UNIVERSITÀ
DEGLI STUDI DI TRIESTE

Anno accademico 2020-2021

Erosione, alterazione e forme associate

L'evoluzione dei paesaggi

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DEGLI STUDI DI TRIESTE

Programma della lezione

- Definizione di *weathering* (**alterazione/degradazione meteorica**), *erosion* (**erosione**) e *denudation* (**denudazione**)
  - *Mechanical weathering* (**alterazione/degradazione meccanica**)
  - *Chemical weathering* (**alterazione/degradazione chimica**)
  - *Biological weathering* (**alterazione/degradazione biologica**)
- Erosion (**erosione**)
- Tassi di erosione costiera e continentale

Definizione

Weathering and erosion

Processi di degradazione ed erosione

- La degradazione/alterazione delle rocce (*Weathering*) è il processo di alterazione delle rocce per via chimica o fisica in risposta alle condizioni ambientali; è una conseguenza dell'esposizione delle rocce all'ambiente. Si divide in:
  - **degradazione chimica (***chemical weathering*), ovvero il processo che demolisce la roccia per alterazione della sua struttura mediante qualsiasi modificazione chimica;
  - **Degradazione meccanica, o fisica** (*mechanical, or physical weathering*) è un processo che demolisce la roccia senza causare alterazioni chimiche
  - Degradazione biologica (*biological weathering*) coinvolge sia processi chimici che meccanici a carico degli organismi

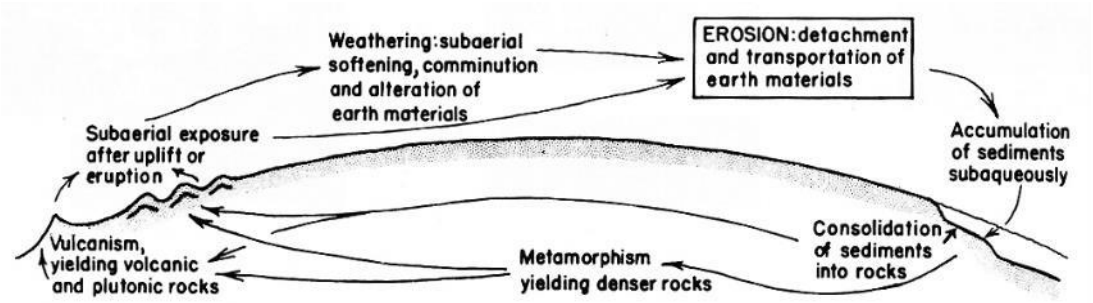
- Erosione (*erosion*) è la distruzione e la rimozione delle rocce a carico delle stesso tipo di forze. L'erosione implica il movimento.

- Denudazione (*denudation*) è la somma dei processi di alterazione ed erosione. Il risultato è l'abbassamento delle superfici topografiche.

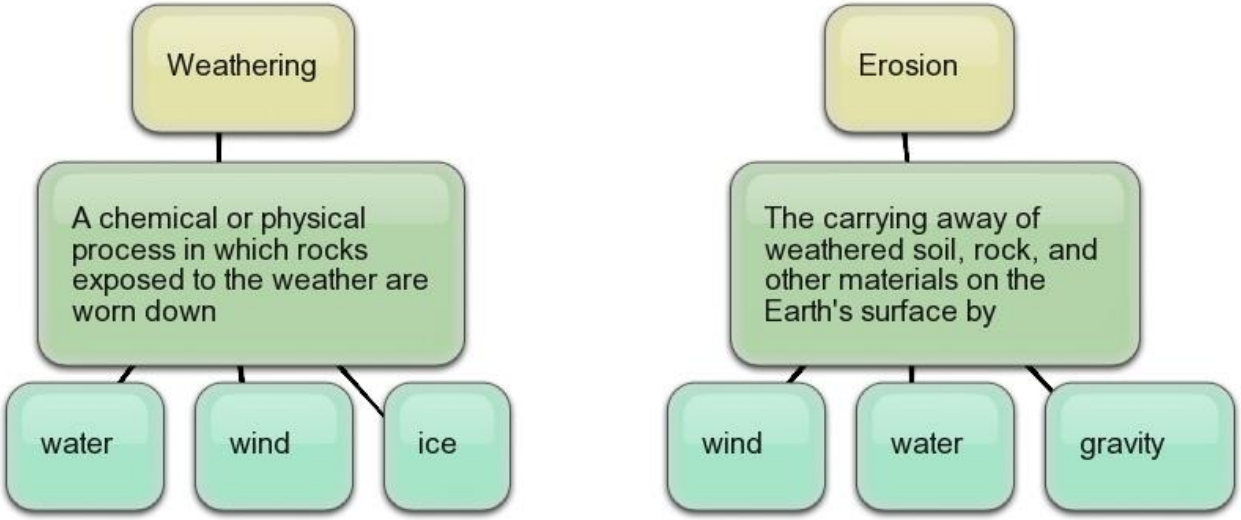
Qual è la differenza?

