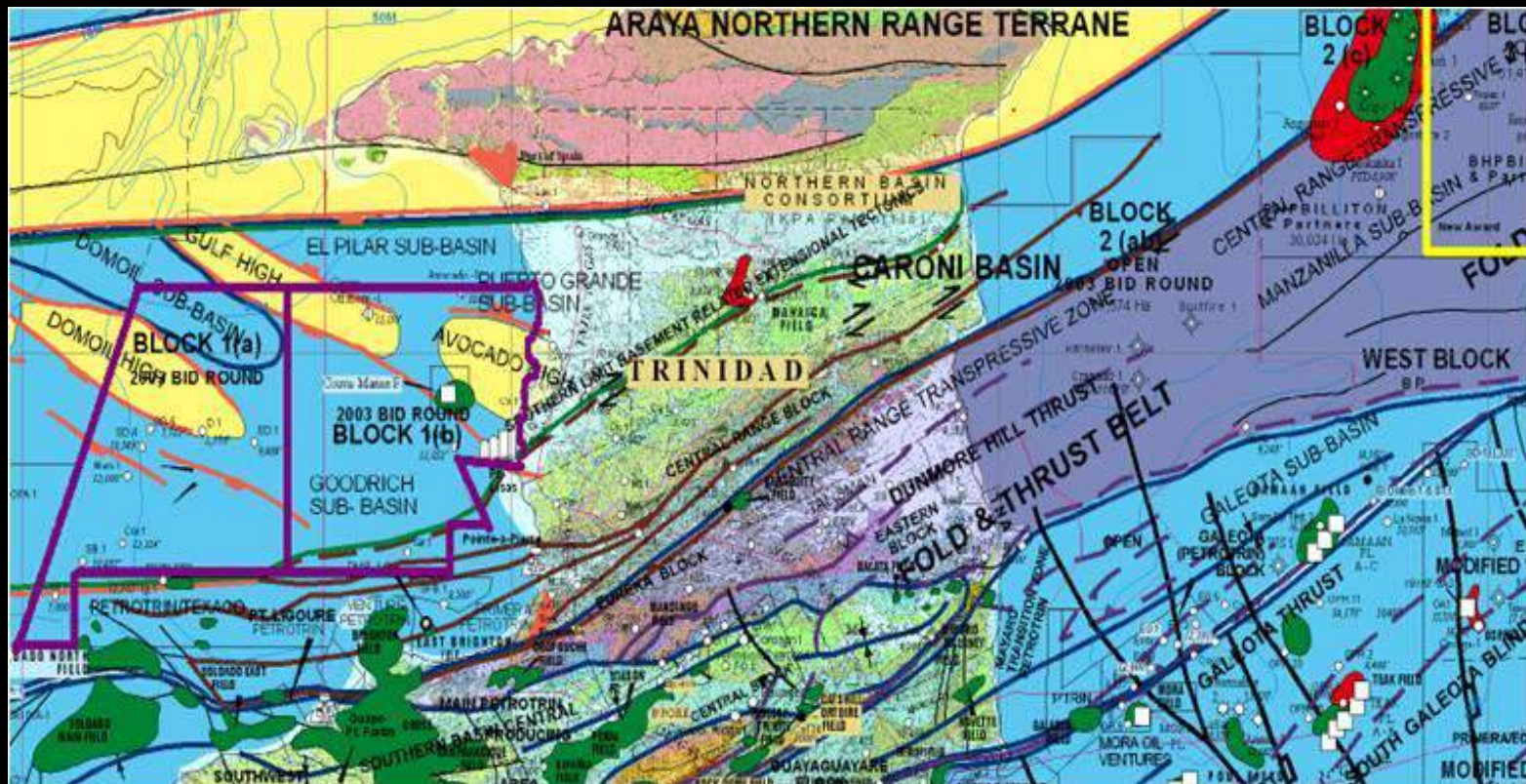
FOLD AND THRUST BELT

The Gautier/Naparima Hill-Pointe a Pierre/San Fernando () System... no correlation between source and reservoir.

GEOGRAPHIC EXTENT... along the flanks of the Central Range Uplift PETROLEUM ACCUMULATIONS

No commercial petroleum accumulations found to date

An Eocene sand tested 4.53 MMCFGD at depths between 4855 and 4867 feet in Emerald 1, Block 3



CARONI BASIN/GULF OF PARIA PULL APART BASIN

Two petroleum systems are known to within the Gulf of Paria portion of the Caroni Basin.

