Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2024 - 2025

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Domani, 25 ottobre ore 11-13?

Unit	*Topic*	*Teacher*	*Date*
1.2	Methods (geophysics, but not only)	Geletti/Rebesco	23-set
1.3	Mechanisms of basin formation (geodynamics, tectonics…)	Lodolo	26-set
1.1	Introduction to the course	Rebesco	30-set
6.1	Visit to the icebreaker Laura Bassi (along with Geologia Marina)	Rebesco	04-ott
1.4	Seismic interpretation, facies and primary structures	Rebesco	11-ott
2.1	Sedimentary processes in river & deltas	Rebesco	14-ott
2.2	Action of tides and waves, wind and ice	Rebesco	17-ott
2.3	Density currents, bottom currents and mass transport	Lucchi/Rebesco	18-ott
3.1	Alluvial deposits, lakes and deserts	Rebesco	21-ott
3.2	Barrier systems and incised valleys	Rebesco	24-ott
3.3	Continental shelves (wases, storms, tsunamis)	Rebesco	25-ott
3.5	Submarine fans (gravity flows on the continental slope)	Lucchi	28-ott
3.6	Sediment drifts (bottom currents along the continental slope)	Rebesco	31-ott
3.4	Abyssal plains (hemipelagic fallout) and continental margins	Rebesco	04-nov
3.7	Carbonatic environments, faults, volcans	Rebesco	07-nov
4.1	Sequence stratigraphy: introduction	Rebesco	08-nov
4.2	Sequence stratigraphy: closer view	Rebesco	11-nov
4.3	Sequence stratigraphy: applications (e.g. hydrocarbon reservoirs)	Rebesco	14-nov
5.1	Excercise (part 1)	Rebesco	15-nov
5.2	Excercise (part 2)	Rebesco	18-nov
1.5	Energy storage & CCUS	Volpi/Barison	21-nov
3.8	Glacial depositional systems	De Santis	25-nov
			28-nov
			02-dic
			05-dic
6.2	Visit to CoreLoggingLAB (along with Geologia Marina)	Camerlenghi	09-dic
3.9	Mass transport deposits	Ford	12-dic
6.3	Visit to OGS (SeisLab)	Camerlenghi	16-dic
			19-dic

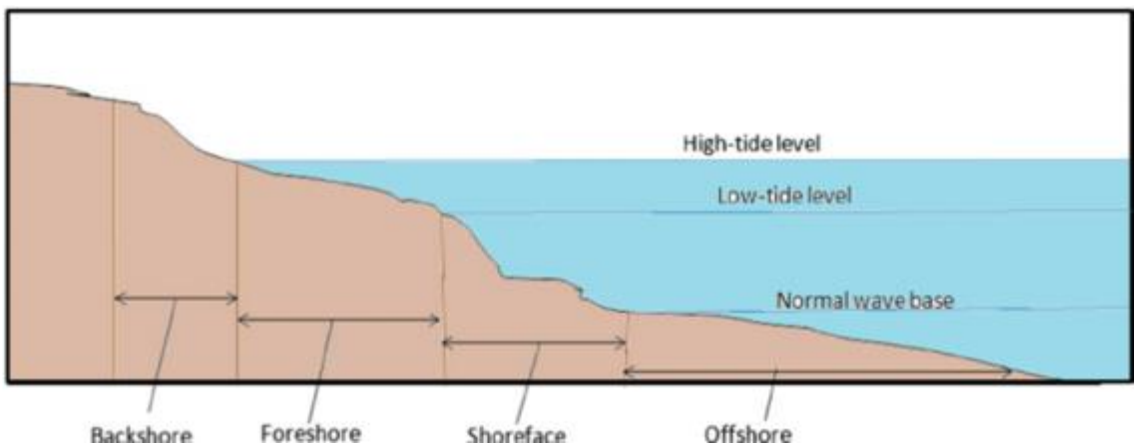
Module 3.2
Coastal deposits

Outline:

- Barrier systems
- Glossary
- Examples of Barrier system components
- Clinoforms

Shorefce versus Foreshore

The shoreface is the nearshore zone of the inner continental shelf that is bounded landward by the low-water line and that extends seaward to where the influence of wave action on sediment transport is on average minor compared to other influences



The foreshore is the part of the shore which is between the highest and lowest points reached by the water

Barrier system

Barriers are wave-built accumulations of sediment that accrete vertically due to wave action and wind processes. Most are linear features that tend to parallel the coast, generally occurring in groups or chains.

A chain of barrier islands and spits along an open-ocean coast, composed of several distinct island

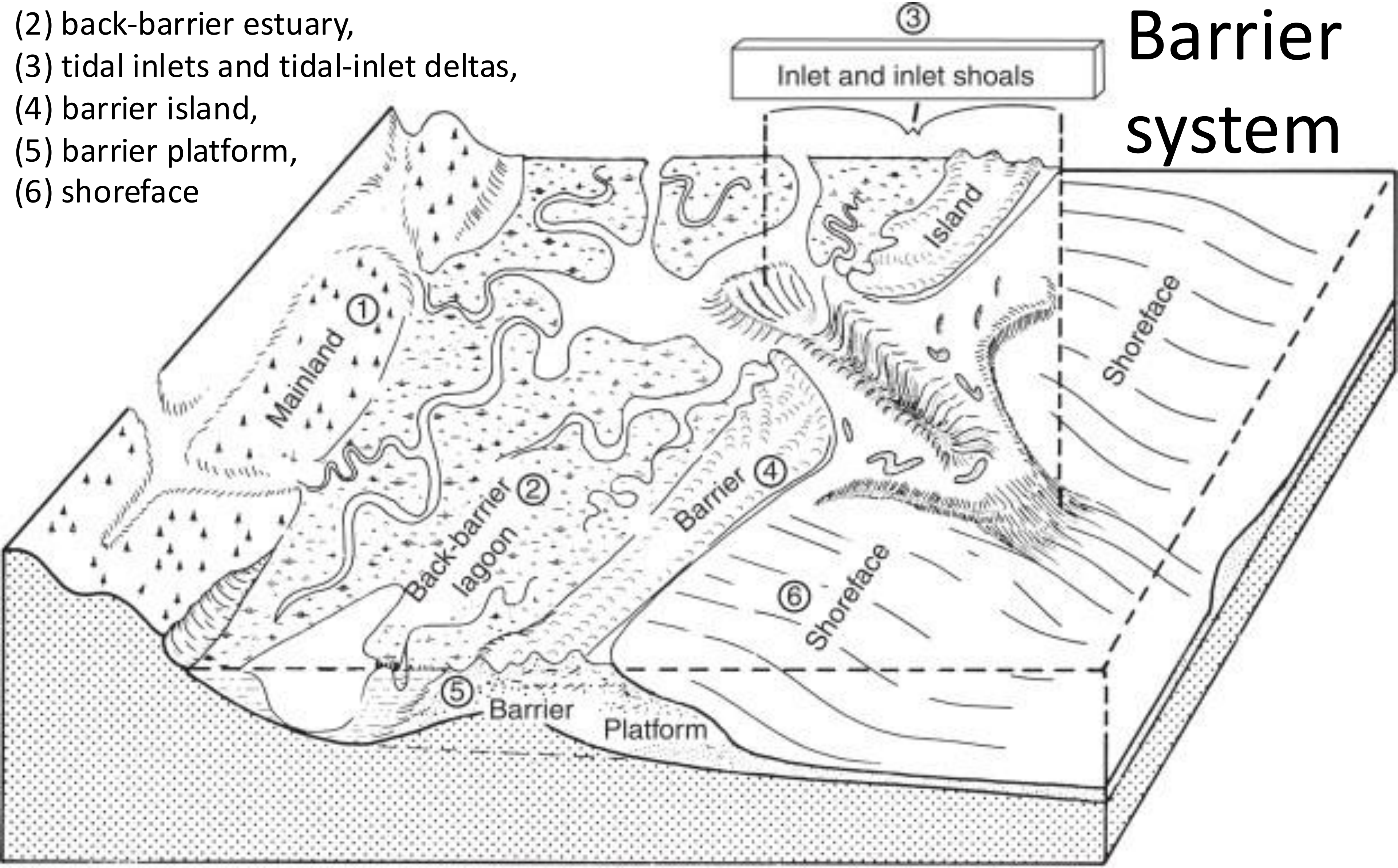
The subaerial expression of an accumulation of wave-, wind-, and/or tide-deposited sediments between two active tidal inlets and this sediment accumulation (barrier island) lies between the shoreface and the back-barrier estuary (Oertel, 1985).

Morphodynamics of Barrier Systems: A Synthesis.
McBride et al., Treatise on Geomorphology, Academic Press, 2013

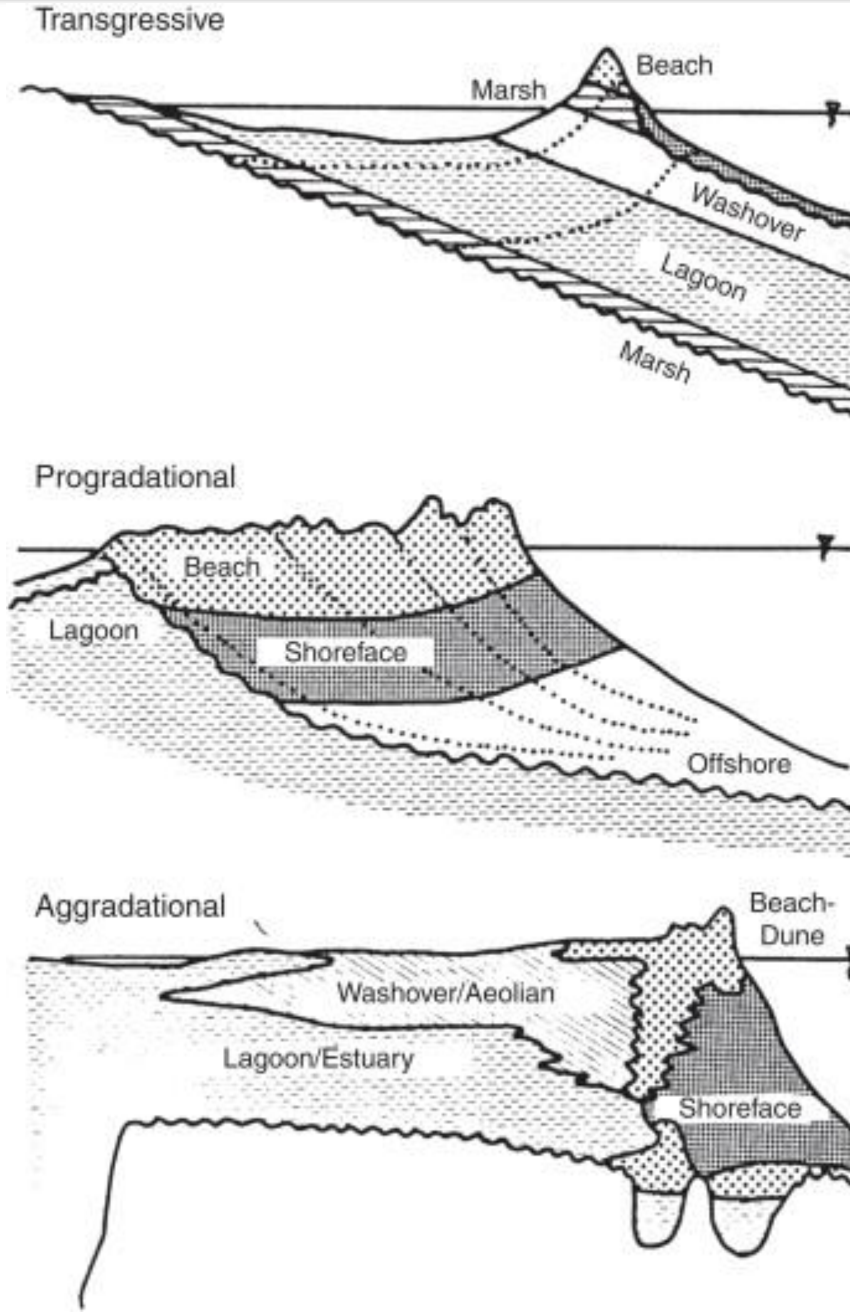
For a littoral sand body to be designated a barrier island, six required sedimentary environments must be present:

(1) mainland,
(2) back-barrier estuary,
(3) tidal inlets and tidal-inlet deltas,
(4) barrier island,
(5) barrier platform,
(6) shoreface

Barrier system



Morphodynamics of Barrier Systems: A Synthesis. McBride et al., Treatise on Geomorphology, Academic Press, 2013



Generalized stratigraphic models of coastal response for transgressive, progradational, and aggradational barrier systems because of changes in relative sea level, sediment budget, coastal processes, and/or other factors

Glossary

Strandplain: Broad accumulations of sediment formed in parallel or semiparallel ridges oriented approximately parallel to the coastline. Often lack tidal lagoons, salt marshes, and incising tidal creeks; rather, they are connected directly to the mainland, though they may border estuaries whose creeks extend into the plain.

Beach ridge: The clastic sand and/or gravel ridges – often regressive and containing shell fragments – that are built primarily by wave processes, such as the emergence and growth of longshore bars during constructional wave activity, or the erosion of the lower beach and deposition by wave swash along the upper beach during storms. Low areas are called swales.

Foredune: A sand dune located immediately landward of the beach-backshore area and oriented parallel or near parallel to the shoreline. The first or foremost dune also known as the fore dune ridge or primary dune.

Chenier: An isolated transgressive sandy and/or shelly ridge with progradational littoral mudflat deposits both landward and seaward of the ridge.

Barrier spit: Elongated, wave-built accumulation of sand that is built laterally through longshore sediment transport and is attached on one end to a mainland coast

Glossary

Outwash plain: broad, low-relief plain composed of sediment (typically sand and fine gravel) deposited by meltwater flowing as confluent alluvial fans that emerge from multiple meltwater valleys at the terminus of a glacier.

Overwash: The process where sediment is transported by swash landward from the beach across a barrier system and is deposited in an apron-like accumulation along the backside of the barrier island or barrier spit. Overwash usually occurs during storms when waves break through the frontal dune ridge and flow landward toward the marsh or estuary.

Washover fan: A fan-shaped body of sediment that is transported landward by marine waters flowing through or across a coastal barrier (e.g. a barrier bar or island). Such bodies are formed especially during storms, when the barriers are likely to be breached

lagoon

A lagoon (ephemeral feature in geologic time that is gradually filled in with available sediment) is a shallow body of water separated from a larger body of water by a narrow landform, such e.g. barrier islands. Lagoons are common coastal features around many parts of the world

Venice lagoon

Estuary

A semi-enclosed coastal body of water that extends landward to the effective limit of tidal influence and within which seawater enters from one or more free connections with the open sea and is diluted by freshwater derived from land drainage

Isonzo estuary

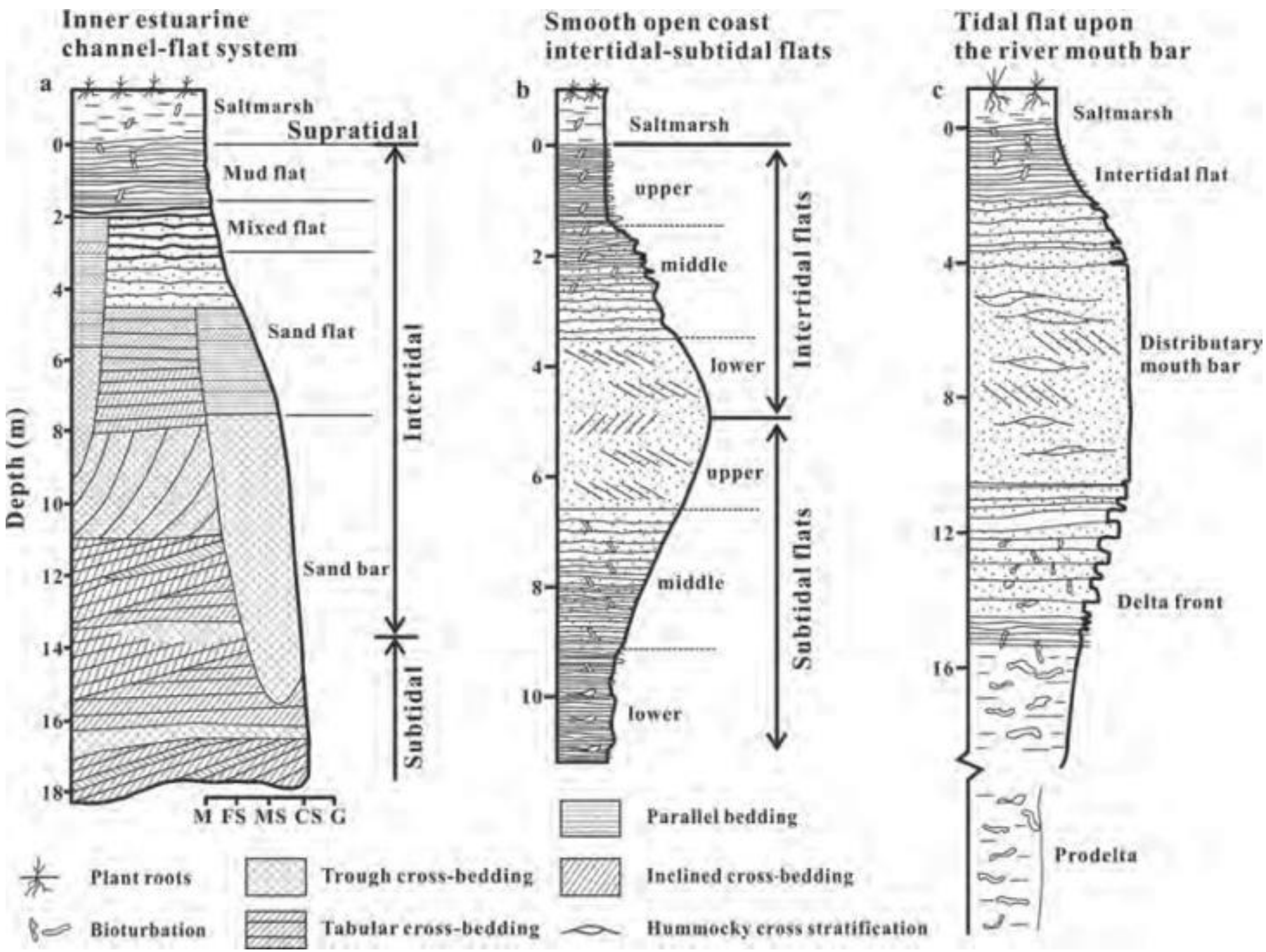
Tidal flat

Tidal flats are intertidal platforms commonly located in sheltered areas such as bays, estuaries and lagoons, where sediments from river runoff, or inflow from tides, deposit mud or sand.

Venice lagoon

tidal-flat successions

Schematic models showing the three most common progradational tidal-flat successions in the sheltered, open coast and deltaic environments



Marsh

a tract of low wet land, often treeless and periodically inundated, generally characterized by a growth of grasses, sedges, cattails, and rushes.

Isola della Cona

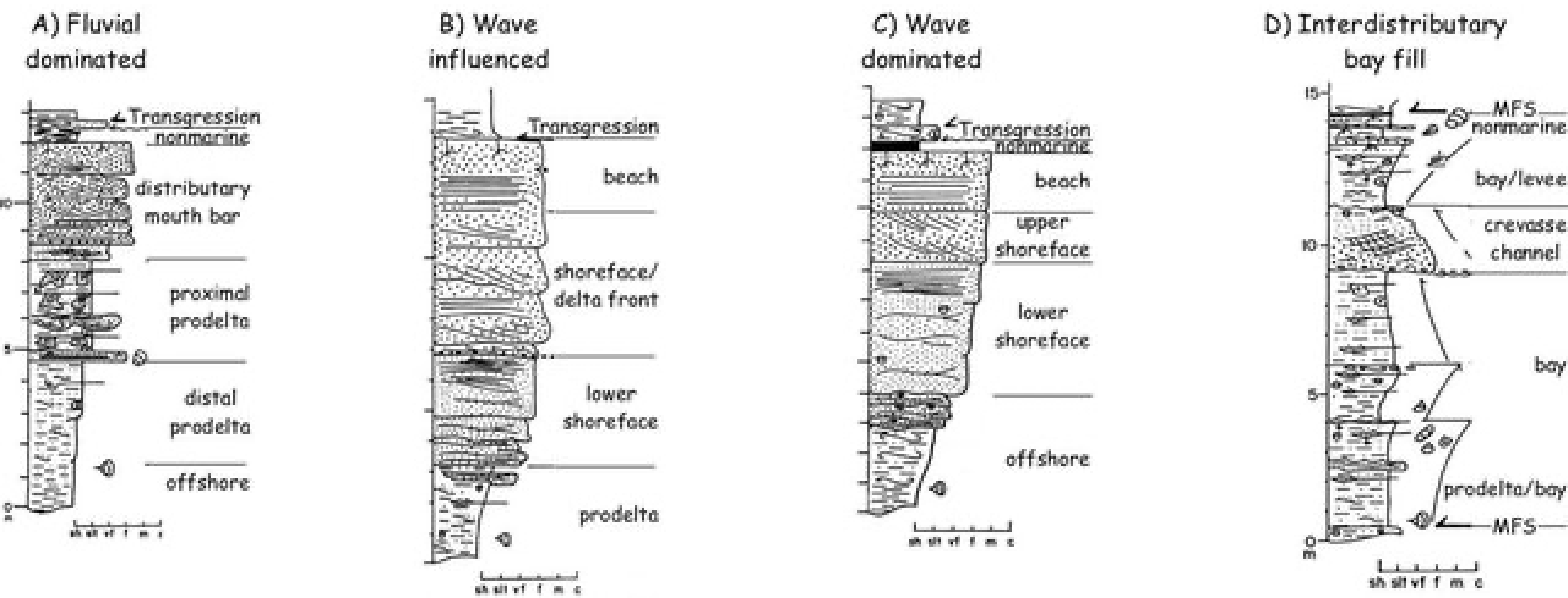
Delta

A usually triangular mass of sediment, especially silt and sand, deposited at the mouth of a river.

