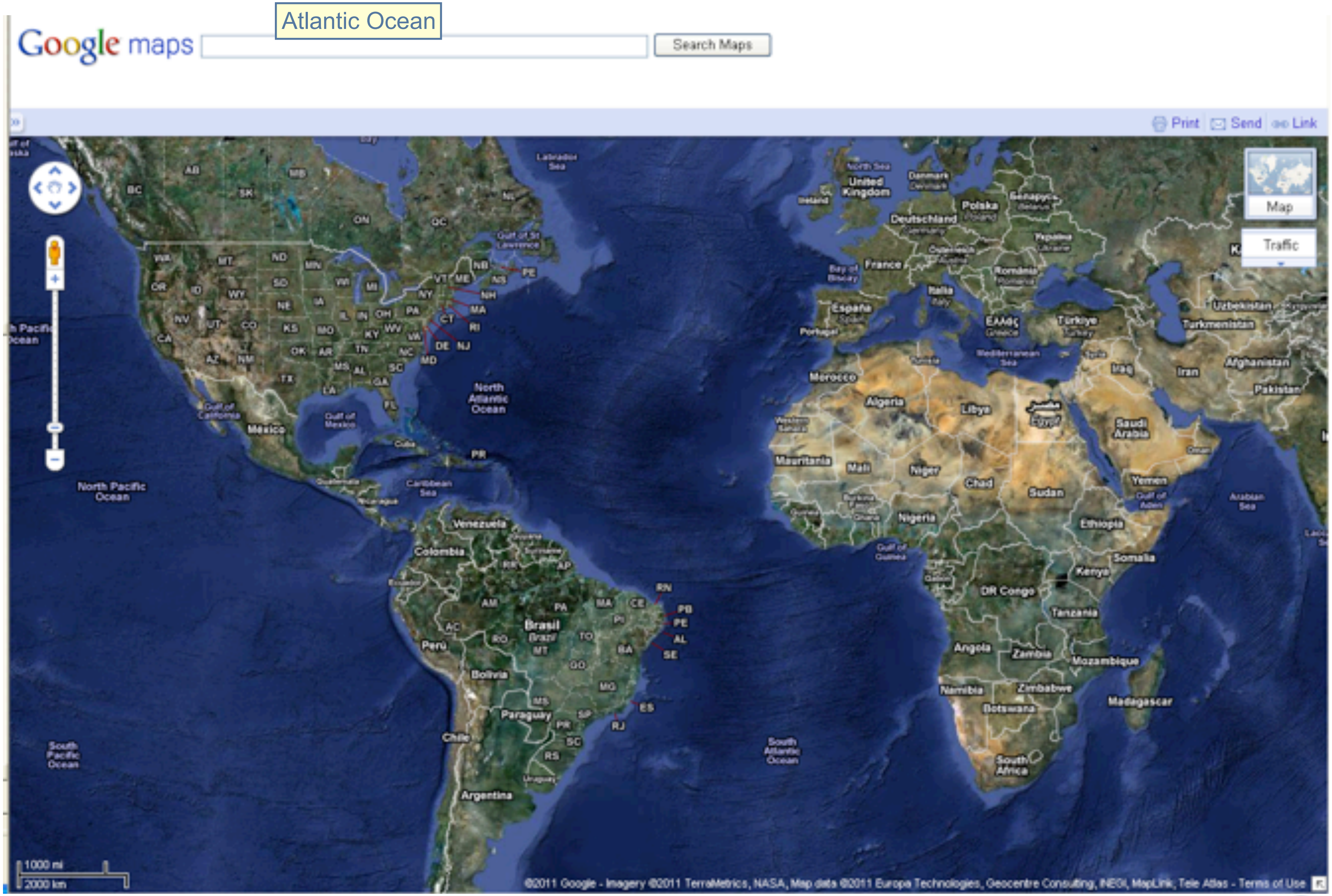
Atlantic Ocean



Classical passive margins in both sides of the ocean
Age 170 million years

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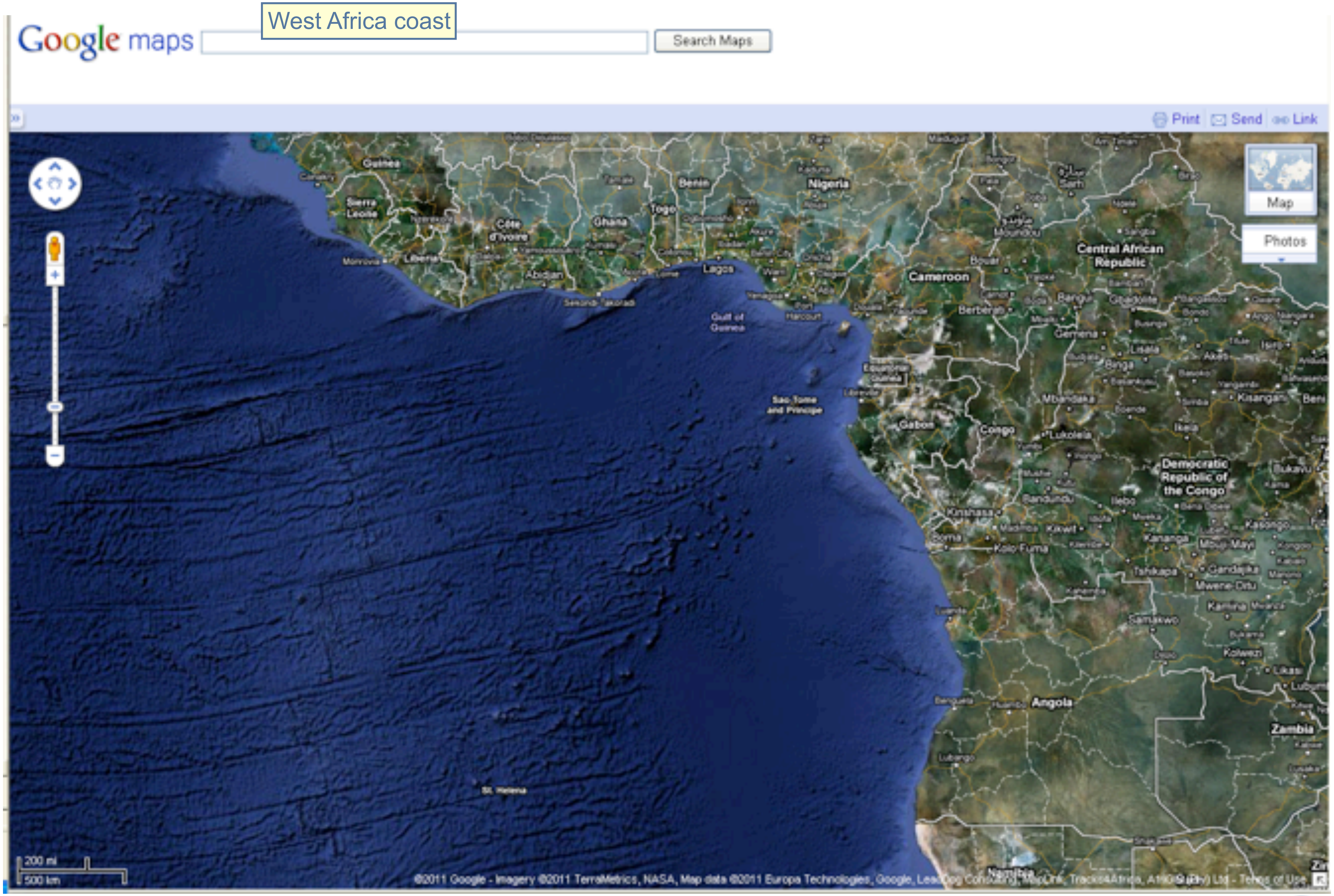
West Africa coast



Salt tectonics make the geological situation complicated

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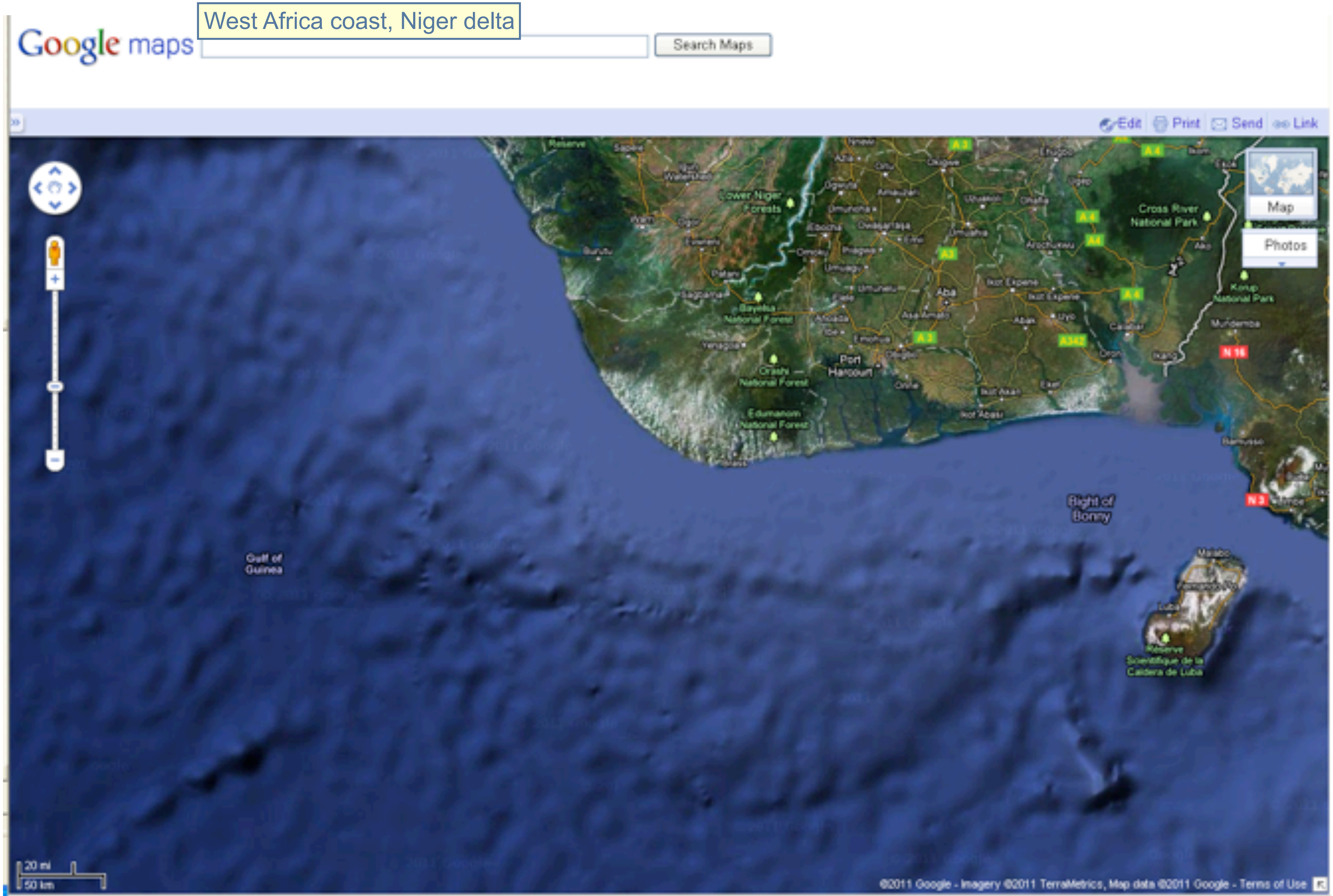
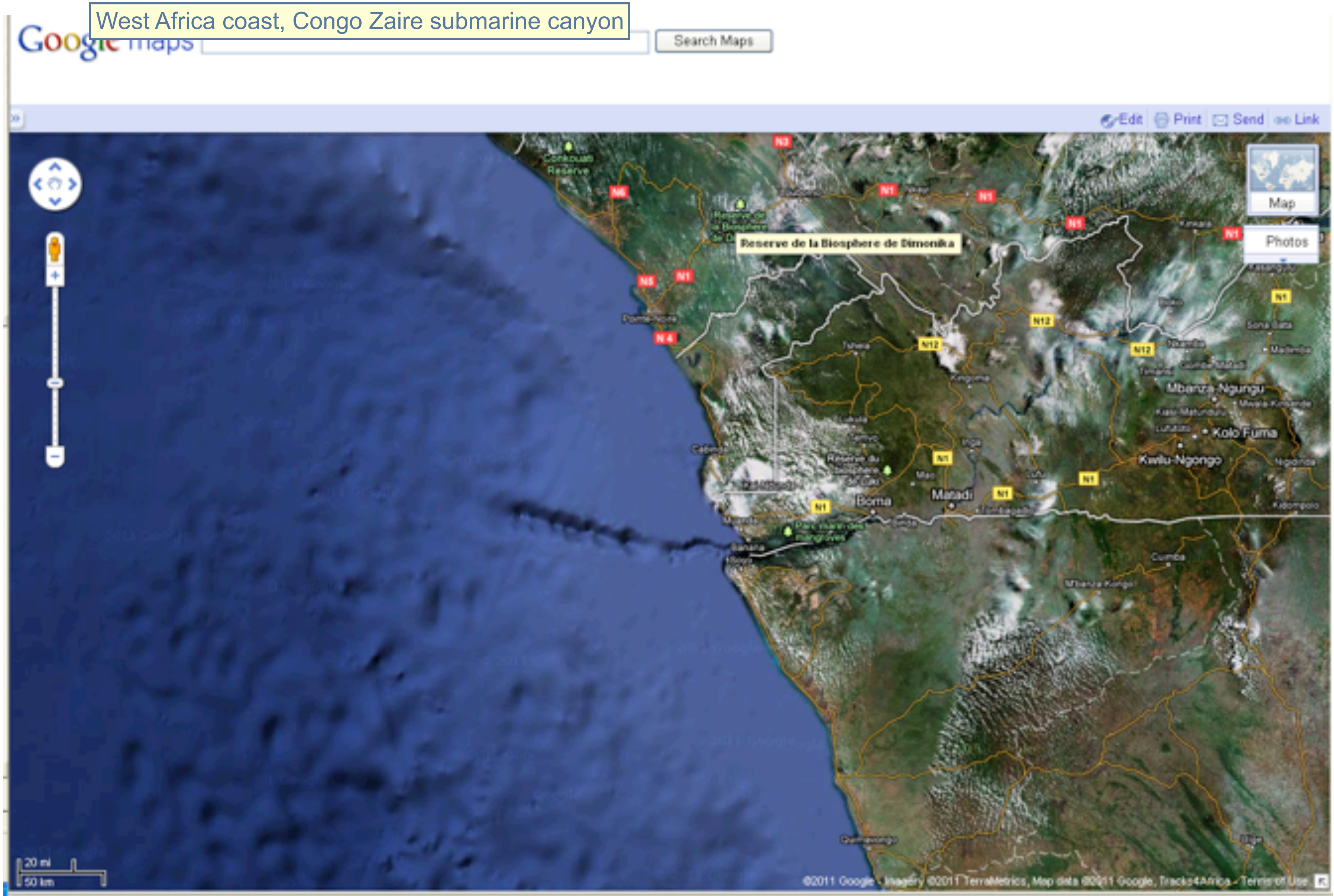
West Africa coast, Niger delta

