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Lecture 4: Rocky coasts

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Colin Woodroffe (2002) "Coasts: Form, Process and Evolution", Outline of Chapter 4:

Chapter 4. Rocky Coasts

L4/2

General features (often true – but not always)

-- Resistant
-- High energy
-- Steep
-- Slow evolution

-- Platforms or notches associated with wave action
-- Talus

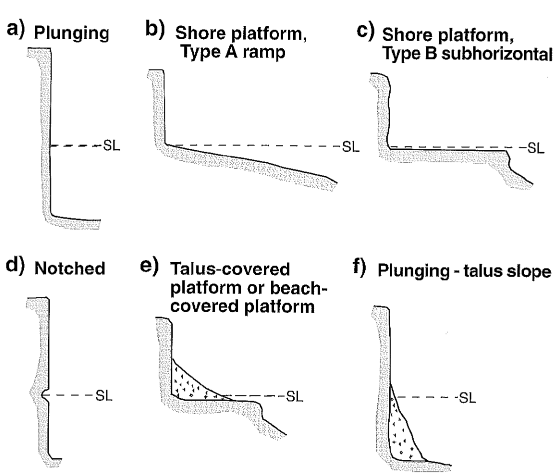


Figure 4.1. Major types of cliff and shore platform.

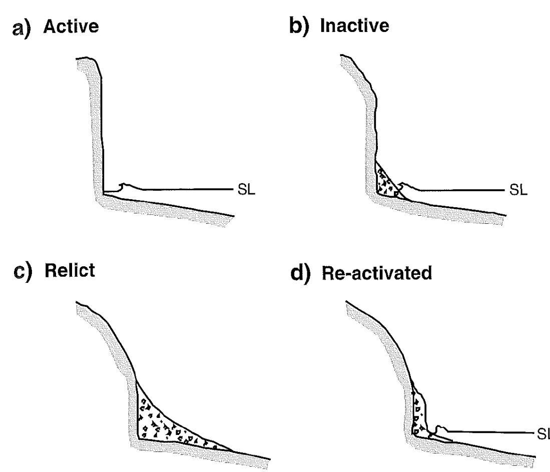


Figure 4.2. Cliff types in terms of activity (based on Emery and Kuhn, 1982).

4.1. Historical Perspective

4.1.1. Darwin, Dana and Davis

Lyell (1832) – Platforms at base of rocky shorelines are cut to wave-base.
Darwin (1846), Dana (1849) – Platforms cut to wave breaking depth.
Davis (1928) – Subsidence (or sea level rise) needed for rapid platform formation.
King (1930, 1963) – Uplifted rocky shore platforms indicate past shorelines.

4.1.2. Lithology and Weathering

Archer (1911) – "Slope-over-wall" – Waves cut vertical cliff into sub-aerially weathered slope.
Savigear (1952) – Abandoned wave-cut cliffs sub-aerially weather to more gentle slope.
Edwards (1958) – Resistant rocks protrude; soft rocks erode faster.
Tricart (1962) – Protruding cliffs are more likely in dry climates, gentle cliffs in wet climates.
Bartrum (1916-1938) – Platform lowering by intertidal weathering.

4.2. Plate-Tectonic Setting and Wave Planation

4.2.1. Plate-Tectonic Setting

Collision coasts – Uplift leads to preserved subaerial marine terraces.
- N. /S. American west-coast terraces weather away in ~1,000,000 yrs.
- Coral terraces are very useful for dating sea level high-stands.

Passive margin – Uplift less common, but uplifted terraces associated with glacial rebound.
- Very fast glacial rebound limits cliff cutting because waves don't have time to act.
- Basement rocks are more likely to be cloaked in sediment.
- Characteristic cliff patterns (alternating headlands/bays) occur mainly along-shore.

4.2.2. Shelf Abrasion and Island Planation

Stable tectonics leads to very large platforms (1000 km x 10 km along east Australia).
Mid-plate islands are ringed by broad, horizontal terraces, indicating tectonic stability.
Wave-planed islands eventually subside leaving guyots.
New islands may be cut at 10s of meters per year; old coasts may have terraces reoccupied.
Coral can protect islands where coral is regenerated faster than it erodes.