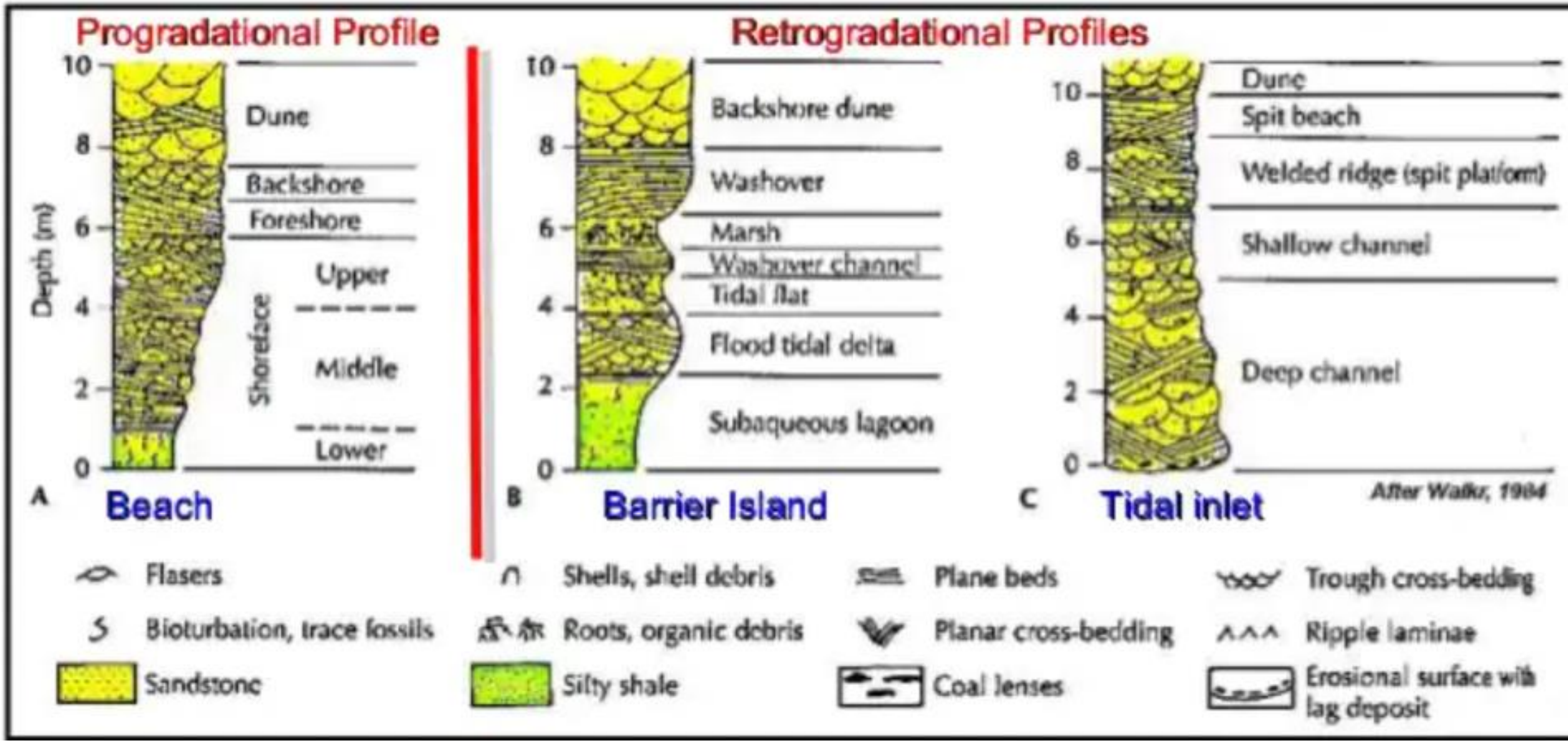
Po delta

Delta sequences of deltas in the Upper-Cretaceous Funvegan Formation, Alberta (Bhattacharya and Walker, 1992).

Delta front successions for socalled A) fluvial-dominated, B) wave-influenced, and C) wave-dominated deltas; proximal prodelta is equivalent to bar front. D) Interchannel bay fill in a riverdominated delta.

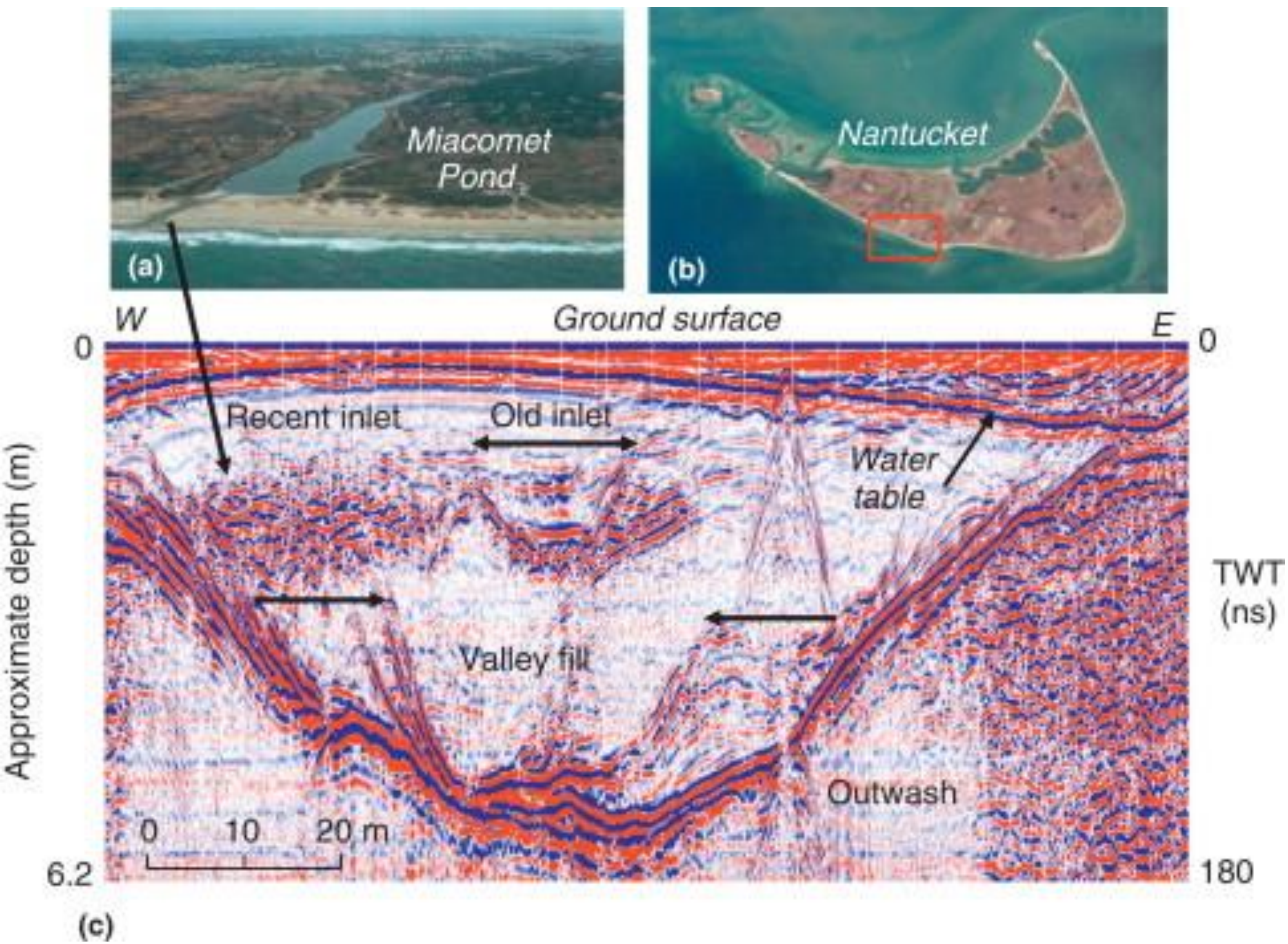


Three end-member facies models



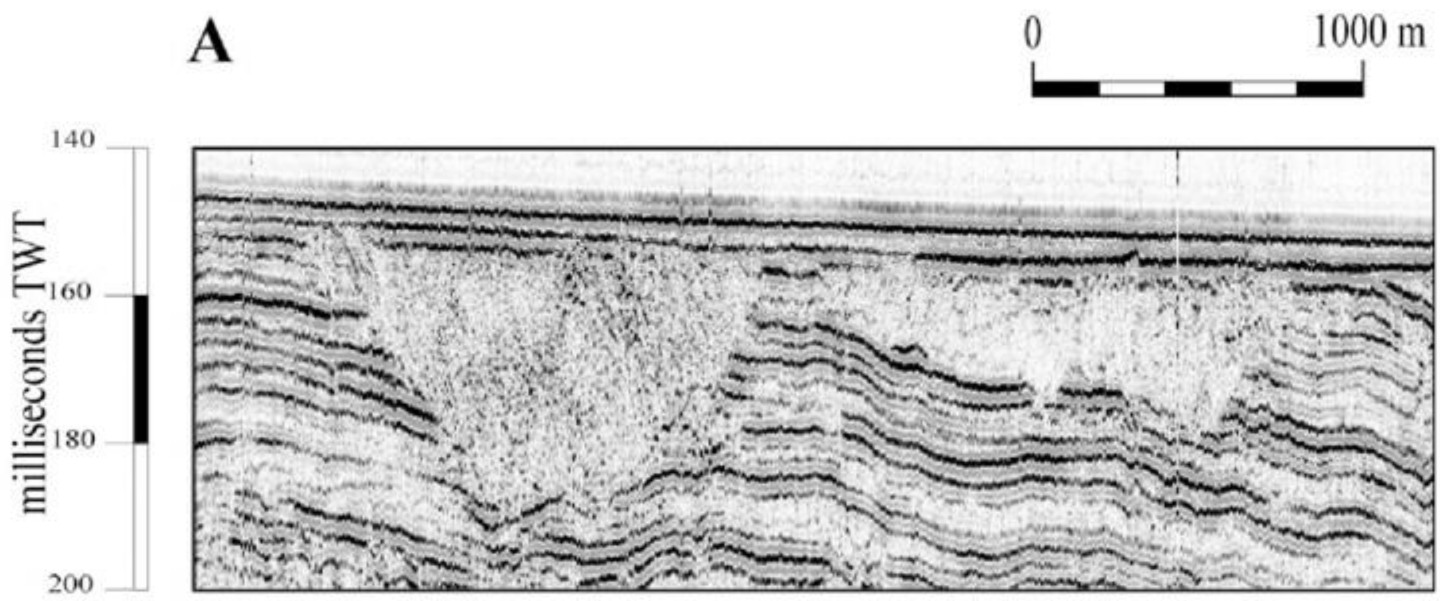
A) a prograding barrier island, B) a transgressive barrier island and C) a channel inlet migration

Baymouth barrier, southern shoreline of Nantucket Island



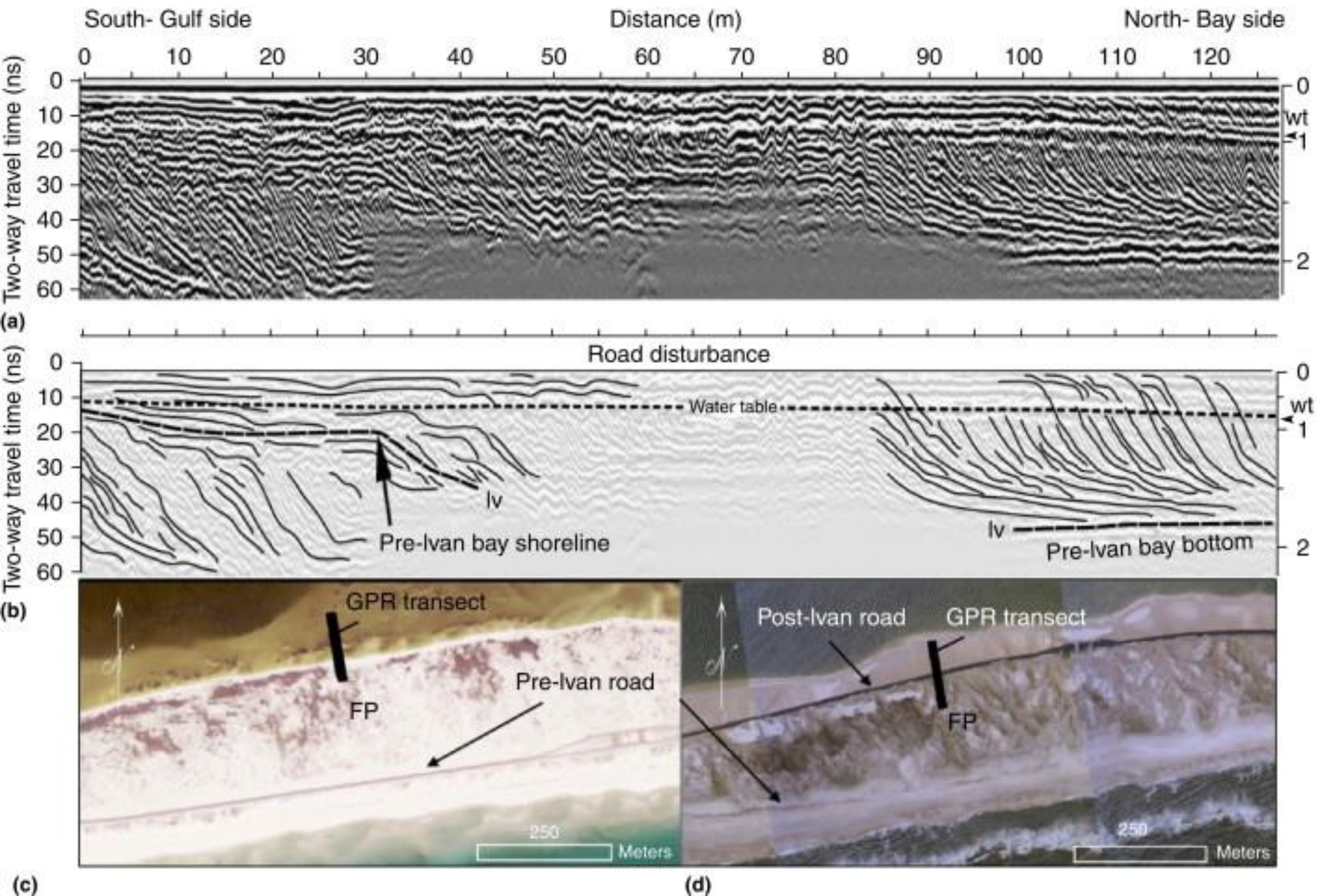
(a) Pond, outwash plain, and small inlet. (b) Location. (c) Shore-parallel geophysical image revealing the outline of a spring-sapping valley, the bidirectional valley fill (inward-facing arrows), as well as two shallow channel structures.

Incised valley: The channel or valley formed by fluvial systems that extend their channels basinward and erode into underlying strata in response to a relative fall in sea level.



Stevenson I., Mcmillan I. 2004. Incised valley fill stratigraphy of the Upper Cretaceous succession, proximal Orange Basin, Atlantic margin of southern Africa Environmental Science, Geography, Geology Journal of the Geological Society DOI:10.1144/0016-764902-003

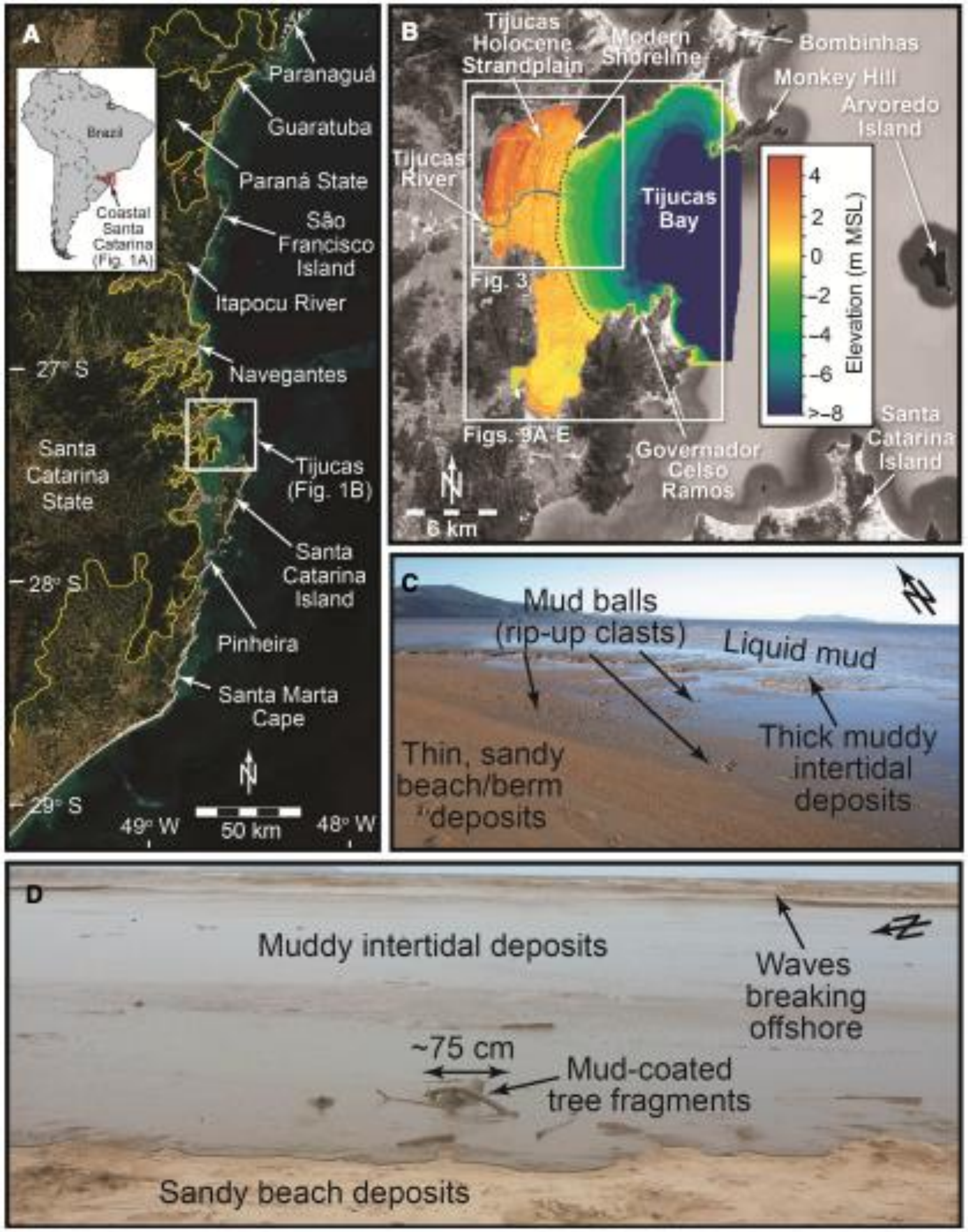
GPR transect across Santa Rosa Island and pre- (c) and post-Ivan (d) aerial photos.