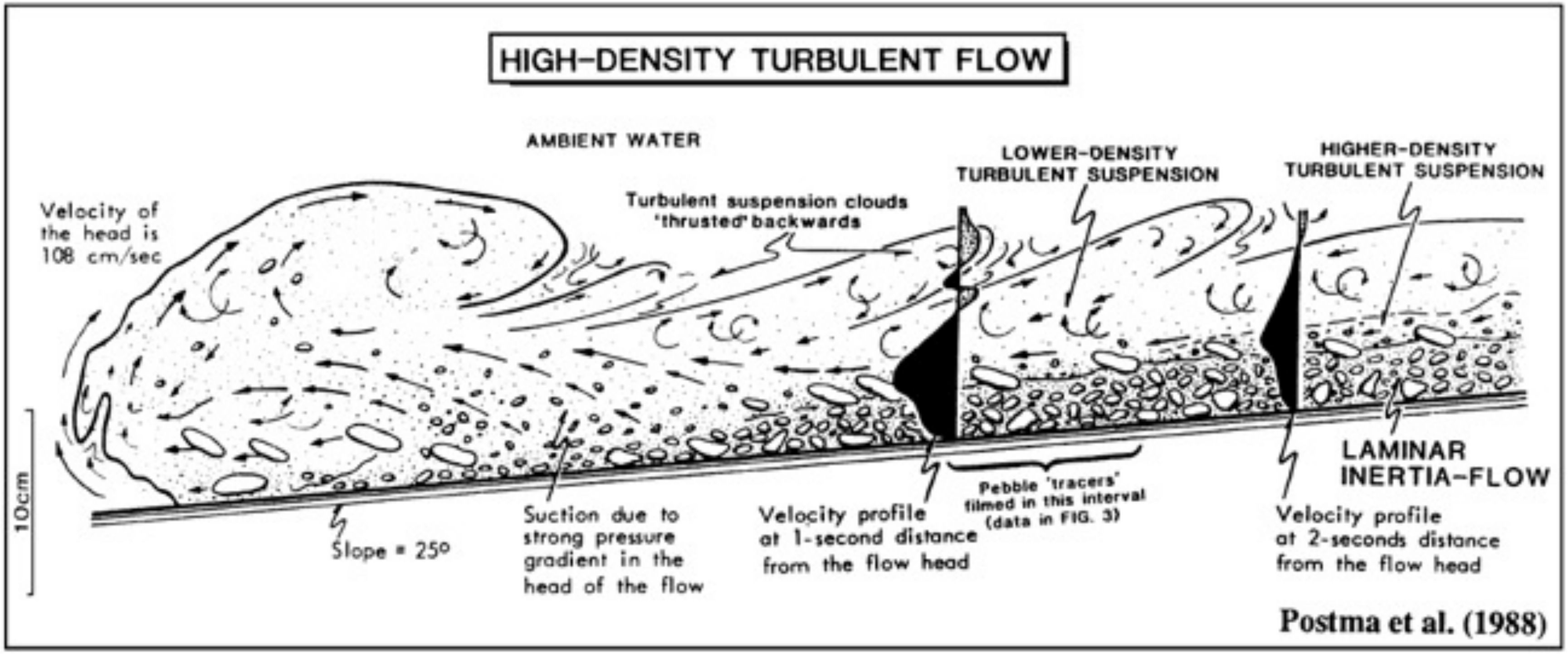


Niger delta, salt tectonics, tilted blocs, shelf break in echelon

TOTAL

West Africa coast, Congo Zaire submarine canyon





A profile of experimental "high-density turbidity current" showing density stratification. Note a lower laminar inertia-flow and an upper turbulent flow. From Postma et al. (1988).

It is the deposit of a more complex flow whose final state is that of a fully turbulent turbidity current.

This includes all those beds which appear to have formed through genetically related gravity flows the last of which is a waning and depleting turbidity current

What is a turbidite ?

A turbidite is a graded bed consisting of a sandstone-mudstone couplet which has been deposited by a turbidity current

Grain Size		Bouma (1962) Divisions	Interpretation
Mud	T_{ep}	Pelite	Pelagic sedimentation
Mud	T_{ef}	Massive or graded Turbidite	fine grained, low density turbidity current deposition
		Upper parallel laminae	? ? ?
Sand / Silt	T_c	Ripples, wavy or convoluted laminae	Lower part of Lower Flow Regime
	T_b	Plane parallel laminae	Upper Flow Regime Plane Bed
Sand (to granule at base)	T_a	Massive graded	(?) Upper Flow Regime Rapid deposition and Quick bed (?)

The division Ta would be the “en masse” deposit of an inertia flow which underwent freezing because of internal friction

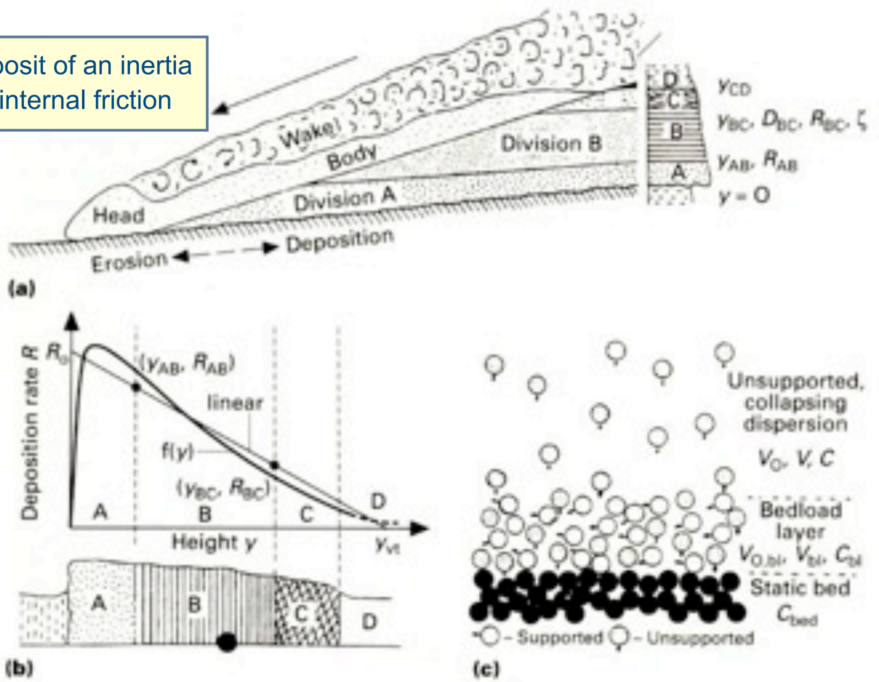


Figure 10.25 Features of a turbidity current and its deposits. (a) Streamwise profile of a flow showing its major zones and the likely sites of deposition of the Bouma intervals. (b) Depositional rate and its relationship to the Bouma sequence. (c) Possible layer structure of the flow during deposition (after J.R.L. Allen, 1991).

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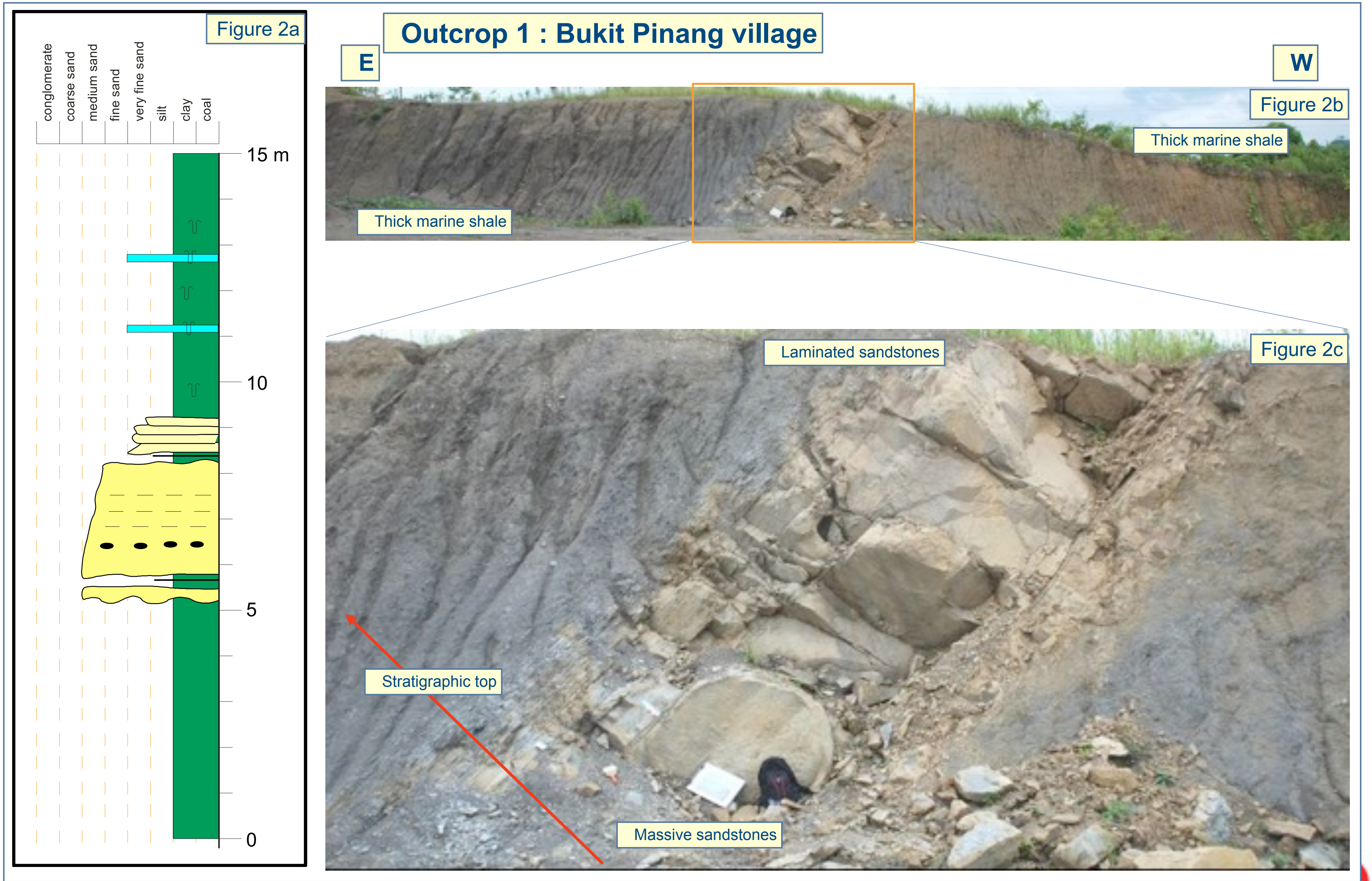