4.3. Cliff and Shore Platform Morphology; 4.3.1. Planform of Rocky Coasts

Concordant coast – parallel to geological structure (e.g., N./S. America at large scales).
Discordant coast – across geological structure (e.g., N./S. America at small scales).
Role of bed dip – Dip away from coast more stable; dip toward coast leads to landslides.
Caves, Blowholes, Arches, Tunnels, Stacks – resistant rock with narrow zones of weakness (cracks, fissures, cleavage, joints, faults, folds).

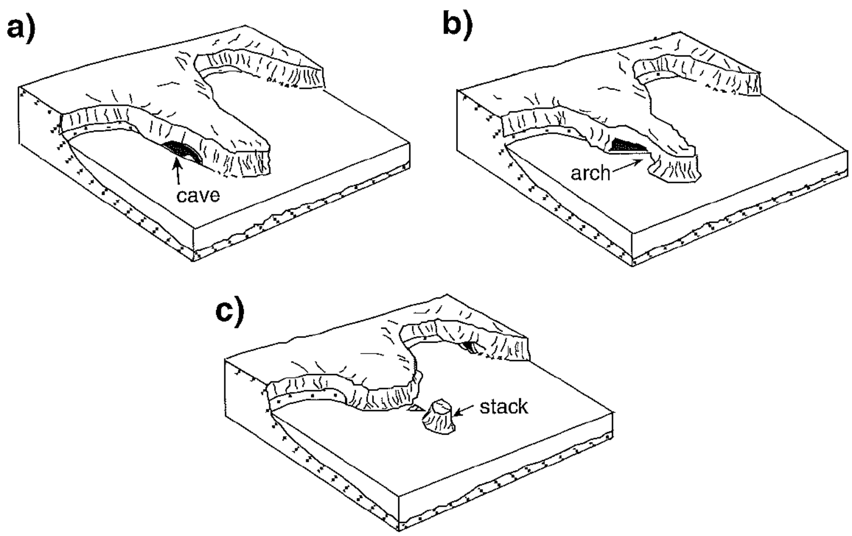


Figure 4.5. Progressive formation of sea cave, arch and sea stack on an eroding cliff shoreline

4.3.2. Cliffs in Profile

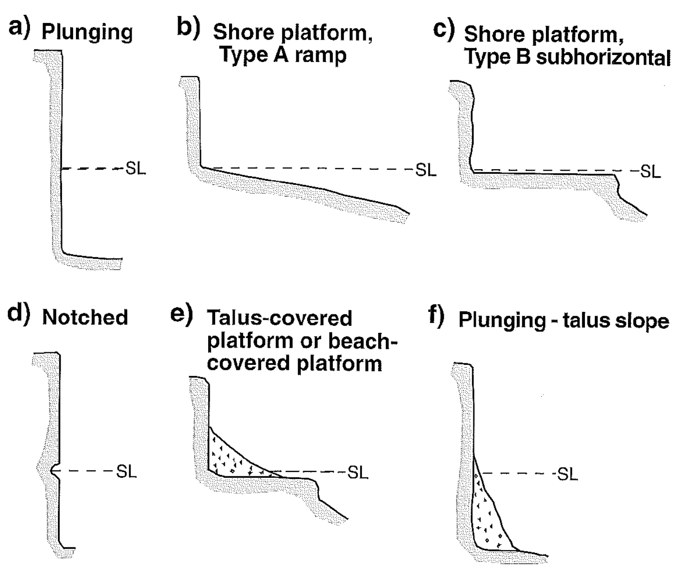


Figure 4.1. Major types of cliff and shore platform.

a) Plunging – Very resistant rock, may involve faulting or drowning.
b) Platform ramp – wave cutting in less resistant rock or abrasion by cobbles, or macrotidal.
c) Horizontal platform – relatively resistant and ≤ mesotidal.
d) Soft rock or wave/bio-enhanced dissolution (limestone).
e) More rubble than can be removed by waves.
f) Dominance by tectonics and production of rubble.

