[PS]Stratigraphic Units in the North Marine Area: How Are They Defined and What is the Nature of the Contacts Between Them?*

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Abstract

The North Marine area is located in the east central part of the Gulf of Paria, on the western coast of Trinidad. Formations penetrated in the area range in age from the Pleistocene Talparo Formation to the early o mid Miocene Brasso and Nariva Formations. Deposition of the Pliocene Manzanilla and Springvale and the Pleistocene aged Talparo Formations was influenced by the availability of accommodation space formed by a mid-Miocene tectonic event, the interaction of the Warm Springs and Los Bajos Faults and subsequent transtensional faulting.

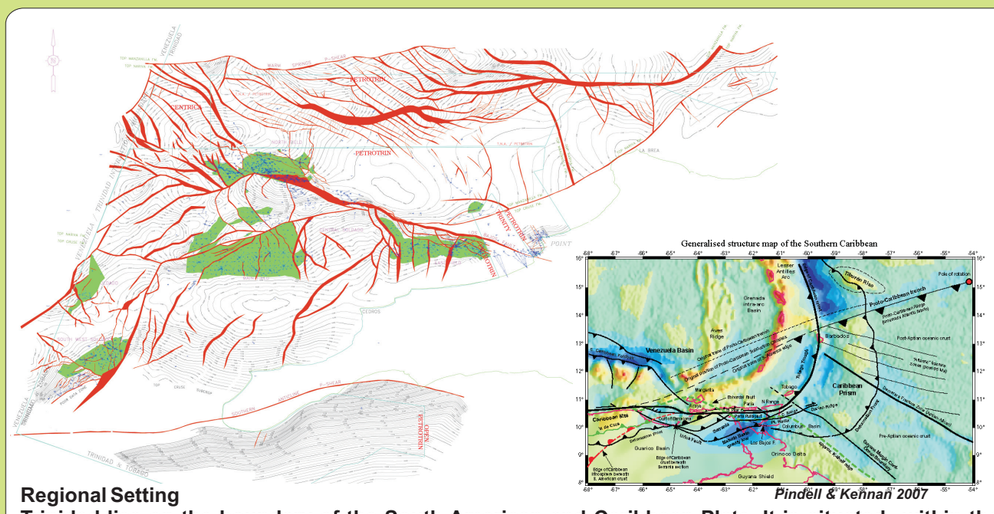
The existing stratigraphic chart for Trinidad is based entirely on outcrops in the onshore of Trinidad. These formations and their members have been defined either on unique lithological or biostratigraphic characteristics. They are also separated by strong angular unconformities.

Examination of well and 3D seismic data in the North Marine area indicates significant differences from the onshore picture. Cuttings and cores from wells indicate that a number of the members of the Springvale and Manzanilla Formations are missing. The 3D seismic data show that both have an angular contact with, and also onlap, the older underlying Miocene sediments. However, while members are "missing" based on onshore data, the 3D seismic data show that the contacts are all planar parallel. Examination of dipmeter data shows no significant change in either the direction or amount of dip across the formation / member contacts.

Onshore, bivalves and gastropods were originally used to define the formations. Later, benthonic foraminifera were used. In the western offshore, foraminifera have also proved useful in identifying tops. The base of the Talparo Formation is defined by the highest occurrence of *Elphidium* 15 and the top by the occurrence of small species of *Rotalia* (especially *Rotalia* 6). The Manzanilla Formation is typified by the presence of *Textularia* 22, *Anomalina* 4 and *Uvigerina* 3 with associated *Rotalia* and *Elphidium*. Pollen has proved useful in identifying the top of the Pliocene and the Miocene.

Stratigraphic units in the North Marine area, how are they defined? and what is the nature of the contact between them?

Nancy Gallai-Ragobar & Curtis Archie

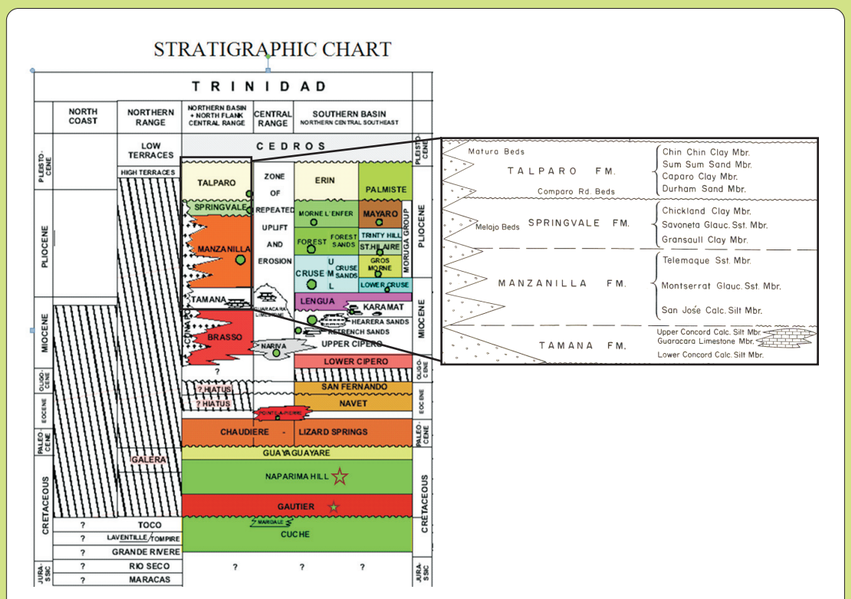


Regional Setting

Trinidad lies on the boundary of the South American and Caribbean Plate. It is situated within the Eastern Venezuelan Basin but more specifically within the Maturin sub Basin.

