International degree on

Geosciences and Georesources

Course of
Applied Stratigraphy and Sedimentology

3. Sedimentology

3a. Origin of sediments; **3b.** Clastic and non-clastic sediments; **3c.** Main processes of erosion, transport and sedimentation; **3d.** Main sedimentary processes (tractive, mass, etc …); **3e.** Facies, facies associations, depositional environments and systems. **3f**. Georisources of sedimentary origin.

GEORESOURCES

Natural asset (at solid, liquid or gas state) deriving from geological processes and of economic/social relevance. Such resources must be protected and preserved from an unexcessive exploitation and consequent depletion.

MINERAL RESOURCES

- Precious metals
- Coals
- Gems

HYDROCARBONS

- Oil
- Natural gas

WATERS

- Juvenile
- Connate
- Acquifers
- Natural lakes

SEDIMENTARY RESOURCES

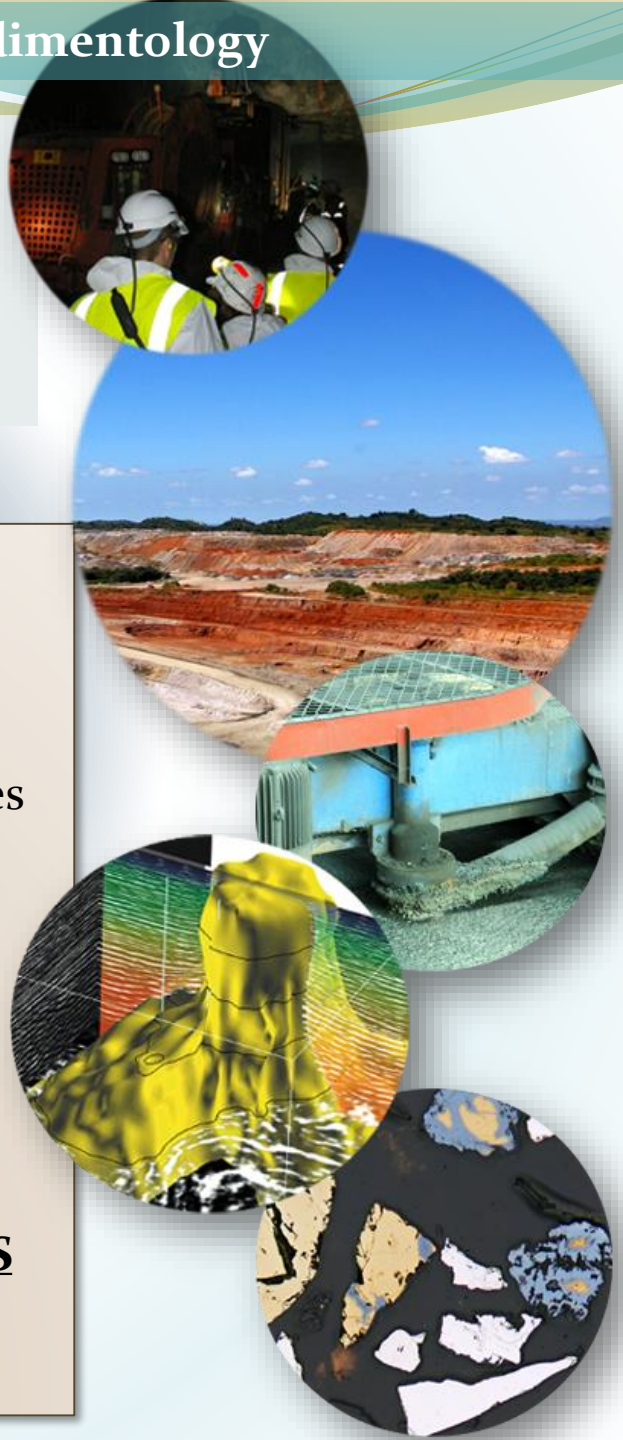
- Lapideous materials used as coating or covering
- sand for industrial uses
- Littoral sands
- Gems

