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 - 2024

Analisi di Bacino e Stratigrafia Sequenziale (426SM)

Docente: **Michele Rebesco**

Today →

Friday

31/10?

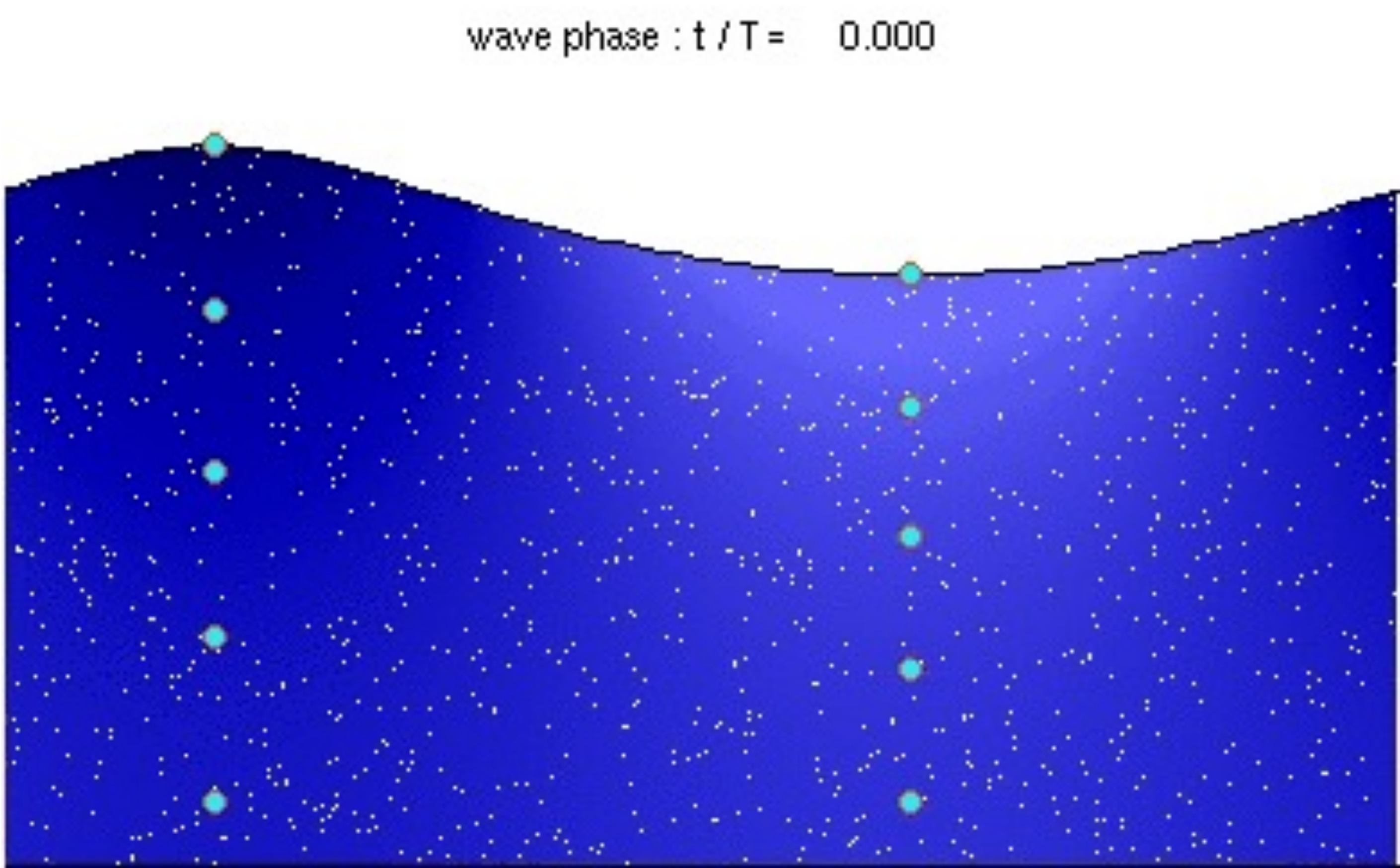
Unit	*Topic*	*Teacher*	*Date*
1.1	Introduction	Rebesco	25/09/23
1.2	Methods (geophysics, but not only)	Geletti/Rebesco	28/09/23
1.3	Mechanisms of basin formation (geodynamics, tectonics...)	Lodolo	02/10/23
1.4	Seismic interpretation, facies and primary structures	Rebesco	06/10/23
1.5	Energy storage & CCUS	Volpi/Barison	09/10/23
2.1	Sedimentary processes in river & deltas	Rebesco	12/10/23
2.2	Action of tides and waves, wind and ice	Rebesco	16/10/23
2.3	Density currents, bottom currents and mass transport	Lucchi/Rebesco	20/10/23
3.1	Alluvial deposits, lakes and deserts	Rebesco	23/10/23
3.2	Barrier systems and incised valleys	Rebesco	26/10/23
3.3	Continental shelves (wases, storms, tsunamis)	Rebesco	30/10/23
	No lesson		02/11/23
3.6	Submarine fans (gravity flows on the continental slope)	Lucchi	06/11/23
	No lessons from from 9 to 16 November		
3.7	Sediment drifts (bottom currents along the continental slope)	Rebesco	20/11/23
3.4	Mass transport deposits	Ford	23/11/23
3.5	Abyssal plains (hemipelagic fallout) and continental margins	Rebesco	27/11/23
3.8	Glacial depositional systems	De Santis	30/11/23
3.9	Carbonatic environments, faults, volcans	Rebesco	04/12/23
4.1	Sequence stratigraphy: introduction	Rebesco	07/12/23
4.2	Sequence stratigraphy: closer view	Rebesco	11/12/23
4.3	Sequence stratigraphy: applications (e.g. hydrocarbon reservoirs)	Rebesco	14/12/23
5.1	Excercise (part 1)	Rebesco	18/12/23
5.2	Excercise (part 2)	Rebesco	21/12/23
	No lesson 23rd December till 7th January		
6.1	Visit to CoreLoggingLAB (along with Geologia Marina)	Rebesco	08/01/24
6.2	Visit to OGS and SEISLAB (along with Geologia Marina)	Rebesco	11/01/24

Module 2.2
tides and waves, wind and ice

Outline:
- Wave action
- Tidal action
- Ice action
- Aeolian transport

Waves

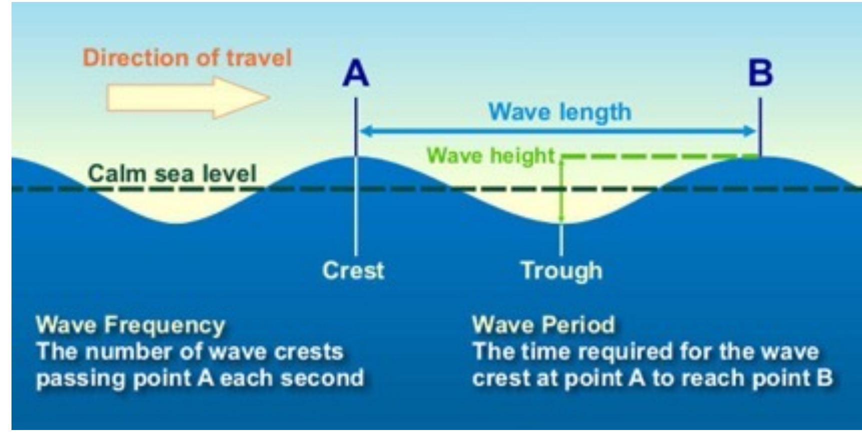
Wind blowing over the surface of water transfers energy to the water through friction. The energy transferred from wind to water causes waves to form. Waves move as individual oscillating particles of water. As the wave crest passes, the water is moving forward. As the wave trough passes, the water is moving backward.



Salt Lake Community College

Wave terms

Salt Lake Community College



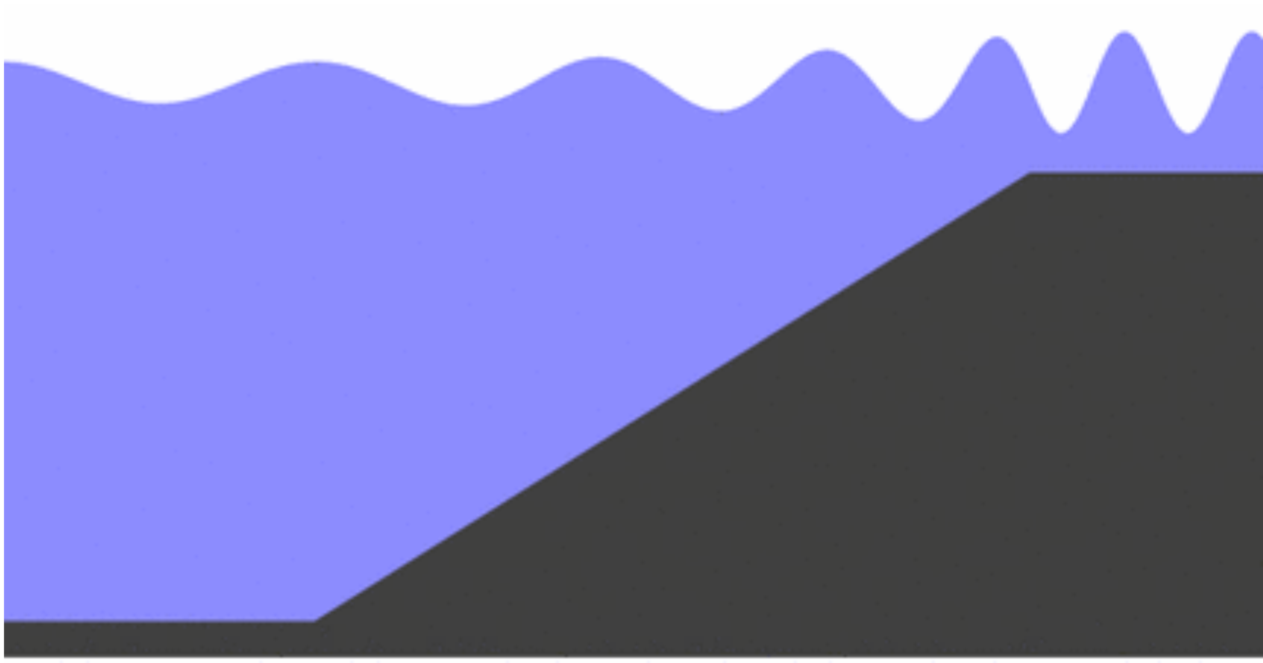
Important terms include: the **wave crest** is the highest point of the wave; the **trough** is the lowest point of the wave. **Wave height** is the vertical distance from the trough to the crest and is determined by wave energy. **Wavelength** is the horizontal distance between consecutive wave crests. **Wave velocity** is the speed at which a wave crest moves forward and is related to the wave's energy. **Wave period** is the time interval it takes for adjacent wave crests to pass a given point.

Winds blowing in a relatively constant direction generate waves moving in that direction. Such a group of approximately parallel waves traveling together is called a **wave train**. A wave train coming from one fetch can produce various wavelengths. Longer wavelengths travel at a faster velocity than shorter wavelengths, so they arrive first at a distant shore. Thus, there is a wavelength-sorting process that takes place during the wave train's travel. This sorting process is called **wave dispersion**.

Tsunamis

A special type of wave is called a tsunami. Tsunamis are generated by energetic events affecting the sea floor, such as earthquakes…. Water is suddenly lifted creating a bulge at the surface and a wave train spreads out in all directions traveling at tremendous speeds [over 322 km/h) and carrying enormous energy.

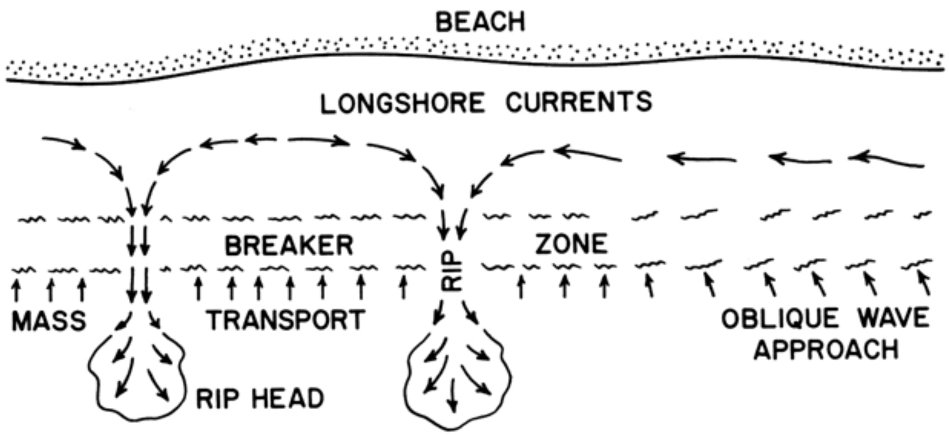
Tsunamis may pass unnoticed in the open ocean because they move so fast, the wavelength is very long, and the wave height is very low. But, as the wave train approaches shore and each wave begins to interact with the shallow seafloor, friction increases and the wave slows down. Still carrying its enormous energy, wave height builds up and the wave strikes the shore as a wall of water that can be over 30 m high. The massive wave, called a tsunami runup, may sweep inland well beyond the beach. As the trough water in front of the tsunami wave is drawn back, the seafloor is exposed.



Wave Action

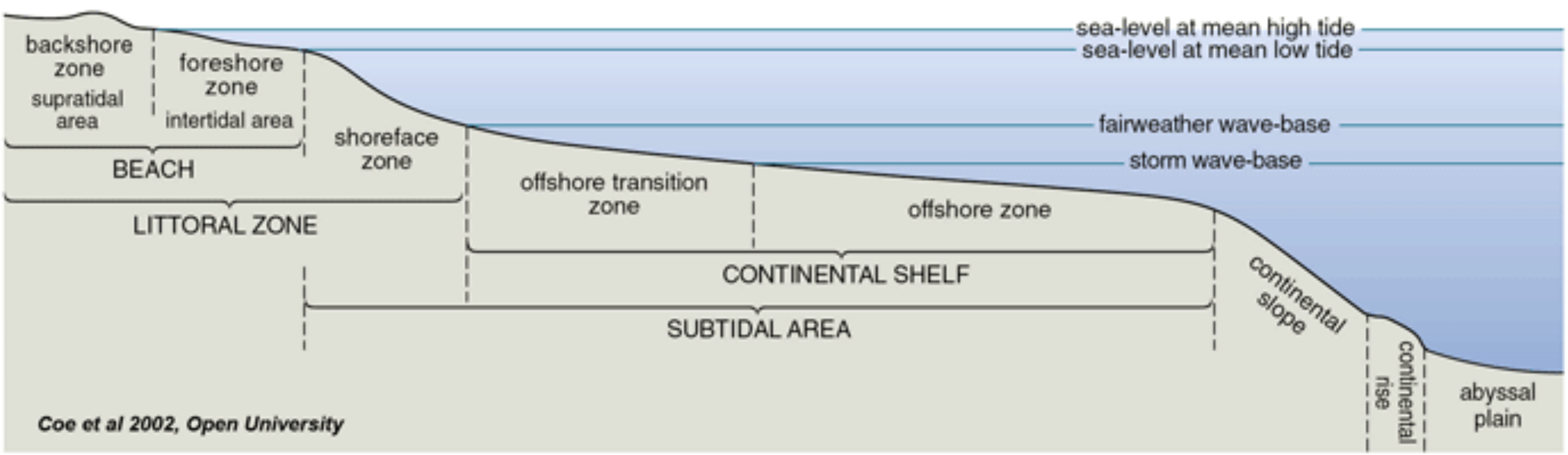
A number of features are formed by wave action. In the region of the beach termed the shoreface, the base of the waves first begin to affect the bottom at depths of about 10 – 20 meters, depending on the size of the waves. In the region termed the middle shoreface, where the shoreward drag of the **wave base** and the backwash of the **breakers** is balanced, the wave action is more pronounced. The upper shoreface, also called the **surf** zone, is dramatically affected by wave-driven **longshore currents** but more so by the plunging effect of breaking waves.