- La degradazione interessa processi *in situ*

- L'erosione coinvolge lo spostamento di parti di roccia alterata o integra

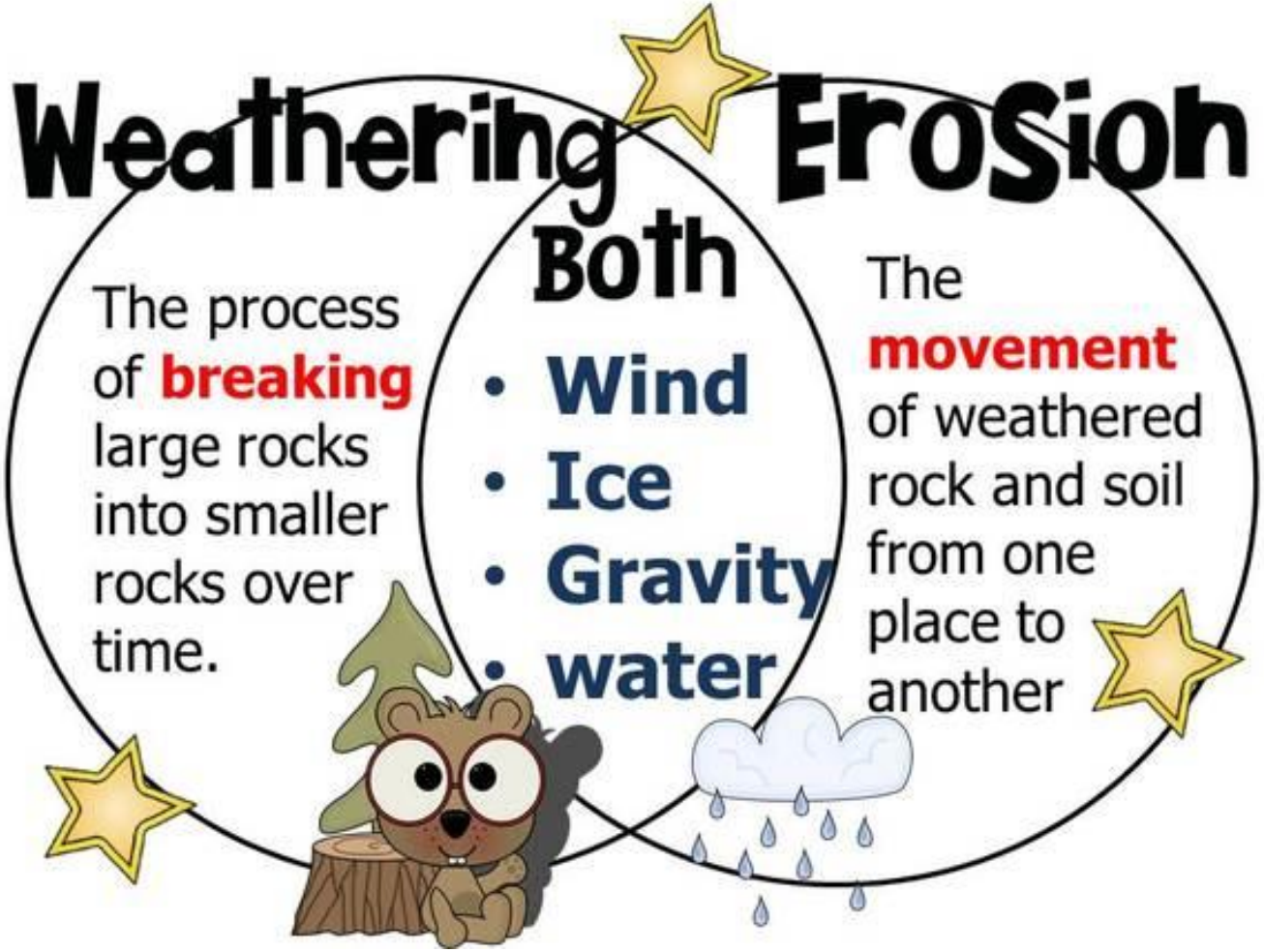


Relazione tra processi geomorfologici (da Fairbridge, 1965)

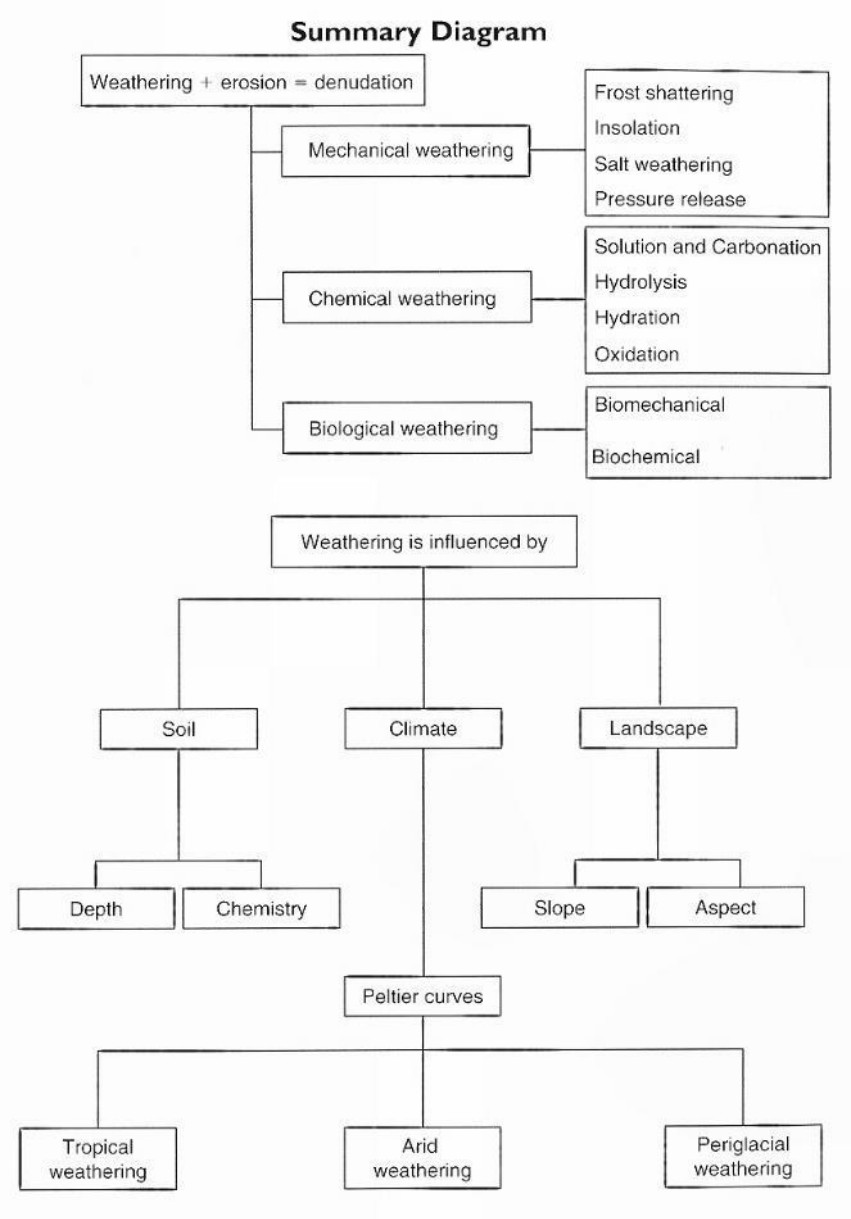


https://socratic.org/questions/what-is-weathering-and-how-is-it-different-from-erosion

…rottura e movimento…



From: https://sites.google.com/a/gx.camden.k12.ga.us/vurnakes6-1/science-units/weathering-and-erosion



Sketch of weathering and erosion processes (from Atkinson, 2004)

Alcuni esempi di processi di weathering







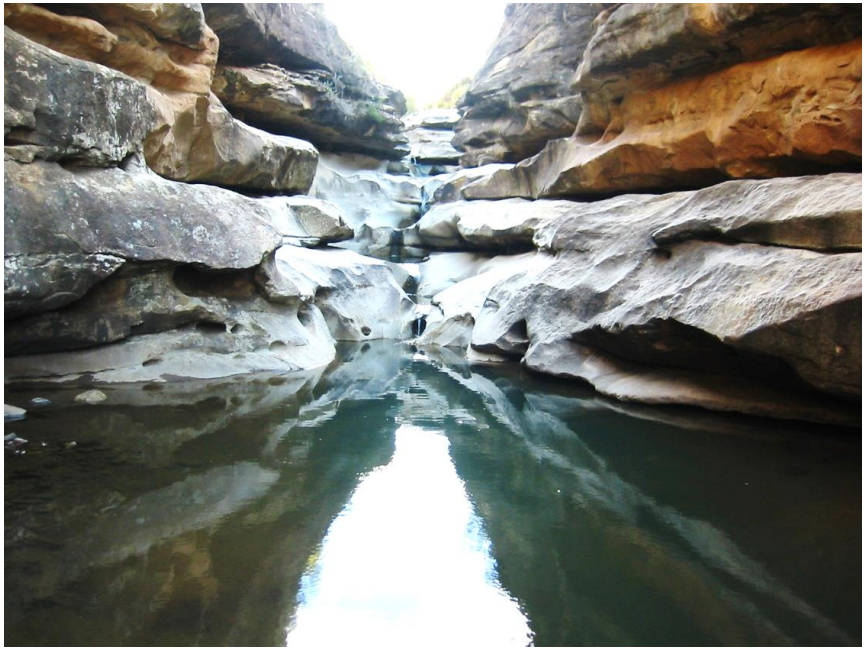
Rocce alterate




Tempio di Poseidone (Capo Sunio, Grecia)

San Giovanni, ex-OPP (Trieste)

Alcuni esempi di processi di erosione



Termini correlati

- Abrasione (*abrasion*) è il processo di strofinamento, graffiamento, consumazione, e sfregamento delle rocce;

- Corrosione (*corrosion*) in geografia fisica include i processi chimici e biologici;

- Corrasione (*corrasion*) indica il processo di erosione meccanica della superficie della Terra causato dal materiale trasportato dalle acque correnti, onde, ghiacciai, vento o movimenti gravitativi di versante che risultino nell'abrasione delle rocce originarie