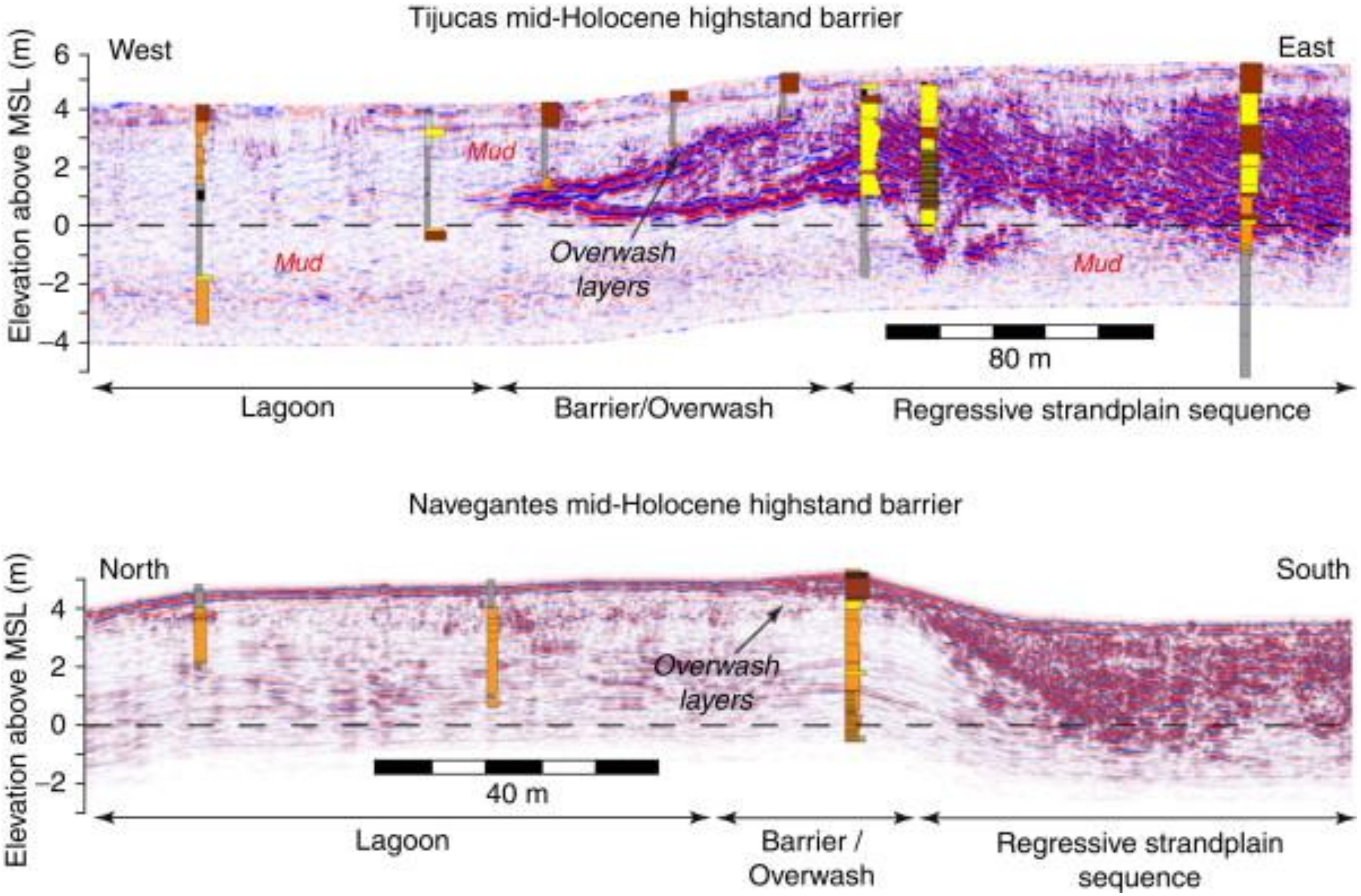
Erosional and depositional characteristics of regional overwash deposits caused by multiple hurricanes

Hein et al., 2016. Sedimentology. Complex coastal change in a sub-tropical Holocene strandplain

(A) Map of the coast ofSanta Catarina, Brazil. (B) Digital elevation model of Tijucas Strandplain and Tijucas Bay. (C) Tijucas Beach during calm conditions in March 2009, four months following a large flood event on the Tijucas River. (D) Image of Tijucas Beach during a moderate-energy event in November2012. The lower beach face was coated with ca 2 cm of fine silt and clay during this event

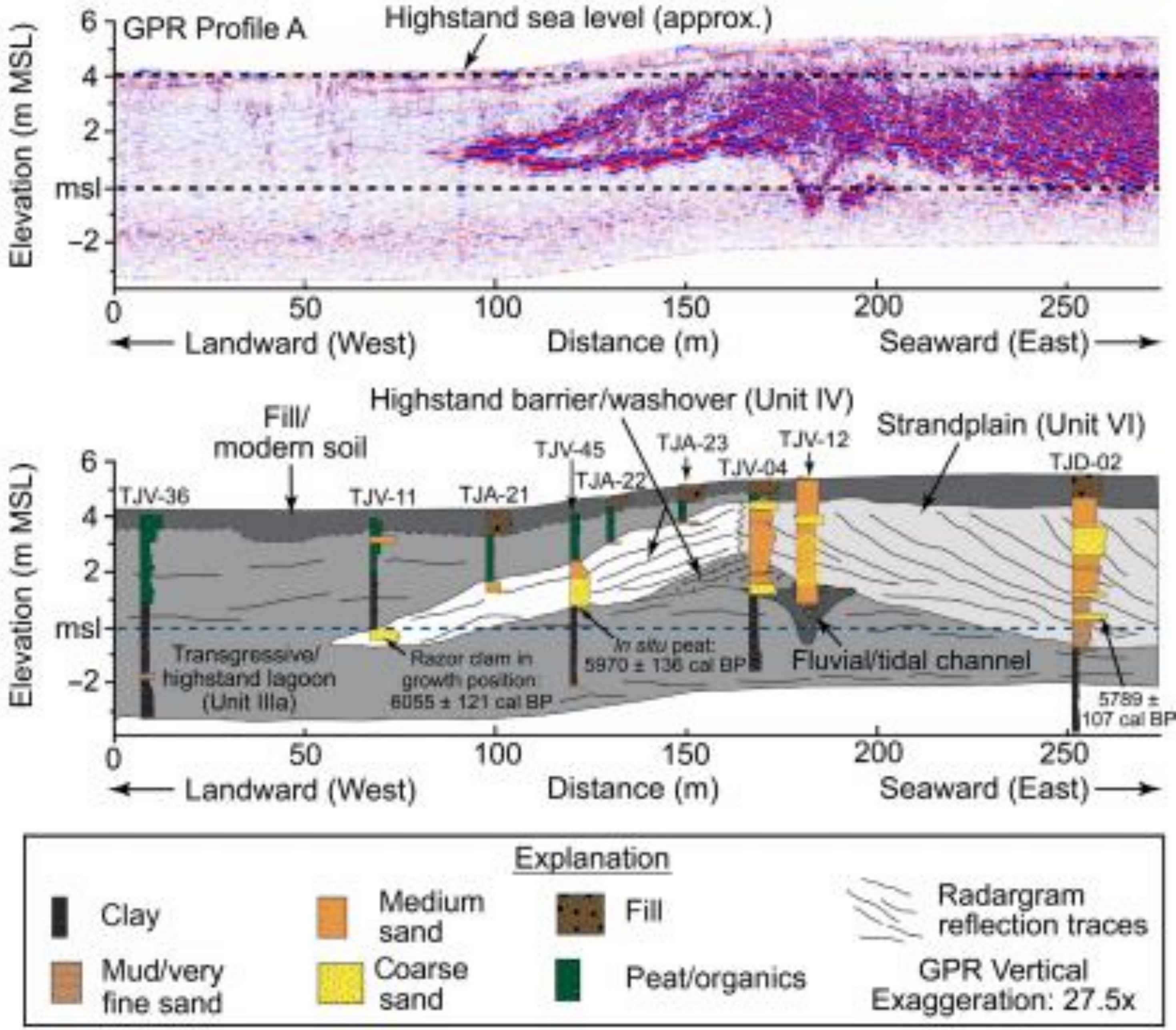


highstand barriers in Tijucas and Navegantes



Barriers are denoted by topographically high ridges and the presence of overwash layers. They are backed by lagoons (muddy in Tijucas, where the Tijucas River delivers large quantities of mud; and sandy in Navegantes, where the Itajaí River generally delivers only sand) and fronted by seaward-dipping regressive strand plain systems deposited as sea level fell

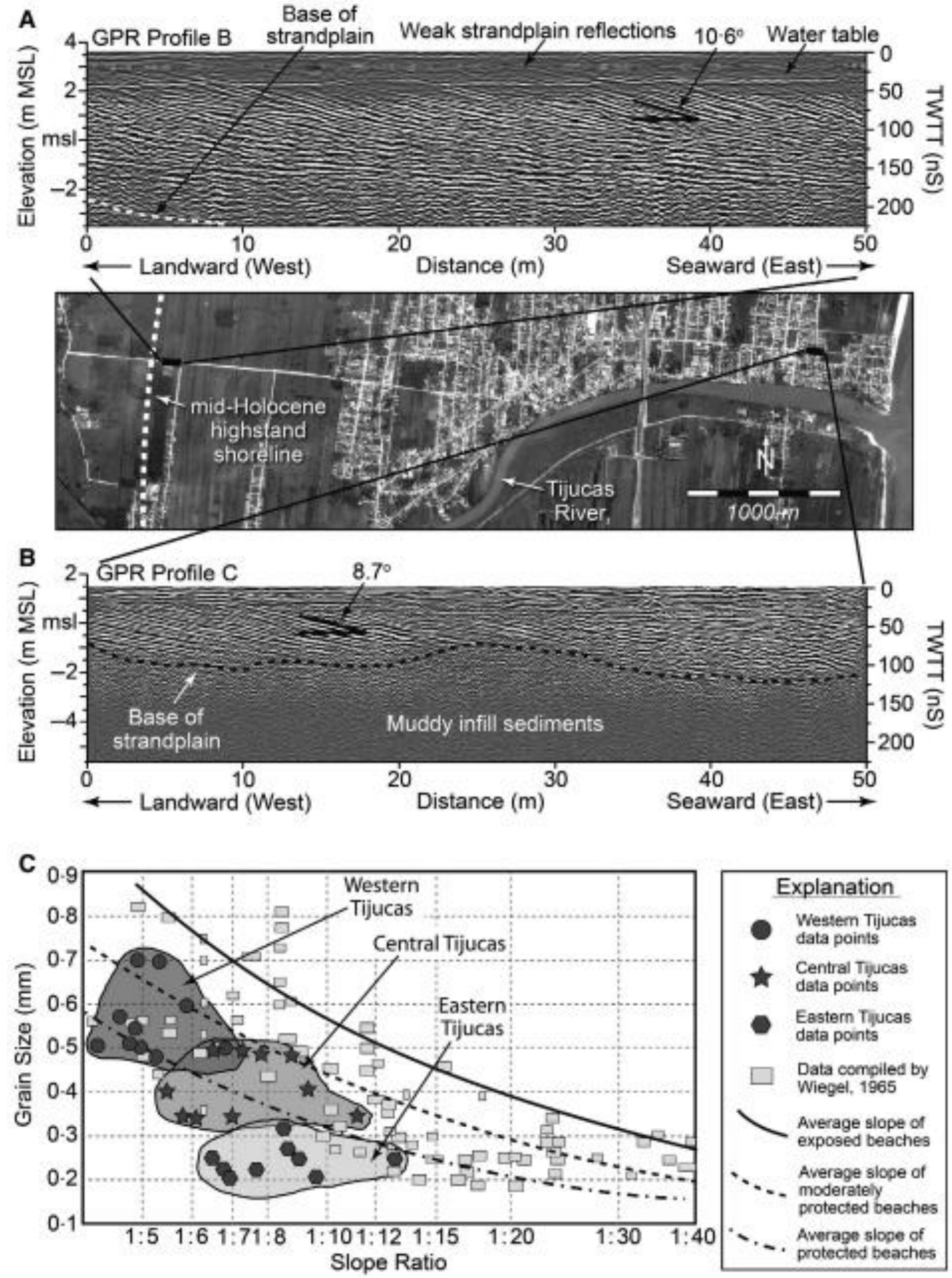
barrier ridge in central Tijucas



Hein et al., 2016

Changes in beachface slope across the Tijucas Strandplain

(A) GPR Profile C, collected ca 200 m seaward (east) of the mid-Holocene highstand barrier in a sand-dominated section of the plain. (B) GPR Profile D, collected ca 650 m landward (west) of the modern shoreline in a sandy section of the mud-dominated eastern plain. Note the gentle shallowing of shoreface reflectors and the thinning of sandy strandplain units as mud-dominance increases in a seaward direction. (C) Slopes of sandy beachface (strandplain) GPR reflections and associated sediment grain sizes from across the Tijucas Strandplain

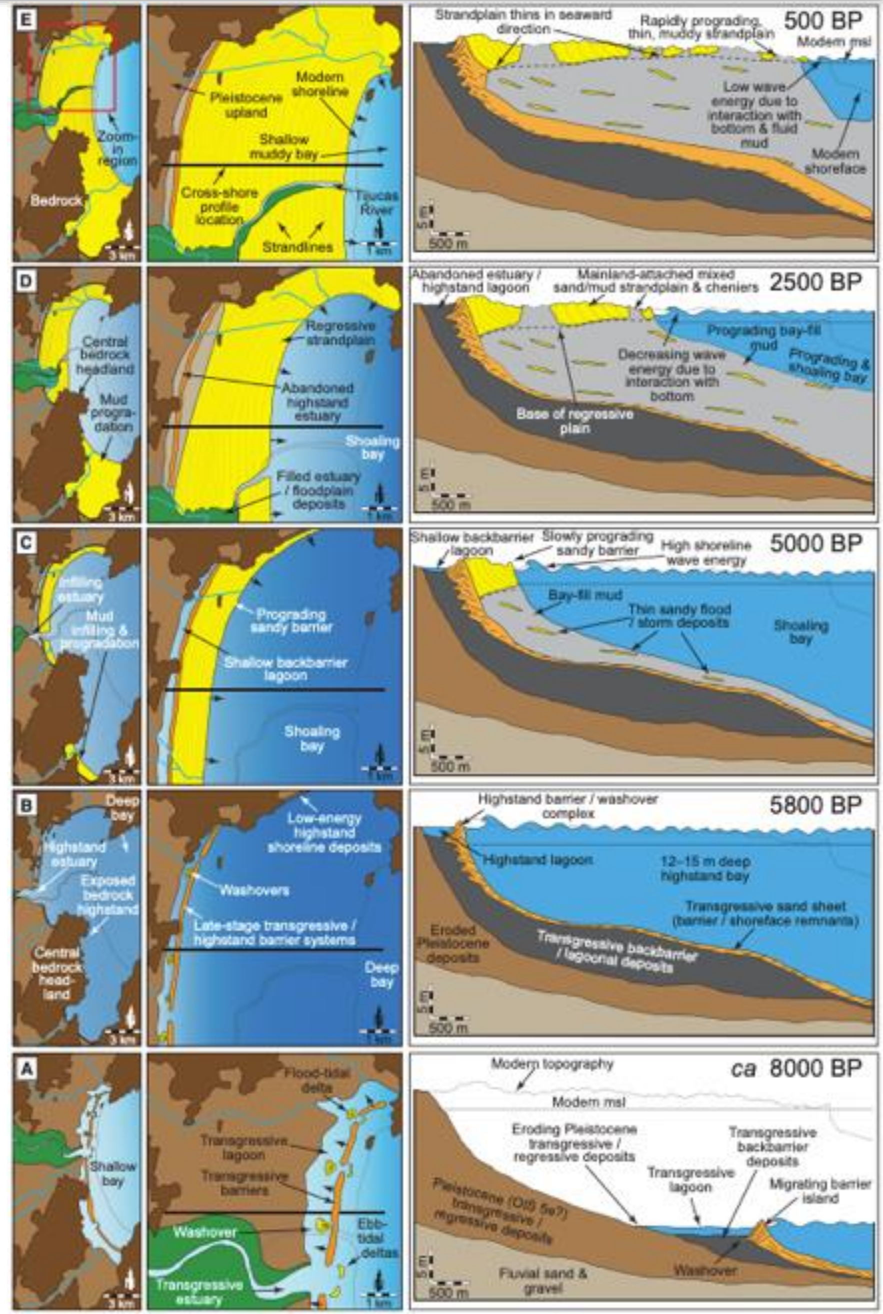


Hein et al., 2016

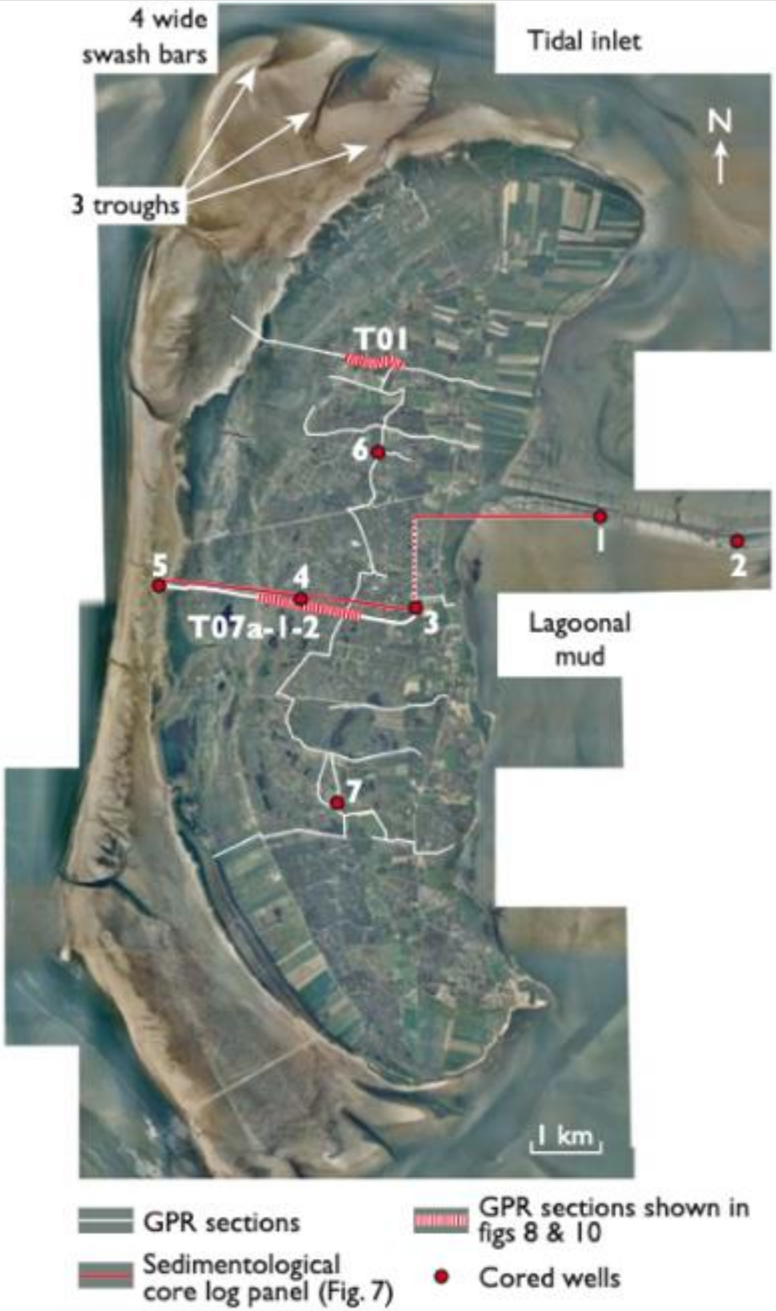
Holocene evolution of Tijucas Bay and the Tijucas Strandplain

Simplified map and cross-section views show major events and drivers [relative sea-level (RSL) change, sedimentation and bay shoaling] of coastal change in this system from ca 8 ka to present.