The Gautier/Naparima Hill-Manzanilla/Springvale/Talparo (!) System

The Ciperio-Brasso/Manzanilla (!) Petroleum System

CARONI BASIN/GULF OF PARIA PULL APART BASIN

The Gautier/Naparima Hill-Manzanilla/Springvale/Talparo (!) System

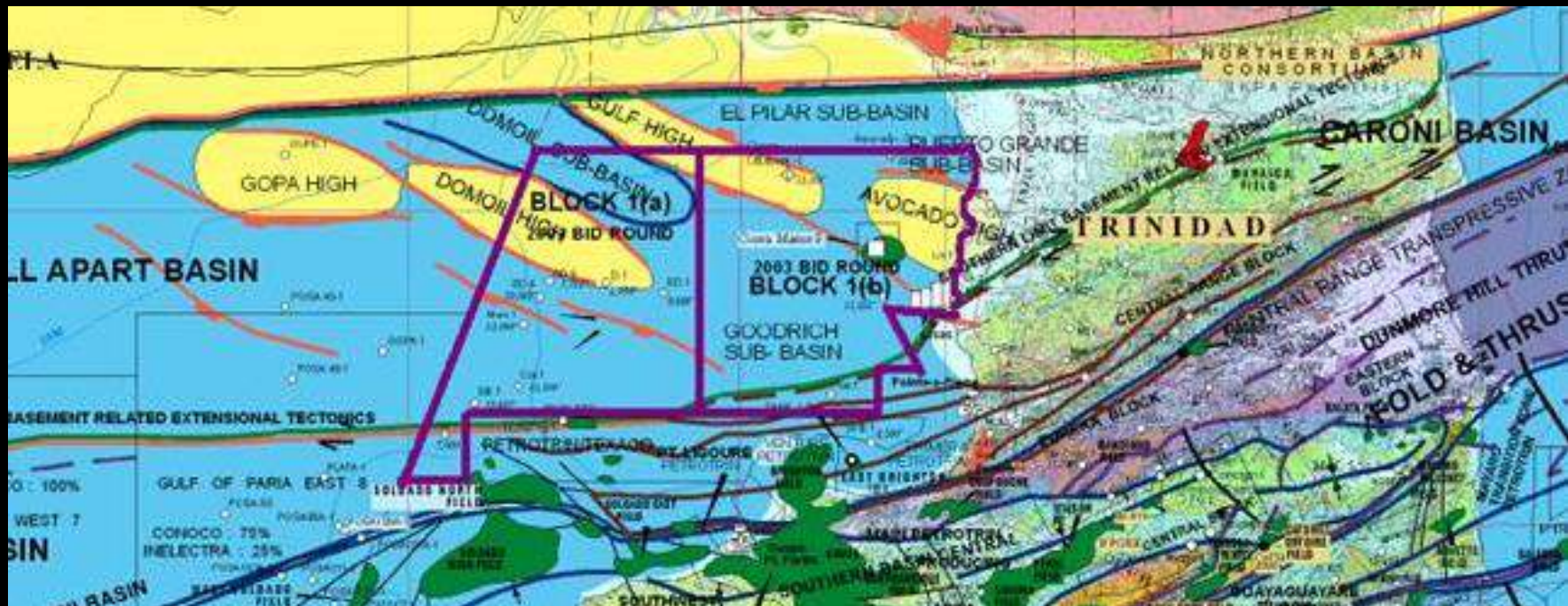
GEOGRAPHIC EXTENT

Found in the southern portion of the Caroni Basin offshore in the Gulf of Paria and. It may extend into the southern portions of onshore and eastern offshore parts of the Caroni Basin.

PETROLEUM ACCUMULATIONS

Commercial production of over 200 million barrels of oil to date.

Large heavy oil accumulations have been found totalling over 1.5 billion bbls OOIP.



CARONI BASIN/GULF OF PARIA PULL APART BASIN

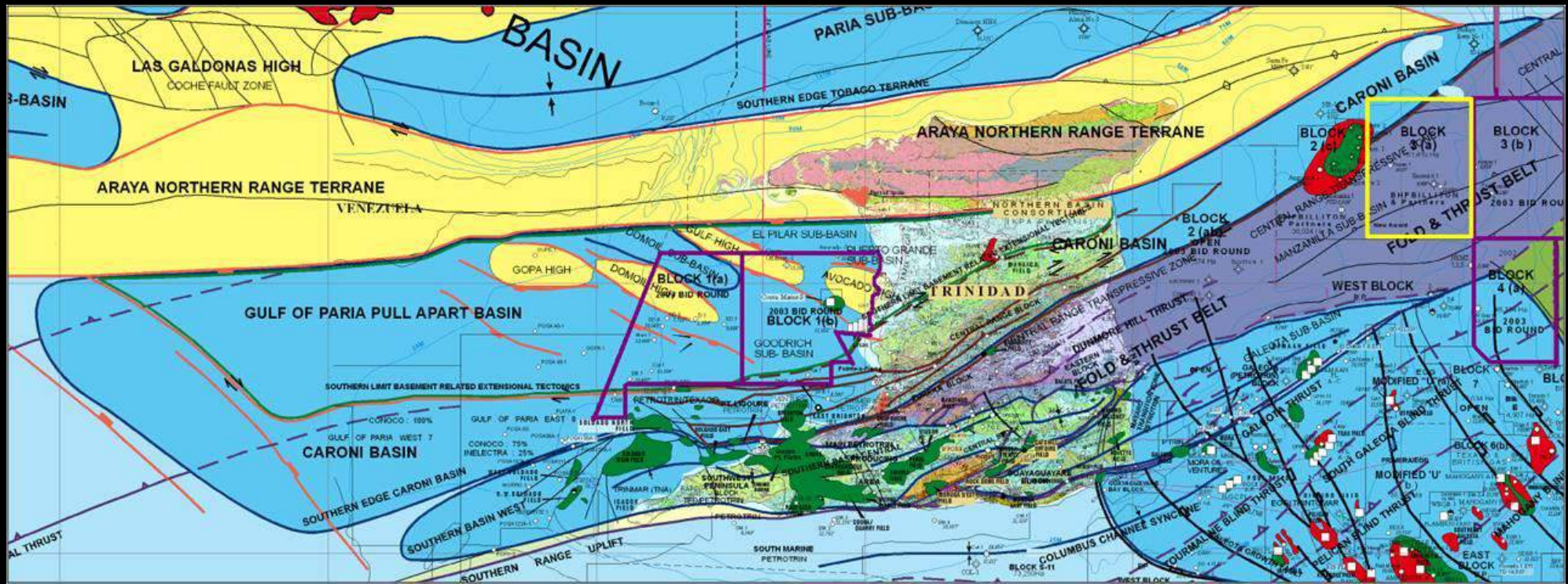
The Ciperro-Brasso/Manzanilla (!) Petroleum System

GEOGRAPHIC EXTENT

Found in the southern portion of the Gulf of Paria Pull Apart Basin onshore in Eastern Venezuela. We postulate its extension into the southern portions of onshore part of the Caroni Basin

PETROLEUM ACCUMULATIONS

Minor amount of very waxy light oil produced from the Couva Marine sourced from Brasso shales



