Field Guide

Transition from Tidal to fluvial dominated deltaic deposits. A transect through the Morne L'Enfer to basal Erin Formation, Puerto Grande Bay, South Coast, Trinidad

Hasley Vincent
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Overview

This Field trip will investigate a section of Upper Morne L'Enfer Member and basal Erin Formation outcropping along Puerto Grande Bay, south coast, Trinidad. (Figure 1). The transect begins approximately 400 metres west of Erin Village fishing depot and end at Puerto Grande road towards the west. The Morne L'Enfer and Erin Formations are Upper Pliocene to Pleistocene in age and outcrops only in the western part of the Southern Basin of Trinidad. Hydrocarbons are being produced from Morne L'Enfer reservoirs within several fields in the Southern Basin (North Palo Seco, Coora, Forest Reserve) Commercial hydrocarbons have not been discovered within the Erin Formation. It is used mainly as a freshwater reserve over large areas of the Southern Basin. Both the Morne L'Enfer and Erin Formations represent the latter stages of sediment infilling into the Southern Basin, with relatively shallow-water sediments relative to older formations.

The Morne L'Enfer comprises four members: Upper Morne L'Enfer, Lot 7 Silt, Lower Morne L'Enfer and Upper Forest Clay (Table 1). The total thickness of the Morne L'Enfer may reach some 900 metres (3000 feet) (Donovan 1994). The top of the Morne L'Enfer is marked by Porcellanite beds at Quion Cliff. The field trip will examine a minimum of 30 feet of basal Erin outcrops.

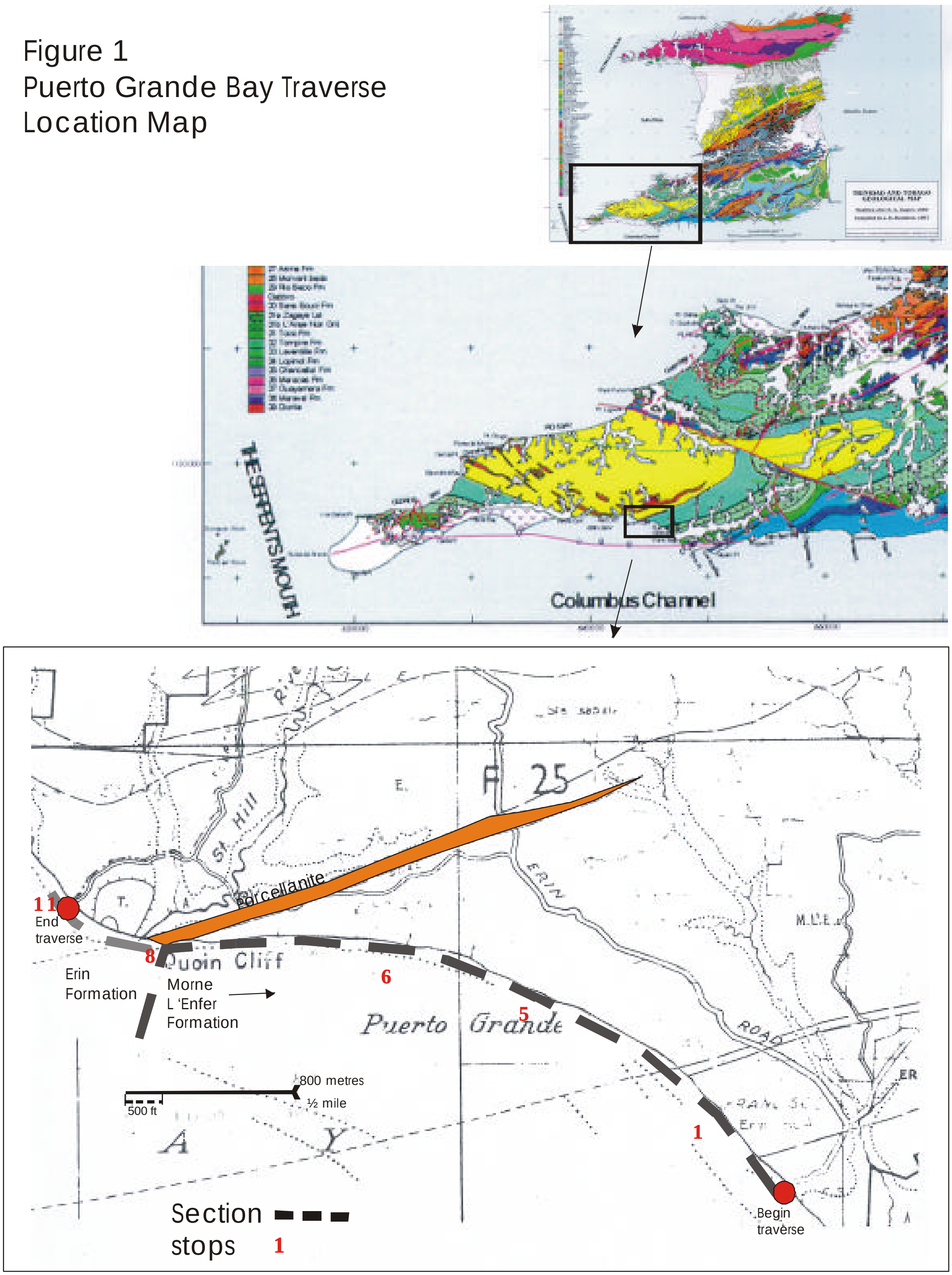
Age	Formation	Member
Pleistocene	Erin	
Plio-Pleistocene	Morne L'Enfer	Upper Morne L'Enfer
		Lot 7 Silt
		Lower Morne L'Enfer
		Upper Forest Clay

Table 1 Stratigraphy encountered along traverse of Erin Bay section

Journey

The section begins at the Erin Fishing Depot at Erin Village. It can be reached by driving south and west along the Southern Main road, through Debe, Siparia and Palo Seco from San Fernando. Alternatively, it can be reached by driving south along the South Trunk Road from San Fernando through La Brea to Point Fortin, Buenos Ayres and then Erin. From San Fernando, one can expect approximately one hour driving time. At the end of the section, one can arrange for a vehicle pick-up after Quion Cliff (Puerto Grande road). This traverse direction follows the section from older to younger rocks.

Figure 1
Puerto Grande Bay Traverse
Location Map



Hazards

Attention must be paid to the following:

- Rising Tides. Sections of outcrop protrude seaward and is difficult to pass during high tides. eg. Porcellanite.
- Parts of the shoreface may be cut off with rising tides as it is dissected by numerous runoff channels.
- High cliffs with very unconsolidated, weathered rocks prone to slumping and landslides. Several landslides will be observed along the traverse. Attention must be paid to loose overhead rocks and wetting of the cliff face which increases the likelihood for landslides.
- Parts of the section are obscured by vegetation. It is not advisable to traverse through the bushes alone or without first clearing a pathway.
- Look out for wasps along the outcrops.