BIOGENIC RESOURCES

- Fossils
- Footprints

TOURISTIC GEORESOURCES

- Geosites
- 'Open-sky' museums



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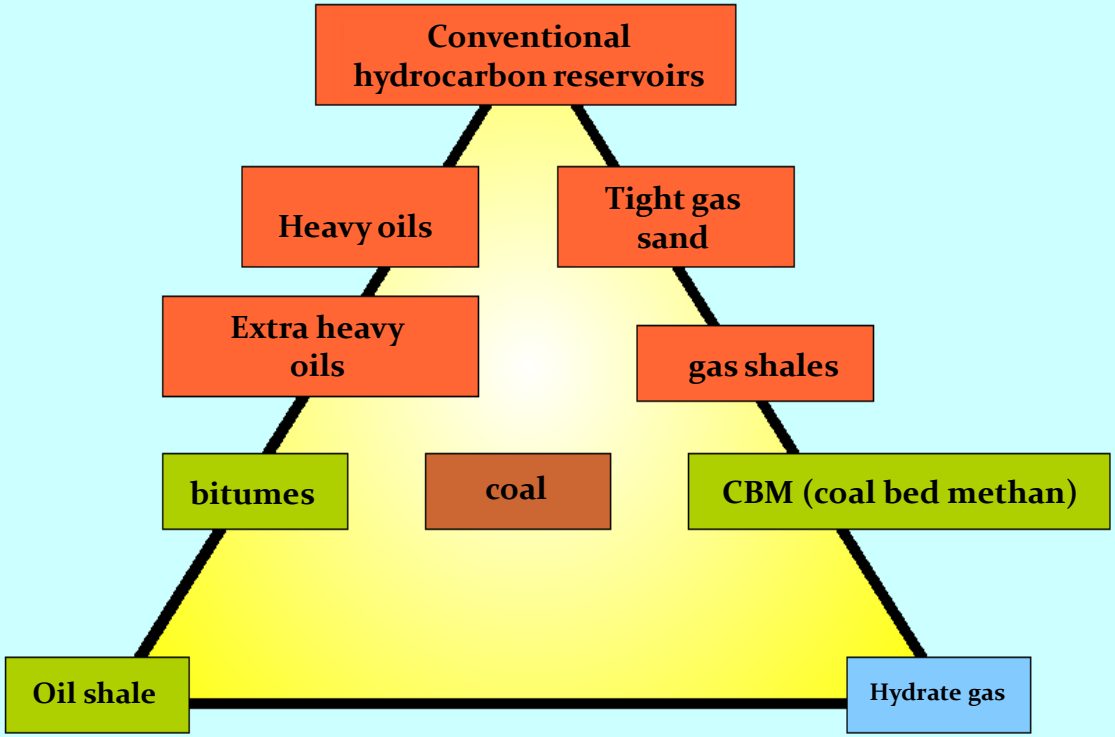
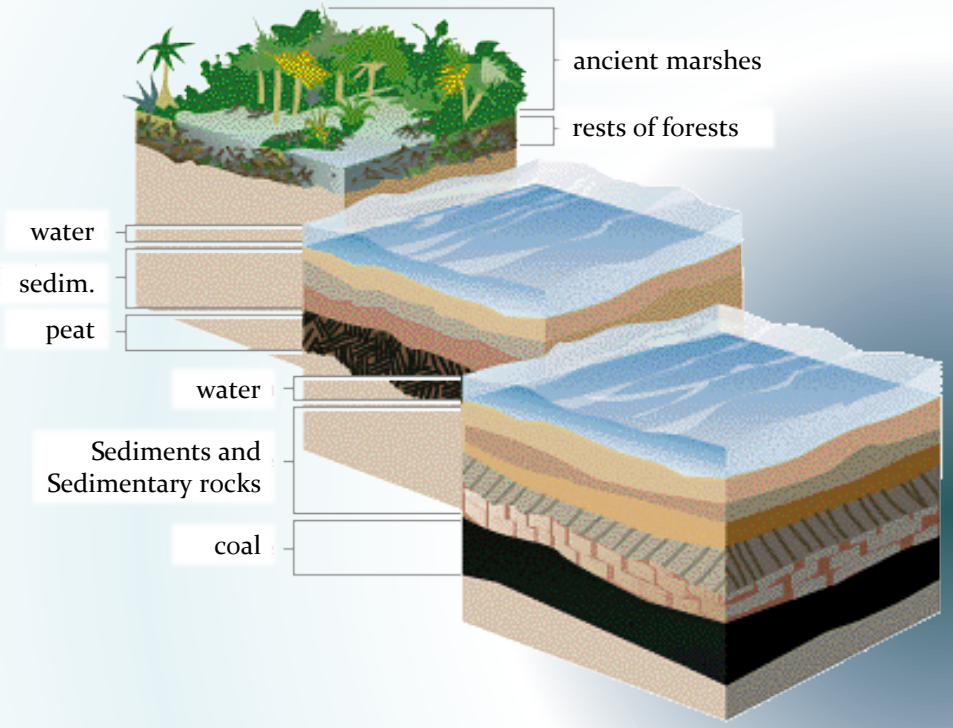
Mineral resources and hydrocarbons

FOSSIL FUEL PLOT



Mineral resources (Coals – Carbon fossili)



Coals represent a product of the transformation of organic matter of vegetal orgin. Compacted, multiple layers of organic matter (**peats** - **torba**) can rapidly be covered by younger sediments.

Pressure and temperature of the overlying deposits can reduce humidity, increasing the content of Carbon of the peat, givin rise to the **coal**.

As the depth of burial and the temperature increase, coal can be subject to a progressive loosing of residual organic components (maturation process), increasing the quantity of Carbon

LIGNITE (lignite)	BITUMINOUS COAL (litantrace)	ANTHRACITE (antracite)

CONTENT of CARBON

TIME

CALORIFIC POWER

Mineral resources (Coals – Carbon fossili)

LIGNITE: 'poor' combustible coal, it can include wood fragments still well preserved, often of matte black collour.