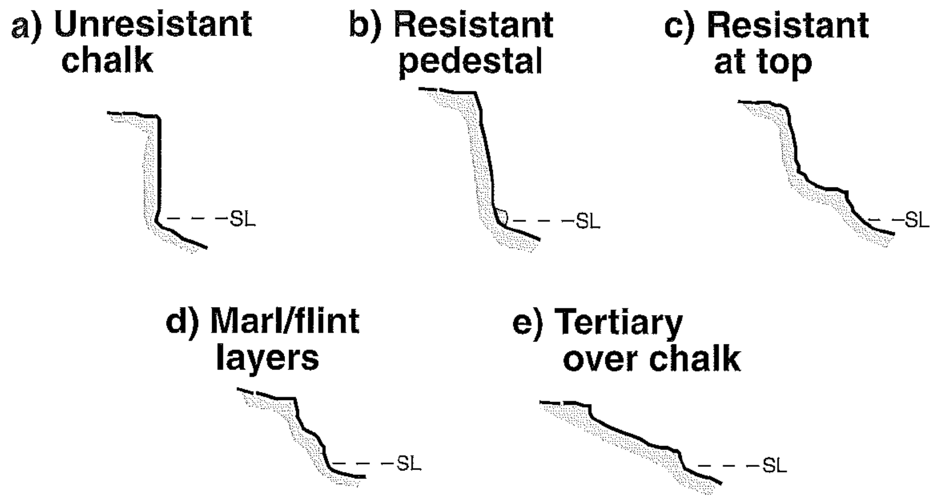
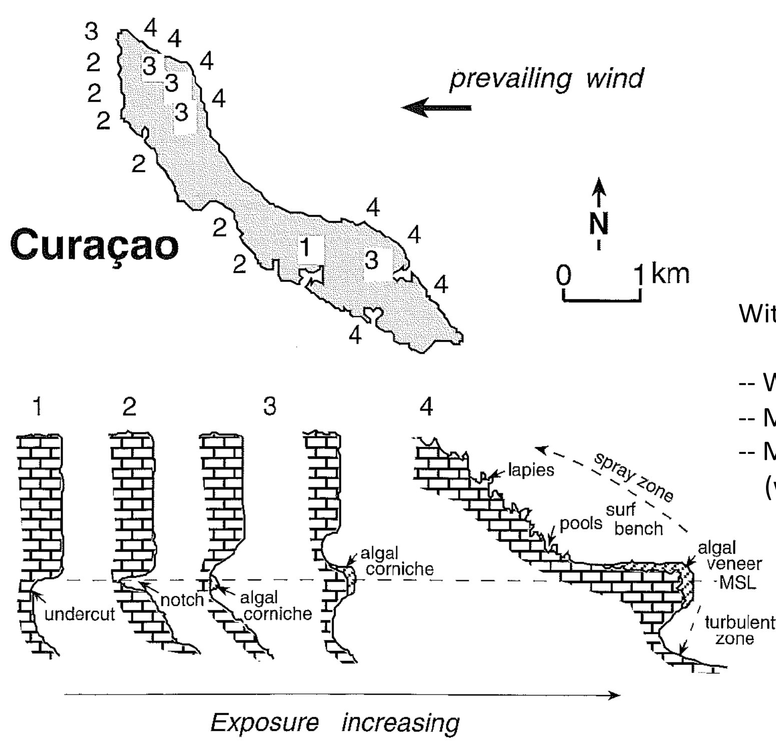


Figure 4.8. Cliff profile types in chalk characteristic of the coast of southern England and northwest France (based on Prêcheur, 1960; May and Heeps, 1985).

a) Weak (steep, notched with ramp).
b) Slower retreat allows for subareal erosion and rounded cliff.
c) Middle, weak layer erodes fastest.
d) Alternating weak and resistant layers.
e) Landslides may cause gentle slopes, especially with clay layers.