Notes on Tidal Flats/ Estaurine Environment

Within a tide-dominated deltaic environment, tidal processes dominate the pattern of sedimentation relative to wave and fluvial processes. The lowermost reaches of an estuary are susceptible to marine processes and normally lie within the subtidal zone (below the level of low tide). The uppermost reaches (supratidal) are influenced to a larger degree by fluvial processes. This zone normally lies above the influence of high tides and is only occasionally inundated by flooding events. Between these two zones lies the intertidal zone, subject to diurnal fluctuations in tidal range leading to current variations. The latter is responsible for some of the distinctive features of tidal deposits. Tidal / Estuarine deposits show a decrease in energy regime landward. The highest energy is associated with the marine interface where wave action and tidal current reversals are commonly associated with well sorted, fine grained sandstones. Marine/ tidal energy decreases landward where vertically accreted mudstones are associated with river discharge. These mudstones are commonly organic rich, typical of a lagoonal/ marsh environment of supratidal areas.
The decrease in energy landward produces a fining upward progradational sequence of subtidal and intertidal channel sands and tidal bars overlain by fine silts and mudstones of upper intertidal to supratidal areas. These may in turn be capped by organic rich mudstones or lignite beds representative of lagoonal/ marsh environments (Figure 2).

Processes

Major active processes within tidal dominated deltas include:

- Bi directional tidal currents (ebb and flood)
- Lateral accretion of migrating tidal channels / tidal creeks
- Migrating sand bedforms
- Vertical accretion (slack water muds, supratidal muds and silts)
- High biological activity (large quantities of a small number of species).

Other active processes include:

- Wind induced wave currents
- Wave processes
- Fluvial input

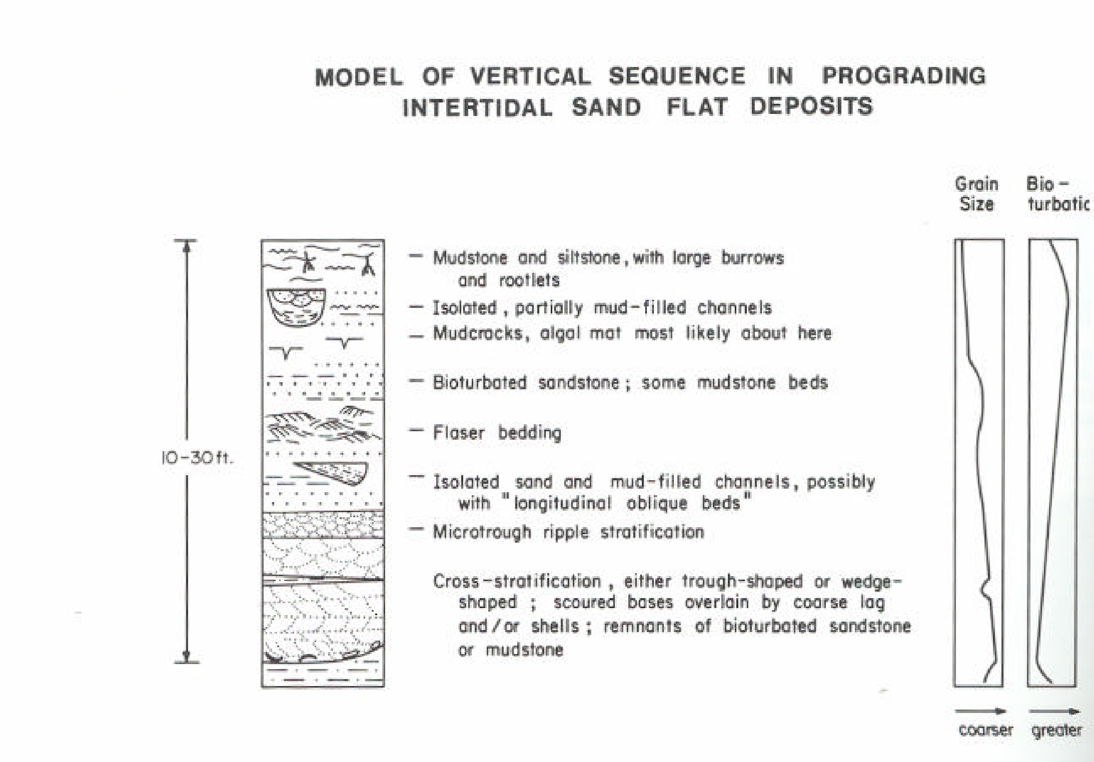


Figure 2. Model of inferred vertical sequence in prograding intertidal sand flat deposits. From Weimer, Howard, Lindsay (1982) Fig. 22

Common Sedimentary Structures

Sedimentary structures common (but not limited) to tidal-dominated deposits include:
Flaser bedding and anastamosing shales
Lenticular sands
Bi-directional cross beds (herring bone)
Bi-directional ripple lamination
Thin sandstone beds interbedded with mudstone beds (sometimes rhythmic)

General Observations

The Morne L'Enfer comprises fine to very fine grained sandstones, grey laminated and organic rich mudstones, thin lignite beds, and porcellanites. Sandstones vary from thin, parallel beds interbedded with grey shales to more large scale trough cross bedded sand complexes with very little shale content. Sandstones are dominantly very fine to fine grained, micaceous and weathered tan to yellow in colour.   Mudstones generally display various shades of grey. They occur as parallel laminated facies or as individual beds within sand/ shale sequences. They are occasionally burrowed and bioturbated, but commonly contain wood and other organic fragments. The latter may be present as distinct horizons within the mudstone. Occasional black, fissile shales are also present. Lignite beds are common, reaching up to 10ft in thickness. Porcellanite beds occur at the top of the Upper Morne L'Enfer Section.

Facies Types

The abundance of organic matter, presence of wood fragments and lignite beds throughout the section suggests continental/ deltaic processes. Other sedimentary structures were used to differentiate related environments. Five facies types have been interpreted from observations. These are presented below with descriptive characteristics.

<u>Tidal dominated intertidal to sub-tidal facies</u>

- Most variable net/ gross relative to other facies.
- Sandstone very fine to fine grained, thin bedded.
- Wave ripple laminations; Ripple-topped sandstone beds; mud drapes in troughs of ripples.
- Lenticular sands displaying bi-directional cross bedding, flaser bedding, anastamosing mud layers.
- Cross bedded sands with mud drapes; herring bone cross bedding; rare swaley cross bedding; mud rip-up clasts.
- Abundant Vertical burrows.
- Flame structures; contorted bedding.

<u>Supratidal – upper intertidal lagoonal facies</u>

- Dominated by grey laminated mudstones with siltstones and occasional cross bedded sands.
- Organic rich – organic content either dispersed or present as laminations within mudstones.
- Wood fragments.
- Lignite beds up to 4 feet thick.
- Commonly bioturbated
- Leaf imprints (as seen in porcellanites)

<u>Upper delta plain distributary channel facies</u>

- Occurs near top of section
- Very high net/ gross.
- Abundant trough and planar cross beds.
- Graded bedding.
- Lignite bed up to 10 feet thick.

- Multiple erosional surfaces.
- Abundant mud rip-up clasts.

Shallow Marine/ delta front deposits

- Clearly defined coarsening upward sequences
- Grey mudstone with rare or no organic fragments

Alluvial fan facies

- Conglomeratic units displaying faint bedding. Some grading. Rare pebble alignment.