Figure 2

Friday, 7 October 2011

Figure 3a

Massive sandstone with clay clasts

Figure 3b

Leaf prints in the bedding plane

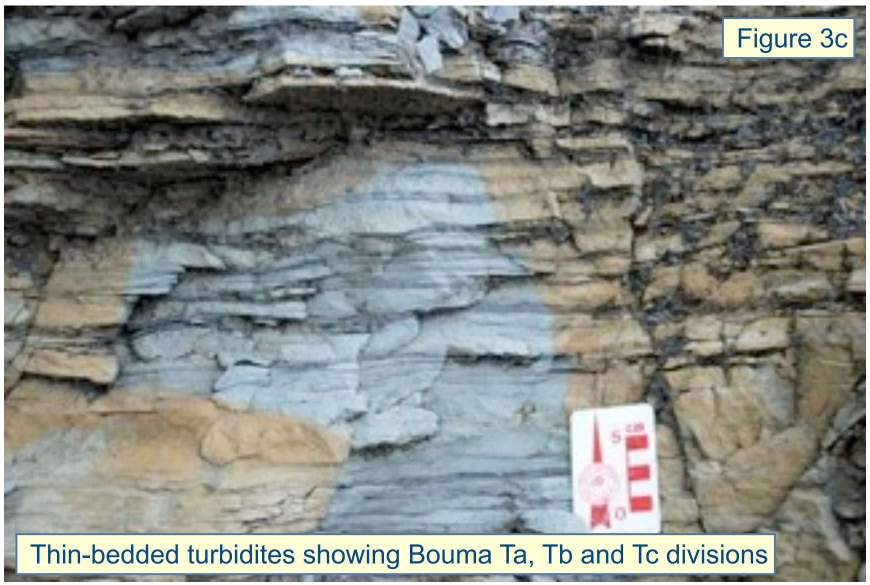


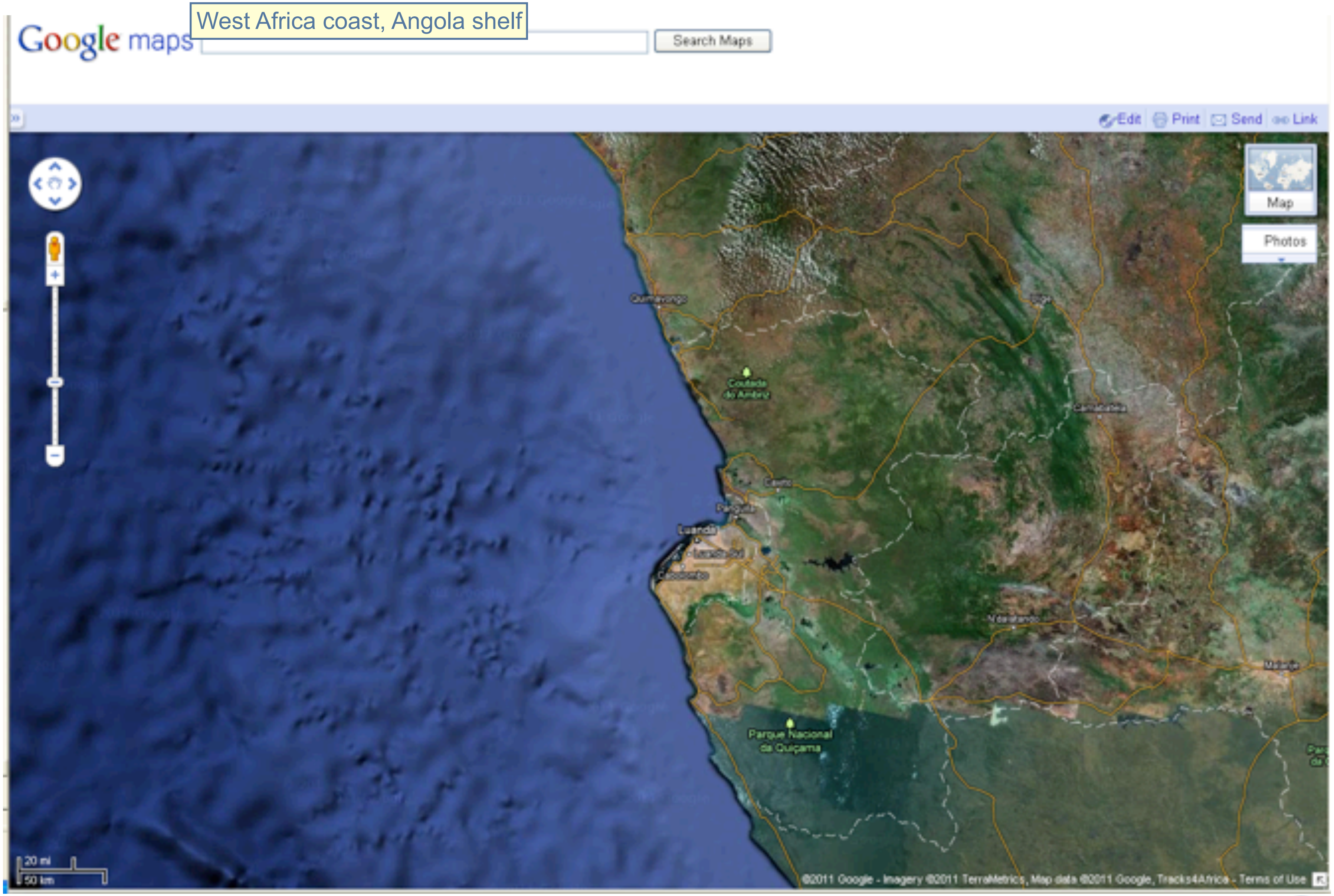
Figure 3c

Thin-bedded turbidites showing Bouma Ta, Tb and Tc divisions

Figure 3d

Bioturbated shales

West Africa coast, Angola shelf



TOTAL

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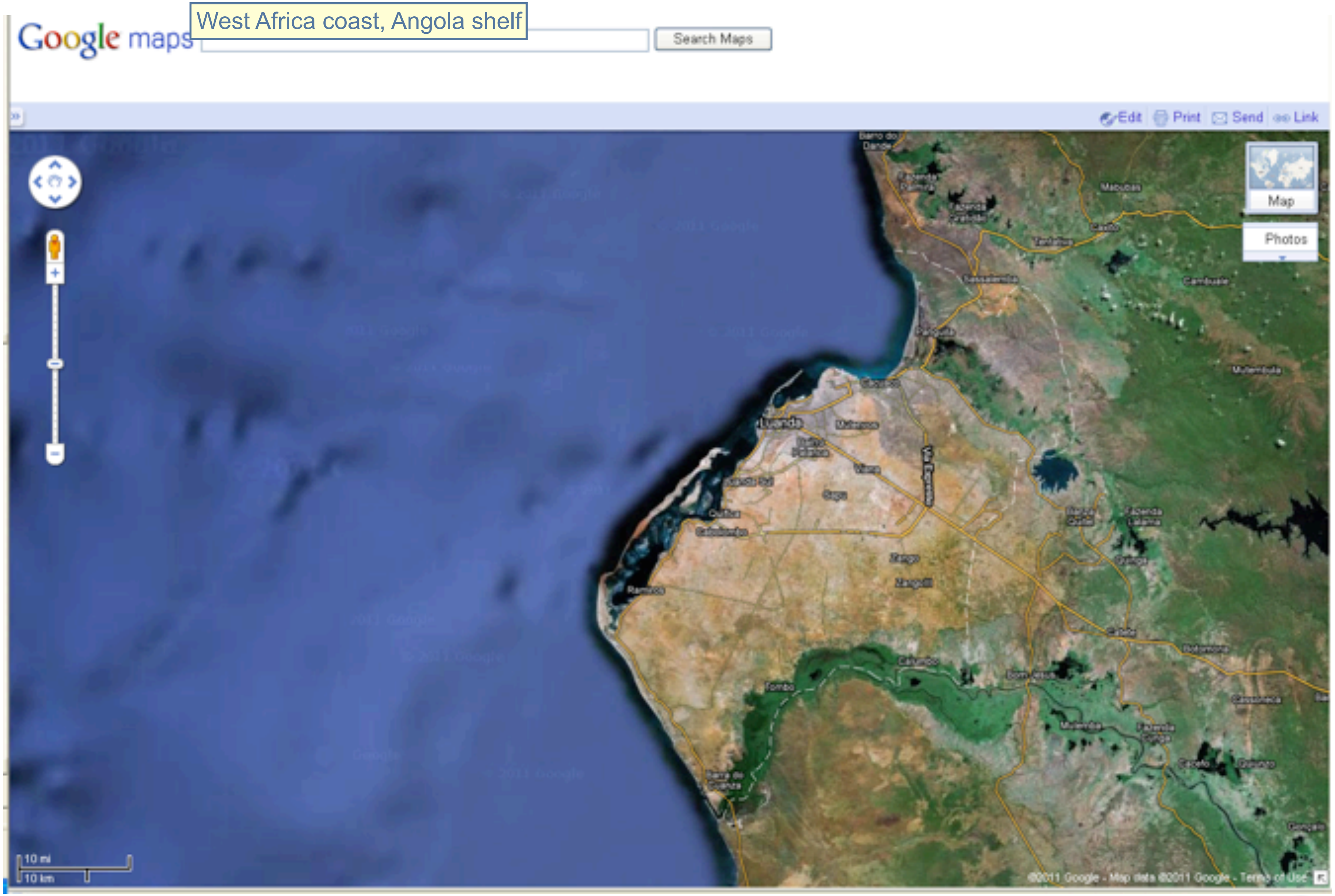
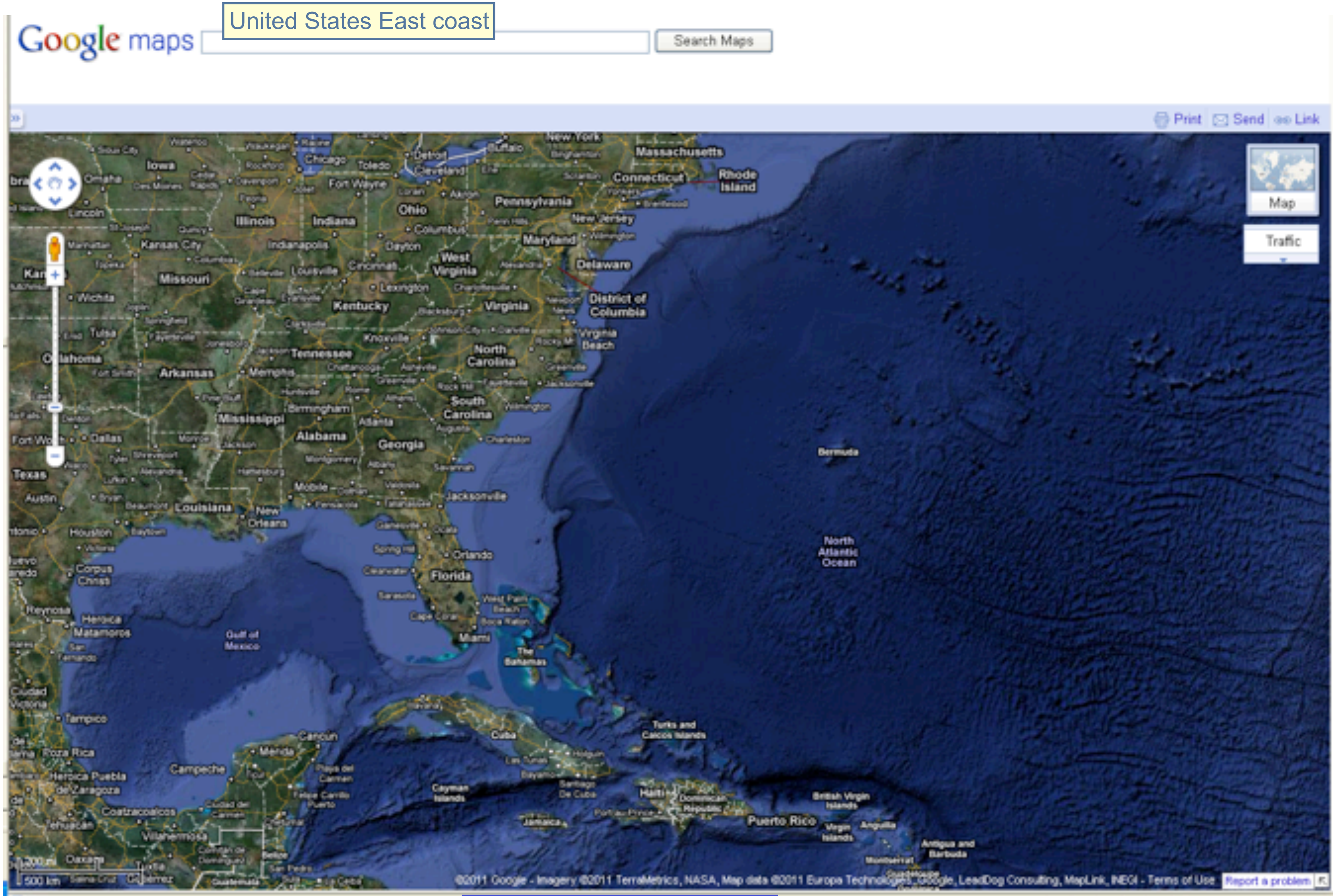
West Africa coast, Angola shelf



Littoral barriers creating lagoons

United States East coast



The best studied area in the world.
Golf of Mexico – internal sea
Bahamas barrier reef
East coast shelf

TOTAL

Outcrop 5 : Bukit Pinang hutan

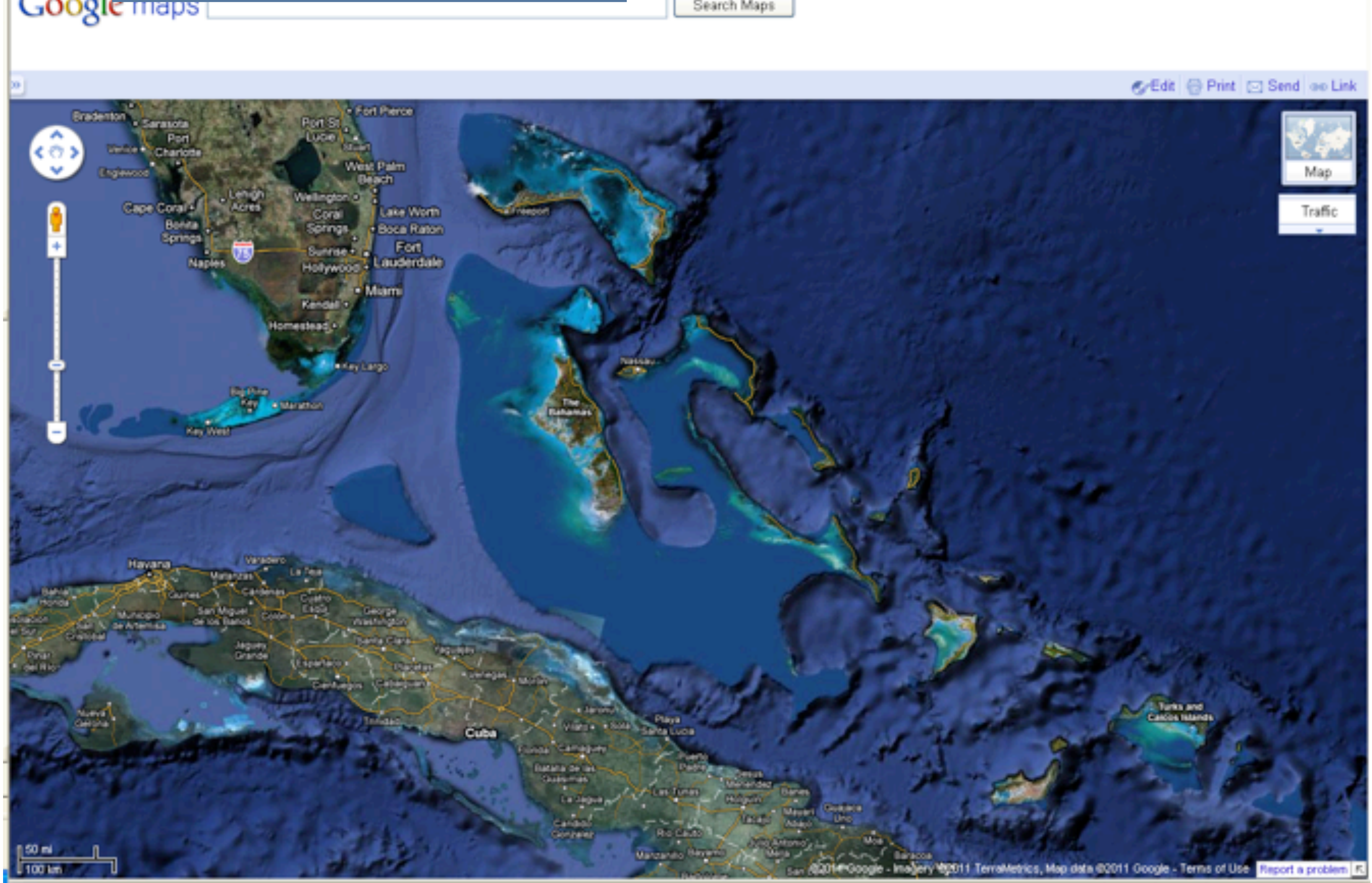
Bioturbated thin-bedded turbidites, slope turbidites

Levee complex

Outcrop 5 : Bukit Pinang hutan

Bioturbated thin-bedded turbidites, slope turbidites

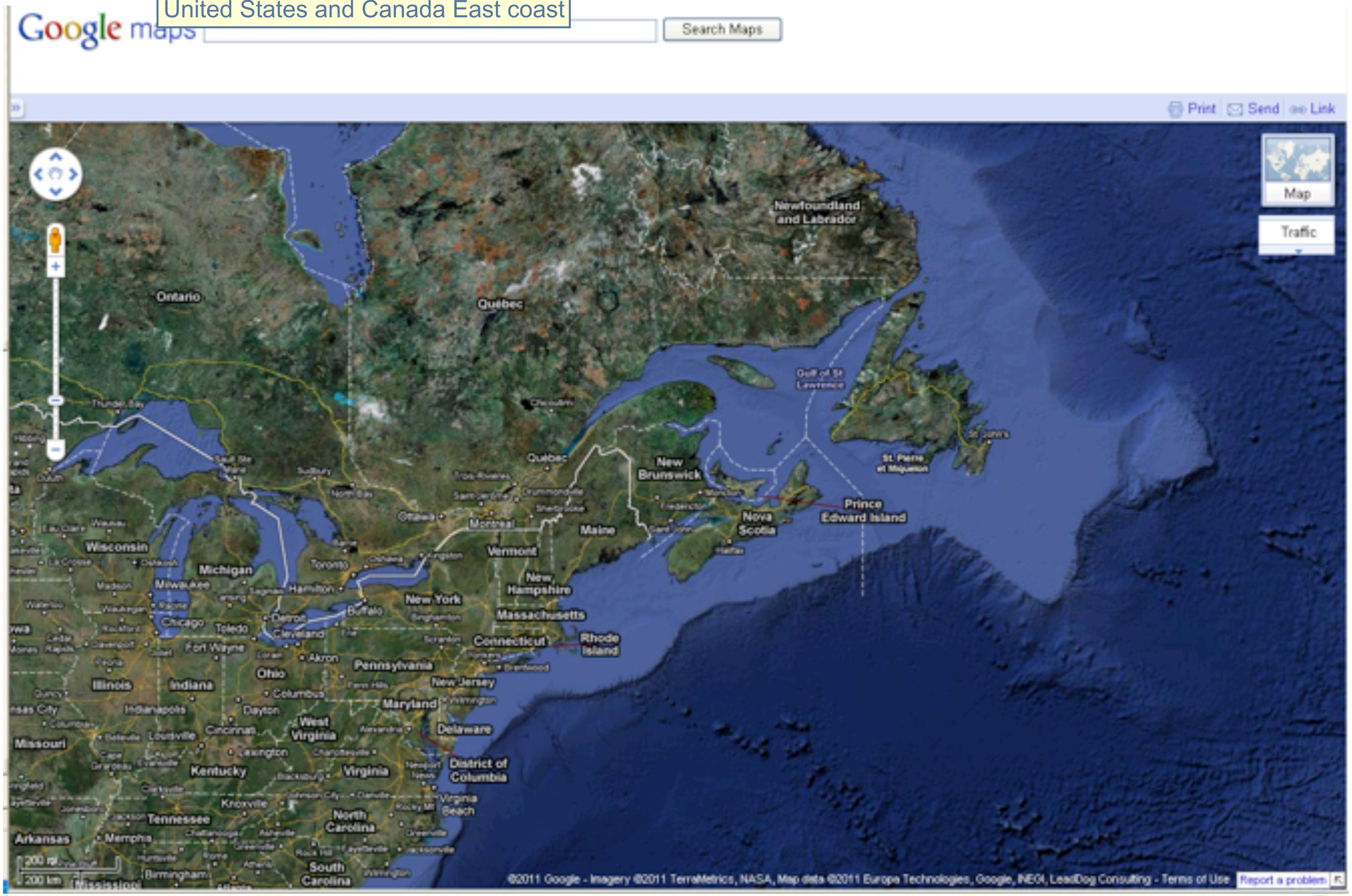
United States East coast, Great Bahamas reef