Hein et al., 2016



Architecture of an Upper Jurassic barrier island sandstone reservoir, Danish CentralGraben JOHANNESSEN 2010, Petroleum Geology Conference series



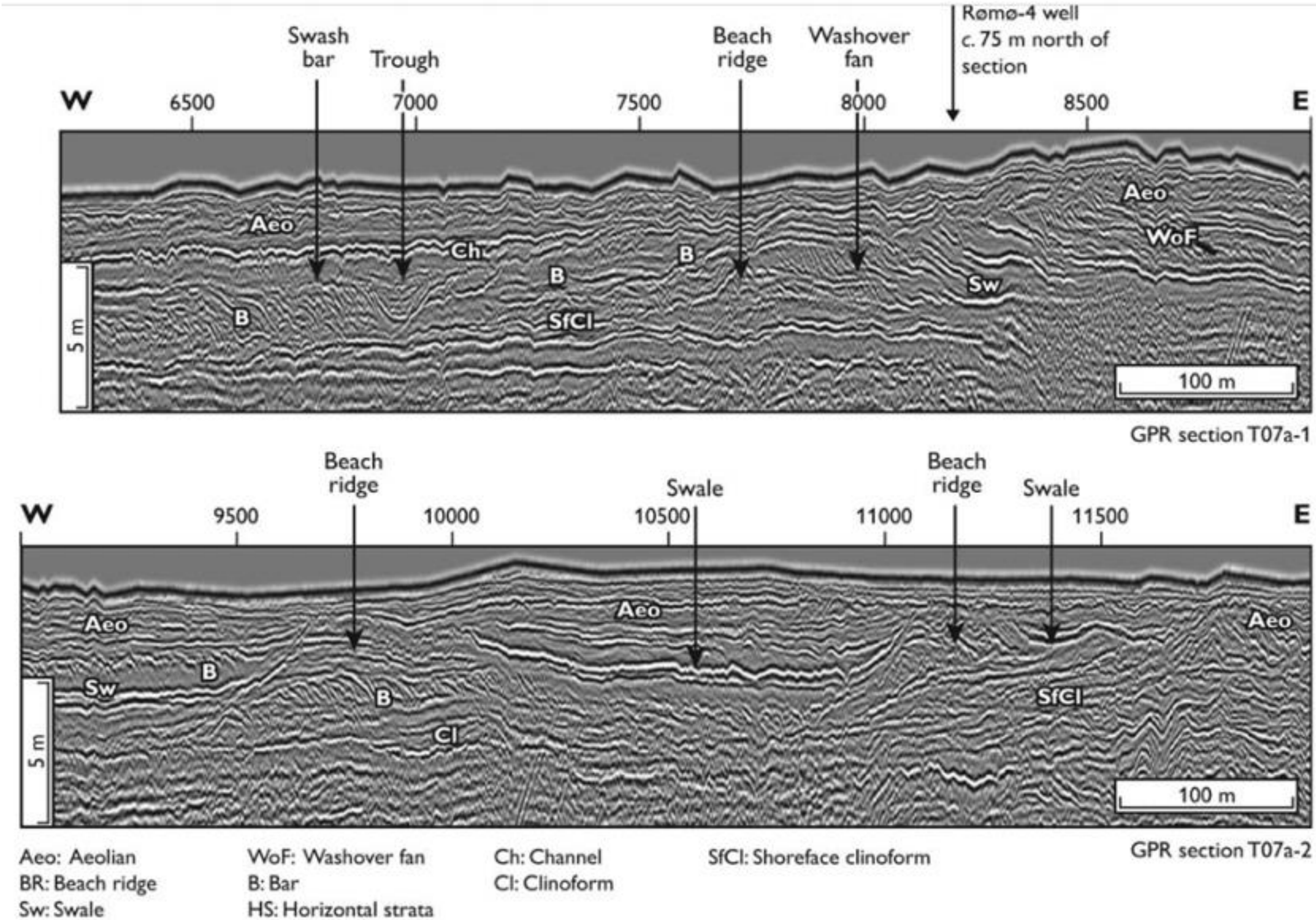
Ortho photo of the Rømø barrier island showing the distribution ofGPR reflection profiles and position of the seven cored wells. Very widetidal flat sands characterize the NW and SW end of Rømø. The island isdominated by aeolian dune sand.

(a)

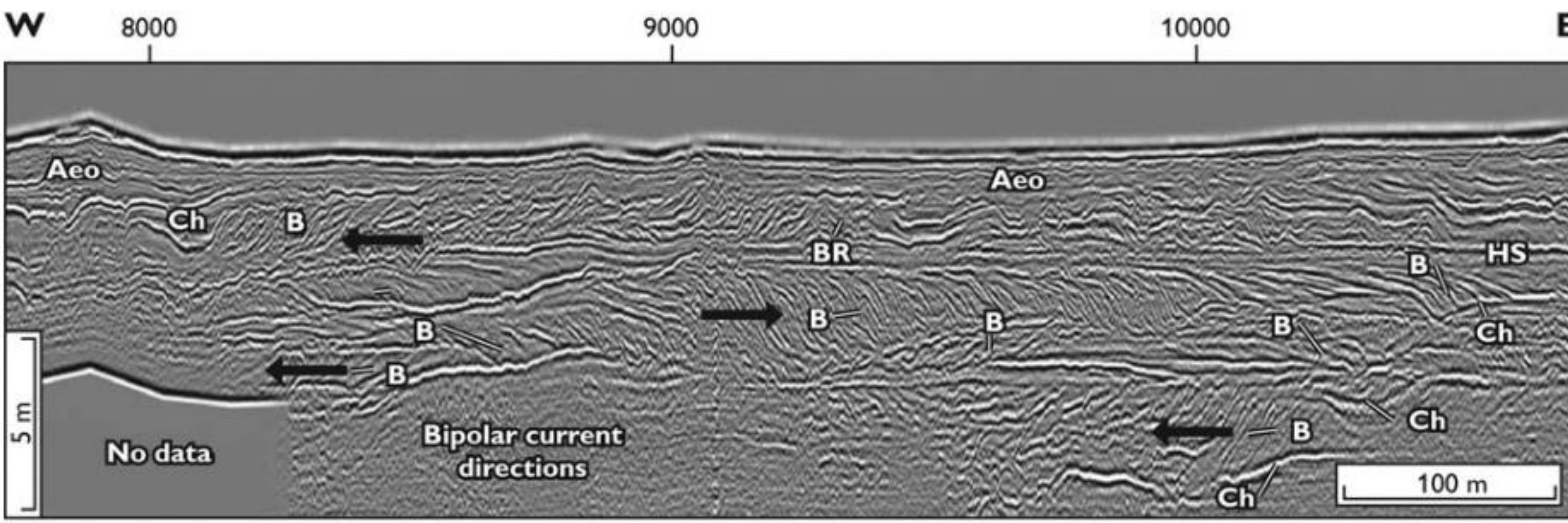
(b)

Recent development of washover fan (1990) over the Skallingen peninsula situated in the northernmost part of the Danish Wadden Sea. (a) The washover fan is 250 m long and wide and was deposited in the lagoon within a few hours during a storm flood tide. Storm surgesbroke through the beach ridges and aeolian sand dunes. (b) Washover fan with steep slipface terminating in the lagoon. Internally the c. 0.5 m thick washover fan is characterized by steep foresets. The washover fan was deposited several metres above mean sea-level as it formed during astorm when the storm peak sea-level was elevated by more than 4 m due to the combined effect of high tide and storm surge. Photo by Niels Nielsen.

GPR profile on Rømø barrier island. The succession of beach ridges show shoreface progradation towards the west. The upper part of the section consists of aeolian sand

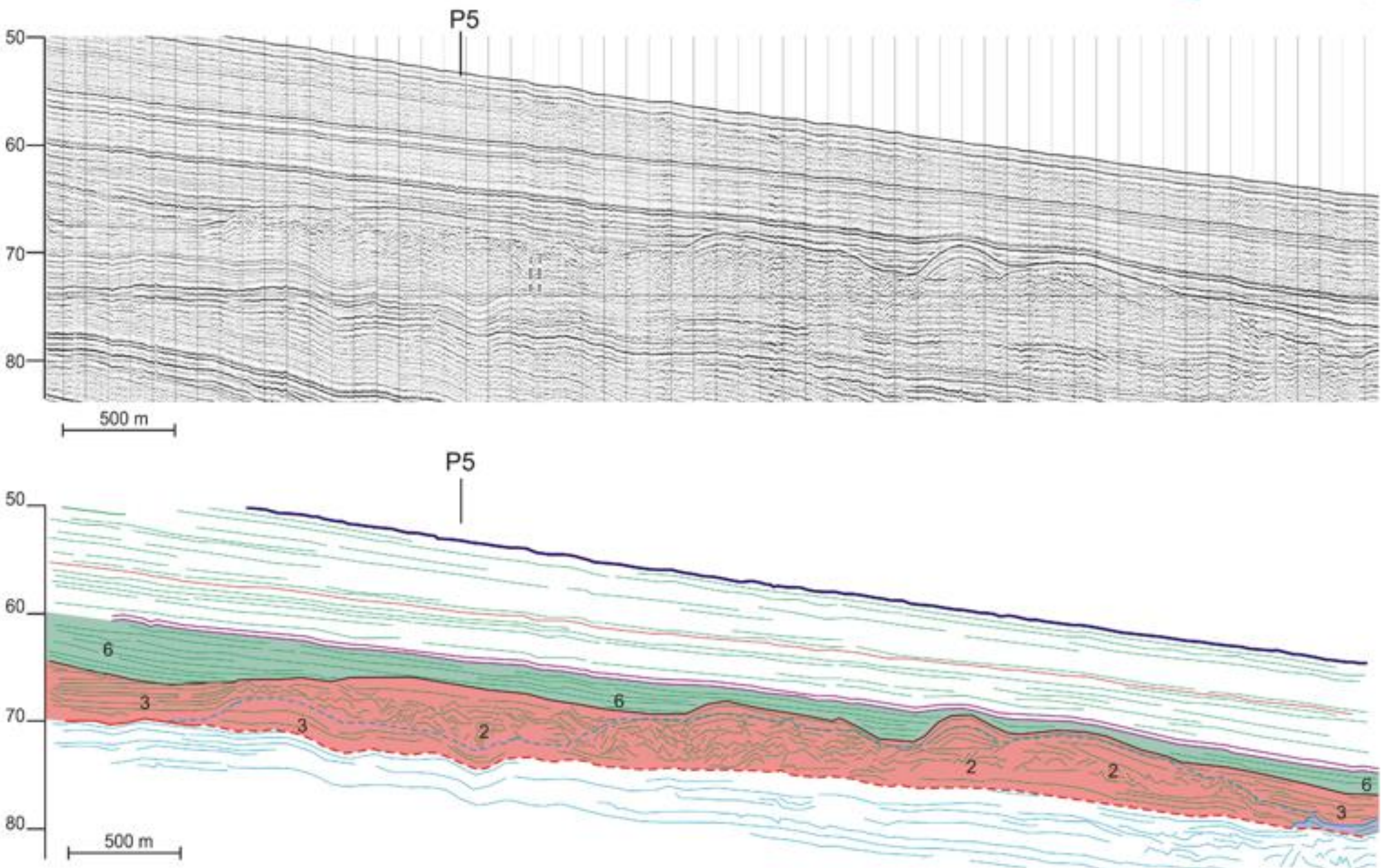


GPR profile on Rømø barrier island, which contains abundant tidal inlet sands



Aeo: Aeolian	WoF: Washover fan	Ch: Channel	SfCl: Shoreface clinoform
BR: Beach ridge	B: Bar	Cl: Clinoform	
Sw: Swale	HS: Horizontal strata		

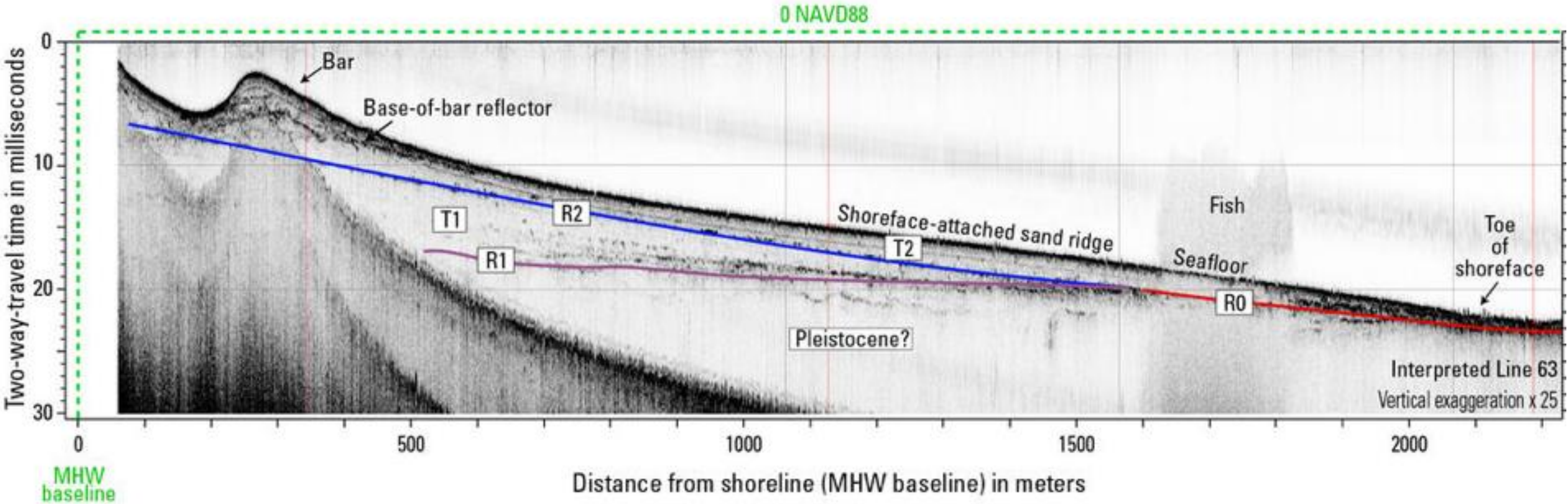
Holocene transgressive architecture in the Manfredonia Gulf of the southern Adriatic Sea



De Santis et al, Geosciences 2020

lowstand during the late Bølling-Allerød and during the Younger Dyas: formation of the coastal barrier system with a continuous landward backstepping process, due to the combination of the enhanced sediment input, low-gradient setting and slow sea-level rise

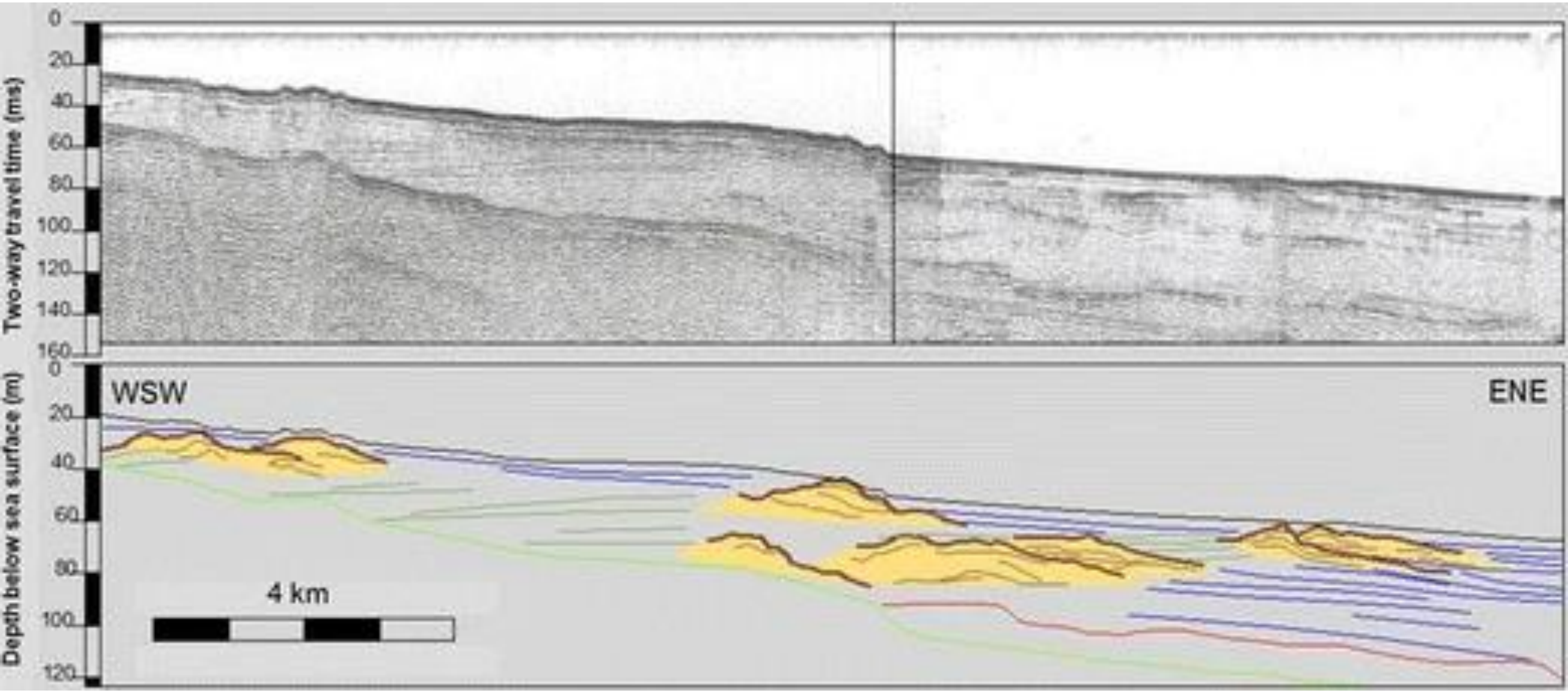
seismic profile collected from the shoreface of Fire Island, NY



The profile shows a steep shoreface, a nearshore bar, a sand ridge, and the geology beneath it all. The sediment above the blue and red lines is thought to be available for transport by waves or longshore drift.