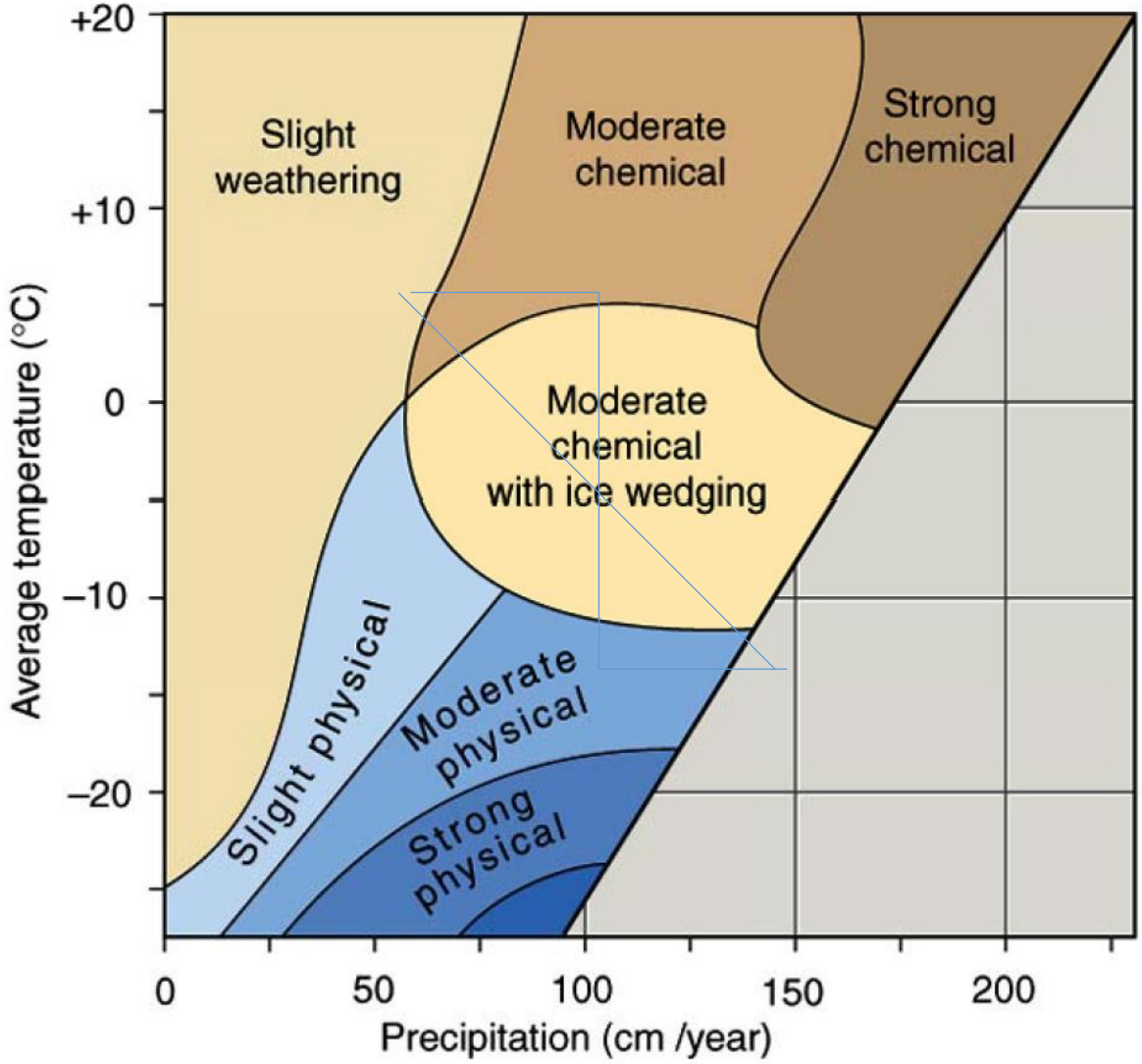
Studi sul weathering ed erosion (Trudgill, 1983) riguardano:

- Il potenziale di weathering ed erosion inerente l'ambiente;
- La suscettibilità dei materiali coinvolti nell'ambiente potenziale;
- I tassi relativi ai processi nel sito di reazione;
- I tassi e l'ammontare di perdita di massa (materiale) dal sito di reazione;
- I materiali residui lasciati in situ dopo la reazione.

I processi di alterazione

	Processi	*Agenti*	*Tipi di rocce*	*Zone climatiche*	*Acqua*	*Prodotti*
Disgregazione fisica	CRIOCLASTISMO	ghiaccio	tutte	fredde-umide	sì	crioclasti
	TERMOCLASTISMO	insolazione	tutte	calde-aride	no	termoclasti
	IDROCLASTISMO	acqua	argillose	umide	sì	idroclasti
	ALOCLASTISMO	sali	tutte	varie	sì	aloclasti
	BIOCLASTISMO	esseri viventi	tutte	varie	no	bioclasti
Alterazione chimica	SOLUZIONE	acqua e CO_2	evaporitiche e carbonatiche	varie, umide	sì	minerali residuali
	IDROLISI	acqua	silicatiche	calde-umide	sì	minerali argillosi, ossidi, silice
	IDRATAZIONE	acqua	alcune	umide	sì	minerali idrati
	OSSIDAZIONE	ossigeno	alcune	varie	no	ossidi
	AZIONI BIOCHIM.	esseri viventi	tutte	varie	sì	suoli

Fattori che influenzano il weathering



From: http://greenfieldgeography.wikispaces.com/IGCSE+and+GCSE+Weathering

Dove si attua prevalentemente il weathering?

- Microscopic cavities (**cavità microscopiche**)
- Joints (**fratture**)
- Faults (**faglie**)
- Lava holes, tubes, etc (**vescicole di lava, ecc**)
- Solution holes, etc (**karren, ecc**)

Degradazione meccanica

Principi e tipi di mechanical (or physical) weathering

Principi

- La degradazione meccanica coinvolge processi di rottura delle rocce in frammenti più piccoli;
- Fornisce materiali per la sedimentazione e roccia fresca per l'alterazione chimica e meccanica;
- Avviene lungo linee di debolezza, fratture, ecc, nella roccia

Alterazione meccanica di arenarie (Piazza Unità, Trieste)

Wetting and drying (slacking)

- Wetting and Drying is effective at breaking up rocks that contain clay.
- If clays get wet they swells up. When they dry they shrinks again.
- Rocks are repeatedly swelling and shrinking causing them to crack and fall apart.

Ustica (I)

Aloclastismo (*Salt weathering*)

- Salt crystallization, also called haloclasty, causes disintegration of rocks when saline solutions seep into cracks and joints in the rocks and evaporate, leaving salt crystals behind. The latter expand as they are heated up, exerting pressure on the confining rock.

- The most effective salts, such as sodium sulfate and calcium chloride, can expand up to three times or even more.

- Salt weathering is usually associated with arid climates and along coasts.

- An morphological example of salt weathering are the honeycombes, tafoni, which are related to both chemical and salt weathering processes.