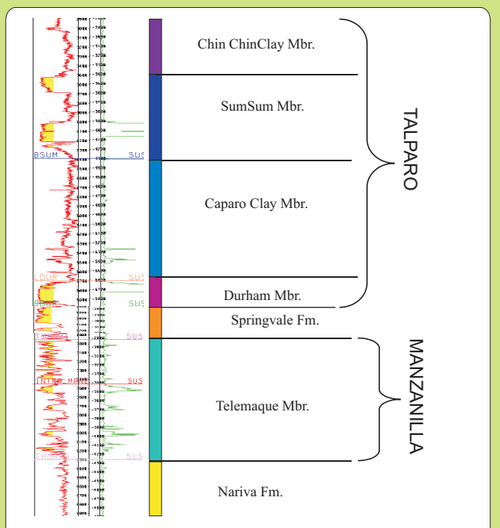
The major structural features within the southern Gulf of Paria are the Southern Anticline, the Erin Syncline, Main Field Anticline, Los Bajos Fault, Jubilee Syncline, Brighton High, NM Master Fault ,the Warm Springs Fault, the NM-5 fault system and the North Marine Syncline.

The faulting pattern within the North Marine block is the result of the interaction the right lateral motion of the Warm Springs and Los Bajos Faults. This has set up a transtensional stress field with has resulted the faults all being extensional and with throw down to the east. As both faults propogated eastward as the Caribbean Plate entered Trinidad, the normal faults were firstly initiated in the west and new faults were formed sequentially from west to east that merged to form a larger fault, the North Marine Master Fault. This fault has significant throw down to the north. These normal faults usually detach near the 10.5 my uncf or within the upper part of the Miocene.



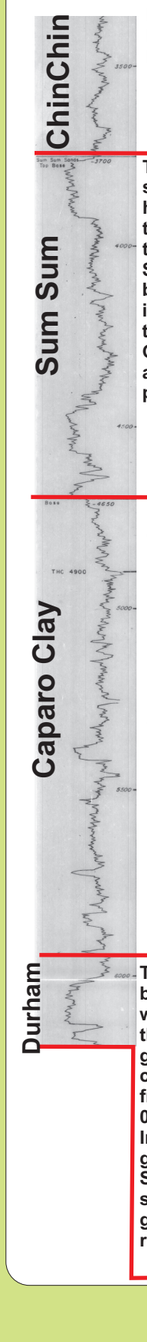
This stratigraphic chart for Trinidad is based entirely on outcrops in the onshore of Trinidad. These Formations and their members have been defined either on unique lithological and or biostratigraphic characteristics. They are also separated by strong angular unconformities. Formations penetrated in the area range in age from the Pleistocene Talparo Formation to the early Miocene Nariva Formation. There are no Cretaceous penetrations, however in the Brighton area just to the east a number of wells have penetrated the Naparima Hill and Guayaguayare Formations.

In the onshore bivalves and Gastropoda were originally used to define the formations, later benthonic foraminifera were utilised. In the Gulf of Paria, forams have also proved useful in identifying tops.



Composite log of a typical well situated in the North Marine area

Examination of well and 3D seismic data in the North Marine area indicate significant differences from the onshore picture. Cuttings and cores from wells have indicated that a number of the members of the Springvale and Manzanilla Formations are missing .



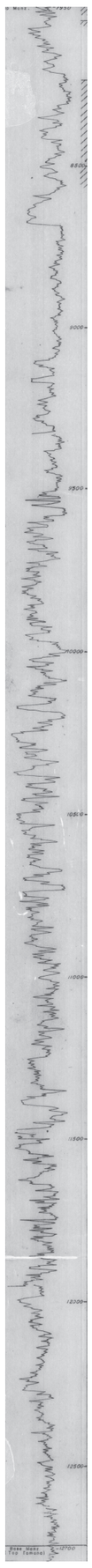
The Talparo Formation as used by Petrotrin is a biostratigraphic unit consisting of "Rotalia/Elphidium faunas with occasional beds of richer more varied assemblages with Nonion, Uvigerina and other calcareous forams. No markers are known to be confined to the formation. The base of the Talparo Formation was defined by the highest occurrence of Elphidium 15, towards the bottom, Miliammina telemaquensis may be found together with calcareous foraminifera. The top by the highest occurrence of certain small species of Rotalia (especially Rotalia 6), often having a distinctive brown preservation.

The Sum Sum traditionally been mapped as a single unit where no seismic exists, however there are two sands that can be mapped and have different geographic extents. The oldest or "lower" Sum Sum typically has a blocky log profile, in places there is a short fining upward top. This is the most laterally extensive unit. The second unit or "upper" Sum Sum extends from the Venezuelan border to the western 1/3 of the block where it disappears based on well data. These sands have been interpreted to have been deposited in a sw -ne trending estuary with tidally dominated sediments. Generally consists of two sands in the North Soldado – North Marine area and can be correlated as far as Barrancones-1 using the ΔIVE pollen zone that is found at the base of the units.

The Caparo Clay Member is made up of light blue – pale grey claystones There are rare thin glauconitic sandy clays with molluscs. Claystones are light – dark grey, non very soluble, soft – occasionally firm – occasionally blocky, occasionally well compacted, non – slightly calcareous, occasionally carbonaceous. Siltstones are light medium grey – brown grey, moderately – well indurated, non calcareous. Limestone are white, tan, grey, blocky, hard brittle, micro – cryptocrystalline – massive, often abundant free calcite and fossil fragments. Sand s clear, tan, translucent, opaque, very fine grained – fine grained, moderately – well sorted, poor – moderately well consolidated, sub rounded – sub angular, occasionally sucrosic, generally loose, present as thin films ccasionally up to 50%. slightly calcareous and gypsiferous.