The Cretaceous-Tertiary () Petroleum System

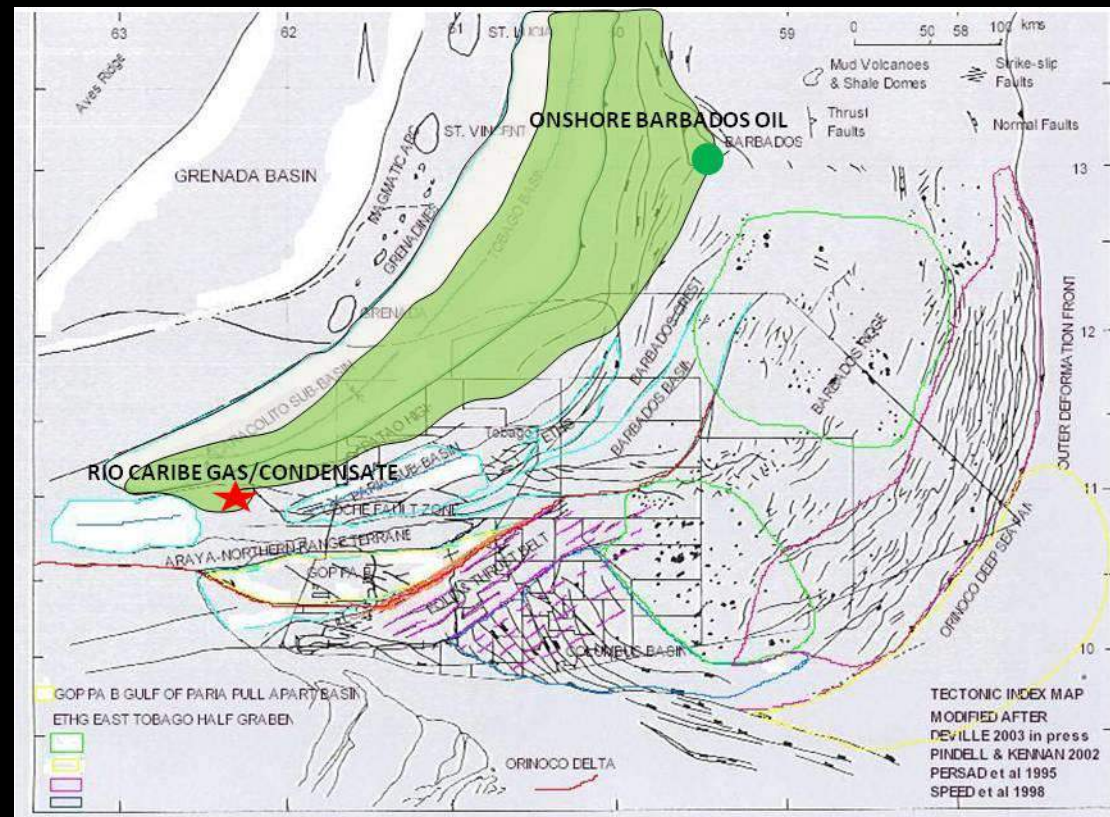
GEOGRAPHIC EXTENT

May be present in the entire Tobago Trough which extends from the Caracolito Sub-basin in the south-west to north of offshore west of Barbados, where oil of an U. Cretaceous marine source is being produced on the island of Barbados.

It may also be present in parts of the Paria and Patao sub-basins.

PETROLEUM ACCUMULATIONS

12 MMBO produced from the Woodbourne field, Barbados



The Tertiary-Neogene () Petroleum System

GEOCHEMICAL ANALYSIS OF HIBISCUS CONDENSATE (Persad 2011)..revealed Tertiary source

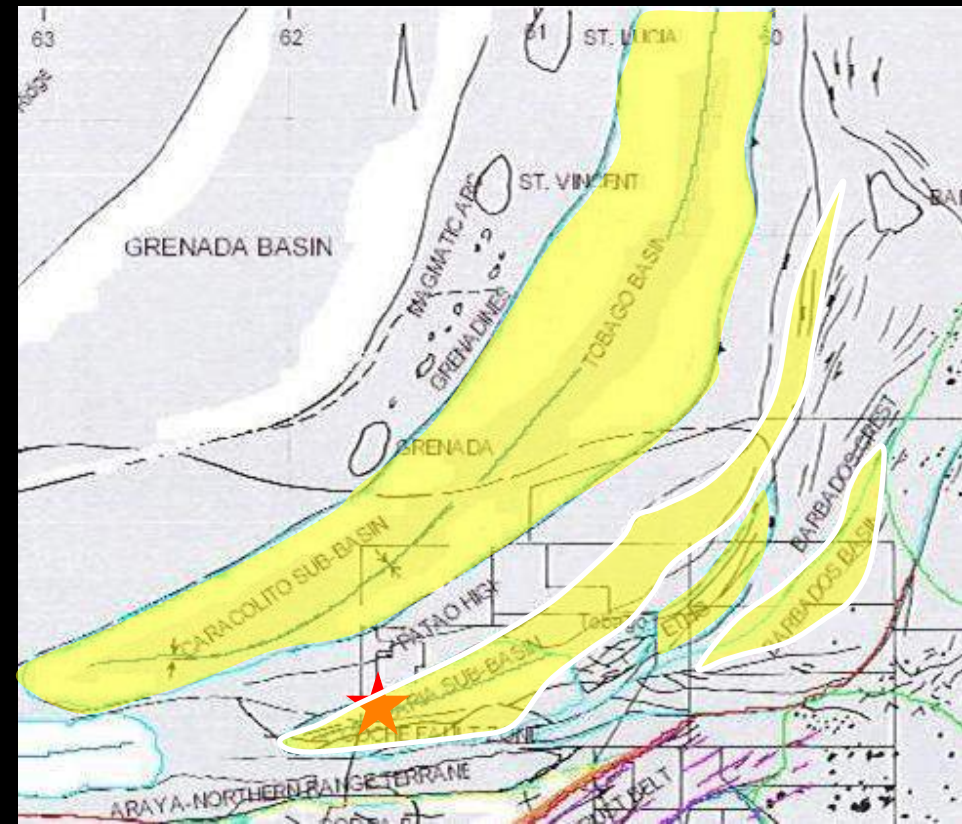
GEOGRAPHIC EXTENT

Known to be present along parts of the Patao High (Hibiscus wells) and in the Rio Caribe and Patao wells

Expected to be present in the Paria Sub-basin

May extend eastward into the East Tobago Half Graben and the Barbados Basin.

Speculated as being present in the entire Tobago Trough which extends from the Caracolito Sub-basin in the south-west to north of offshore west of Barbados.