Storms, with their high energy, are capable of moving huge amounts of water with the high winds that are usually associated with them. As gravity is the law, this water must move, if forced, and must recede when the force is removed. Water is one of the great eroding forces of the planet



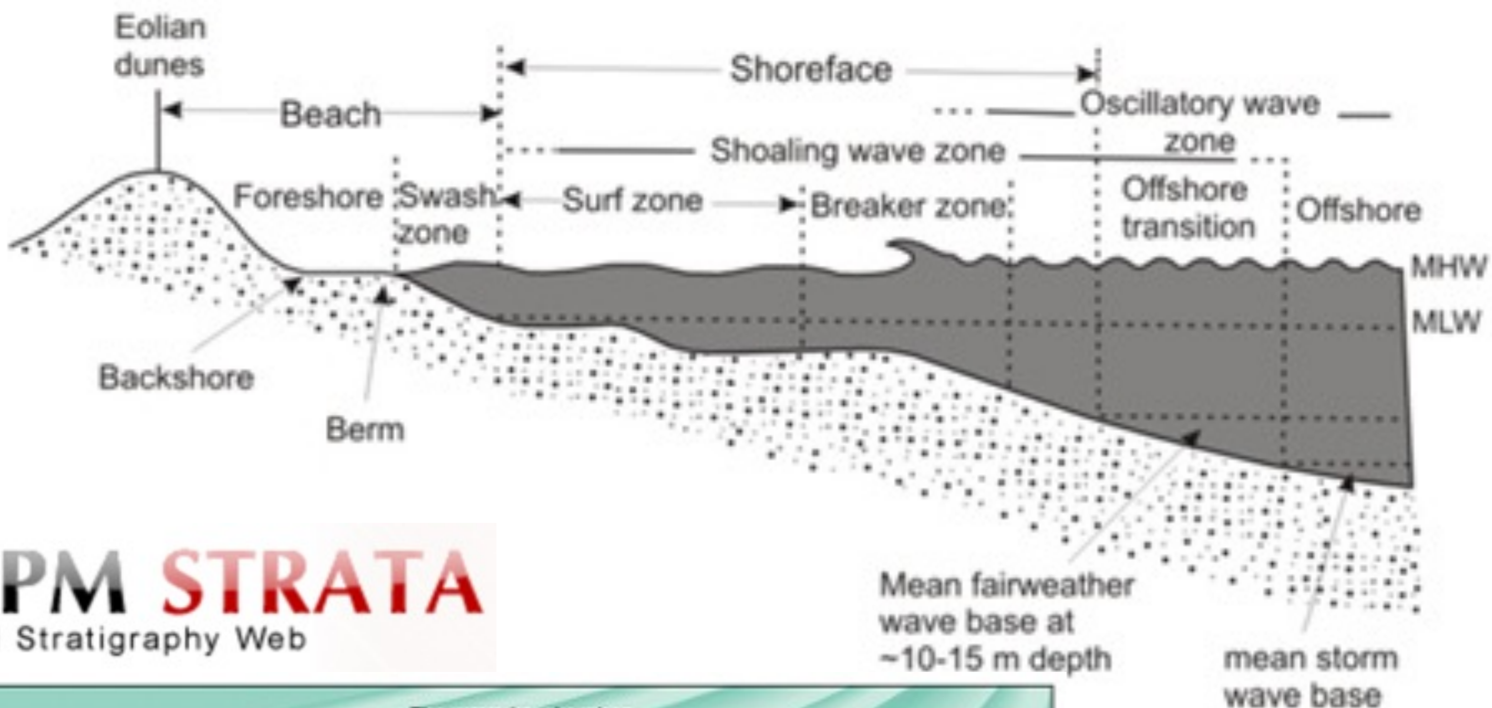
Wave base

The wave base is the water depth beneath which there is no wave movement. This depth has been determined to be half the distance between the crests of waves. Fairweather wave base refers to the depth beneath the average daily waves while storm wave base refers to the depth beneath storm driven waves and is often much deeper.



SEPM STRATA
SEPM Stratigraphy Web

Wave zones



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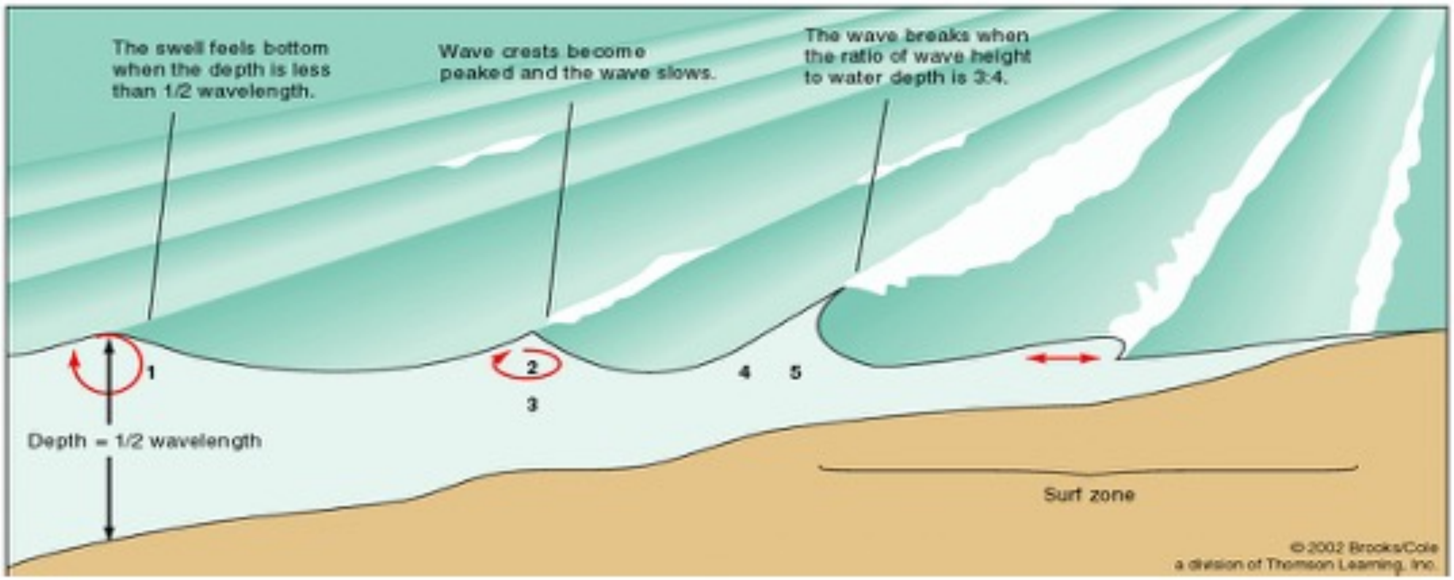


Sand transport processes

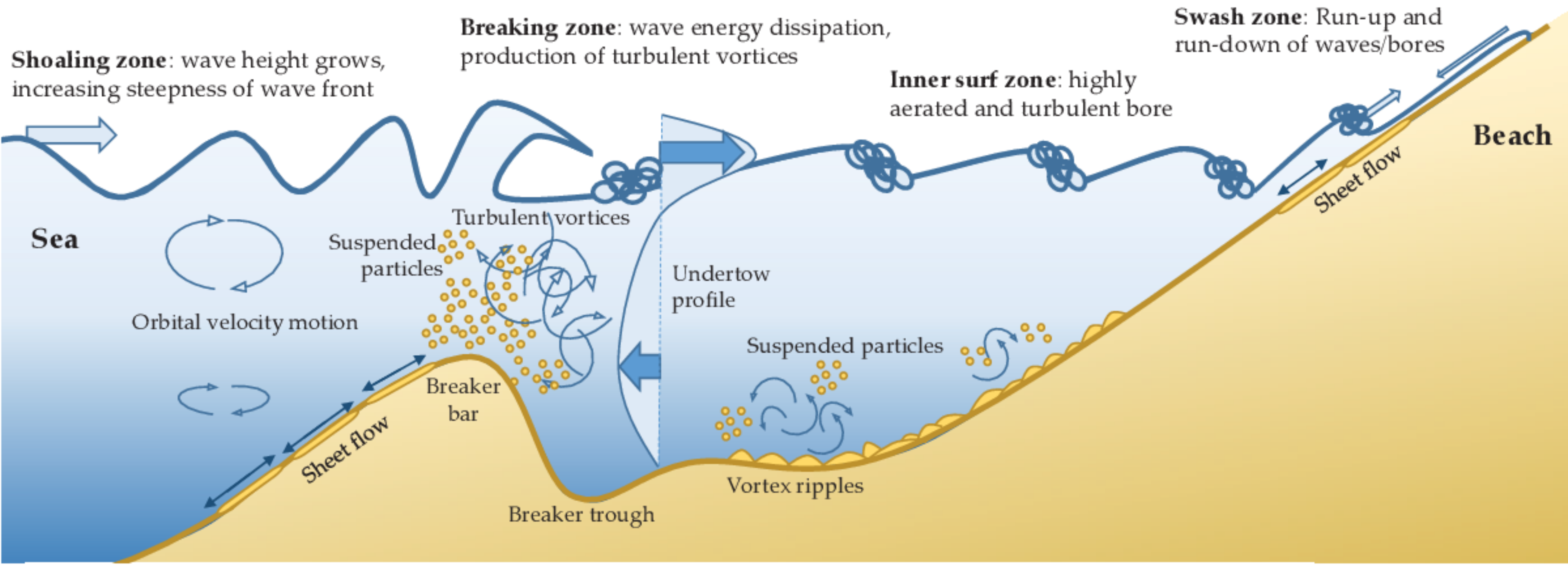
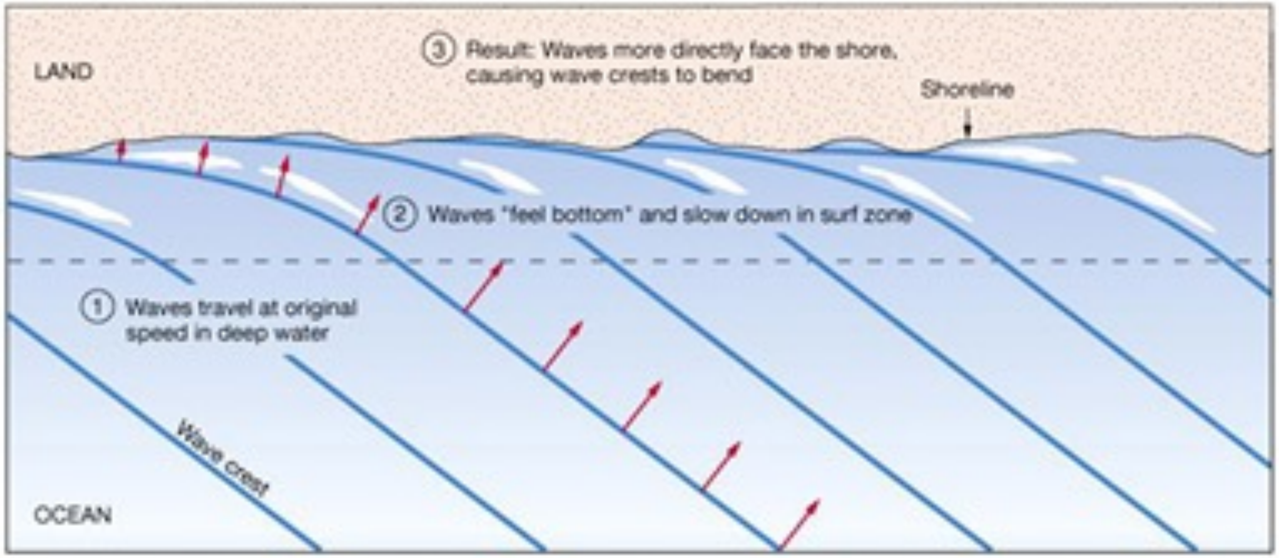


Figure 1.2. Conceptual drawing of cross-shore sediment processes in the near-shore region.

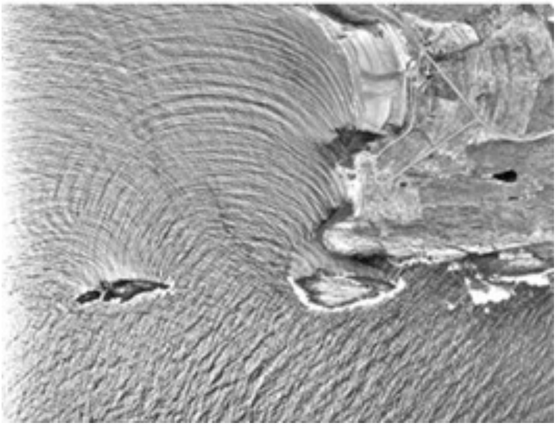
van der Zanden, 2016. Sand transport processes in the surf and swash zones. PhD Thesis, University of Twente

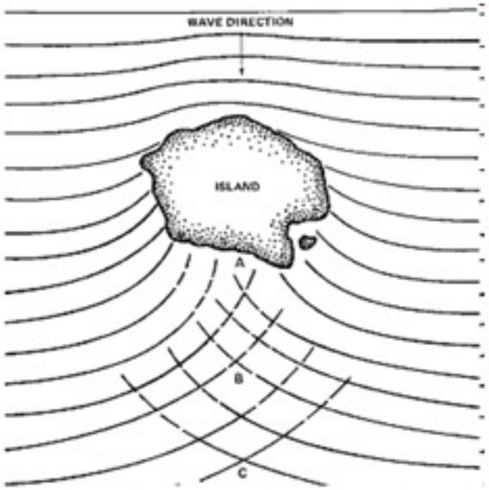
Wave refraction

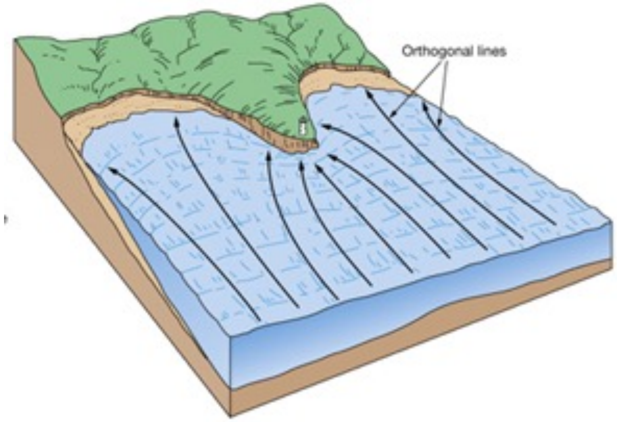
As waves approach shore, the part of the wave in shallow water slows and part of the wave in deep water continues at its original speed, causing wave crests to refract (bend)



Results in waves lining up nearly parallel to shore
Wave energy is concentrated at headlands and dispersed in bays