The Durham can be sub-divided into two members a lower unit dominated by a sand with a blocky log character and an upper unit with thin sands with a spiky log character. The base of the blocky sand is considered to be the base of the Durham. In the western part of the block ,sands are fine - vf grained , well sorted and sub-angular, accessory mineral include common carbonaceous material, rounded – sub angular siderite shell fragments, rare dark pyritic grainsporosity ranges from 20.5 -32.5, perms 0.5 – 35 md., claystones are pure , non calcareous, hard, greenish grey.

In the middle of the block sediments are dominantly claystone green – grey, firm, blocky – slightly fissile, non-calcareous, pyrite carbonaceous. Siltstone- grey, firm, very carbonaceous, argillaceous, occasionally sandy, slightly – non calcareous. Sand off white – light grey, very fine grained, non-calcareous, moderately hard, occasionally loose, clear, sub rounded, pyrite, slightly carbonaceous.



The Manzanilla Formation is typified by the presence of Textularia 22, Anomalina 4 and Uvigerina 3 with associated Rotalia and Elphidium .

According to Kugler (2001)The Manzanilla Formation can be subdivided into four Members , however only the Telemaque Sand Member has been identified in any well.

- It can be subdivided into two units a lower unit with thick sands and minor lignites. The upper unit contains thin coarsening upwards sands and thicker lignites. Telemaque faunas are typified by floods of Miliolid 6 with levels of Rotalia and Elphidium. Haplophragmoides 16 often occurs in the lower part

The Montserrat Glauconitic Sandstone - a bivalve and Gastropod rich sandstone with glauconite pellets. In outcrop this unit is only about 10'.

The Los Atajos Silt and Conglomerate.

North of the North Marine Master Fault, thin limestones are found in the lower part of the Telemaque. These limestones are, white – grey, moderately hard – hard, micro crystalline, very argillaceous, dense, silty or conglomeratic, white, black, spotty, massive, medium – coarse grained, well consolidated, generally homogeneous, sample consists of limestone fragments, silts and lignites. Sands are sand clear , loose very fine grained, sub rounded – sub angular, light grey, very fine grained- fine, friable, moderately – poorly consolidated, very calcareous – non calcareous, carbonaceous – glauconitic, pyrite, loose fossils. Porosity ranges from 17.6 – 26%. Claystones are dark grey – grey, firm – very firm-moderately hard, blocky moderately fissile, non – moderately silty, slight – non carbonaceous, slightly calcareous. Lignite black hard, dense, blocky shiny, anthracitic lustre. anhydrite, cream, white, hard, granular, pyritic. Fossil fragments highly fragmented unrecognizable, pearly lustre, bivalves.

South of the North Marine Master Fault ,sands from west to east are are very fine grained, silty, dirty with shale inclusions, non calcareous, porosity ranges from 31.3% -36.1%, perms 350 – 1550md, abundant glauconite and reworked Nariva fauna are present. firm - soft, very fine grained, with shale & lignite inclusions, non calcareous, accessories muscovite and carbonaceous material , porosity ranges from 24.8 -35.9, perms 37 – 1480md. Shale – silty, non calcareous, olive grey, rare muscovite and forams.

Some wells have described a Tamana "Formation" that is characterised by a rich calcareous assemblage including Angologenerina1, Cibicides 4, Bolivina 21, Uvigerina 3, Cassidulina 3, together with Amphistegina spp and Planorbulinella spp. It varies from a firm, very fine grained sand, very shaly, very calcareous, very fossiliferous with mineral fluorescence in NM-8 to a limestone in NM-3.

The Brasso is defined by its rich foraminiferal content together with abundant molluscs. 3,000' was drilled in NM-1, elsewhere it averages 700'. is a hard calcareous medium grey claystone up to 2500' thick or completely absent due to erosion.

The Nariva in the Gulf of Paria is a biostratigraphic unit containing a distinctive arenaceous assemblave characterised by Valvulina 6 and Tritaxilina 1. It may contain varing porportions of calcareous fauna and as such may in certain areas be regarded as transitional to the Brasso. it ranges from the Globigerina 24/32 zone to the Globigerina 31/100b zone. It has been penetrated by 3 north marine wells NM-1, NM-4 and NM-9. In NM-4 a thickness of 6,900' was penetrated, probably due to repetition. The interval is claystone dominated with a few well developed quartzose sands. In NM-4 a thickness of 6,900' was penetrated the shale has been described as slightly silty, slightly calcareous – non calcareous, hard light brownish-grey.

The Top Springvale is defined on the first drilled occurrence of Elphidium 15. Elphidium 1/3 and pyritised molluscs and Ostracods are also characteristic of this fauna.

The Springvale Formation is divided into three members :

Chickland Clay Member ,an unctuous blue-grey clays, silts and sandy clays, thin glauconitic sand and lignitic sandy clay. There are occasional thin "conglomerates" made up of Oyster shells.

Savaneta Glauconite Sandstone Member - The Savanetta Glauconitic Sandstone is at its maxiumum thickness in outcrop only 10'. It is a yellowish brown limonitic calcareous coquina of sandy aspect with broken shells and entire molluscs.