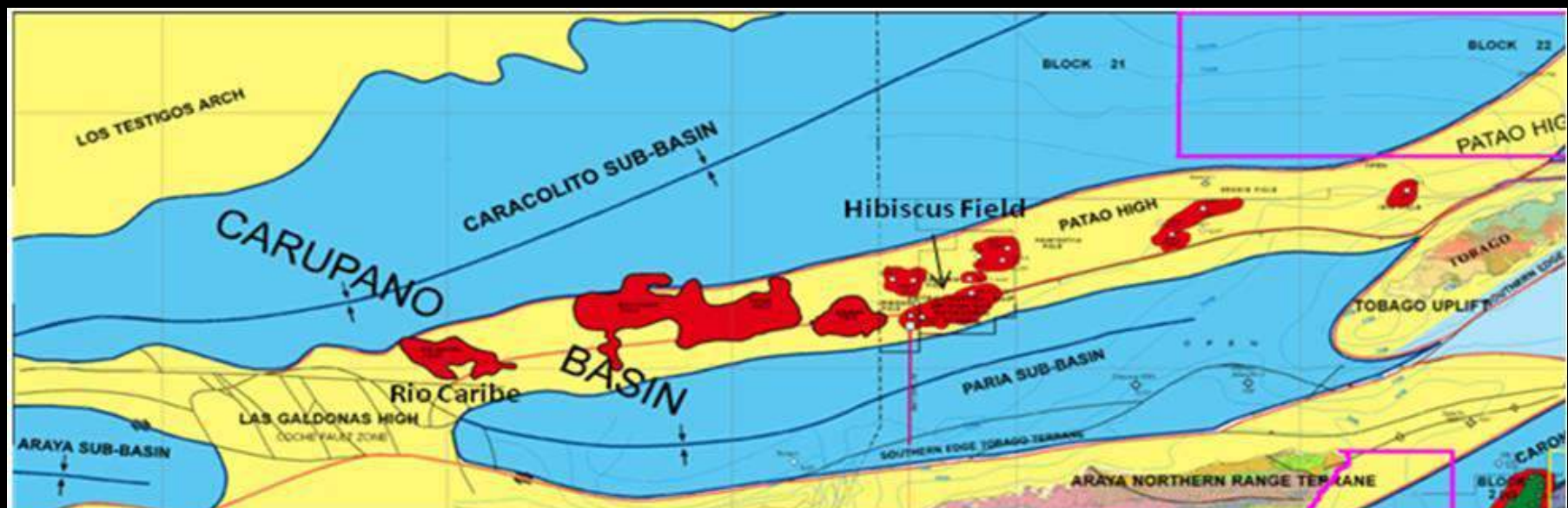


The Tertiary-Neogene () Petroleum System

PETROLEUM ACCUMULATIONS

This system is an exciting possibility as it points to a previously unknown source for liquid hydrocarbons even though it is lean. To this time liquids have been found in the Hibiscus Field (minor) and in the Rio Caribe wells (richer). The Rio Caribe wells tested 10 to 20 MMCFD of gas and 1000 to 2,000 barrels condensate per day

No wells have been drilled into the flanks of the Tobago trough either in Trinidad waters to the south or Grenadian waters to the north but these areas are highly prospective for gas richer in condensate.



OTHER PETROLEUM SYSTEMS

**We have no doubt that other petroleum systems will be identified.
There are three obvious candidates:**

- 1. In the “sub-salt” i.e. below the evaporite known to be present in the Gulf of Paria Pull-apart Basin we can expect pre-Cretaceous reservoirs and source rocks.**
- 2. In the deeper horizons of the East Coast offshore we can expect to find reservoirs and source rocks in the syn-rift sediments of Lower Cretaceous to Jurassic age, similar to what is found to the south-east in the Guyana-Suriname Basin and offshore Angola (which is our probable pre-rift counterpart to the east).**
- 3. In the deeper horizons of the North Coast Marine Area we can expect to find reservoirs and source rocks in the syn-rift sediments of Lower Cretaceous to Jurassic age, similar to what is found to the north-west off-shore Yucatan and in the Gulf of Mexico (which are our pre-rift counterparts to the north and west).**

FUTURE POTENTIAL

**A KNOWLEDGE OF PETROLEUM GEOCHEMISTRY HAS
PROVIDED VALUABLE CLUES FOR FUTURE EXPLORATION
IN TRINIDAD IN THREE MAIN AREAS**

DEEPER POOLS

EXTENSIONS OF TRENDS

FRONTIER AREAS

FUTURE POTENTIAL

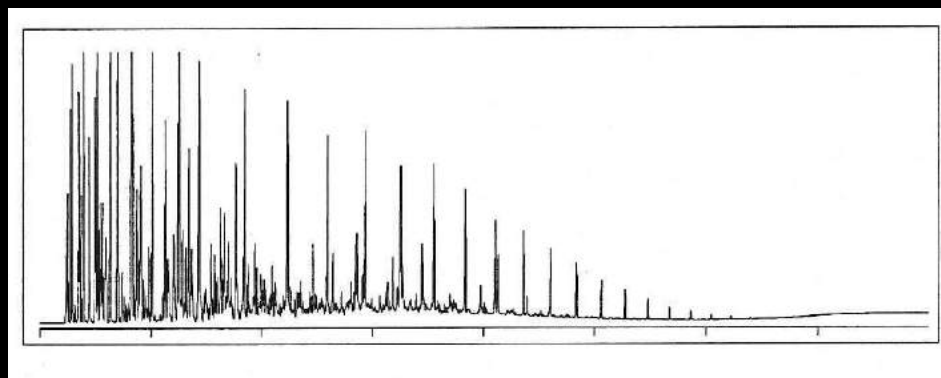
DEEPER POOLS

ECMA...COLUMBUS BASIN

Talukdar et al (1989....26 years ago) predicted deeper pools of residual oil below gas/condensate fields in ECMA

**ALL (MECHANICALLY SUCCESSFUL) DEEPER POOL WELLS IN GAS/CONDENSATE FIELDS IN THE ECMA HAVE FOUND BLACK OIL BELOW
eg MAHOGANY & IMMORTELE/AMHERSTIA**