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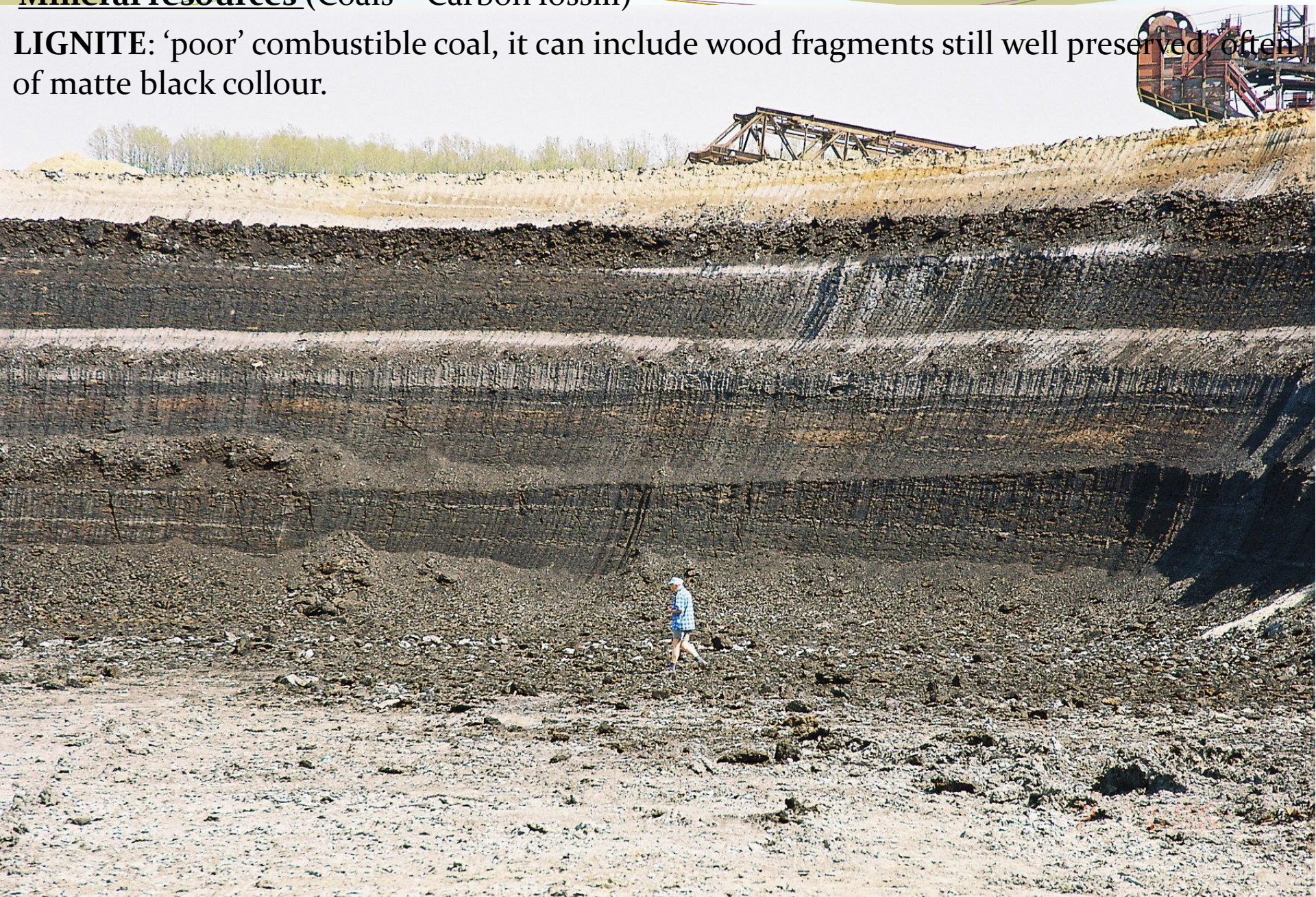
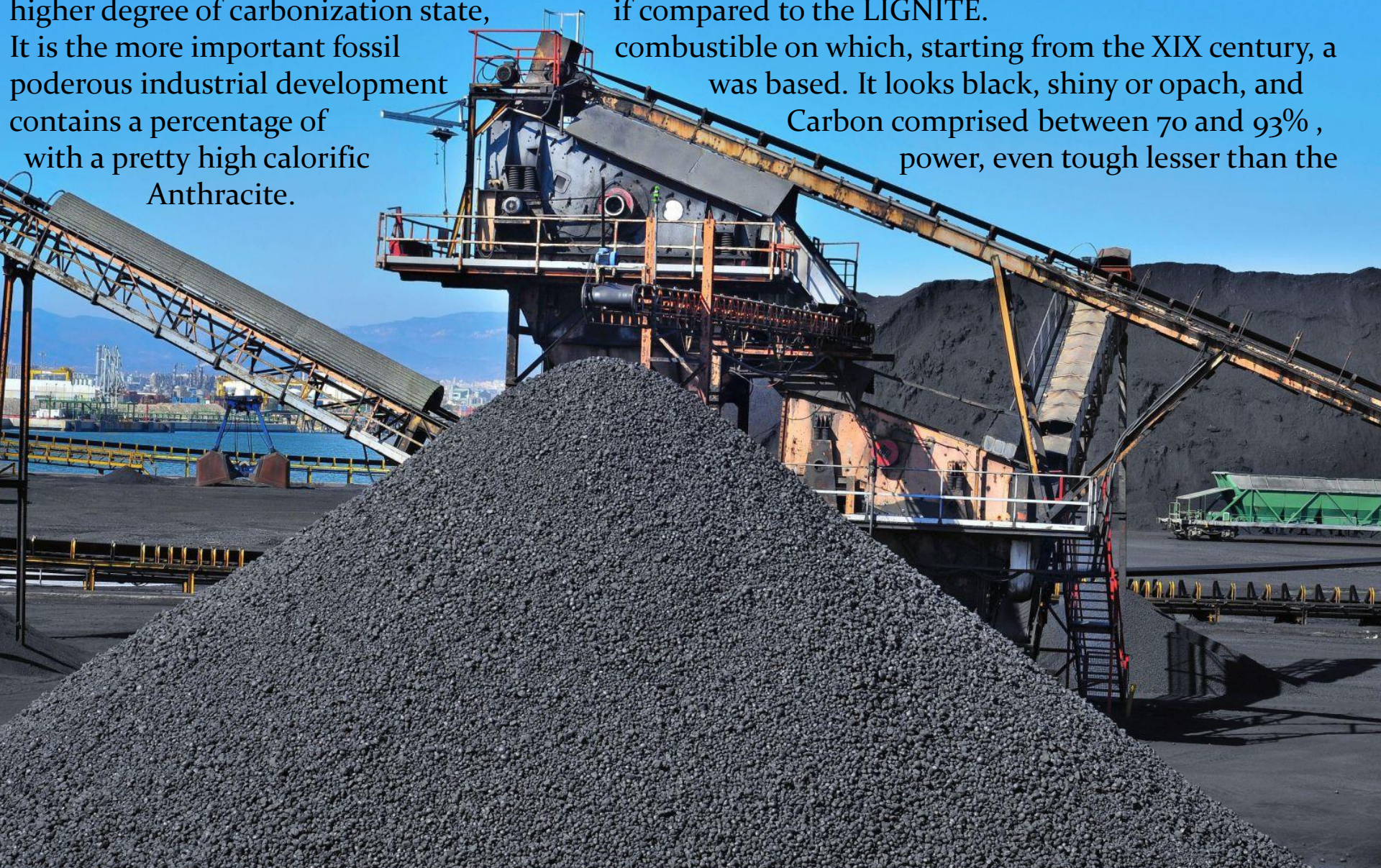