Examples of salt weathering (**aloclastismo**)

Sardinia (I)


Sardinia (I)

Crioclastismo (*Frost weathering, ice wedging*)

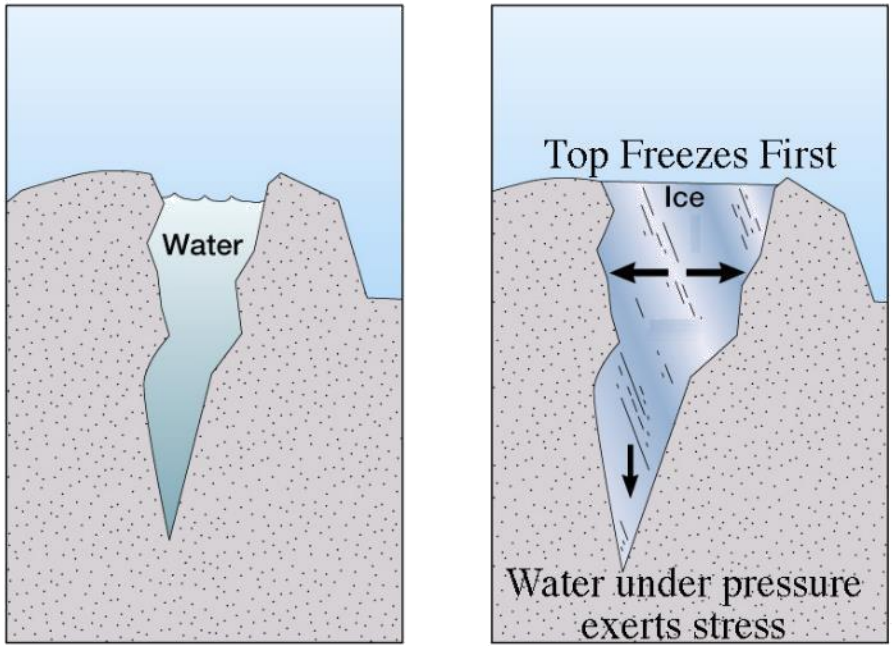
- Freeze-thaw weathering, also called frost weathering or ice wedging is the general name involving ice degradation of rocks.

- These processes include frost shattering, frost-wedging and freeze-thaw weathering.

- Frost weathering is particularly effective in mountains when the temperature ranges around the freezing point of water.

- Frost weathering produces large amounts of rock fragments located at the foot of mountains or along slopes.

Crioclastismo



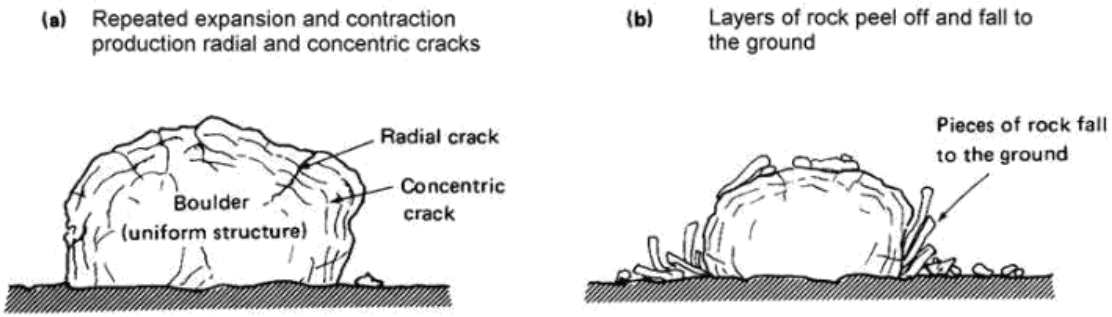
From: http://alliance.la.asu.edu/
Arizona Geographic Alliance

Crioclastismo

Debeli Rtic (Slovenia)

Espoliazione (*exfoliation*)

- It occurs in rocks with homogeneous strucure
- Repeated heating and cooling by daily temperature changes affect weathering
- Repeated expansiona dn contraction create stress in rock and produce radial and concentric cracks
- The outer layers eventually peel off to form exfoliation



Little Shuteye Pass (USA)

Degradazione chimica

Methods of evaluation of chemical weathering

Principi

- Chemical weathering involves the alteration of the minerals of rocks by chemical reactions

- They can be influenced by biological processes, so often it is very difficult to distinguish them

- It is related to the surface area available for chemical and biological processes

Variabili

- Water: in general, the more precipitation, the greater the rate os weathering. As a consequence, dry climates show slow rates

- Temperature: the higher rates of chemical weathering occur in warm, wet climates, while very cold climates show slow rates.

Dissoluzione

- Many minerals can be dissolved by water because it is a bipolar molecule.
- The bonds of ions at the mineral surface are loosen
- Salt and gypsum are easily dissolved
- Also some silicates, such as pyroxene, can be dissolved in carbonic acid
- Carbon dioxide forms carbonic acid in water. It can dissolve calcite following the formula:

$$CO_2 + H_2O + CaCO_3 \longrightarrow Ca(HCO_3)_2$$

$$Ca(HCO_3)_2 \longrightarrow CO_2 + H_2O + CaCO_3$$

Lapiez, pinnacoli (Ahrax Point, Malta)

Solution pan dissected by cliff retreat (Malta)

Idratazione

- A mineral reacts with either the H^+ or the OH^- from water to produce a new mineral

- Aluminium silicates do not dissolve in water

- Weathered feldspar, such as plagioclase, forms clay

$$NaAlSi_3O_8 + H_20 + H_2CO_3$$

$$Na^+ + HCO3^- + H_4SiO_4 + Al_2Si_2O_5(OH)_4$$

Ossidazione e riduzione

- The chemical combination of oxygen with a mineral
- It is fundamental in weathering of iron-rich silicates, such as pyroxene, olivine, biotite, amphibole
- The final products are hematite or lemonite

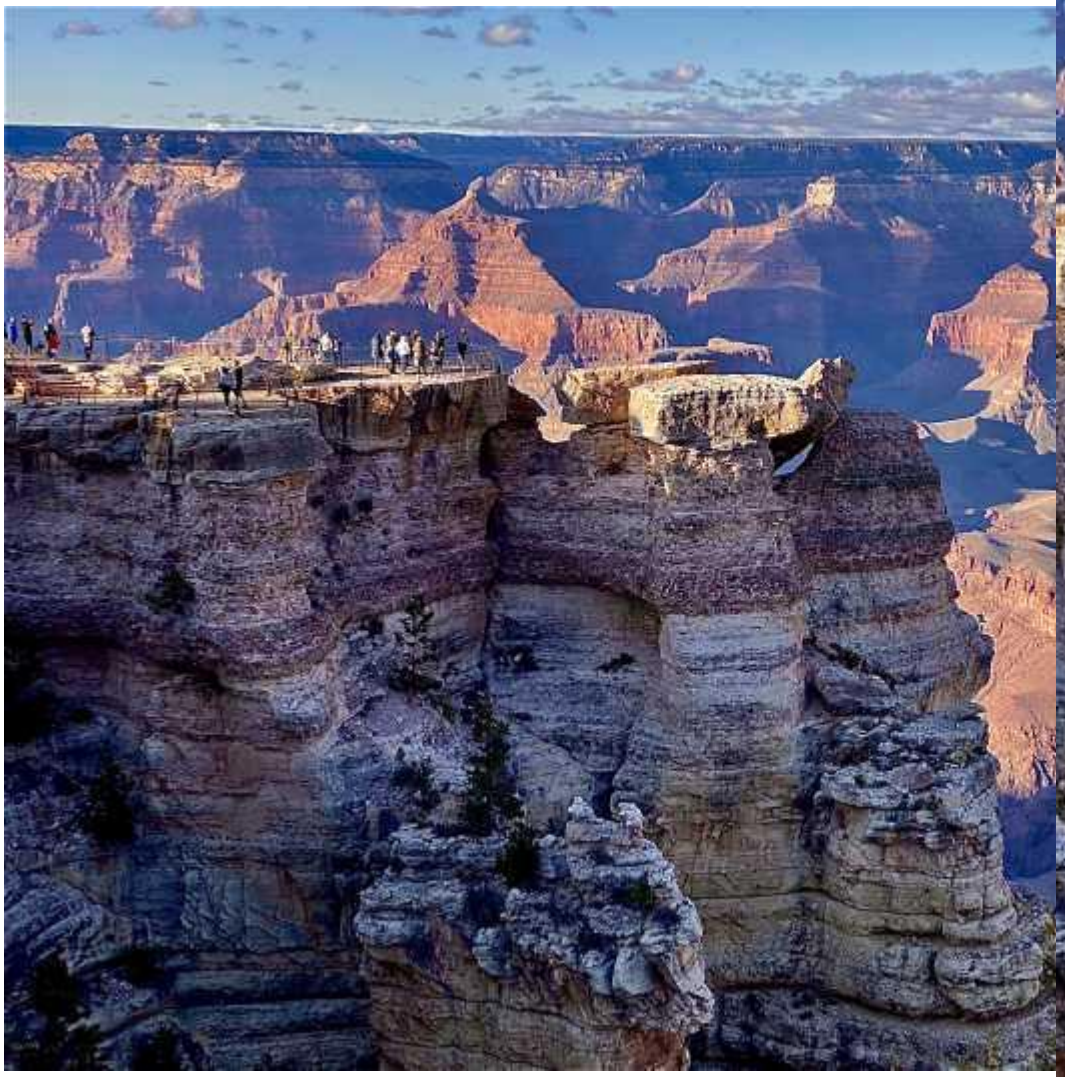
$$2Fe_2SiO_4 + 4H_2O + O_2 \; 2Fe_2O_3 + 2H_4SiO_4$$

