Università degli studi di Trieste

LAUREA MAGISTRALE IN GEOSCIENZE

Classe Scienze e Tecnologie Geologiche

Curriculum: Esplorazione Geologica

Anno accademico 2022 - 2023

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Unit 3.9
Faults, volcanoes, carbonate sediments, synthesis

Outline:

- Faults (after Anna Del Ben)
- Volcanoclastic deposits/ Volcanoes in the seismic records
- Carbonate sediments
- Synthesis

Anna Del Ben: Course of «Interpretazione sismica»

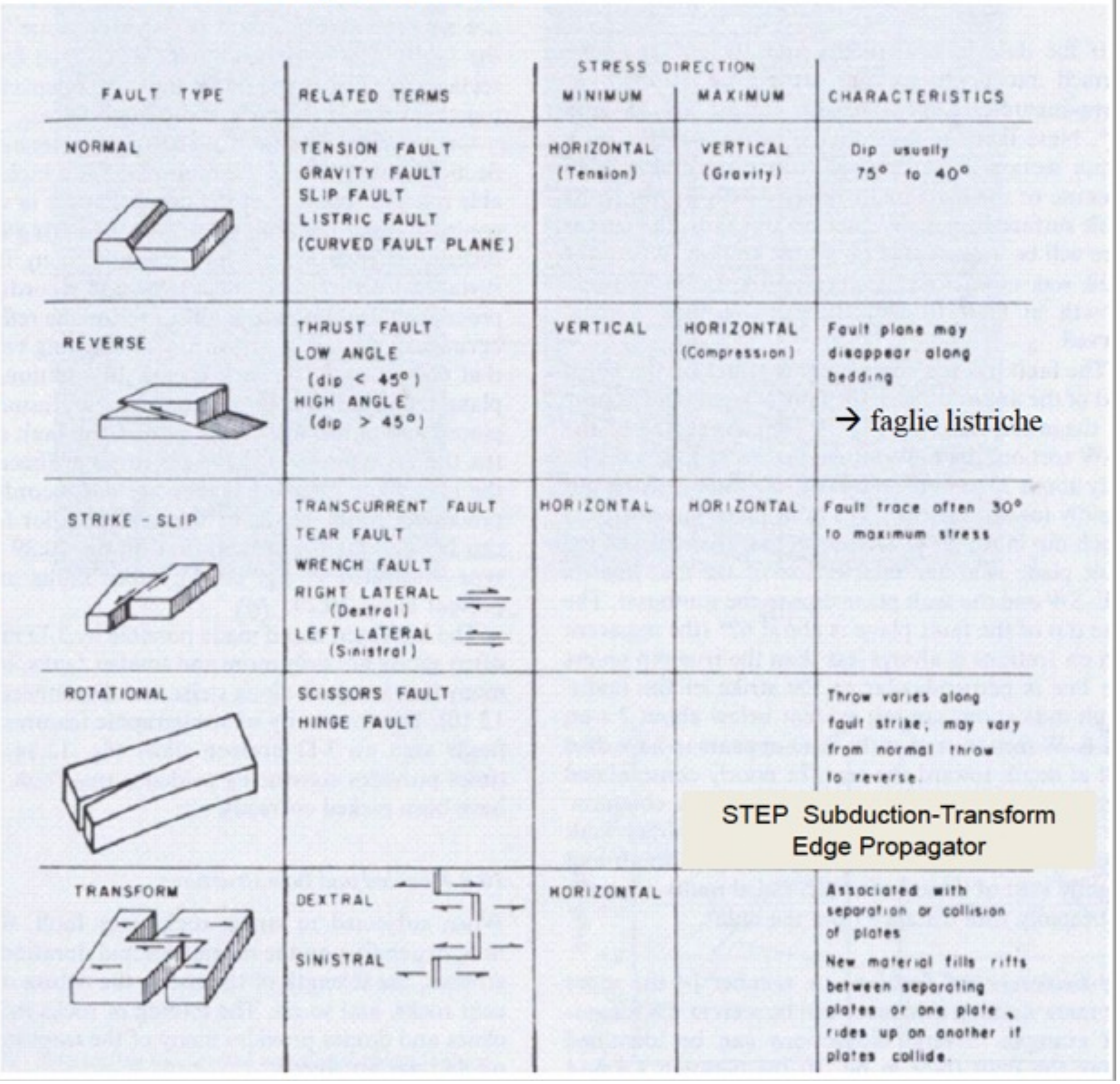
Evidenze sismiche di (sistemi di) faglie

Un regime tettonico è caratterizzato dalla presenza di un sistema più o meno complesso di fratture associate alla deformazione fragile degli strati sedimentari, a cui si associa spesso una deformazione duttile.

Diversi tipi di faglie

Lungo i profili sismici le faglie possono avere aspetto molto variabile: superfici di riflessione vera e propria o sistemi diffusi di fratture che interrompono la continuità dei riflettori.

La pendenza è apparente, in funzione delle velocità delle onde P, del fattore di scala adottato (esagerazione verticale), della direzione del profilo sismico rispetto alla direzione della faglia.

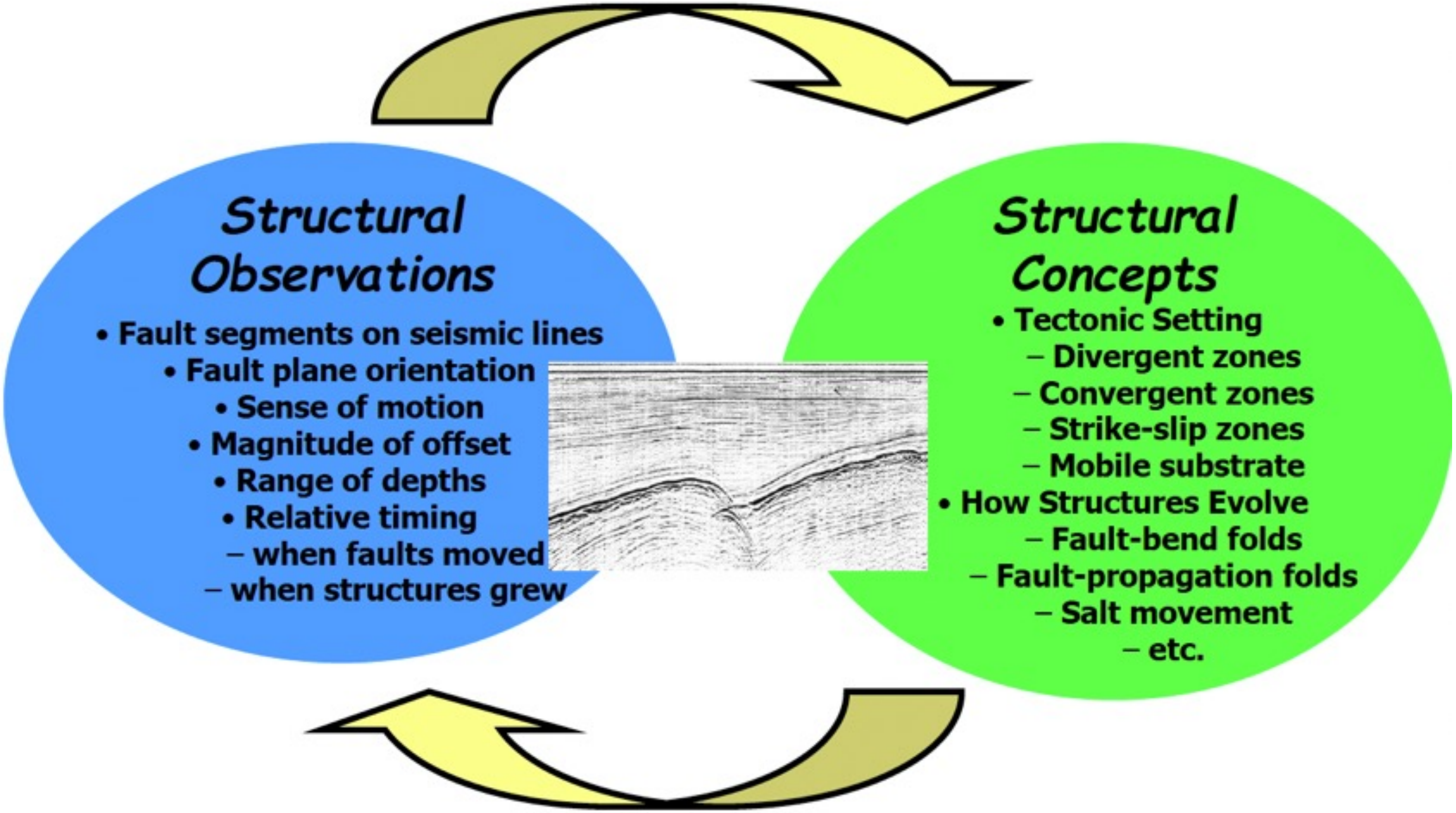


FAULT TYPE	RELATED TERMS	STRESS DIRECTION MINIMUM	STRESS DIRECTION MAXIMUM	CHARACTERISTICS
NORMAL	TENSION FAULT GRAVITY FAULT SLIP FAULT LISTRIC FAULT (CURVED FAULT PLANE)	HORIZONTAL (Tension)	VERTICAL (Gravity)	Dip usually 75° to 40°
REVERSE	THRUST FAULT LOW ANGLE (dip < 45°) HIGH ANGLE (dip > 45°)	VERTICAL	HORIZONTAL (Compression)	Fault plane may disappear along bedding
STRIKE - SLIP	TRANSCURRENT FAULT TEAR FAULT WRENCH FAULT RIGHT LATERAL (Dextral) ⇌ LEFT LATERAL (Sinistral) ⇌	HORIZONTAL	HORIZONTAL	Fault trace often 30° to maximum stress
ROTATIONAL	SCISSORS FAULT HINGE FAULT			Throw varies along fault strike; may vary from normal throw to reverse.
TRANSFORM	DEXTRAL SINISTRAL	HORIZONTAL		Associated with separation or collision of plates New material fills rifts between separating plates or one plate rides up on another if plates collide.

→ faglie listriche

STEP Subduction-Transform Edge Propagator

Interpreting Faults



Structural Observations

- Fault segments on seismic lines
- Fault plane orientation
- Sense of motion
- Magnitude of offset
- Range of depths
- Relative timing
  - when faults moved
  - when structures grew

Structural Concepts

- Tectonic Setting
  - Divergent zones
  - Convergent zones
  - Strike-slip zones
  - Mobile substrate
- How Structures Evolve
  - Fault-bend folds
  - Fault-propagation folds
  - Salt movement
  - etc.

Courtesy of ExxonMobil

Riconoscimento di faglie

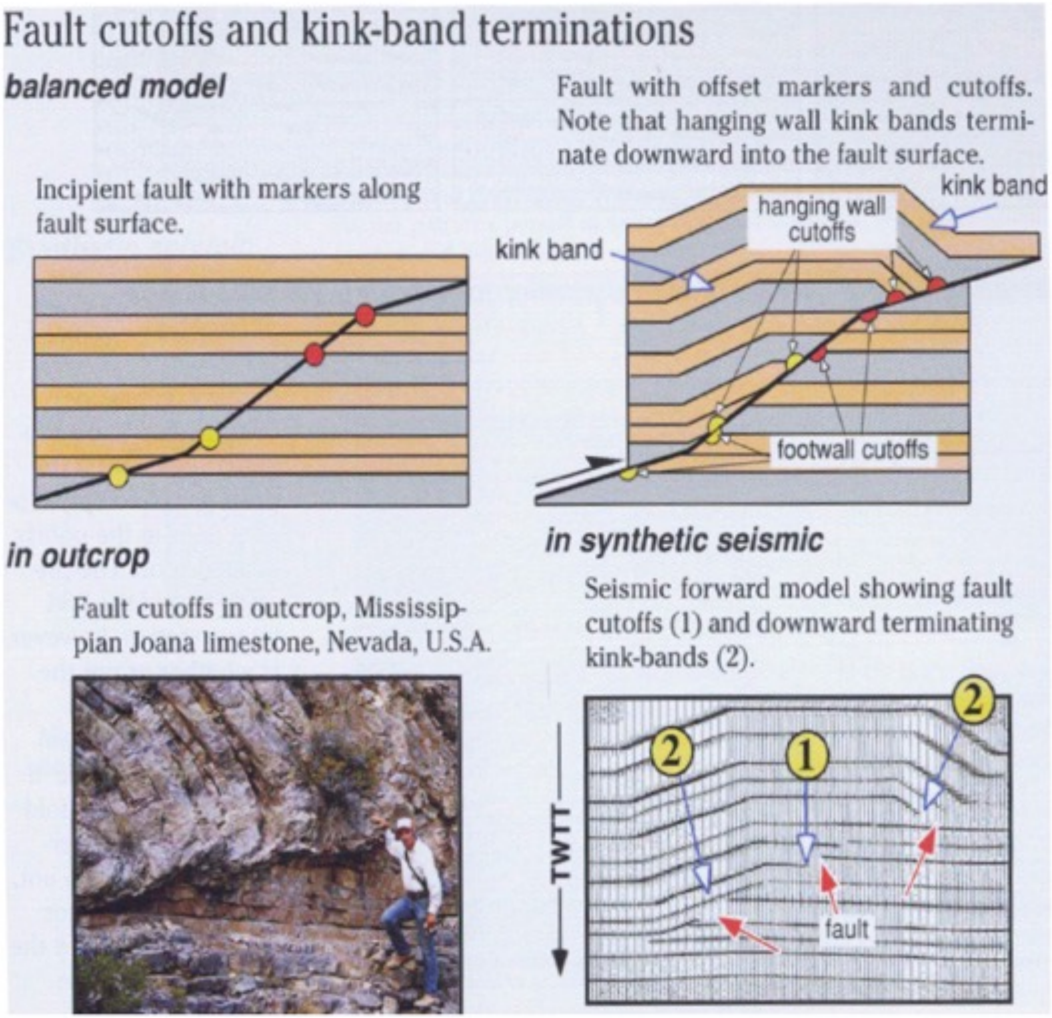
Le faglie vengono identificate nei profili sismici in base a:

1 - *Fault cutoffs*: terminazione delle riflessioni o brusca variazione degli attributi

2 – *Kink bands*: “piega a gomito” degli strati

3 – Riflessione direttamente dal piano di faglia.

I criteri 1 e 3 forniscono direttamente la posizione della faglia; tutti i tre criteri, se applicabili, sono utili per identificare e interpretare correttamente una faglia.



Fault cutoffs and kink-band terminations

balanced model

Incipient fault with markers along fault surface.

Fault with offset markers and cutoffs. Note that hanging wall kink bands terminate downward into the fault surface.

in outcrop

Fault cutoffs in outcrop, Mississippian Joana limestone, Nevada, U.S.A.

in synthetic seismic

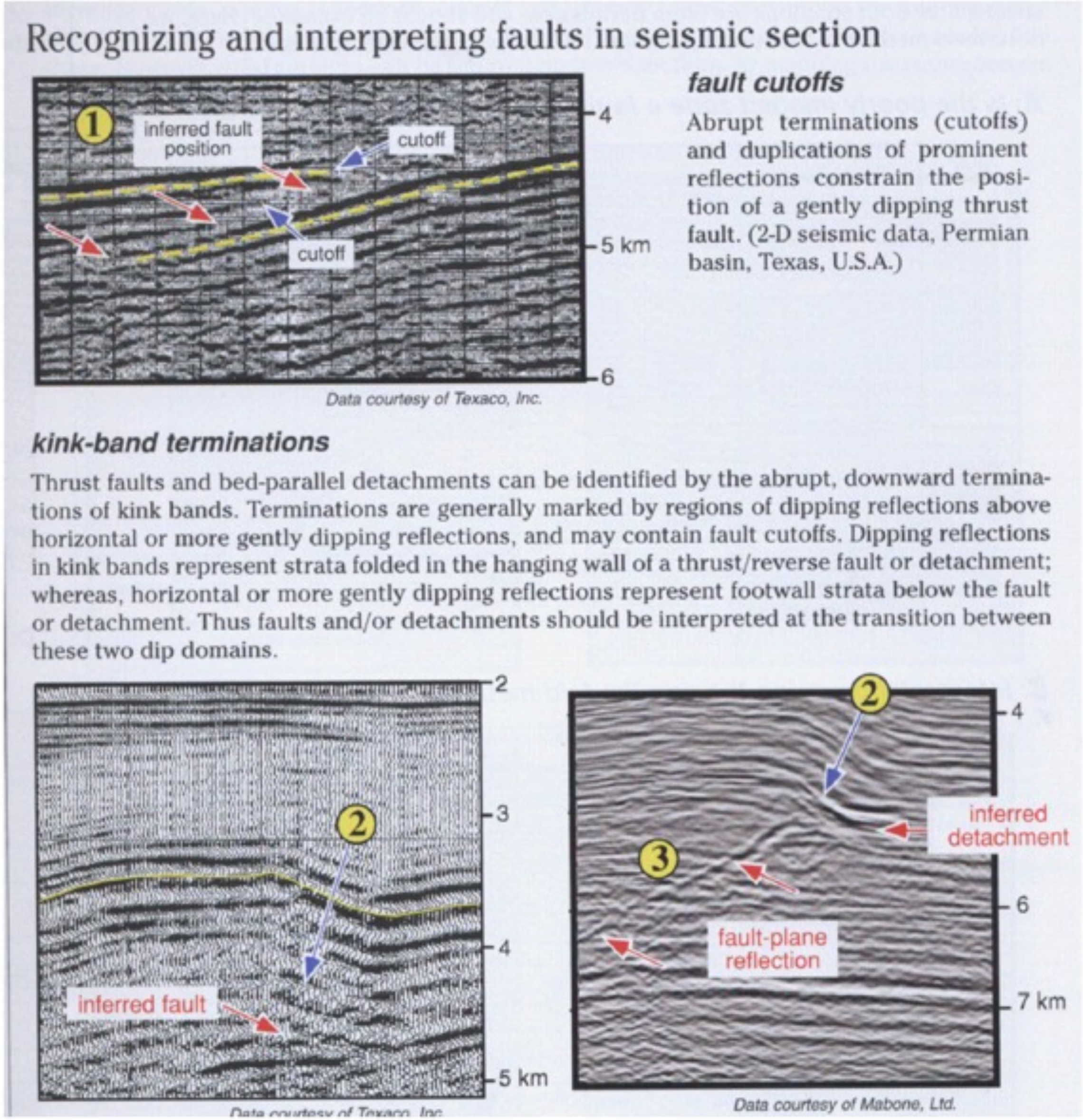
Seismic forward model showing fault cutoffs (1) and downward terminating kink-bands (2).

Esempio di profili sismici in cui si possono riconoscere:

1 - *Fault cutoffs*: terminazione delle riflessioni o brusca variazione degli attributi

2 – *Kink bands*: “piega a gomito” degli strati

3 – Riflessione direttamente dal piano di faglia



Recognizing and interpreting faults in seismic section

fault cutoffs

Abrupt terminations (cutoffs) and duplications of prominent reflections constrain the position of a gently dipping thrust fault. (2-D seismic data, Permian basin, Texas, U.S.A.)

Data courtesy of Texaco, Inc.

kink-band terminations

Thrust faults and bed-parallel detachments can be identified by the abrupt, downward terminations of kink bands. Terminations are generally marked by regions of dipping reflections above horizontal or more gently dipping reflections, and may contain fault cutoffs. Dipping reflections in kink bands represent strata folded in the hanging wall of a thrust/reverse fault or detachment; whereas, horizontal or more gently dipping reflections represent footwall strata below the fault or detachment. Thus faults and/or detachments should be interpreted at the transition between these two dip domains.

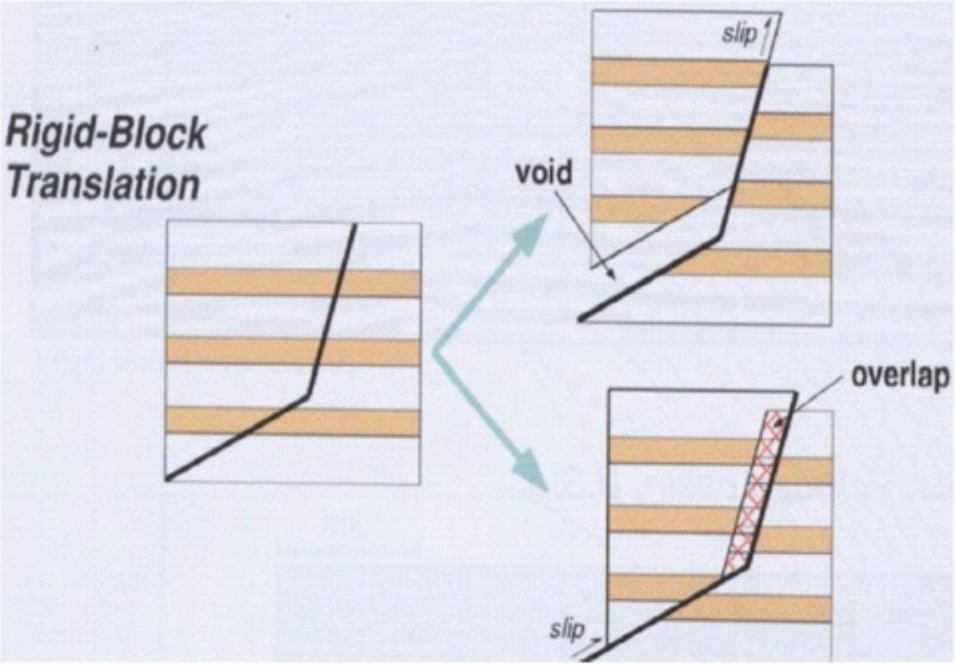
Data courtesy of Texaco, Inc.

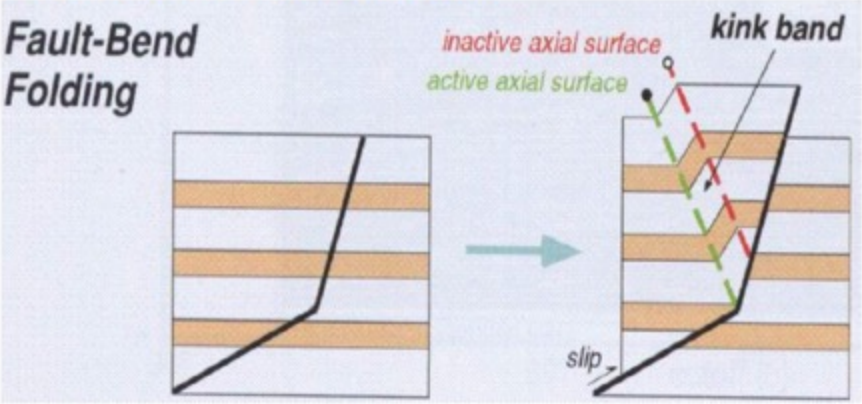
Data courtesy of Mabone, Ltd.

Fault-bend folds

(bending of fault blocks as they ride over non planar fault surfaces)

Si formano quando l'*hanging wall* si muove sopra il "gomito" di una faglia.
Nello scorrimento lungo segmenti diversi della faglia, la traslazione di un blocco rigido produrrebbe un vuoto o una sovrapposizione → tra i due blocchi delimitati dalla faglia.
Entrambe queste situazioni sono irrealizzabili nella realtà.