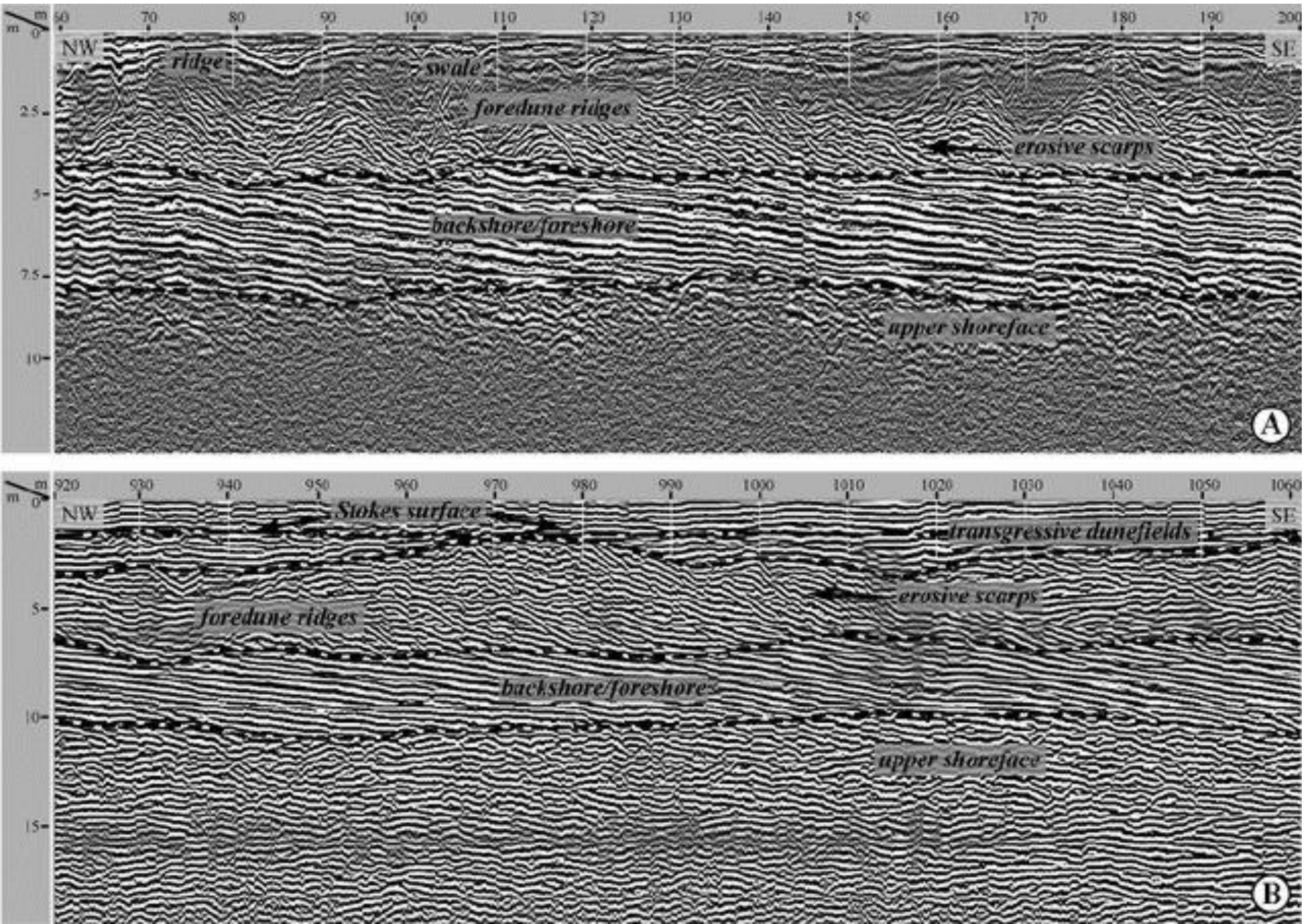
Locker et al., 2017

coastal sand barriers



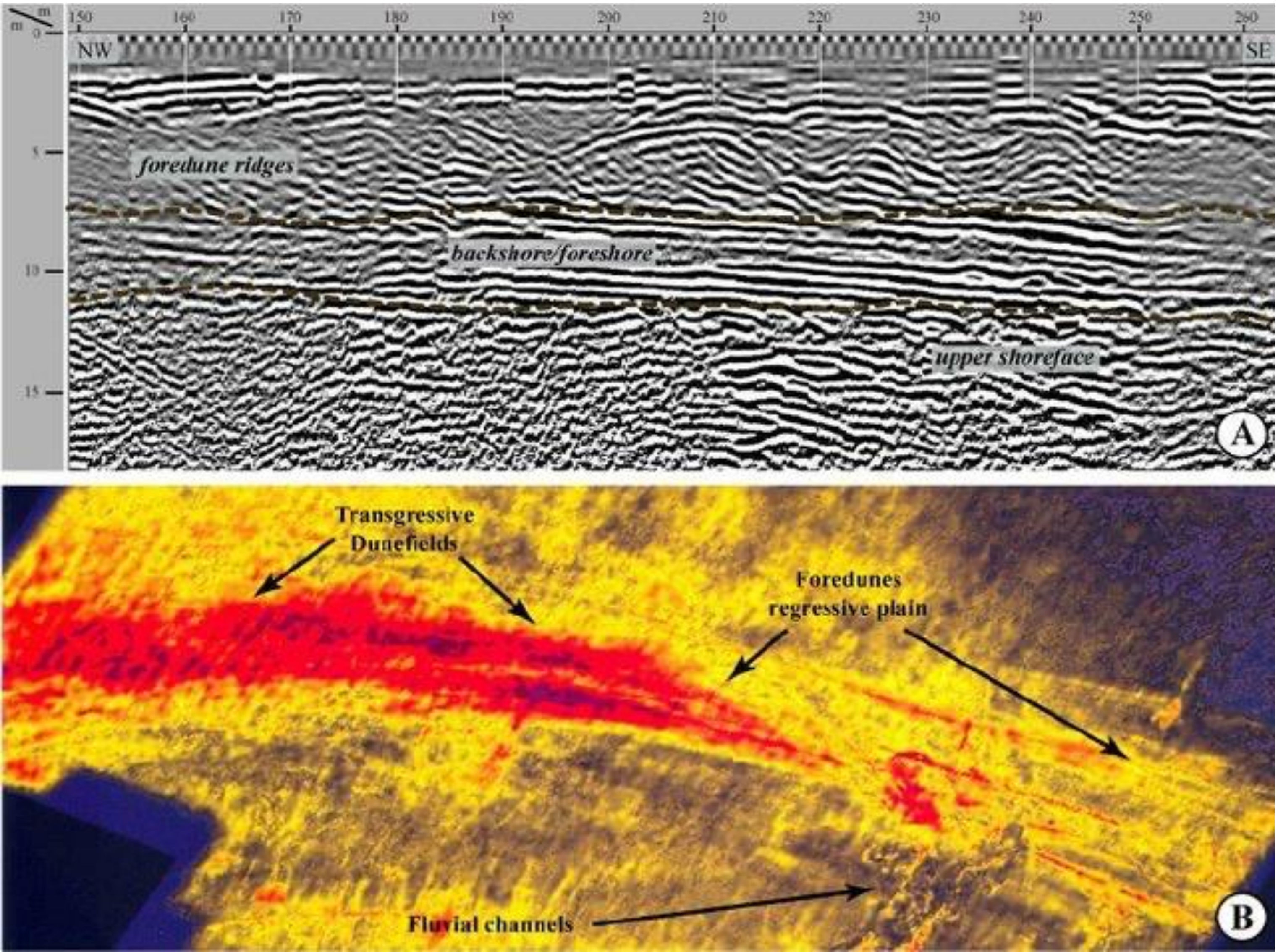
Seismic units of the southernmost seismic profile: top original migrated profile; bottom interpreted profile: light green acoustic basement, yellow coastal sand barriers, green coastal lagoon, blue continental shelf facies.
Albarracín et al. Seismic evidence for the preservation of several stacked Pleistocene coastal barrier/lagoon systems on the Gulf of Valencia continental shelf (western Mediterranean). Geo-Mar Lett 33, 217–223 (2013)

Barboza et al., 2013. Journal of Coastal Research. Foredunes in the stratigraphic record



Progradational sector in a coastal embayment. In both records the same progradational pattern is observed, but in B transgressive dunes and deflations plains dominate and low angle reflectors (downlap) dip landwards.

dunes in ancient regressive systems

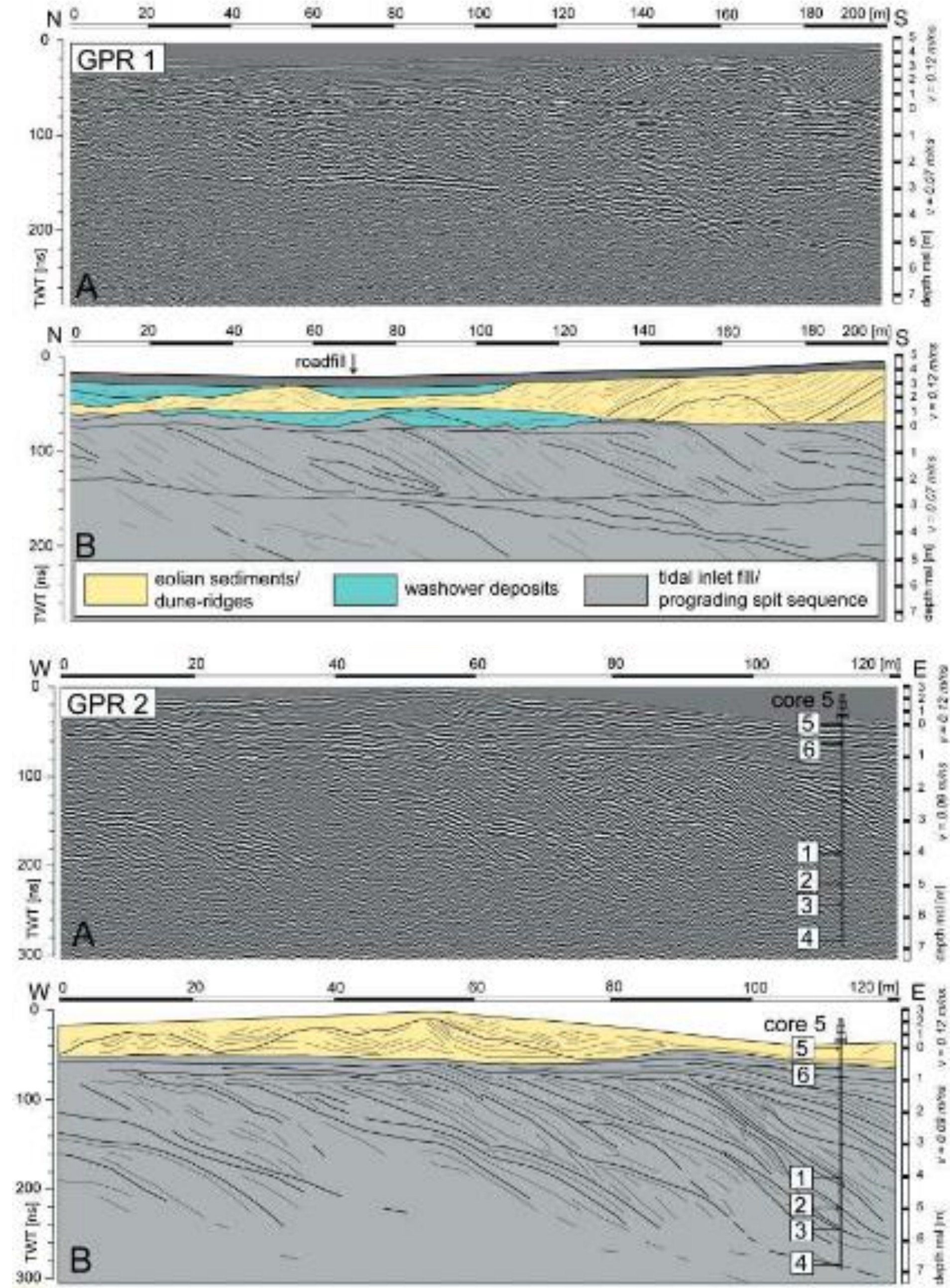


A) Foredune ridges in a context related to a Pleistocene barrier 120 ka in age. B) Time slice of the Santos Basin (southeastern Brazilian margin). At this site preservation of a sector containing regressive coastal foredune ridges and transgressive dunefields may be observed

Barrier rollover and spit accretion due to the combined action of storm surge induced washover events and progradation

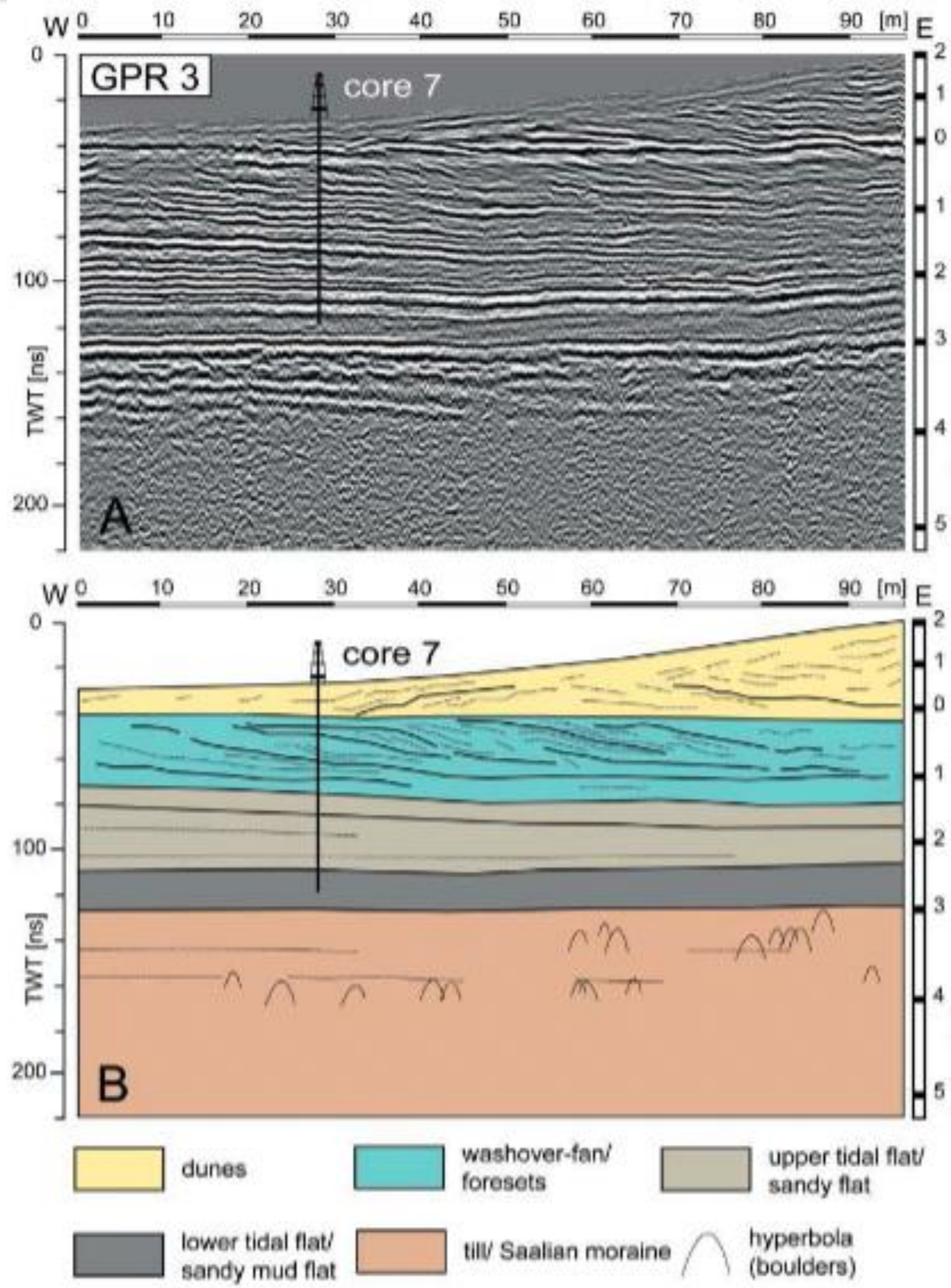
GPR line 1 and 2 represent the outer barrier island spit-end zone. The upper part of both profiles contains inclined reflections of the dune facies. This facies is interpreted as cross-bedded aeolian strata formed by migrating dunes of various dimensions. Internal bounding surface reveal two different dune generations.

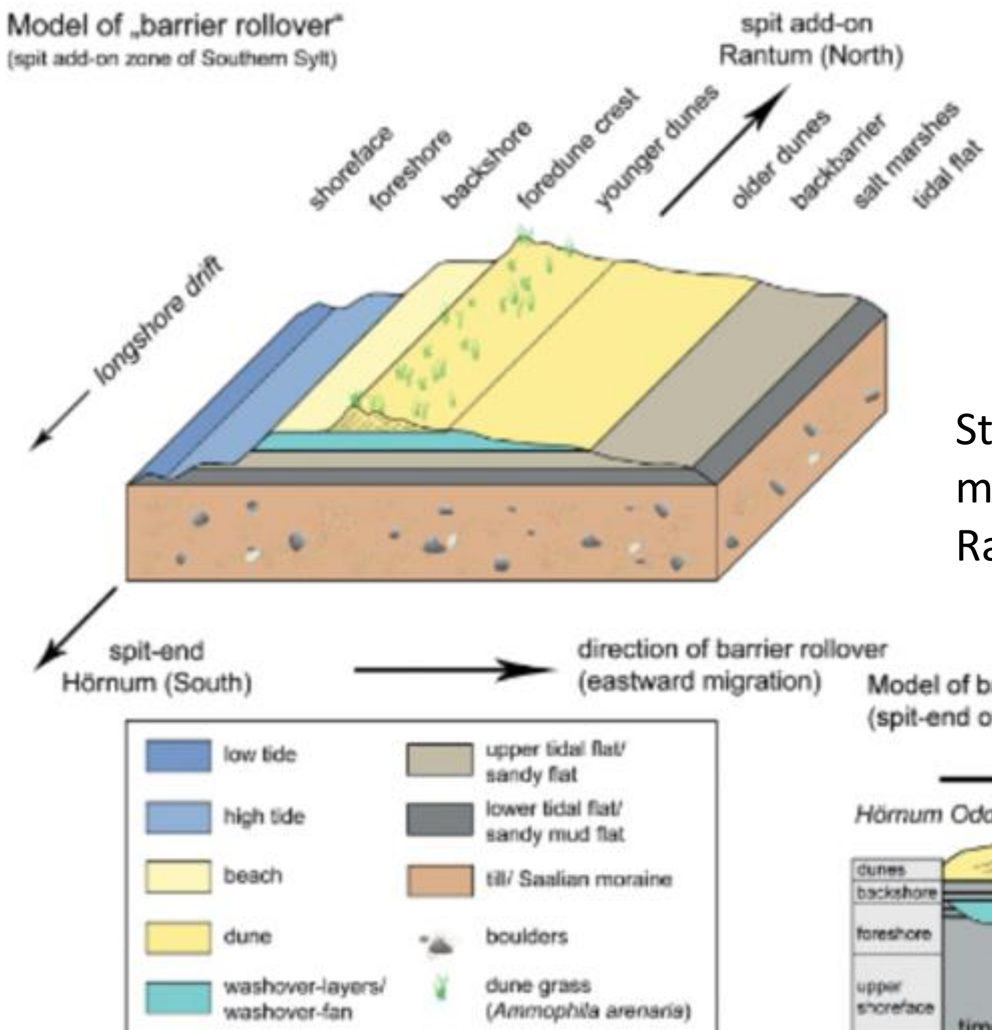
Tillmann & Wunderlich (2013)
Journal of Coastal Research.



Typical radarfacies and stratigrapy order in this spit add-on region

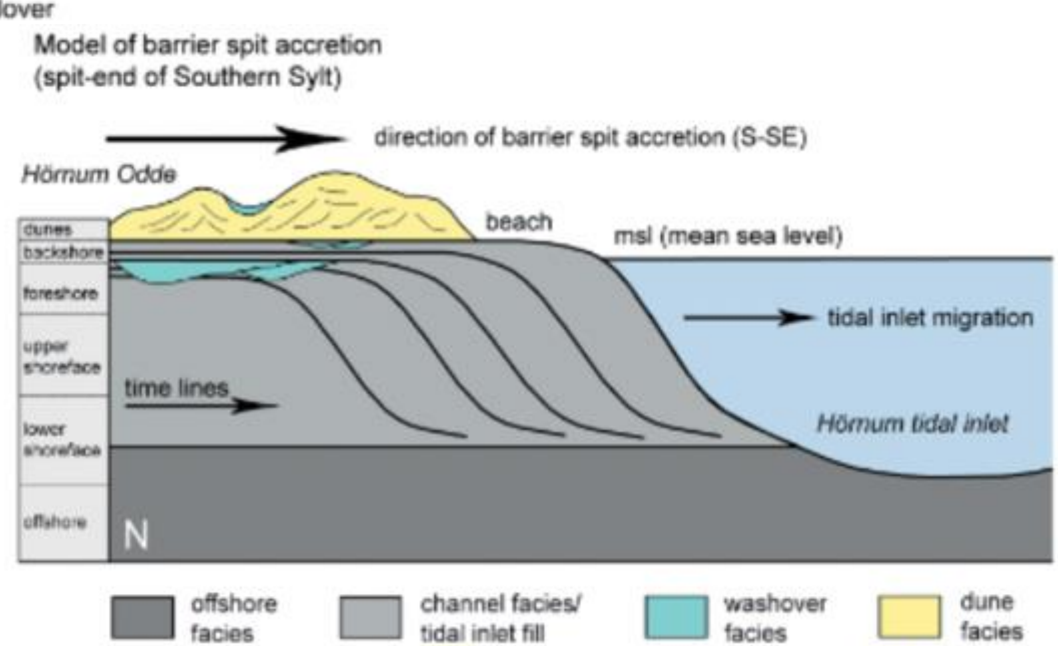
Profile 3 can be subdivided into five main parts. The upper part of the profile which is located above the groundwater table merely contains inclined reflections of the cross-bedded aeolian dune facies. Directly beneath the groundwater table reflections occur which indicate a gentle landward dipping and are interpreted as washover foresets strata caused by flooding and inundation during several washover events. These washover foresets are parallelly orientated to the dominant washover flow direction from the west coast to the eastern part of the barrier and belong morphologically to a washover fan or a washover sheet. Post-storm aeolian modification of at least the upper-most washover layers is certain



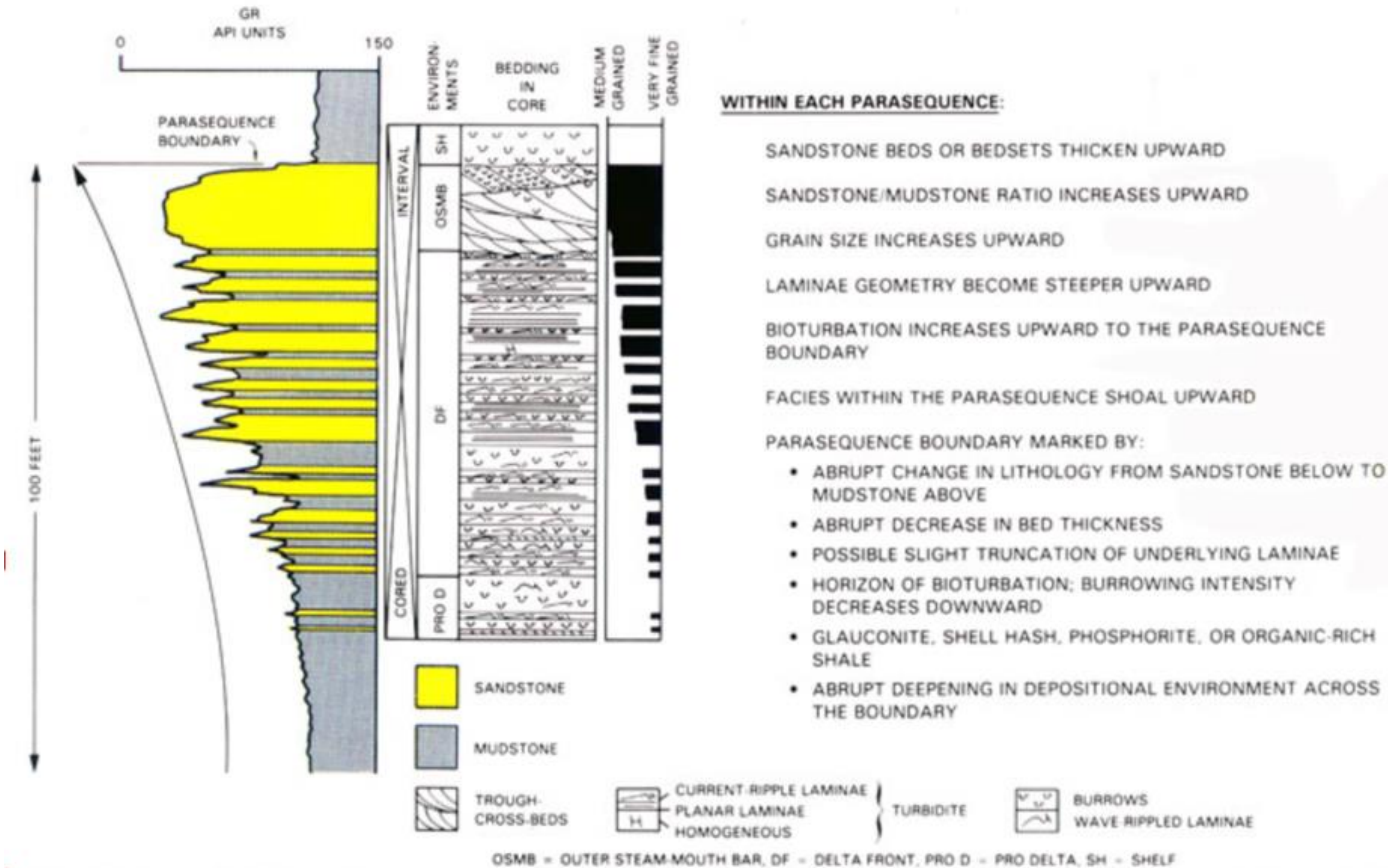


two stratigrapic models of barrier island genesis for the southern spit of Sylt.