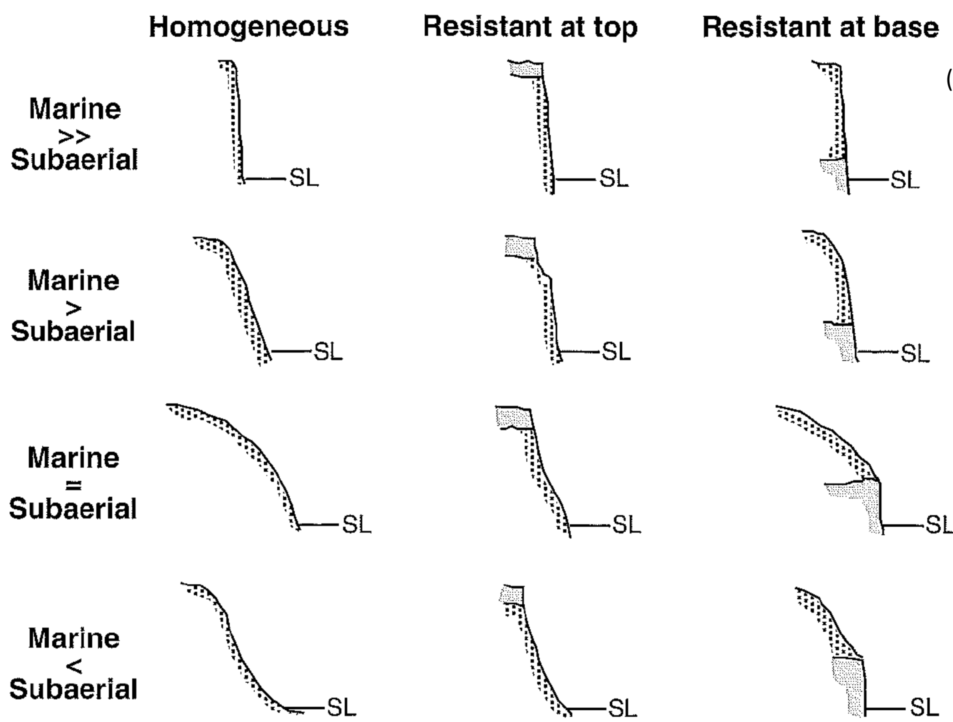


With increased waves:

-- Wider zone of impact
-- More algal growth
-- Multiple bioerosion zones (waves plus boring may drive dissolution)

Figure 4.9. Coastal morphology on tropical limestone coasts around the island of Curaçao in relation to biodegradation and water turbulence which is a function of wave energy (based on Focke, 1978a,b). 1, sheltered; 2, leeward; 3, lateral (intermediate); and 4, windward.

Relative Effectiveness of Marine vs. Subaerial Processes of Erosion: L4/9



(Woodroffe Fig. 4.13)

Timing matters too – ancient subaerial followed by recent marine erosion = "polygenic"