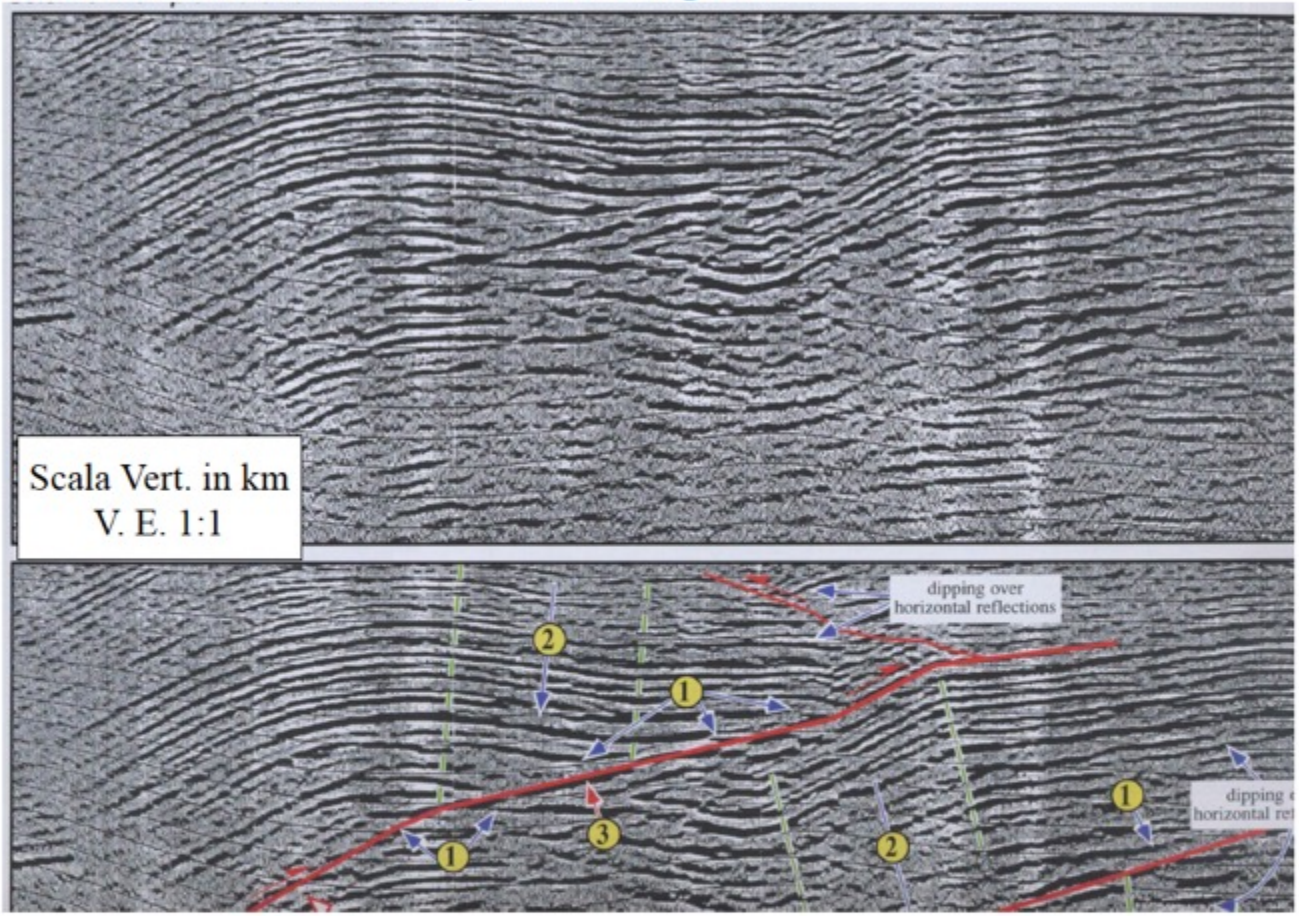




L'accomodamento si ottiene attraverso la formazione di una piega nel blocco di *hanging wall*, localizzata lungo una superficie assiale attiva, mentre la superficie assiale inattiva localizza la superficie attiva nella fase iniziale.

https://www.researchgate.net/profile/John_Suppe/publication/237044249_Geometry_and_Kinematics_of_Fault-bend_Folding/links/0c960522d463fbbfe6000000/Geometry-and-Kinematics-of-Fault-bend-Folding.pdf

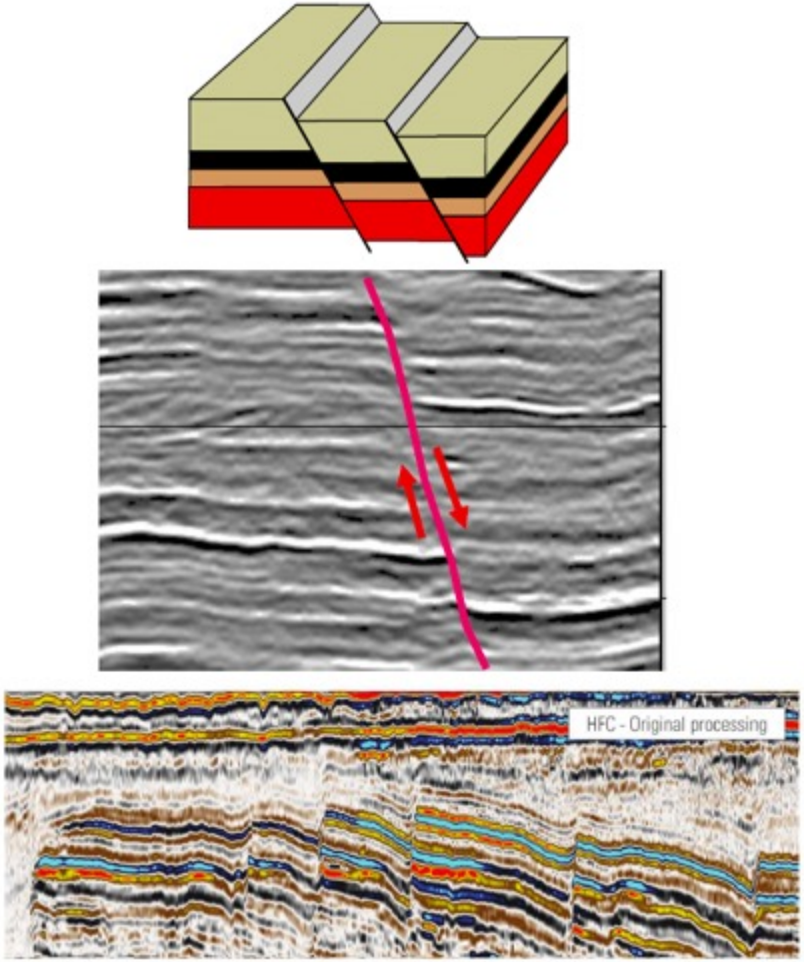
Esempio di interpretazione di una faglia inversa basata sul riconoscimento di:
1 - *Fault cutoffs*: terminazione delle riflessioni o brusca variazione degli attributi
2 – *Kink bands*: “piega a gomito” degli strati
3 – Riflessione direttamente dal piano di faglia

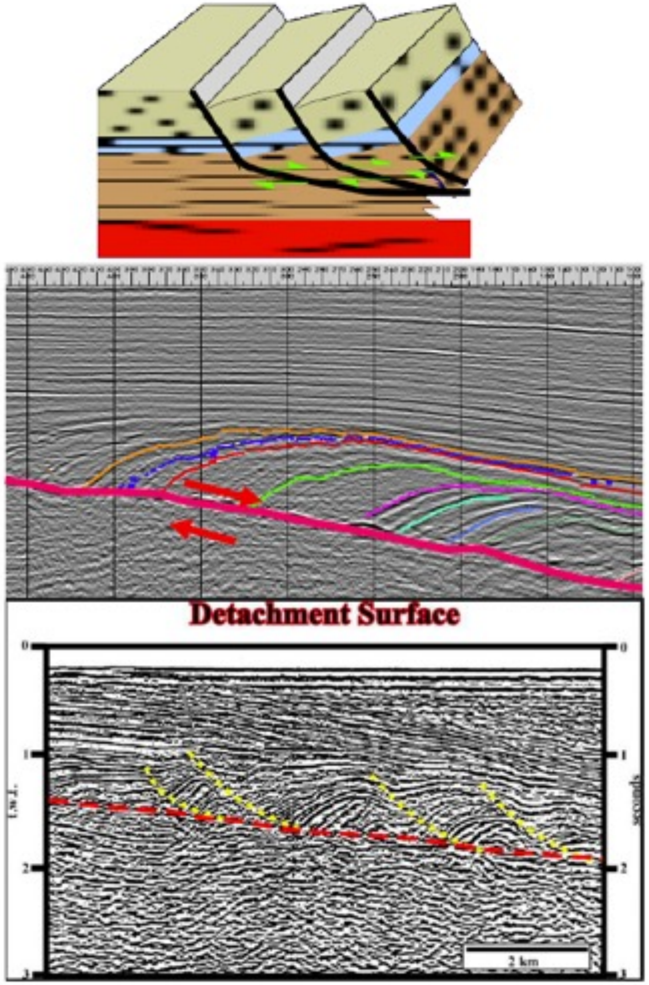


Faglie normali

Planari

Listriche



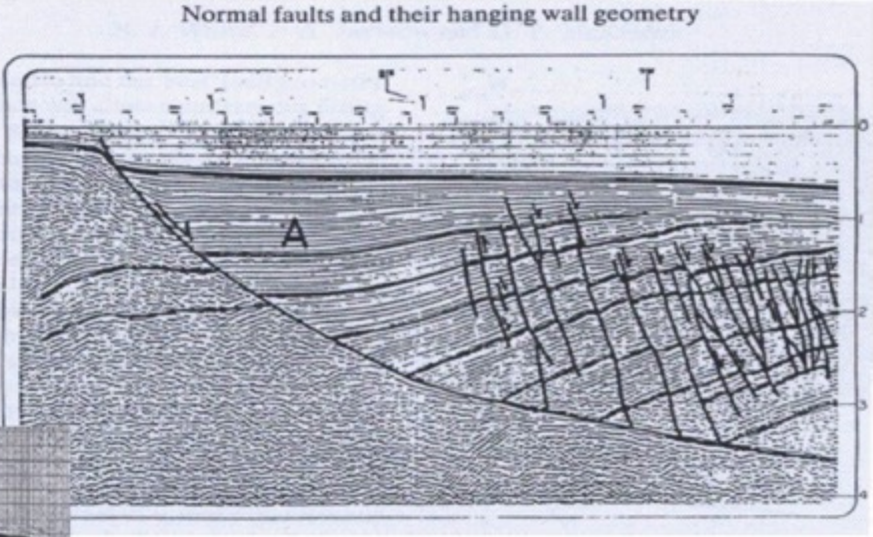


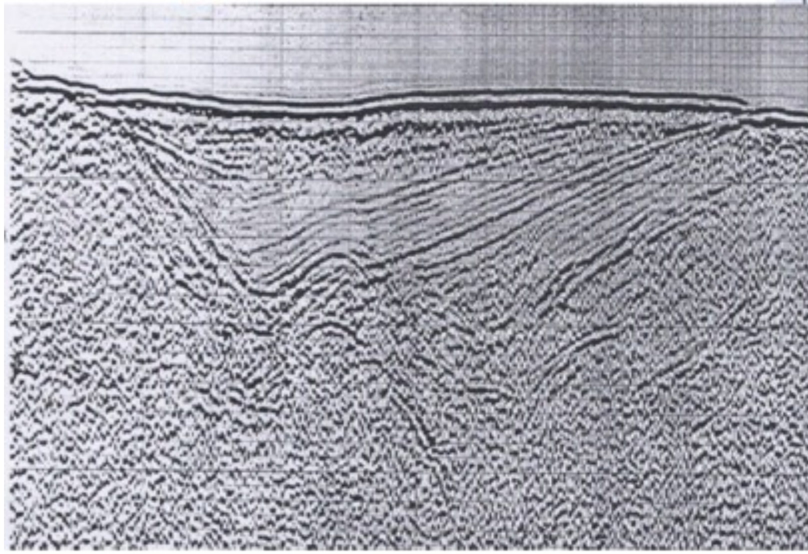
GROWTH (o SYNTECTONIC) STRATA

Sono intervalli stratigrafici **depostisi durante la deformazione**.
La loro età definisce, quindi, l'età della deformazione.

In regime distensivo danno luogo ad un caratteristico cuneo sedimentario (*sedimentary wedge*): in tale contesto possono assumere notevole importanza i fenomeni di *tuning.*

Normal faults and their hanging wall geometry



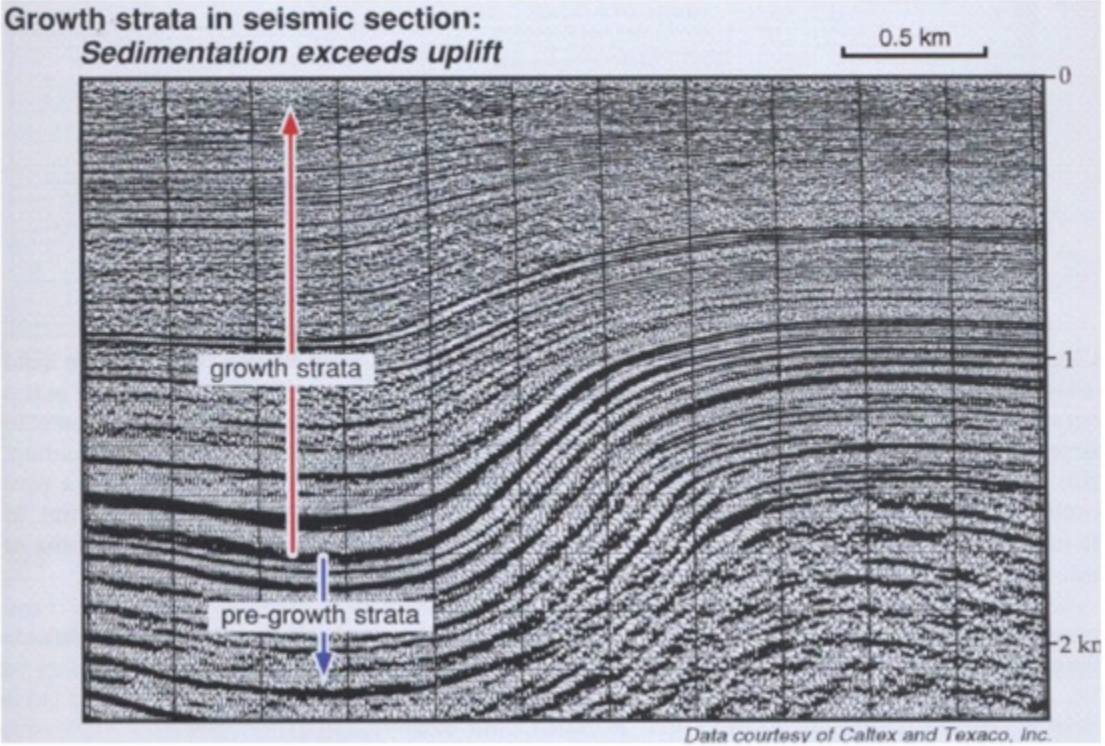


A sn:cuneo sedimentario sintettonico nello Ionio occidentale, testimone di una deformazione a carattere distensivo

GROWTH o SYNTECTONIC STRATA

In regime compressivo i *growth strata* si assottigliano verso l'alto strutturale.

La variazione laterale di spessore denota la sedimentazione sintettonica.

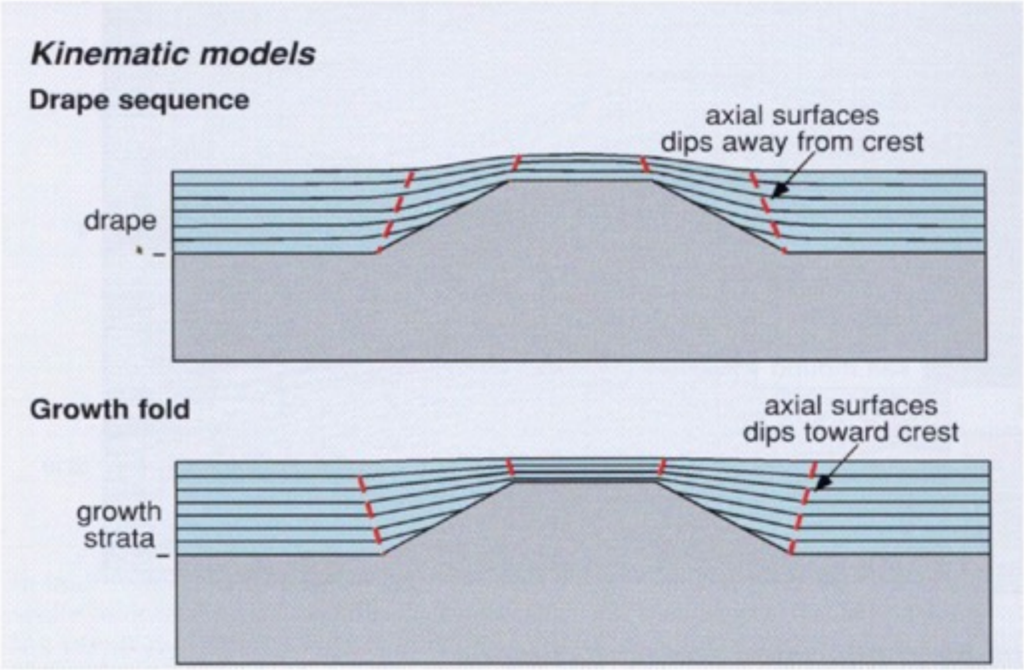


Data courtesy of Caltex and Texaco, Inc.

Analogia tra "*growth folding*" e "*drape folding*"

Una "*sedimentary drape sequence*" è un intervallo stratigrafico depostosi sopra una struttura dopo che la deformazione sia cessata. I sedimenti possono essere leggermente inclinati sia per deposizione primaria che per compattazione differenziata.

Talvolta tali sequenze possono assomigliare a dei *growth strata*, inducendo ad errori nella valutazione della datazione della deformazione.



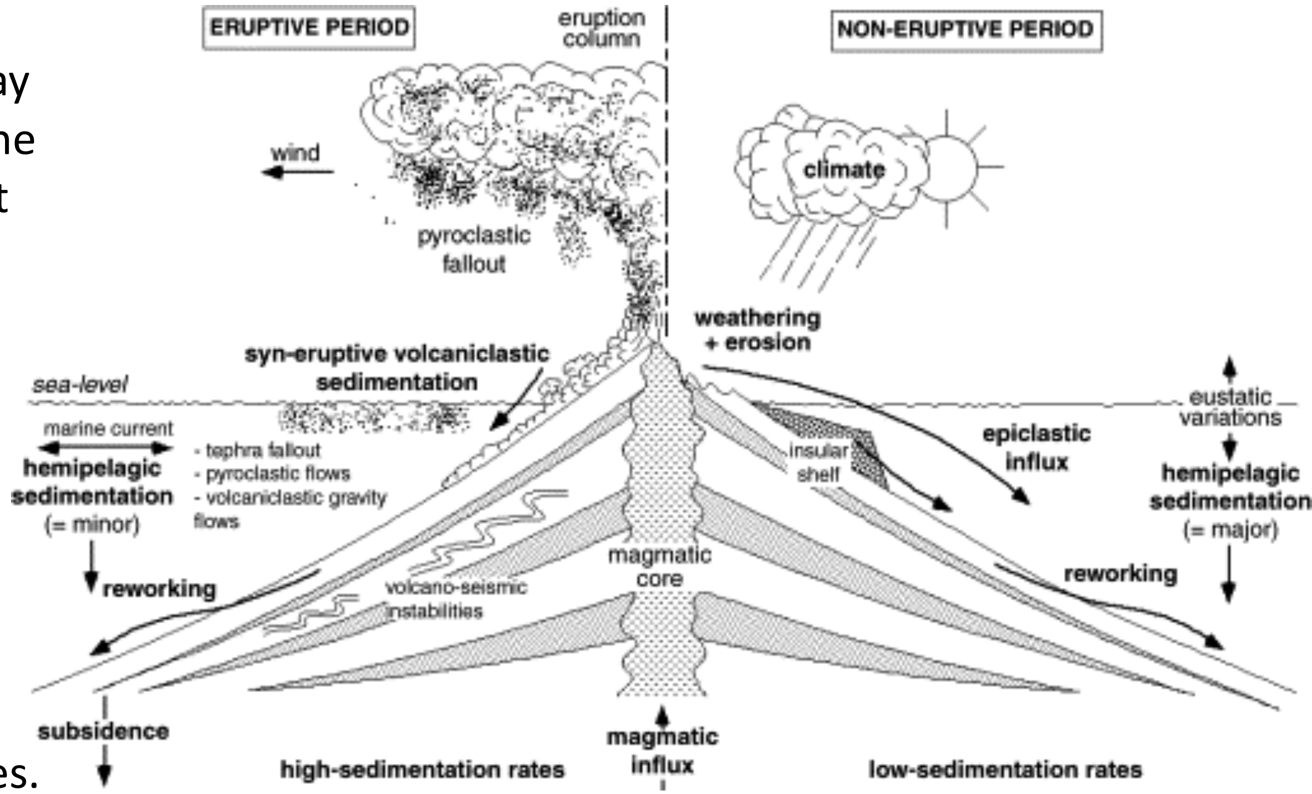
Anche se non sempre facili da distinguere tra loro, spesso gli assetti stratigrafici specifici permettono una corretta interpretazione: si notino le diverse vergenze delle superfici assiali.

volcaniclastic deposits

volcaniclastic deposits

Facies Model, Walker and James, 1992

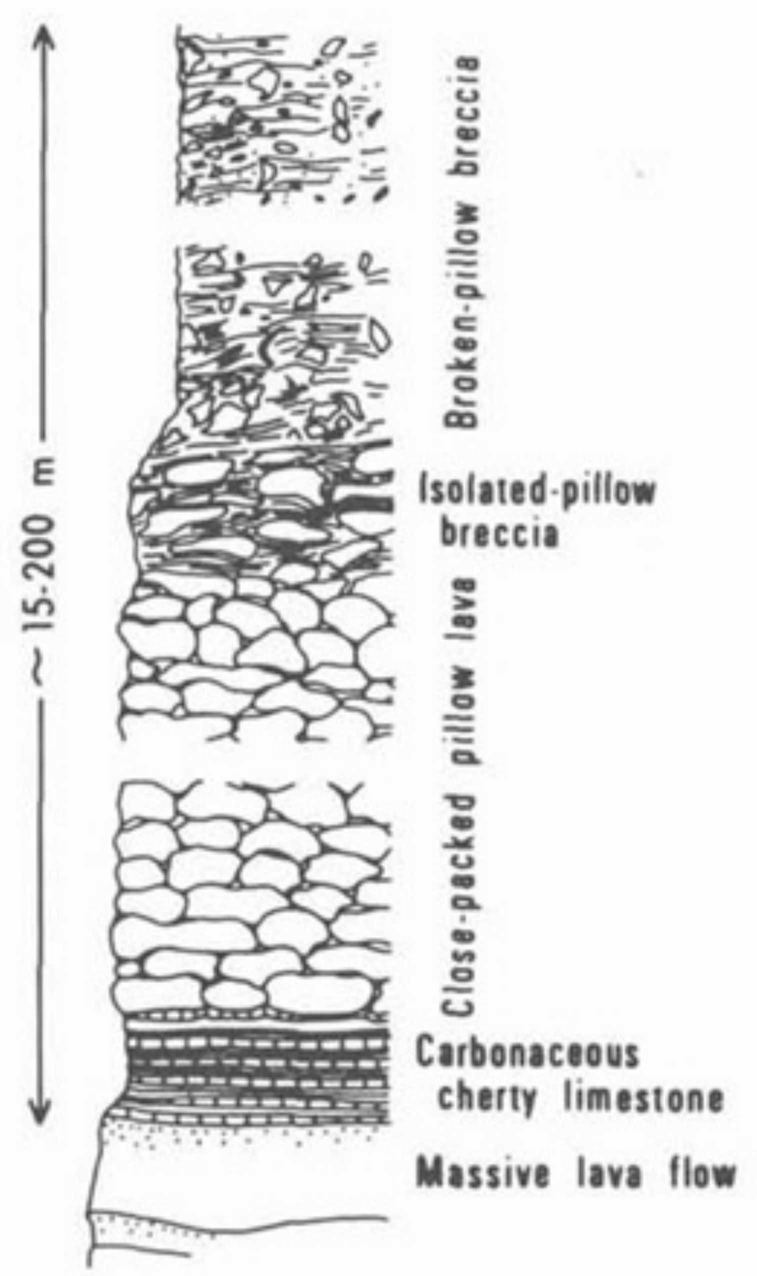
Oceanic volcanism at midocean ridges, seamounts, and oceanic islands is dominantly basaltic. Due to the lower volatile content of basaltic magmas, volcaniclastic rocks in these regions tend to be formed by fragmentation of lava flows rather than by explosive eruptions. Pillow breccias and hyalo- clastites are commonly formed. By contrast, island arc environments are dominantly basaltic to andesitic in composition. Explosive volcanoes com-monly produce subaerial and sub- aqueous pyroclastic fallout and flows. Remobilized volcaniclastic mass flows and turbidites may be deposited in the submarine environment. Continental rift environments are commonly associated with caldera structures where pyroclastic deposits are found. Basaltic cinder cones and tuff rings also occur here, and are commonly associated with lava flows. Thus, different tectonic environments have distinctive volcaniclastic facies.



Typical pillow breccia-hyalo- clastite sequence.

Triassic of Quadra Island, British Columbia. From Carlisle (1 963).