HRGCs Immortelle Field

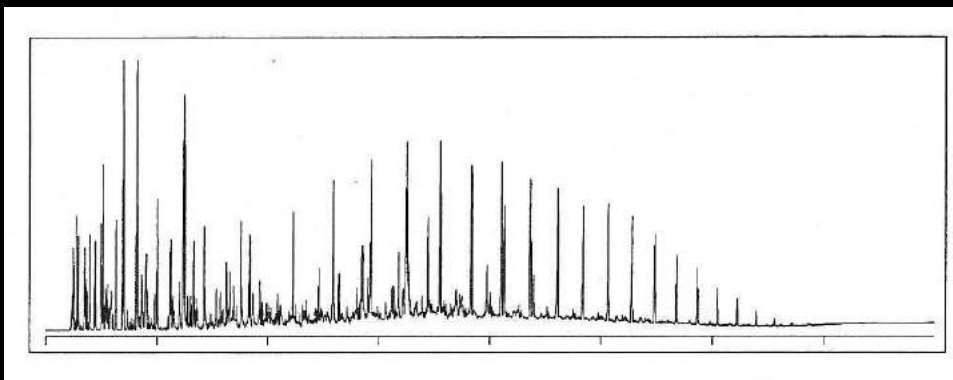


Immortelle Shallow

Very light fractionated condensate

API 49.5 degrees

Rich in light aromatics depleted in heavy waxy hydrocarbons



Immortelle Deep

Heavier condensate

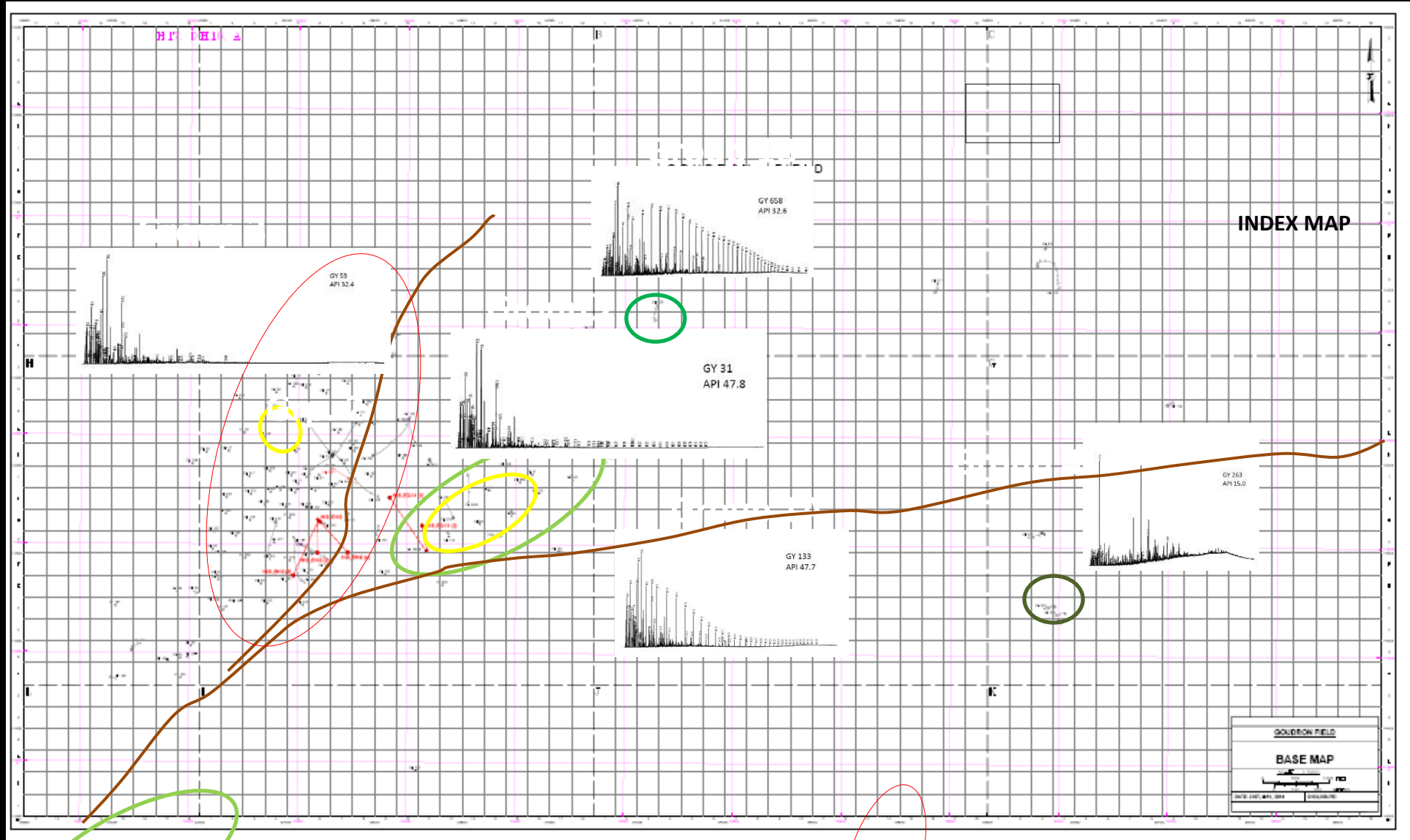
API 42.8 degrees enriched in waxy hydrocarbons.

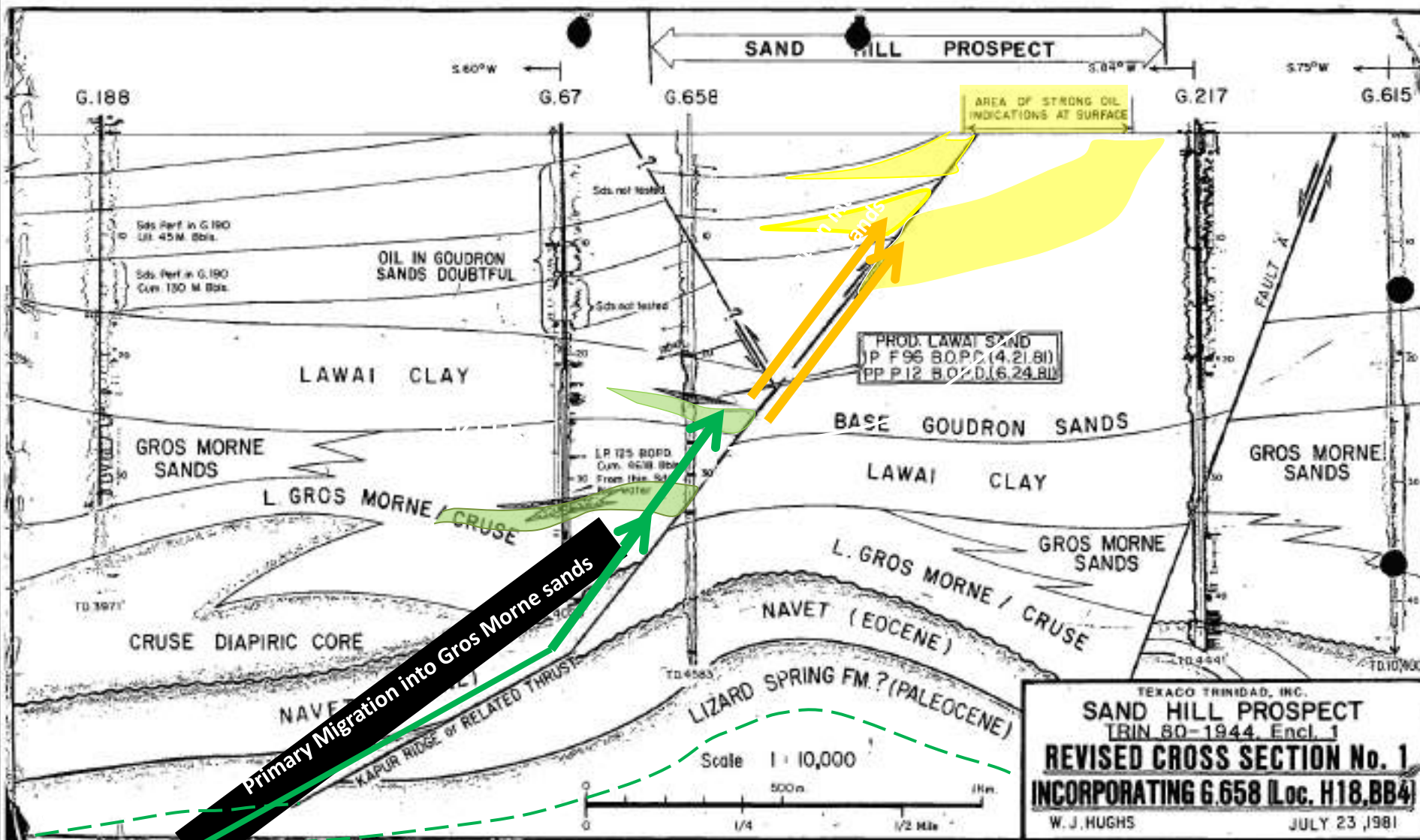
It is probably a residual oil

**FUTURE POTENTIAL
DEEPER POOLS
EASTERN ONSHORE**

Persad, Talukdar and Ritson (2015) have identified deeper pool residual oil prospects (AND shallow evaporatively fractionated condensate prospects) in the Goudron Field based on analyses of fourteen oils from the field area