Mineral resources (Coals – Carbon fossili)

BITUMINOUS COAL: combustible fossil, representing the second step of maturity of coals and a higher degree of carbonization state, if compared to the LIGNITE.
It is the more important fossil combustible on which, starting from the XIX century, a poderous industrial development was based. It looks black, shiny or opach, and contains a percentage of Carbon comprised between 70 and 93% , with a pretty high calorific power, even tough lesser than the Anthracite.



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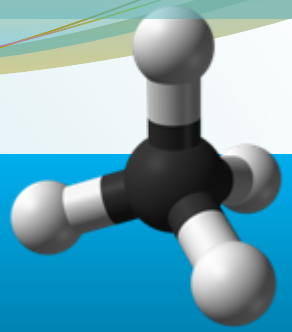
Mineral resources (Coals – Carbon fossili)

ANTHRACITE: coal of more ancient origin, if compared to the prvious ones; it contains more than the 90% of Carbon, it is shiny, heavy and hard; burns slowly even in environments with scarcity of air, with a short flame, developing much warm.

Natural Gas



Natural gas is a fossil fuel, such as oil and coal, consisting of a gaseous mixture of hydrocarbons, predominantly methane and other substances, such as anhydride carbon, nitrogen, oxygen, noble gases, and hydrogen sulfide present in trace amounts.

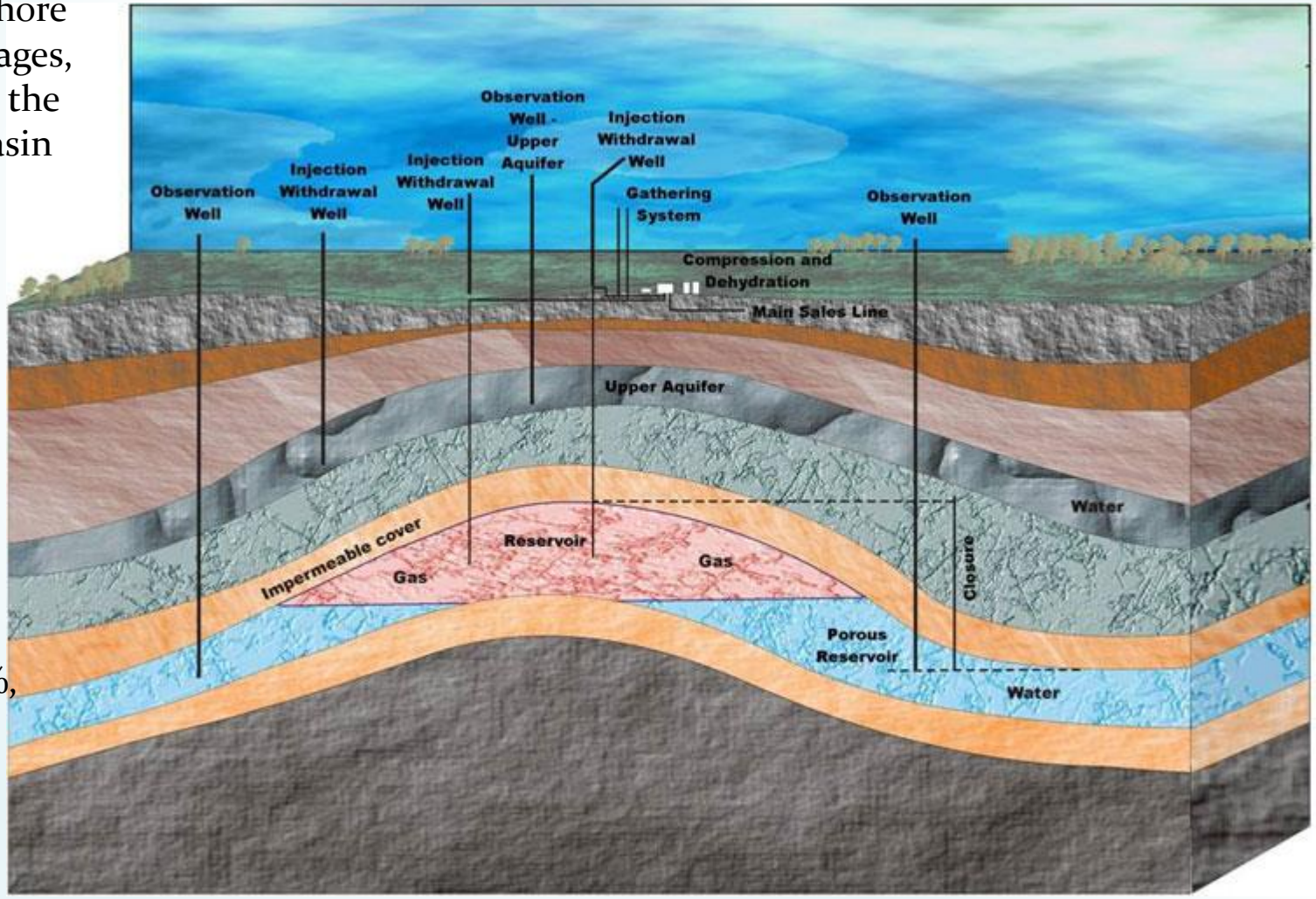
The formation of natural gas derives from the decomposition of organic substances, which accumulated during hundreds of millions of years, and the presence or absence of bacterial activity during the process of decomposition. Biogenic gas is composed essentially of pure methane and is derived from bacterial activity occurred in shallow sediments.