Acknowledgements:

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References:

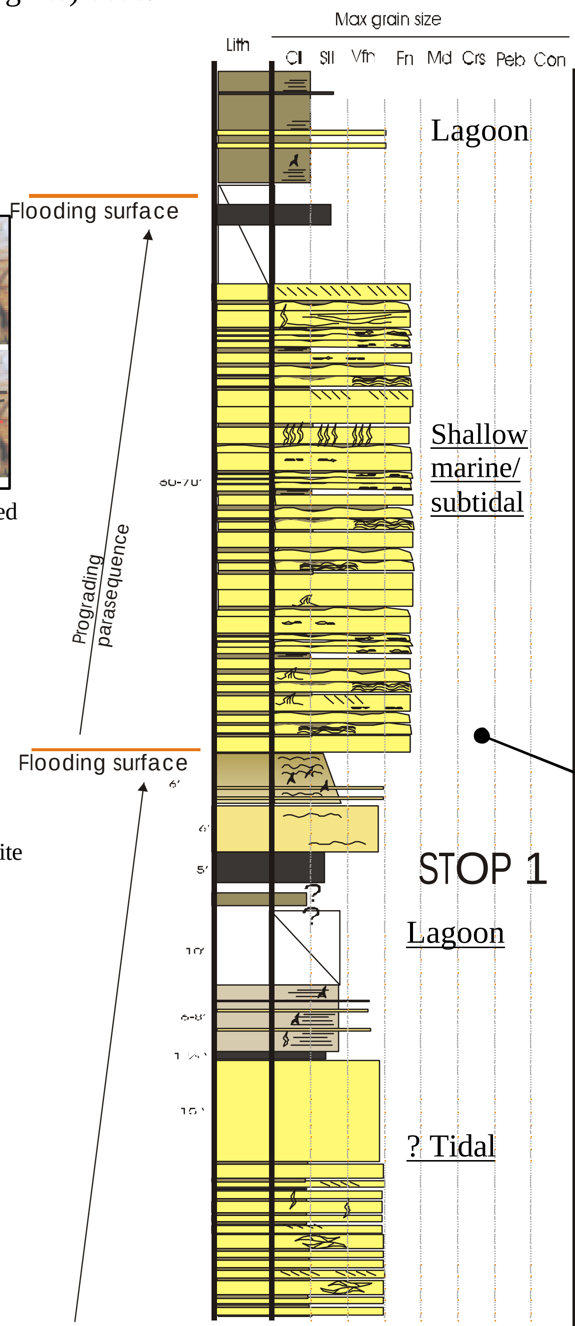
Donovan, S.K., 1994, Trinidad. In: Donovan, S.K. & Jackson, T.A., 1994, Caribbean Geology an Introduction, The University of the West Indies Publishers' Association, Mona, Jamaica, pg. 209-228.

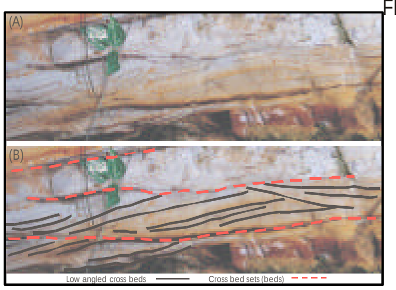
Weimer, R., Howard, J.D., Lindsay, D.R., 1982, Tidal Flats and Associated Tidal Channels. In: Scholle, P.A. & Spearing, D., 1982, Sandstone Depositional Environments, AAPG Memoir 31, American Association of Petroleum Geologists.

Stop 1

Second lignite bed walking west from Erin Fishing depot (approx. 400m)

A 5 feet thick lignite bed overlies claystone beds and laminated organic rich siltstone. Lignite and organic rich beds overlie sandy, thin bedded sequence with common burrows and bi-directional cross lamination. No distinctive features, except that bi-directional cross lamination suggests variable current flow regime of probable tidal origin. Organic-rich beds cap the underlying tidal influenced sequence. A flooding surface occurs at the top of the organic rich sequence overlain by sands of shallow marine origin as suggested by the presence of low angled, sigmoidal cross bedding (swaley) indicating a landward shift in facies associated with increasing water depths. This parasequence is also capped by organic rich (lignite) beds.

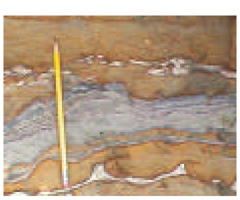




Low angled, sigmoidal shaped cross bed sets characteristic of wave processes.

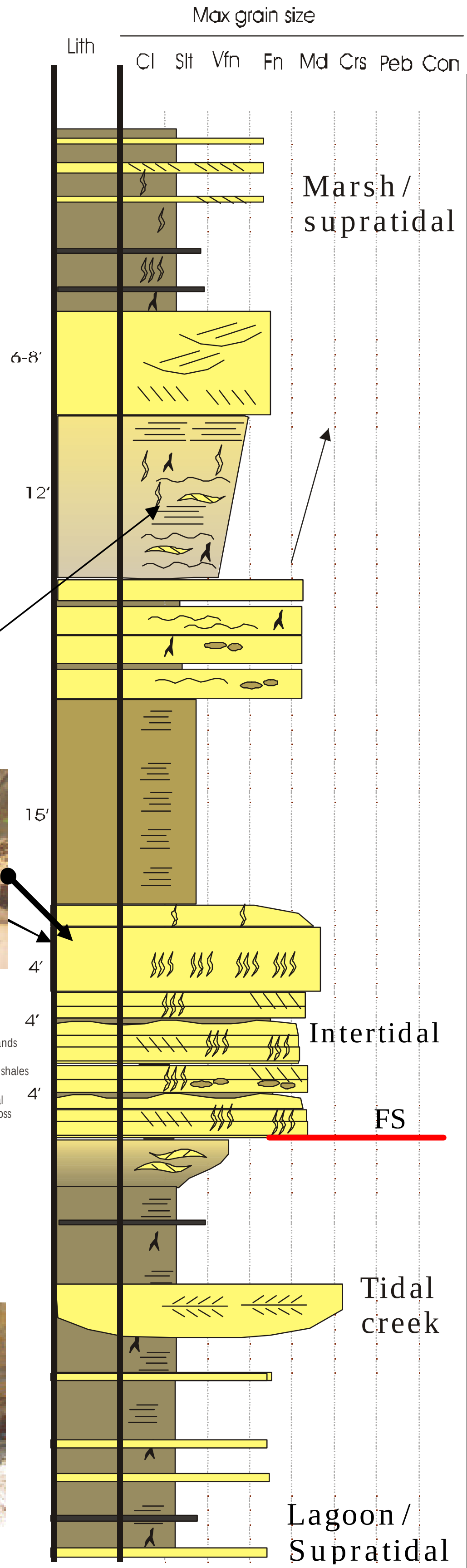
Lignite bed marks the beginning of Stop 1

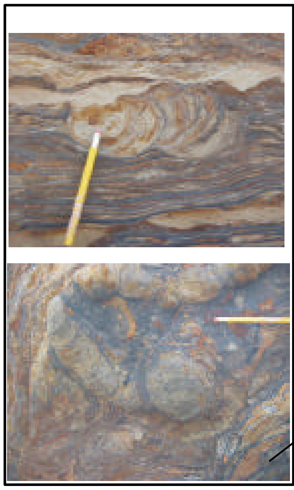
Shallow marine/ subtidal interbedded sandstone and shale



Anastamosing shale/ flame structures

STOP 2.
Transgression from organic-rich lagoonal deposits to bioturbated intertidal sands. Lagoonal muds again cap the section. A flooding surface is proposed at the base of the intertidal sands associated with increased water depth.