L4/10

"Subaerial" physio(bio)chemical weathering – salt, chemical, boring

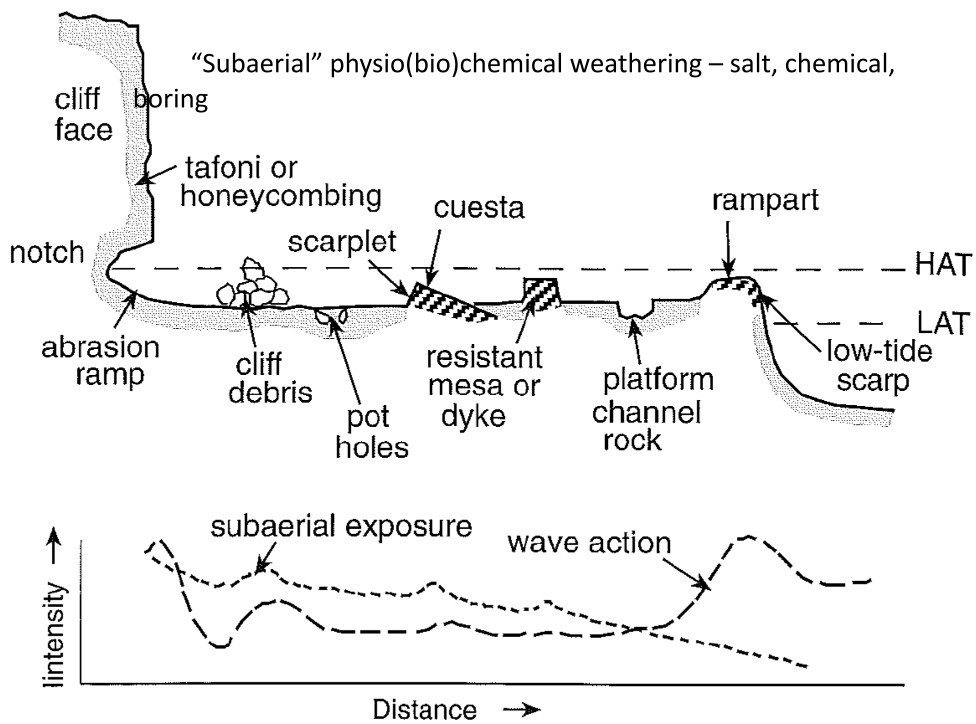


Figure 4.15. Schematic cross-section of a subhorizontal (Type B) shore platform.

4.4. Processes and Rates of Erosion; 4.4.1. Operative Processes

Hydraulic wave action
- – Alternating increase and release of hydrostatic pressure
- -- Dynamic pressure of breaking, non-breaking shocks (e.g., water hammer)
- -- Pneumatic stresses (e.g., air compression)

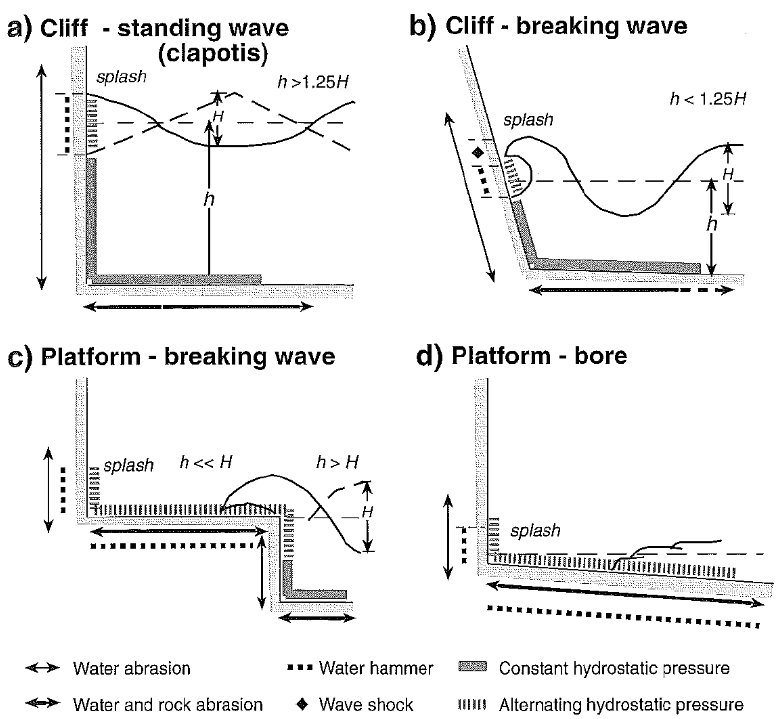
Mechanical wave action
- -- Abrasion with sediment particles (e.g, potholes, attrition, etching) including talus.

Physiochemical action
- -- Honeycombing/tafoni = pitting from halite crystal growth
- -- Ponded water/water layer weathering and dissolution
- -- Thermal wetting/drying stress; freeze/thaw stress

Biological action
- -- Bioerosion (e.g., boring and dissolution enhancement, etching by grazers)
- -- Protection by biocoating (e.g., coralline algae, some gastropods and worms)

Subaerial slope processes
- -- gentle slope: creep, slope wash
- -- steep slope: toppling, sliding
- -- more lithified: block fall, slips, slumps
- -- less lithified: avalanches, mudslides, spalling, slumps, landslides
- -- triggers: marine undercutting, groundwater, rainwater, tectonics