Stratigraphy of the eastward migrating barrier add-on zone of Rantum affected by “barrier rollover"



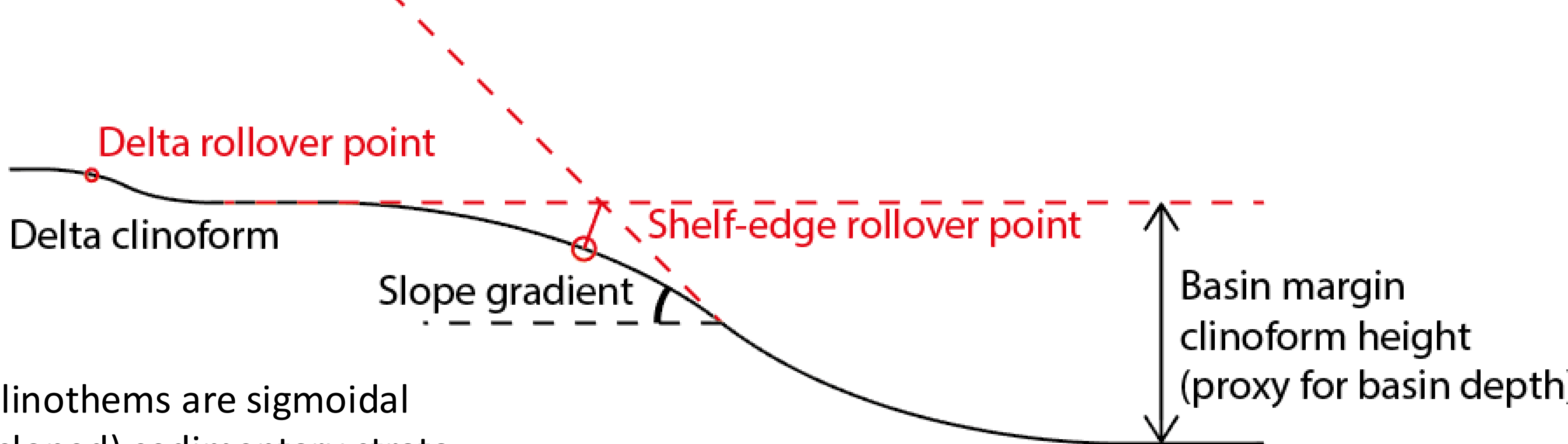
Model of barrier spit accretion concerning the spit-end of Southern Sylt based on GPR and sedimentological dat



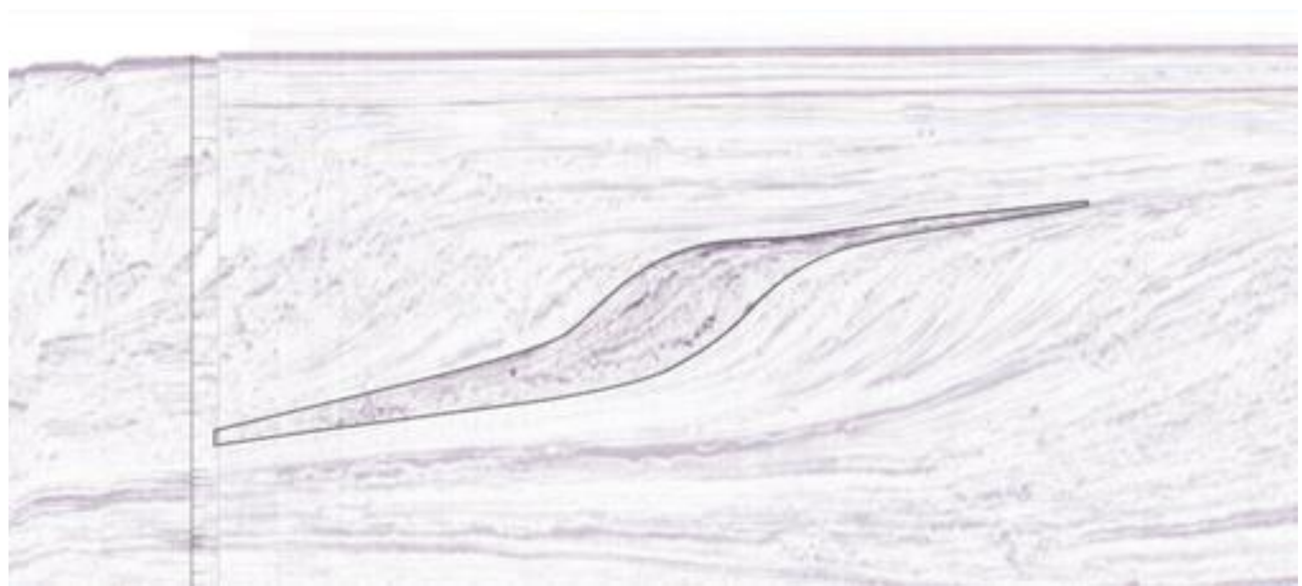
Stratal characteristics of an upward-coarsening parasequence. This type of parasequence is interpreted to form in a deltaic setting on a sandy, fluvial- wave dominated shoreline (after Van Wagoner et al, 1990).

Clinoforms

Clinoforms are defined as sloping depositional surfaces



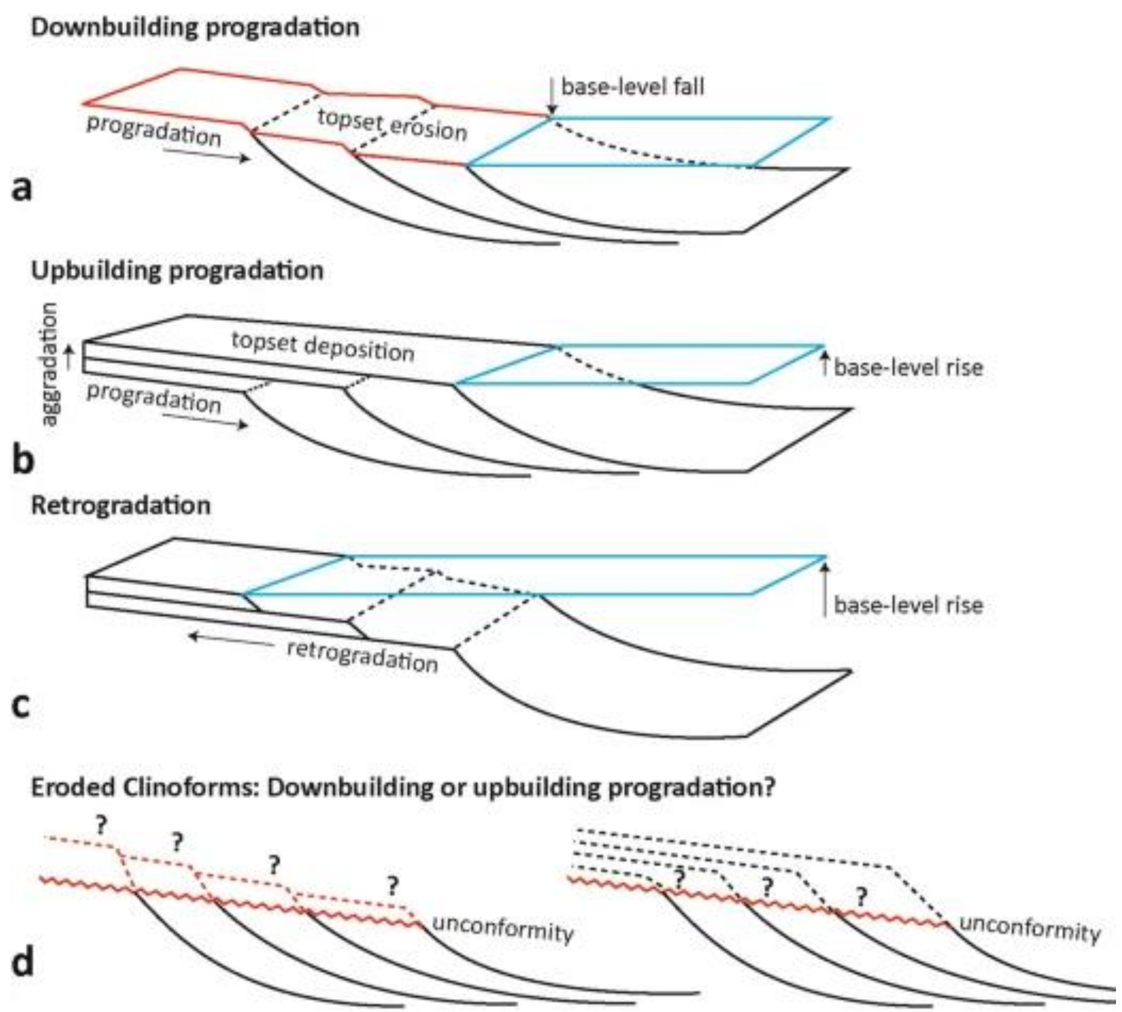
clinothems are sigmoidal (sloped) sedimentary strata bounded by clinoforms and represent a span of geological time. They are formed when sediments prograde into the basin. clinothem volumes are often subdivided into topset, foreset and bottomset compartments, which are each associated with specific sedimentary facies



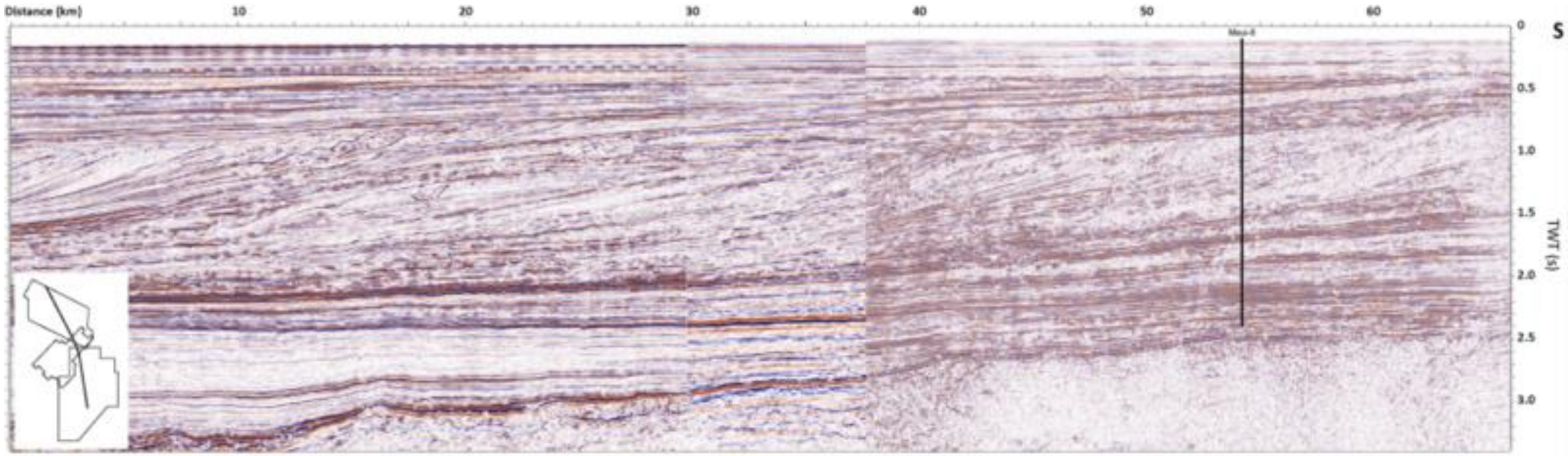
Franzel & Back (2019) Int J Earth Sci. Three-dimensional seismic sedimentology and stratigraphic architecture of prograding **clinoforms**, central Taranaki Basin, New Zealand

Key stratal associations that result from the interplay of accommodation and sedimentation: downbuilding progradation, upbuilding progradation, and retrogradation.

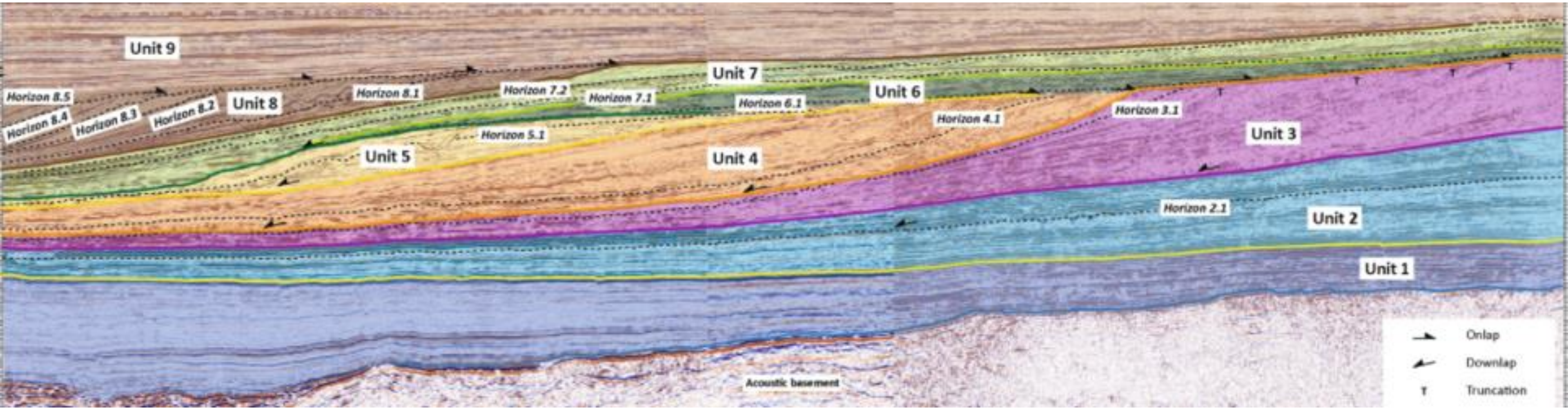
a Downbuilding progradation results from a base-level fall and the seaward migration of a shoreline independent of sediment supply. b Upbuilding progradation is driven by sediment supply, in which the sedimentation rate outpaces the rates of base-level rise at the shoreline. c Retrogradation of depositional systems results from a base-level rise, in which the rates of base-level rise outpace the sedimentation rates at the shoreline. d Erosion of clinoform topsets hampering the differentiation between downbuilding and upbuilding progradation



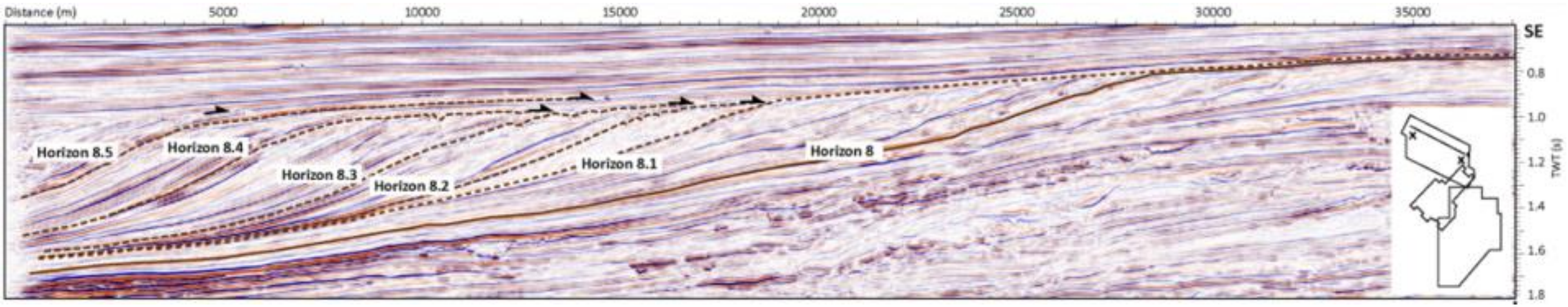
Franzel & Back (2019) Seismic overview

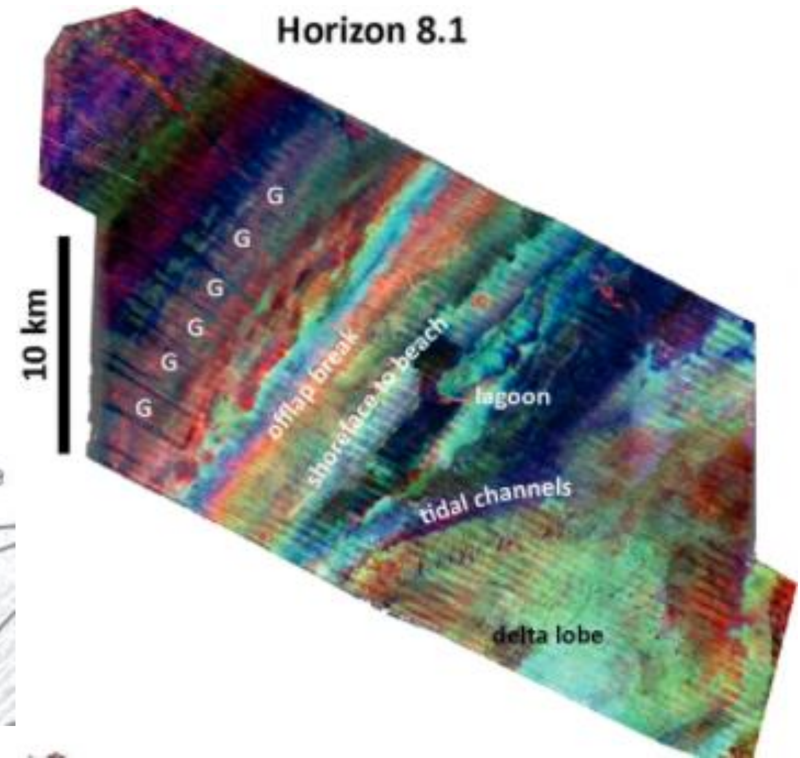


Dashed lines indicate areas in which downbuilding progradational, upbuilding progradational, and retrogradational units are separated by zones of reflection termination instead of a single sharp, precisely defined bounding reflection

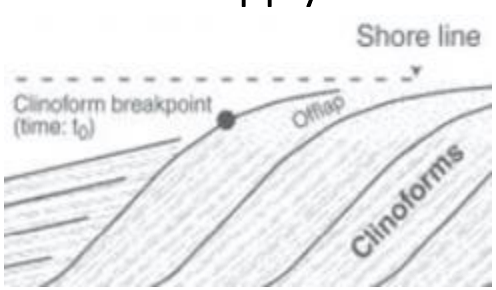


Vertical reflectivity section across Pliocene–Pleistocene downbuilding clinoforms of Unit 8. Black arrows mark onlap reflection terminations.





At and landward of the clinoform breakpoint, which was in the downbuilding clinoform unit 8 likely in the shoreface depositional environment, foreshore processes (tidal currents and waves) as well as backshore and coastal-plain erosional systems seem to have controlled the respective gully position, and, therefore, sediment supply to the clinoform foresets.