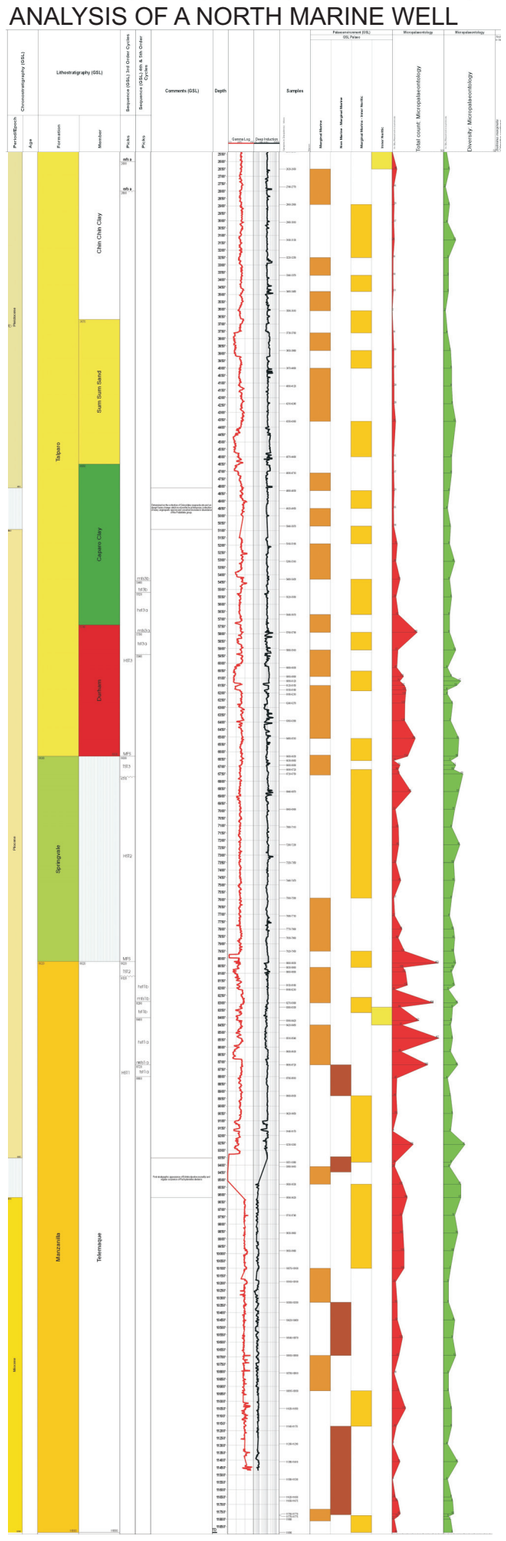
Gransaull Clay Member - The Gransaul Clay is a monotonous sequence of generally fine grained sand, sandy clay and clays, with the clays being blue-grey, slightly calcareous and gypsiferous. There are occasional thin glauconitic sands rich in fossils.

These members are certainly not recognisable in the Gulf of Paria wells.

North of the North Marine Master Fault lithologies include sands that are white - light grey, tight, occasionally dirty, very fine grained – moderately Sand- loose, clear , translucent, , sub rounded – sub angular moderately – well sorted, moderately – well cemented, friable, occasionally free quartz, non-calcareous, carbonaceous, glauconite, trace limestone, hard, brown, white micro crystalline, trace silt, trace shell fragments.

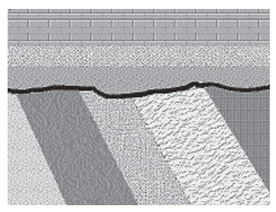
Claystones are light grey – green grey, soft occasionally soluble, non-calcareous, blocky – slightly fissile, pyrite nodules, occasional shell fragments. Shales are green – grey, non - very calcareous, soft – very firm, occasionally silty, trace pyrite, abundant shell fragments, gastropods and bivalves. Siltstones are light grey, poorly – moderately indurated, slightly – very carbonaceous, arenaceous – argillaceous, occasionally pyrites.

HIGH RESOLUTION BIOSTRATIGRAPHIC ANALYSIS OF A NORTH MARINE WELL

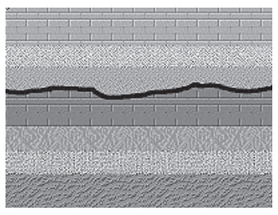


An unconformity is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.

An angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers. The whole sequence may later be deformed and tilted by further orogenic activity. e.g. 1.8 my & Top Forest.

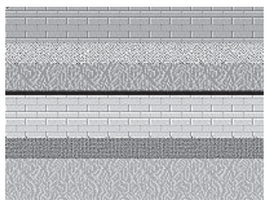


A disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition. Disconformities are marked by features of subaerial erosion.

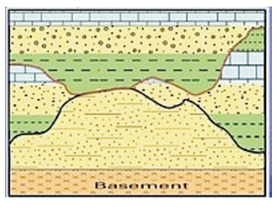


A paraconformity is a type of unconformity in which strata are parallel; there is little apparent erosion and the unconformity surface resembles a simple bedding plane. It is also called nondepositional unconformity or pseudoconformity.

http://en.wikipedia.org/wiki/Unconformity



. Biconformity is an unconformity surface that represents two known unconformity surfaces of different ages but directly overlying each other as though they both were a single unconformity surface.



Stratigraphic units in the North Marine area, how are they defined? and what is the nature of the contact between them?