No clastic input, permanent water flow to the GOM

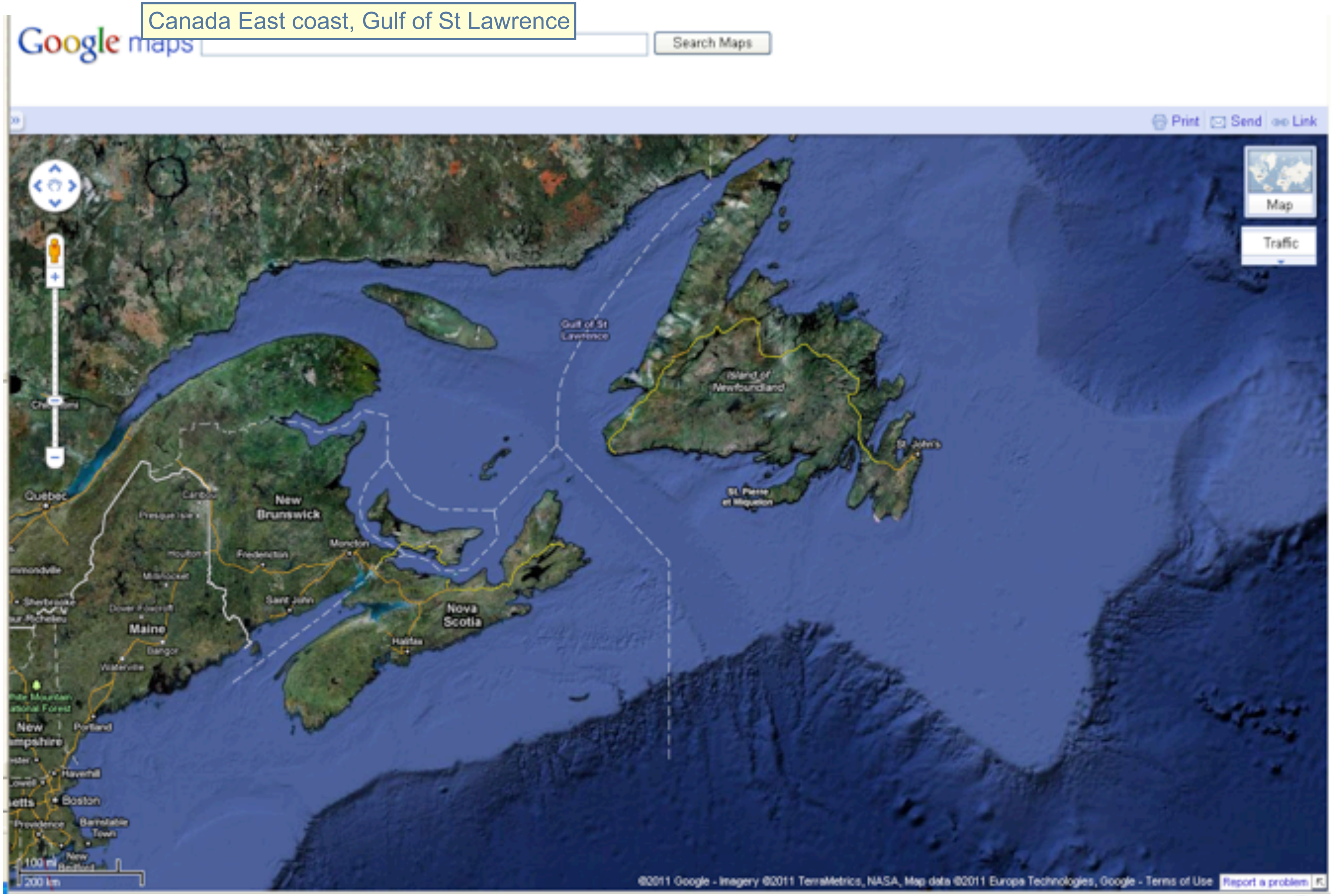
TOTAL

United States and Canada East coast

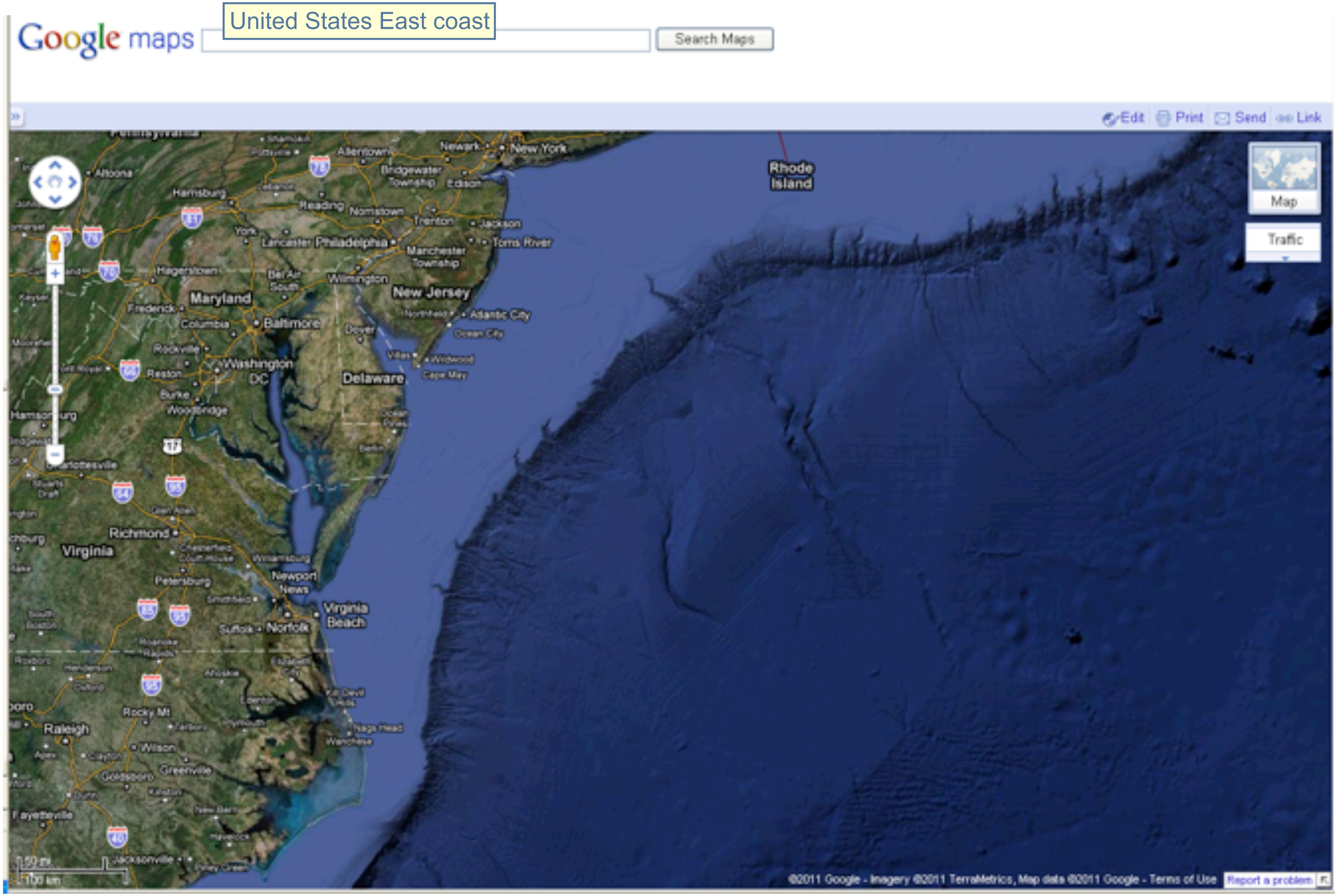


Internal seas, estuaries, lagoons, barriers

Canada East coast, Gulf of St Lawrence



TOTAL


United States East coast
Google maps
Search Maps
Edit
Print
Send
Link
Map
Trafic
Rhode Island
Newark
New York
Allentown
Harrisburg
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Philadelphia
Toms River
New Jersey
Atlantic City
Maryland
Baltimore
Dover
Washington DC
Delaware
Cape May
Richmond
Virginia
Newport News
Virginia Beach
Norfolk
Raleigh
Fayetteville
Greenville
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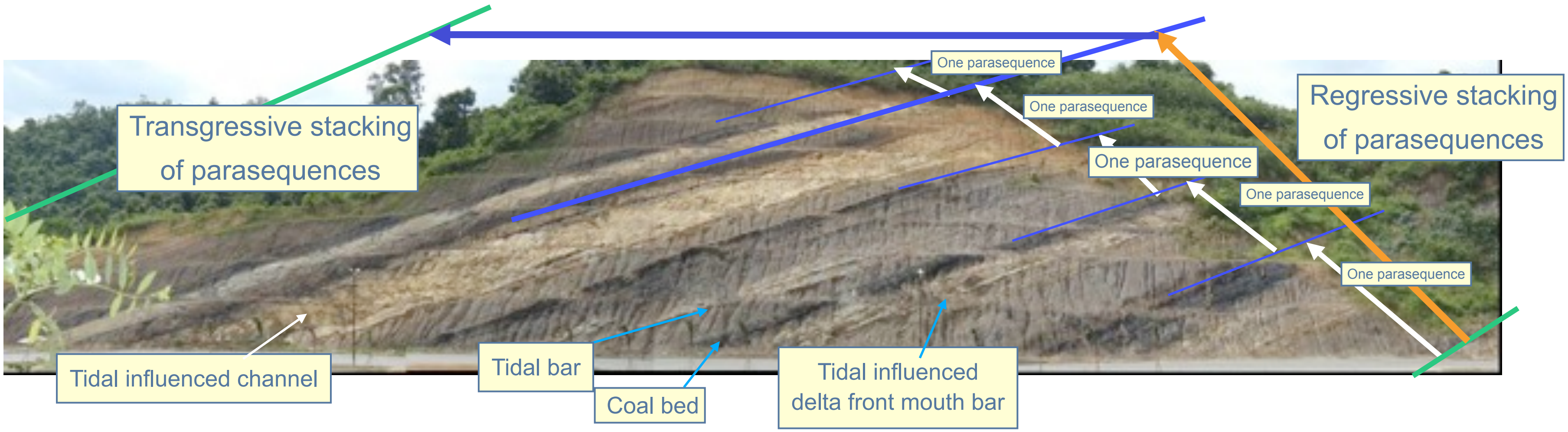
Report a problem

Tidal flat dominated by mud sedimentation

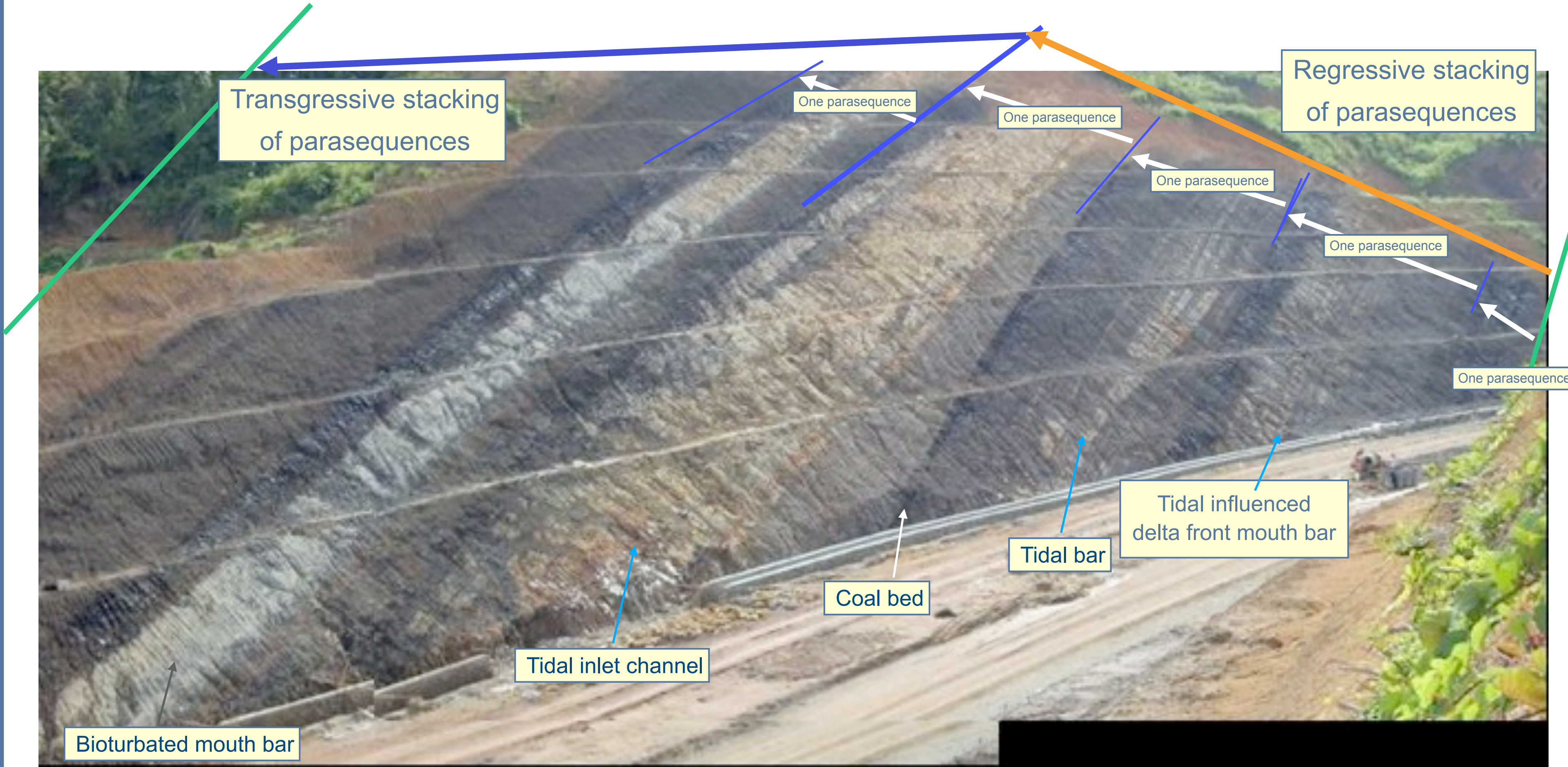
Stop 5 – Stadion Utama – deltaic parasequences, stratigraphic hierarchies



Outcrop example of individual deltaic cycles vertically stacked in a Regressive-Transgressive cycle

TOTAL

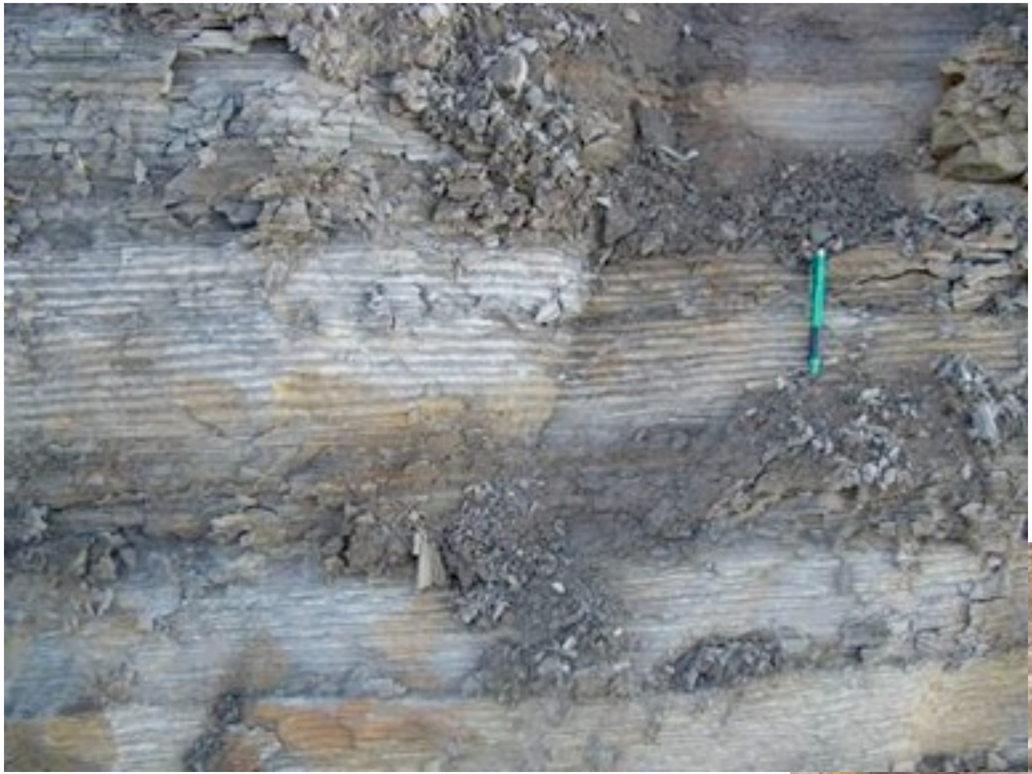
Stop 5 – Stadion Utama – deltaic parasequences, stratigraphic hierarchies



Outcrop example of individual deltaic cycles vertically stacked in a Regressive-Transgressive cycle