$$Fe_2O_3 + H_2O \; 2FeO(OH) \text{ (limonite)}$$

Alterazione/erosione selettiva

- Rocce diverse vengono alterate a tassi diversi;
- Questo da luogo a forme protuberanti a scale diverse (es. canyon slopes, mesa, etc)

Grand Canyon

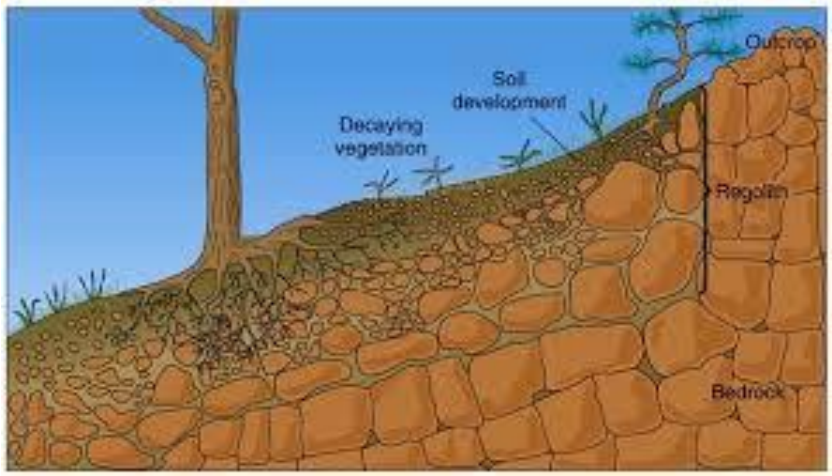


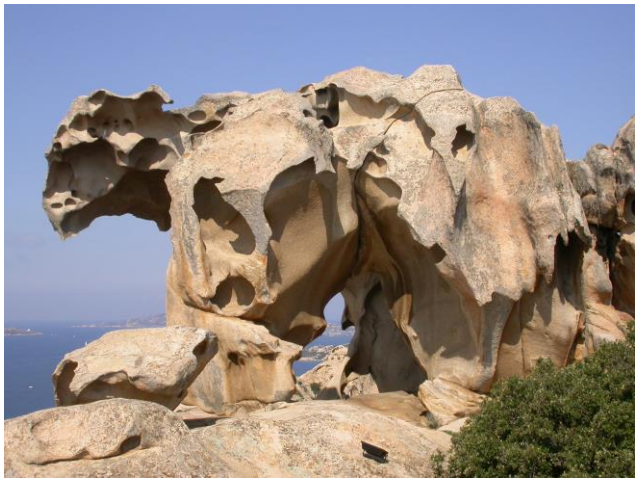
Sequoia National Park, California (USA)

Kamenjak, Premantura (Croatia)

Risultati della degradazione

- Blocchi di dimensioni più piccole (es. grize, ecc)
- Forme particolari (es. tafoni, ecc)
- Regolite
- Suoli





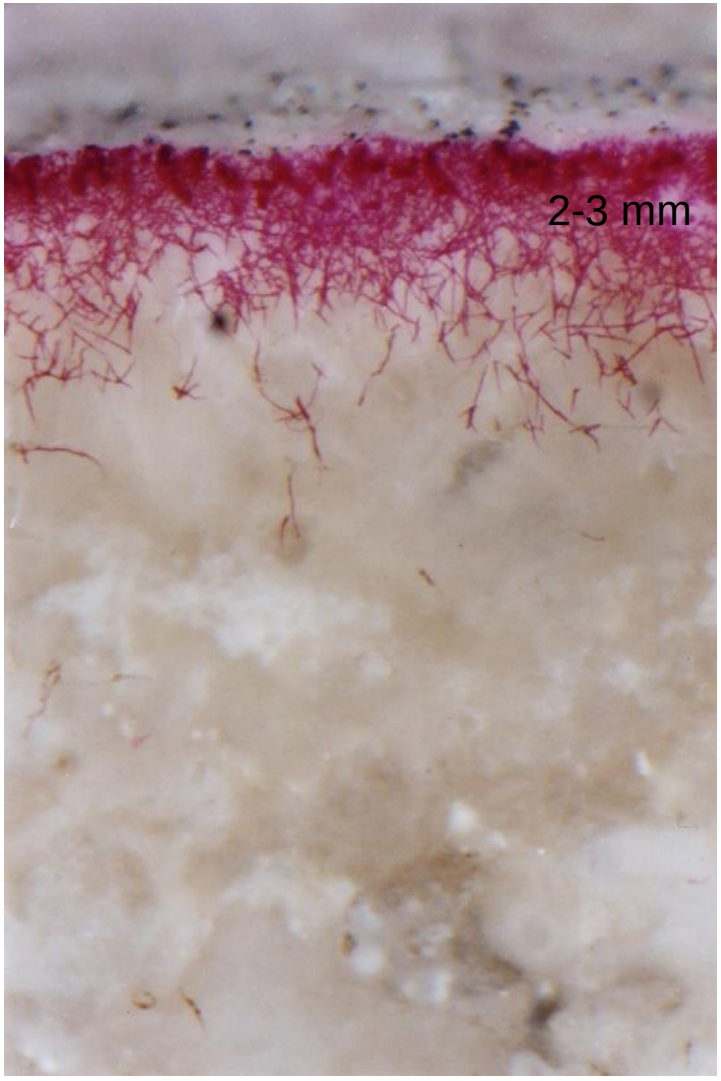
Alterazione biologica

How living organisms destroy rocks

Processi biologici

- Biomechanical weathering (plant roots, animal burrows, etc)
- Biochemical weathering (solution, etc)
- Some plants like mosses and lichens are capable of growing without soil on bare rock.
- When they do this their roots penetrate pores and crevices and cause rocks to split apart as the roots force their way down through the rocks.

Pitting due to chemical weathering on limestone (M. Tretiach).