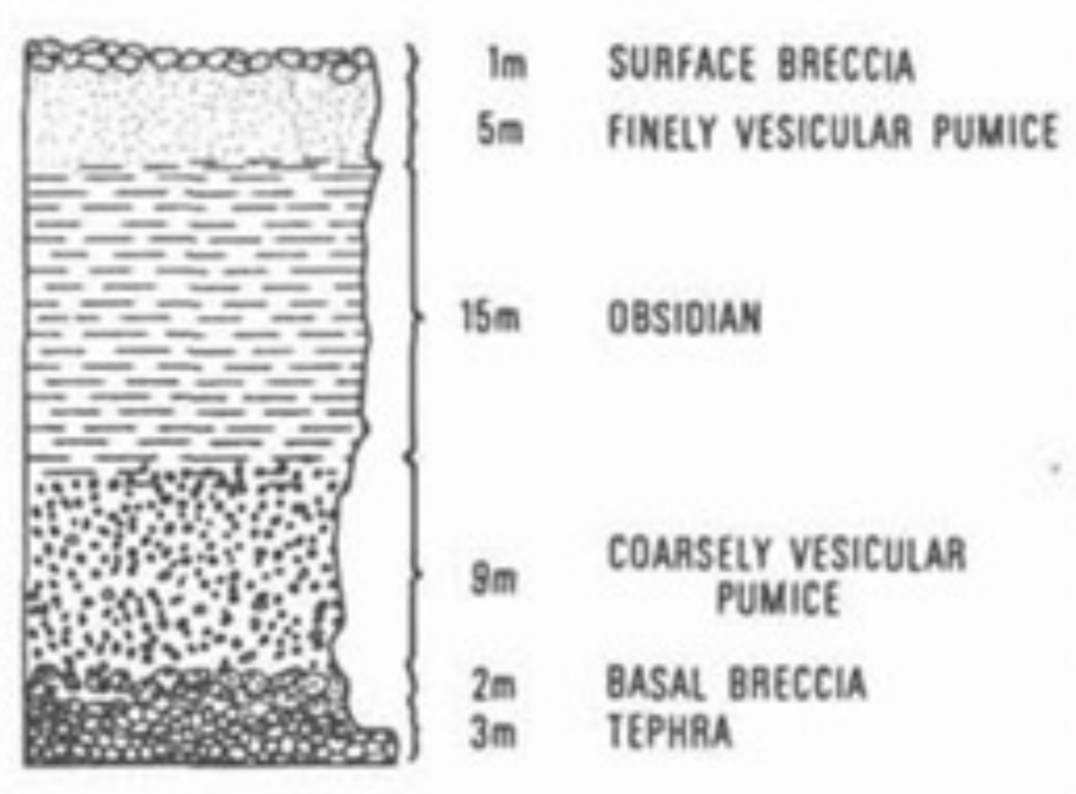
The pillowed (basaltic) lava grades upward into an isolated-pillow breccia that is overlain and transitional with a broken-pillow breccia. In this succession, clast size decreases from base to top. This grain size variation cannot properly be called graded bedding because there is no bedding to begin with. The clasts are formed in situ rather than being transported and deposited. The distinctive characteristics of this type of breccia are the monogenetic composition of the clasts and the transitional contact with the underlying lava.



Schematic cross section of rhyolitic obsidian flow. After Fink (1980), based also on studies from Lipari in the Eolian Islands

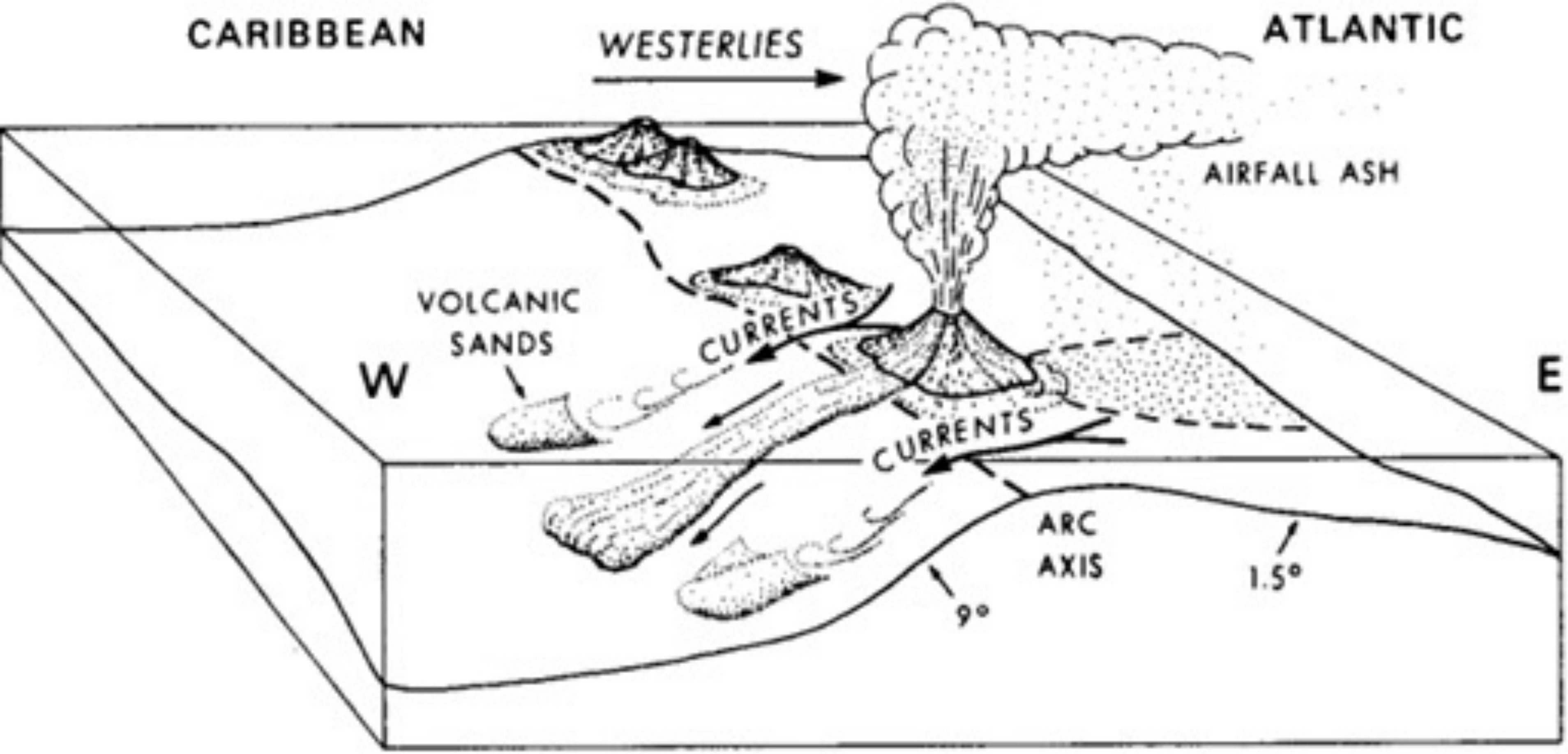
Subaerial lava flows of acid composition commonly have flow breccias which underlie and/or overlie the lavas.

The approximately 30 m-thick lava flow has a two m-thick breccia at the base and a one m-thick flow-top breccia. The texture and composition of the fragments are similar to those of the associated parent lava flow. Compared to flow breccias of basaltic composition, however, the breccias of acid flows are thinner; the transition with the parent lava is more abrupt, and may even be sharp; and the fragments are large and chaotically organized.



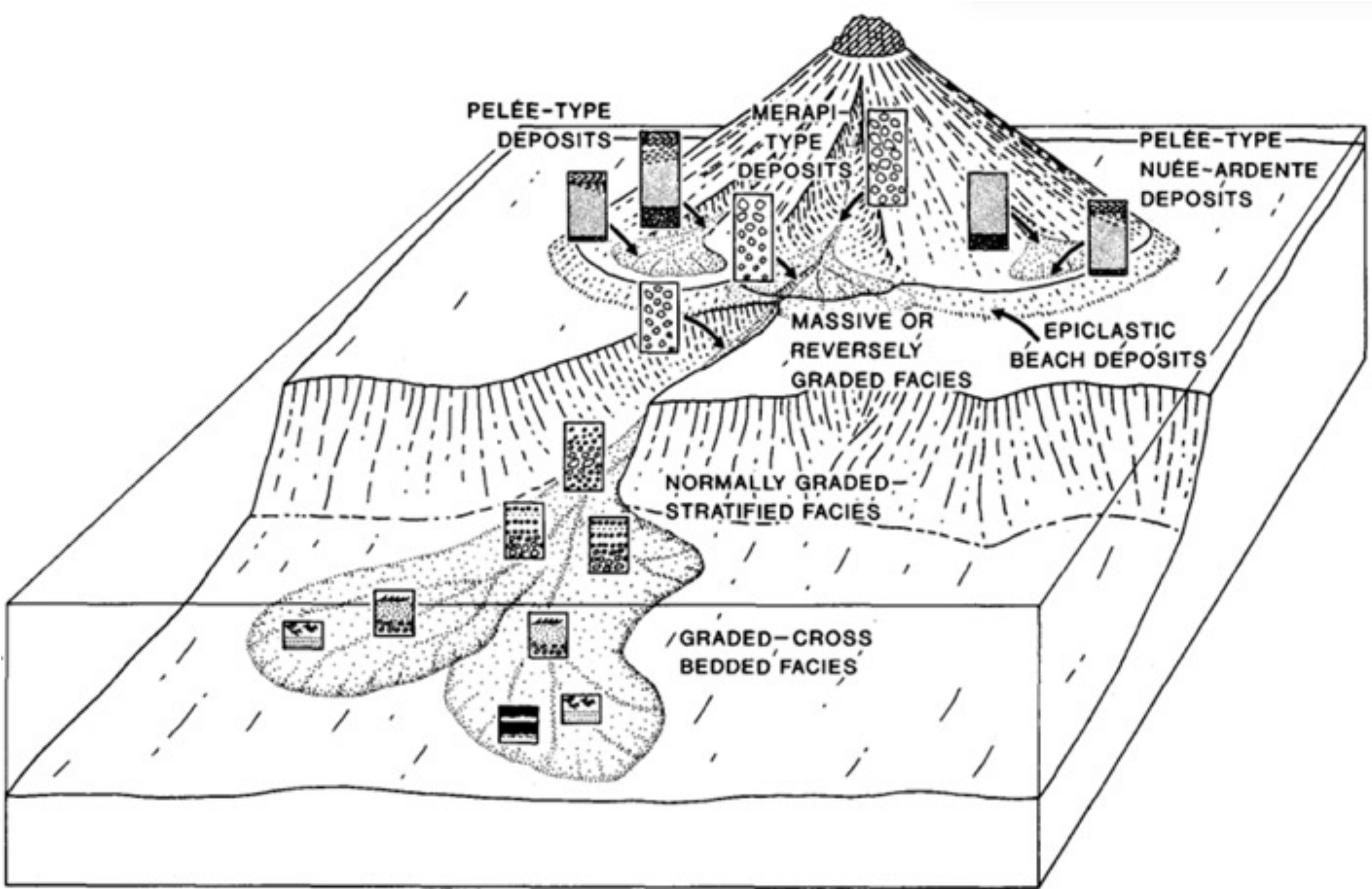
influence of the environment

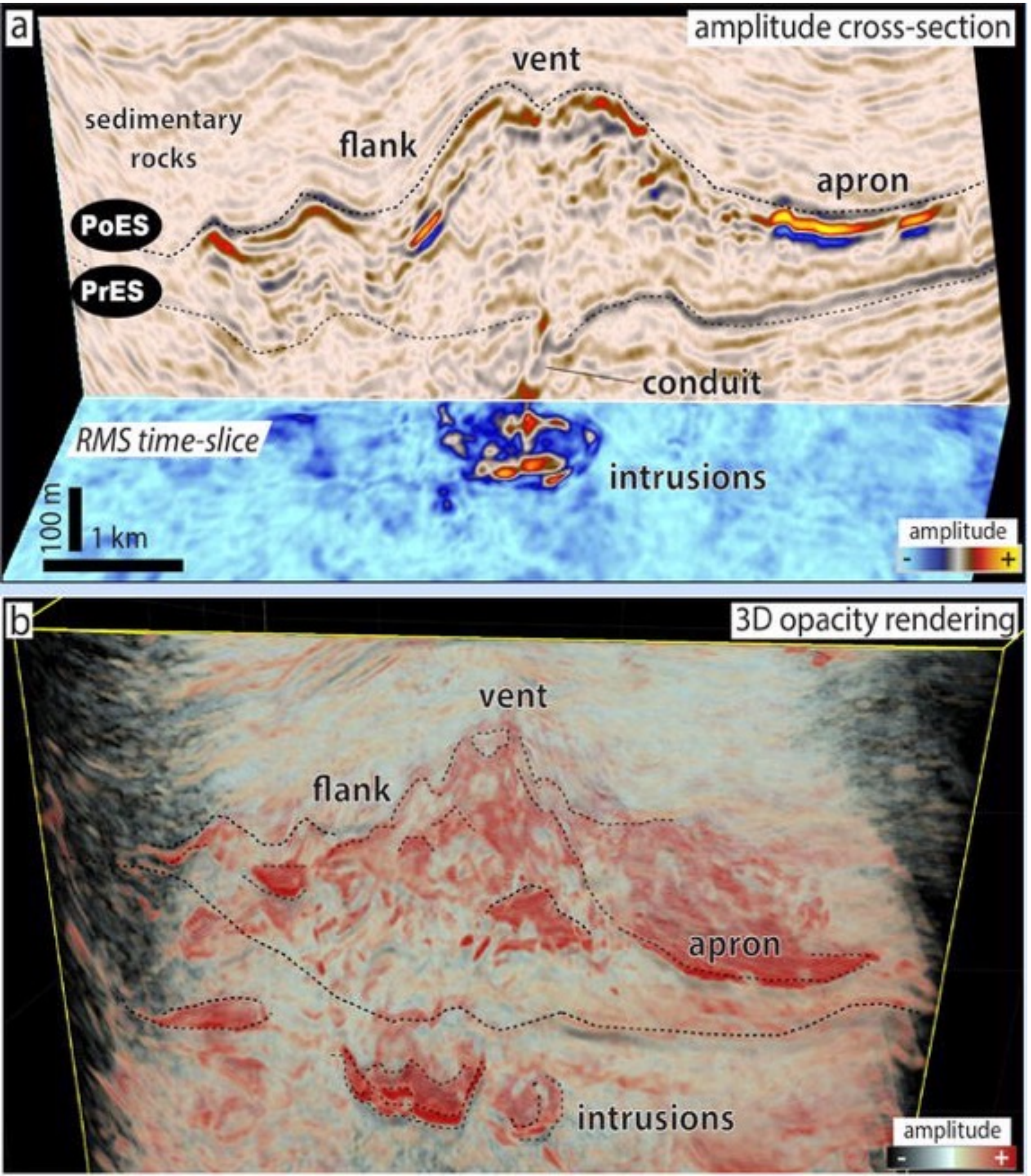
On the west side of the Lesser Antilles arc, nubes ardentes entering the Caribbean Sea descend on steep slopes and are transported into deep water where their characteristics are preserved, and they form various types of density-current deposits. Conversely, due to the prevailing winds, most of the fallout deposits are found on the Atlantic side of the arc.



Idealized vertical and lateral facies variations in subaerial and subaqueous environments for an explosive island volcano

In subaqueous deposits the grading of all fragments is generally normal, but in many subaerial deposits pumices and scoriae are re- versely graded. The primary structure sequences vary systematically down- flow in most of the deposits and depict changing flow conditions and grain sizes that are beingtransported.

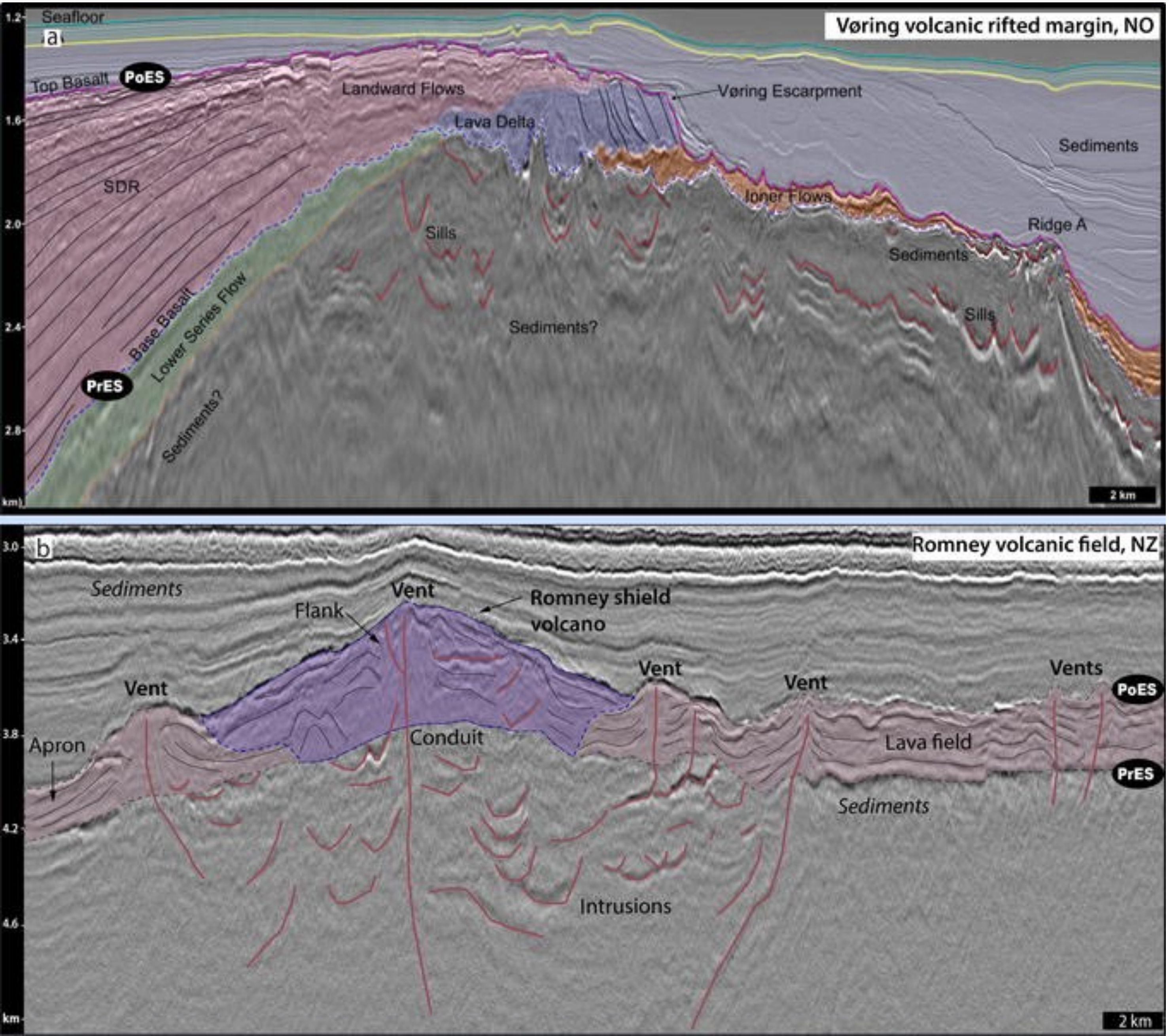




Seismic Geomorphology, Architecture and Stratigraphy of Volcanoes Buried in Sedimentary Basins

Bischoff et al., 2021. DOI: 10.5772/intechopen.95282

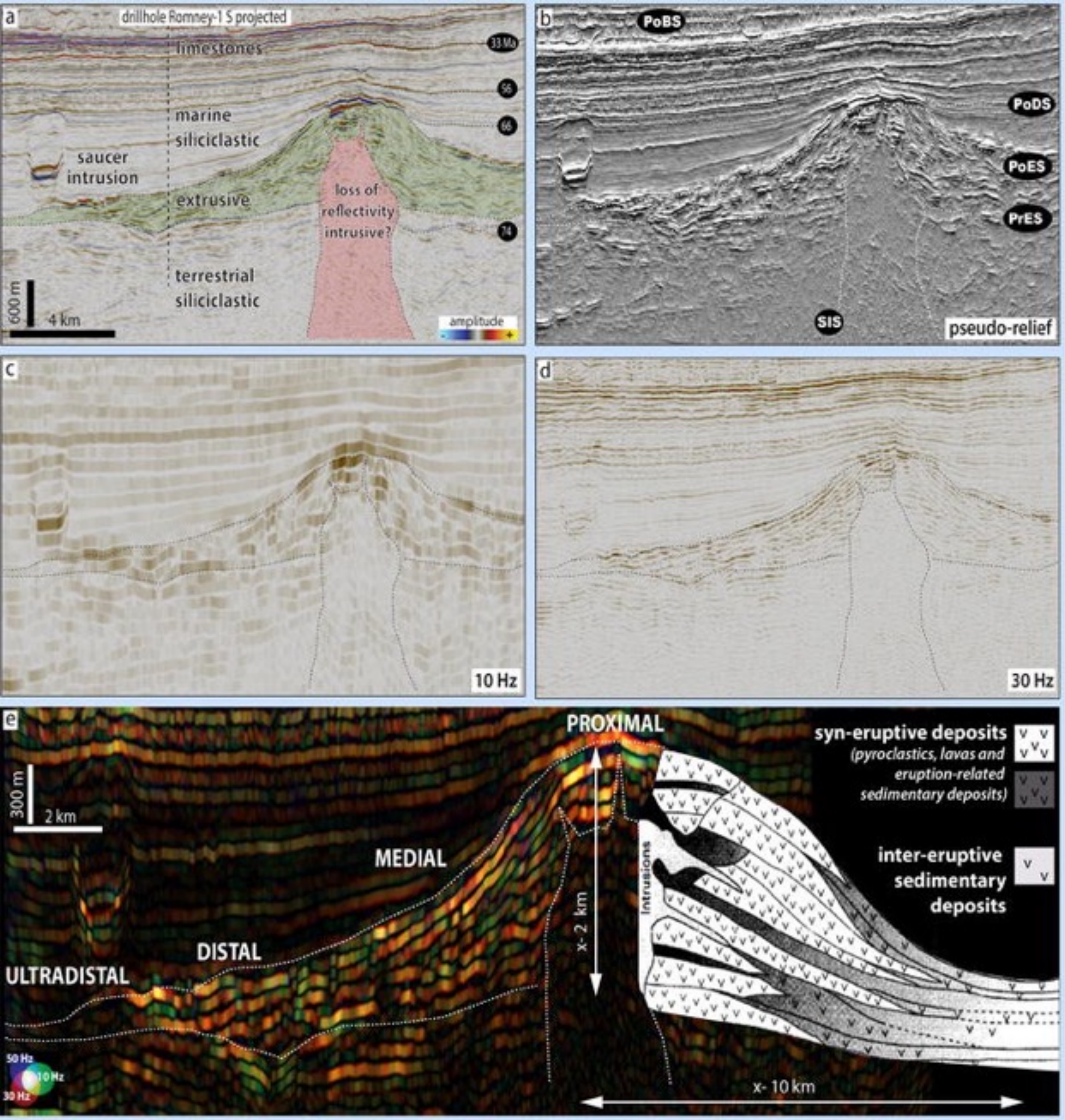
Seismic reflection visualisation of a small cone-shaped volcano buried in the Taranaki Basin, New Zealand. (a) amplitude display of a seismic profile coupled with time-slice RMS amplitude display of its plumbing system. (b) 3D opacity-rendered perspective view and its shallow (<200 m) plumbing system, in which the low-amplitudes are set as transparent. Note the spatial relationship between the saucer-shaped intrusion and the central vent of the volcano. PrES = pre-eruptive surface and PoES = post-eruptive surface.



Amplitude display of seismic reflection profiles across the Vøring volcanic rifted margin, offshore Norway (a) and the Romney volcanic field, offshore New Zealand (b).

Note that the internal and external configuration of seismic reflections determines the spatial relationship of distinctive seismic units, providing information about the succession of events that have formed these units.