Stop 5 – Stadion Utama – deltaic front tidal bars

Jalan Baru (Palaran), Stadion Utama



Vertically aggraded tidal deposits

Current ripples and desiccation cracks

TOTAL

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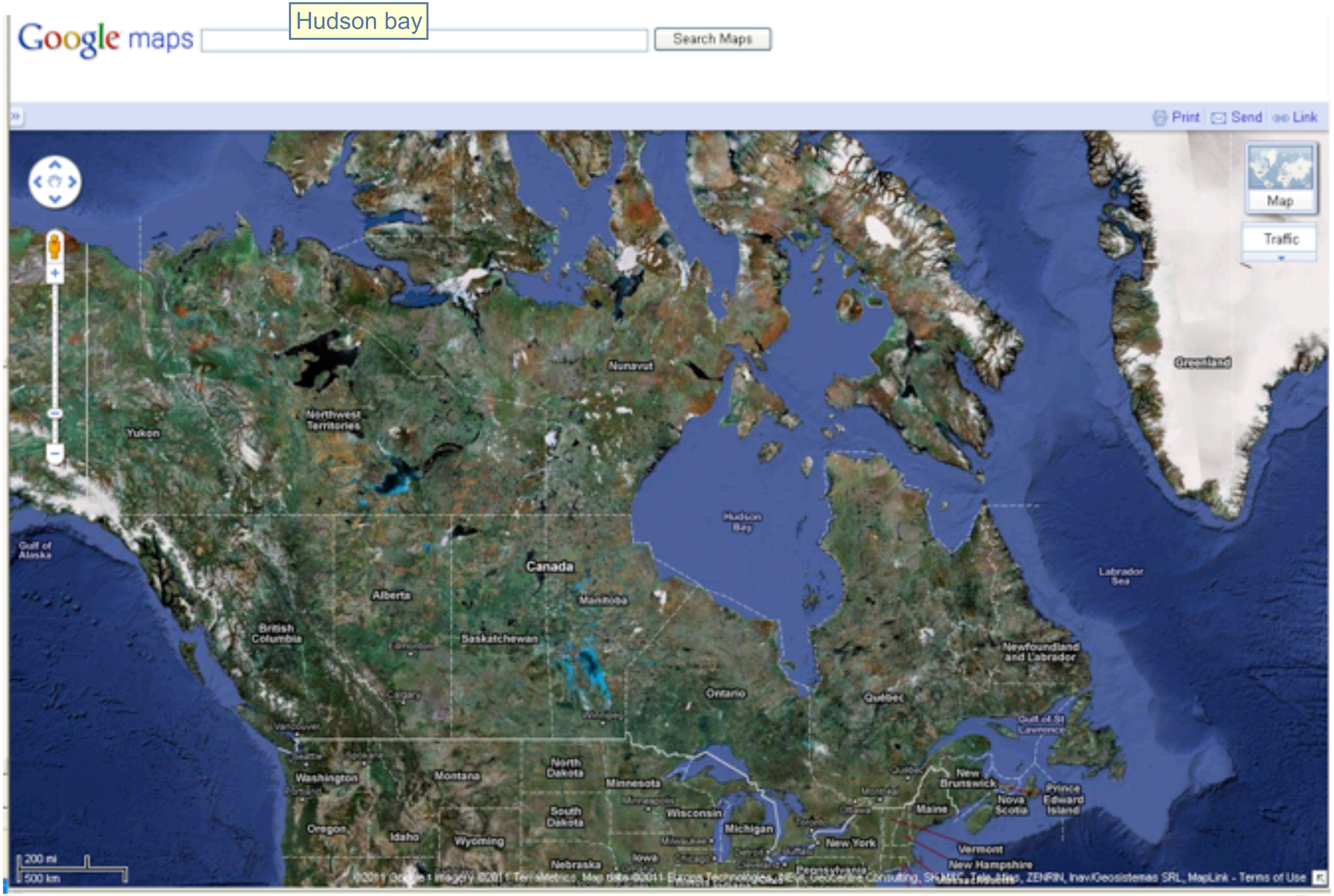
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Search Maps
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Traffic
Nunavut
Greenland
Northwest Territories
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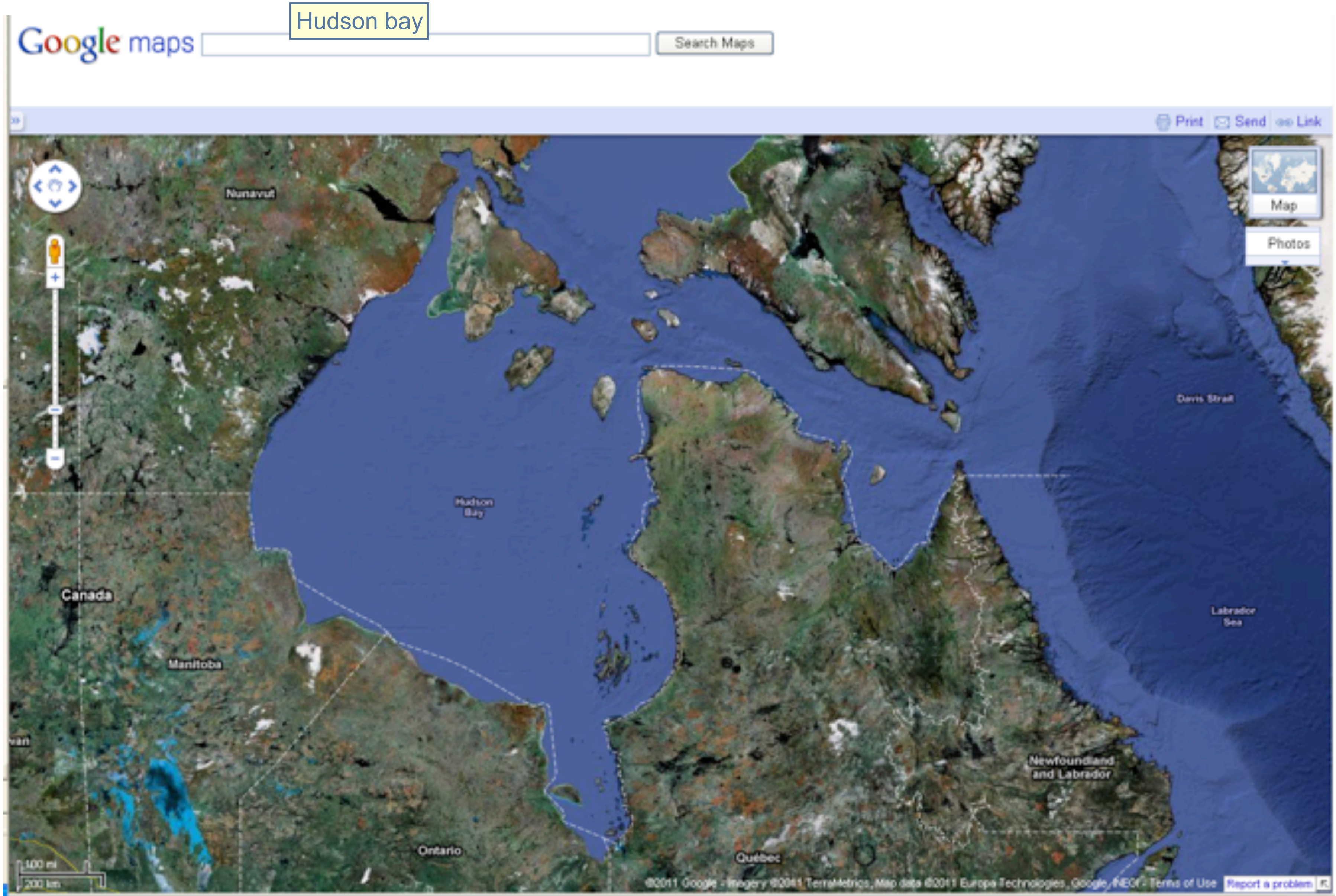
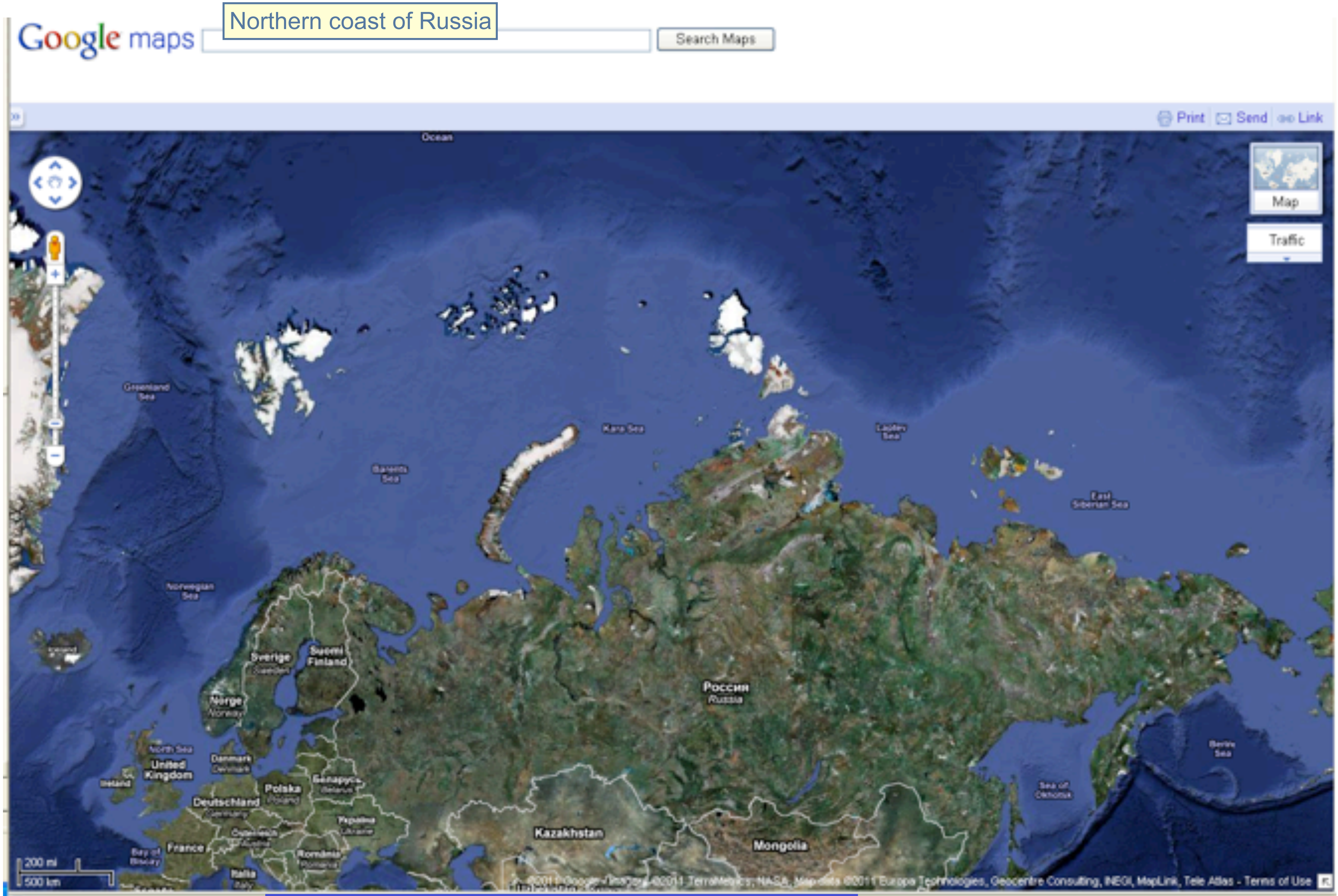
Canada
Alberta
Manitoba
British Columbia
Saskatchewan
Labrador Sea
Newfoundland and Labrador
Ontario
Quebec
North Dakota
Montana
Washington
Minnesota
Wisconsin
Michigan
South Dakota
Oregon
Idaho
Wyoming
New York
New Brunswick
Maine
Nova Scotia
Prince Edward Island
Vermont
New Hampshire
Nebraska
Iowa
200 mi
500 km


Hudson bay
Google maps
Search Maps
Print
Send
Link
Map
Photos
Nunavut
Hudson Bay
Davis Strait
Canada
Manitoba
Labrador Sea
Newfoundland and Labrador
Ontario
Québec
100 mi
200 km
Report a problem

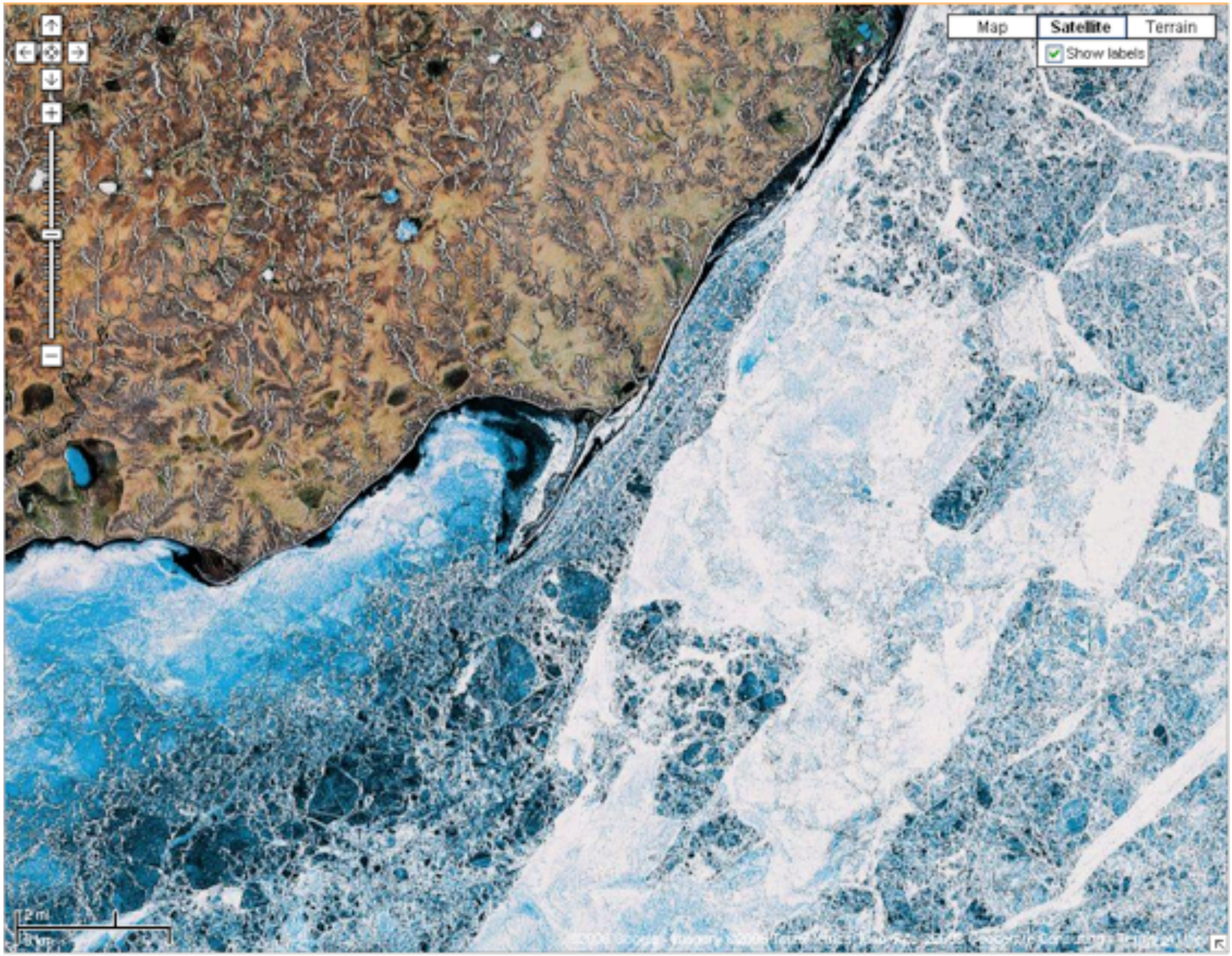
TOTAL

Northern coast of Russia



A major river arriving to the coast every 200 – 500 km
A very wide and extensive shelf dominated by catastrophic storms
Freezing temperature