**MOST WESTERN OILS ARE FRACTIONATED CONDENSATES....POTENTIAL FOR DEEPER
RESIDUAL OILS**
**NORTH-CENTRAL OIL IS RESIDUAL...POTENTIAL FOR EVAPORATIVE CONDENSATE
NEARBY**



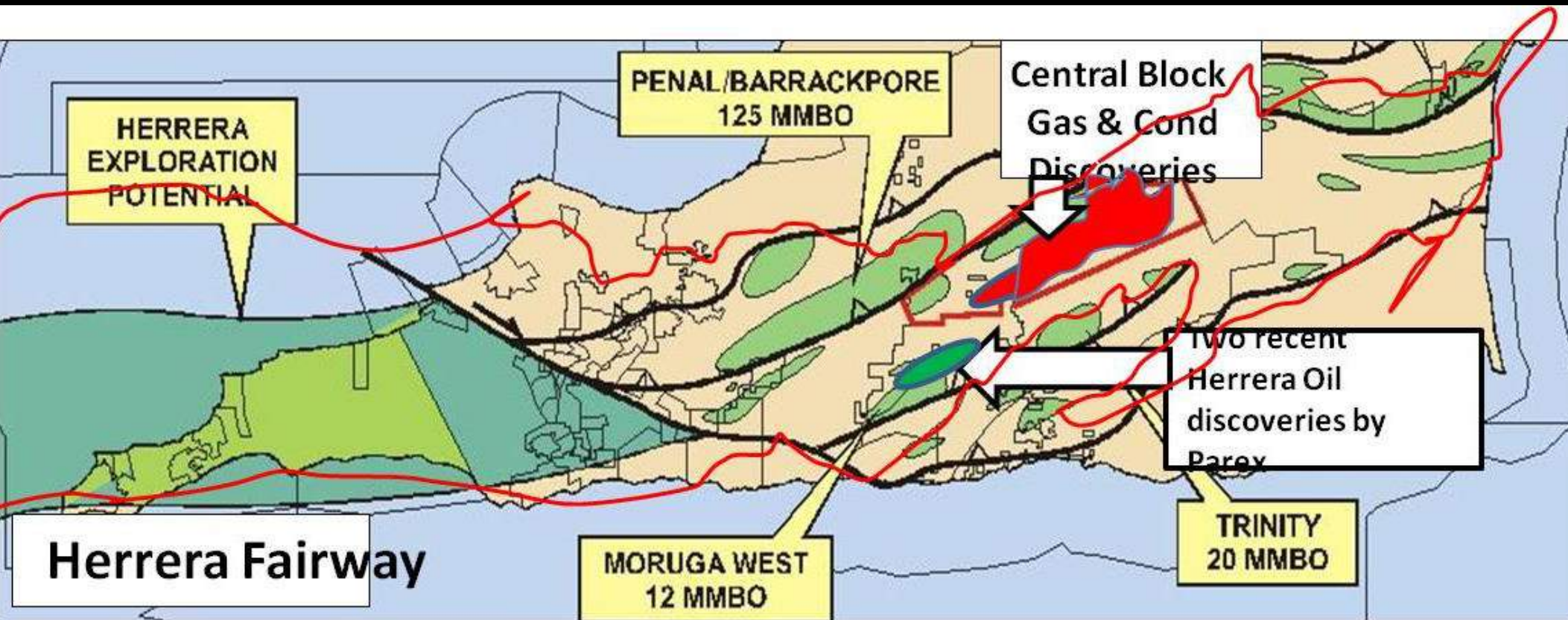


Earlier operator found “strong oil indications at surface” east of Gy 658.
 We interpret primary migration from Up. Cretaceous source rocks into Gros Morne Sands and re-migration (EVAPORATIVELY FRACTIONATED OILS) into Goudron Sands

FUTURE POTENTIAL

SOUTHERN ONSHORE and GULF OF PARIA

DEEP HERRERA POTENTIAL (TURBIDITES)



FUTURE POTENTIAL

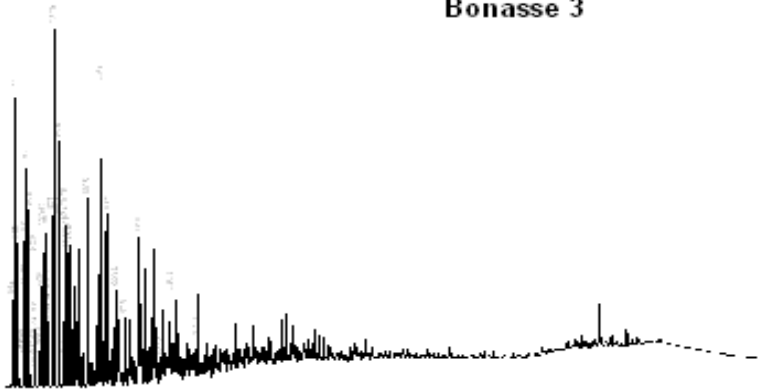
EXTENSIONS OF TRENDS e.g.