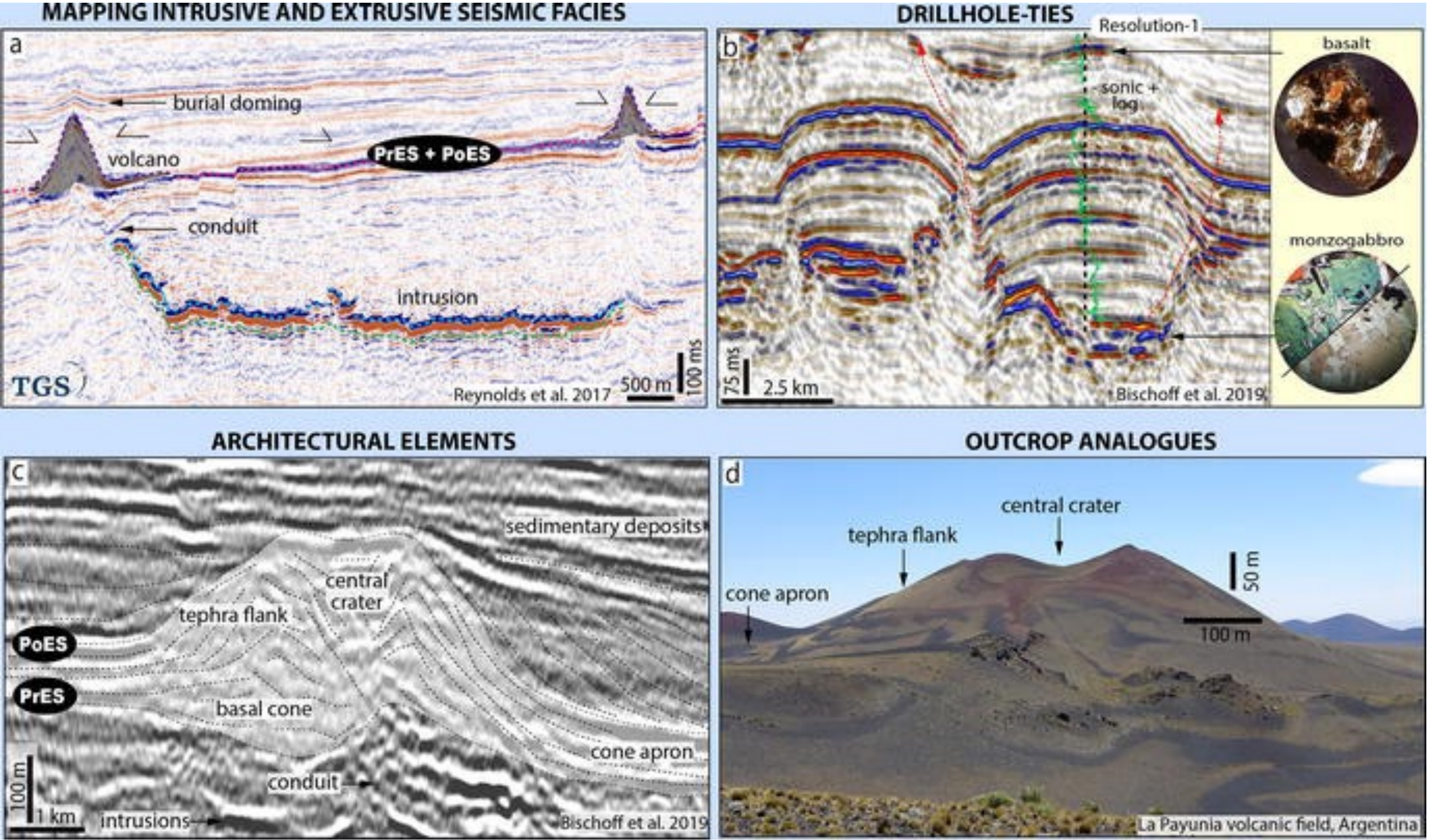
Vulcan composite volcano, offshore Deepwater Taranaki Basin, New Zealand



(a) Amplitude display of a seismic reflection profile, illustrating a variety of intrusive, extrusive and sedimentary seismic facies.
(b) Pseudo-relief and amplitude displays (c and d) seismic profiles that highligh the differences between igneous and sedimentary rocks.
(e) Spectral-decomposition display of a seismic reflection profile illustrating the idealised facies architecture of large polygenetic volcanoes.

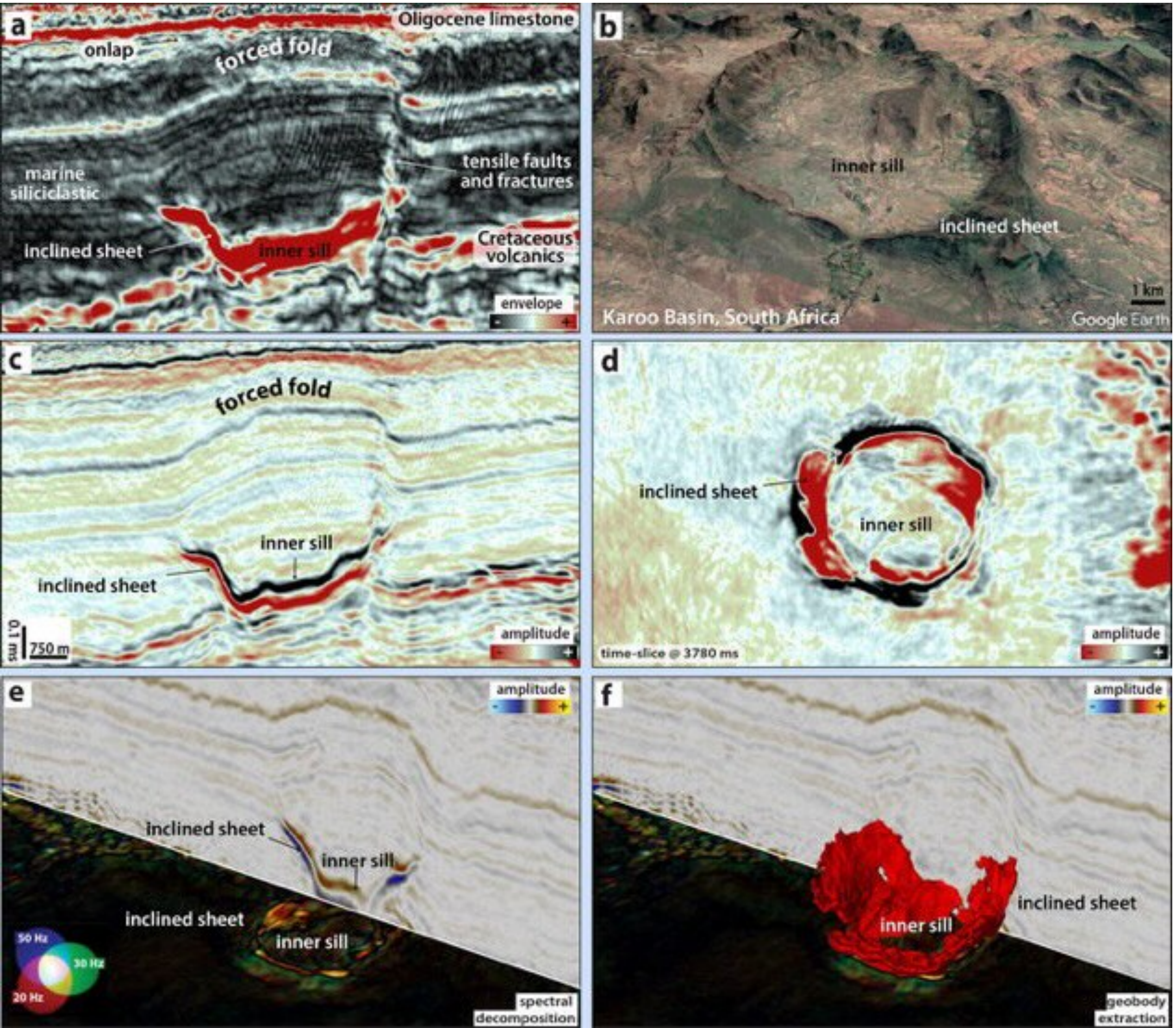
similar morphology of volcanoes in seismic imagery and modern outcropping analogues

(a) Amplitude display of typical saucer-shape sill and related vents above, Bight Basin, S. Australia. (b) 2D seismic section showing a monzogabbro intrusion and associated volcanogenic deposits, Canterbury Basin, New Zealand.



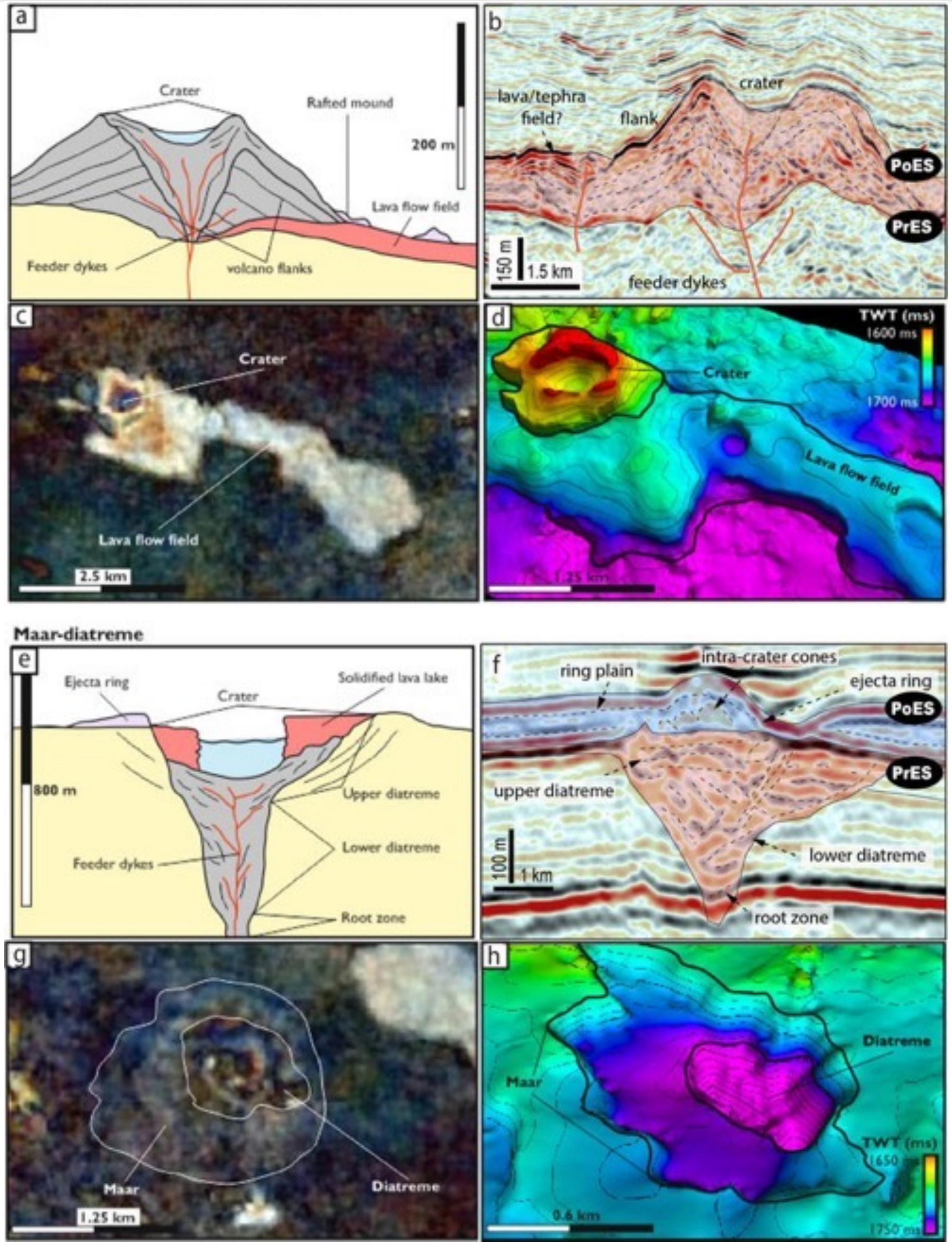
(c) 2D amplitude seismic section illustrating the architectural elements of a small mound-shaped volcano buried in the Canterbury Basin, New Zealand. (d) Photograph illustrating the main architectural elements of a Holocene cinder cone in the La Payunia volcanic field, Argentina.

Seismic and outcrop examples showing the typical geometry of saucer-shaped intrusions



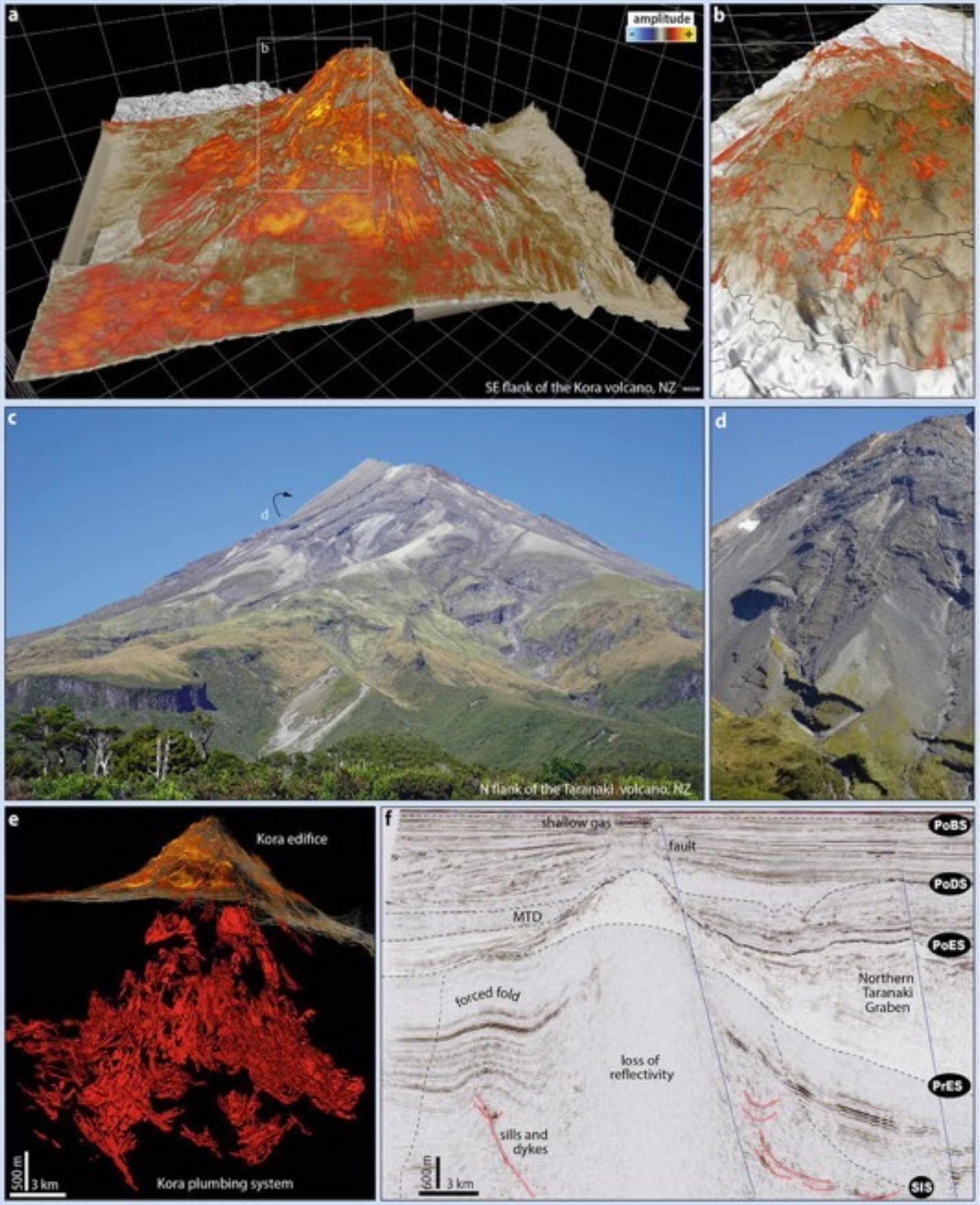
Displays of saucer hybrid intrusion comprising an inner sill parallel to the sedimentary strata, and peripheral inclined sheets cross-cutting the host strata, Deepwater Taranaki Basin, New Zealand: Envelope (a), amplitude (c), plain view (d), composite 3D perspective of an amplitude section and a time-slice of a spectrally decomposed seismic cube (e), extracted seismic geobody (f). (b) Saucer-intrusion emplaced in sedimentary strata of the Karoo Basin, South Africa.

small-volume cones and craters with associated lava flow



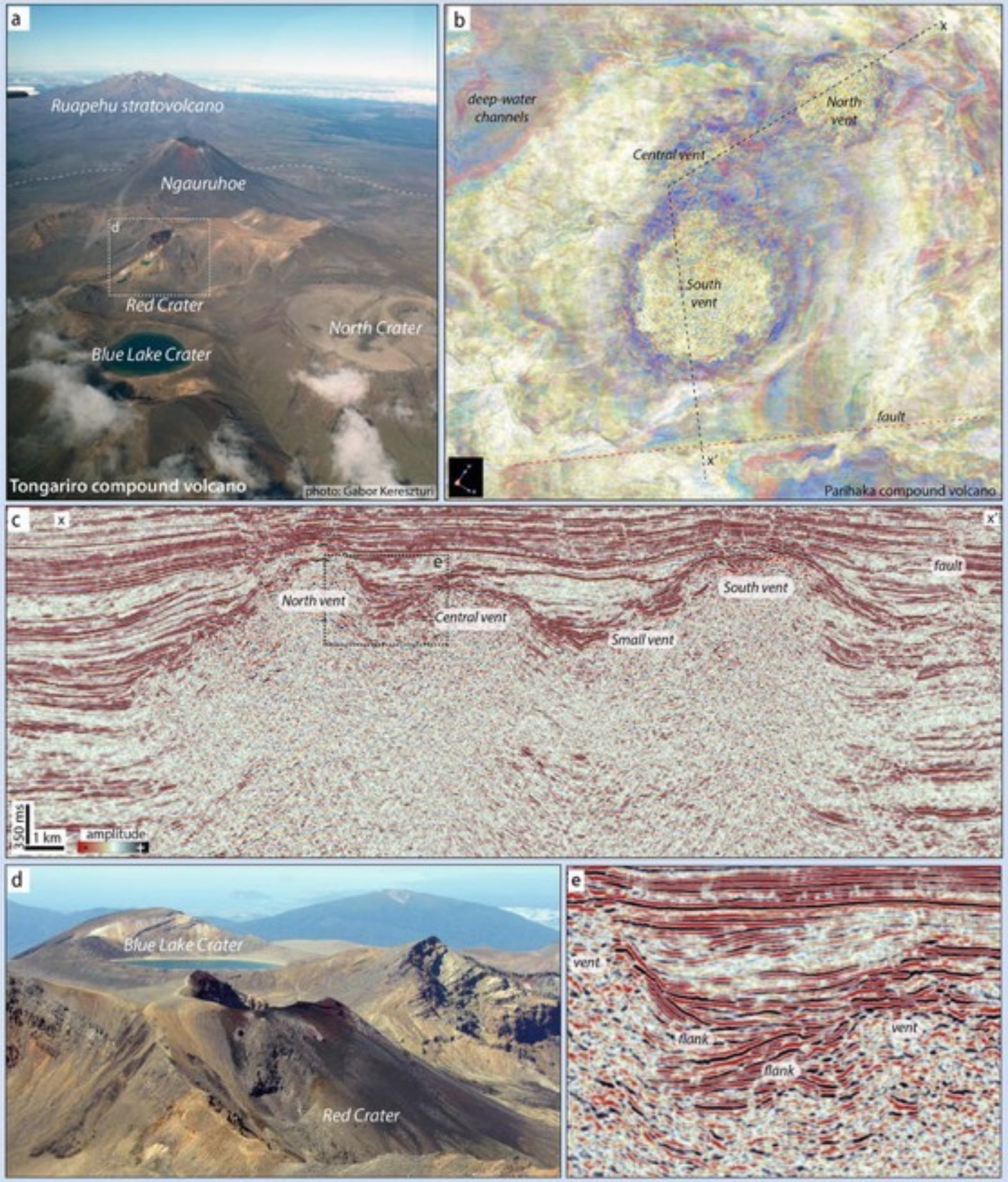
(a) Schematic cross-section. (b) Seismic section offshore Taranaki Basin, New Zealand. (c) Plan view spectral decomposition and (d) Horizon mapping of the top surface of the cinder cone taken from the Winnie 3D survey, Eromanga Basin, Australia. (d) Schematic cross-section through a maar-diatreme. (f) A seismic line across a maar-diatreme volcano buried in the offshore Banks Peninsula, New Zealand. (g) Plan view and spectral decomposition and (h) oblique, TWT view of a maar-diatreme buried in the Eromanga Basin, Australia.

Seismic and outcrop examples of large (>5km^3) **composite volcanos** (single cone-shaped body with a central vent)



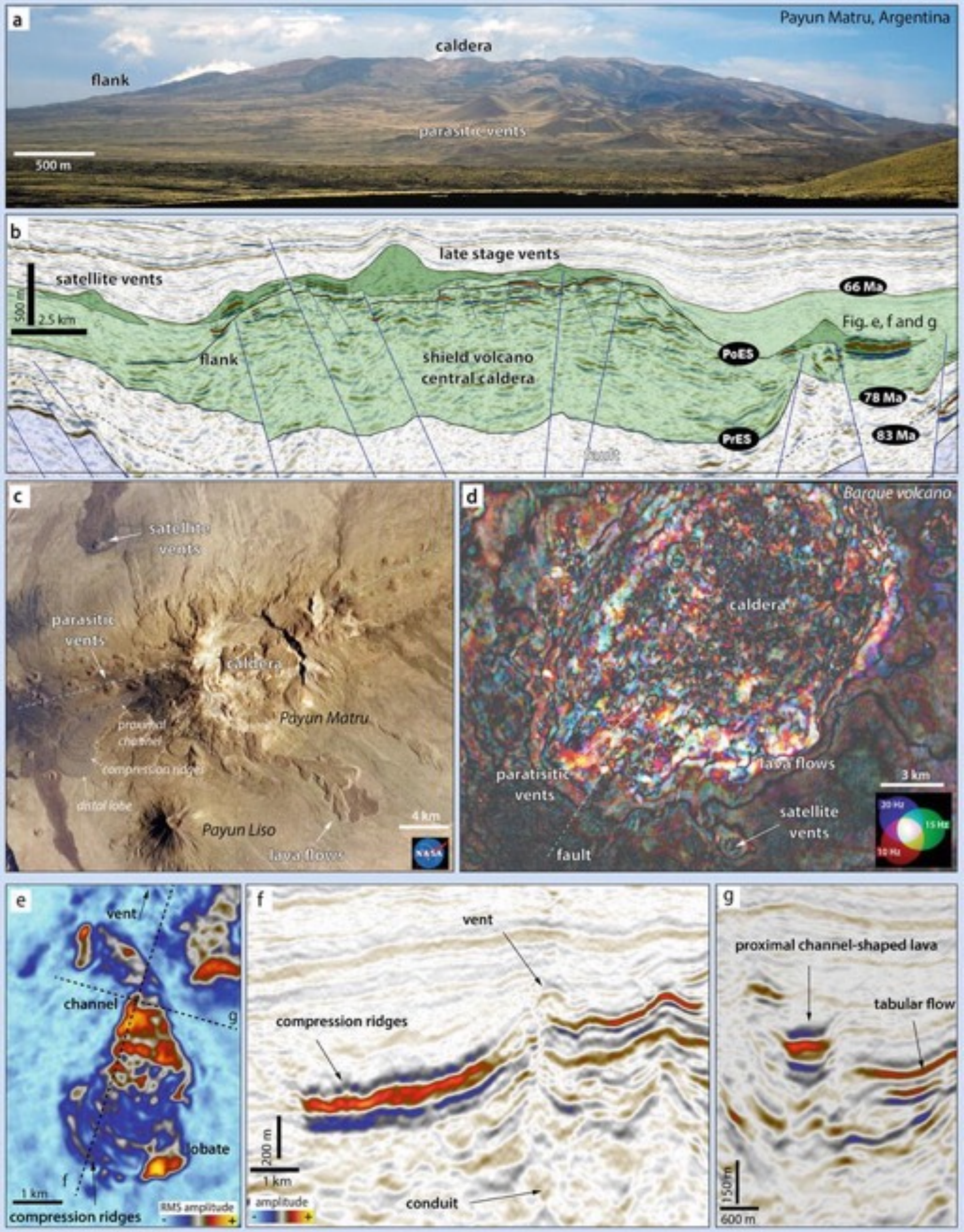
Kora volcano, New Zealand: (a and b) 3D perspective of a rendered amplitude seismic cube, (e) oblique 3D view with the edifice highlighted by an opacity rendered amplitude cube, and the plumbing system mapped as numerous interconnected geobodies, (f) amplitude display of a seismic section. (c and d) View of the north flank of the Taranaki volcano, New Zealand. Note in (b) the discontinuous and disrupted high-amplitude reflections (red), which likely reflect multiple depositional and erosional events, such as observed to form at the flanks of Taranaki volcano in (d).