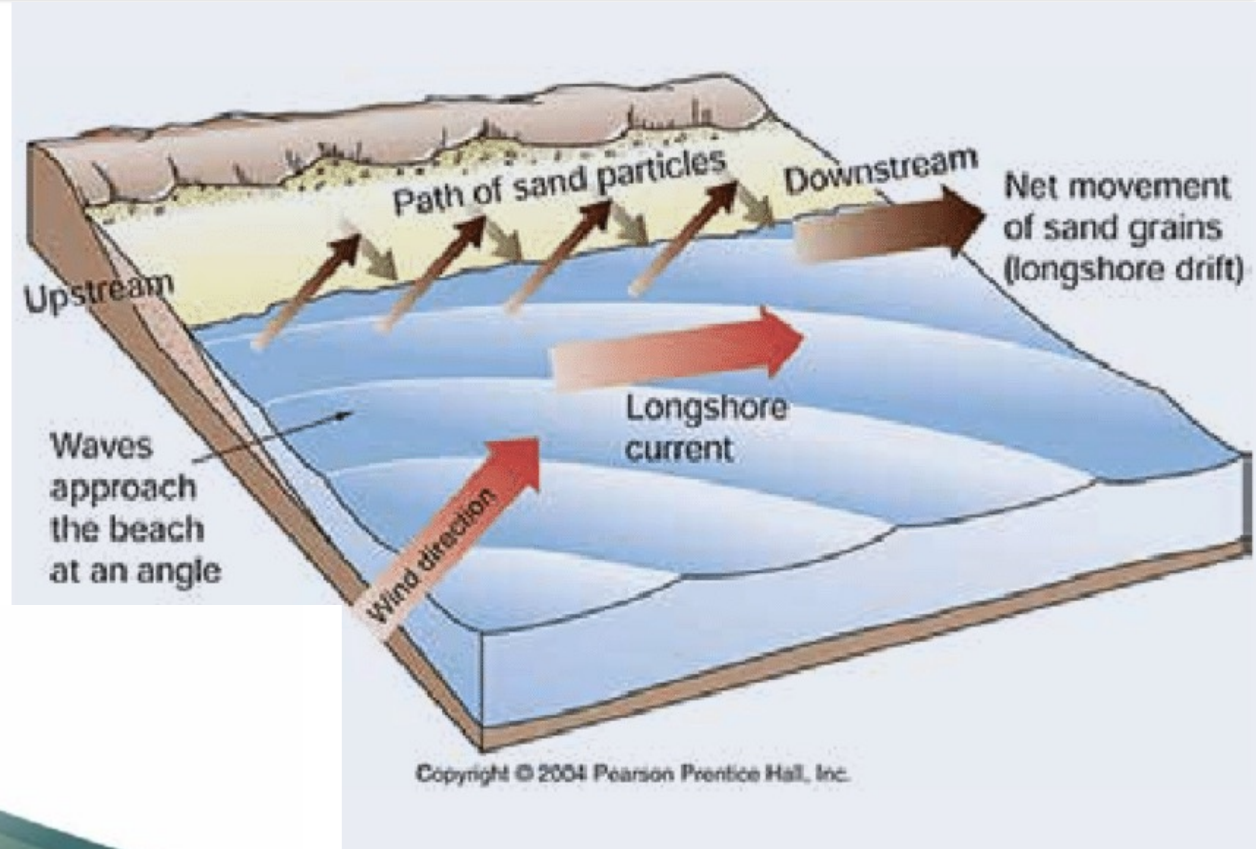


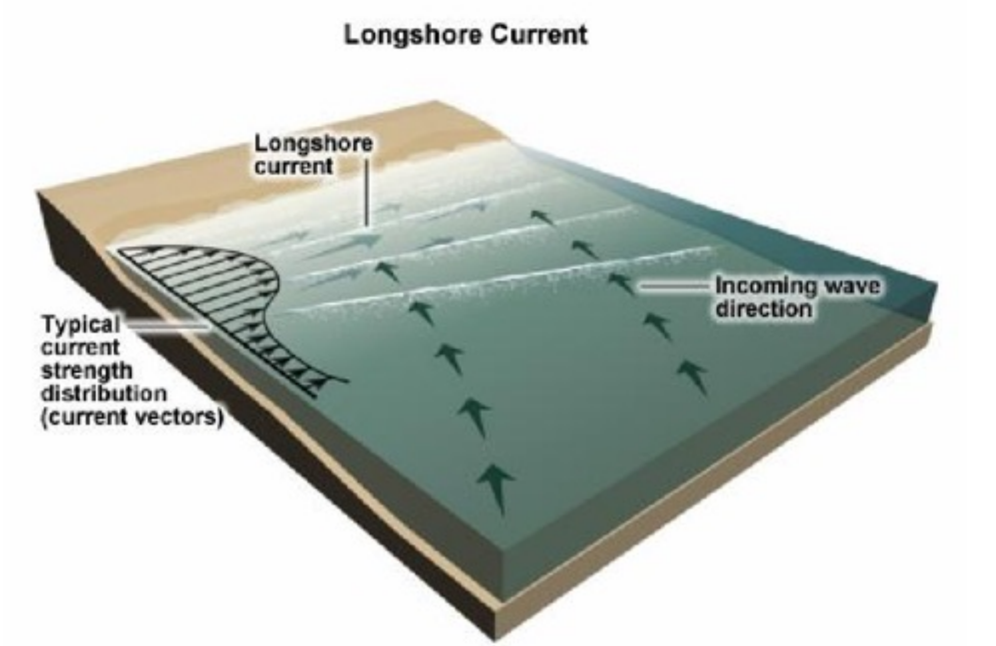




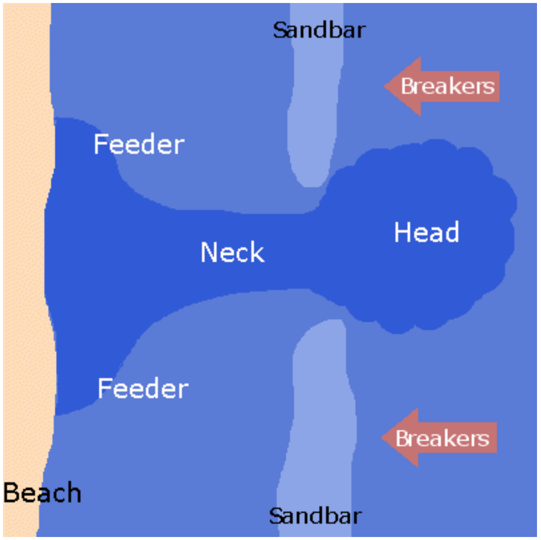
Shoreline Approach, INSTAAR, Colorado

Longshore current





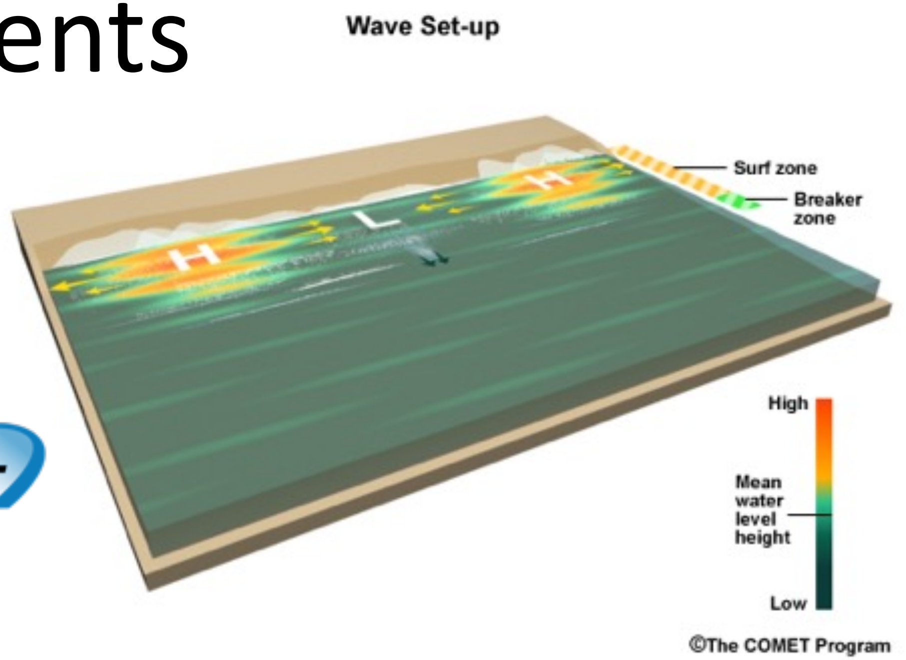
Current running parallel to the shore generated by obliquely incident waves.

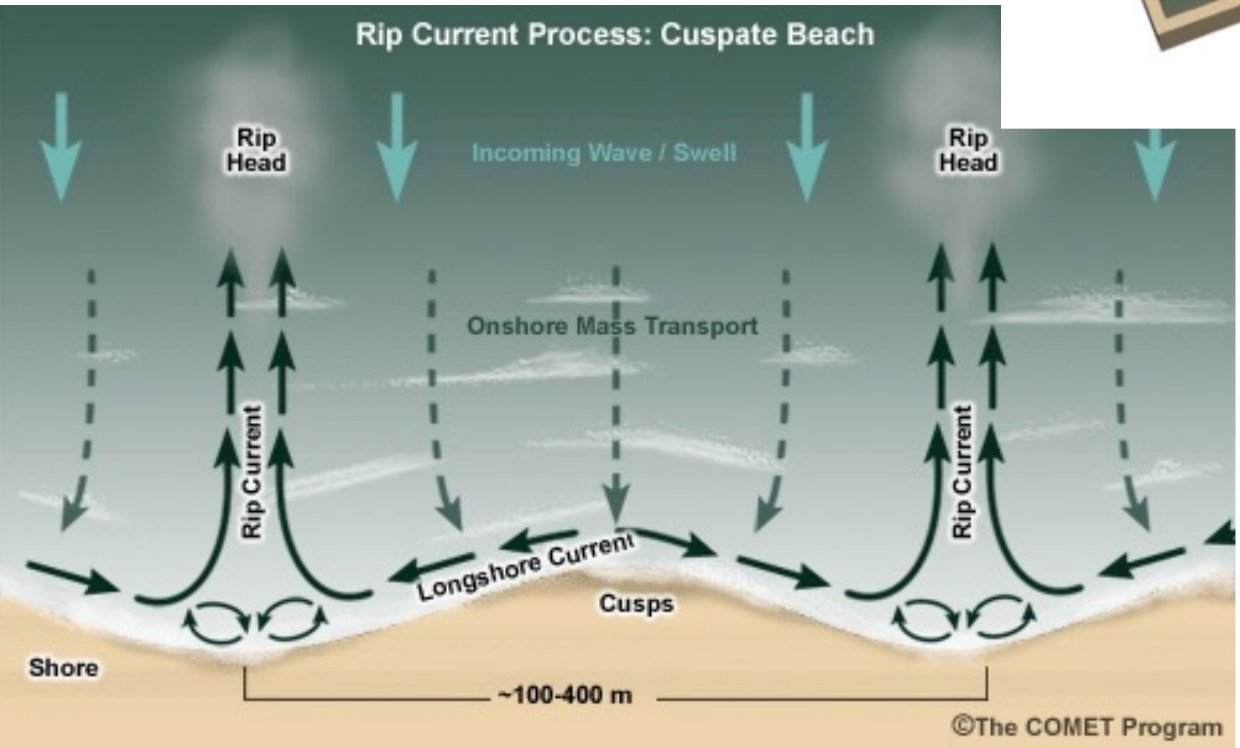


Rip currents

An intermittent strong surface current flowing seaward from the shore.

UCAR COMMUNITY PROGRAMS COMET





When waves break on a beach, they produce a rise in the mean water level that causes a rip current to form in the low set-up points and transport the displaced mass of water back offshore.

Tides

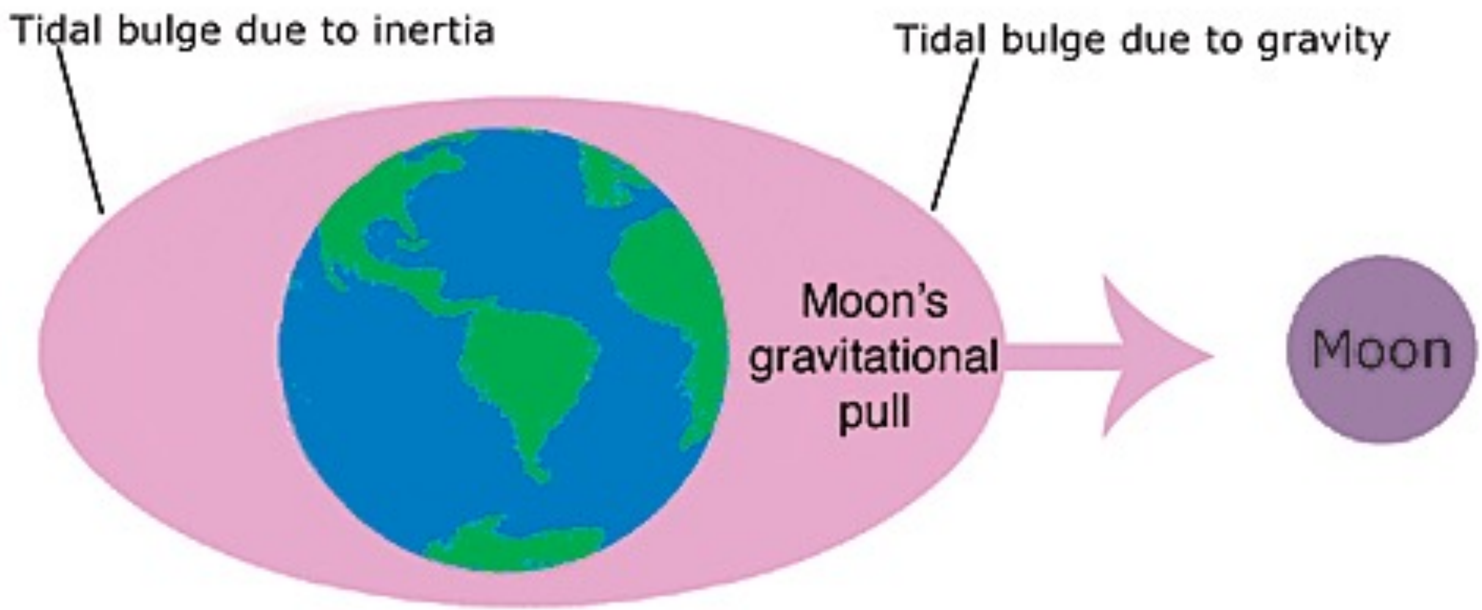
The alternate rising and falling of the sea, usually twice in each lunar day at a particular place, due to the attraction of the moon and sun.

Tidal currents occur in conjunction with the rise and fall of the tide. The vertical motion of the tides near the shore causes the water to move horizontally, creating currents. When a tidal current moves toward the land and away from the sea, it "**floods**." When it moves toward the sea away from the land, it "**ebbs**."