Thermogenic gas may contain traces of carbon dioxide and hydrogen sulphide and is created in sedimentary rocks in very deep and at high temperatures without the intervention of bacteria.

Natural Gas

Over 95% of the Italian natural gas deposits contain biogenic gas. The gas which on average is employed in our country is therefore made up of methane, 99.5% and small amounts of ethane (0.1%) and nitrogen (0.4%). Hydrogen sulfide is present in the gas produced in the basins of the Apennines and the Sicilian offshore and in their appendages, while not present in the product in the Po basin and in the northern Adriatic.

Today, natural gas is in third place in the global energy consumption. World reserves of natural gas contains about 187 trillion cubic meters, most of which, about 64%, located in the Middle East and Russia.



Oil

The oil is a natural mixture composed mainly of hydrocarbons in the liquid state, gaseous or solid, contained in the pores of sedimentary rocks in deposits called **reservoirs**.

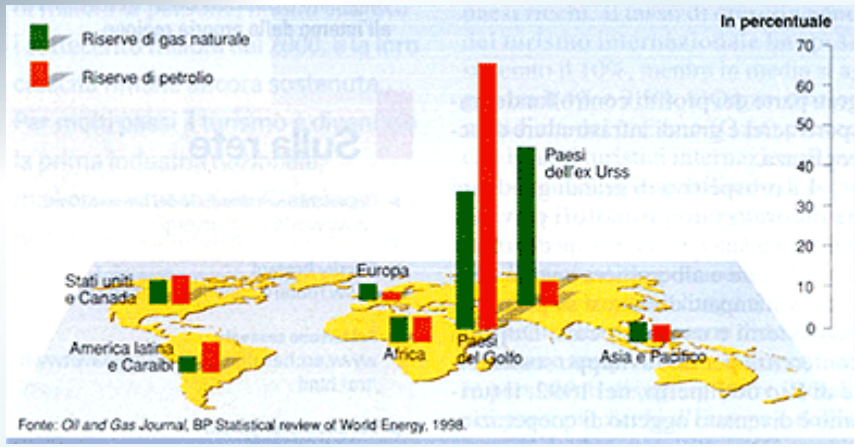
Its formation is due to a process of transformation and decomposition of organic matter - the remains of plants and animals - average duration of hundreds of millions of years.

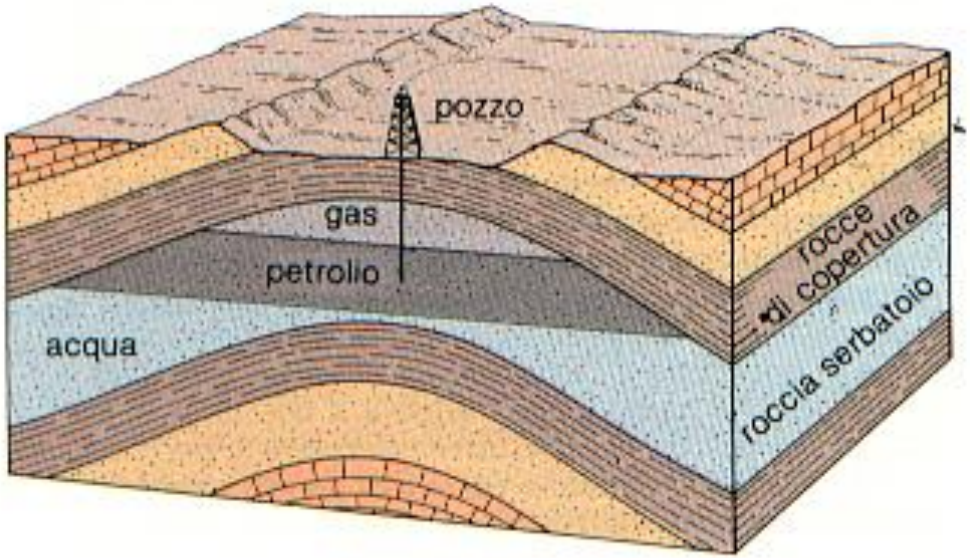
From the chemical point of view the hydrocarbons are chains of carbon atoms and hydrogen with presence in traces of heavy metals and so-called NSO, nitrogen (N), sulfur (S) and oxygen (O).