Seismic and outcrop examples of large (>5km^3) compound volcanoes (several overlapping randomly distributed vents)



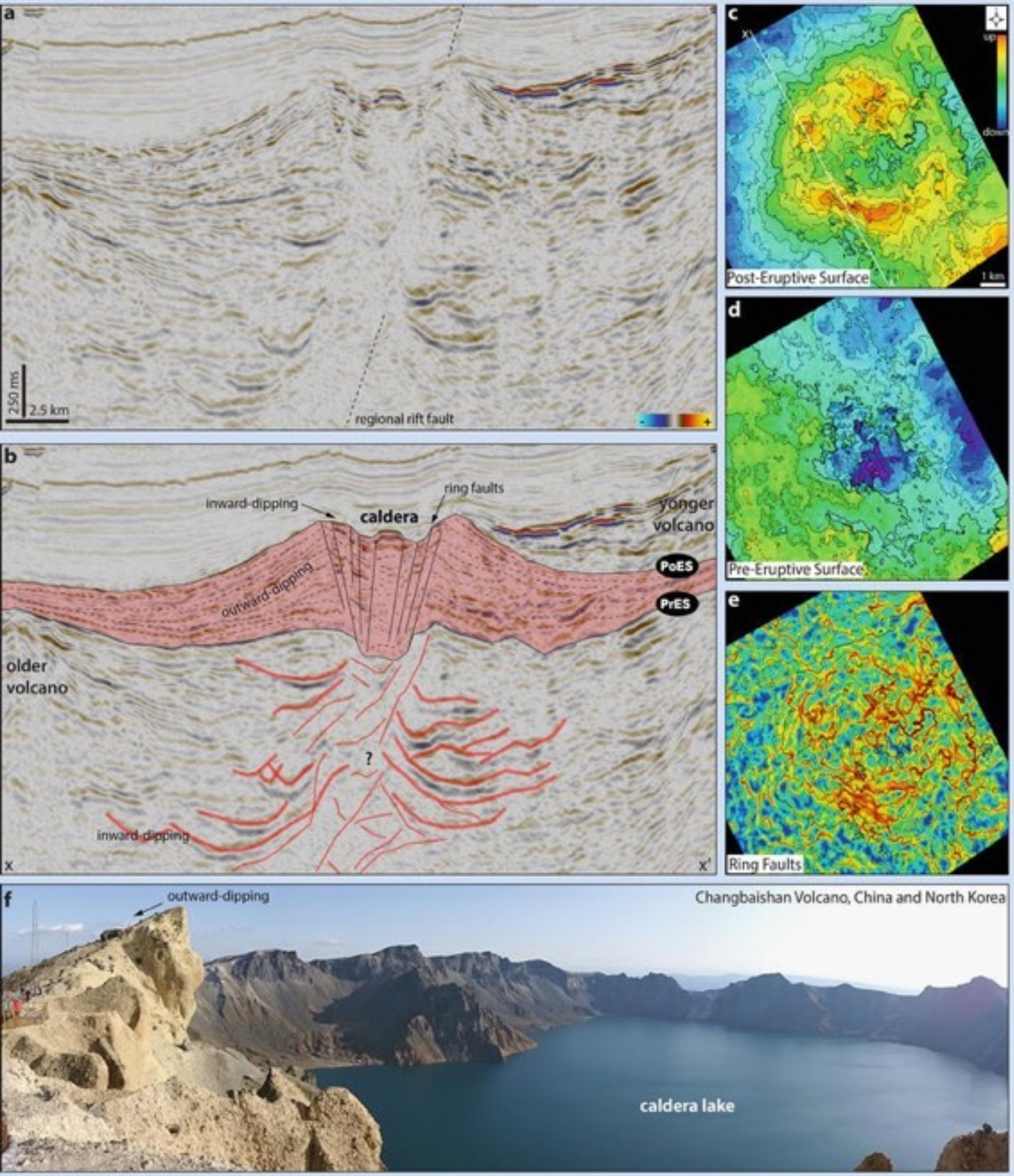
Tongariro compound volcano: (a) An aerial view with the Ruapehu stratovolcano in the background and (d) Photograph from the summit of the Ngauruhoe volcano showing a detailed view of the Red Crater, Blue Lake Crater and overlapping lavas of the Mangahouhounui Fm. (b) Plain view over a rendered amplitude seismic cube and (c) amplitude display (close-up in e) of a seismic section showing the location of three main vents within the Parihaka compound volcano, New Zealand.

Seismic and outcrop examples of shield volcanoes with a central caldera



Payun Matru Volcano, Argentina: (a) photograph of the northern flank and (c) aerial view. Barque volcano, offshore Canterbury Basin, New Zealand: (b) amplitude display of a seismic section and (d) plain view of a decomposed seismic cube. Lava flow of the Barque volcano: (e) plain view of an RMS seismic cube across and (f and g) amplitude display of a seismic section.

Seismic and outcrop examples of shield volcanoes with a central caldera



(a) Uninterpreted and (b) interpreted amplitude display of a seismic section across the Hades caldera, offshore Deepwater Taranaki Basin, New Zealand. (c) Post-eruptive, (d) pre-eruptive and (e) Pre-eruptive surface isochron horizon maps (the last applying an edge-detection attribute, which is enhancing a series of ring-shaped faults at the location of the caldera depression). (f) Photograph of the crater lake at the summit of the Changbaishan Volcano, Chinese and North Korean border.

Seismic and outcrop examples of volcanic rift margins and lava-fields

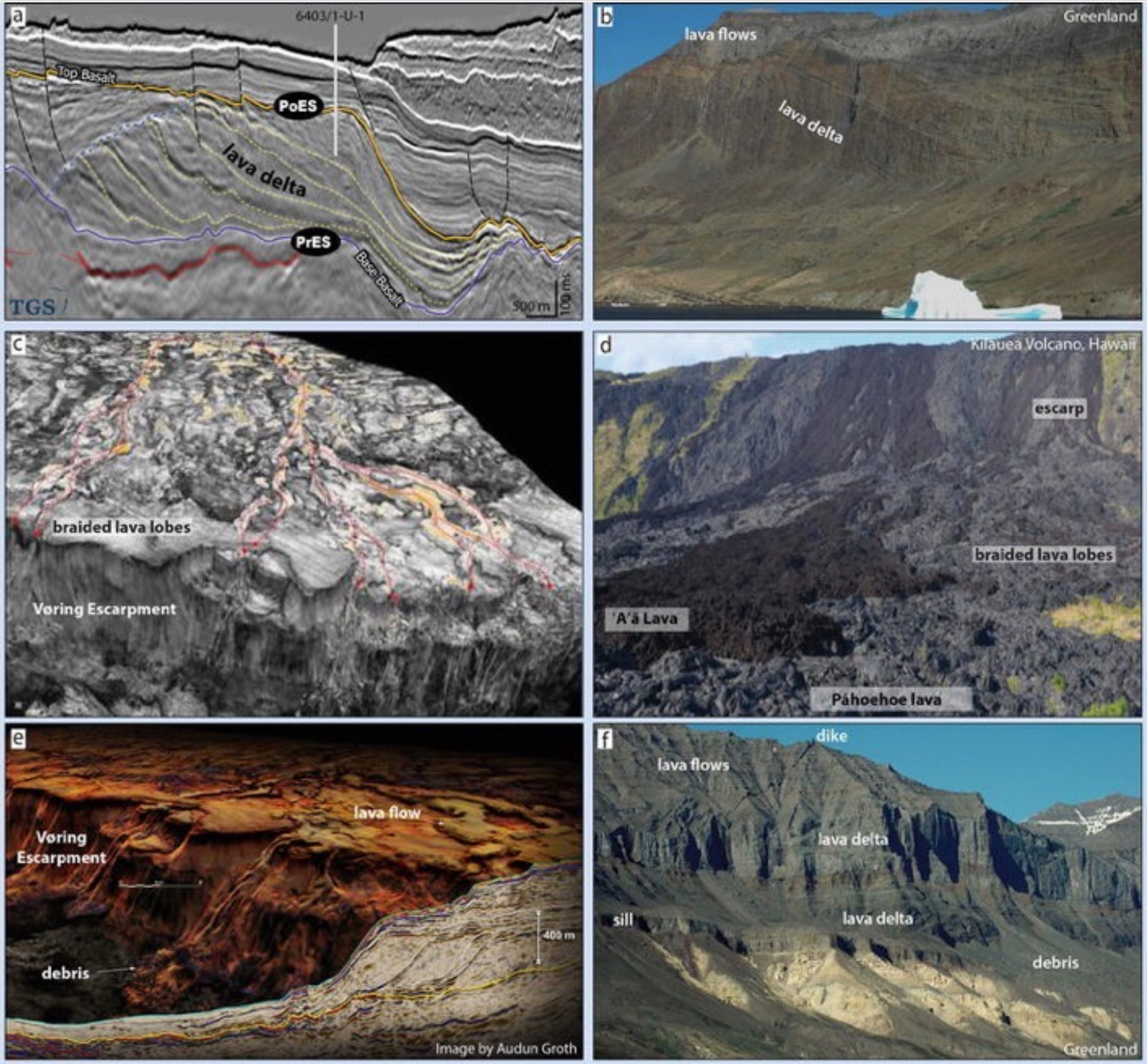
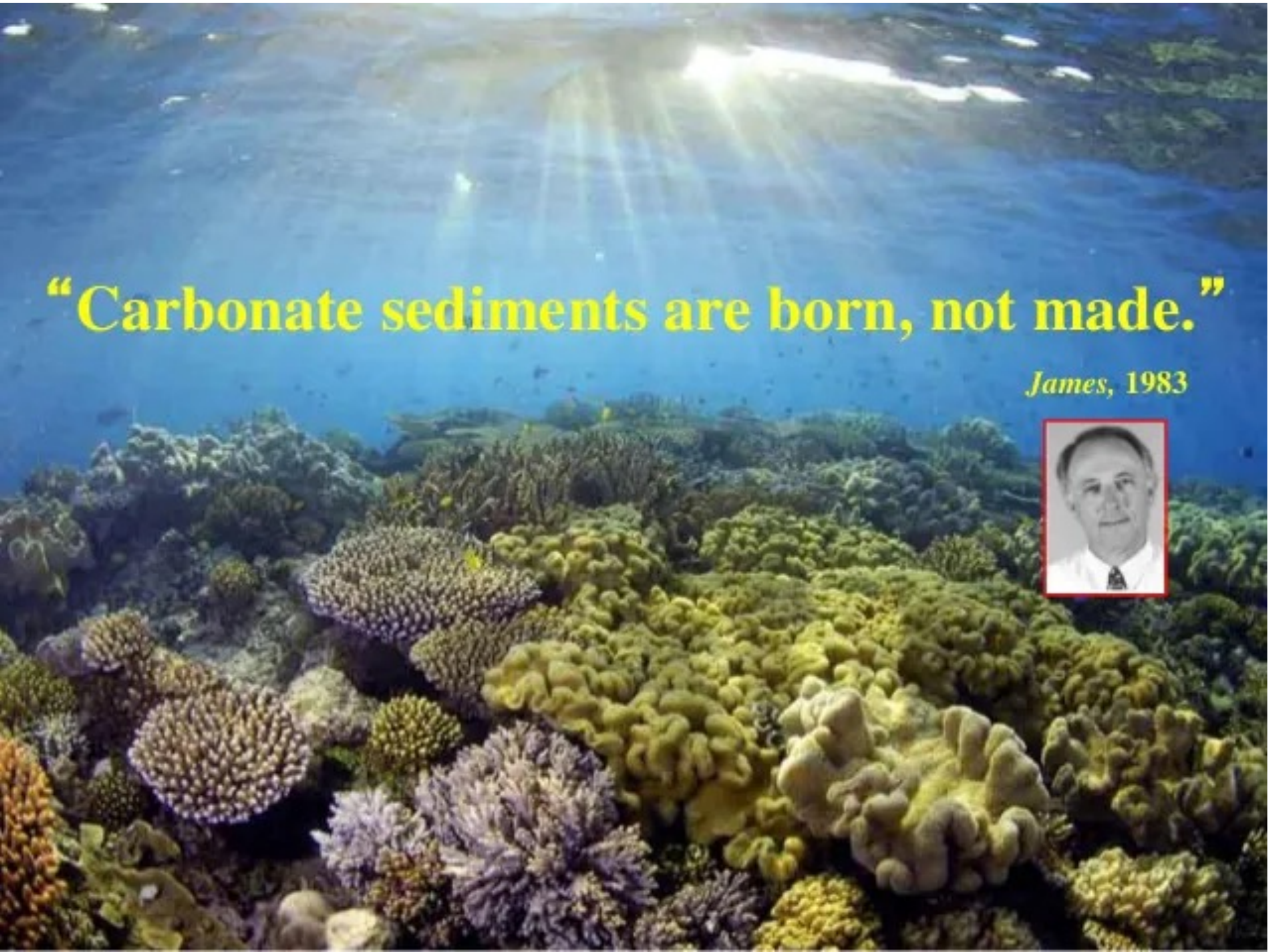


Image by Audun Groth

(a) amplitude display across the Kolga Lava Delta, offshore Norway. (b) prograding foresets of a lava delta in w. Greenland. (e) perspective view of the Vøring Escarpment, offshore Norway and (c) of its top-basalt horizon. (d) Lava field and escarpments of the Kilauea Volcano, Hawaii. (f) intrusive and extrusive bodies, lava field in w. Greenland.

Terrigenous clastic sediments are made primarily by the disintegration of parent rocks and are transported to the depositional environment. Once there, patterns of texture and fabric are impressed upon them by the hydraulic regime. The signatures of such facies are in their sedimentary structures and grain-size variations.



Carbonate and evaporite sediments are "born" as precipitates or skeletons within the depositional environment.

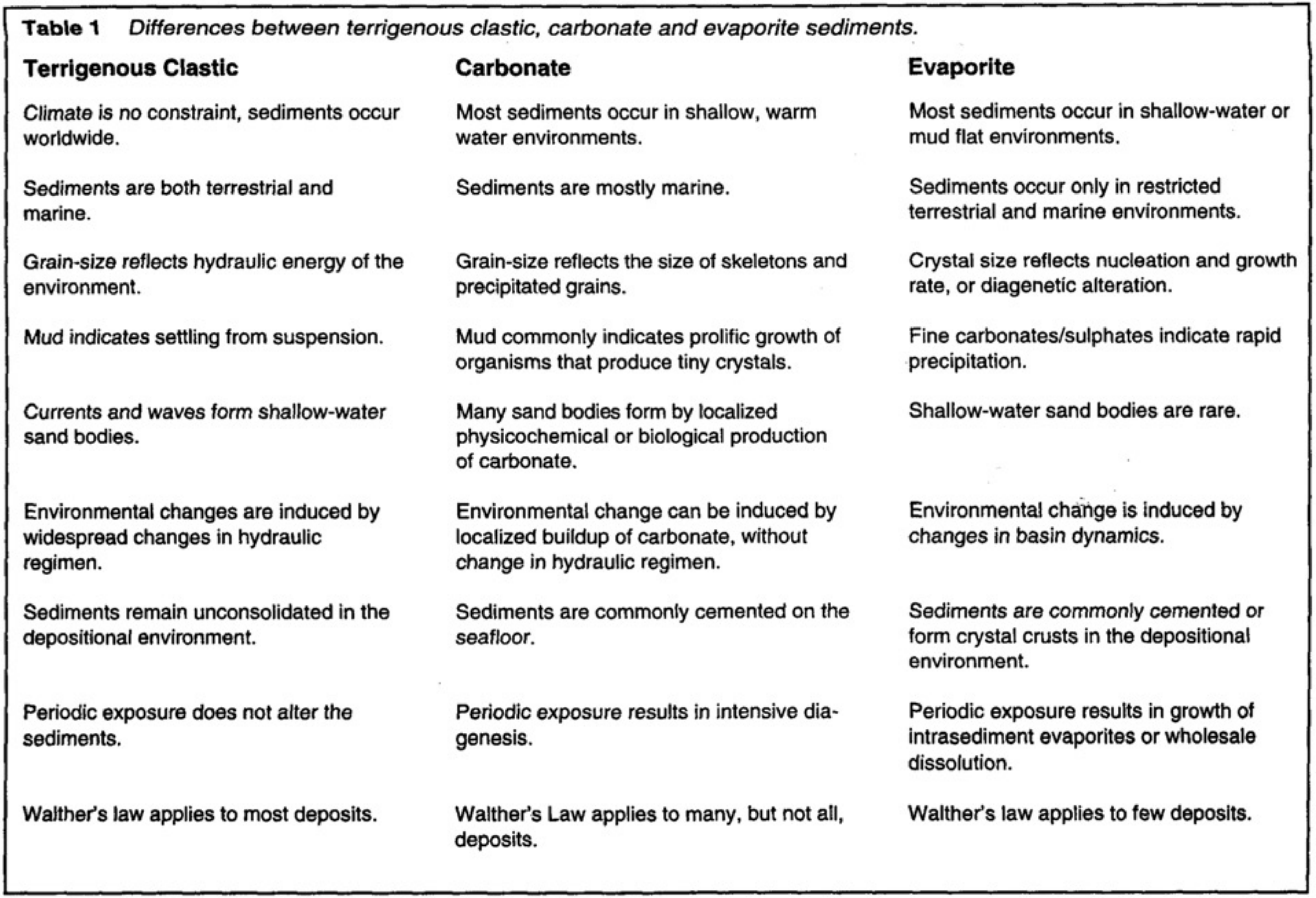
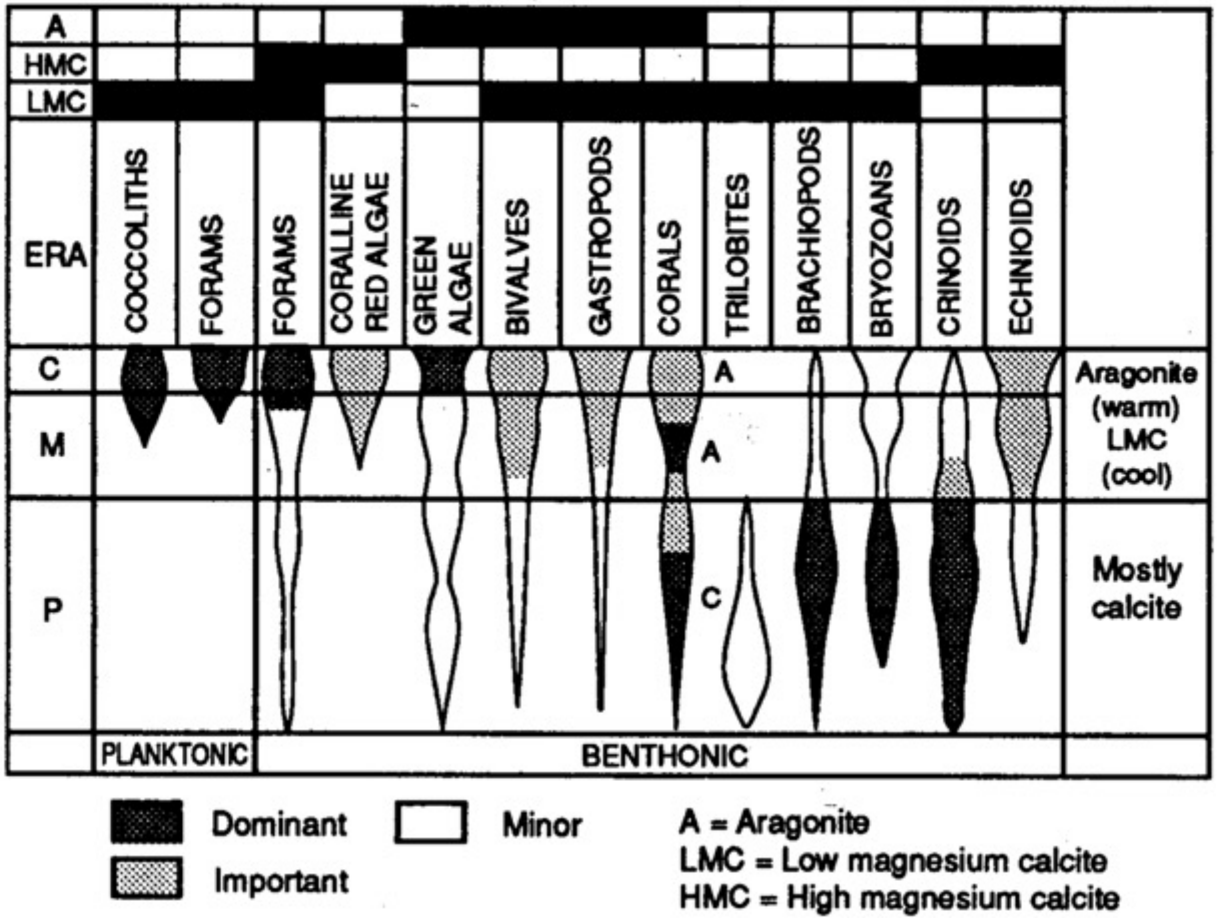


Table 1 *Differences between terrigenous clastic, carbonate and evaporite sediments.*

Terrigenous Clastic	Carbonate	Evaporite
Climate is no constraint, sediments occur worldwide.	Most sediments occur in shallow, warm water environments.	Most sediments occur in shallow-water or mud flat environments.
Sediments are both terrestrial and marine.	Sediments are mostly marine.	Sediments occur only in restricted terrestrial and marine environments.
Grain-size reflects hydraulic energy of the environment.	Grain-size reflects the size of skeletons and precipitated grains.	Crystal size reflects nucleation and growth rate, or diagenetic alteration.
Mud indicates settling from suspension.	Mud commonly indicates prolific growth of organisms that produce tiny crystals.	Fine carbonates/sulphates indicate rapid precipitation.
Currents and waves form shallow-water sand bodies.	Many sand bodies form by localized physicochemical or biological production of carbonate.	Shallow-water sand bodies are rare.
Environmental changes are induced by widespread changes in hydraulic regimen.	Environmental change can be induced by localized buildup of carbonate, without change in hydraulic regimen.	Environmental change is induced by changes in basin dynamics.
Sediments remain unconsolidated in the depositional environment.	Sediments are commonly cemented on the seafloor.	Sediments are commonly cemented or form crystal crusts in the depositional environment.
Periodic exposure does not alter the sediments.	Periodic exposure results in intensive diagenesis.	Periodic exposure results in growth of intrasediment evaporites or wholesale dissolution.
Walther's law applies to most deposits.	Walther's Law applies to many, but not all, deposits.	Walther's law applies to few deposits.

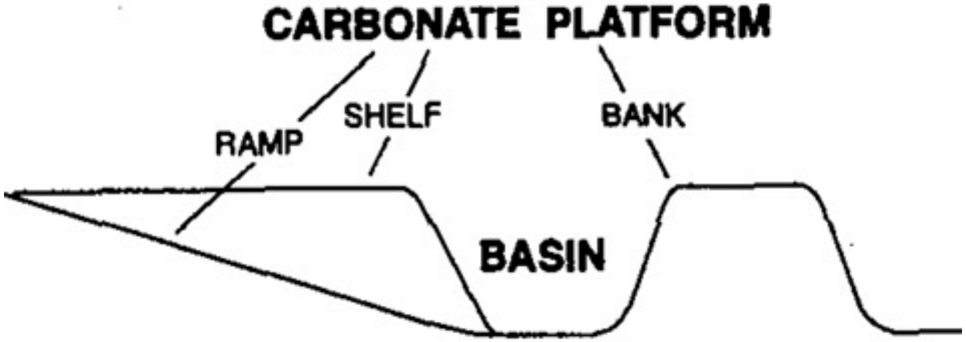
Organisms have changed with time

Dynamic stratigraphy demands that the input distilled from modern and ancient environments should be as fully understood as possible. Problems arise for some carbonates because the ecology of extinct rock-forming organisms may not be fully known. These difficulties are even more prevalent for evaporites because many have no Holocene analogue.