Tidal currents experience a "slack water" period of no velocity as they move from the ebbing to flooding stage, and vice versa. After a brief slack period, which can range from seconds to several minutes and generally coincides with high or low tide, the current switches direction and increases in velocity.

gravitational force

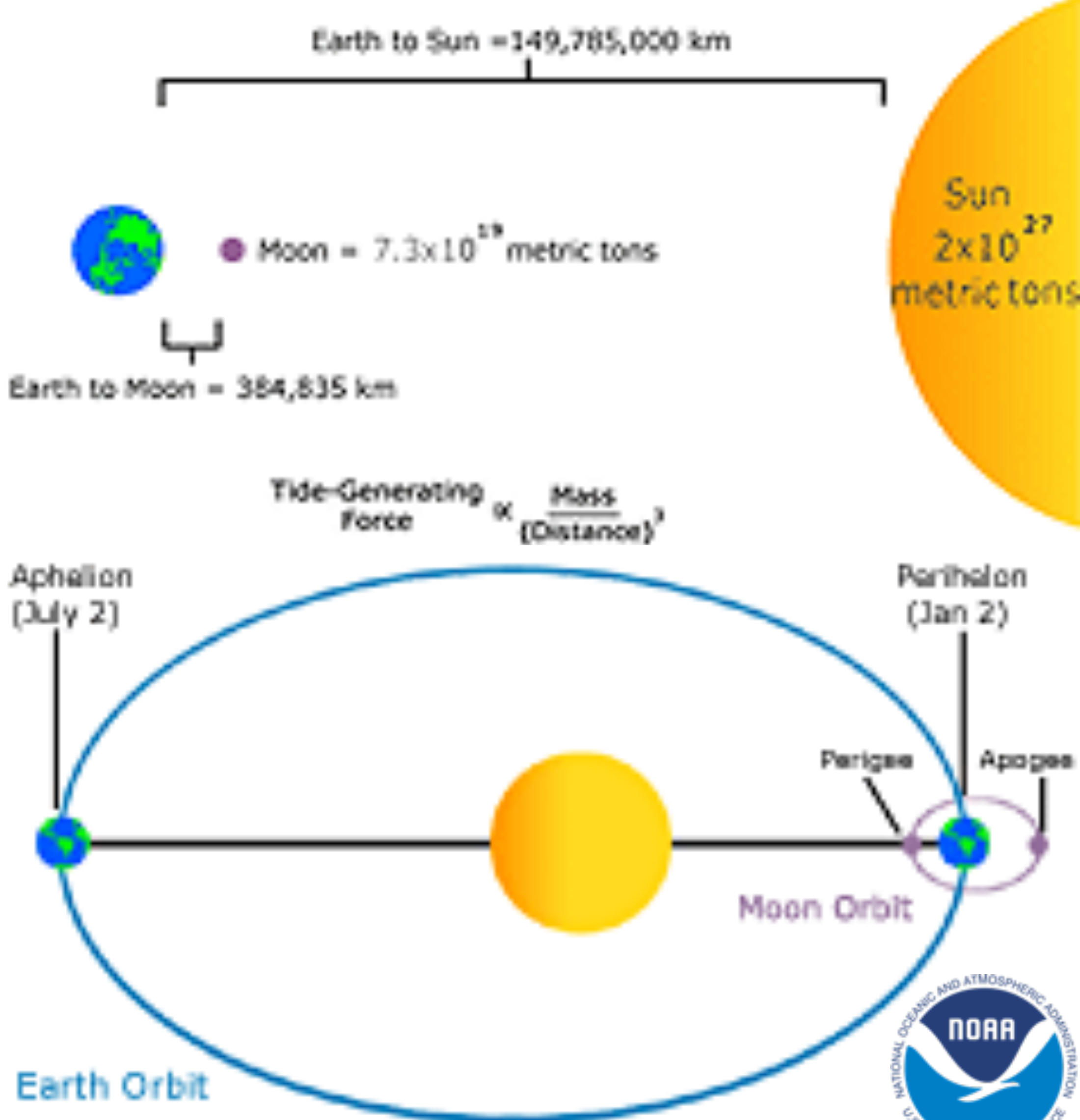
The gravitational force acts to draw the water closer to the moon causing a "bulge" of water on the near side toward the moon. On the opposite side of the Earth, or the "far side," the gravitational attraction of the moon is less because it is farther away and inertia exceeds the gravitational force, moving water away from the Earth, also forming a bulge.



Because water is fluid, the two bulges stay aligned with the moon as the Earth rotates. The sun also plays a major role, affecting the size and position of the two tidal bulges. The interaction of the forces generated by the moon and the sun can be quite complex.

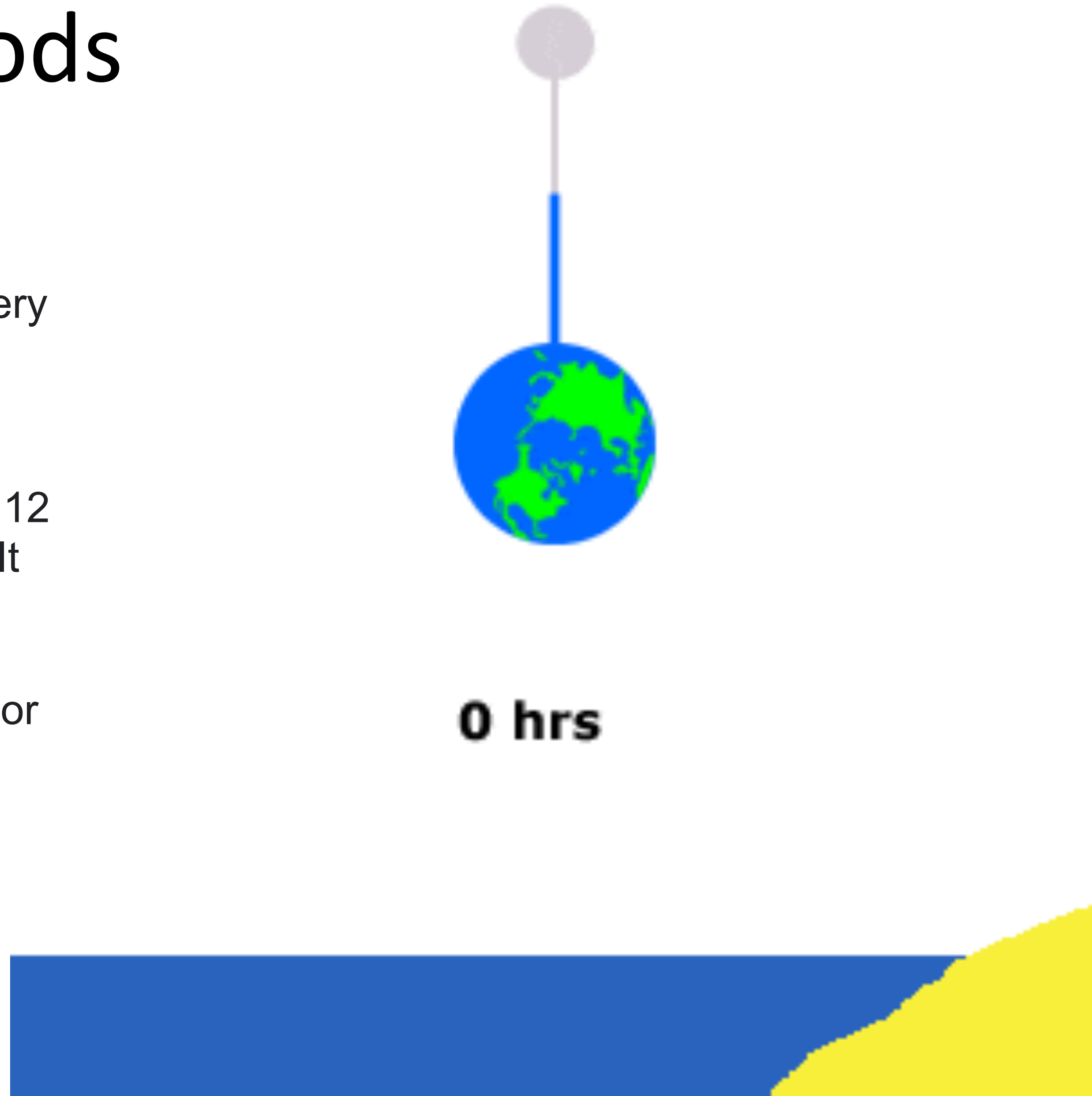
relationship between the Earth, moon, and sun

The moon's force is much greater than that of the sun because it is 389 times closer to the Earth than the sun is. Tidal currents, just like tides, are affected by the different phases of the moon. When the moon is at full or new phases, tidal current velocities are strong and are called "spring currents." When the moon is at first or third quarter phases, tidal current velocities are weak and are called "neap currents." When the moon and Earth are positioned nearest to each other (perigee), the currents are stronger than average and are called "perigean currents." When the moon and Earth are at their farthest distance from each other (apogee), the currents are weaker and are called "apogean currents."



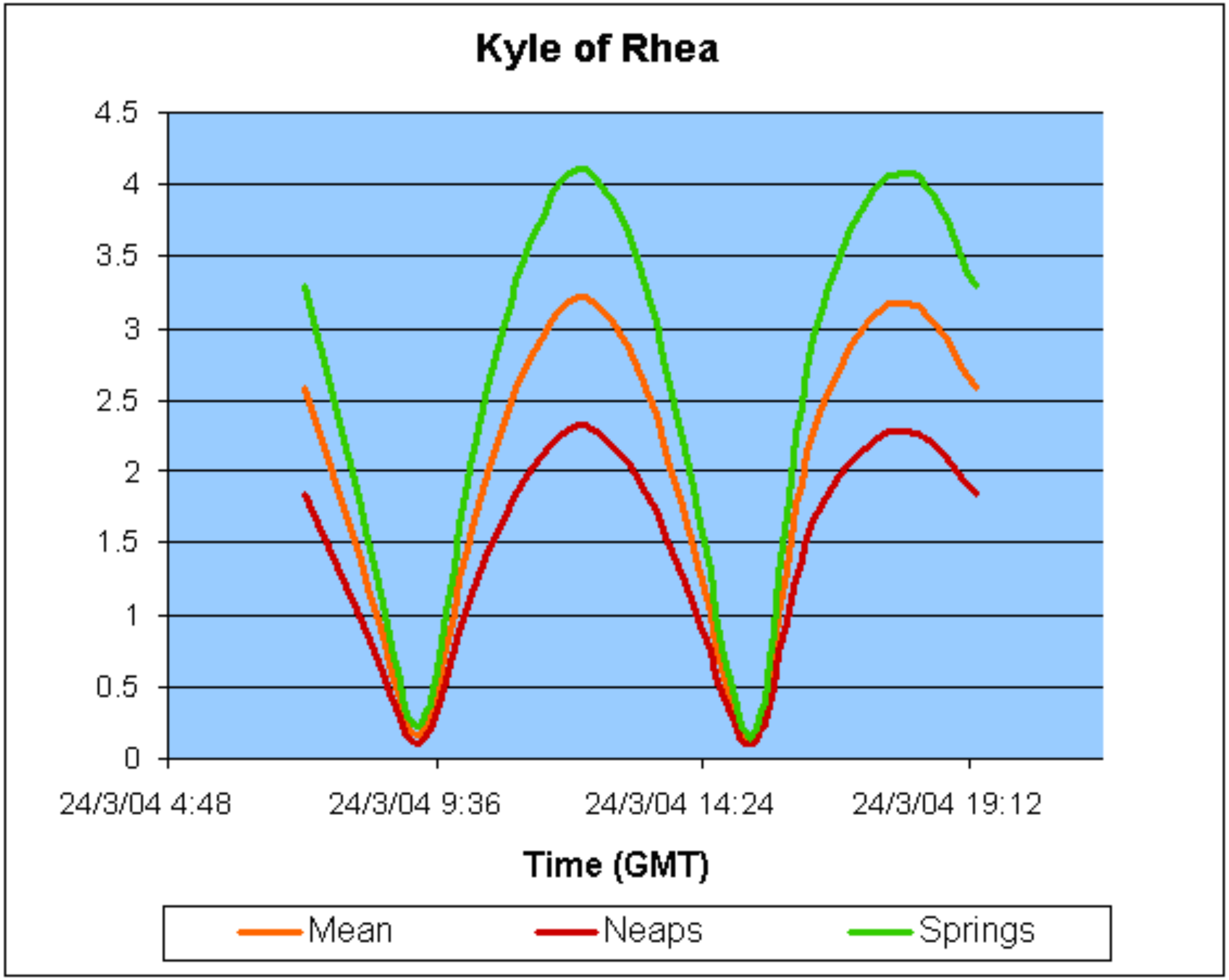
Tide periods

Because the Earth rotates through two tidal "bulges" every lunar day, coastal areas experience two high and two low tides every 24 hours and 50 minutes. High tides occur 12 hours and 25 minutes apart. It takes **six hours and 12.5 minutes** for the water at the shore to go from high to low, or from low to high.



Tide speed

Near estuary entrances, narrow straits and inlets, the speed of tidal currents can reach up to several kilometers per hour.