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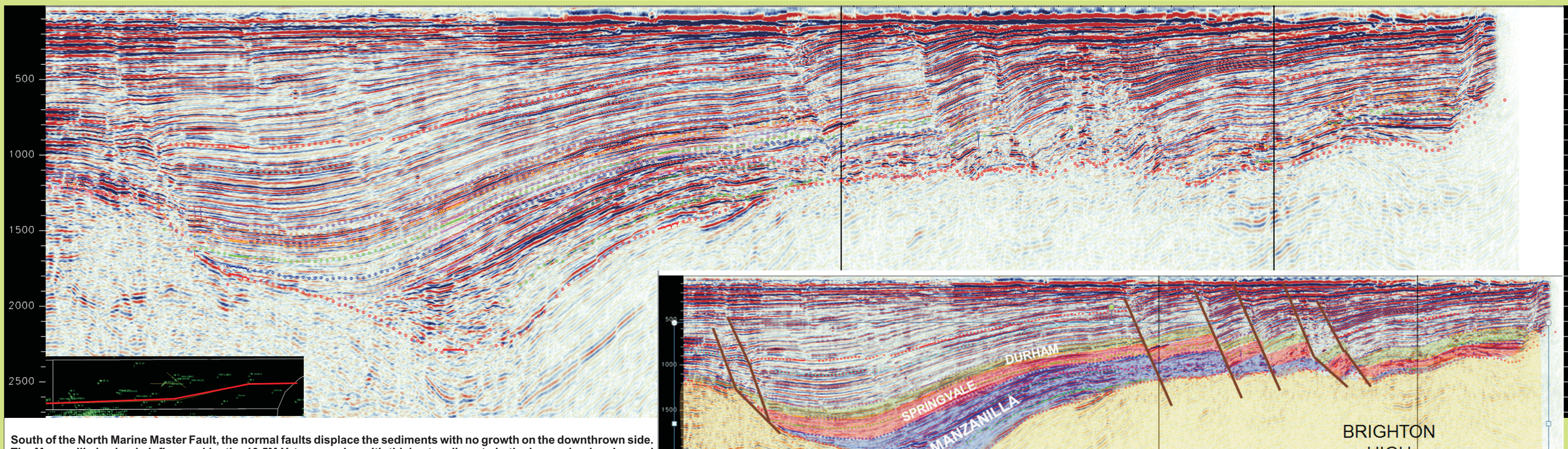
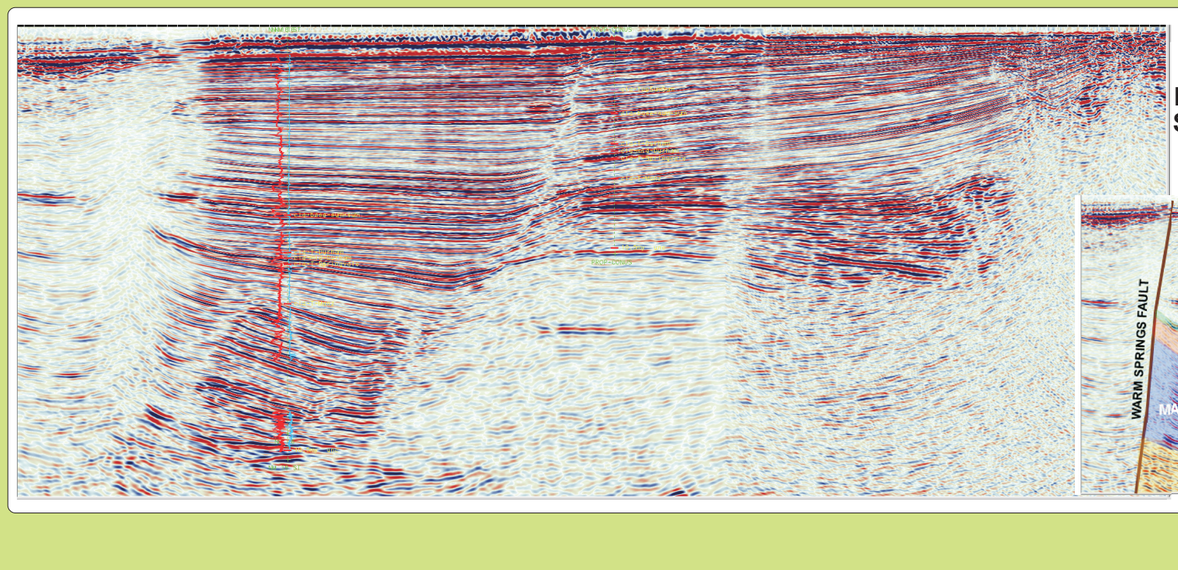
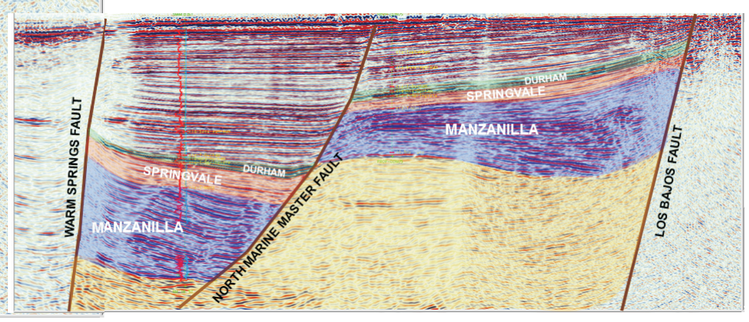


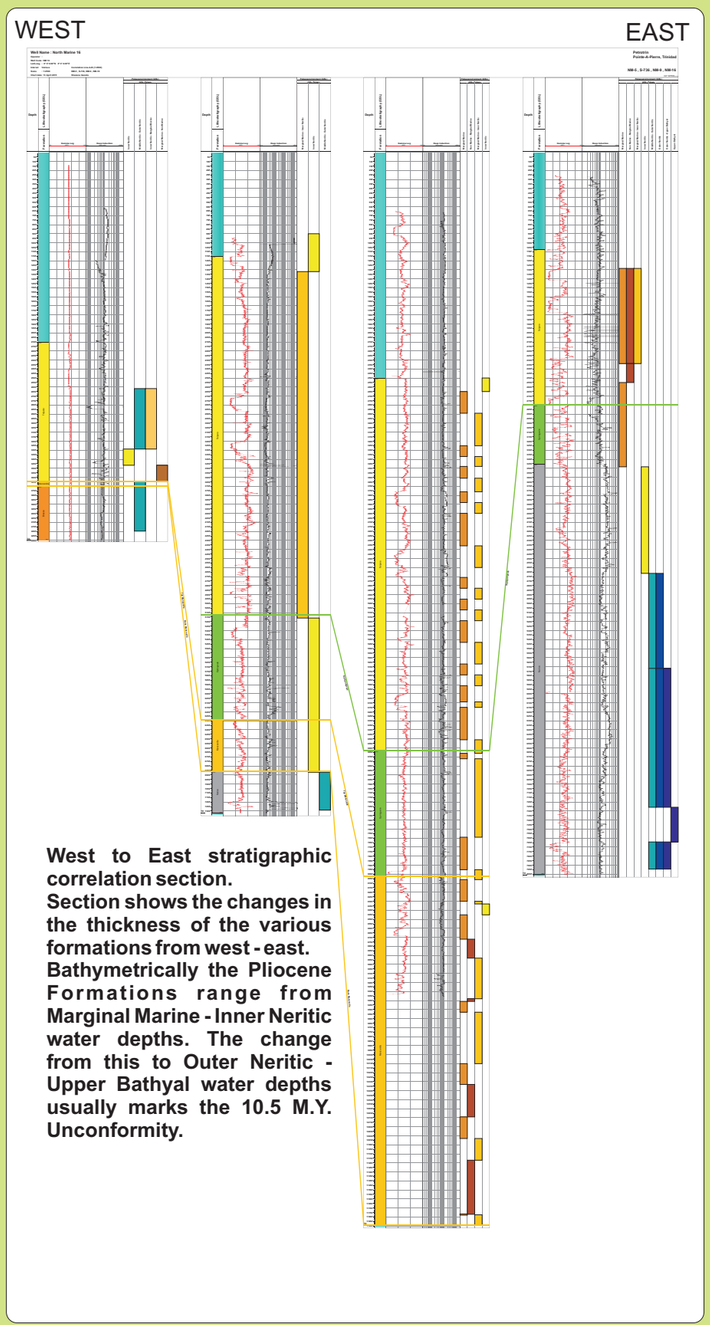
Regional seismic line located to the south of the North Marine Master fault.