4.4.2. Relation of Process to Morphology

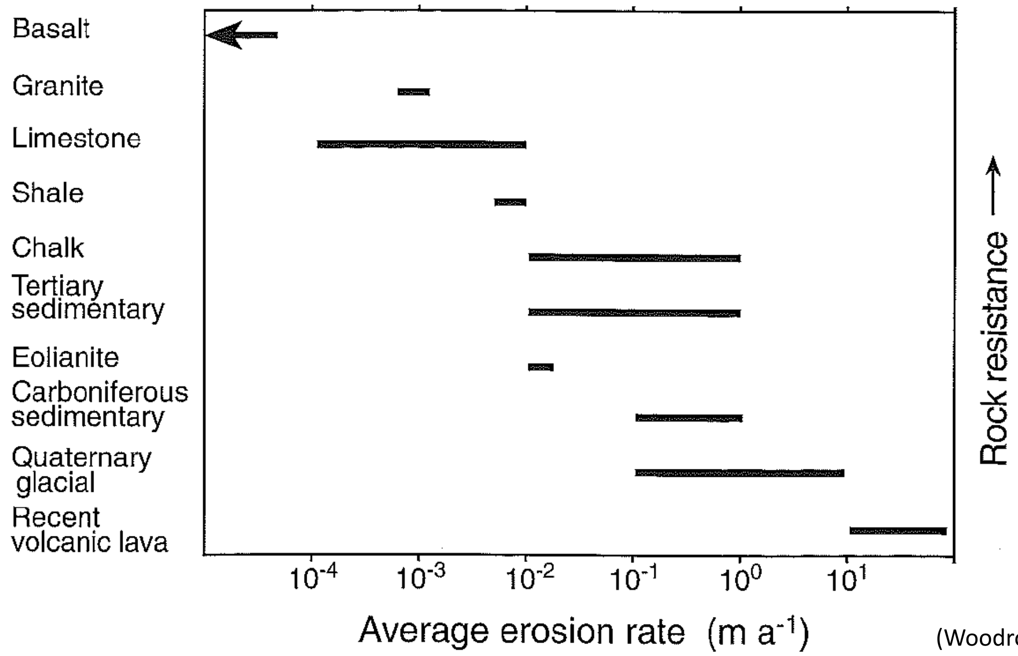


a-b) Plunging cliffs

c-d) Shore platforms

Figure 4.17. Relationship between wave form and cliff or platform morphology, and the processes that operate.

4.4.3. Cliff and Shore Platform Erosion Rates



(Woodroffe Fig. 4.18)

4.5. Cliff Morphodynamics; 4.5.1. Wave Energy and Rock Resistance

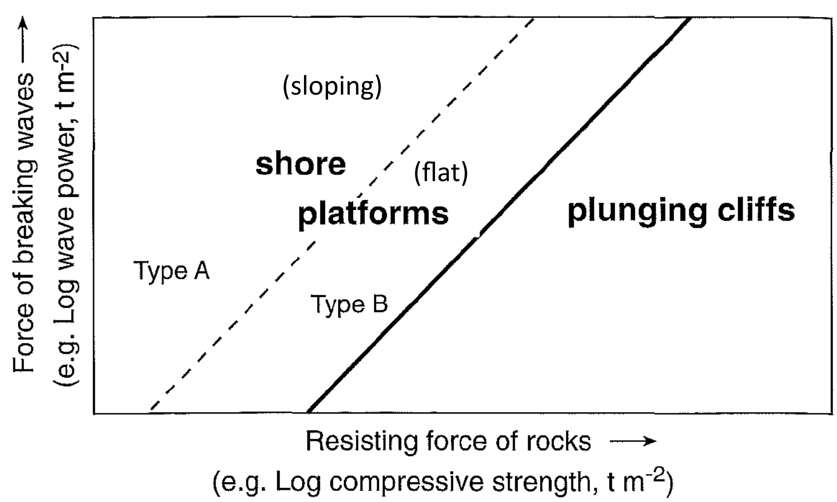
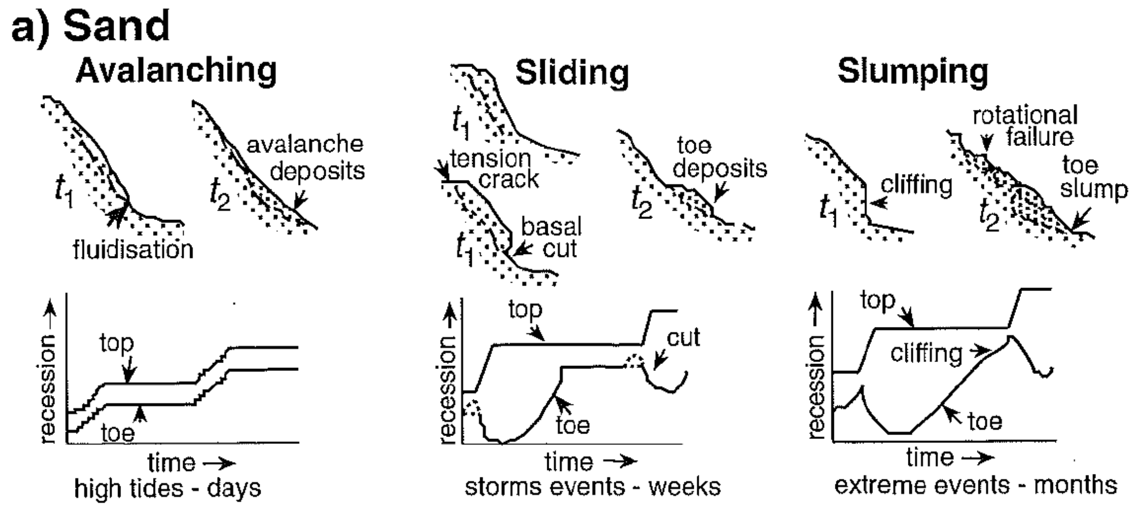