Distribution of main groups of animals and plants through the Paleozoic (P), Mesozoic (M), and Cenozoic (C). The fact that the different groups of animals and plants have skeletons formed of different mineralogies means that there are substantial differences between the Paleozoic and Mesozoic/ Cenozoic sediments and cool versus warm water sediments

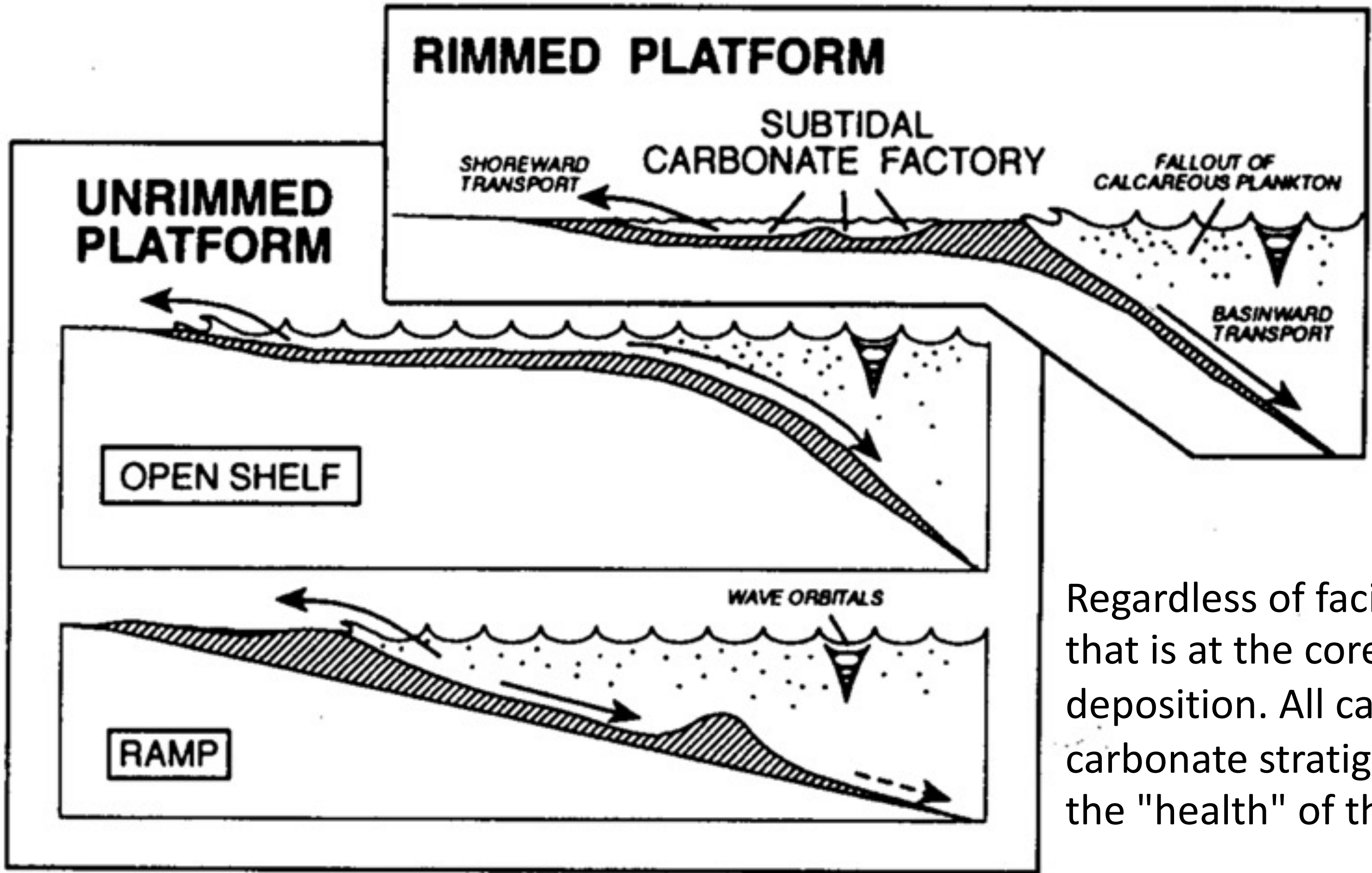
Terminology



- A carbonate platform is a large edifice formed by the accumulation of sediment in an area of subsidence.
- A carbonate bank is an isolated platform surrounded by deep ocean water and cut off from terrigenous clastic sediments.
- A carbonate atoll is a specific type of bank developed on a subsiding volcano.
- Atolls and banks can be so dominated by reefs that their geological expressions are termed reef complexes or carbonate buildups.
- A rimmed platform has a segmented to continuous rampart of reefs and/or lime sand shoals along the margin that absorbs ocean waves.
- An unrimmed or open platform, is one in which there is no barrier.
- A ramp is an unrimmed shelf that slopes gently basinward at angles of less than 1 degree.
- Evaporites are either confined to marginal shelves built on the shallowest parts of older ramps, or they form on the deepest parts, when the adjacent basin desiccates.
- Deep water environments are significant repositories for carbonate sediment and evaporite depositional basins suffered partial or complete desiccation during isolation from the sea.

The carbonate factory

The carbonate factory is the shallow, illuminated seafloor. Particles of all grain sizes are born here, either crystallizing as skeletons or precipitating directly out of seawater. Sediments mostly remain in place forming widespread "subtidal" deposits or reefs and mounds.



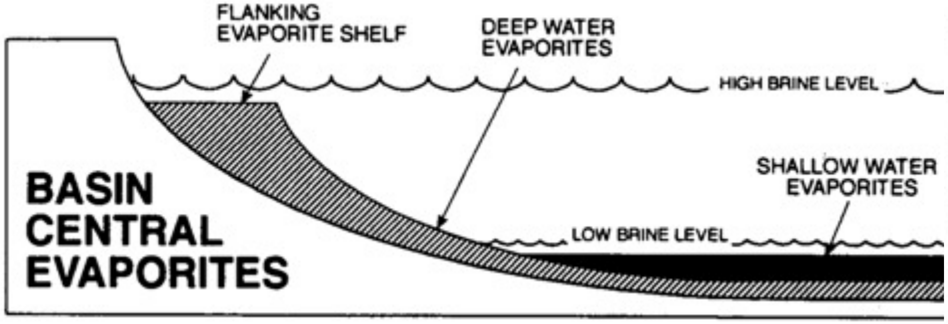
Fine sediment is also swept seaward where, together with sediment gravity flows originating at the margin, it accumulates on the slope and on adjacent basin margin.

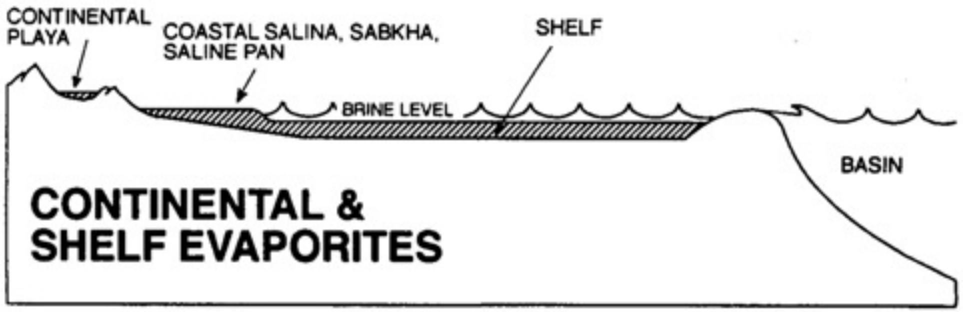
Regardless of facies, it is the factory that is at the core of carbonate deposition. All carbonate facies and carbonate stratigraphy depend on the "health" of this production unit.

The evaporite factory

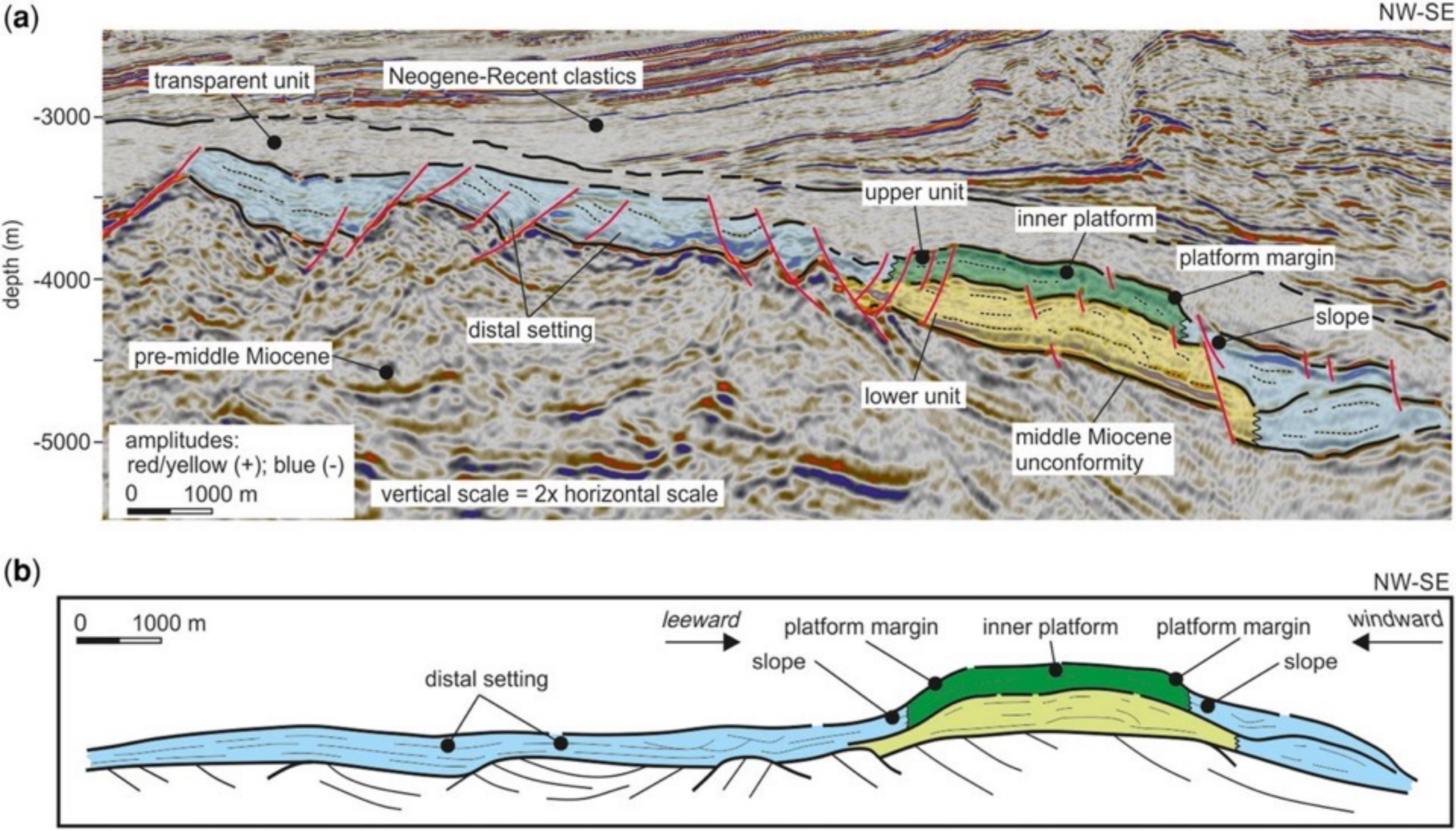
Evaporites can accumulate in both terrigenous clastic and carbonate settings, most rapidly in shallow water conditions. Export of sediment from this evaporite factory does occur, but it is substantially less than in carbonate settings because so much of the sediment is lithified initially, or quickly becomes cemented. Environments range from continental lakes to coastal salinas and sabkhas to shelf-wide complexes. Evaporites can also develop in shallow- and deep-water basin centres.

The original overall composition and mineralogy of an evaporite provide information about the type of water being evaporated, the brine temperature and salinity, and the degree of basin isolation. However: 1) most early models were chemical in nature and/or based upon few examples, 2) evaporites exposed in outcrop (uncommon) are much altered, and subsurface core is limited, 3) no areas of present-day evaporite deposition compare in size with many ancient basins, 4) changes in depositional conditions are rapid, profound and commonly result in superimposed facies, making original environmental recognition difficult, 5) characteristically, new environments destroy and replace older ones, rather than moving laterally, so that associated facies are unreliable when interpreting poorly preserved deposits, and 6) evaporites are susceptible to wholesale, postdepositional change that can remove all primary features.





shallow carbonate platforms



Berrocoso et al., 2021. Challenges of carbonate platform identification and characterization from seismic data in frontier exploration. Geological Society, London, Special Publications 509, 57-88

isolated carbonate buildups

Burgess et al, 2013. identification of isolated carbonate buildups from seismic reflection data AAPG 97

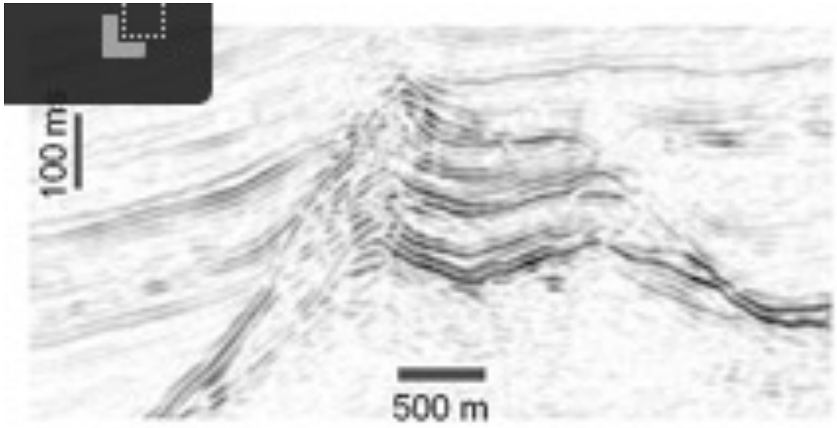
The term “buildup” = positive relief. “carbonate buildup” could include pinnacle reefs, carbonate mud mounds, attached carbonate platforms, and volcanoes.

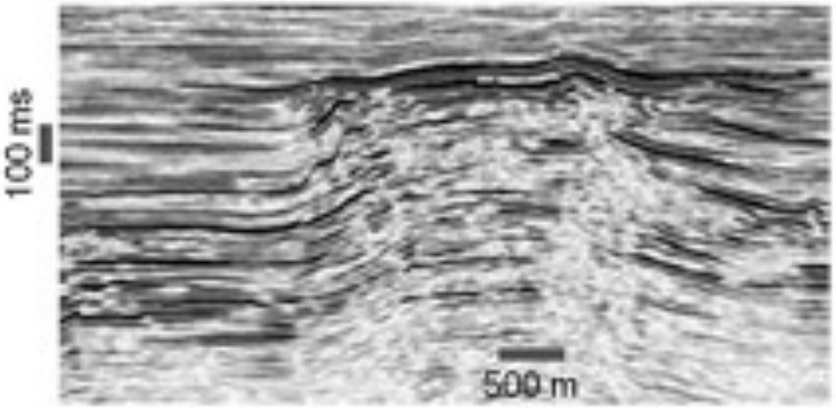
carbonate platform including several depositional environments. The reference to the several depositional elements highlights the important distinction between an isolated carbonate platform, a pinnacle reef, and a mud mound.

An isolated carbonate platform contains a series of different depositional elements (such as reefs, lagoons, tidal flats, and flanking slopes), may be several kilometers in length, and commonly contains strata with good reservoir properties.

A pinnacle reef is an ICB composed of just one reef and probably has a very small areal extent and, therefore, a small volume and so is of less interest to an explorer.

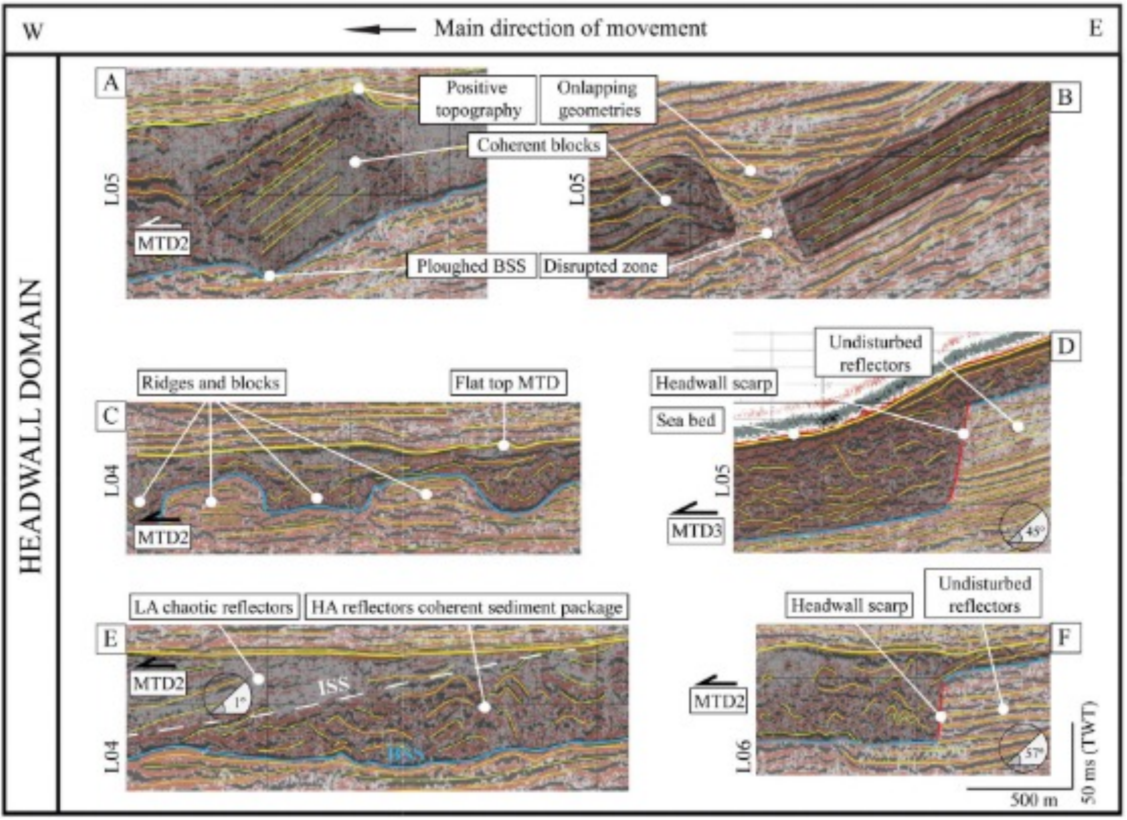
A mud mound is another type of ICB with quite different depositional elements that probably does not develop in shallow water and has potentially very different reservoir properties.

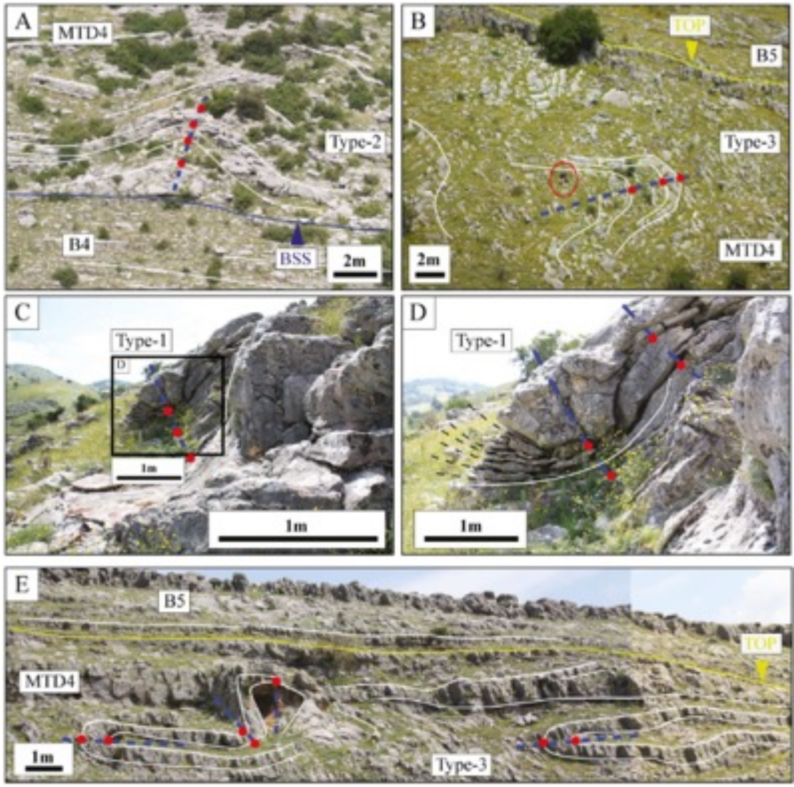




Carbonate slopes

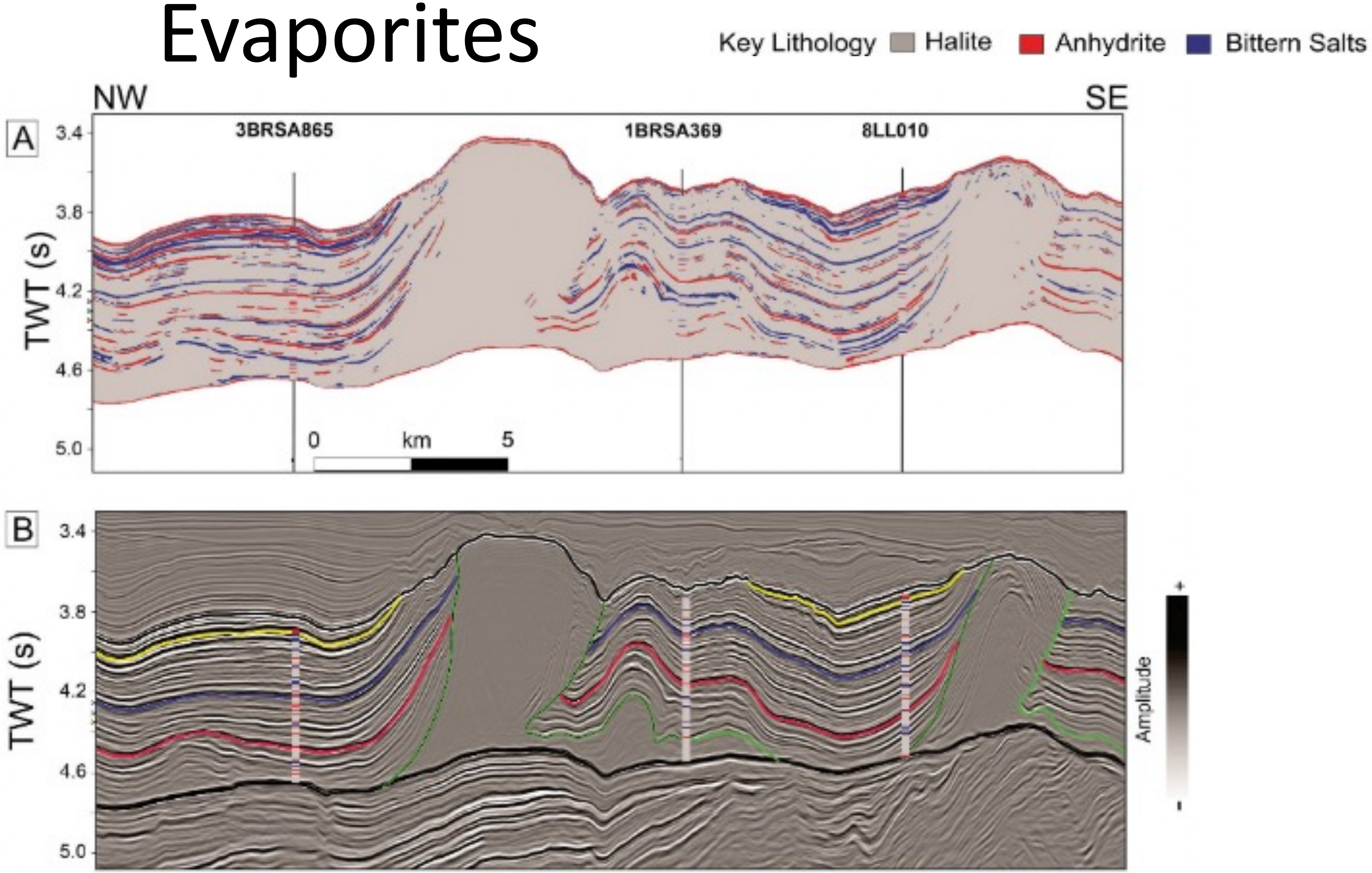
Mass-transport deposits (MTDs) cover a depositional continuum from slides to slumps, creeps and debrites, capturing a broad spectrum of synsedimentary deformation processes. MTDs are a common feature on the slopes surrounding large-scale carbonate platforms and hence constitute a significant part of the slope-to-basin depositional record.