SOUTH WEST PENINSULA

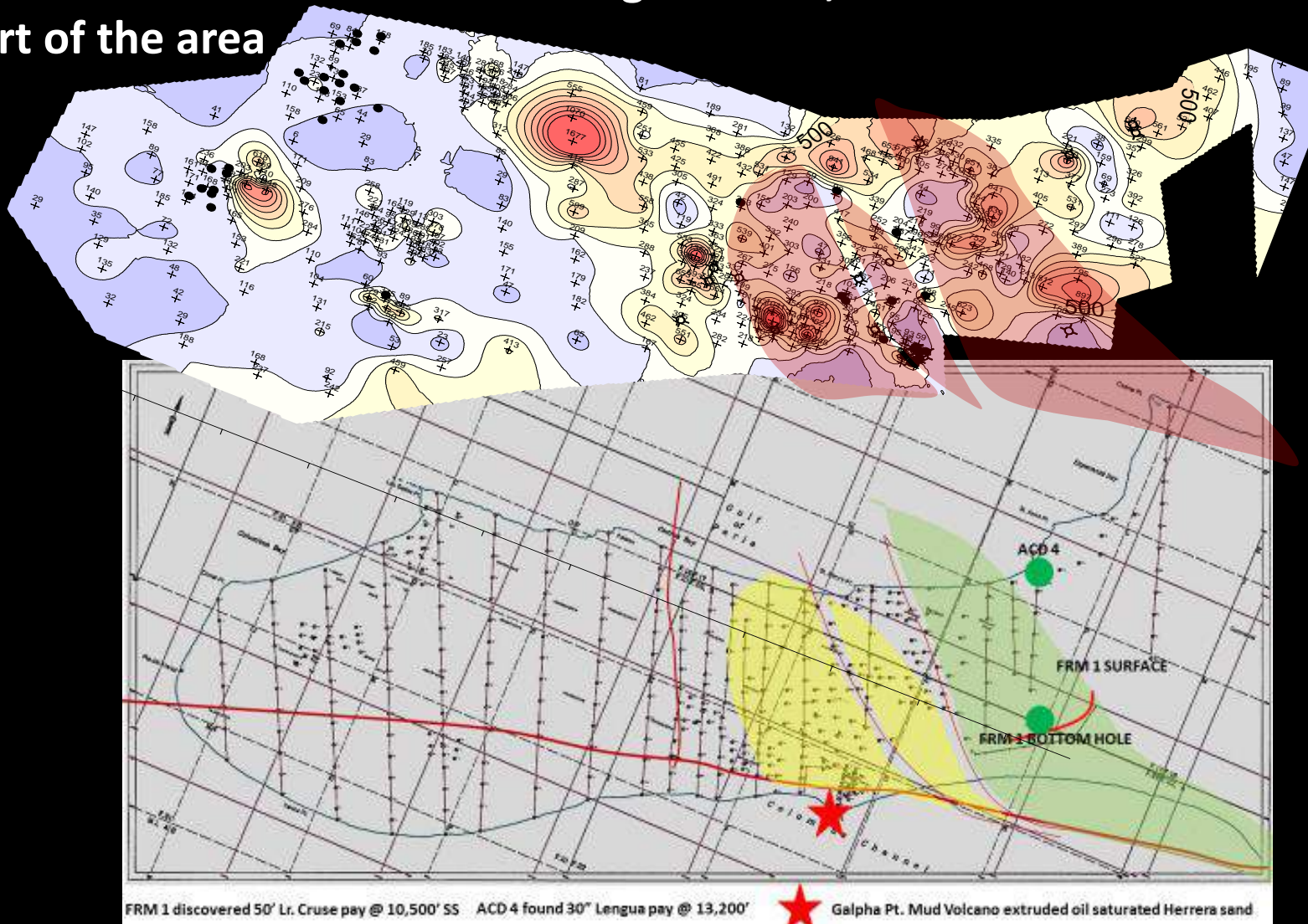
**GEOCHEMICAL ANALYSES OF PRODUCED OILS AND OILS
EXTRACTED FROM MUD VOLCANO EJECTA IN THE SWP
HAVE POINTED TO POTENTIALLY HUGE DEEP OIL
ACCUMULATIONS IN BOLT'S CEDROS ACREAGE**

**SUPPORTED BY 3D SEISMIC, DRILLING
AND NOW BY SURFACE GEOCHEMISTRY**

**Produced oil
Bonasse 3**



**LARGE DEEP PROSPECT IDENTIFIED BY SEISMIC, DRILLING,
PRODUCED OILS,SURFACE GEOCHEMISTRY & OIL EXTRACTED FROM
MUD VOLCANO**



FUTURE POTENTIAL

FRONTIER AREAS

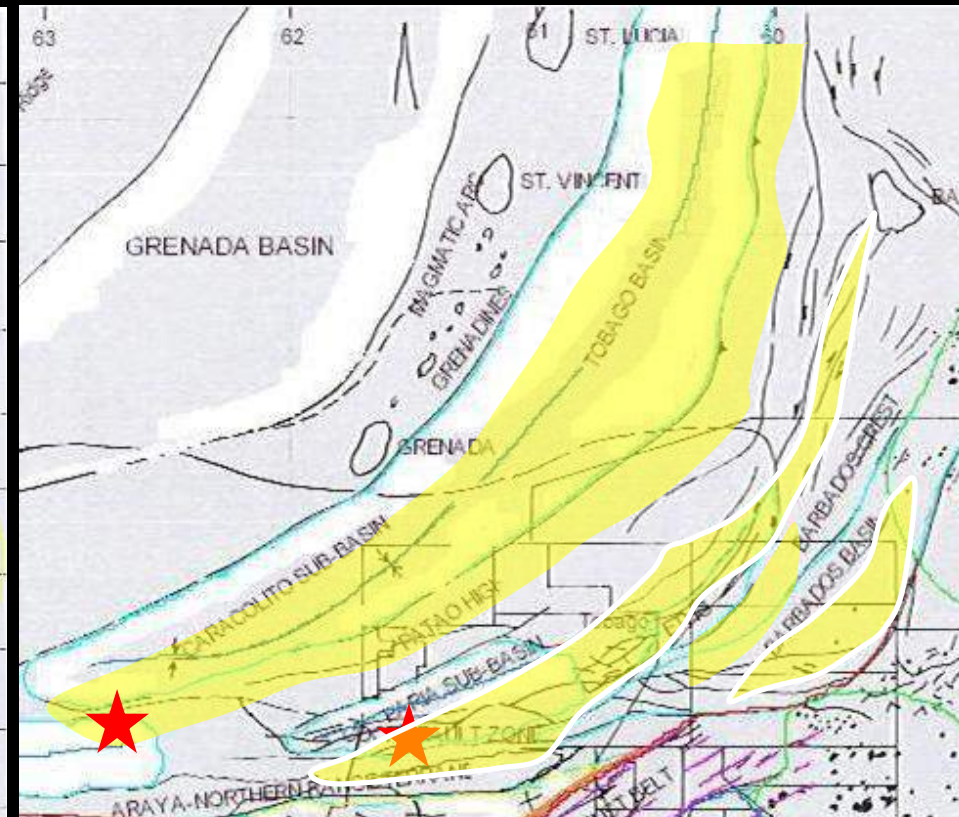
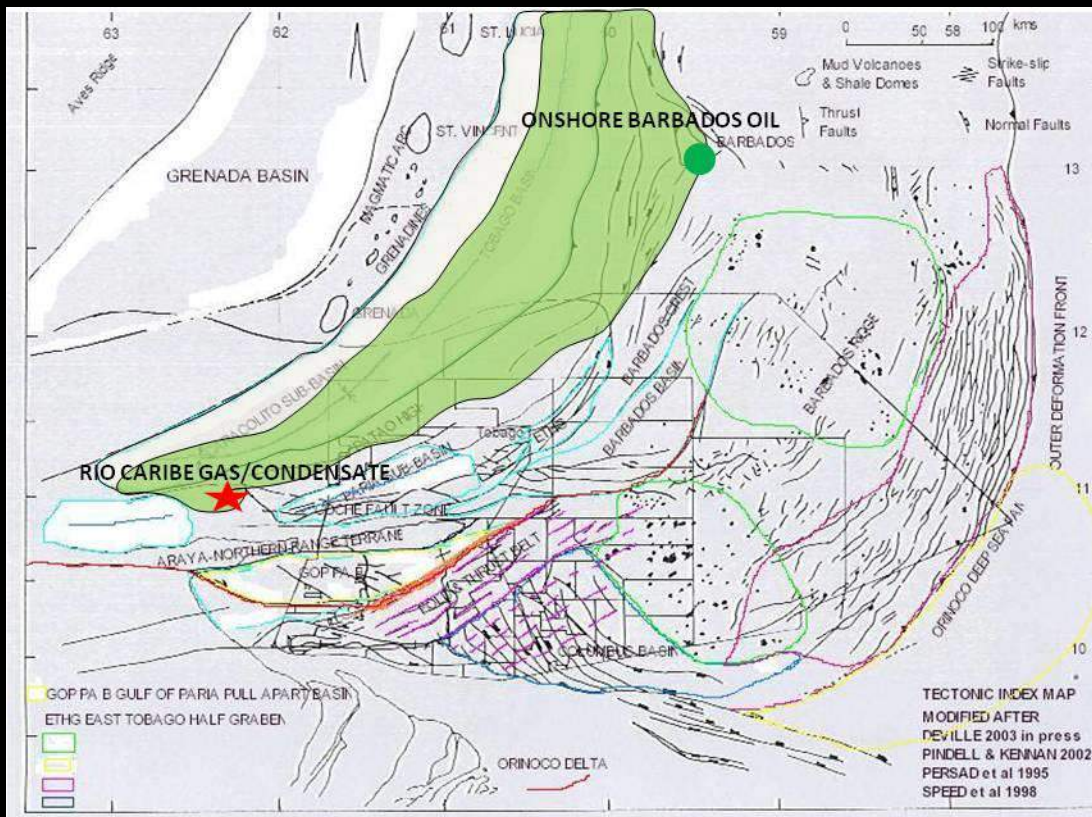
**IDENTIFICATION OF THE PETROLEUM SYSTEMS IN THE
TOBAGO BASINS AND THE ECMA HAS LESSENERD
EXPLORATION RISK**