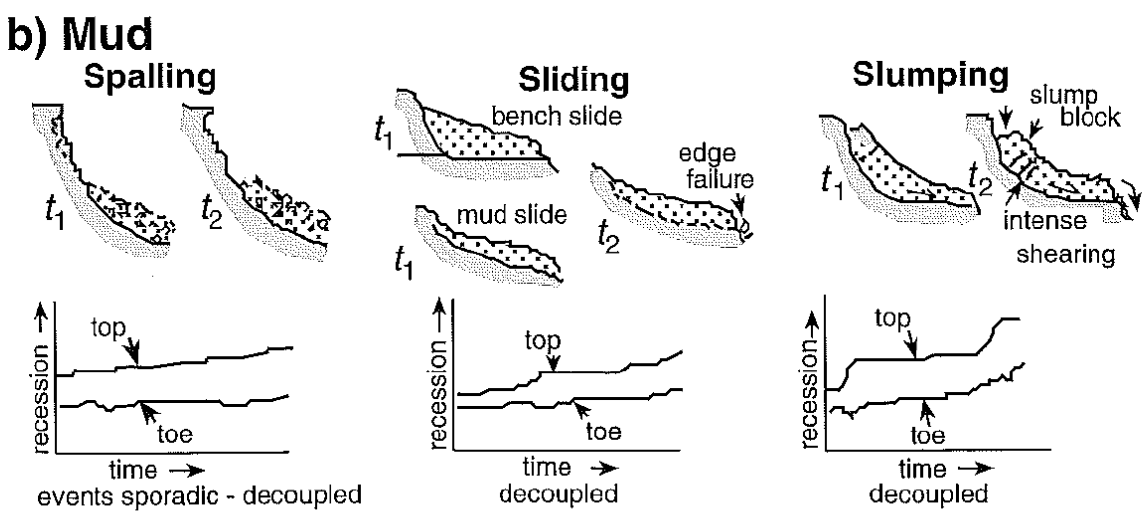
Figure 4.20. Generalised relationship between erosive force of waves and resisting force of rock, and the discrimination of plunging cliffs, and shore platforms (based on Sunamura, 1992). See text for discussion.

Limitations – Cliff recession is extremely episodic; very hard to simulate in laboratory; very hard to quantitatively observe in field (rare and high energy).
Vertical platform erosion more tractable – 0.4 to 2 mm/yr.
Equilibrium – Uplift and platform erosion; wave dissipation across platform.