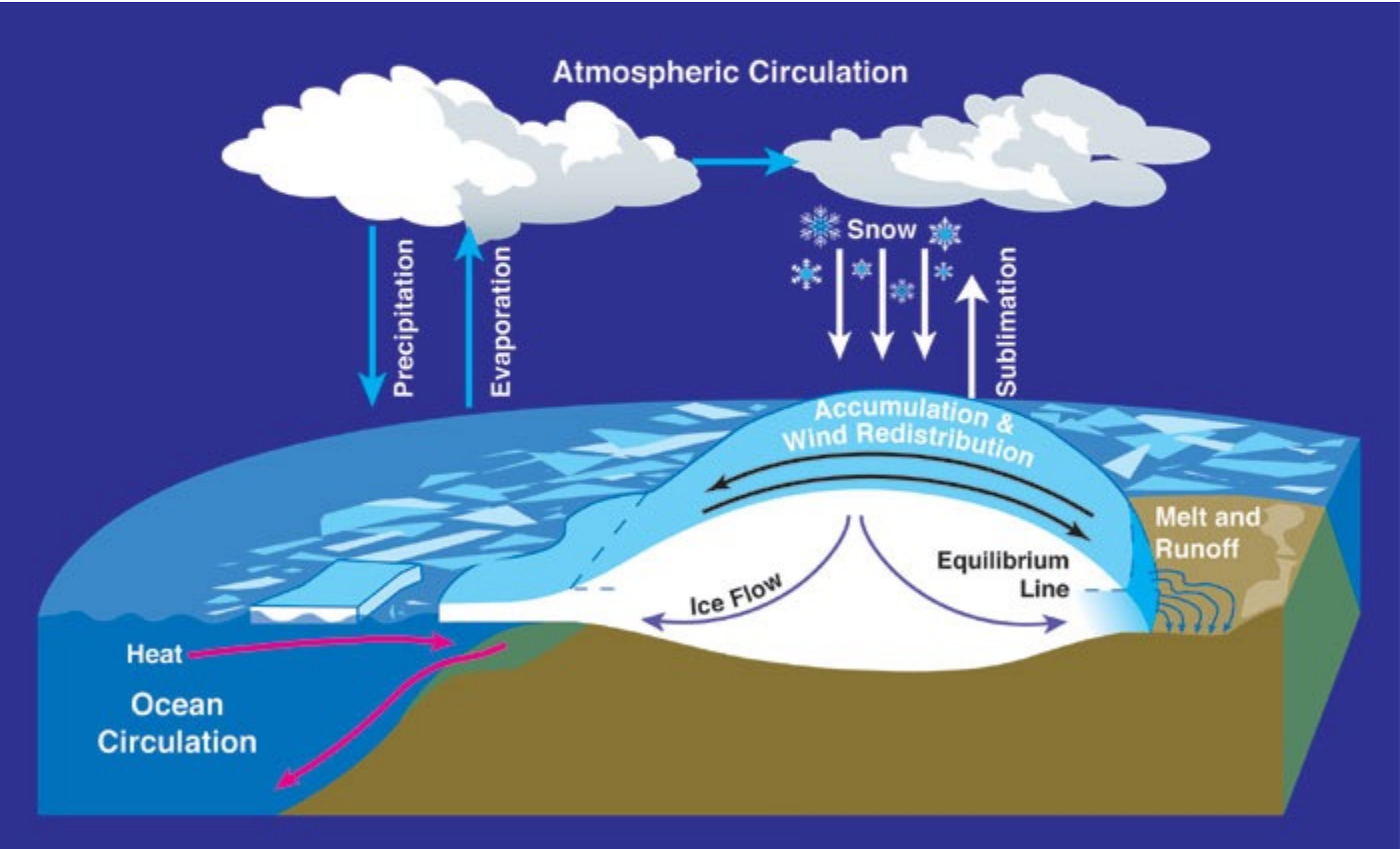
Ice

Ice action

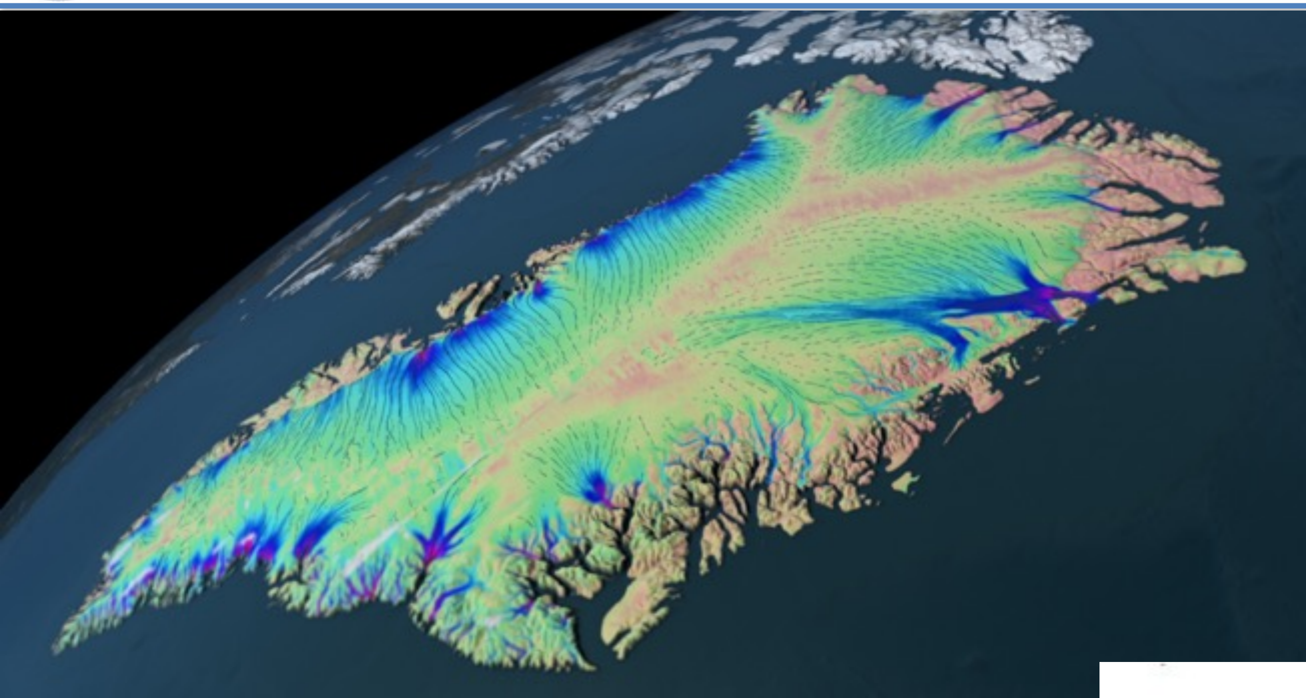
Ice is solid-state water

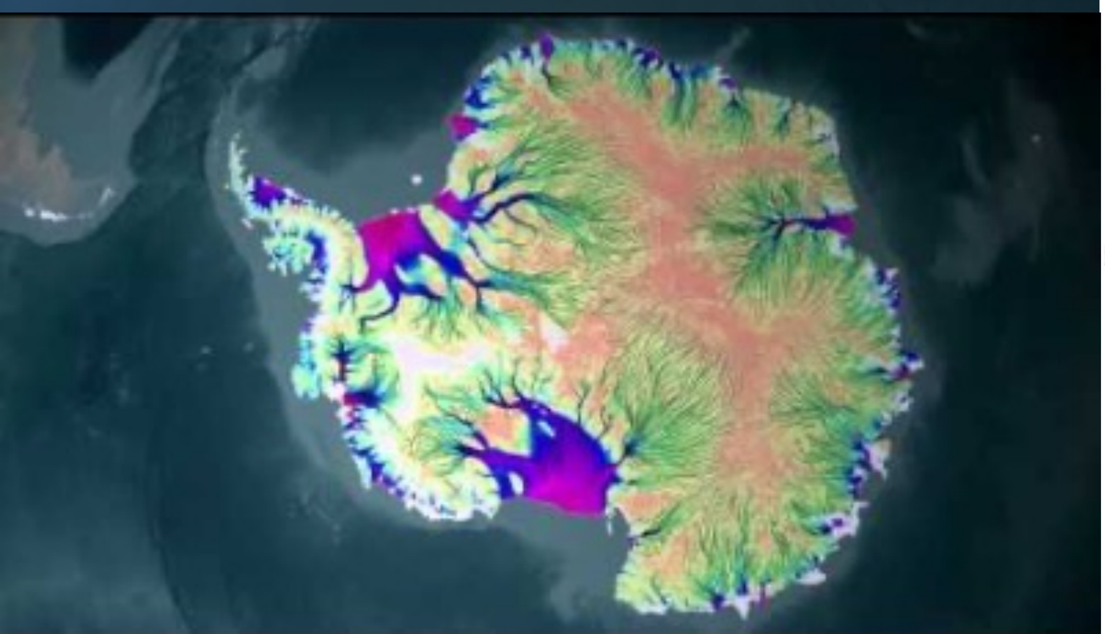
- It is stable at temperatire < 0ºC
- Its density (a 1ºC) is 917 g m^{-3}
- It flows like a very dense fluid
- It deforms in with ductile behavior (if the stress rate is low)

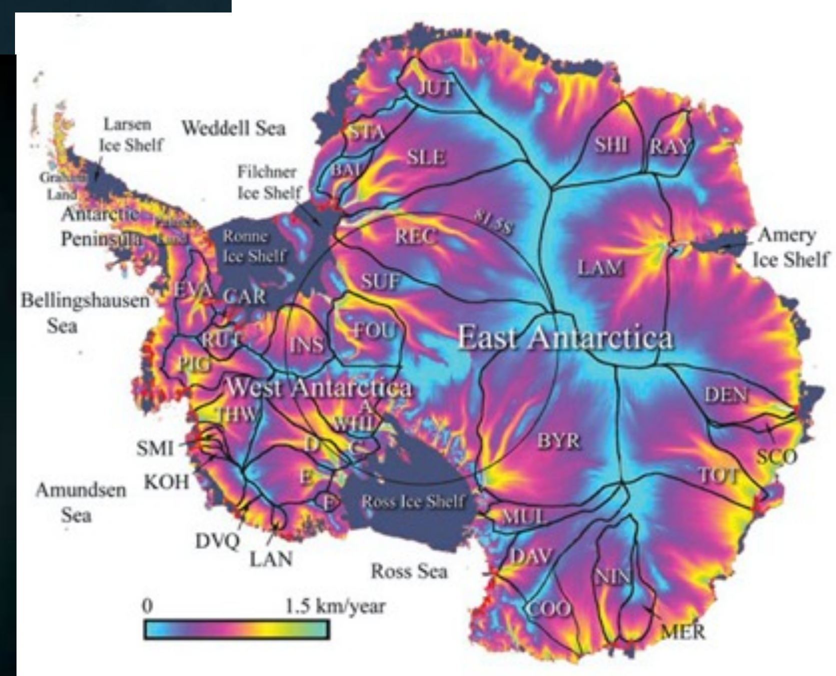
Ice accumulation and redistribution



Ice flow



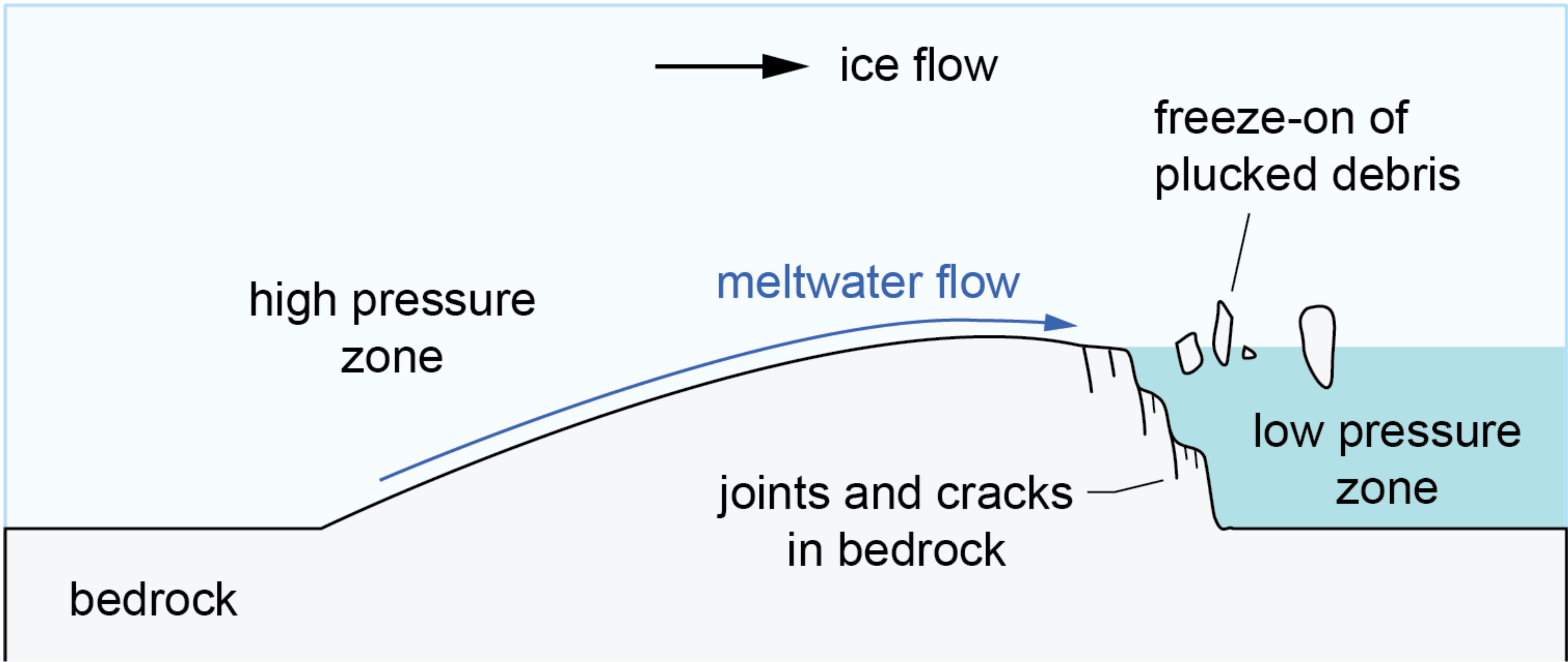



Larsen Ice Shelf
Weddell Sea
Filchner Ice Shelf
Antarctic Peninsula
Ronne Ice Shelf
Bellingshausen Sea
Amundsen Sea
Ross Sea
Ross Ice Shelf
Amery Ice Shelf
West Antarctica
East Antarctica
JUT
STA
SLE
BAI
REC
SUF
FOU
INS
RUT
EVA
GAR
PIG
THW
WHI
SMI
KOH
DVQ
LAN
SHI
RAY
LAM
DEN
SCO
TOT
BYR
MUL
DAV
NIN
COO
MER
0
1.5 km/year

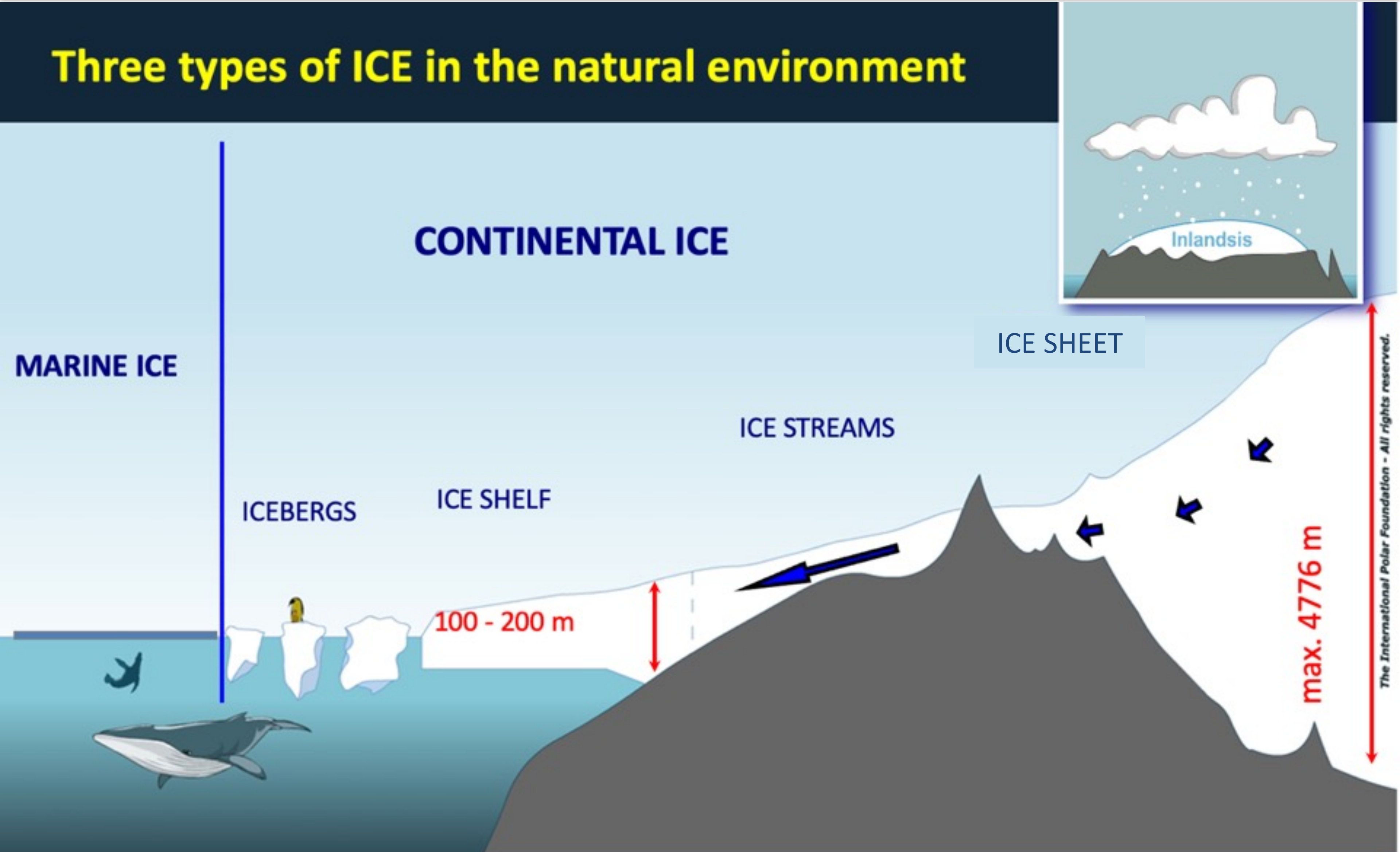
glacier flowing above a cavity beneath the ice on Mont Blanc glacier