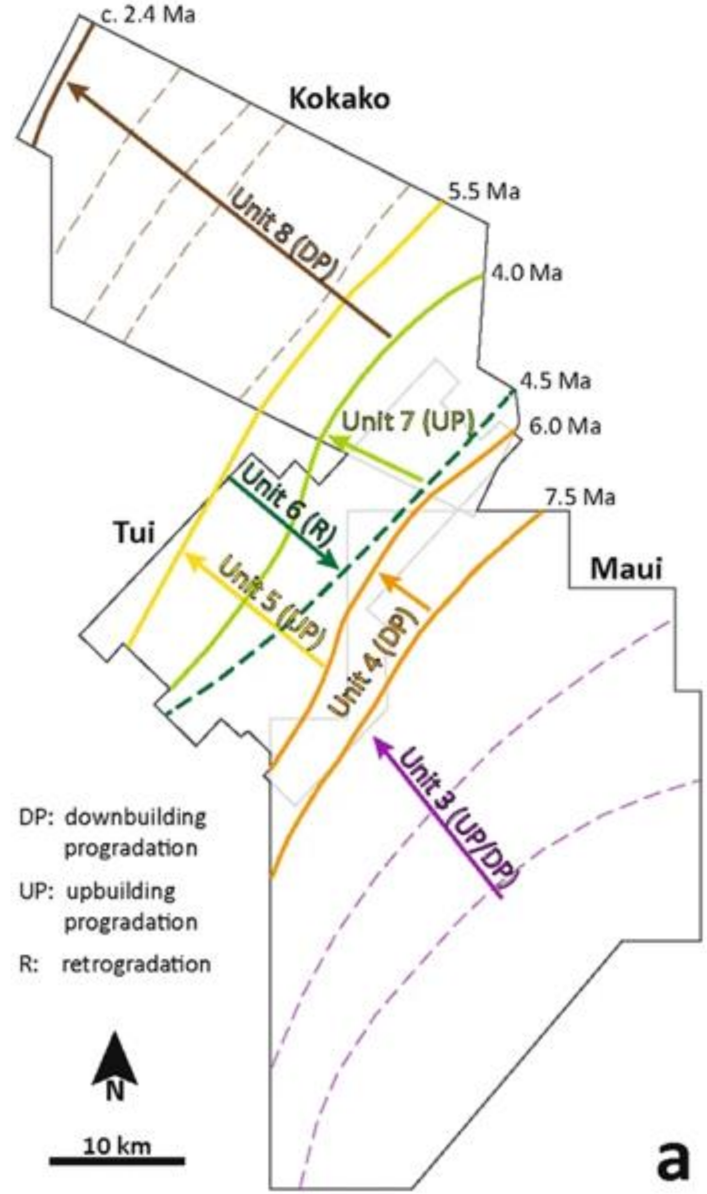


Franzel & Back (2019)

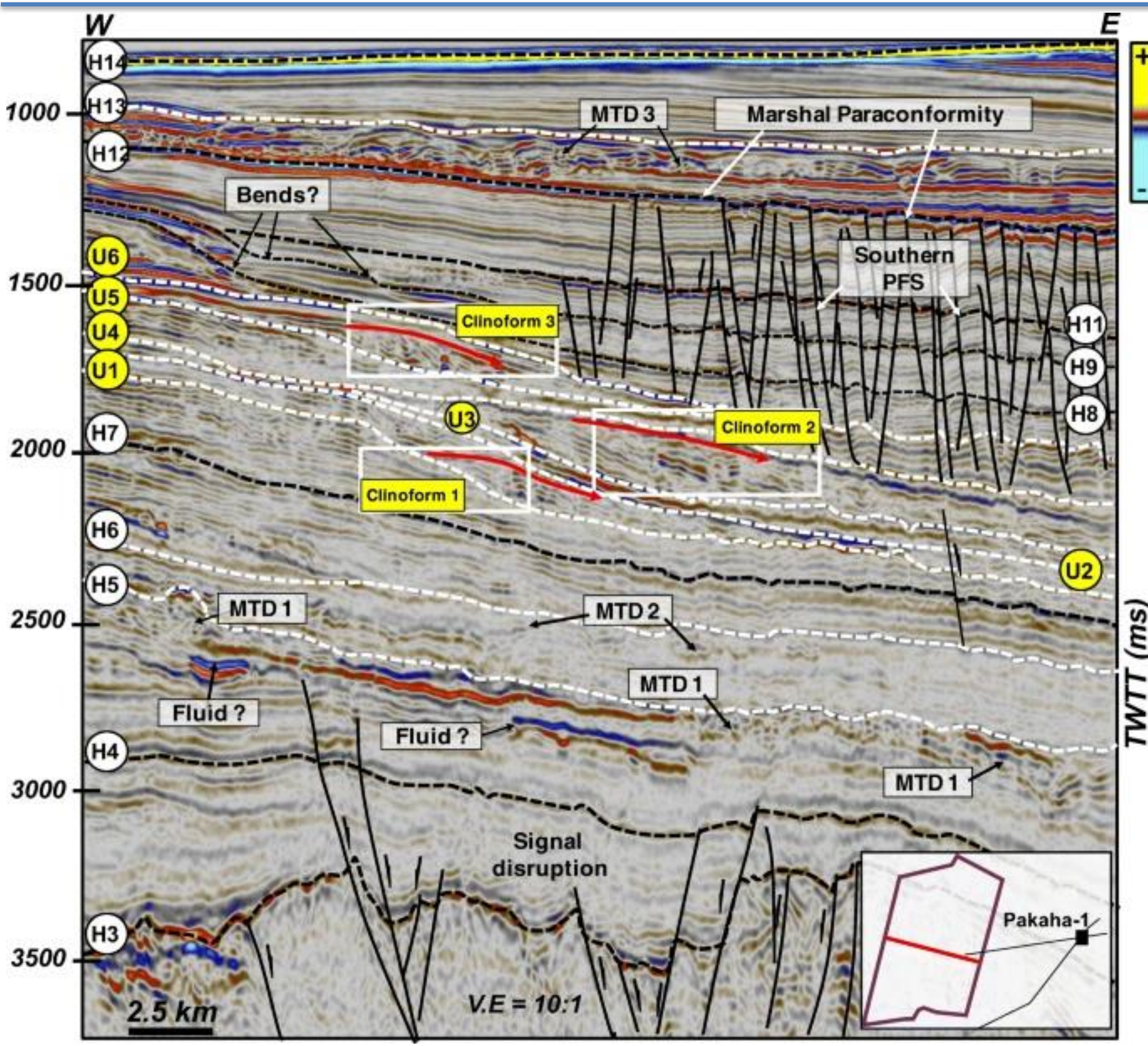
Clinoform breakpoint migration

Clinoform breakpoint migration and depositional elements of units 3 to 8. a Clinoform breakpoint trajectories and approximate stratigraphic ages. Coloured lines indicate maximum progradation or retrogradation in each unit. Purple dashed lines in the Maui area show truncated clinoform foresets and brown dashed lines in the Kokako area indicate offlap breaks of individual clinoform packages.

Franzel & Back (2019)

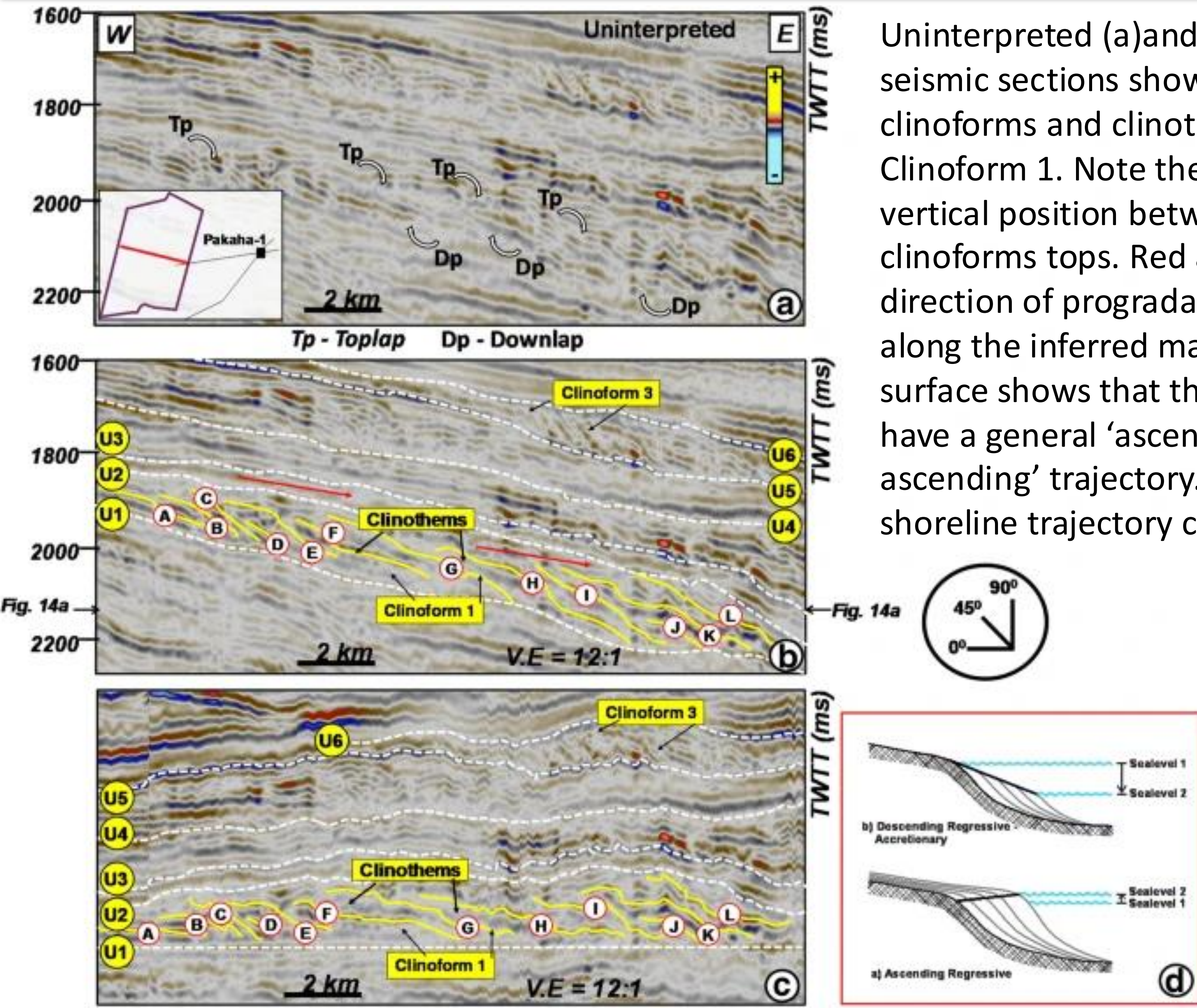


Clinoform breakpoint trajectories (c. 11.0 - 2.4 Ma)

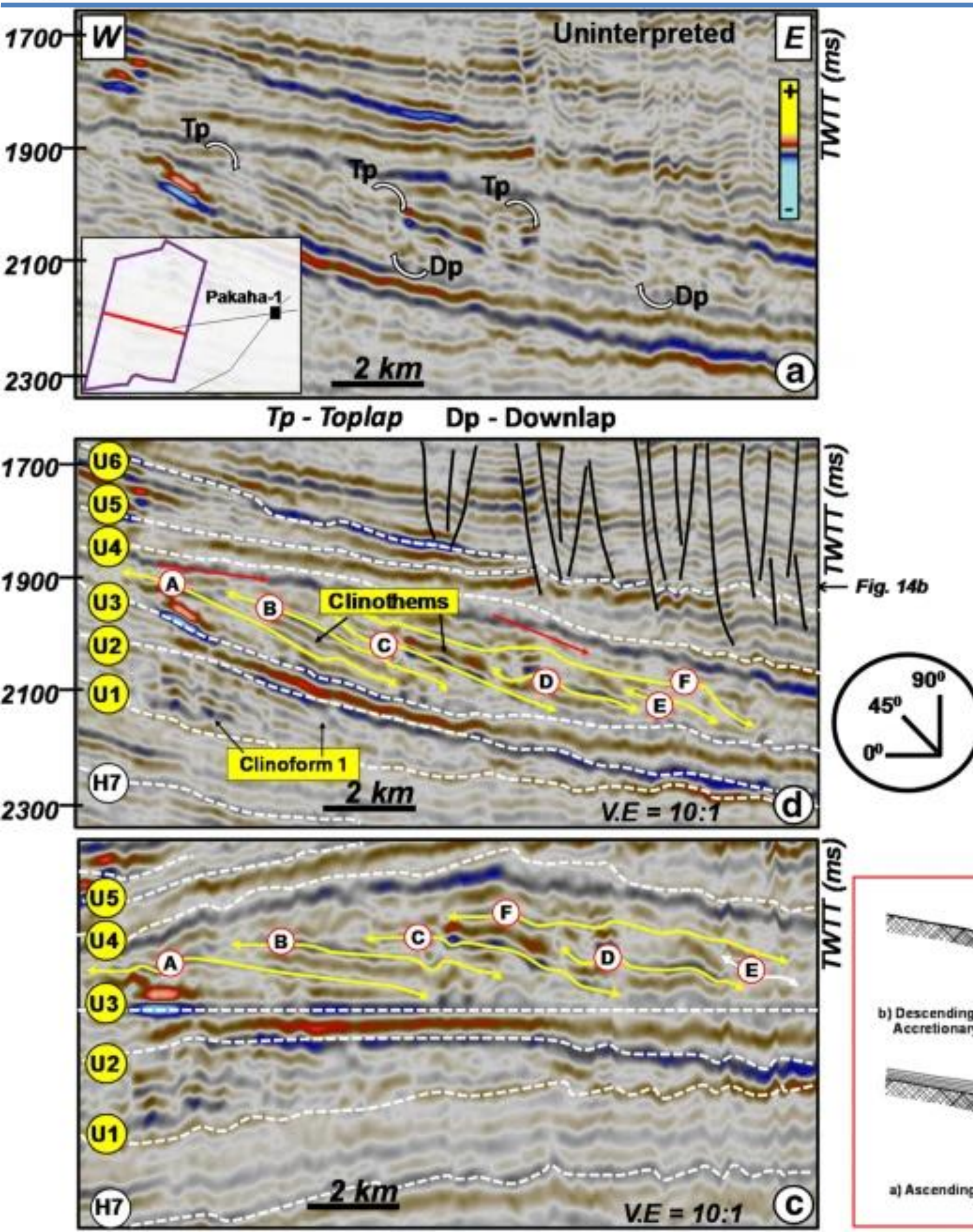


Seismic geomorphology of Cenozoic slope deposits and deltaic clinoforms, Great South Basin, New Zealand Omosanya & Harishidayat (2019). Geo-Mar Lett 39, 77–99

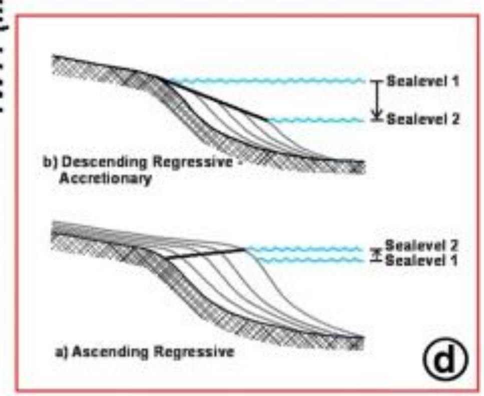
Sigmoidal to oblique Clinoforms 1–3 are here interpreted as deltaic clinoforms because they are less than 100 m in vertical relief and greater than 50 km in length

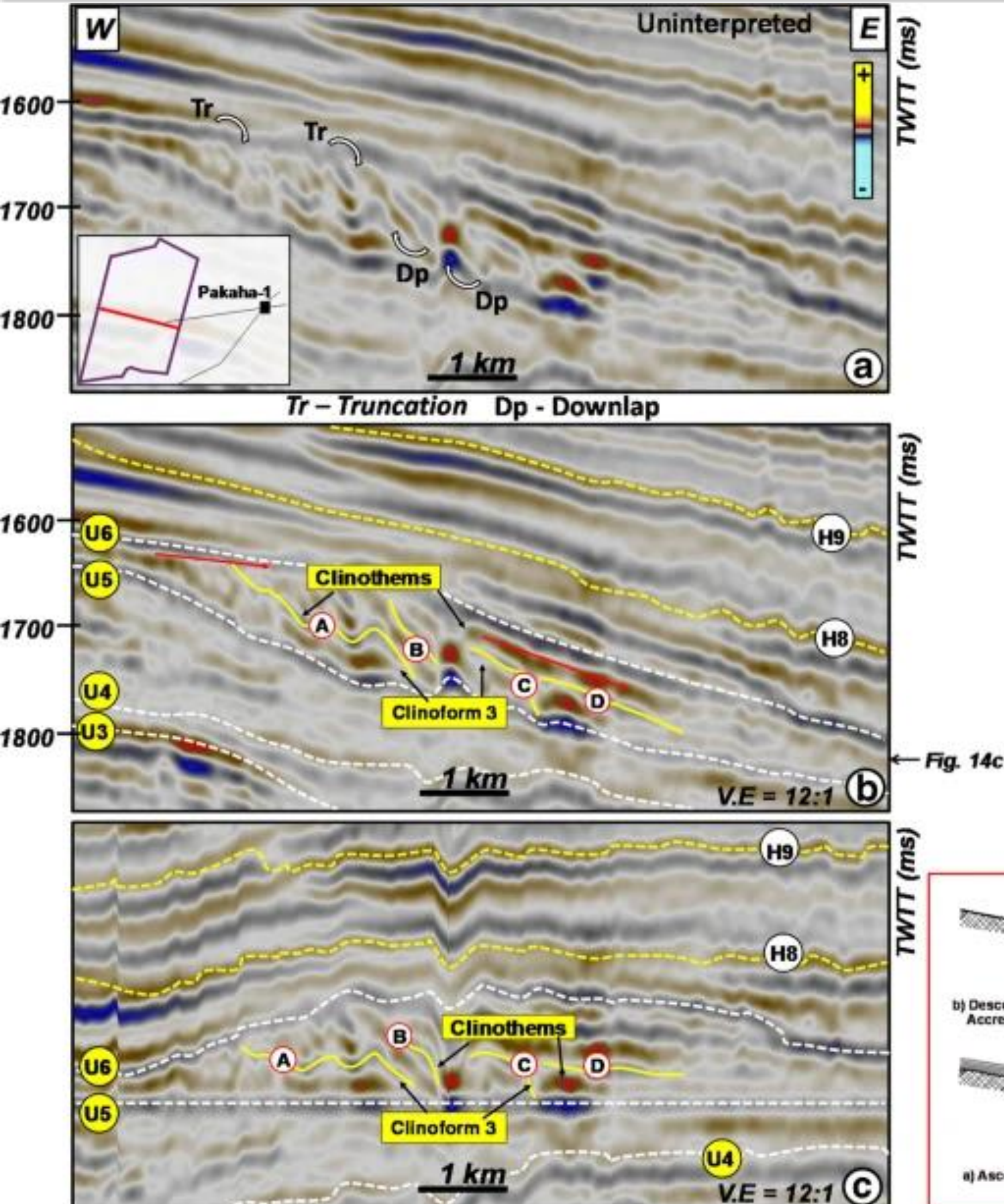


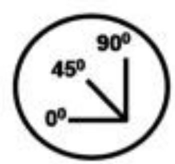
Uninterpreted (a)and interpreted (b) seismic sections showing **sigmoidal** clinoforms and clinothems within Clinoform 1. Note the changing vertical position between the clinoforms tops. Red arrows = direction of progradatio. (c) Flattening along the inferred maximum flooding surface shows that the clinoforms have a general 'ascending-descending-ascending' trajectory. (d) main shoreline trajectory classes



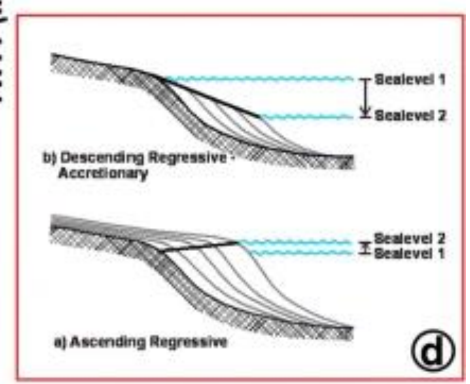
Uninterpreted (a) and interpreted (b) seismic sections showing **complex sigmoid to oblique** clinoforms and clinothems within Clinoform 2. Note the changing vertical position between the clinoform tops. Red arrows = direction of progradation. (c) The flattening of U3 shows that clinoforms have a descending-ascending trajectory. (d) main shoreline trajectory classes