The Cretaceous-Tertiary () Petroleum System

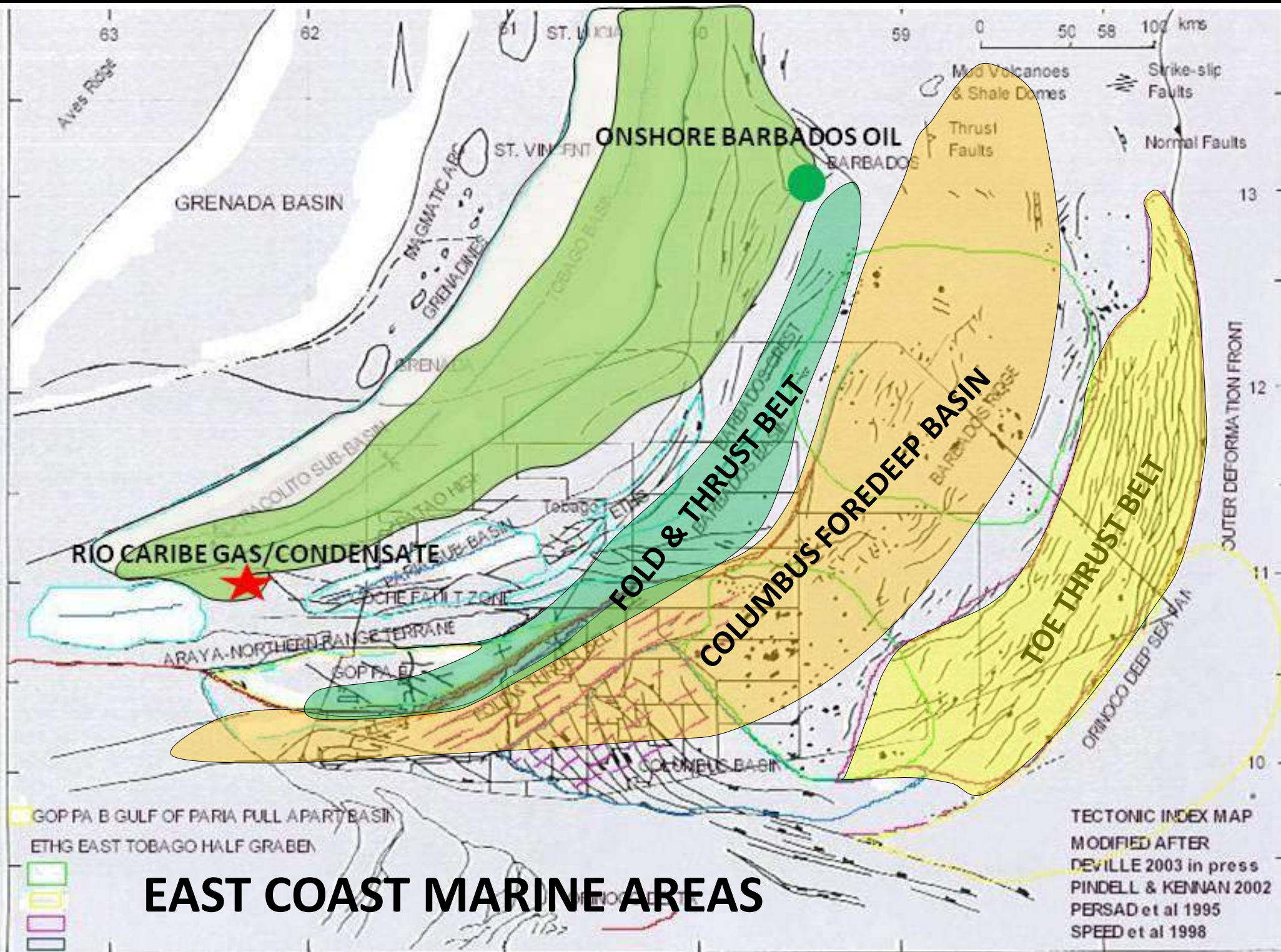
May be present in the entire Tobago Trough

The Tertiary-Neogene () Petroleum System

May be present in the entire Tobago Trough, Patao High, Paria Sub-Basin, East Tobago Half Graben and Barbados Basin



MAJOR POTENTIAL FOLD & THRUST BELT COLUMBUS FOREDEEP BASIN TOE THRUST BELT



QUESTIONS