South of the North Marine Master Fault, the normal faults displace the sediments with no growth on the downthrown side. The Manzanilla is clearly influenced by the 10.5M.Y. topography, with thickest sediments in the low and onlapping and pinching out onto the NM-5 and Brighton Highs. The Springvale is more uniform in thickness and thins slightly onto the Brighton high, but onlaps and pinches out onto the NM-5 High. The Durham maintains a uniform thickness even over the highs.

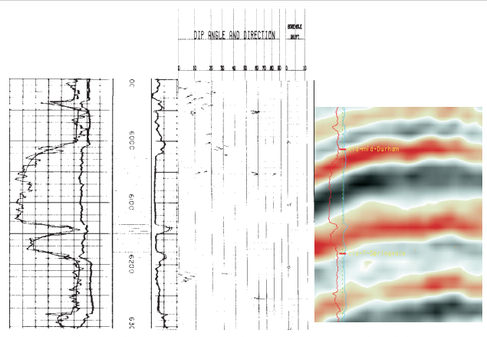


NORTH- SOUTH SEISMIC LINE BETWEEN THE WARM SPRINGS, NORTH MARINE MASTER AND LOS BAJOS FAULT

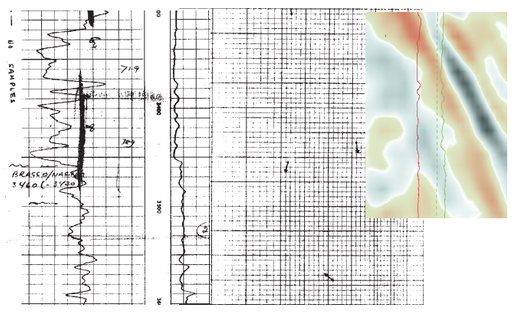




West to East stratigraphic correlation section.
Section shows the changes in the thickness of the various formations from west - east.
Bathymetrically the Pliocene Formations range from Marginal Marine - Inner Neritic water depths. The change from this to Outer Neritic - Upper Bathyal water depths usually marks the 10.5 M.Y. Unconformity.



Examination of dipmeter data also shows that there is no significant change in either the direction or amount of dip across the formation / member contacts.