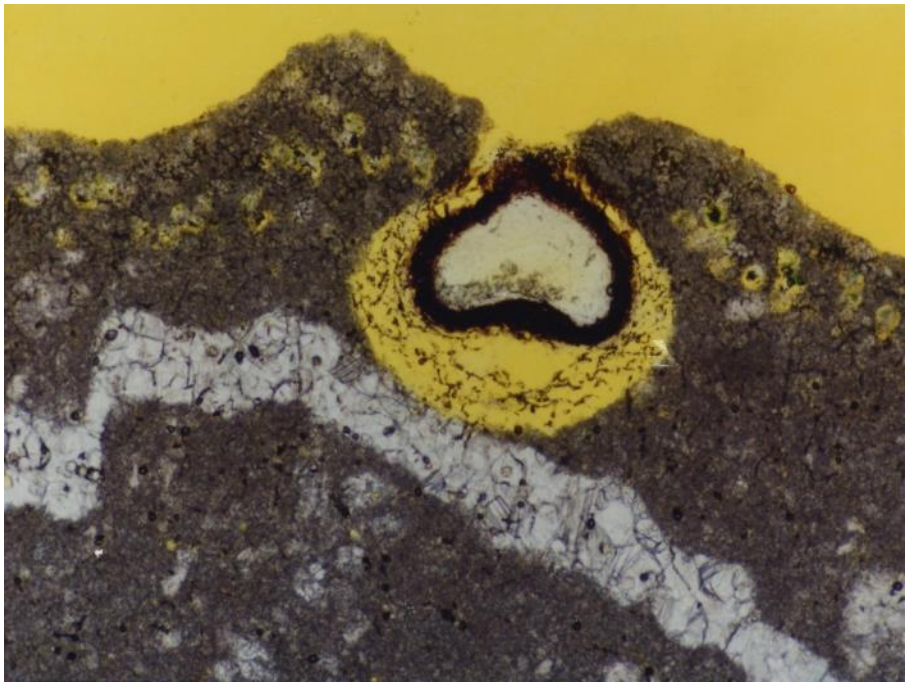


The penetration of fungus filaments (hyphae) inside the rock

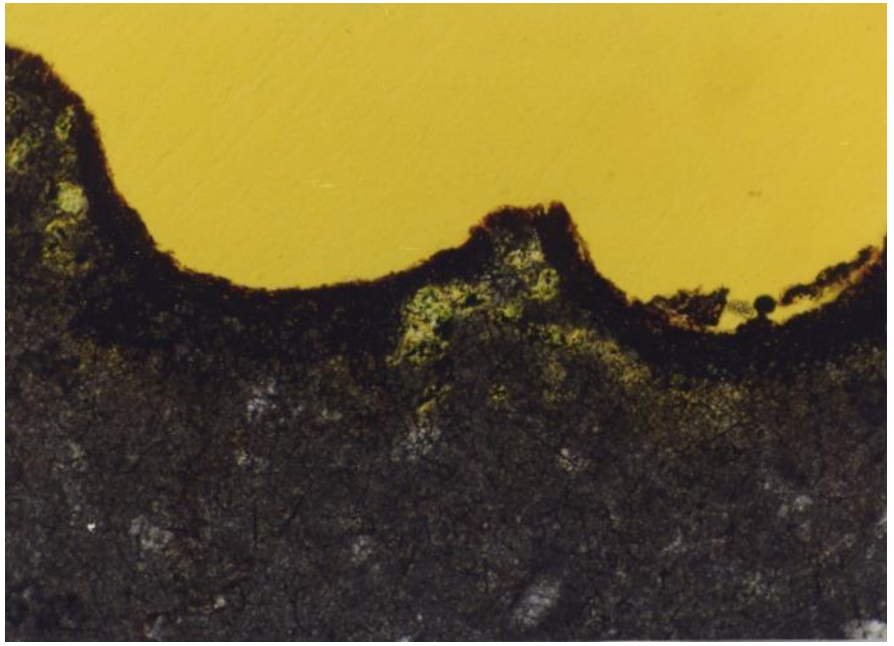
Lithocortex

Colonies of the photobiont

pseudomedulla

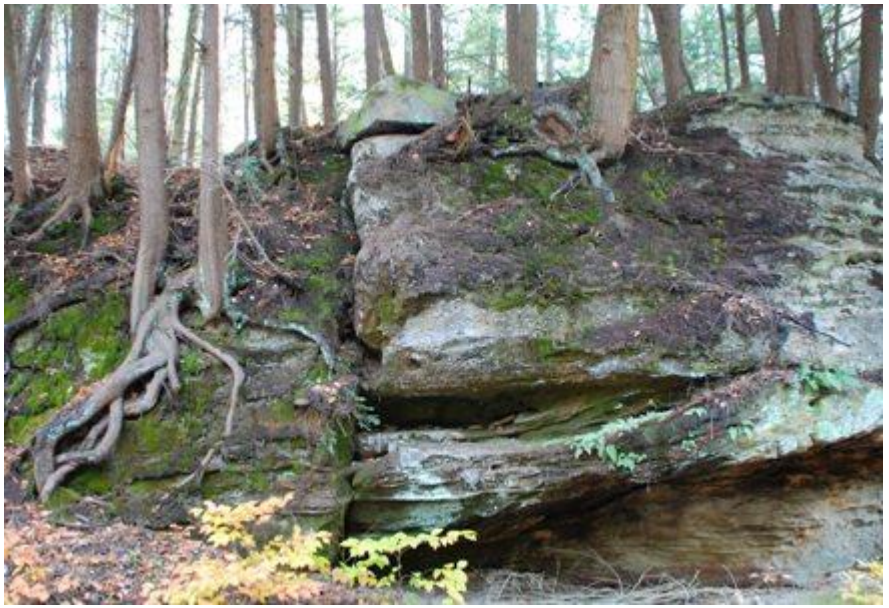


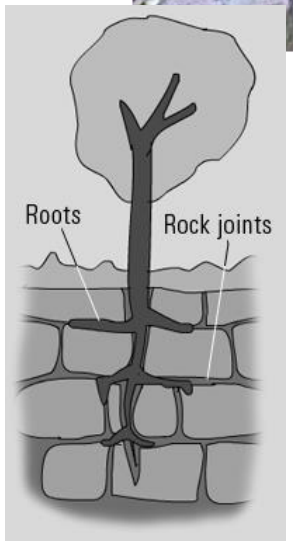
Limestone weathering by hyphae



Biological weathering along the Croatian coast

Biodegradazione delle piante





Tassi di microerosione

- Erosion rates are very slow compared with the time span of human life (Trudgill, 1983)

- Very precise instrument allow to do accurate measures and obtain data reliable and interpretable in few years

- These methods allow to assess erosion rates by repeated measurements of surface lowering, if it is fast enough to be measured

Bedrock lowering

Evaluation of surface lowering rates of hard rocks

Micro erosion measurements

- MEM, TMEM
- Mass-loss tablets
- Gravestones and dated buildings
- Erosion pins
- Differential erosion
- Glacial erratic pedestals
- Marine borers and grazers
- Abrasion experiments

The method of tablet

Samples of limestone from the Trieste Classical Karst used to evaluate limestone solution rates

The micro erosion meter (MEM)

- The micro erosion meter allows to collect from 1 to 3 measure for each station
- Measures must be collected for many years

The traversing micro erosion meter (TMEM)

- Many measuring points can be obtained for each station
- A statistical analysis of erosion rates can be carried out
- Data canbe directly downloaded to the laptop

The automatic micro erosion meter (AMEM)

- It is completely authomatized
- Hundreds of data can be obtained in few time
- Data can be collected also on vertical or sub-vertical surfaces

Coastal vs inland rates

Rates and values of coastal landform evolution

The particularity of the littoral zone

Coastal processes

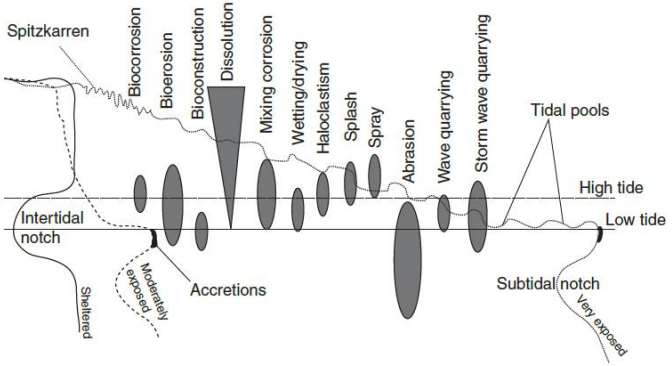


Figure 2 General scheme of the vertical zonation of geomorphic processes on a sheltered, moderately exposed, and very exposed limestone coast at middle and low latitudes.