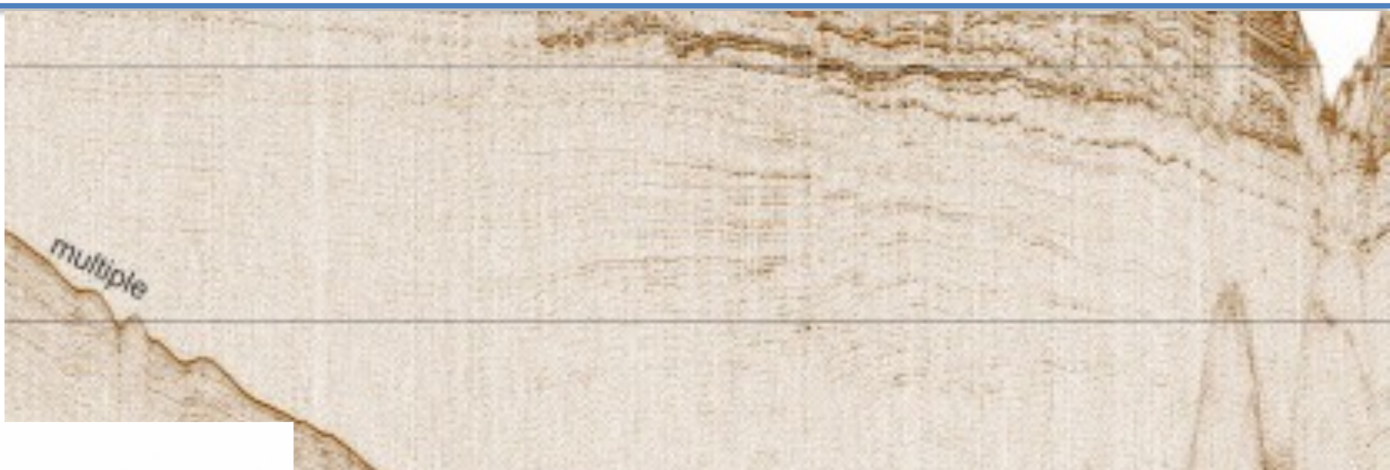
Le Goff et al., 2020. Carbonate slopes of Great Bahama Bank & Apulian Carbonate Platform. Marine Geology 427

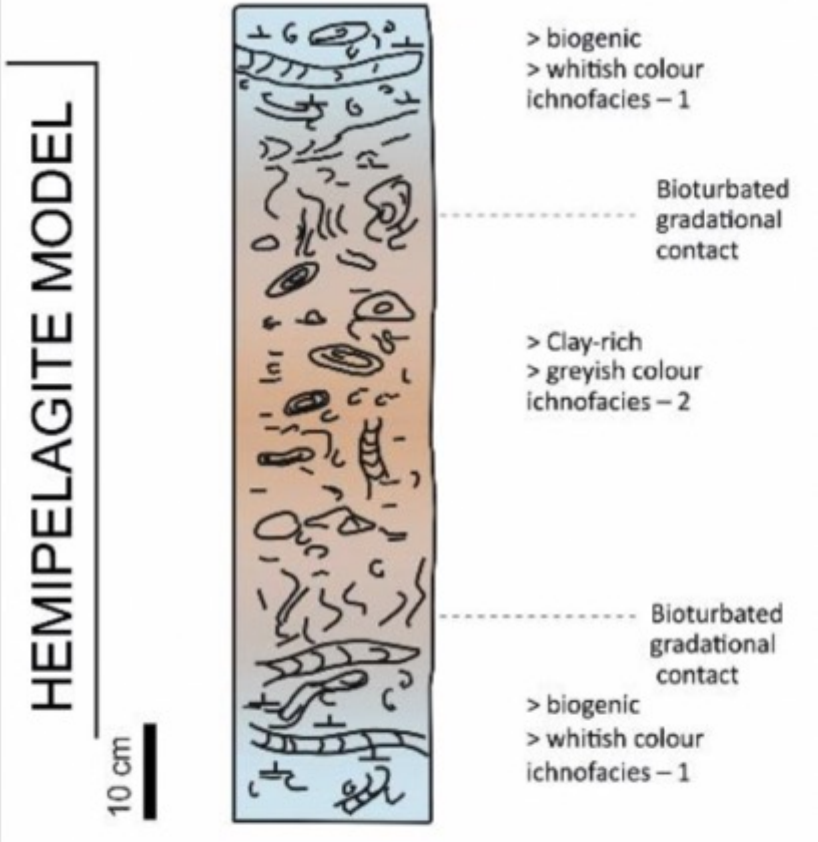
Evaporites



Teixeira et al. (2020), Quantitative seismic-stratigraphic interpretation of the evaporite sequence in the Santos Basin. Marine and Petroleum Geology 122

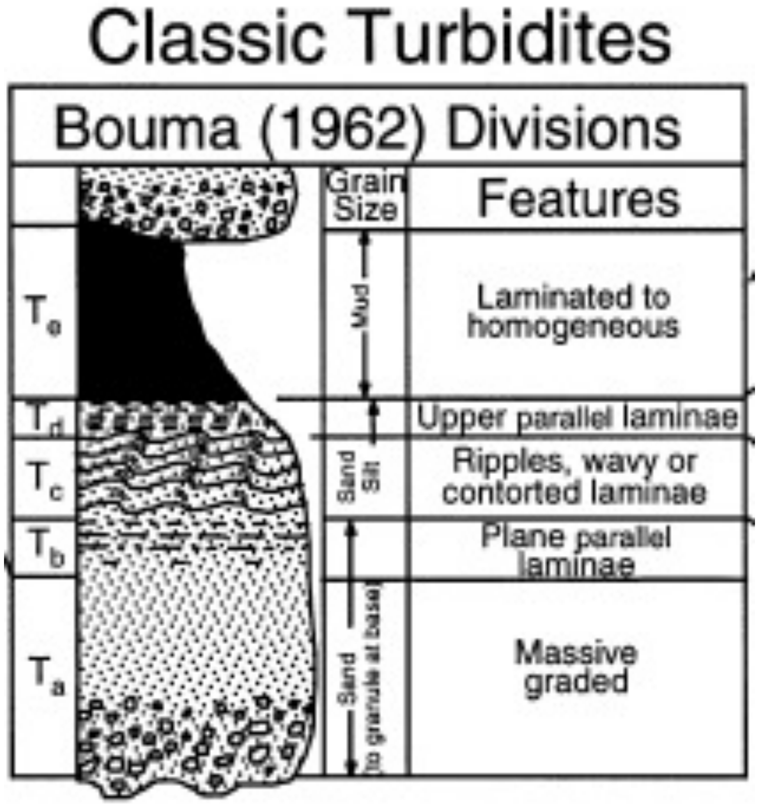
Depositional environments (synthesis)