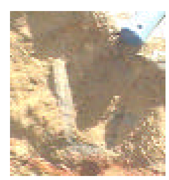


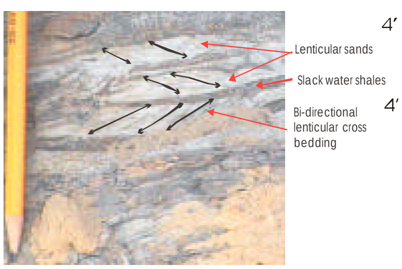

Thalassinoides burrows

Ripple laminated siltstone facies. Dark grey organic- rich layers stand out from brown vf grn sandstone. Increase sand content to top.
Horizontal to sub horizontal burrows with fine grained to silty substrate. Dwelling/ feeding burrows. (Thalassinoides).

Grey parallel laminated mudstone.

Fine grained sst & mud rip-up clasts associated with channel; probably upper intertidal suggested by good preservation of biogenic activity.


Bi-directional cross bedding in lenticular sands.

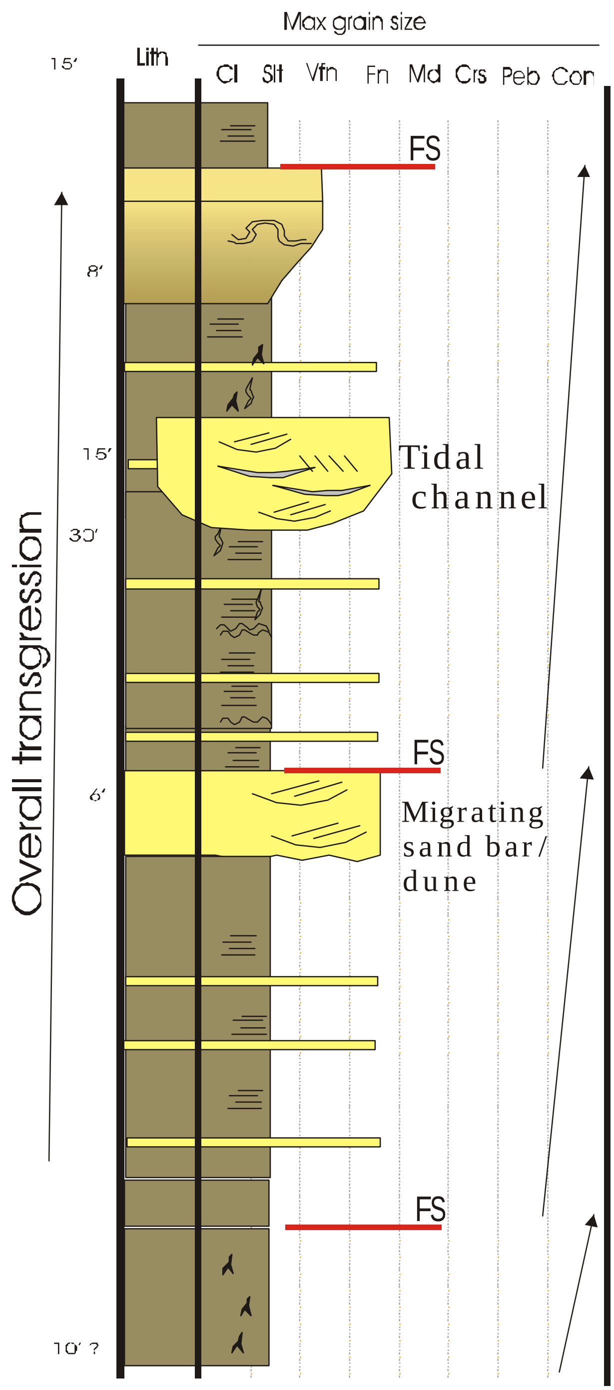


Lenticular sands

Fine to medium grained sandstone bed, (< 6' exposed) displaying bi-directional cross bedding (Herring bone).

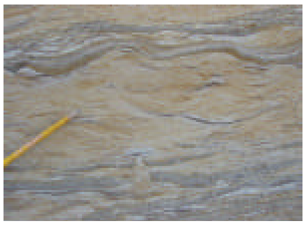

Herring bone cross bedding

STOP 3

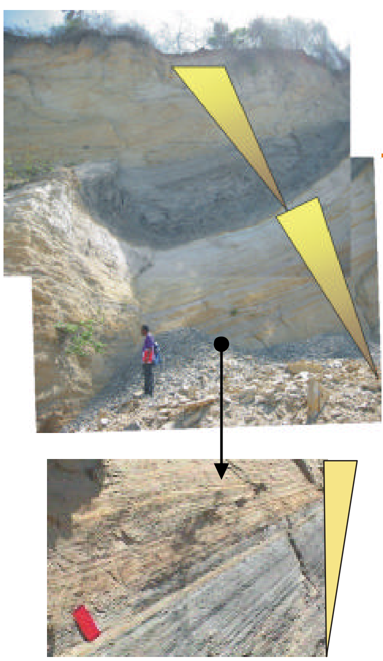


STOP 3
Change in mudstone colour (grey) and general absence of organic matter suggests that mudstone may have a more distal (marine) origin. Thinner organic-rich mudstone intervals suggest a return to more proximal environments (lagoonal). These intervals define the top of sequences and are overlain by a flooding event of marine mudstones (no organic content) and coarsening upward sandstones. This stop may represent the onset of more distal marine conditions relative to previous stops. Coarsening upward signatures become well defined upwards (see stop 4).