- The littoral zone is interested both by marine processes and subaerial processes
- Subaerial processes decrease toward the sea, while marine and, on the contrary, marine processes increase

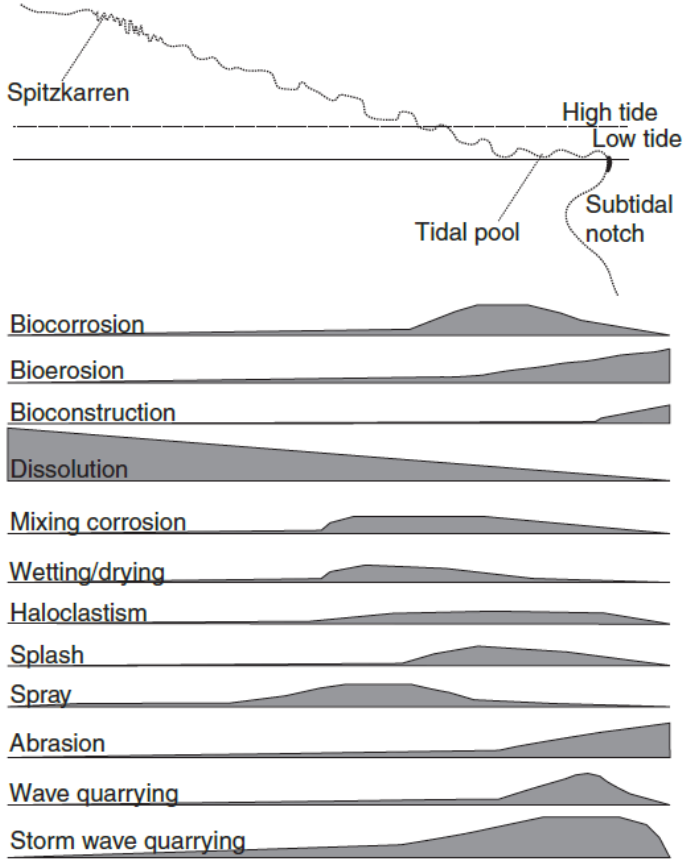
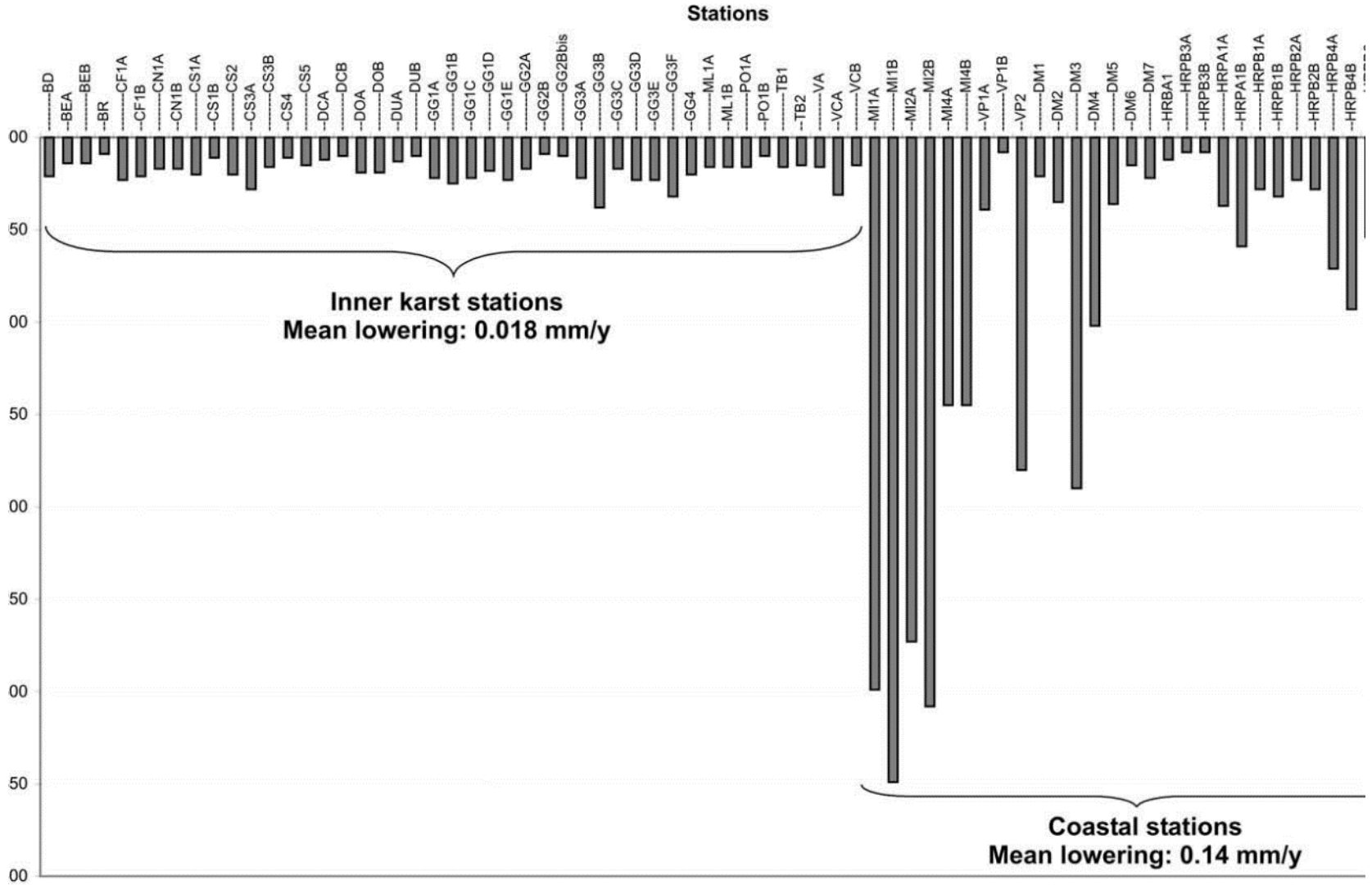


Figure 3 General scheme of the horizontal zonation of geomorphic processes on a limestone coast at middle and low latitudes. Thickness of gray horizontal bars is indicative of the importance of the process.

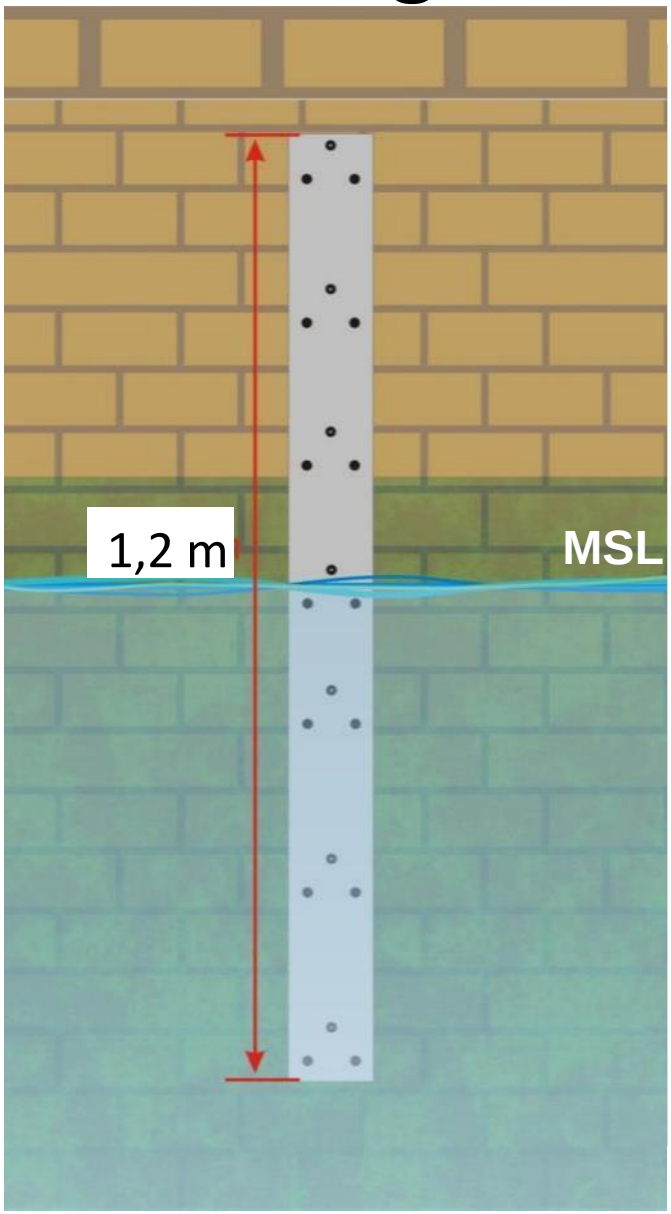
DE WAELE & FURLANI (2013) – Treatise on Geomorphology