It is a fossil fuel, such as coal and natural gas, after the extraction step, needs to be worked and refined before becoming a transport fuel, fuel for the production of energy or any object in plastic.

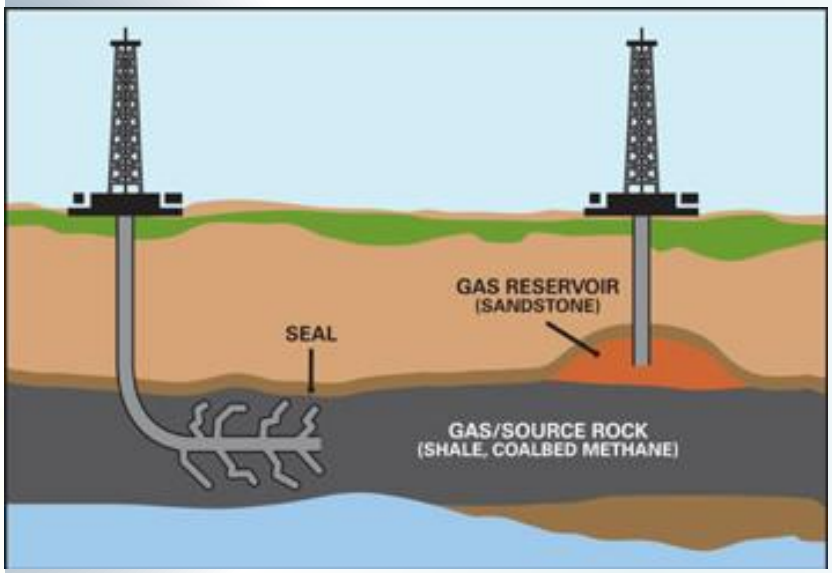
To date, the production of oil covers about 35% of world energy consumption.

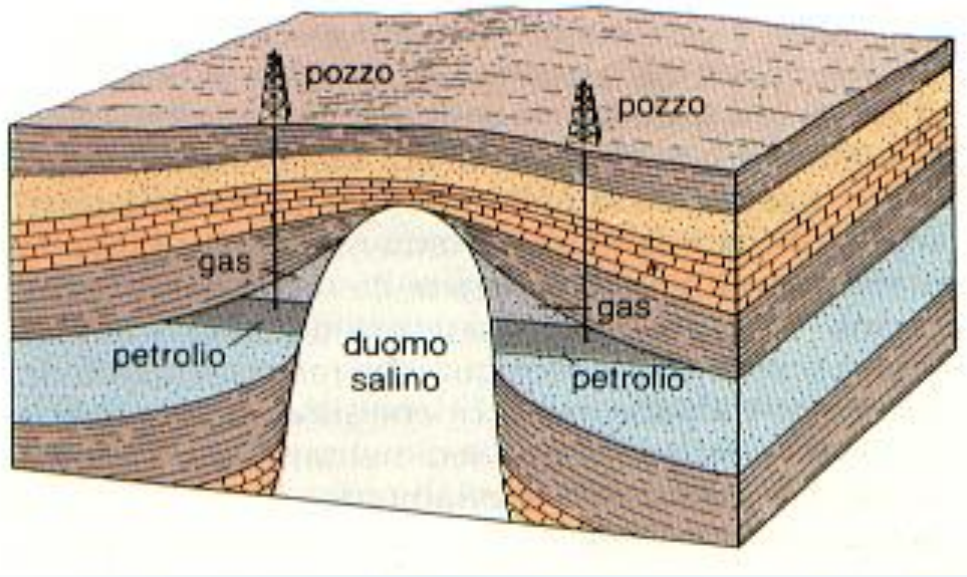
Most of these reserves are located in the Middle East (63.3%), Latin America (11.3%), Africa (10%), Europe and Central Asia (9.4%).