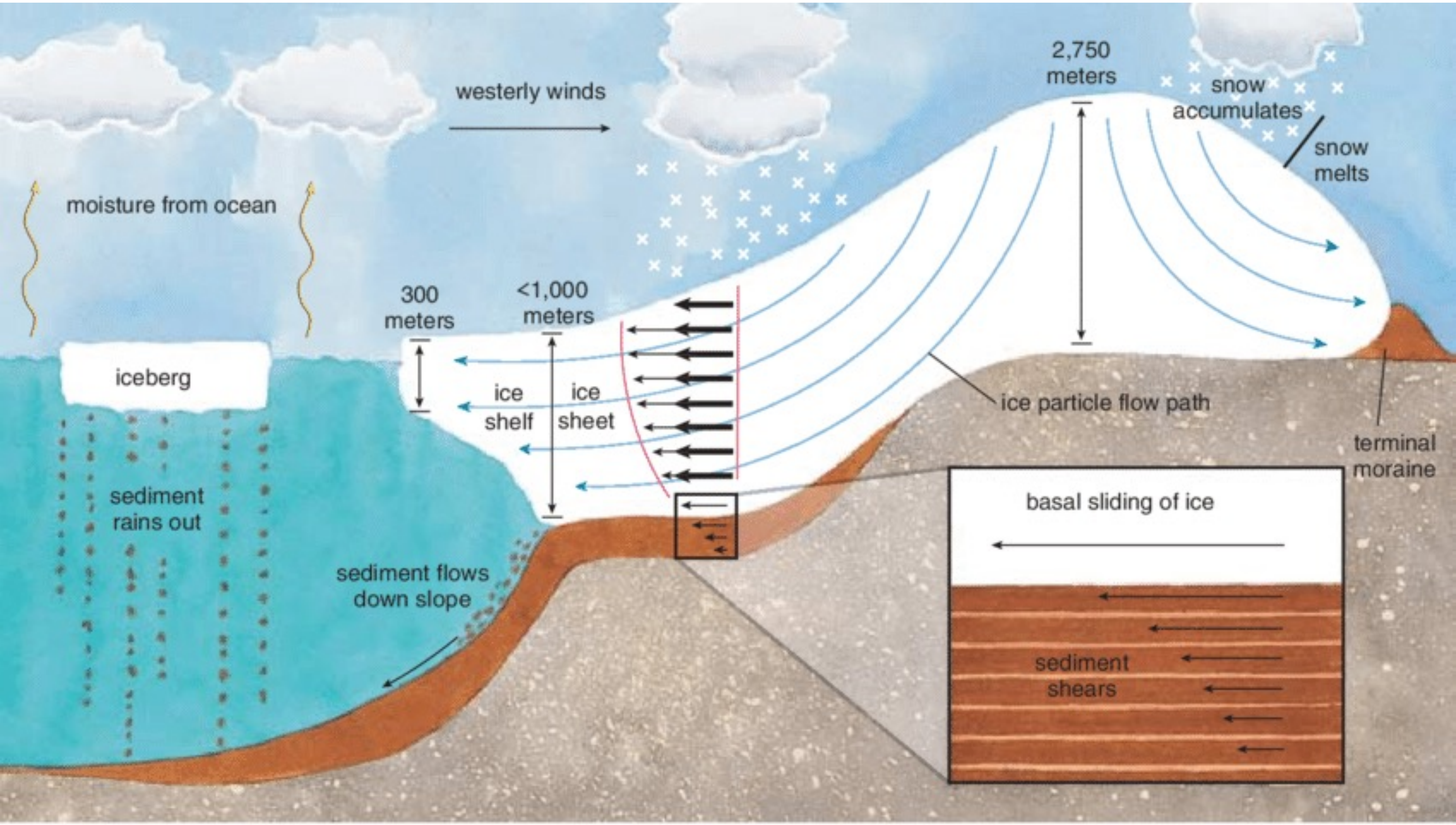
Glacial erosion (quarrying)

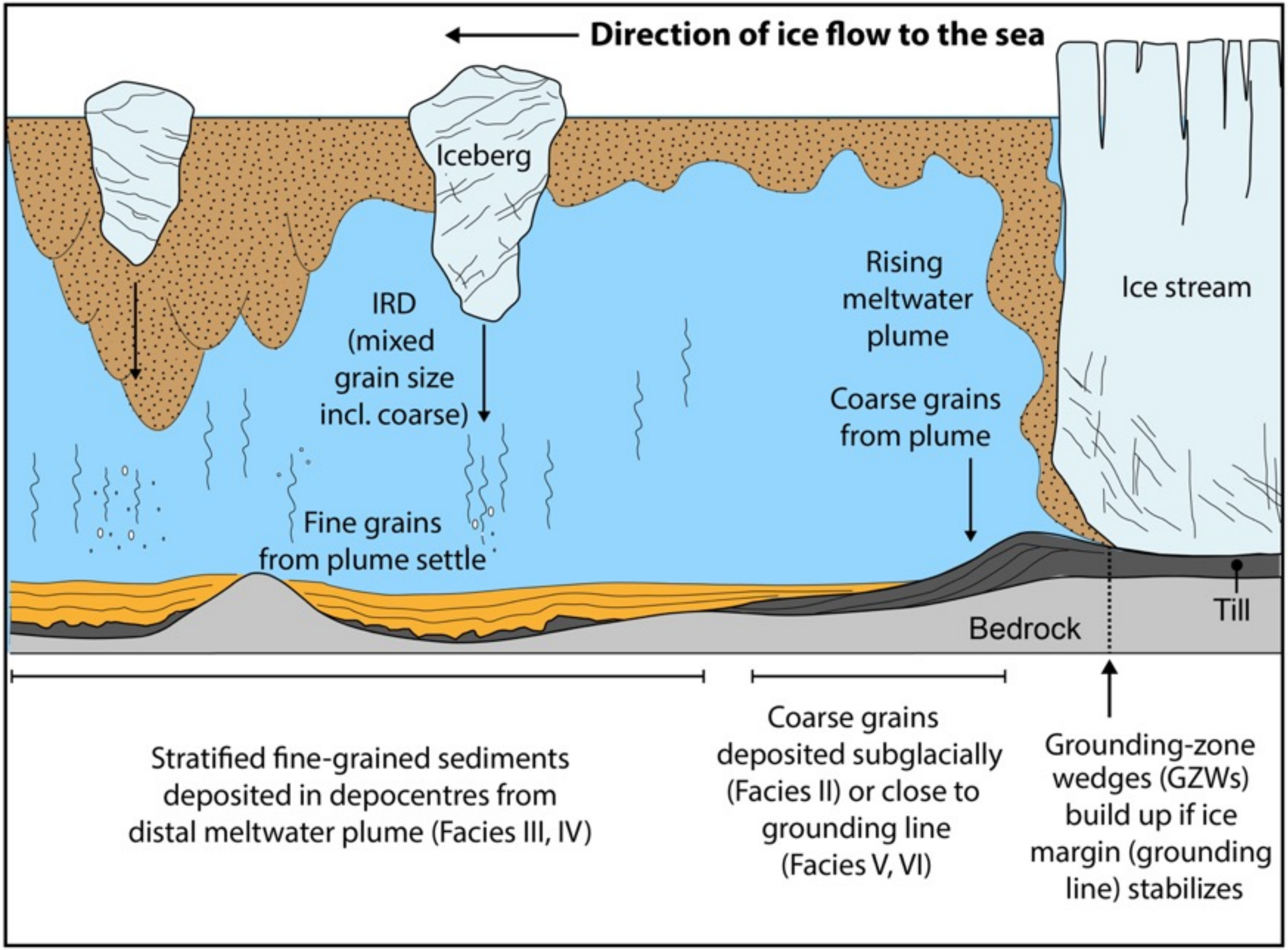
Freeze-on of plucked (quarried) debris in a low pressure zone at the downglacier end of a bedrock bump, due to refreezing of meltwater associated with regelation. Source: Jacob M. Bendle.

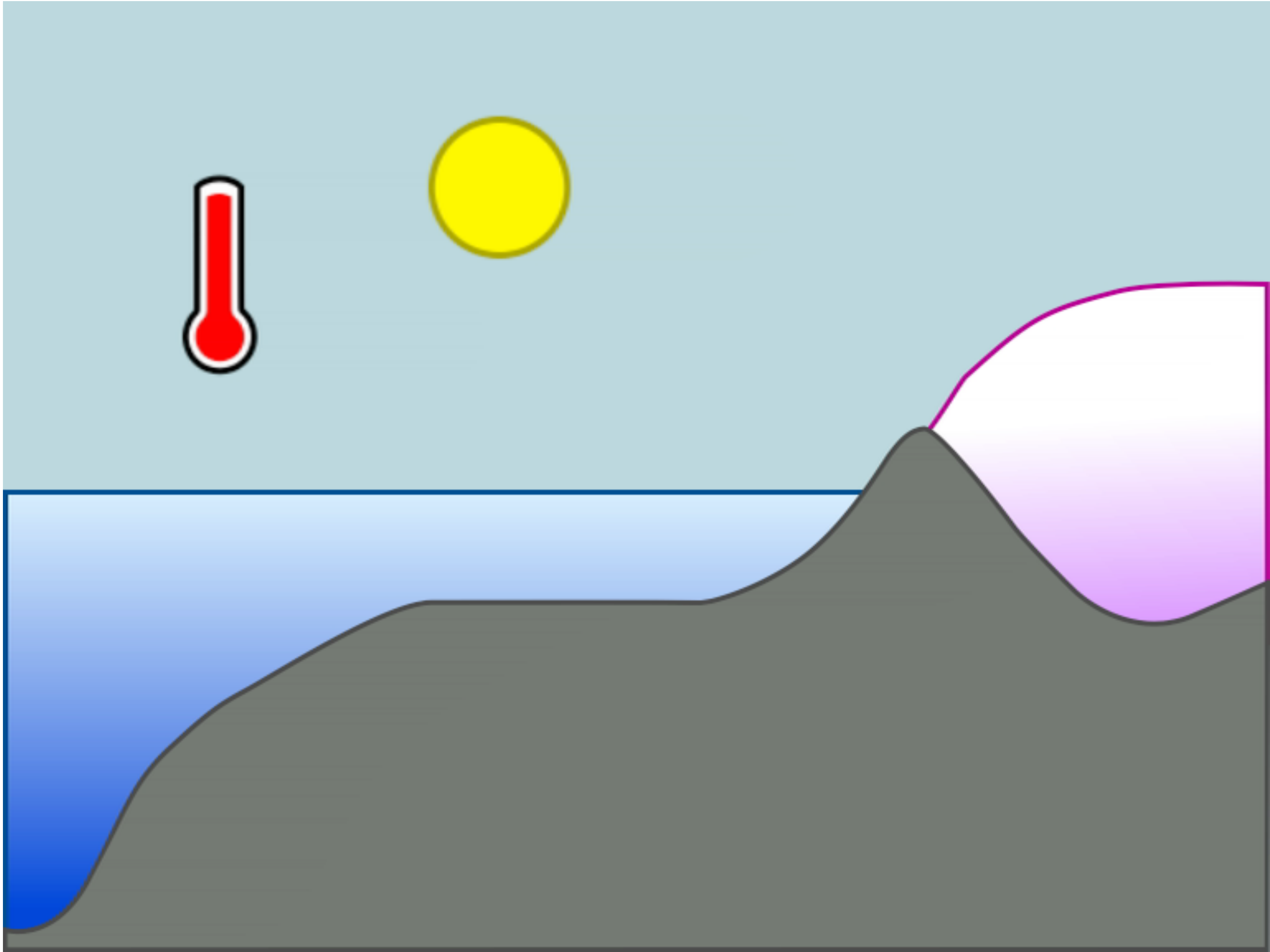


Three types of ICE in the natural environment



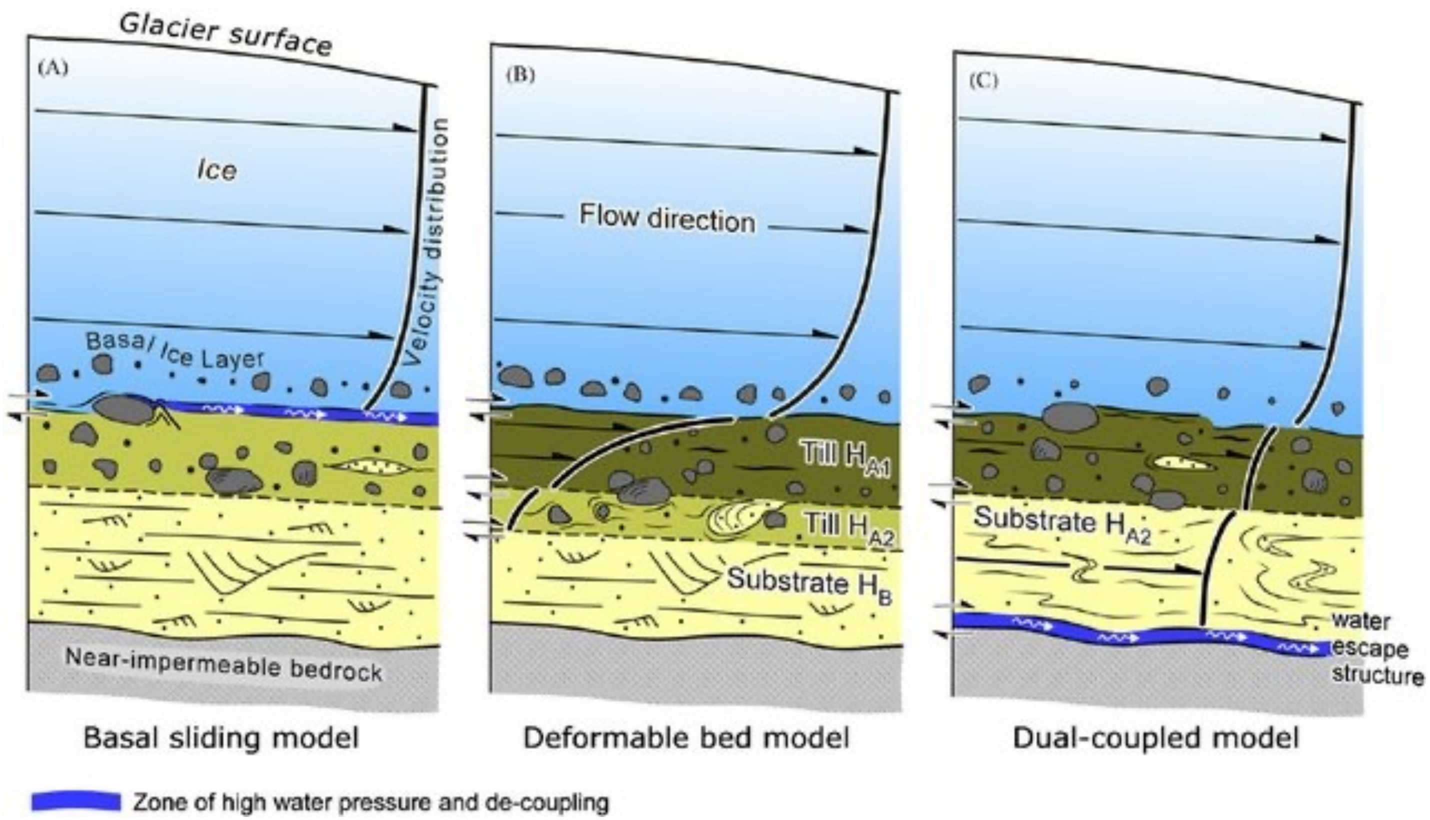

westerly winds
2,750 meters
snow accumulates
snow melts
moisture from ocean
300 meters
<1,000 meters
iceberg
ice shelf
ice sheet
ice particle flow path
terminal moraine
basal sliding of ice
sediment shears
sediment rains out
sediment flows down slope


Direction of ice flow to the sea
Iceberg
IRD
(mixed
grain size
incl. coarse)
Rising
meltwater
plume
Ice stream
Coarse grains
from plume
Fine grains
from plume settle
Bedrock
Till
Stratified fine-grained sediments
deposited in depocentres from
distal meltwater plume (Facies III, IV)
Coarse grains
deposited subglacially
(Facies II) or close to
grounding line
(Facies V, VI)
Grounding-zone
wedges (GZWs)
build up if ice
margin (grounding
line) stabilizes