TOTAL

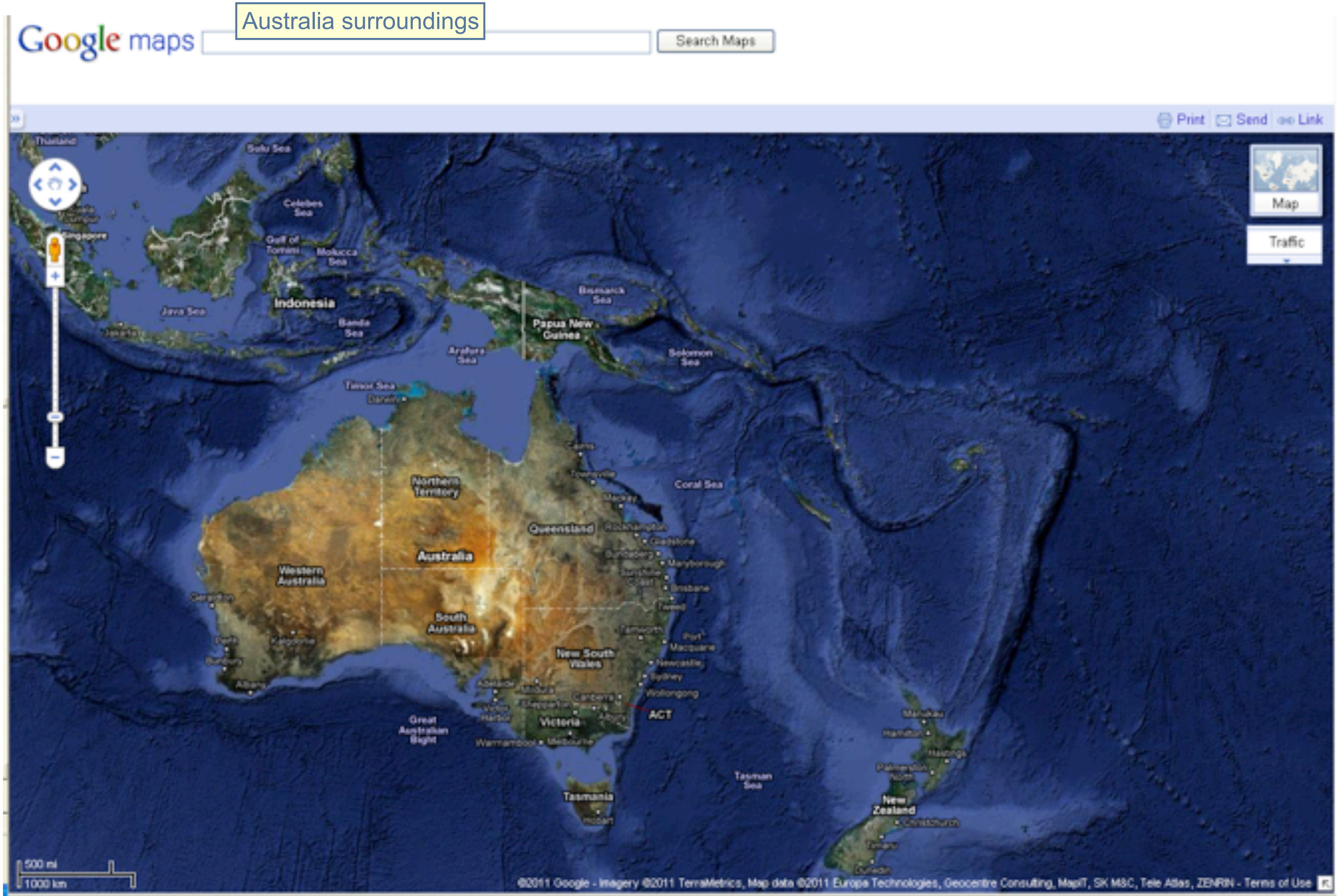


Friday, 7 October 2011

Bykovsky Peninsula

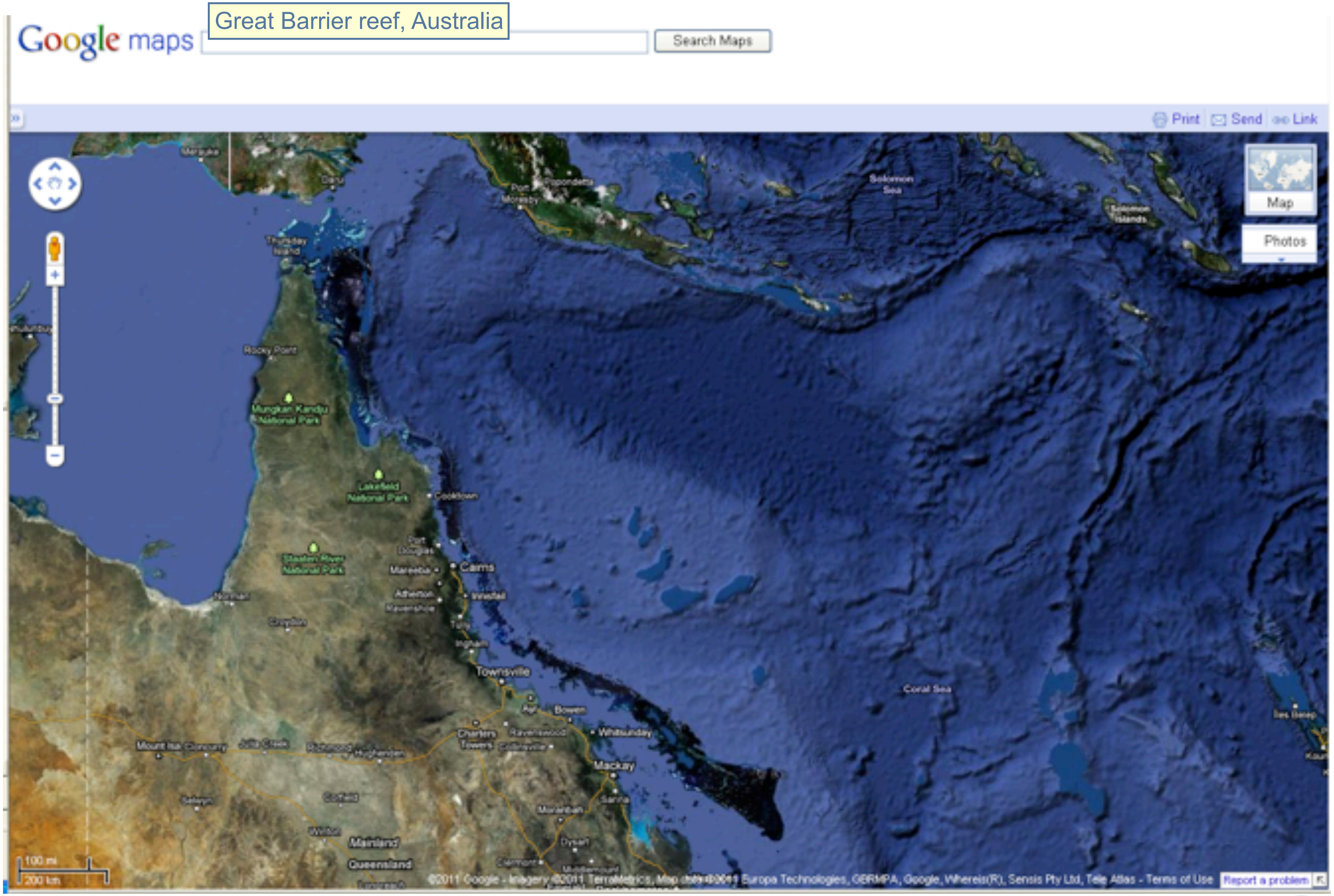
Wood drift in the lagoon

Australia surroundings



No major clastic input in the shelf. Development of great barrier reef.
Volcanic arcs and carbonate rims surrounding them

TOTAL


Great Barrier reef, Australia
Google maps
Search Maps
Print
Send
Link
Map
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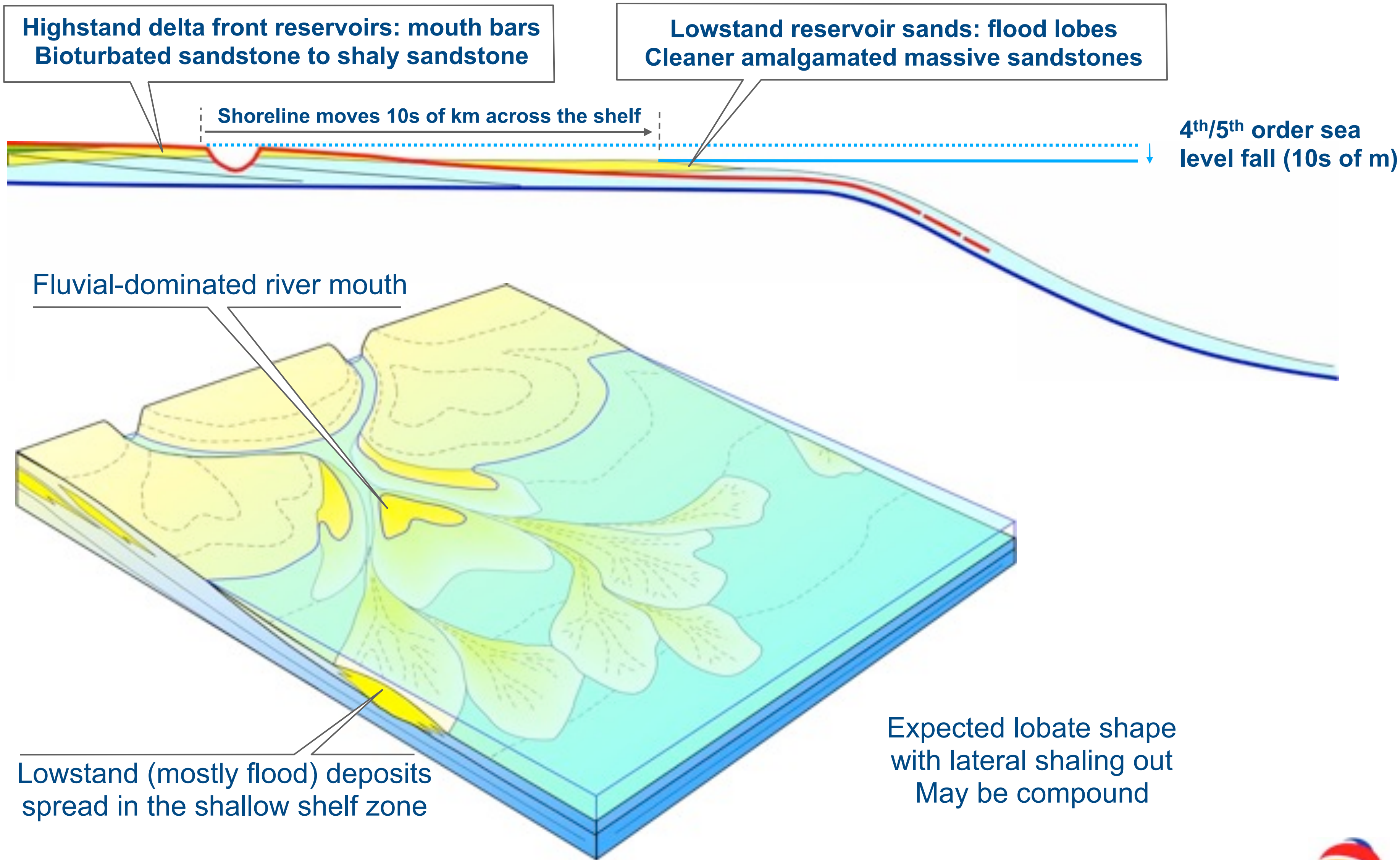
Thursday Island
Rocky Point
Cooktown
Cairns
Innisfail
Townsville
Bowen
Whitsunday
Mackay
Coral Sea
Mainland
Queensland


Highstand delta front reservoirs: mouth bars
Bioturbated sandstone to shaly sandstone
Lowstand reservoir sands: flood lobes
Cleaner amalgamated massive sandstones
Shoreline moves 10s of km across the shelf
4th/5th order sea level fall (10s of m)
Fluvial-dominated river mouth
Lowstand (mostly flood) deposits spread in the shallow shelf zone
Expected lobate shape
with lateral shaling out
May be compound

Stop 5 – Stadion Utama – deltaic parasequences, stratigraphic hierarchies

Outcrop example of individual deltaic cycles vertically stacked in a Regressive-Transgressive cycle

TOTAL

Stop 5 – Stadion Utama – Completely bioturbated delta front mouth bar (transgressive tract)

Close up view of the bioturbated mouth bar

TOTAL

Friday, 7 October 2011

Ichnofabrics and ichnofossils

Biogenic sedimentary structures do not represent the burrowing animals themselves, but show their behaviour.
Each trace fossil tends to be attributed to its trace-making organism,
but they can tell more interesting things than the name of the "architect".

Baisc Ichnological principles

The same species can produce different structures corresponding to different behaviour patterns

The same burrow may be differently preserved in different substrates according to the average grain size, sediment stability, water content, and chemical conditions in sediment.

Different tracemakers with similar behaviour may produce identical structures.

Multiple individuals may produce a single structure.

The burrowing organisms usually have a low potential of preservation as body fossils.

The open burrow is an environment with a higher preservation potential than the rest of the sea floor in general, protecting the fallen in skeletons against the most destructive phases of early diagenesis.

http://www.es.ucl.ac.uk/undergrad/fieldwork/image/fieldtrips/TraceFossils/tracefl.html

Ichnofabrics and ichnofossils

Ichnofabrics and ichnofossils

Ichnofabrics and ichnofossils

Classification principles
Etiological (behavioural) classification

resting traces - **cubichnia** - created by active organisms while at rest or hiding from prey;

locomotion traces - **repichnia** - tracks and trails created while moving across the sediment surface;

dwelling traces - **domichnia** - three dimensional dwelling structures created by burrowing;

grazing traces - **pascichnia** - horizontal feeding traces on the surface of the substrate;

feeding traces - **fodinichnia** - three dimensional networks characterized by the combined functions of deposit feeding and dwelling.

traps and gardening traces - **agrichnia** - regular, patterned branching structures used as traps for migrating meiofauna or as gardening systems where microbes might be cultured for food.

predation traces - **praedichnia** - are common on hard substrates, as round drill holes in shells and shell damage by predators.

equilibrium traces - **equilibrichnia** - are characterized by burrows that must be constantly adjusted within the substrate due to the agradation and degradation processes.

escape traces - **fugichnia** - occur as the animal flees to the new sea floor

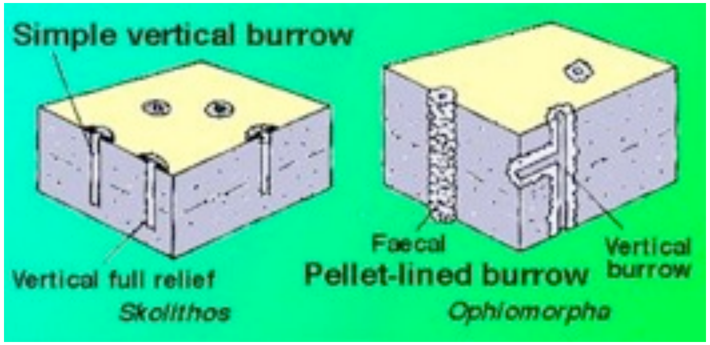
edifices built above the substrate - **aedificichnia** - are structures built of sediment, more or less cemented by the architect

structures made for breeding purposes - calichnia - are structures built for raising larvae and juveniles

Classification principles
Etiological (behavioural) classification

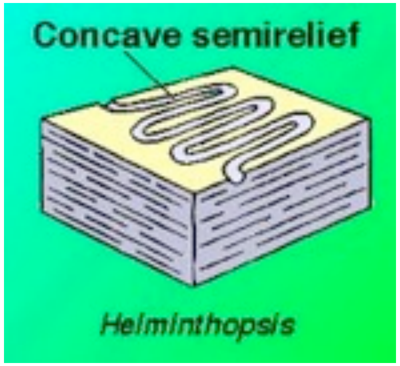
dwelling traces - **domichnia** - three dimensional dwelling structures created by burrowing;

Ophiomorpha



Typical dwelling traces include: Skolithos (a simple, unpaired pipe),
Ophiomorpha (lined with faecal pellets - which determine a nodular outer surface to the burrow
- usually associated with crustaceans),
Teredolites (bivalve borings cut into driftwood), and Gastrochaenolites (bivalve borings cut into firm or rock substrates).

grazing traces - **pascichnia** - horizontal feeding traces on the surface of the substrate;



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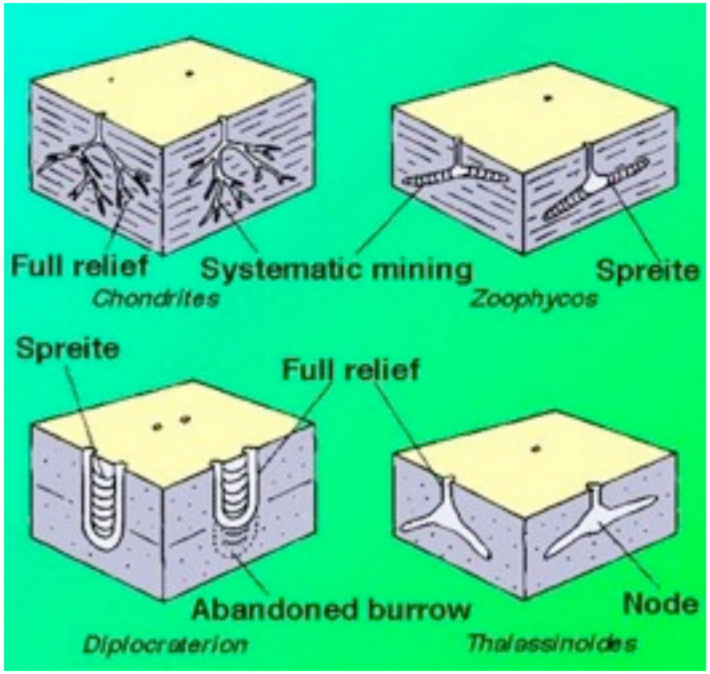
Thick mouth bar sandstone beds. Ophiomorpha trace fossil. Delta front environment

Classification principles
Etiological (behavioural) classification

feeding traces - **fodinichnia** - three dimensional networks characterized by the combined functions of deposit feeding and dwelling.