Stratigrafic traps





Structural traps

BASIC PETROLEUM SYSTEM

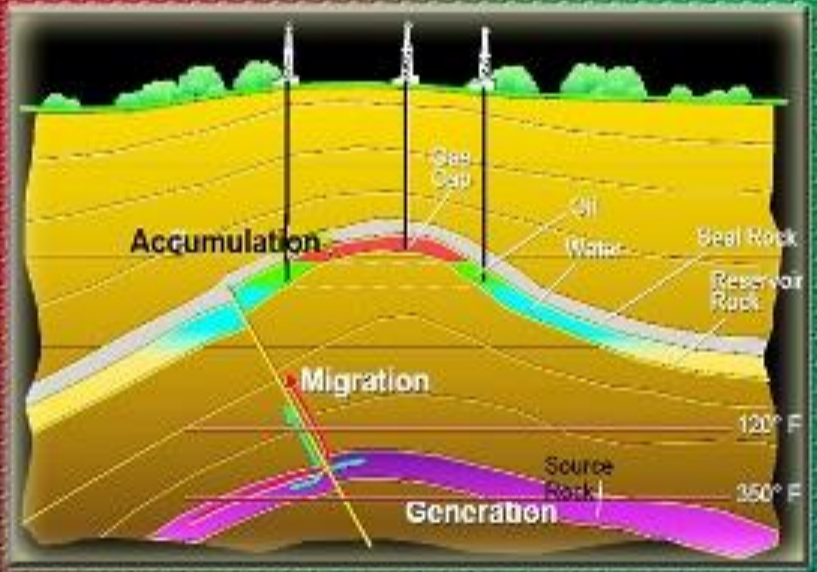
Basic petroleum system is a process to find out hydrocarbon containing in the subsurface. Some components must be present on the basic petroleum system such as source rock, reservoir rock, migration, trap, and seal rock. Appropriate timing of formation in the petroleum system related to the processes of generation, migration and accumulation are necessary for hydrocarbons to accumulate and be preserved. Some geological structures is also an important part in the formation of petroleum system because some geological structure can be the

Source Rocks

Source Rocks is a rocks that containing an oil. Many kinds of Organic matter living in surface waters of rivers, oceans, and lakes is the major constituent from which crude oil and natural gas form. With continued deposition of sediment on top, organic remains become buried before they decay. These buried sediments with preserved organic remains can become source rocks for crude oil or natural gas. The formation of hydrocarbon liquids from an organic rich source rock with kerogen and bitumen to accumulates as oil or gas.

Reservoir Rocks

Reservoir Rocks Is a subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and they form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum ystem. Most oil and gas fields are found in sedimentary rocks like sandstone and limestone, which also called as a reservoir rocks, because they have the interconnected pore spaces needle fo oil and gas to move through and accumulate in, thereby forming a pool or field. The two factors required for this process to work are the pore space, called rock porosity and the interconnectivity of the pore space, called rock permeability. The pore space determines the capacity of the pool and the permeability determines the productivity of the pool.



Seal (Cap Rocks)

Seal (cap rock) is an impermeable rock that acts as a barrier to further migration of hydrocarbon liquids. Rocks that forms a barrier or cap above and around reservoir rock forming a trap such that fluids cannot migrate beyond the reservoir. The permeability of a seal capable of retaining fluids through geologic time is ~ 10-6 to 10-8 darcies. A seal is a critical component of a complete petroleum system.

These are kinds of seal :

- shale, mudstone
- anhydrite
- salt.

Migration

Migration is The movement of hydrocarbons from their source into reservoir rocks. The movement of newly generated hydrocarbons out of their source rock is primary migration, also called expulsion. The further movement of the hydrocarbons into reservoir rock in a hydrocarbon trap or other area of accumulation is secondary migration. Migration typically occurs from a structurally low area to a higher area in the subsurface because of the relative buoyancy of hydrocarbons in comparison to the surrounding rock. Migration can be brief or can occur along distances of hundreds of kilometres in large sedimentary basins, and is critical to the formation of a viable petroleum system.

Trap

Trap is a configuration of rocks suitable for containing hydrocarbons and sealed by a relatively impermeable formation through which hydrocarbons will not migrate. Traps are described as:

structural traps
Hydrocarbon traps that form in geologic structures such as folds and faults

stratigraphic traps
Hydrocarbon traps that result from changes in rock type or pinch-outs, unconformities, or other sedimentary features such as reefs or buildups