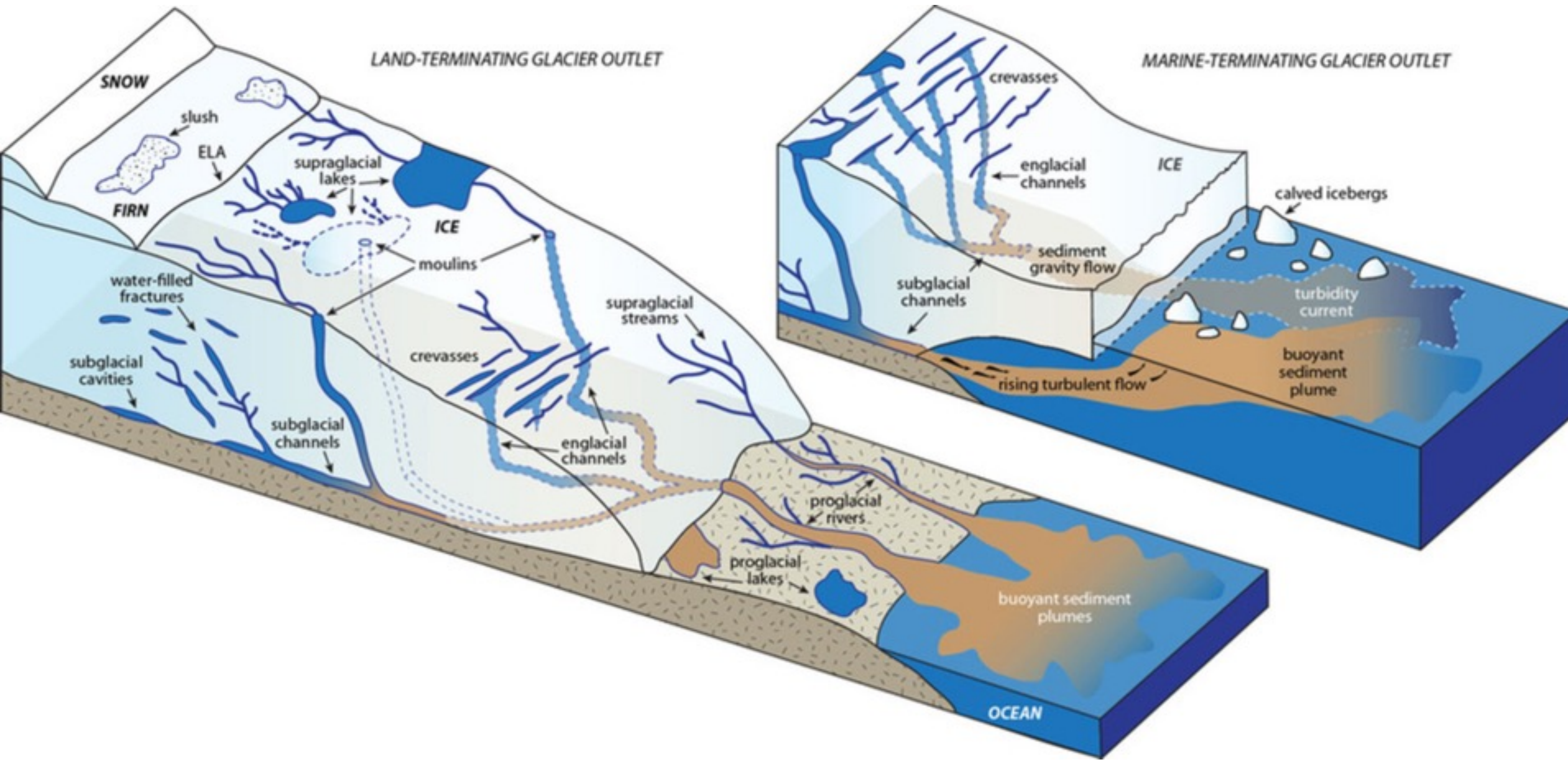
Basal motion models (ice streams)

(A) Decoupling is sustained by enhanced basal sliding across the glacier–till interface with limited or no subglacial deformation (Engelhardt and Kamb, 1998). (B) The glacier is coupled to its bed and fast ice flow is sustained through subglacial deformation of water-saturated sediment with a low effective pressure (Alley et al., 1989). (C) In the dual-coupled model the glacier is coupled to its bed as expressed in slow subglacial deformation, while the substrate is decoupled from the bedrock leading to fast ice flow and a substantial dislocation of sediments.



Kjær et al., 2006. Subglacial decoupling at the sediment/bedrock interface: a new mechanism for rapid flowing ice. Quaternary Science Reviews 25, 2704-2712

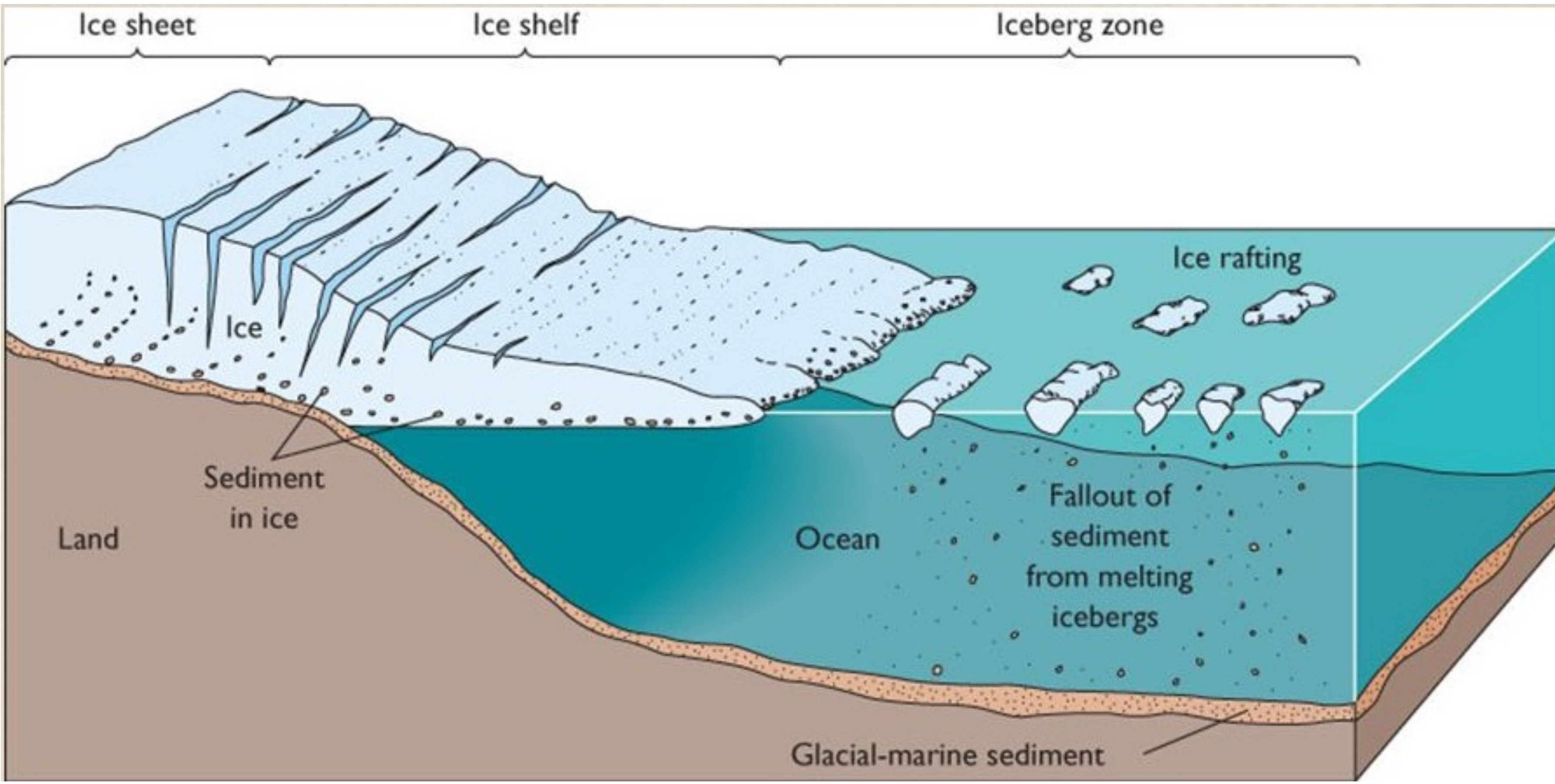
Meltwater



Elements of the Greenland ice sheet hydrologic system. Cuffey and Paterson (2010). The physics of glaciers. Fourth edition. Academic Press. 704 pp.

Ice rafting

The transportation of rocks and sediments of any size, by icebergs, ice floes, or any other form of floating ice. These may sit on top of the ice, be in the ice, or be frozen to the base of the ice.

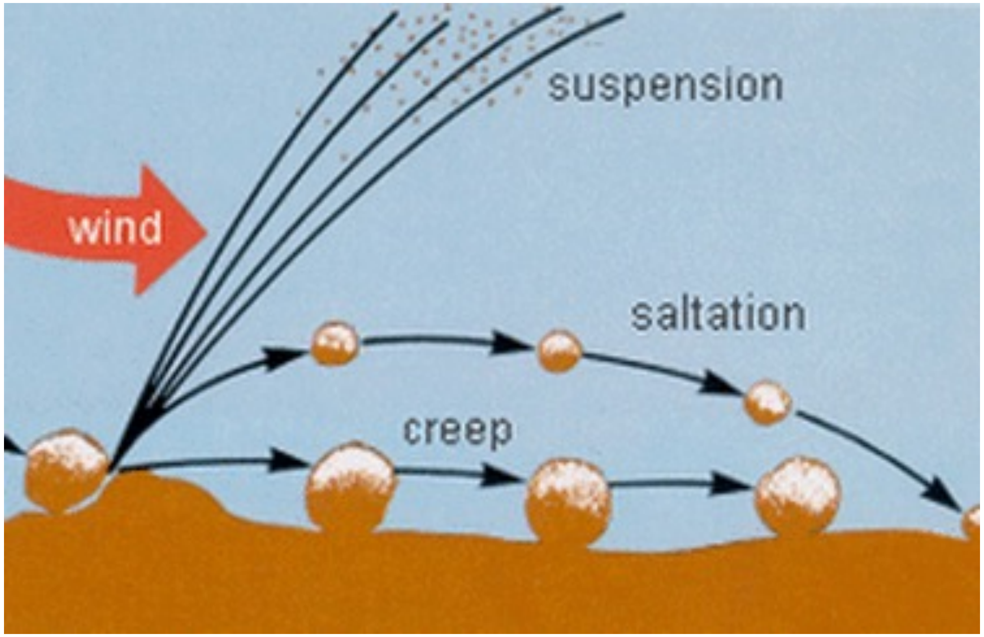


Winds

Aeolian transport

The power of wind to erode depends on particle size, wind strength, and whether the particles are able to be picked up. Wind transports small particles, such as silt, over great distances, even halfway an entire ocean basin. Particles may be suspended for days. Just like flowing water, wind transports particles as both bed load and suspended load. For wind, bed load is made of sand-sized particles, many of which are picked up and bounced along the ground (medium and coarse grained sand), referred to as saltation; or rolled or pushed (coarse sand and gravel), known as surface creep or just creep. The suspended load is very small particles of silt and and clay, transported via suspension.

The ability of wind to move material is small compared to the agents of water and ice, and this is because air is less dense and less viscous. The largest and smallest particles are the most difficult for wind to move; the largest because of weight (too heavy), and the smallest because of the internal cohesion caused by electrostatic forces.

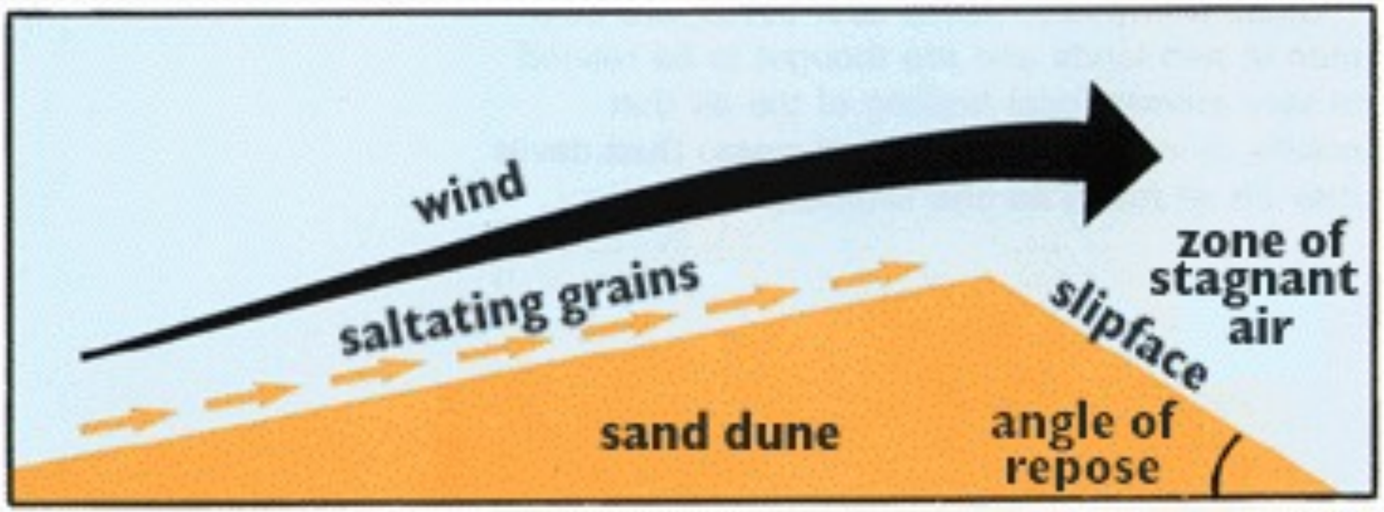


College of Marin, California

Dunes

A dune is wind-sculpted accumulation of sand and other loose material. Dune sands are usually uniform in size and shape. Particles are sand-sized, because sand particles are too heavy for the wind to transport by suspension. They are rounded, since rounded grains roll more easily than angular grains.

For sand dunes to form there must be an abundant supply of sand and steady winds. A strong wind slows down, often over some type of obstacle, such as a rock or some vegetation and drops its sand. As the wind moves up and over the obstacle, it increases in speed. It carries the sand grains up the gently sloping, upwind side of the dune by saltation. As the wind passes over the dune, its speed decreases. Sand cascades down the crest, forming the slip face of the dune. The slip face is steep because it is at the angle of repose for dry sand, about 34 degrees.



College of Marin, California

Loess deposits and wind-blown dust

Loess is eolian (deposited by the wind). During the Ice Age, glaciers advanced, grinding underlying rock into a fine powderlike sediment called "glacial flour."

As temperatures warmed, the glaciers melted and enormous amounts of sediment was deposited on flood plains downstream, creating huge mud flats. Eventually meltwaters would recede, leaving the mud flats exposed. As they dried, fine-grained mud material (silt) was picked up and carried by strong winds and redeposited over broad areas.