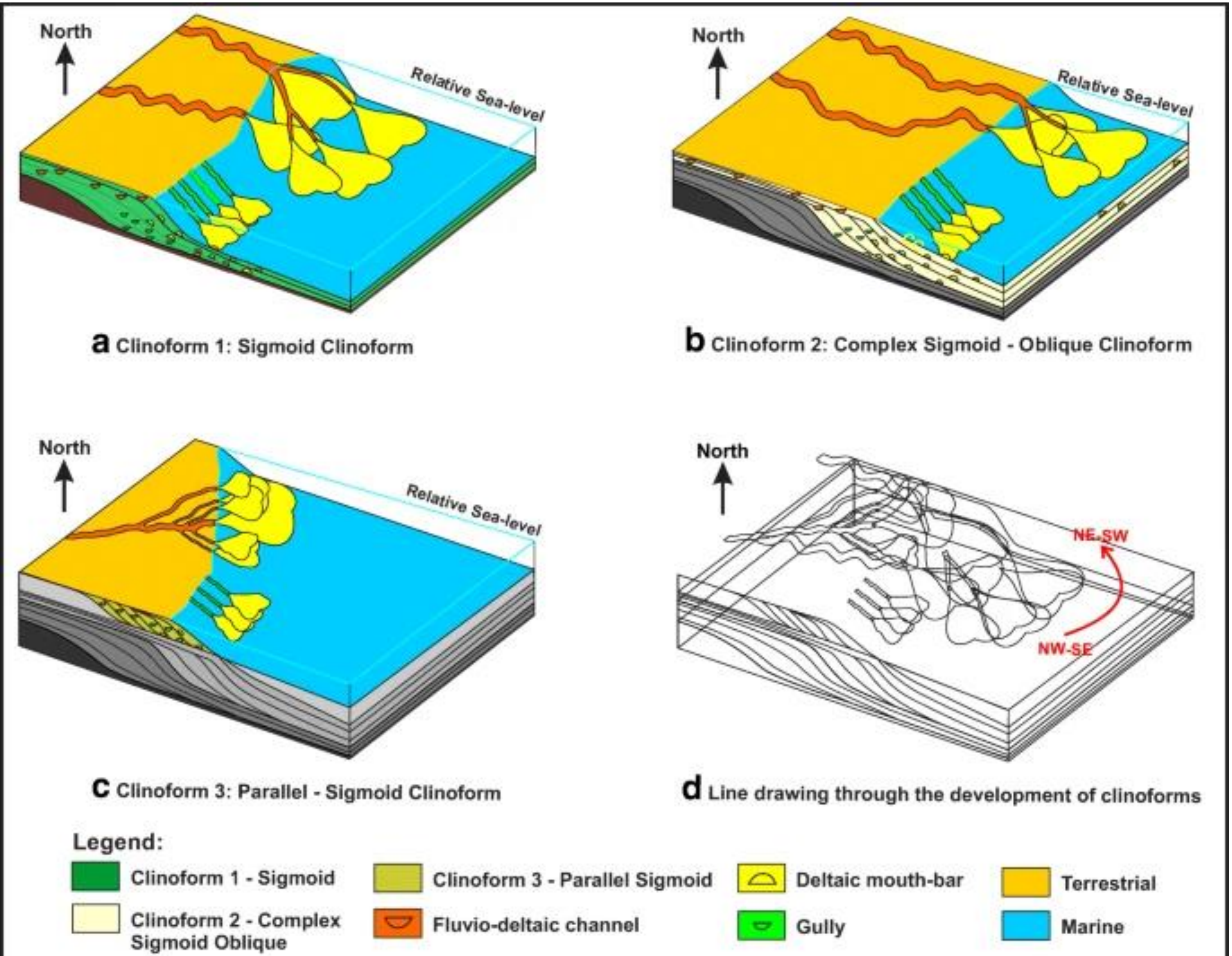




Uninterpreted (a) and interpreted (b) seismic sections showing **parallel-sigmoid** clinoforms and clinothems within Clinoform 3. Note the changing vertical position between the clinoforms tops. Red arrows = direction of progradation. (c) The clinoforms have an ascending to descending trajectory. (d) main shoreline trajectory classes



Evolution of deltaic clinoforms in Clinoform 1 to Clinoform 3



The block diagrams show that these river dominated deltas were fed by fluvial channels, prograded over the shelf and are transported to the SE and NE parts from the Early Eocene to Mid Eocene. The dynamics and orientation of the channels and their lobes may be controlled by regional tectonics during the Eocene or nearshore currents

Interpretation criteria for deltaic clinoforms

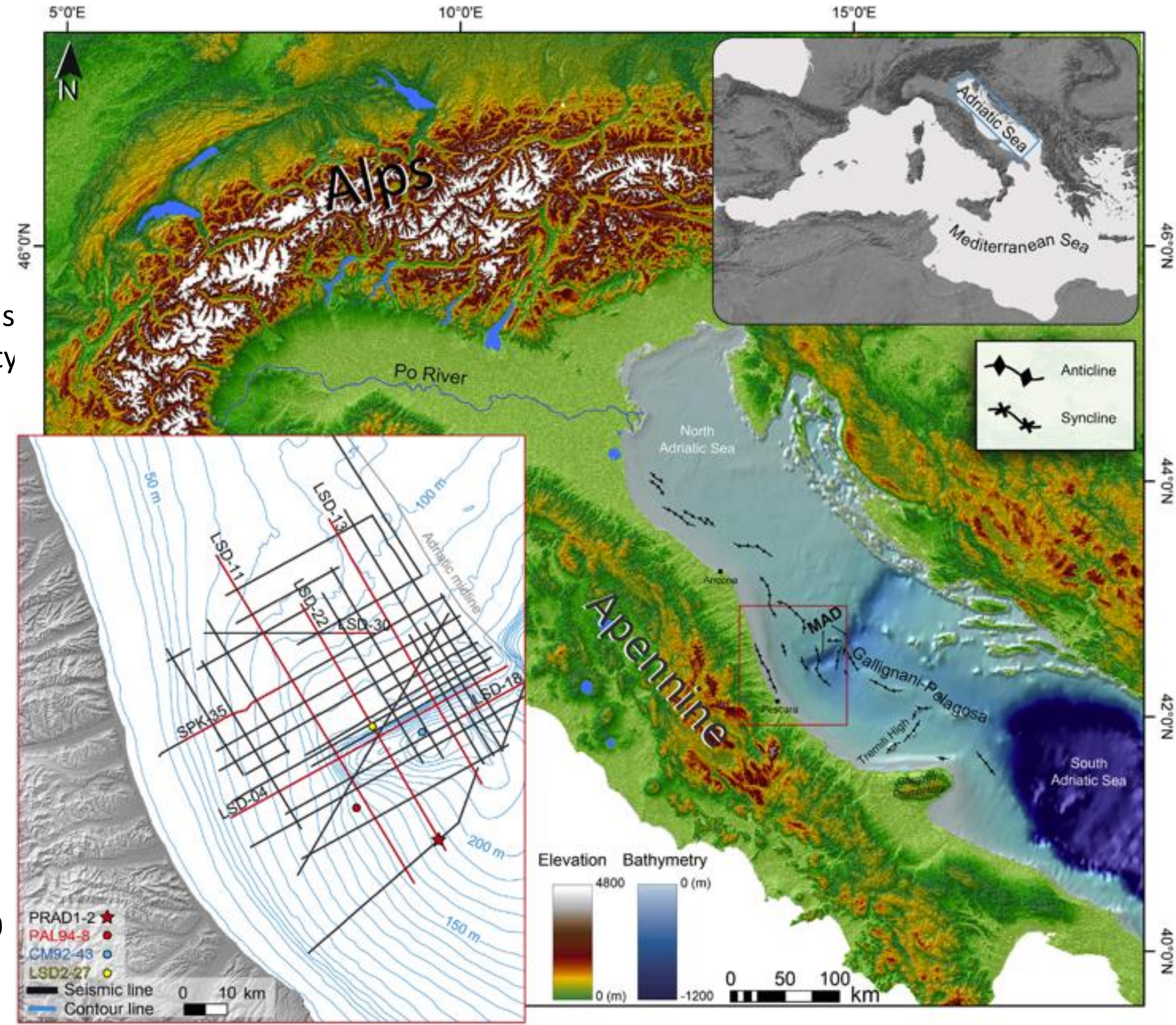
The deltaic systems are characterised by internal reflection terminations such as toplap and downlap, and configurations as mounded reflections. The shoreline trajectory describes the cross-sectional path of the shoreline as it migrates, as a function of bathymetry, sediment supply, eustatic sea-level changes, loading subsidence and compaction. Clinoform shoreline trajectory may include very low angle-ascending trajectory, a high angle-ascending trajectory, a flat trajectory and a descending trajectory. Ascending shoreline trajectories will result in a sigmoidal seismic pattern and long-term rise in the relative base level. Flat and descending trajectories will produce an oblique progradational seismic pattern. A flat trajectory suggests a stable, relative base level through time, usually formed by an optimal sediment supply. A descending trajectory may signify a large sediment supply influenced by relative sea-level fall and strong fluvial input

Exercise

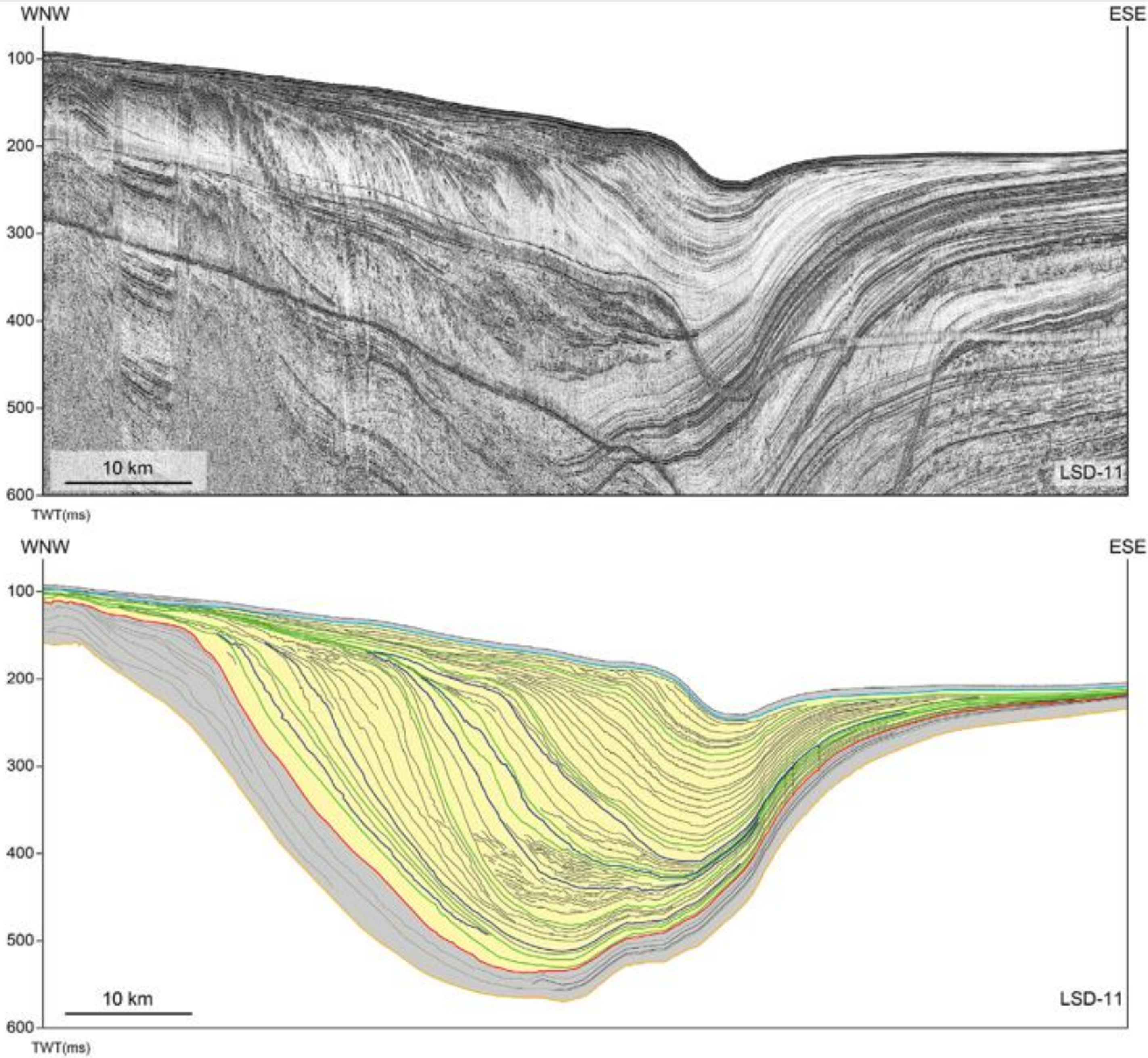
The late Pleistocene Po River lowstand wedge in the Adriatic Sea: Controls on architecture variability and sediment partitioning

Pellegrini, C., Asioli, A., Bohacs, K.M., Drexler, T.M., Feldman, H.R., Sweet, M.L., Maselli, V., Rovere, M., Gamberi, F., Valle, G.D., Trincardi, F.

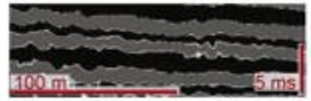
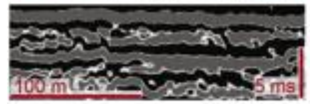
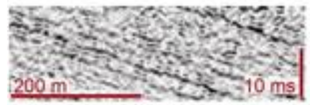
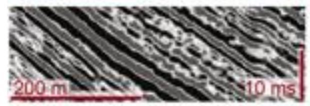
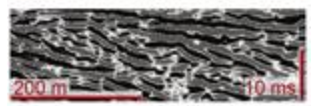
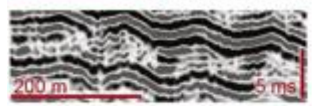
(2018) Marine and Petroleum Geology, 96, pp. 16-50. DOI: 10.1016/j.marpetgeo.2018.03.002

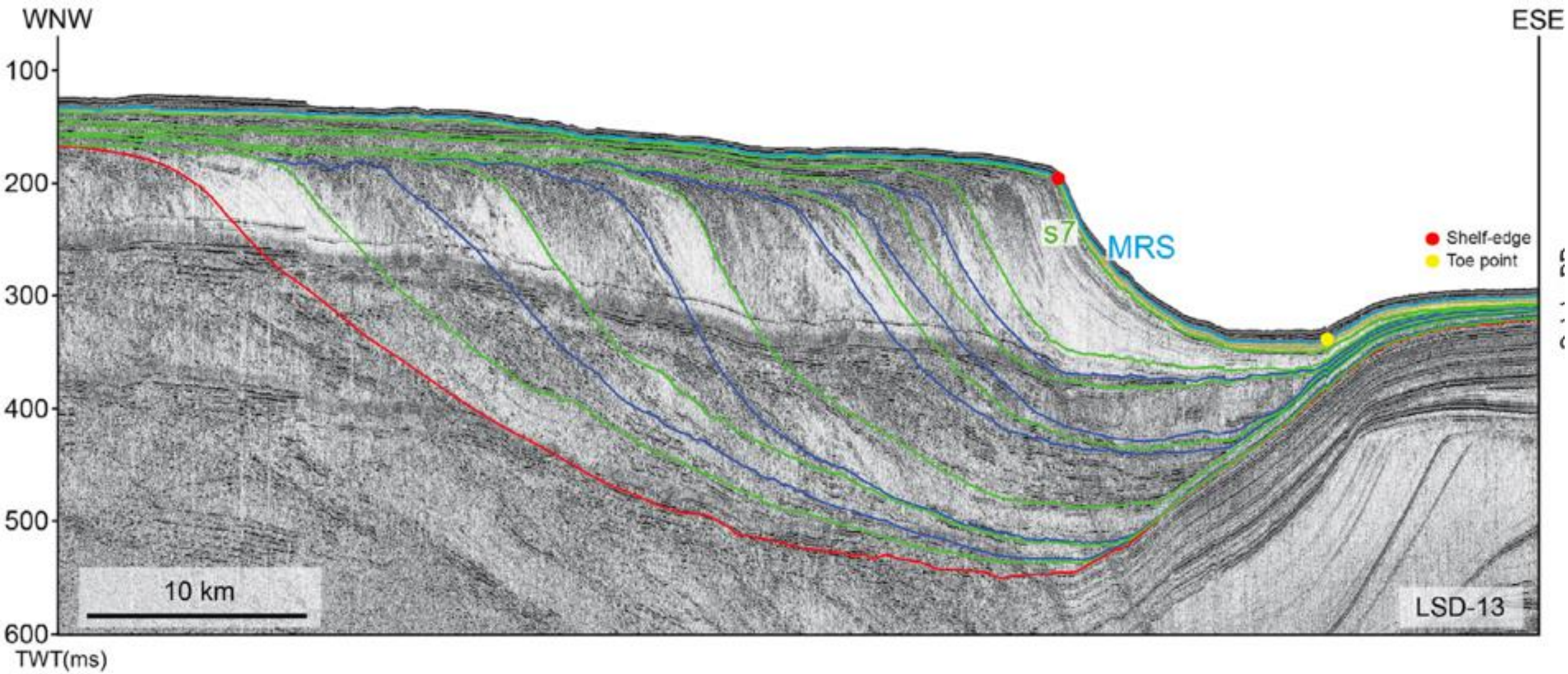


Line drawing of LSD-11 multichannel profile showing the late Pleistocene Po River Lowstand Wedge (PRLW) in yellow

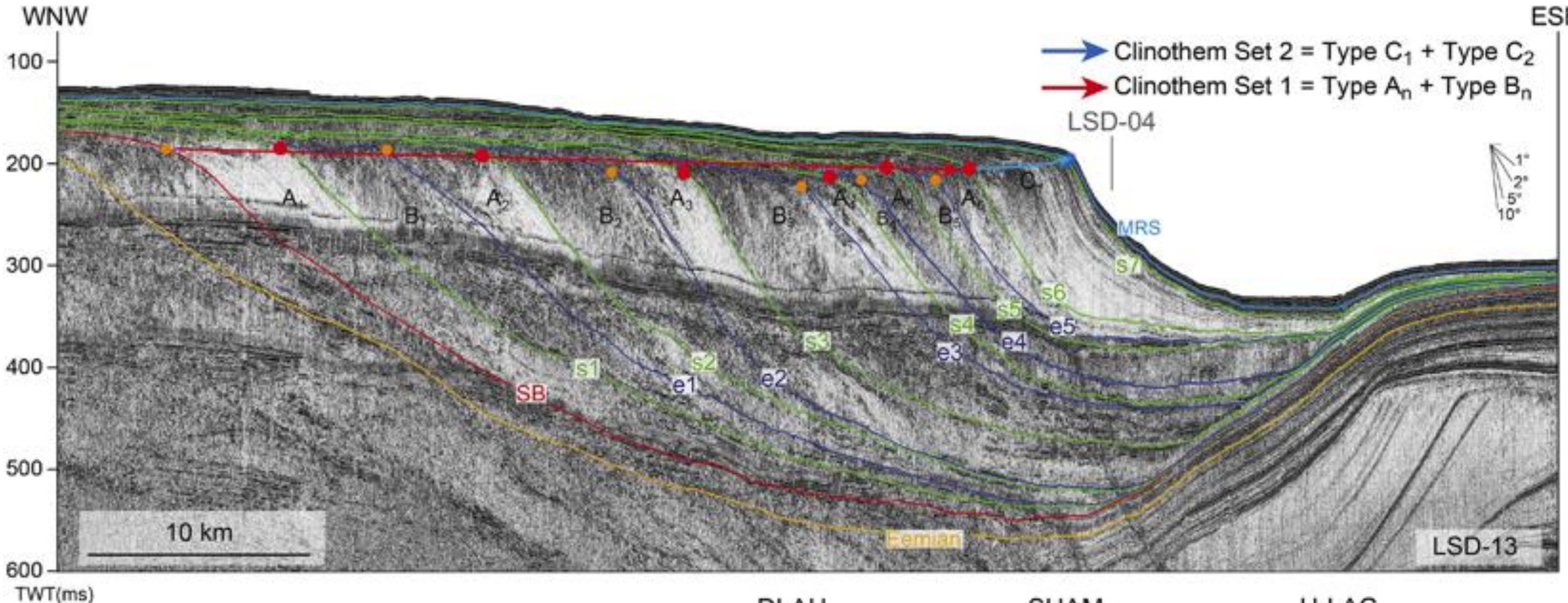


Definition of facies

Seismic facies	Acronym and color in seismic facies map	Internal Reflections	Clinoform sector	Depositional Environment
	HAC	High Amplitude Continuous	Topset	Delta plain/ subaqueous shelf
	HACh	High Amplitude Chaotic	Topset/ Foreset	Delta/Coastal plain
	HAD	High Amplitude Discontinuous	Topset	Lagoon
	LACDip	Low Amplitude Continuous Dipping	Foreset	Prodelta
	HACDip	High Amplitude Continuous Dipping	Foreset	Prodelta
	HAChDip	High Amplitude Chaotic Dipping	Foreset	Prodelta
	HACWDip	High Amplitude Continuous Wavy Dipping	Foreset	Prodelta
	DLAH	Discontinuous Low Amplitude Hyperbolic	Foreset/ Bottomset	Mass-Transport Complexes
	SHAM	Semi-continuous High Amplitude Mounded	Foreset/ Bottomset	Channel-levee Complexes
	LAC	Low Amplitude Continuous	Bottomset	Distal Basin
	HAC	High Amplitude Continuous	Bottomset	Distal Basin


WNW
ESE
100
200
300
400
500
600
TWT(ms)
s7
MRS
Shelf-edge
Toe point
10 km
LSD-13

Top: Dip-oriented multichannel seismic profile LSD-13 illustrating clinothem geometries along the main direction of progradation.



Bottom: Along-strike profile LSD-04 highlighting the seismic facies of basinal deposits