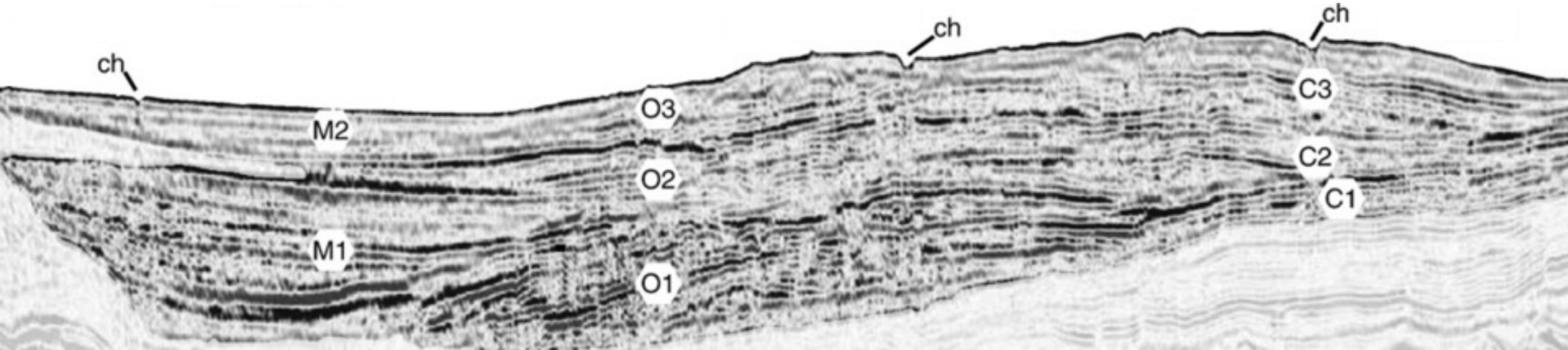




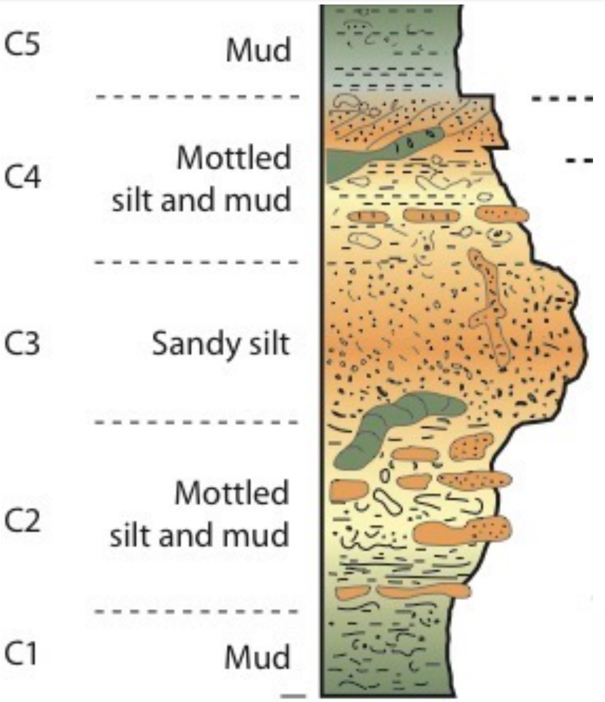
Abyssal plains

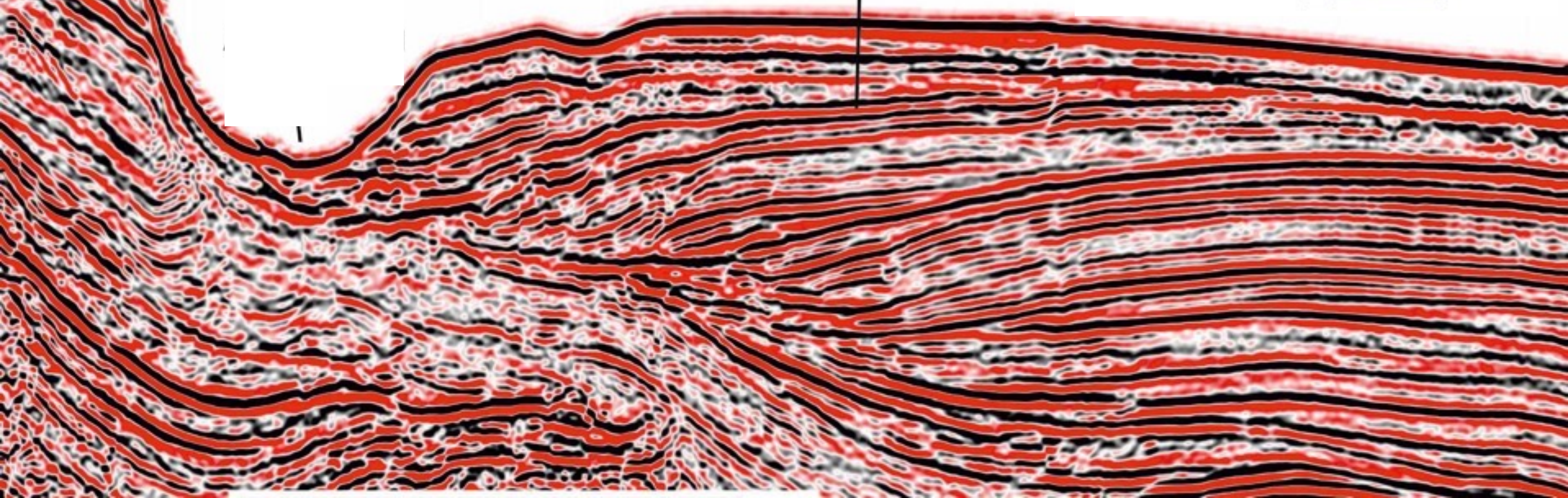
Submarine fans



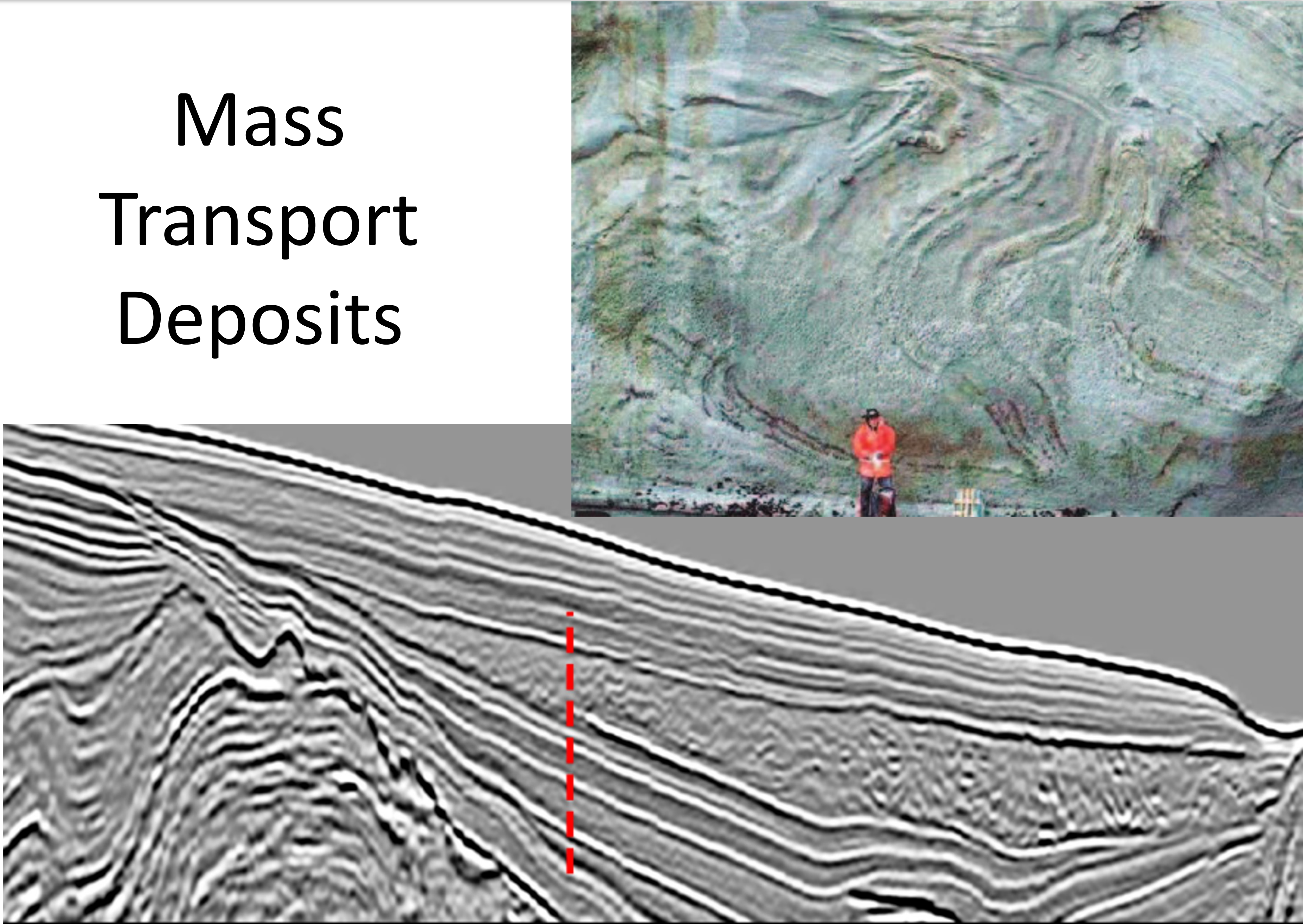


Contourites

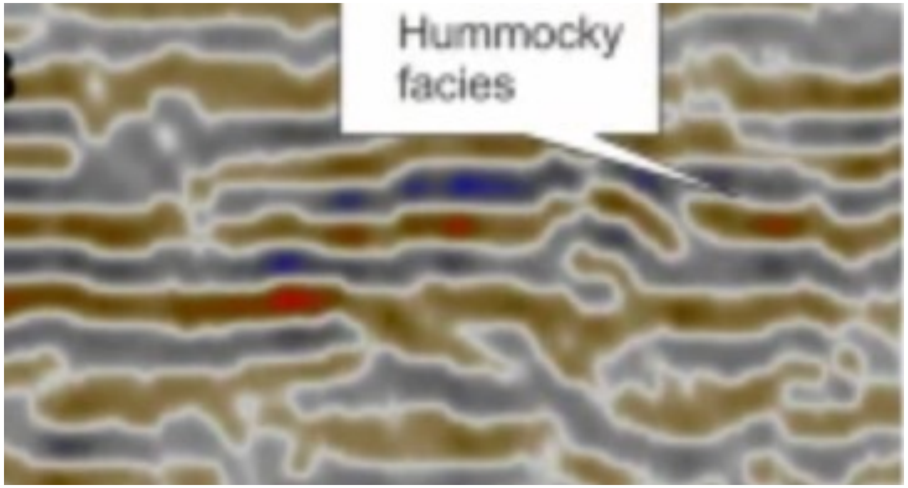


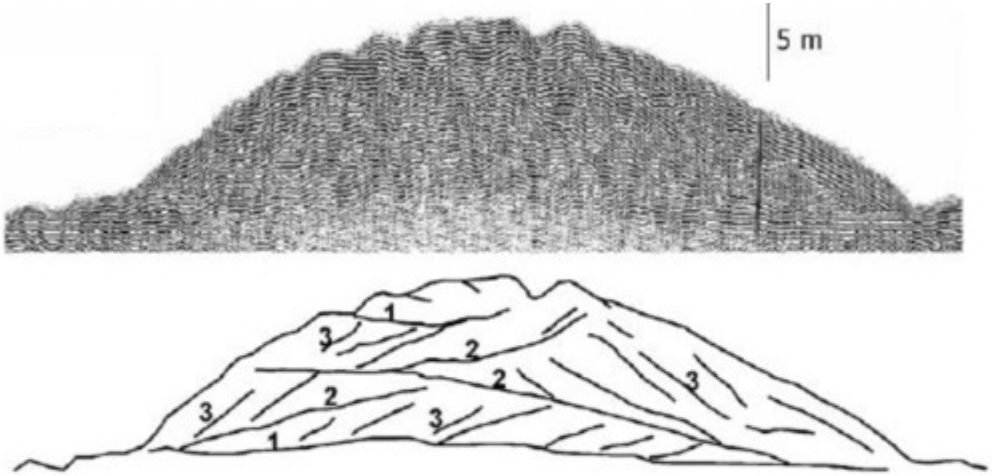


Mass Transport Deposits

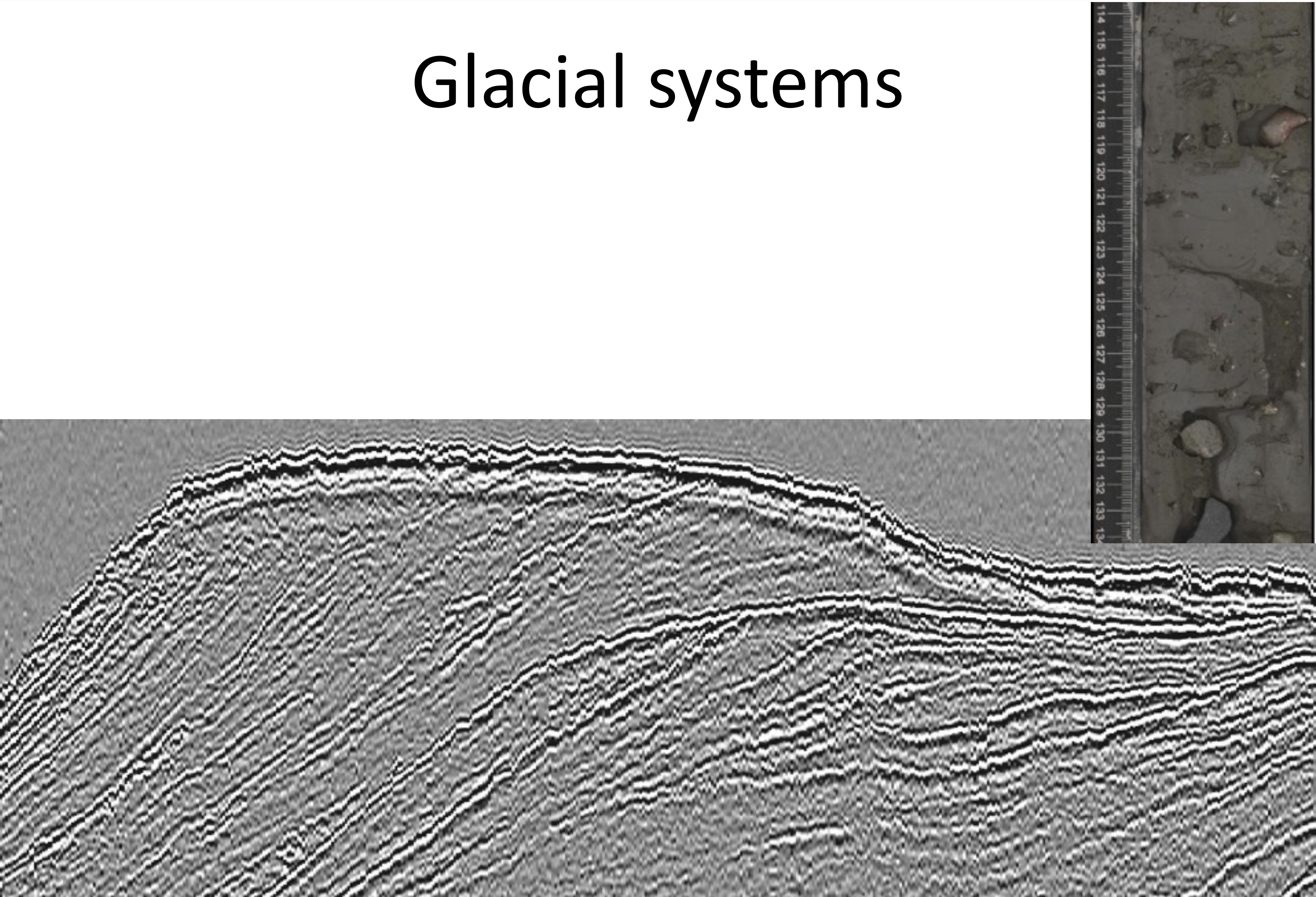


Continental shelves

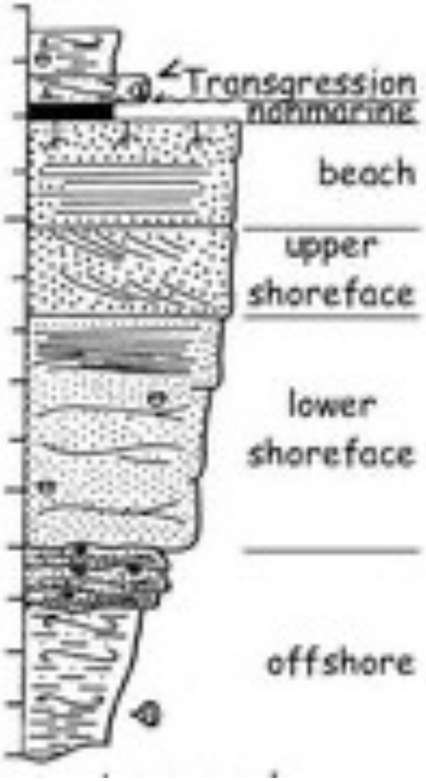


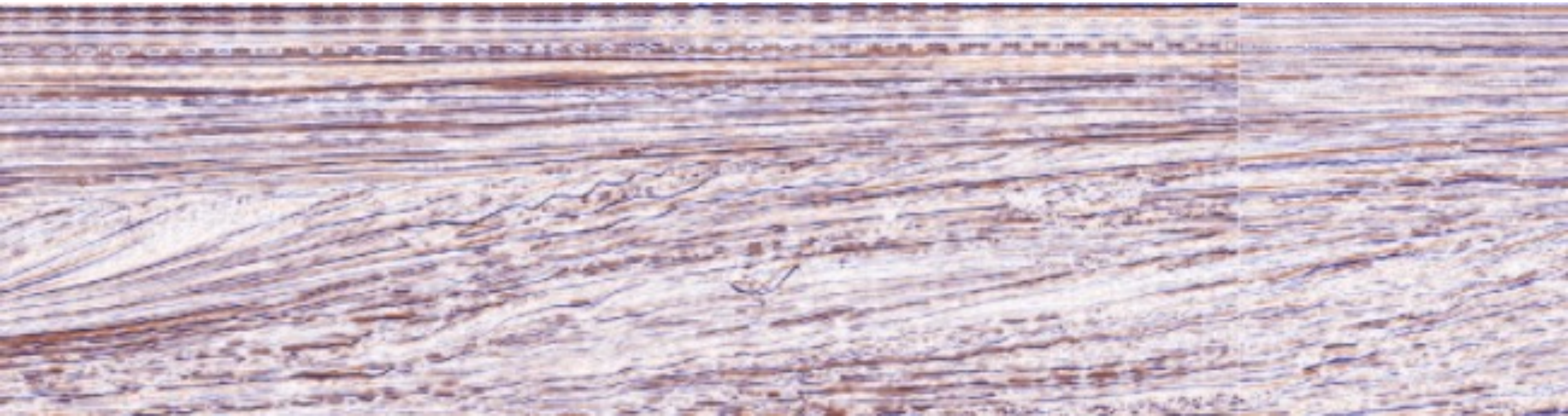


Glacial systems

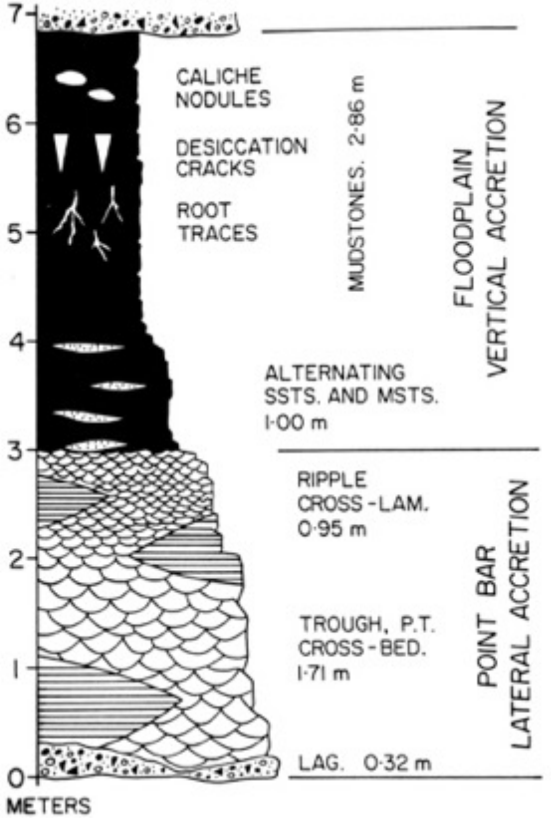


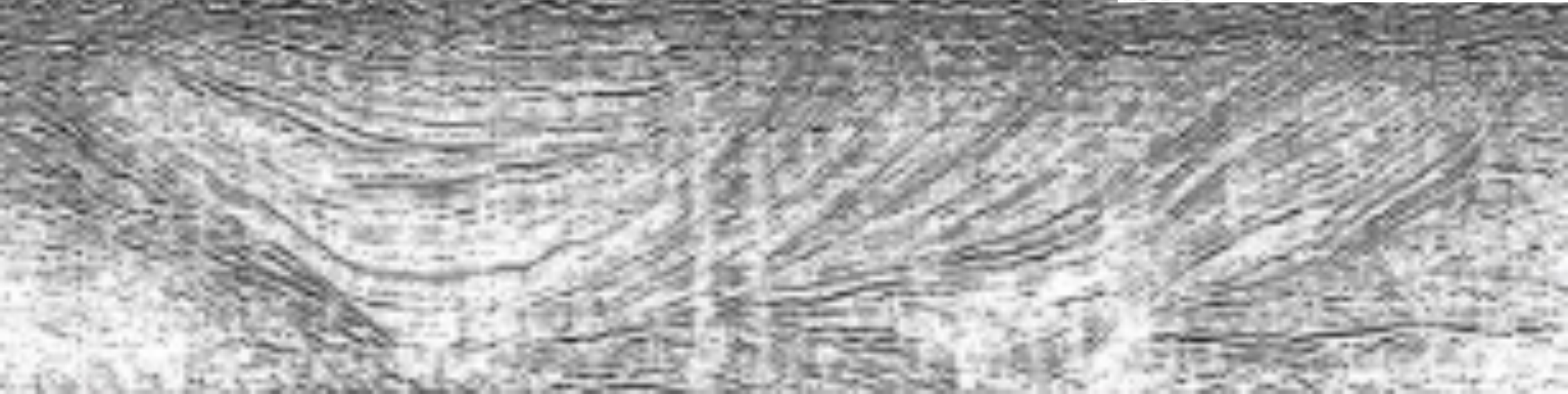
Barrier islands



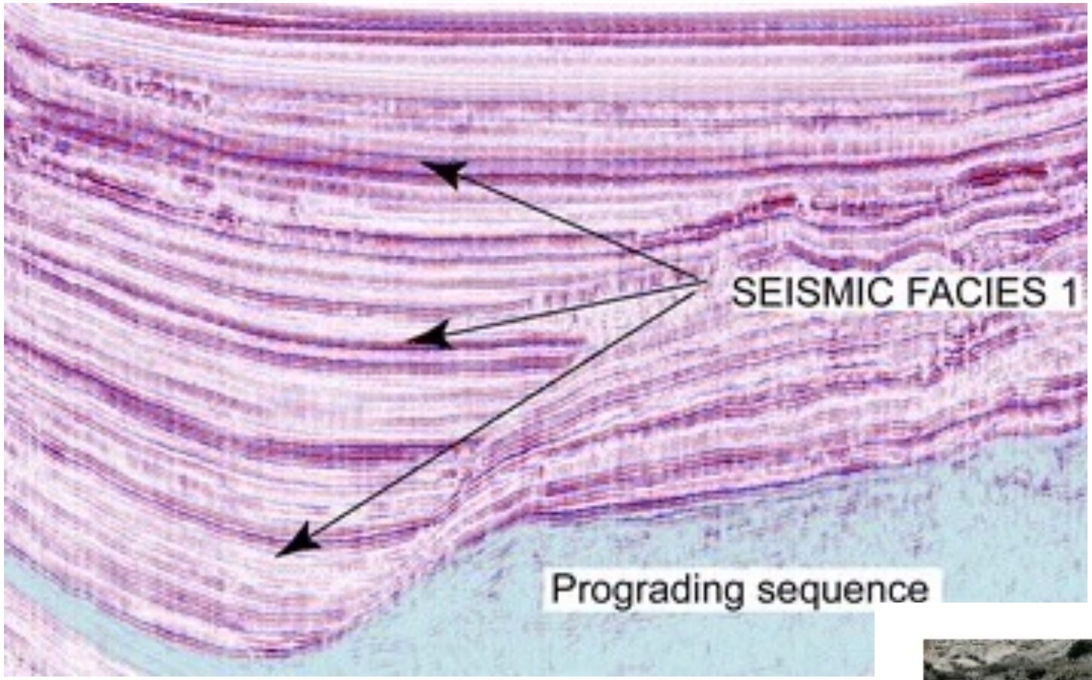


Fluvial deposits

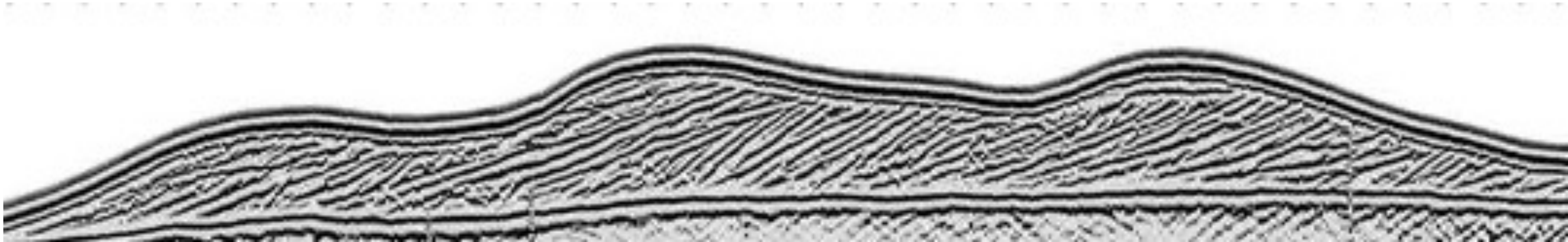


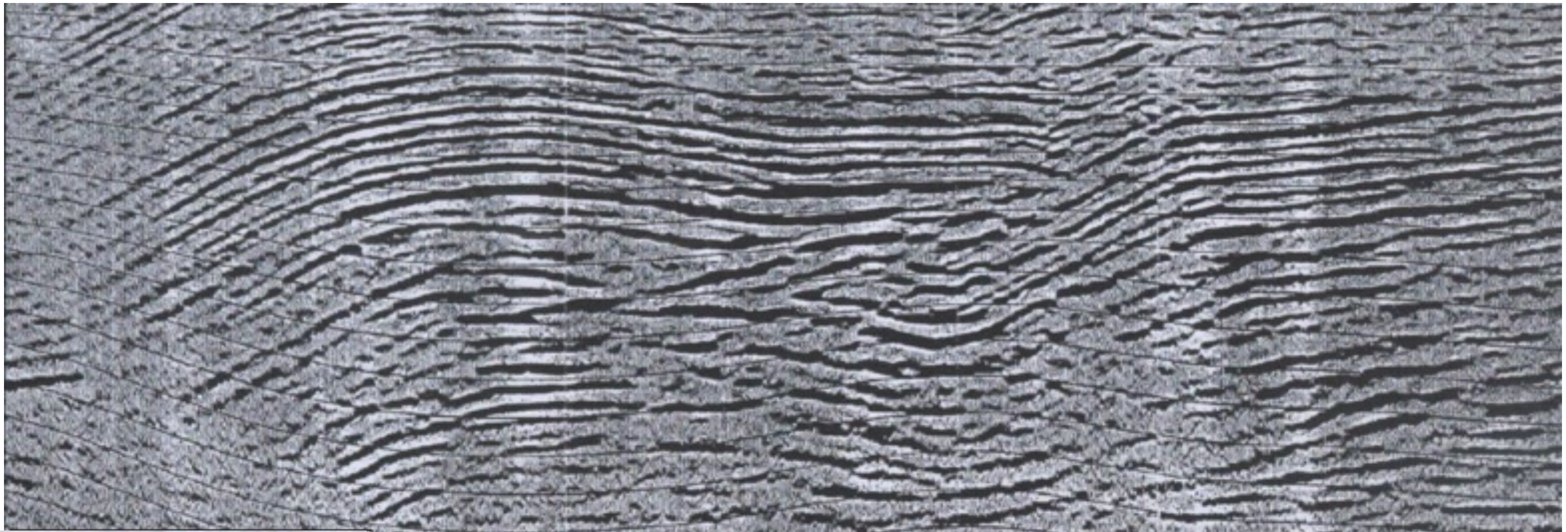


Lakes



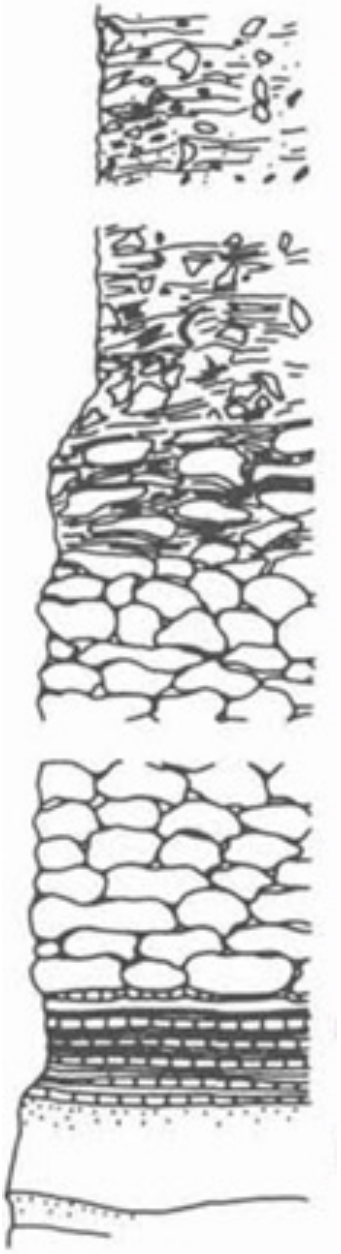
Aeolian dunes

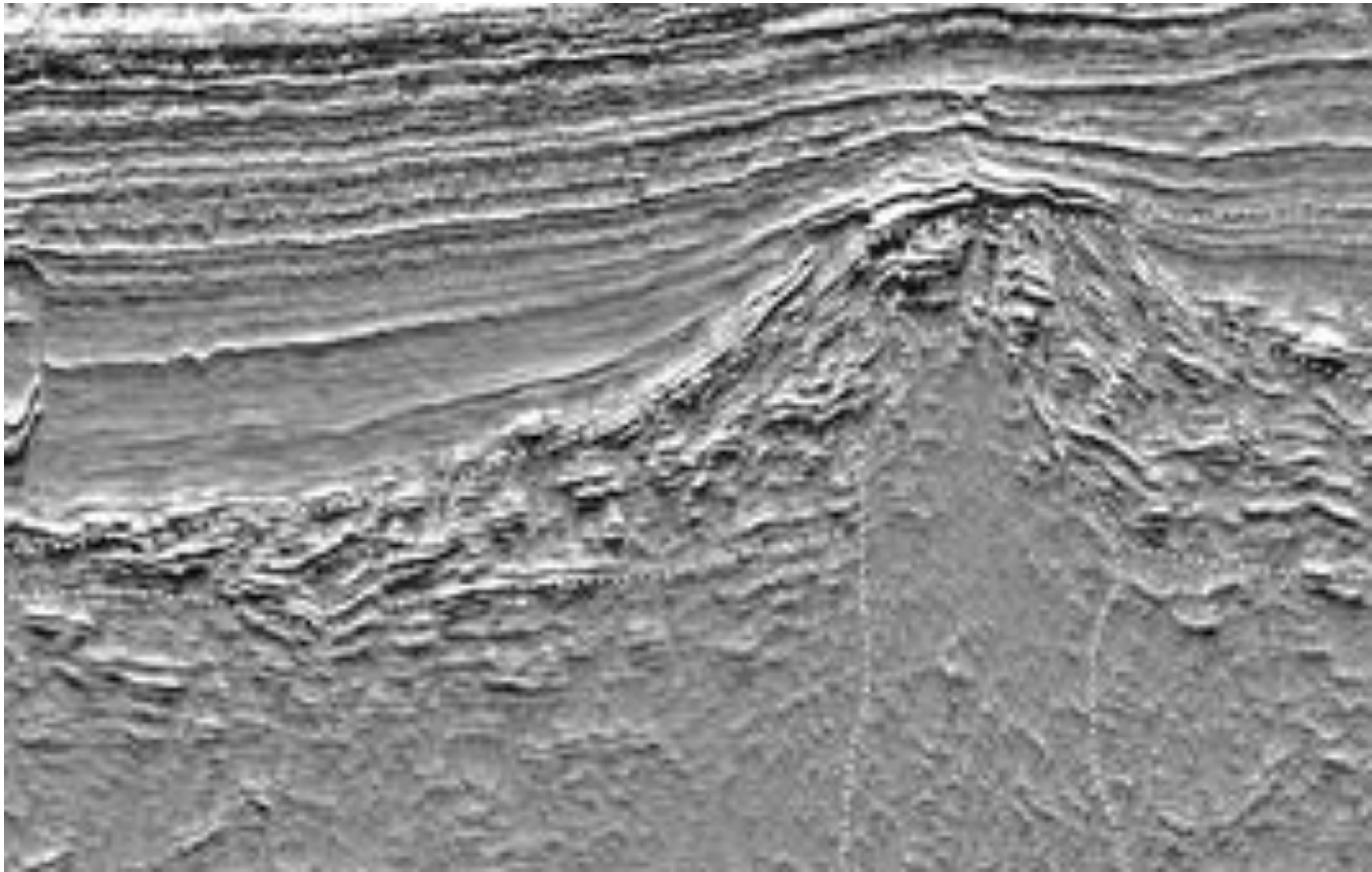




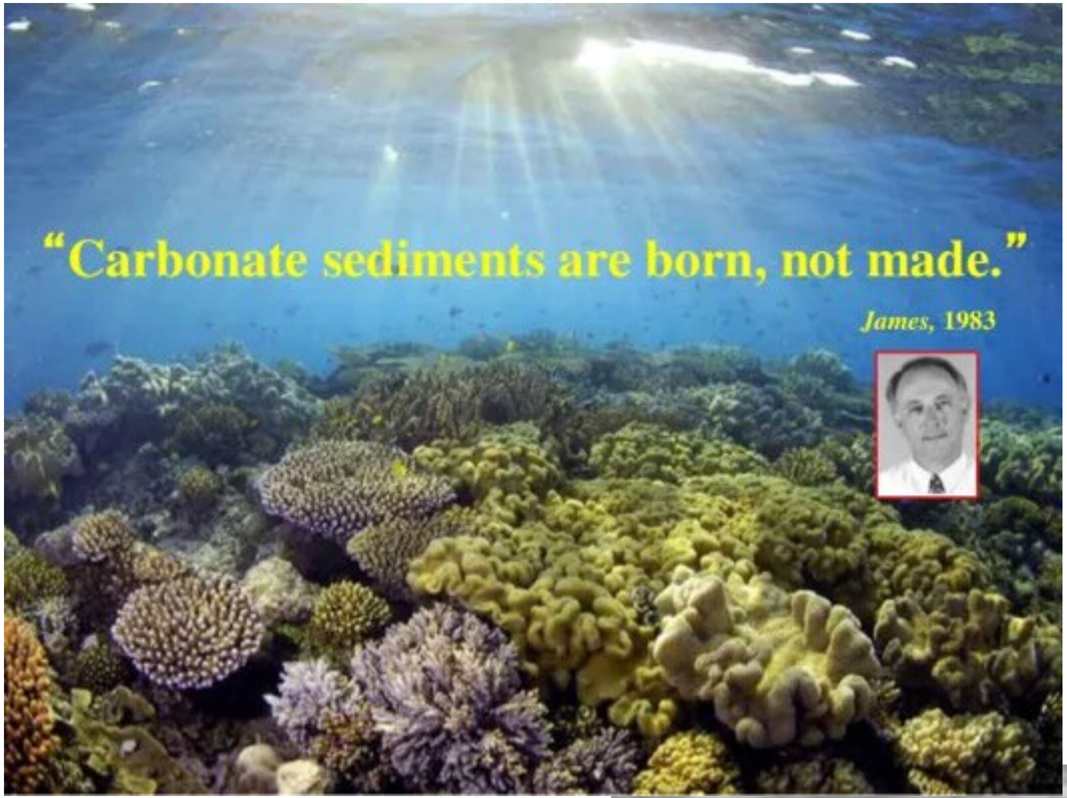
Faults

Volcanoes



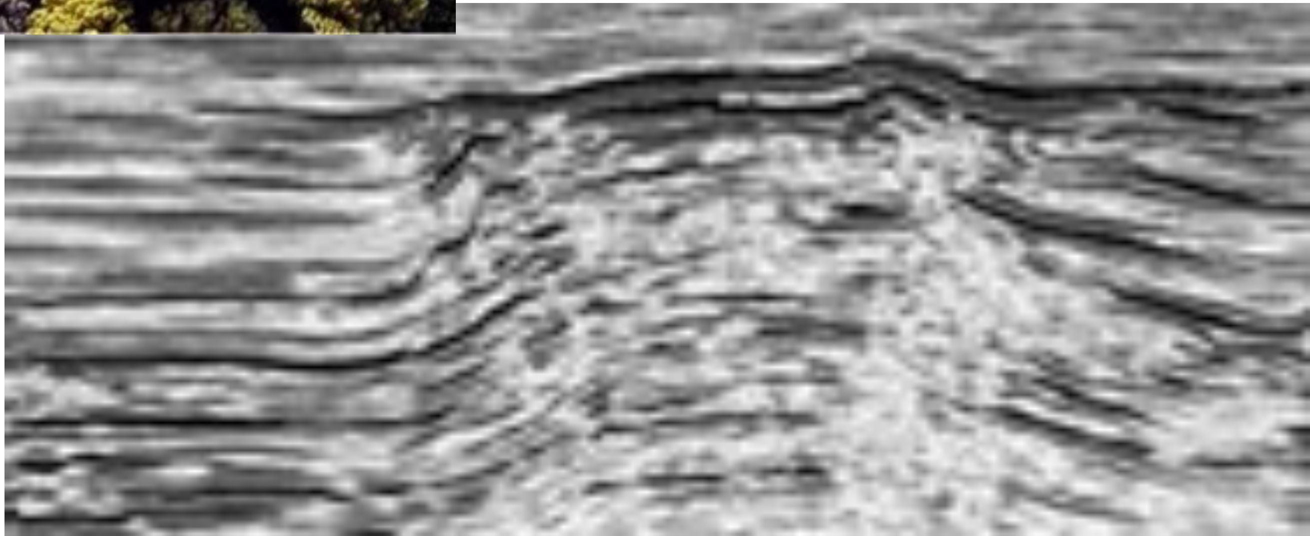


Carbonates



"Carbonate sediments are born, not made."

James, 1983



Sedimentary environments (Synthesis)

All generalizations are false, this one included

Environment	**Sedim. Struct.**	**Seismics**
Abyssal plains	indistinct bedding	low ampl. subparallel comformab.
Submatine fans	Bouma sequence	onlapping/filling terminations
Contourites	bigradational sequences	continuous sigmoidal reflections
Mass transport deposits	deformation structures	transparent/chaotic
Continental shelves	hummocky/mud couplets	hummocky/tidal dunes
Polar systems	deforming till	trough-Mouth Fans
Barrier systems	sand ridges	clinoforms
Alluvial deposits	trough X-strat	lateral accretion packages
Lakes	varves	well stratified subparallel deposits
Deserts	high angle foresets	thick sets of cross-stratification
Carbonatic environments	cemented deposits	build-up
Faults	fracture	fault cutoffs
Volcans	pyroclastic deposits	cones and craters

Unit	Topic	Teacher	Date
1.1	Introduction to the course	Rebesco	03/10/22
1.2	Methods (geophysics, but not only)	Volpi/Rebesco	06/10/22
6.1	Visit to the icebreaker Laura Bassi (along with Geologia Marina)	Rebesco	10/10/22
1.3	Mechanisms of basin formation (geodynamics, tectonics…)	Lodolo	13/10/22
1.4	Seismic interpretation, facies and primary structures	Rebesco	17/10/22
	No lesson: 20th October		
2.1	Sedimentary processes in river & deltas	Rebesco	24/10/22
	No lesson: 27th		
2.2	Action of tides and waves, wind and ice	Rebesco	31/10/22
	No lesson: 3rd November		
2.3	Density currents, bottom currents and mass transport	Lucchi/Rebesco	07/11/22
1.5	Energy storage & CCUS	Volpi/Donda	10/10/22
3.1	Alluvial deposits, lakes and deserts	Rebesco	11/11/22
	No lesson: 14th November		
3.2	Barrier systems and incised valleys	Rebesco	17/11/22
3.3	Continental shelves (wases, storms, tsunamis)	Rebesco	21/11/22
3.4	Mass transport deposits	Ford	24/11/22
3.5	Abyssal plains (hemipelagic fallout) and continental margins	Rebesco	28/11/22
3.6	Submarine fans (gravity flows on the continental slope)	Lucchi	01/12/22
3.7	Sediment drifts (bottom currents along the continental slope)	Rebesco	05/12/22
	No lesson on Thursday 8th December		
3.8	Glacial depositional systems	De Santis	12/12/22
3.9	Carbonatic environments, faults, volcans	Rebesco	15/12/22
4.1	Sequence stratigraphy: introduction	Rebesco	19/12/22
4.2	Sequence stratigraphy: closer view	Rebesco	22/12/??
	No lessons from 23rd December to 8th January		
4.2	Sequence stratigraphy: closer view	Rebesco	09/01/??
4.3	Sequence stratigraphy: applications (e.g. hydrocarbon reservoirs)	Rebesco	12/01/23
5	Excercise	Rebesco	13/01/23
6.2	Visit to OGS and SEISLAB (along with Geologia Marina)	Rebesco	20/01/23
6.3	Visit to CoreLoggingLAB (along with Geologia Marina)	Rebesco	24/02/??