Chondrites

Feeding burrows include: Chondrites (downward branching burrow),
Zoophycos (complex downward spiralling burrow),
Diplocraterion (feeding / dwelling vertical, U-shaped burrow),
Rhizocorallium (feeding / dwelling vertical, then horizontal, U-shaped burrow), and
Thalassinoides (feeding / dwelling trace, displaying a network of 'triple junction' interconnected vertical and horizontal tubes, usually associated with shrimps)

Thin silt lenses surrounded by black shales. Chondrites trace fossil. Prodelta to distal delta front environment

Types of Ichnofacies

The trace fossils have remained in appearance rather constant since Cambrian, even if their producers might have been different.

The trace fossil **assemblages** can be divided according the palaeoenvironmental scheme into a number of ichnofacies named after a characteristic trace fossil.

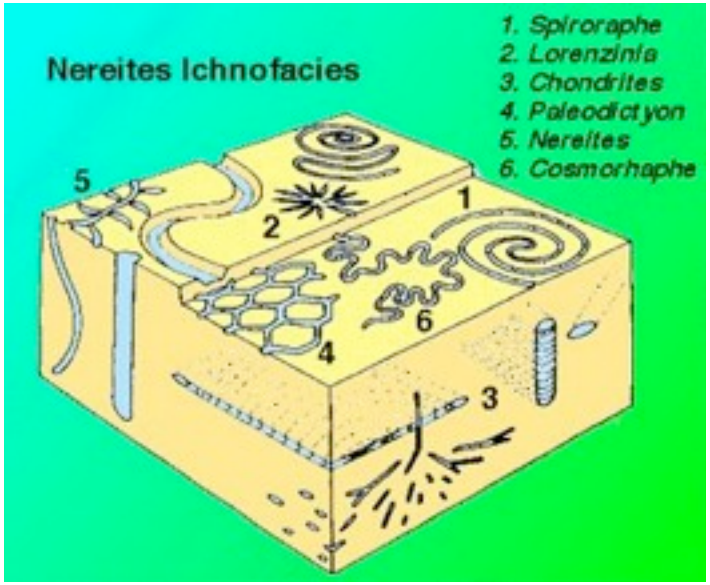
The ichnofacies indicate a particular sedimentary facies and can be identified on the basis of its trace fossil assemblage

Woodground	Rockground	Firmground		Loose- and softground			Sedimentology / environment		
		Marine	Freshwater	Freshwater	Marine		Energy	Bathymetry	Grainsiz e
			Scoyenia	-	*Psilonichnus*		-	Backshore	Sand
				Rusophycos?	*Skolithos*		High	Beach	Sand
				Arenicolites?	*Arenicolites*		Event	Shelf	Sand silt
Teredolites	*Trypanites*	*Glossifungites*	-	*Fuersichnus*?	*Cruziana*		Medium	Lagoon /	Sand, silt
				Mermia	*Nereites*		Event	Slope to	Sand, mud
					Zoophycos		Low	abyssal	Mud

Scheme indicating relationships of ichnofacies with environment (after Bromley, 1996).

Types of Ichnofacies

Nereites Ichnofacies



The Nereites Ichnofacies is recognized by the presence of meandering pascichnia (Nereites, Neonereites and Helminthoide), spiral pascichnia (Spirorhaphe), and agrichnia (Paleodictyon and Spirodesmos).
Vertical burrows are almost entirely absent.

This ichnofacies indicates deep-water environments, including ocean floors and deep marine basins.
The trace fossils occur in muds deposited from suspension, and in the mudstones and siltstones of distal turbidites.

TOTAL

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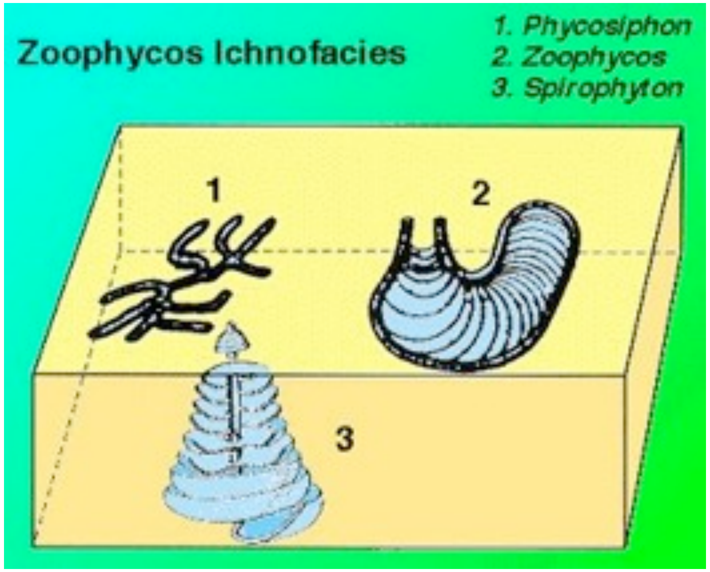
Types of Ichnofacies

Zophycos Ichnofacies

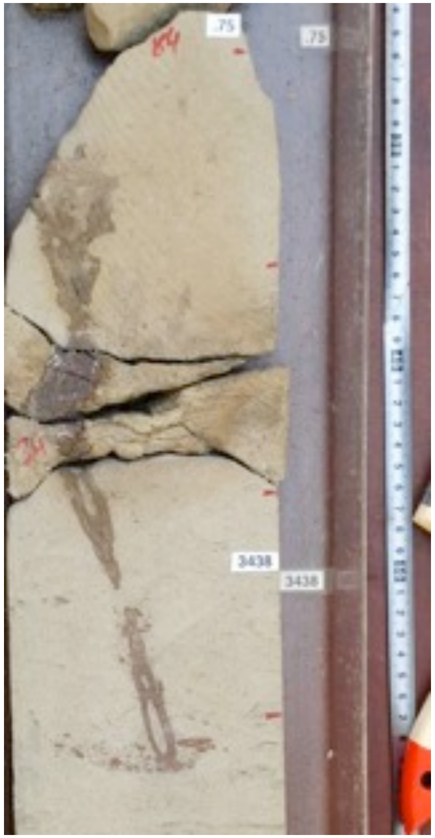


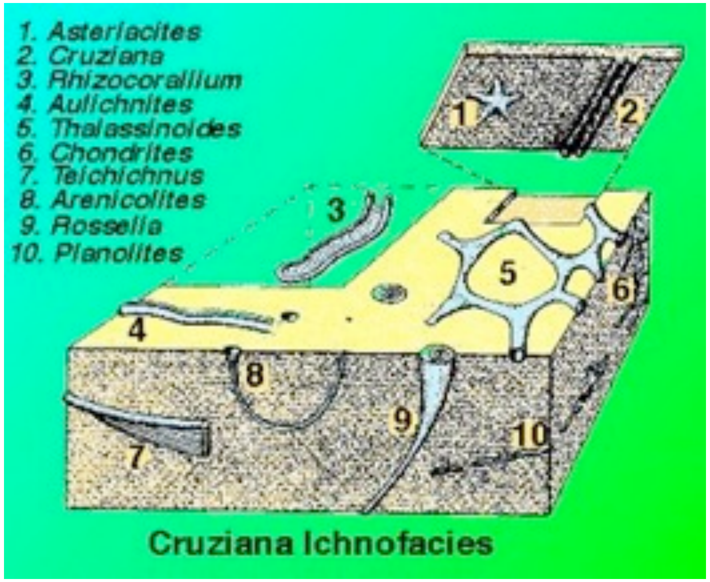
The Zoophycos Ichnofacies is characterized by complex fodinichnia (Zoophycos, and sometimes other deep traces such as Thalassinoides) in tiered arrangements.

The ichnofacies occurs in a range of water depths between the abyssal zone and the shallow continental shelf, in normal background conditions of sedimentation. The Nereites Ichnofacies may be a matching association found at similar water depths during times of turbidite (event) deposition.

Types of Ichnofacies

Cruziana Ichnofacies





Rossellia

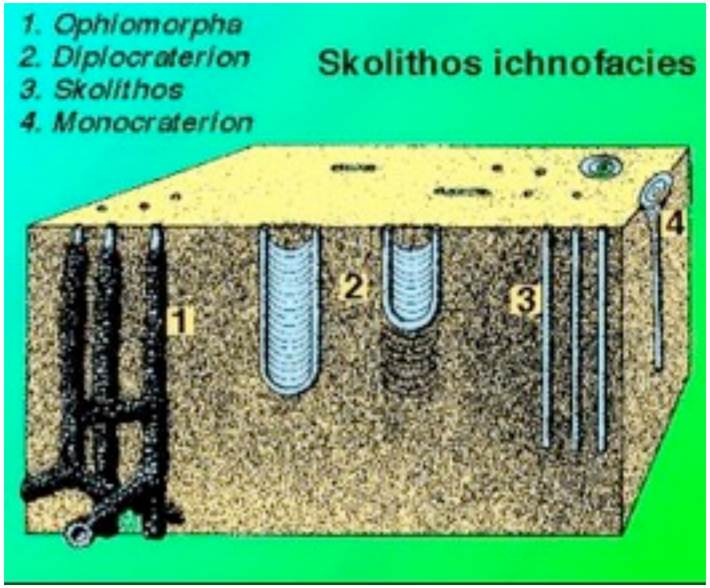
The Cruziana Ichnofacies shows rich trace fossil diversity, with horizontal repichnia (Cruziana and Aulichnites), cubichnia (Rusophycus, Asteriacites and Lockeia), and vertical burrows.

This ichnofacies represents mid and distal continental shelf situations, below normal wave base, but may be affected by storm activity.

Types of Ichnofacies

Scolithos Ichnofacies

Ophiomorpha



The Skolithos Ichnofacies can be recognized by a low diversity of abundant vertical domichnia burrows (Skolithos, Diplocraterion and Arenicolites), fodinichnia (Ophiomorpha), and fugichnia.

All these traces typically indicate intertidal situations where the organisms have to be able to respond rapidly in stressful conditions.
The Skolithos Ichnofacies was at first seen as occurring only in the intertidal zone,
but it is also typical of other shifting sand environments, such as the tops of storm sand sheets and the tops of turbidity flows.

TOTAL

Applications

Trace fossils provide very useful in situ records for palaeoenvironmental interpretation based on factors that influence the individual and the community. In a certain stratigraphic succession the ecological information provided by trace fossils can be pieced together to restore the local history of environmental change and basin evolution.

The importance of trace fossils in geology resides on the following concepts:

Long time range - similar taxa occur in present day environments as they did early in Phanerozoic, a useful concept for palaeoecological interpretations, although the long time range restricts the value of trace fossils in biostratigraphy.

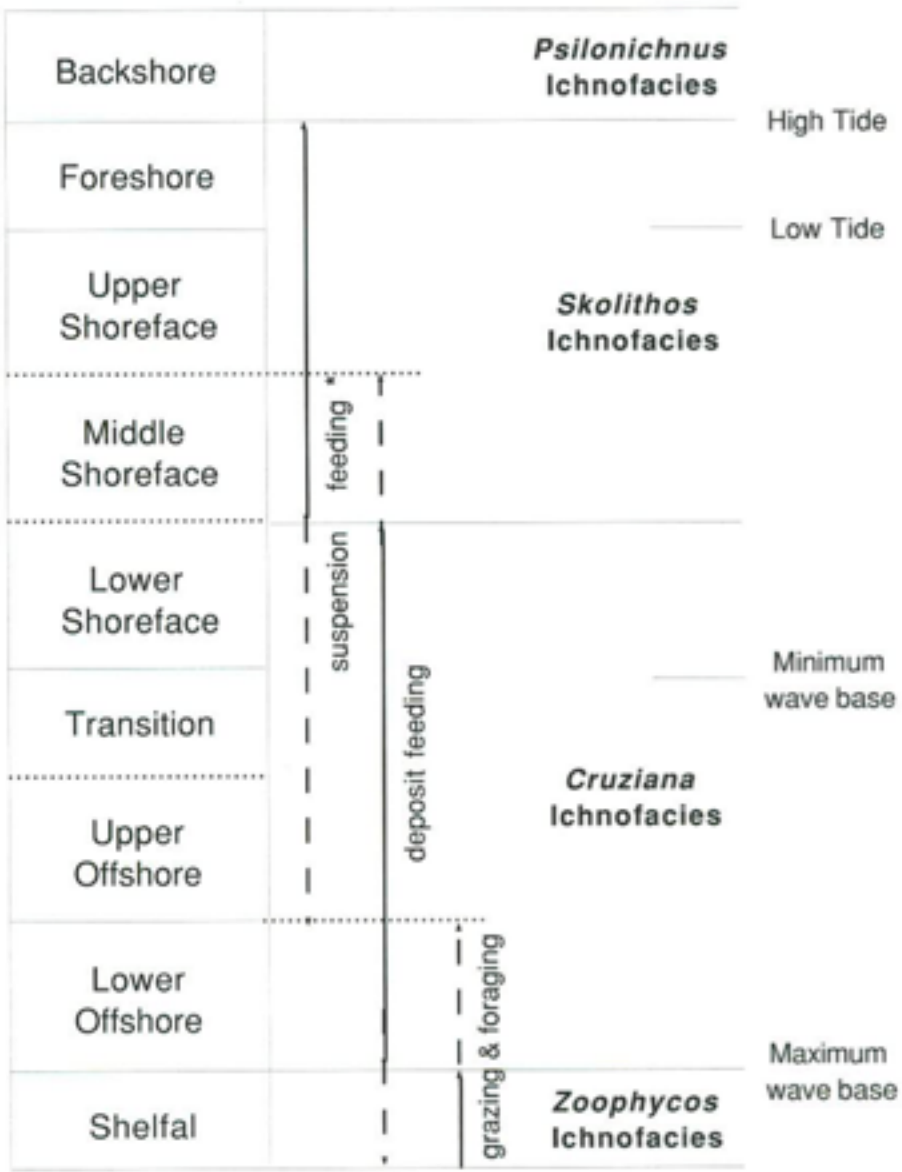
Narrow facies range - certain traces are found in close association with certain substrate (facies type).

No reworking - traces themselves are a part of the fabric of a sedimentary rock, so that they are destroyed by erosion, rather than released and reworked as the body fossils.

Occurrence in nonfossiliferous rocks - is usually of a great help for palaeoecological and stratigraphical studies in hostile, poorly populated environments.

Creation by soft-bodied taxa - trace fossils could give the only information about organisms which are not otherwise found within the sedimentary record, by demonstrating their presence (for instance the existence of soft-body metazoans prior to evolution of hard body parts in Precambrian), or function through the interaction with the sediment.