View over the western Chinese Loess Plateau

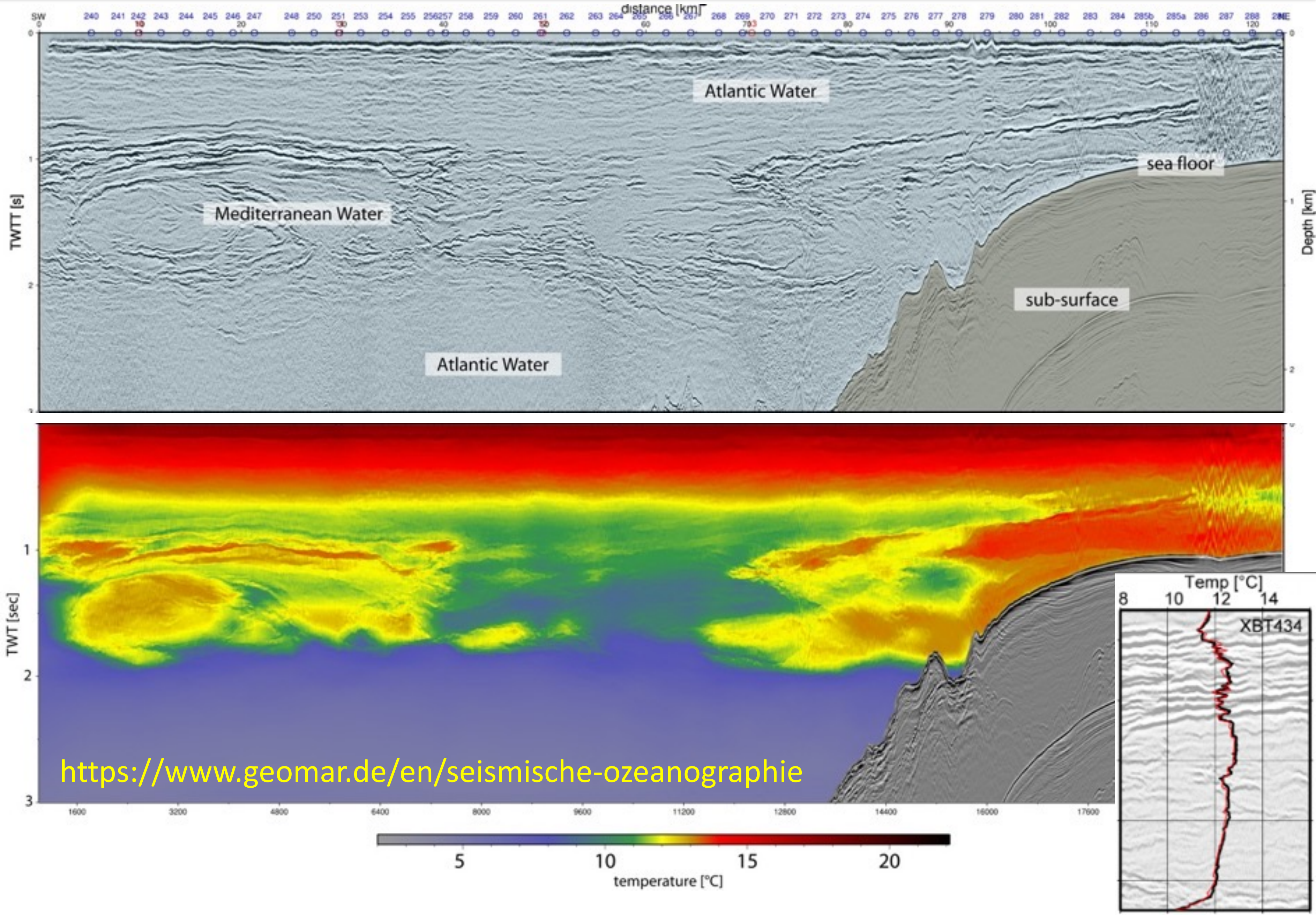
Esercitazione

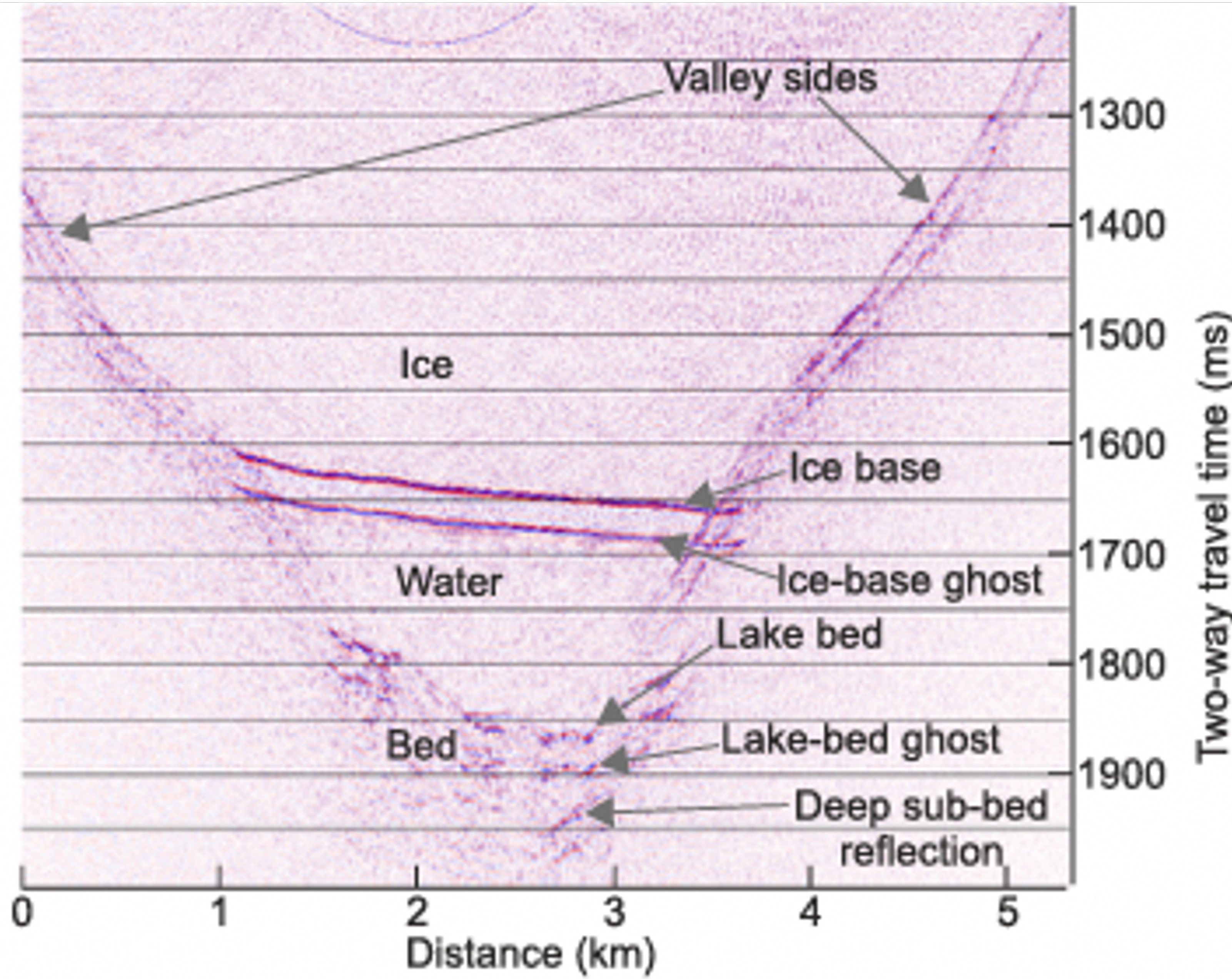
Vi mostro tre profili «particolari»

Chissà se indovinate di cosa si tratta?

Ma ricordate, prima di tutto si osserva e si descrive!

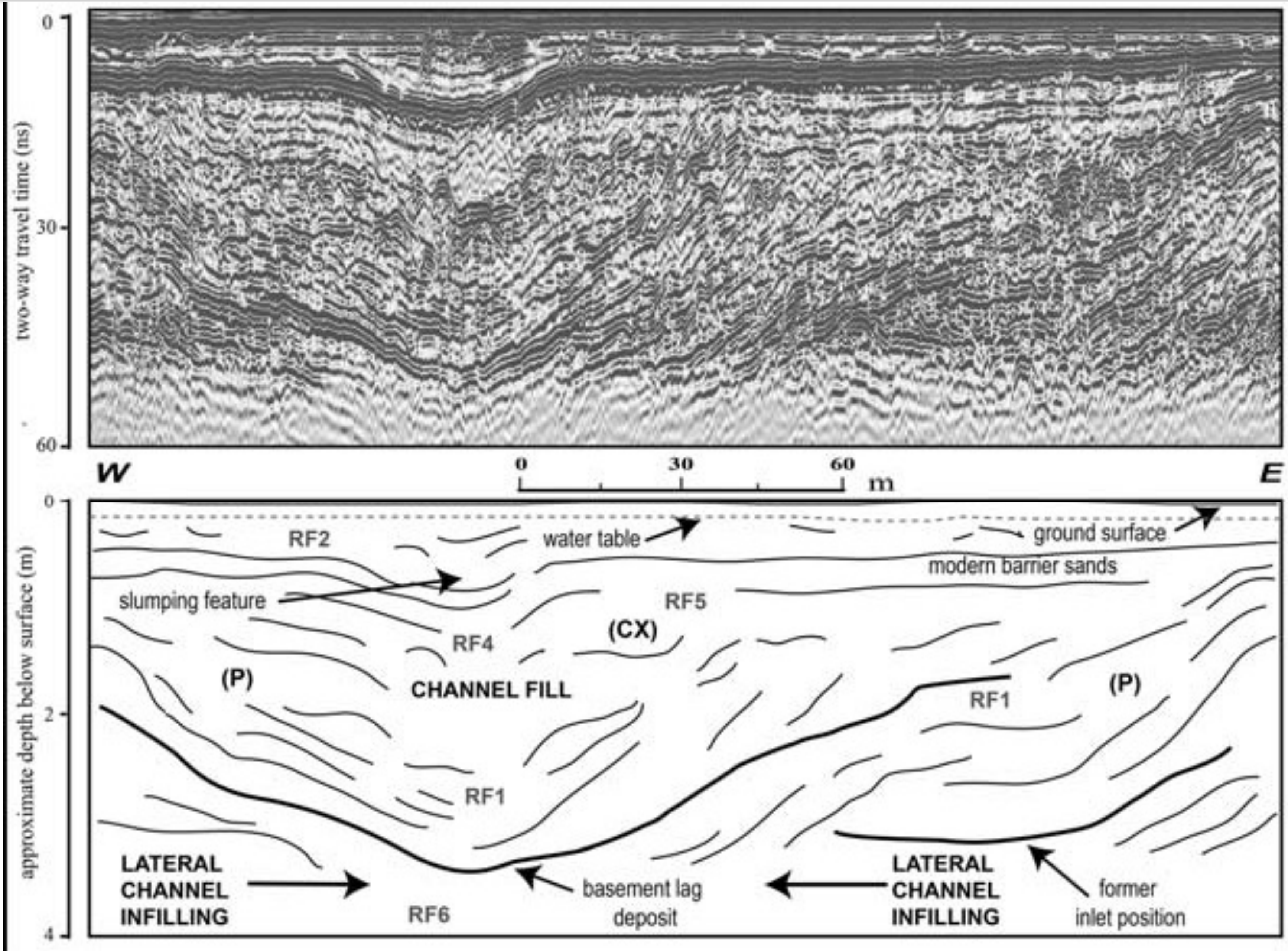
Questo vale anche e soprattutto per la definizione delle facies (quarto esercizio)


distance [km]
SW
NE
TWT [s]
Depth [km]
Atlantic Water
Mediterranean Water
sea floor
sub-surface
Atlantic Water
TWT [sec]
Temp [°C]
8
10
12
14
XBT434
https://www.geomar.de/en/seismische-ozeanographie
1600
3200
4800
6400
8000
9600
11200
12800
14400
16000
17600
5
10
15
20
temperature [°C]

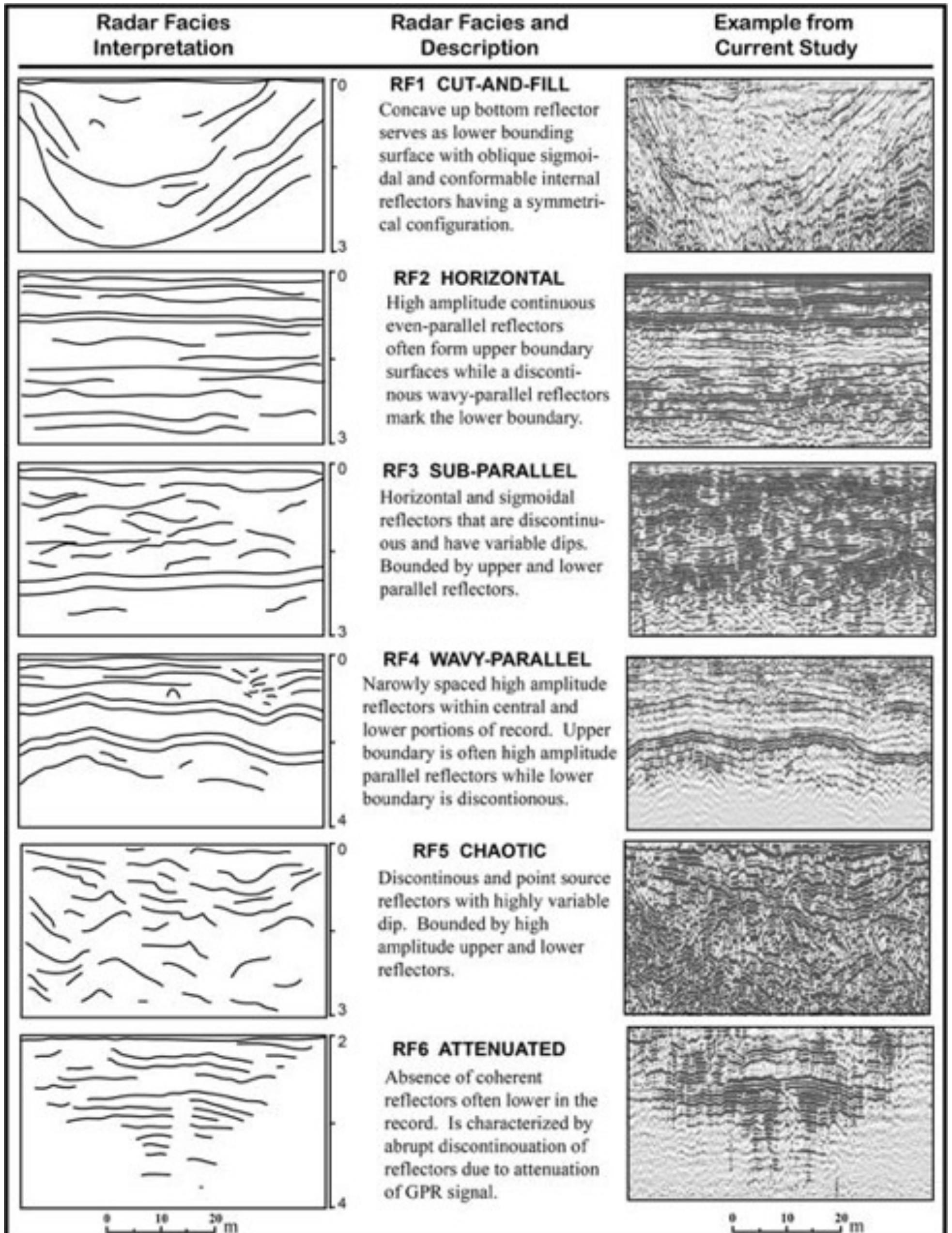


Smith et al., 2018 (EPSL) Evidence for the long-term sedimentary environment in an Antarctic subglacial lake

Processed seismic reflection section covering the Ellsworth subglacial lake, with the main reflections identified.



ground-penetrating radar data on a Barrier System



Maio, C.V., Gontz, A.M., Sullivan, R.M., Madsen, S.M., Weidman, C.R., Donnelly, J.P. (2016)
Subsurface Evidence of Storm-Driven Breaching along a Transgressing Barrier System, Cape Cod, U.S.A.
Journal of Coastal Research, 32 (2), pp. 264-279.