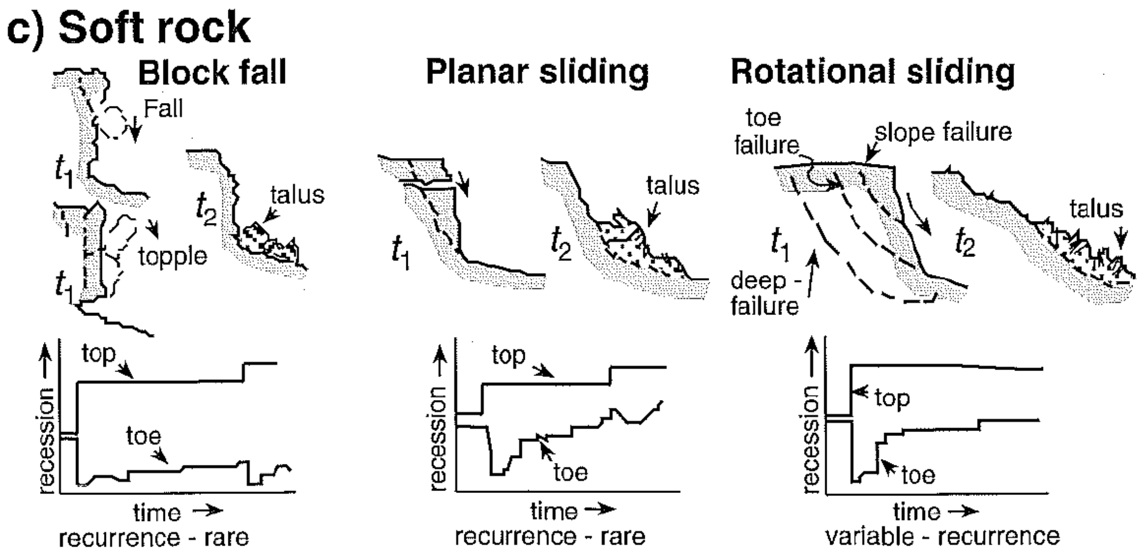


(Woodroffe
Fig. 4.22)

Sliding vs. slumping has to do with how often it occurs (often vs. less often), shape of failure surface (more flat vs. more curved), how far it detaches (more vs. less), how jumbled the moving material becomes (more vs. less) and size (smaller vs. larger). But they are almost the same thing.



(Woodroffe
Fig. 4.22)



(Woodroffe Fig. 4.22)

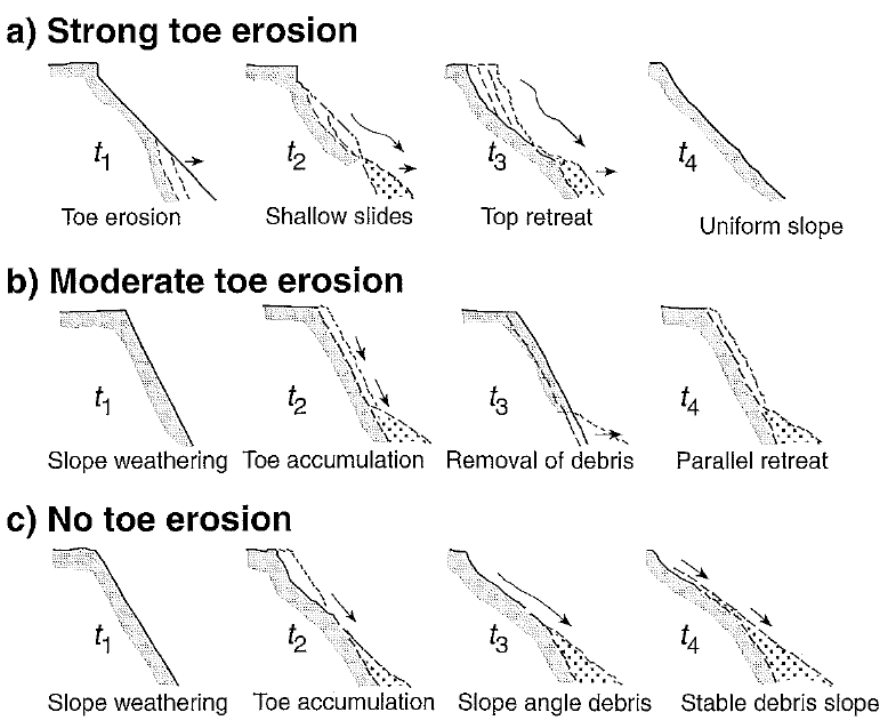


Figure 4.23. Model of the response of cliff retreat to rate of toe erosion (based on studies of glacial bluffs in the Great Lakes by Vallejo and Degroot, 1988).