Examination of well and 3D seismic data in the North Marine area indicate significant differences from onshore Trinidad. Cuttings and cores from wells have indicated that a number of the members of the Springvale and Manzanilla Formations are missing .The 3D seismic shows in places that both Formations have an angular contact with and also onlap the older underlying Miocene sediments . However, while members are "missing" based on onshore data, the 3D seismic shows that the contacts are all planar parallel.
Deposition of the Pliocene Manzanilla and Springvale and the Pleistocene aged Talparo Formations was influenced by the availability of accommodation space created by a mid-Miocene tectonic event , the interaction of the Warm Springs and Los Bajos Faults and subsequent transtensional faulting.
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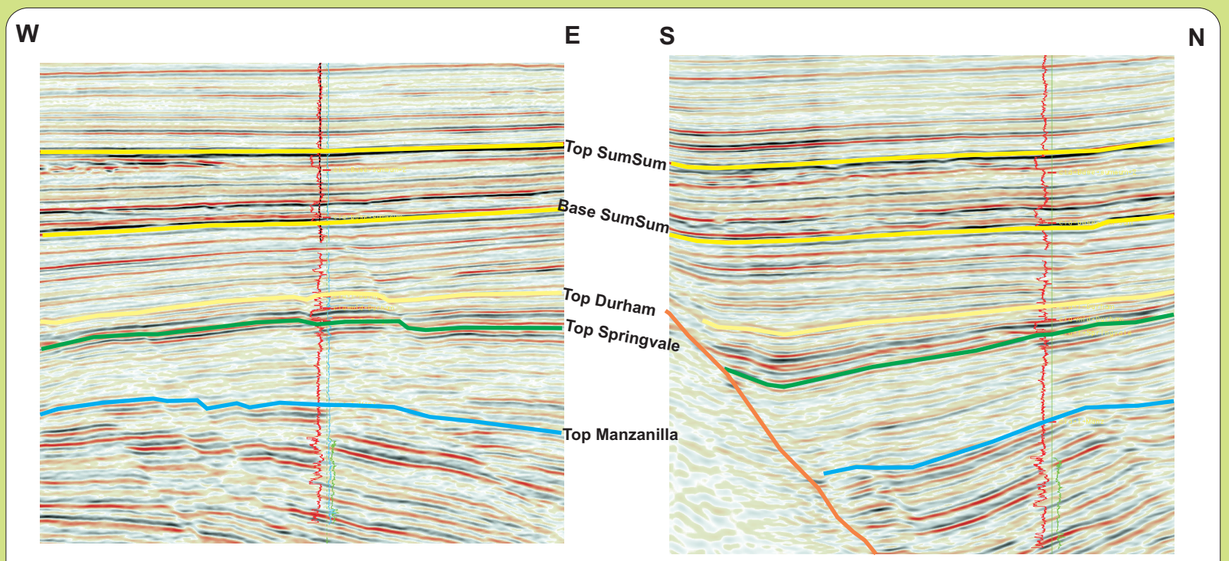
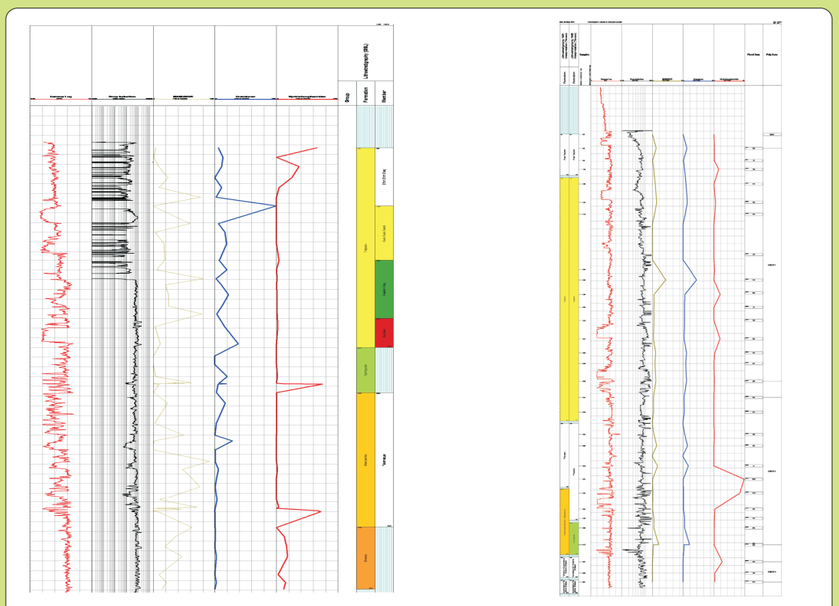


Strike & Dip Line - Well tie to seismic illustrating apparently conformable contacts between Formations and Members

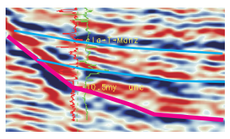


Pollen has proved useful in identifying the top of the Pliocene and the Miocene the Top Pliocene based on the downhole appearance of consistent specimens of *Grimsdalea magnaclavata*, other species used *Alnipollenites verus* (Alnus) modern species grow at an altitude of 2000 - 3000m in the Andes, represents cooling associated with the onset of the Pleistocene, *Echitricolporites mcneilly* has been used to define the Miocene - Pliocene boundary (Shell Trinidad IVC zone) Unconformities are though to occur where various pollen zones are missing, eg at the base of the Sum Sum sand, the Springvale - Telemaque contact, the Telemaque - Brasso & Durham - Brasso contacts.

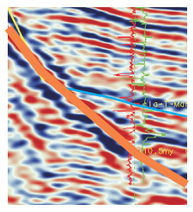
TYPES OF CONTACTS OBSERVED

ANGULAR

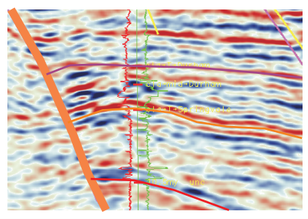
MANZANILLA - BRASSO



10.5 MY UNCONFORMITY = FAULT

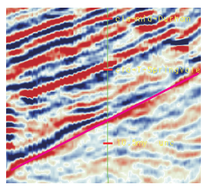


SPRINGVALE - BRASSO = FAULT

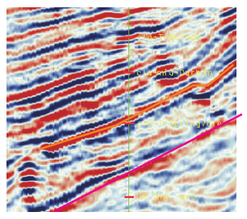


DISCONFORMITY

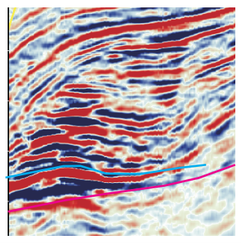
SPRINGVALE - NARIVA CONTACT



DURHAM - SPRINGVALE CONTACT

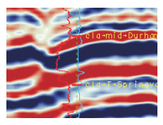


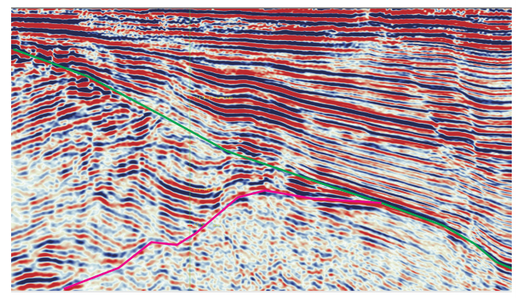
SPRINGVALE - MANZANILLA CONTACT



PARACONFORMITY

DURHAM - SPRINGVALE CONTACT





BICONFORMITY - TALPARO - FOREST- CRUSE - NARIVA

The authors would like to acknowledge the contributions of the staff of the Geological Services Lab at Petrotrin, Christopher Lakhan, Shazana Gazalie

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TALPARO

SUM SUM SAND MEMBER

Alternating sand and claystone beds, contacts planar, sand is pebbly, dominantly metamorphic lithic fragments – platy and rounded, towards the base of the interval sands poorly sorted and pebbly . The sands are made up of occasional angular clear quartz grains, grains dominantly quartz, misc black lithic fragments
The contact between the Sum Sum sand and underlying clays is usually marked by an uneven iron cemented surface. The clays below are blue grey, with abundant Thalassanoides . Angular claystone ripup clasts are common at the contact suggesting that have been sourced from the underlying beds.