SHOREFACE MODEL

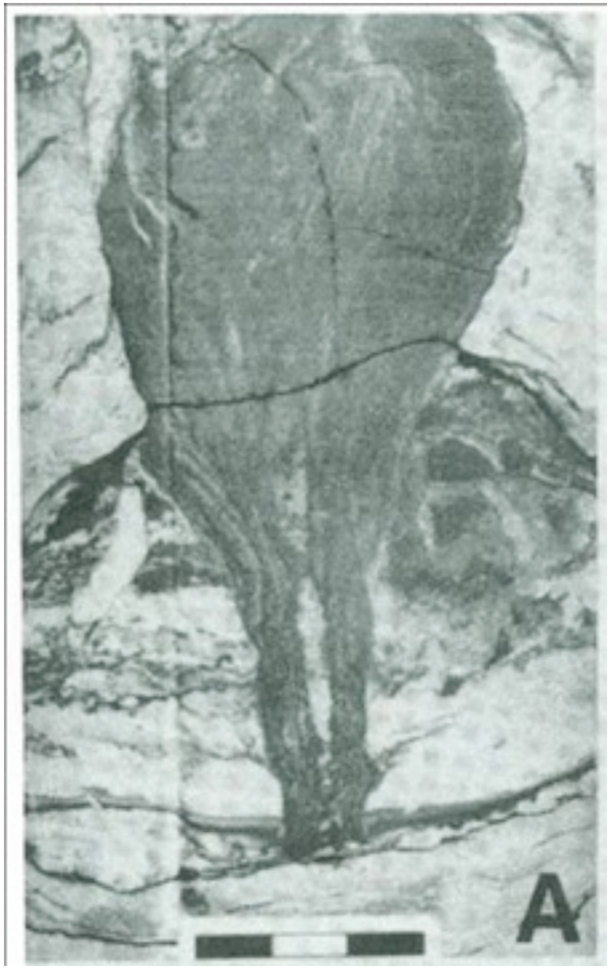


* Many tube dwellers are passive carnivore rather than suspension feeders.

Idealised shoreface model of ichnofacies succession based on observarions of Cretaceous strata of the Western Interior Seaway (McEachern & Pemberton , 1992)

TOTAL

Ophiomorpha



Rossellia

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Ophiomorpha

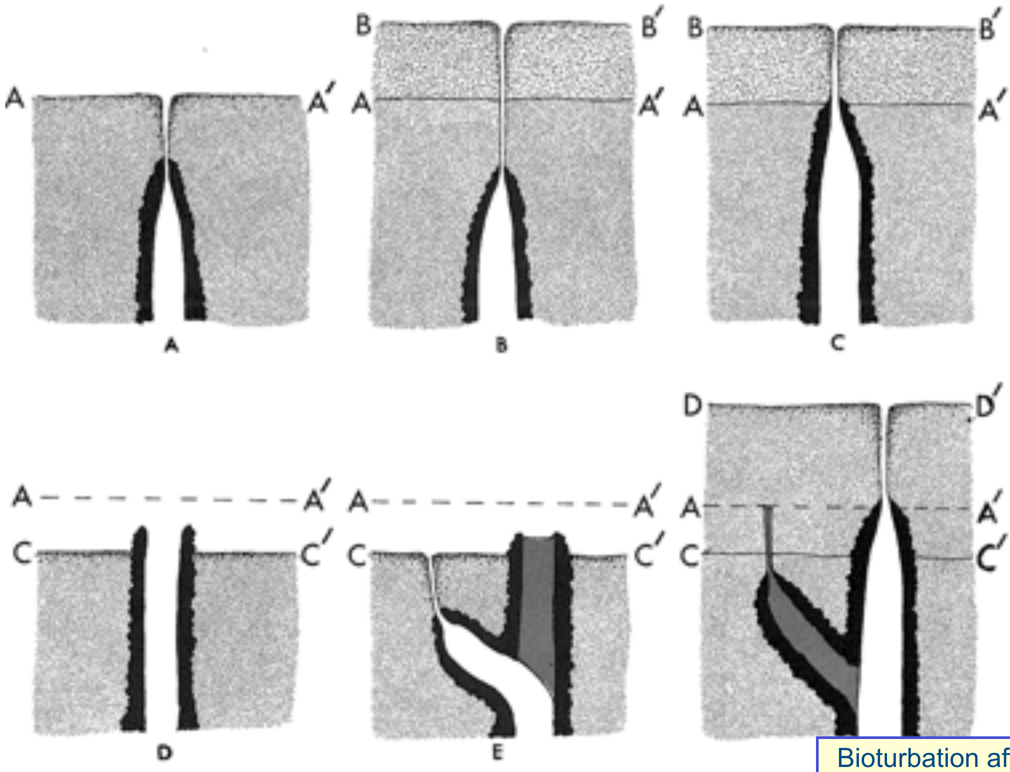


Fig. 7. Response of Callianassa burrows to erosion and deposition.

Bioturbation affecting thick sand beds (Ophiomorpha sp.),
Worms and shrimps dig a web of tubes in sand, and reinforce the walls with pellets,
The tubes are used as a living habitat,
Later on, when the animals die the tubes are filled with sand.

Ophiomorpha

Tunu 17 - 3497.5 – 3498.37 m

Ophiomorpha

TOTAL

Tunu 17 - 3524 – 3525 m

Asterossoma

Exercise

TOTAL

Tunu 6 - 3312.37 – 3313.28 m

TOTAL

Tunu A27 – 3875.37 – 3876.28 m

Top

Ophiomorpha

Tunu A27 – 3876.28 – 3877.15 m

Tunu C3 – 4039.65 – 4040.5 m

Asterossoma

Tunu C3 – 4029.15 – 4030.05 m

Tunu C3 – 3999.25, 4001.05 m

Asterossoma

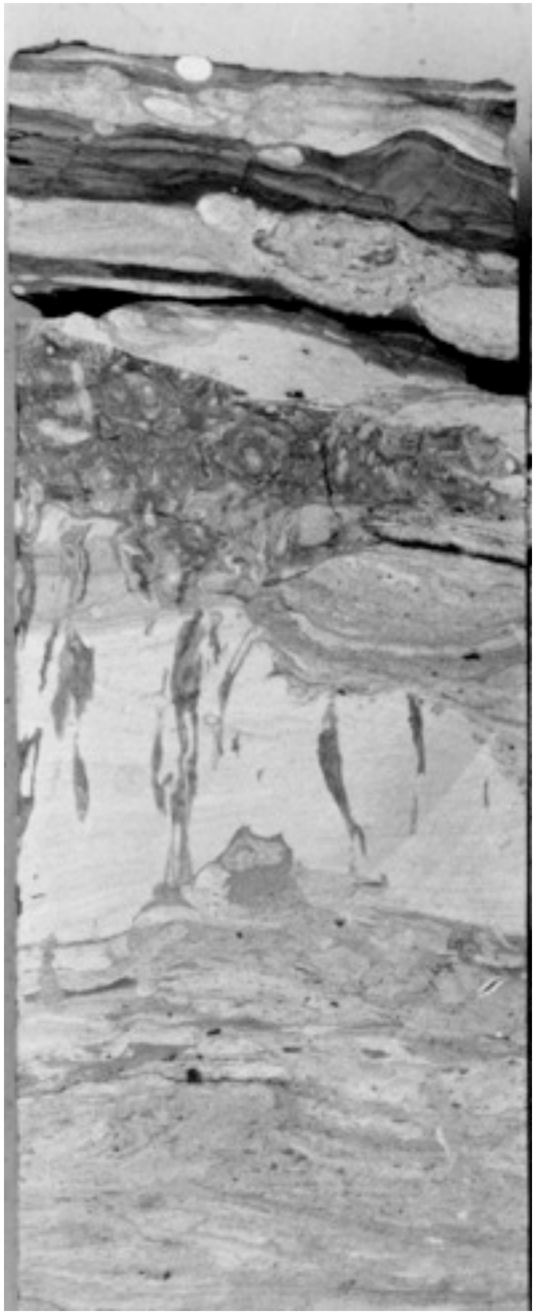
Exercise

TOTAL

Tunu G4 – 4081.1, 4082 m

Rossellia

Exercise



Tunu M2 – 4538.2 m

Asterossoma, Rossellia

Exercise

Friday, 7 October 2011

Tunu M2 – 4542.2 m

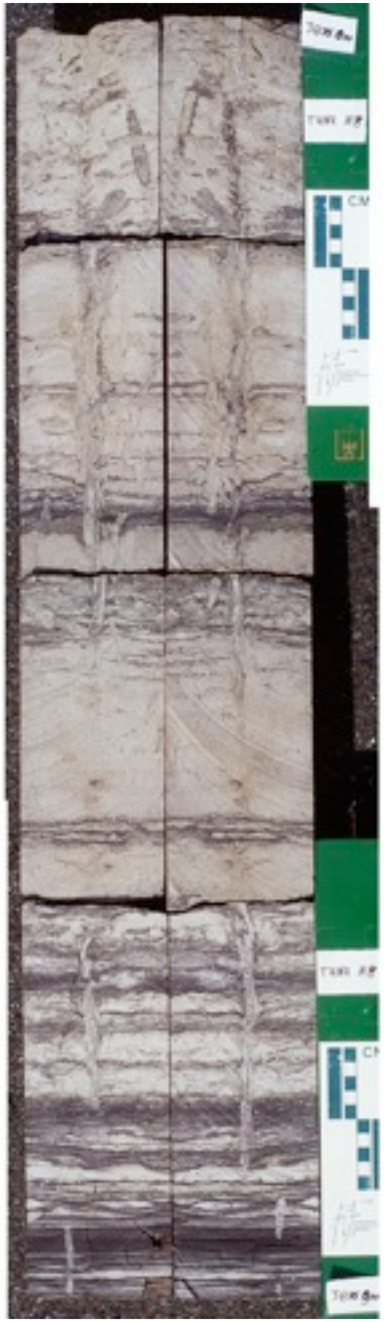
Tunu N1 – 3739.9-3740.3 m

Friday, 7 October 2011

Tunu N8 – 3868-3868.9 m

Friday, 7 October 2011

Tunu N8 – 3875-3875.9 m



Friday, 7 October 2011

Tunu W8 – 3875-3875.9 m

Exercise

TOTAL

Back-up

Outcrop example of the "zebra" facies – distal delta-front mouth bar

Outcrop example of individual mouth

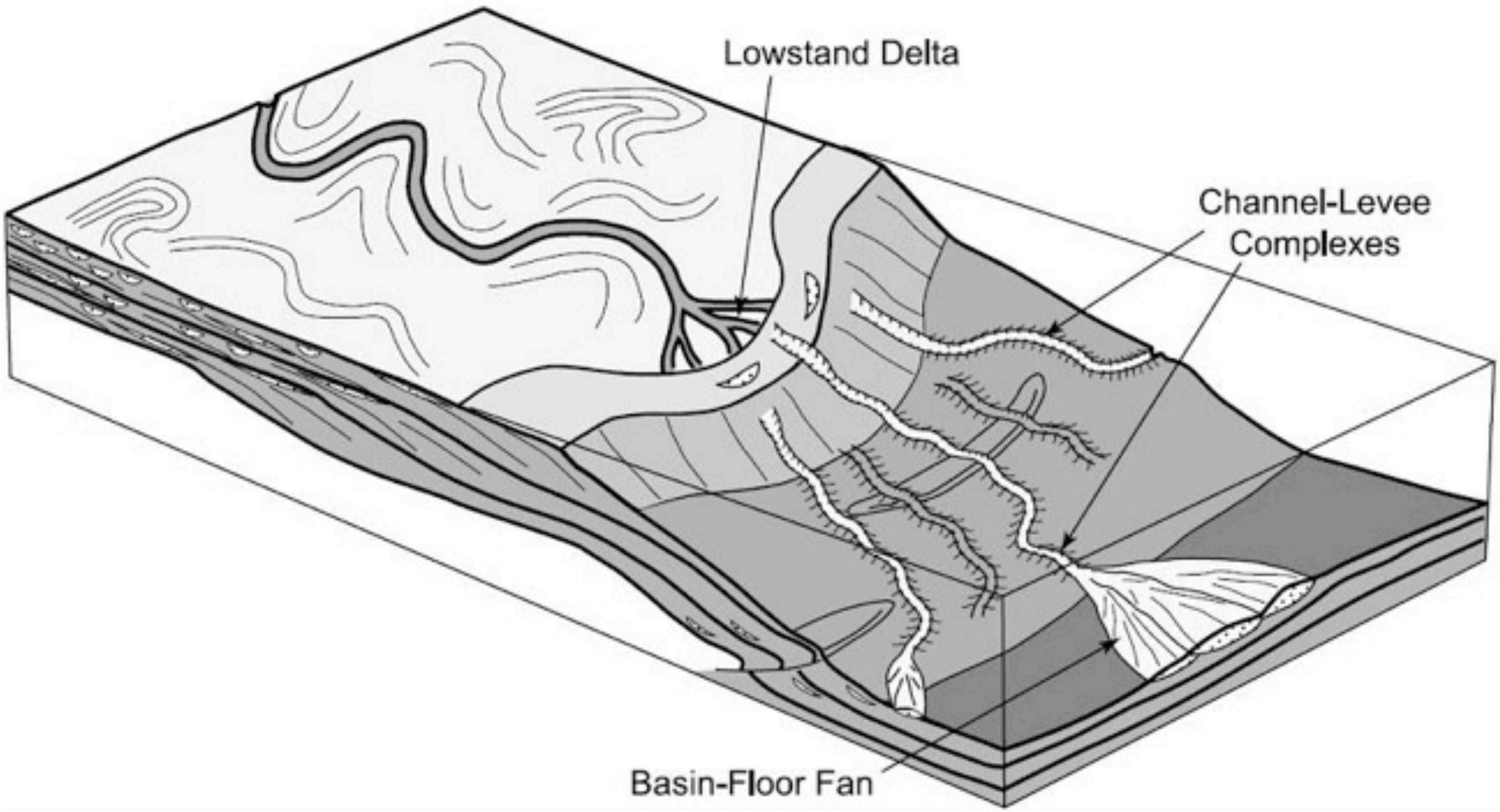
Although the bioturbation is not intense, Ophiomorpha tubes can be many meters long. Assuming their frequency every one meter, they can represent a "forest" of vertical pillars 2-3 cm in diameter. They can act as excellent pathways for fluid flow crossing the local seals between mouth bars.

TOTAL

Friday, 7 October 2011

Outcrop example of an individual mouth

Slope and Basin Floor deposits

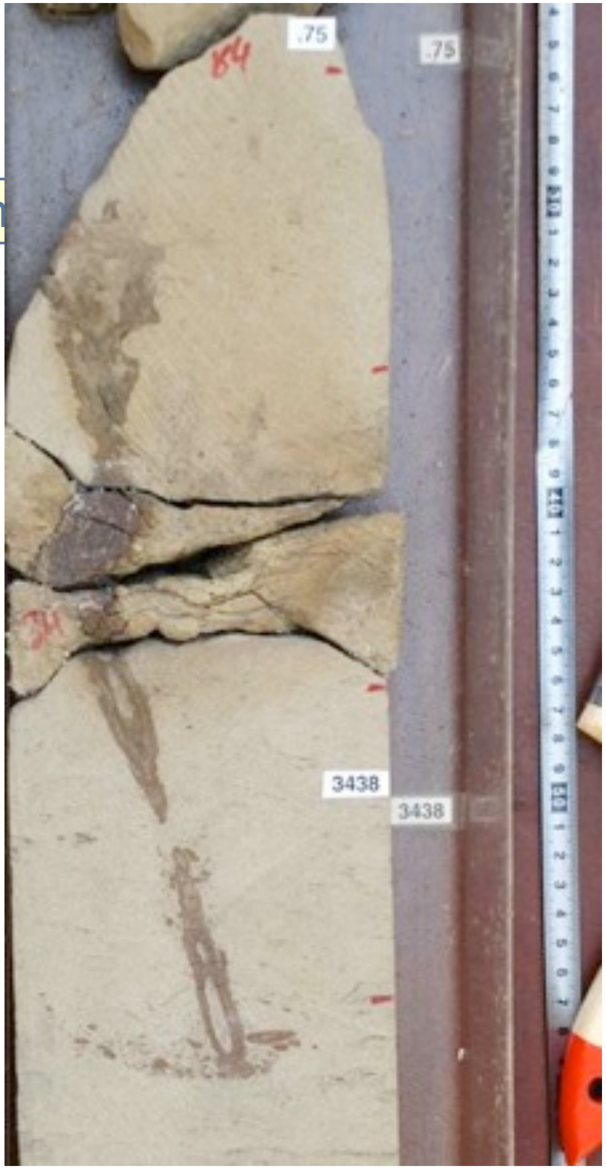


Model for Miocene sand deposition during lowstands of sea level in the Kutei Basin

Saller et al. AAPG Bulletin, v. 90, no. 10 (October 2006), pp. 1585–1608

TOTAL

Photos core Mahakam



TOTAL