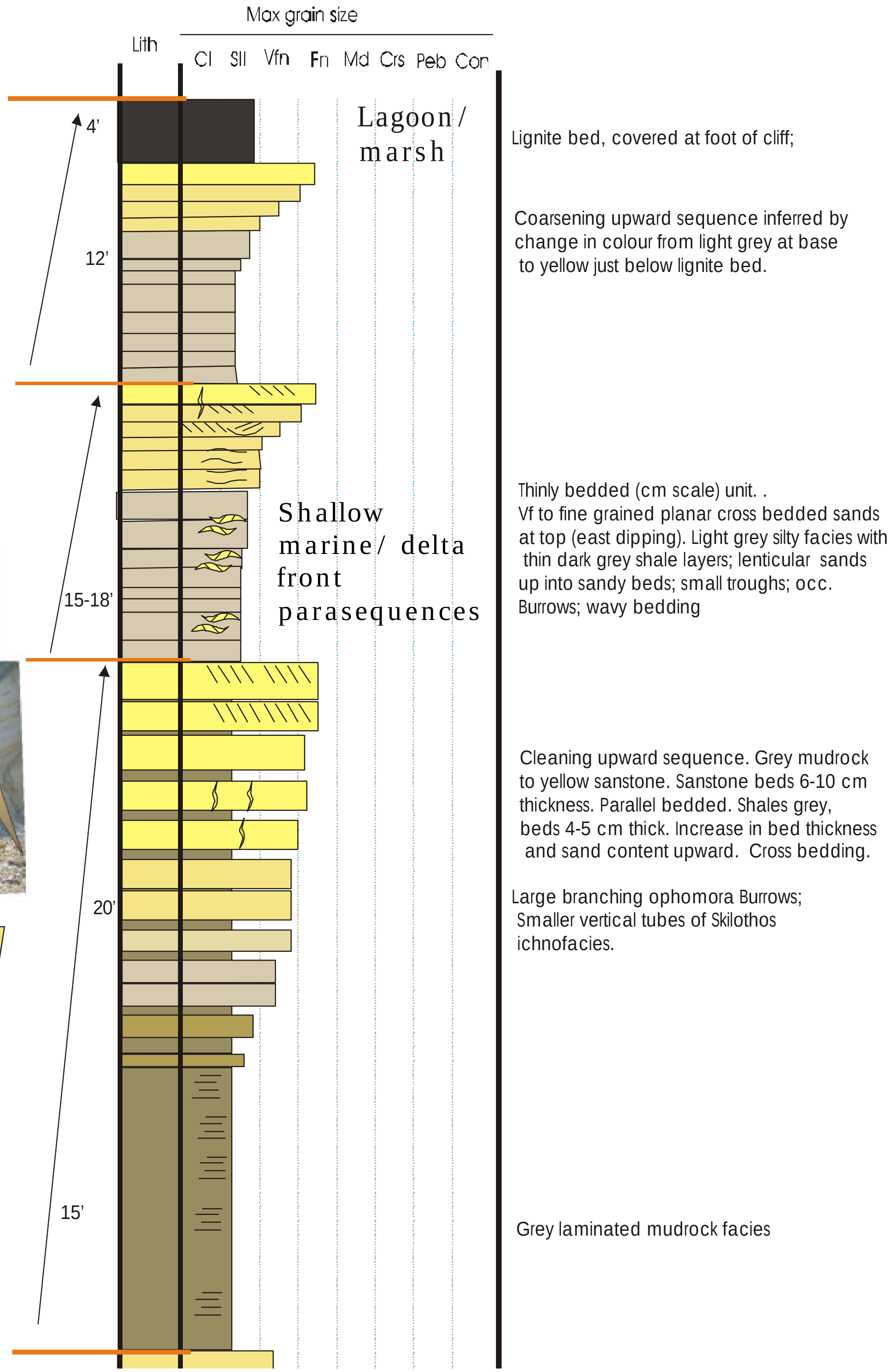
STOP 4



Lenticular and wavy bedding



Coarsening upward subtidal to intertidal delta front sequences



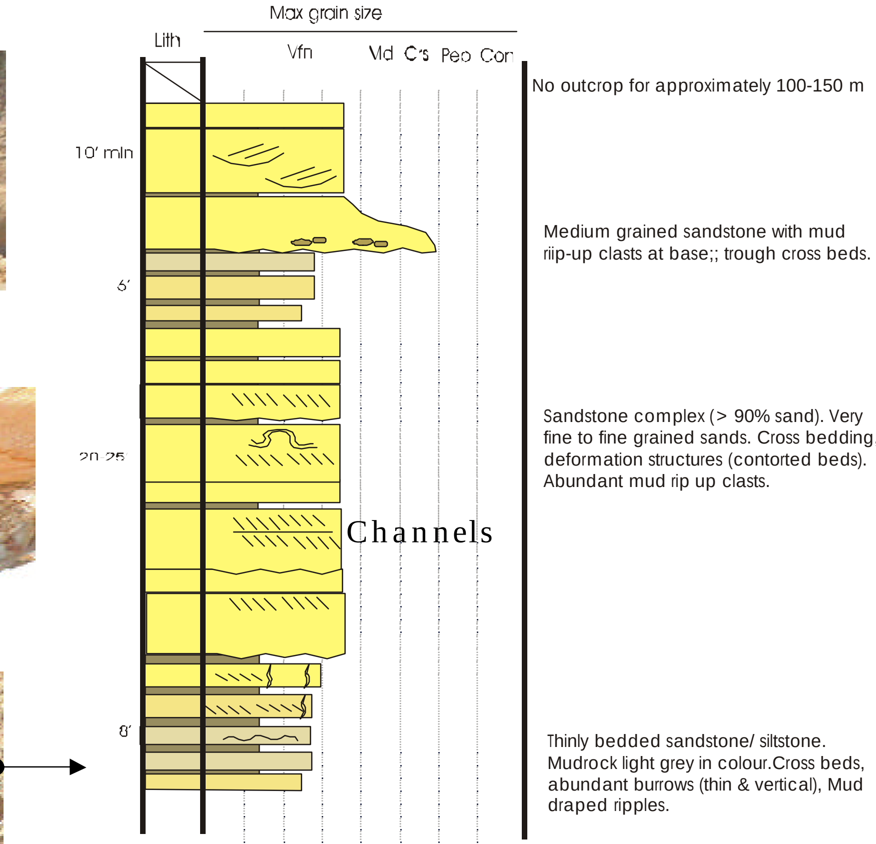
STOP 4

Grey laminated mudrock facies coarsen upwards into thin bedded, bioturbated sandstones. Large Ophiomora burrows and vertical Skilothos burrows are typical of nearshore environments. Sequences probably of delta front/ shallow marine origin but still within tidal influence as suggested by bi-directional ripple lamination and wavy bedding. Flooding surfaces are now represented by shale and not sandy successions as seen in intertidal/ supratidal regime.

STOP 5


Tidal channel sands

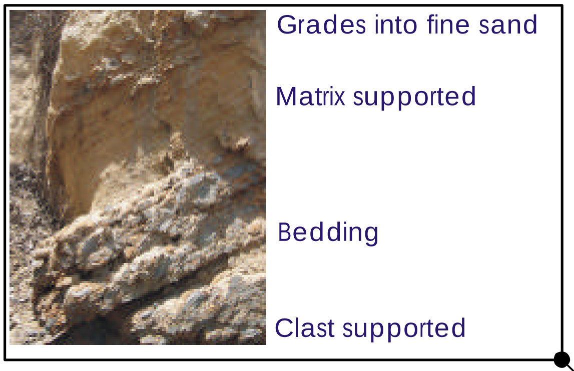

Channel base

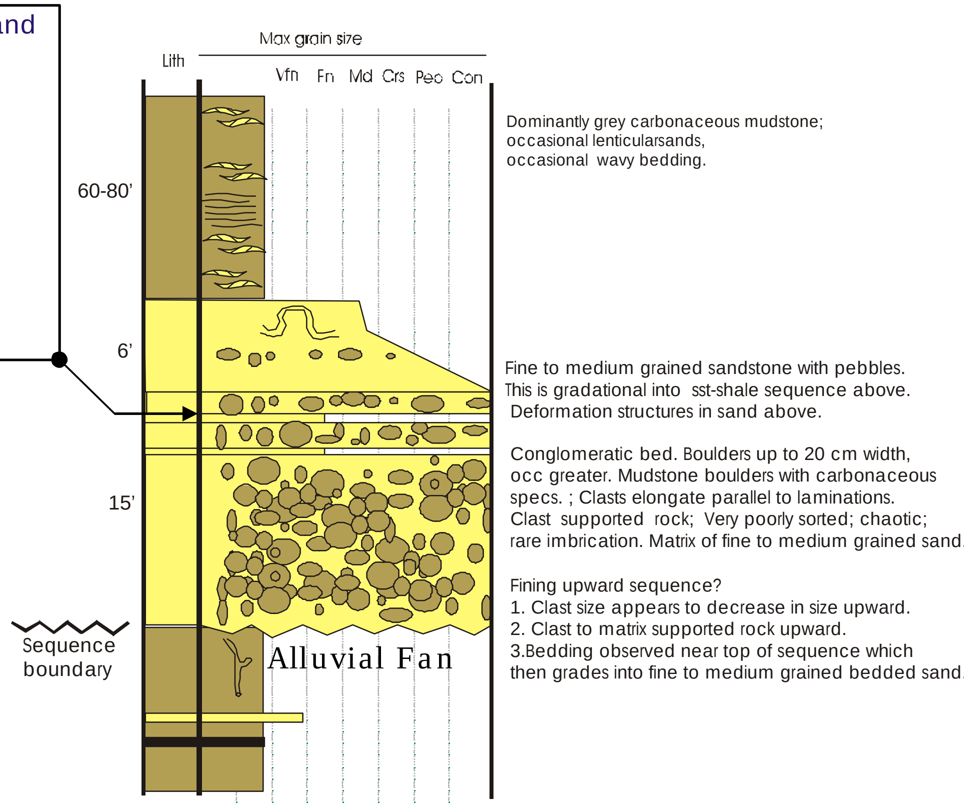


STOP 5

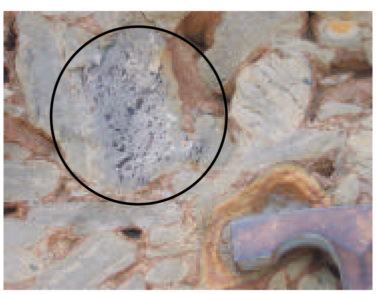
Well-defined channel facies with erosive base, channel lag, internal erosional surfaces, soft sediment deformation.