CAPARO CLAY

The Caparo Clay Member is made up of light blue – pale grey claystones.
Sands are present as thin films ccasionally up to 50%. slightly calcareous and gypsiferous.
There are rare thin glauconitic sandy clays with molluscs and bivavlves including Anadara and Oysters.

DURHAM SAND MEMBER

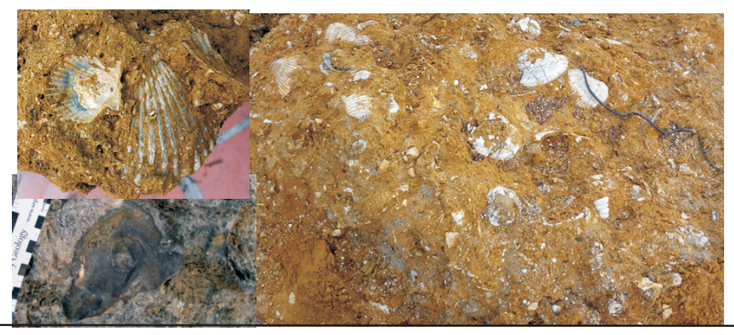
This outcrop shows a gross 'progradation' of sands from left to right (west-east). Evidence is provided by the trough cross bedding and geometry of the beds. The base of some of the sand beds appear to be erosional, this together with the lateral thinning suggest shallow channels. The beds thin upward and are capped by a hard red-brown layer which may represent a weathering surface. Rare vertical Thalassaniodes burrows and turning chambers are present.
Near the basal contact the sand is reddish orange brown, pebbly sand, grains stained, v poorly sorted, grains range from coarse – very fine. Predimonantly quartz, sub rounded, occ. Clear quartz.

SPRINGVALE

CHICKLAND CLAY

The Chickland Clay is an unctuous blue-grey clays, silts and sandy clays, thin glauconitic sand and lignitic sandy clay. There are occasional thin "conglomerates" made up of Oyster shells.

SAVANETTA GLAUC SST



The Savanetta Glauconitic Sandstone is at its maxiumum thickness in outcrop only 10'. consists of a yellowish brown sandstone with abundant shell fragments. The shell material occurs in two ways either, complete shells or fine indeterminate fragments. The large shells are dominantly of two types, Oysters and Pecten, The oysters are all disarticulated and up to 15cm in size and 3cm thick. The Pecten however are commonly articulated and this suggests that they died in place while the oysters may have been reworked. Complete gastropods are also found. Rustch (1942) identified 153 species.

GRANSAUL CLAY

Gransaull Clay Member - The Gransaul Clay is a monotonous sequence of generally fine grained sand, sandy clay and clays, with the clays being blue-grey, slightly calcareous and gypsiferous. There are occasional thin glauconitic sands rich in fossils.

MANZANILLA

TELEMAQUE SAND MEMBER

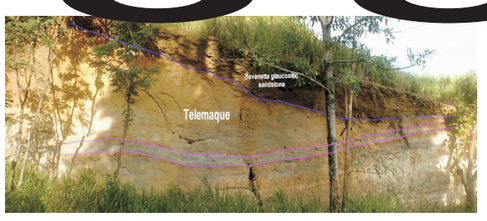
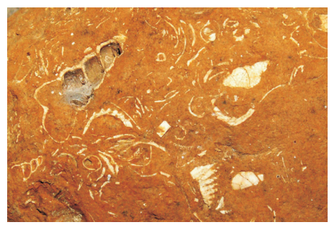


Photo showing the angular unconformity between the Savanetta Glauconitic sandstone and the Telemaque Member of the Manzanilla. The Chickland Clay is missing. Dips in the Telemaque area to the west (35 – 40) while in the Savanetta they are 10^0.

The section exposed at the outcrop consists of two repeated packages, consisting of claystone at the base with a coarsening and thickening up sand beds capped by minor clay and thin lignites, that are in turn capped by claystones.
The Telemaque member of the Manzanilla Formation at this locality is expressed as thick sand units, well bedded with interbedded rippled silt and thin sands. The sand is fine – very fine grained, sub-angular to sub-rounded with abundant clear mica.
Skolithos burrows are common, dominated by two ichnogenera, Ophiomorpha and Thalassinoides. The burrows are robust up to 5 cm in diameter and are present in both the horizontal and vertical planes . The horizontal burrows probably represent the burrow of a callianassid type shrimp. This burrow is restricted to the lower shoreface / low energy environment. The vertical burrows suggest high energy environments with rapid burial of organisms, the burrows representing escape structures. Ophiomorpha are common in sands while Thalassinoides occur in clays.
Based on the sedimentary and biogenic structures observed at the outcrops it is suggested that they represent a series of coarsening up sequences with water depths ranging from lower-shoreface to upper-shoreface.
The presence of lignite beds suggest a lagoonal environment, the absence, however of identifiable plant material or rooted layer, together the presence of extensive bioturbation above and below the layer, and the erosive base of all of the beds indicates a reworked deposit.

MONSTERRAT GLAUC SST



A bivalve and Gastropod rich sandstone with glauconite pellets. In outcrop this unit is only about 10'.

SAN JOSE CALC SILT

The San Jose Calcareous Silt - It has been described as an inky blue unctuous calcareous claystone, in outcrop there are occasional conglomerates with clasts of northern range metamorphics. Bivalves Arca trinitaria and Chione walli are characteristic. To date it has not been identified in any well.