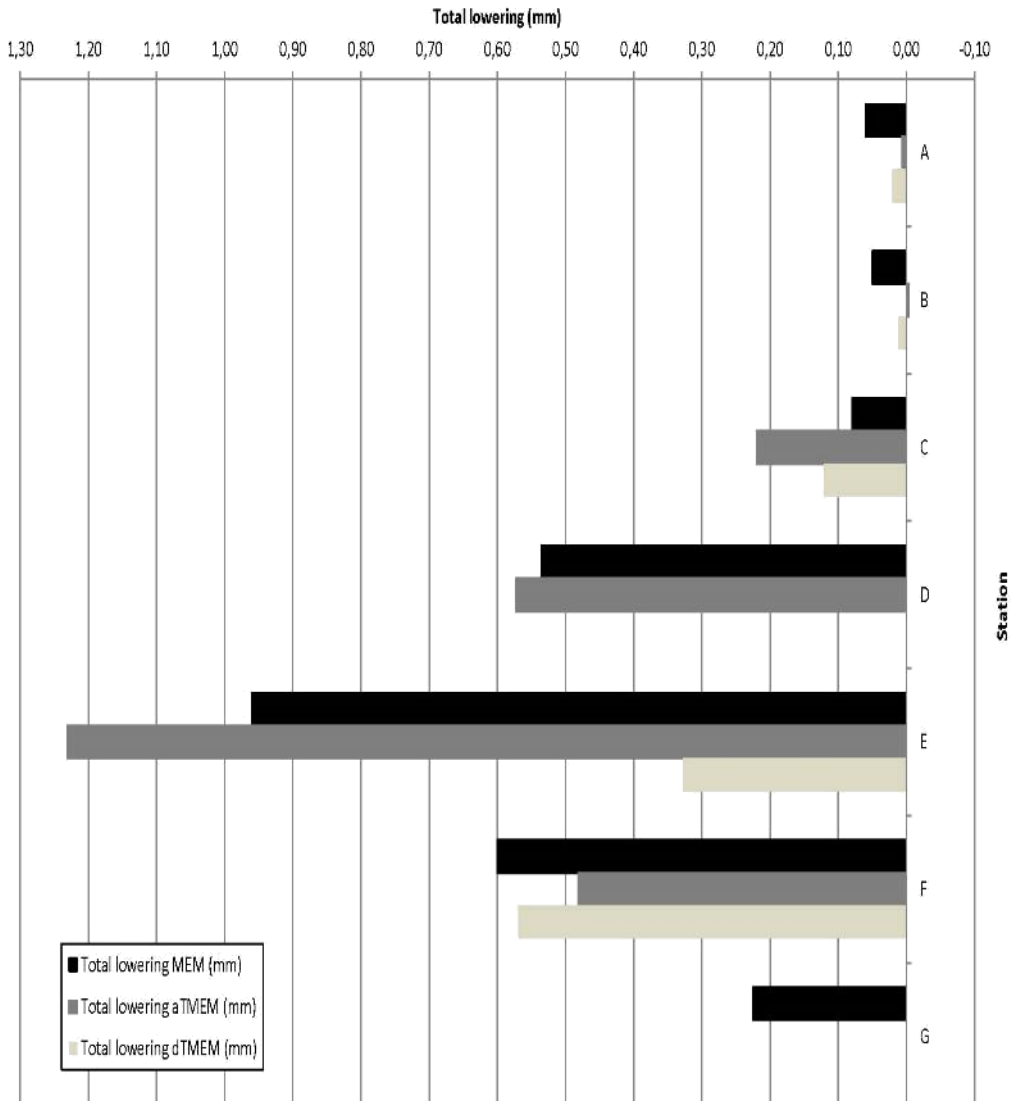
Coastal vs subaerial lowering rates



From FURLANI et al. (2009) - Geomorphology

Lowering rates in the mid-tidal zone





FURLANI & CUCCHI (2013) - Marine Geology

Inland rates and coastal rates

Table 1 Limestone lowering rates collected using MEM, TMEM, and laser scanner

Authors	*Location*	*Mean annual rates (mm yr^{-1})*
Cucchi and Forti (1989)	Coastal classical karst (Italy)	0.009–0.194 (coastal karst morphologies)
Spencer (1985)	Grand Cayman Islands	0.29–3.67 (subtidal), 0.31–3.01 (intertidal), 0.09–1.77 (surf platform)
Kirk (1977)	Kaikoura Peninsula	1.53 (shore platform)
Stephenson and Kirk (1996)	Kaikoura Peninsula	1.10 (limestone platforms)
Stephenson (1998)	Kaikoura Peninsula	0.875 (limestone platforms)
Torunski (1979)	Gulf of Piran, Slovenija	0.07–1.114 (intertidal limestones)
Trudgill et al. (1976)	Aldabra Atoll, Indian Ocean	2.0–4.0
Trudgill et al. (1981)	Country Clare (Ireland)	0.145–0.383
Viles and Trudgill (1984)	Aldabra Atoll, Indian Ocean	1.27 (Ramp edge), 2.20 (Ramp foot)
Neves et al. (2001)	Portugal	0.153 (Intertidal limestone)
Furlani et al. (2009)	Northeastern Adriatic coast	0.08–2.966 (intertidal limestones)
Furlani et al. (2010)	Northeastern Adriatic coast	(intertidal limestone manmade slab)
Swantesson et al. (2006)	Mallorca	0.090 (coastal limestone)

Source: Adapted from Stephenson, W.J., Finlayson, B.L., 2009. Measuring erosion with the micro-erosion meter – Contributions to understanding landform evolution. Earth-Science Reviews 95, 53–62; Furlani, S., Cucchi, F., Forti, F., Rossi, A., 2009. Comparison between coastal and inland Karst limestone lowering rates in the northeastern Adriatic Region (Italy and Croatia). Geomorphology 104, 73–81, and Furlani, S., Cucchi, F., Odorico, R., 2010. A new method to study microtopographical changes in the intertidal zone: one year of TMEM measurements on a limestone removable rock slab (RRS). Zeitschrift fur Geomorphologie N.F. 54, 137–151.

From De Waele & Furlani (2013) – Treatise on Geomorphology

Preservation and erosion of coastal human structure

How long the object?

Open problems

- How long the object?
- How quickly a coastal structures will be weathered?
- Which artifactscan be easily dameged by erosion?
- Where erosion is more effective?

Preservation of archaeological remains

Cosa abbiamo imparato?

- Cos'è l'alterazione (degradazione, weathering) e come si manifesta
- Cos'è l'erosione
- Cos'è la denudazione
- Come si misurano i tassi di erosione
- A che velocità si «consumano» le rocce

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