STOP 6





Alluvial conglomerates

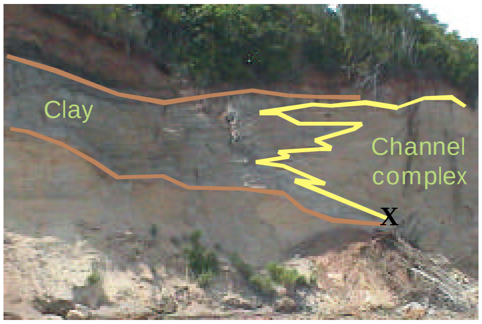


Carbonaceous fragments in mudstone boulders are typical of underlying marsh facies

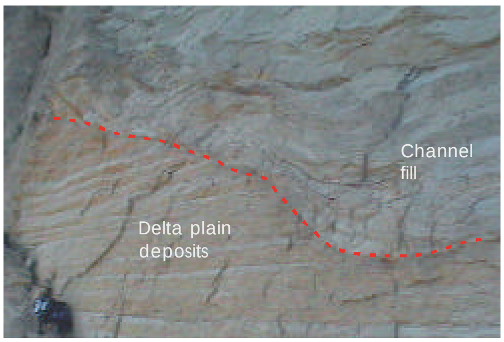
STOP 6

Dramatic facies change from dominantly very fine grained sandstone to conglomerates. The base of this sequence represents a significant downward shift in facies and is here interpreted as a sequence boundary. The conglomerates are interpreted as alluvial fan facies, incised downward into the underlying muddy and carbonaceous lagoonal/ marsh deposits as a response to the change in base level. The conglomerates fine upward until they are capped by tidal-influenced very fine grained deposits representing a transgression into the basin.

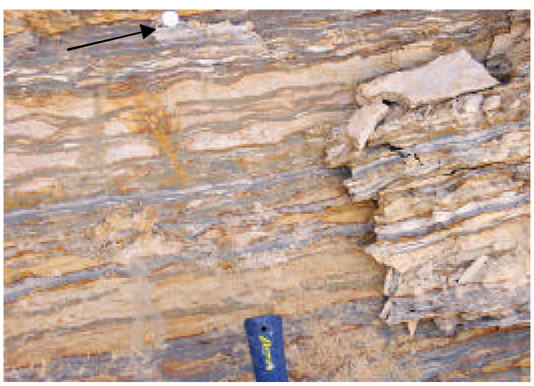
STOP 7



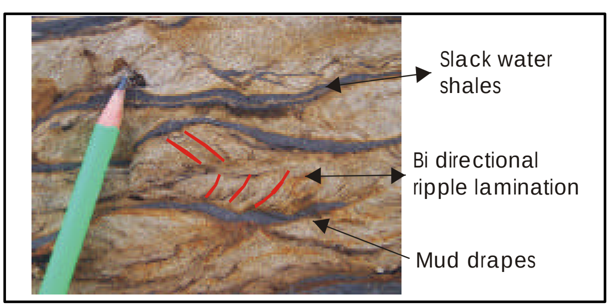
Channel complex . X = photo below



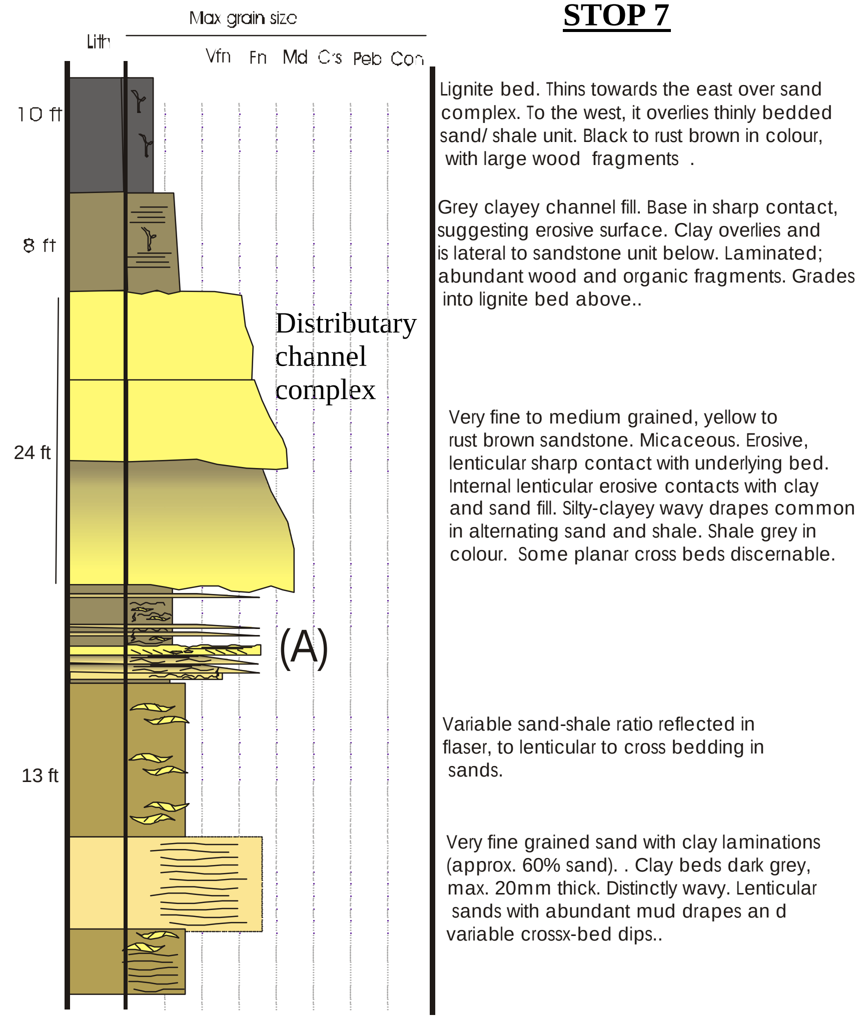
Erosive surface within channel complex located at 'X' in above photo

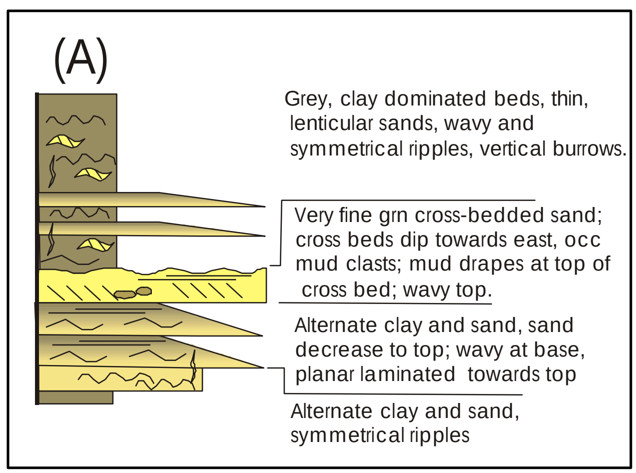


Alternating sand/shale present in tidal deposit. Shale (darker bands) present as anastamosing layers. Coin (arrowed) and hammer handle for scale.



Bi-directional lenticular cross bedding within tidal bundles





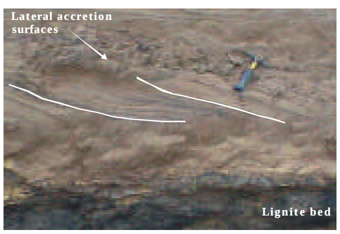
Blow-up of (A) from strip log above

STOP 7. Basin infill distributary channels overlying intertidal deposits. Channel complex with muddy infill capped by lignite horizon may represent a transition to upper delta plain environment of deposition. Bi-directional cross beds, flaser and lenticular bedding and other tidal signatures become rare in younger sequences while trough cross bedding and uni-directional planar cross beds dominate.

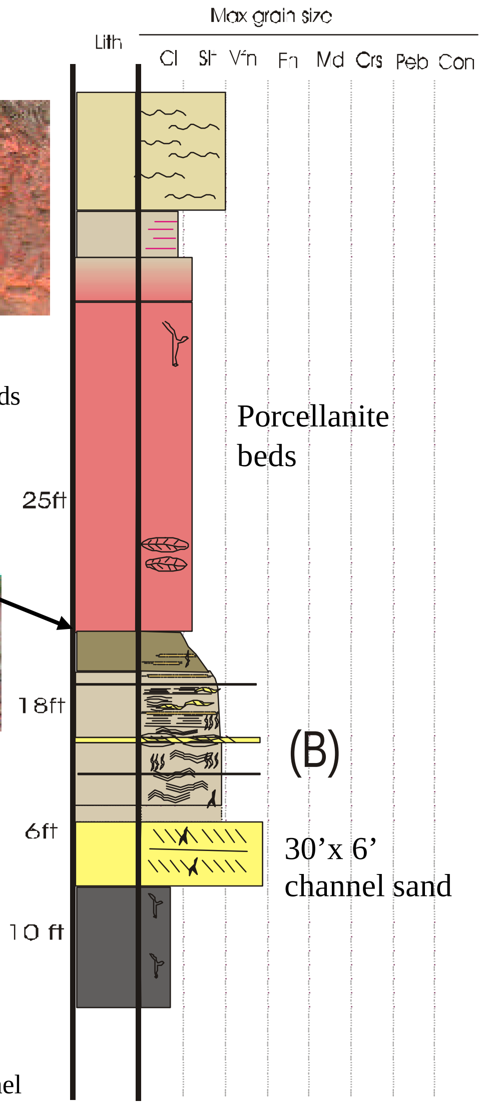
STOP 8

Burnt orange (right) and less burnt (brown) porcellanite beds

Porcellanite above, mudstone below



Lateral accretion in small channel sand



Laminated very fine grained to silty sandstone with symmetrical ripple laminations. Red colouration minimal and disappear upwards. > 70%, very fine grained sand. Mud drapes define laminae.

Top of porcellanite fades to light brown to greyish purple (banded) until a sharp contact with reddish brown unburnt sediments.

Heterogenous textures in Porcellanite, Variable colours highlight bedding. Less 'burnt' areas show very thin bedding/ laminations similar to underlying rocks. Very bright colours towards western face; wood fragment; leaf imprints; bedding dip is consistent with lower rocks at 26° towards O°.

Change to porcellanite noted by change in colour from dark grey mudstone to pink to orange. Gradational change over short interval.

Ophiomora burrow

Vf. Grn cross bedded sandstone with dark organic seams highlighting cross bedding. Cross beds/ lateral accretion surfaces dip to the east. Sharp contact with underlying coal bed. Sand approx. 30' wide, though eastern end covered. Not laterally extensive

Lignite bed (from stop 7)

STOP 8

Porcellanite rocks are theorized to be formed by burning lignite seams within mudstone. 'Original' laminated mudstone observed in less burnt rocks. Bed dips similar to underlying rocks. Leaf imprints and wood fragment suggest proximal environments of deposition. Distinct horizon of Ophiomora burrows just below hard streaks may represent an area of extended surface exposure. Notice textural variations in Porcellanite. What is the nature of the contact with under and overlying rocks?

(B)

Grey clay, bioturbated;numerous hard streaks.Grades into porcellanite above.

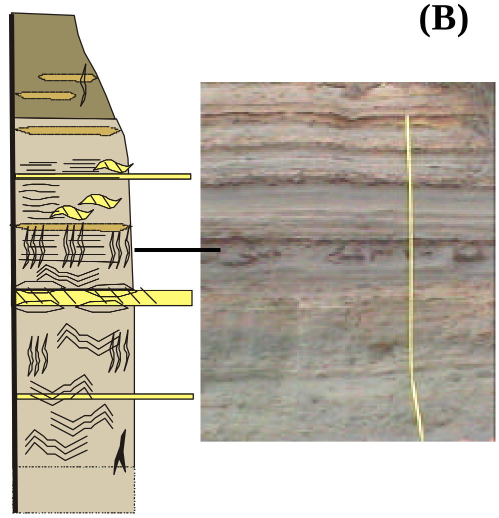
Lenticular sands; wavy laminations at base; parallel laminations at top.

Contorted laminations, vertical and horizontal burrows. Interval overlain by continuous hard streak.

Cross bedded sandstone bounded by nodule layer

Grey-dk grey extensively bioturbated silt, contorted laminations, black carbonaceous streaks at base, vertical burrows at top

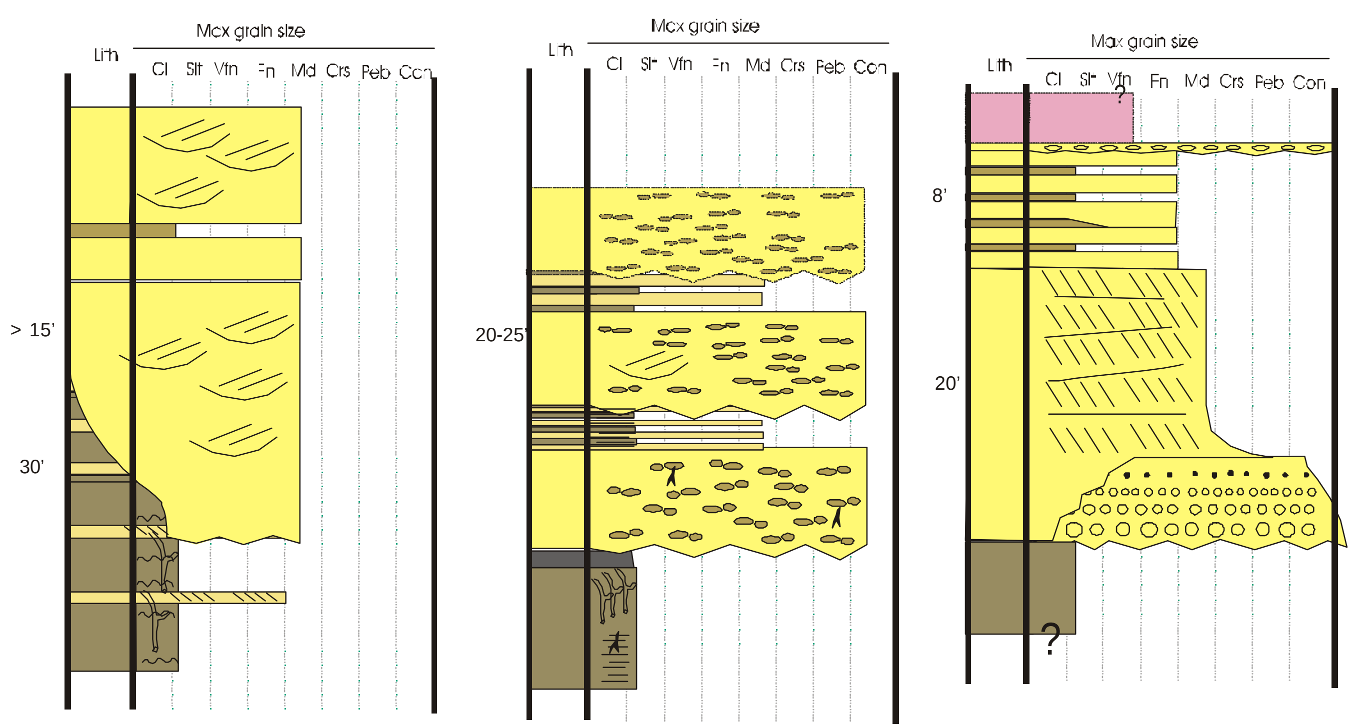
Sharp contact with lower unit.



(**B**) above. Strip log and photo. Upper intertidal to supratidal environment of depostion suggested by good preservation of biogenic activity; lenticular sands, organic content, vertical accretion. Strip log section approximately 18 ft.

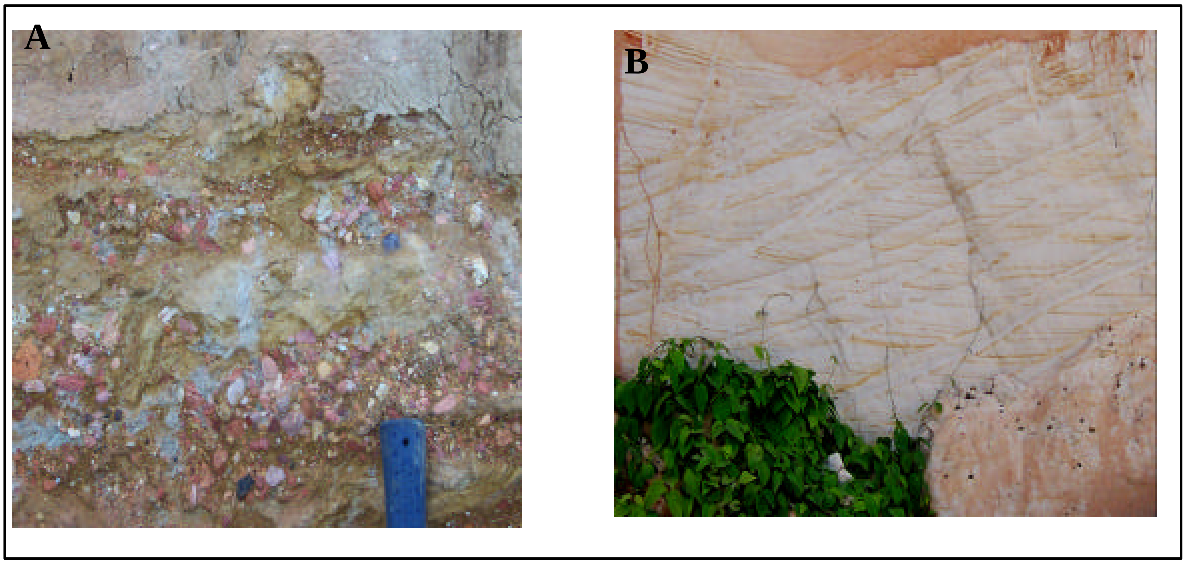
Dipping surfaces (arrowed) below porcellanites interpreted as lateral accretionary surfaces of a major channel. Photo: GSTT website (Curtis Archie)

STOP 11 **STOP 10** **STOP 9**

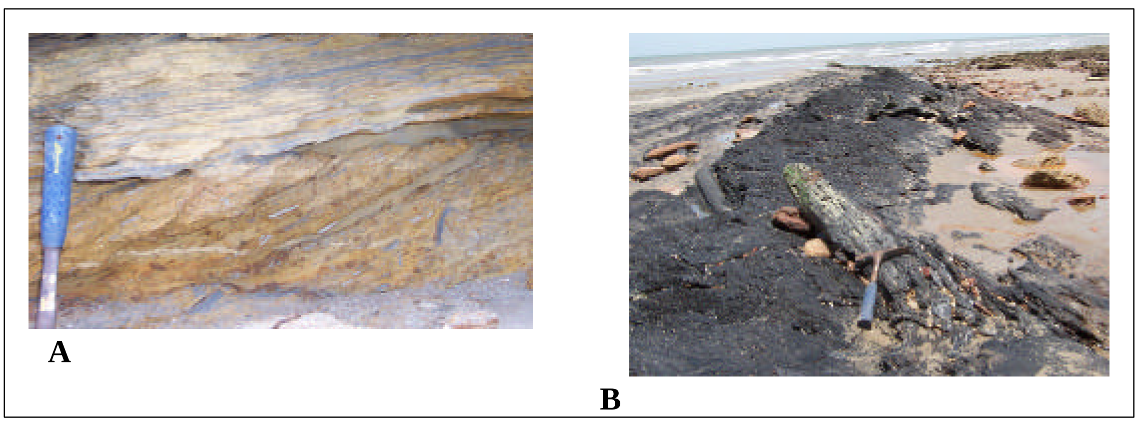


Stop 9, 10, 11. Traverse along depositional strike. Lagoonal mudstone with tree trunks and large wood fragments overlain by high energy, fluvial to alluvial plain environment. Clasts in the latter up to conglomeratic size. Some grading, common trough cross bedding.

Stop 9
First outcrop west from Quion Cliff Porcellanite: Fluvial channel facies. Channel axis recognized by graded pebbles at base overlain by trough and planar cross bedded sandstones. Multiple erosional surfaces are observed within. Channel margin oberserved towards west as thinly bedded mudstone-sandstone sequences lateral to channel axis.



Stop 9. (A) Graded bedding at base of channel comprise porcellanite pebbles. (B) Trough cross beds and lateral accretion surfaces of channel axis.



Stop 10 Fluvial to alluvial plain facies. (A) Conglomeratic bed unconformably overlain by parallel laminated mudstone. This sequence ovelies lignite beds with very large wood fragments shown in (B).

STOP 11. End of traverse. Fluvial delta plain facies predominate. Minimum of 30 feet thick sandstone-prone outcrops displaying large trough cross beds. These deposits overlie the same lagoonal beds from stop 9 as seen in wood fragments at base observed just west of Puerto Grande Road (end of outcrop).

Key to Strip Log