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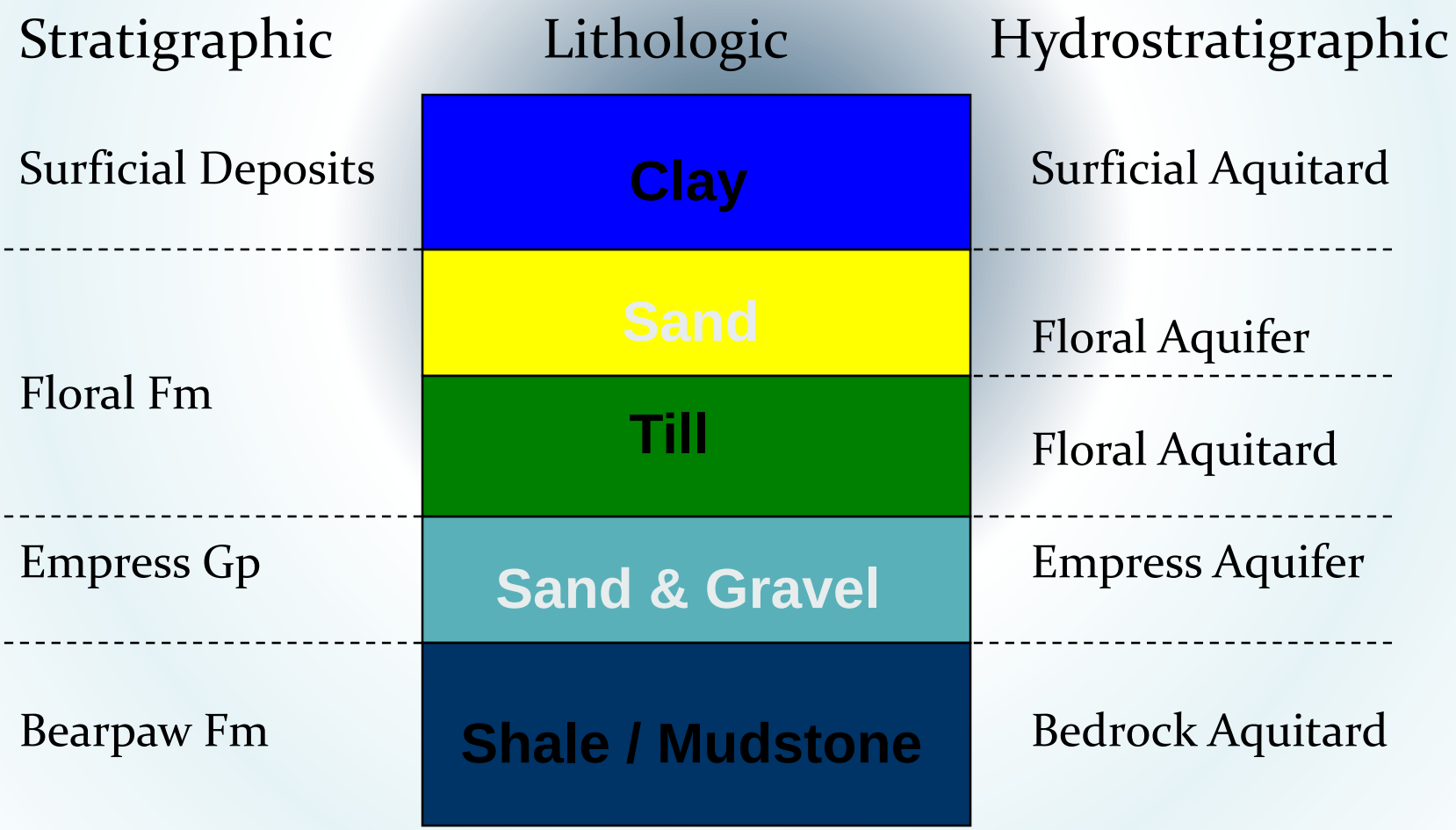
Water Resources and Hydrostratigraphy

HYDROSTRATIGRAPHY

Hydrostratigraphy is the identification of mappable-units on the basis of hydraulic properties (aquifer / aquitard) that have considerable lateral extent and that also form a geologic framework for a reasonably distinct hydrogeologic system.



HYDROSTRATIGRAPHY (historical notes)

The term hydrostratigraphic unit was first proposed by Maxey (1964) for "bodies of rock with considerable lateral extent that compose a geologic framework for a reasonably distinct hydrologic system."

Maxey (1964) identified the need to define ground water units that are based not solely on specific lithologic characteristics but also included parameters "that apply especially to water movement, occurrence, and storage."

Seaber (1982; 1986; 1988) proposed a definition of hydrostratigraphic unit as "a body of rock distinguished by its porosity and permeability," which he considered more consistent with established stratigraphic nomenclature.

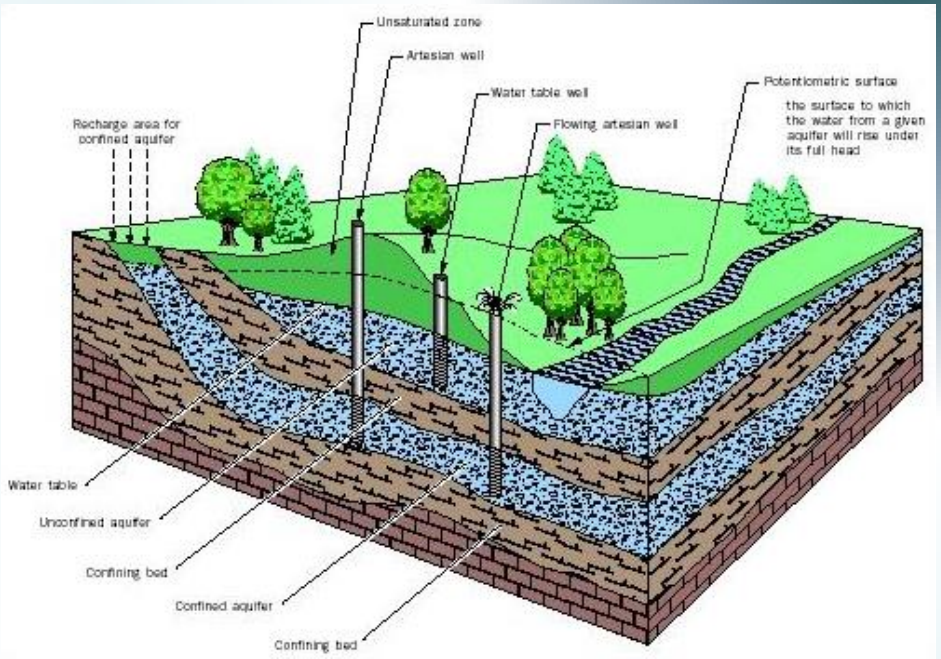
With this definition, Seaber intended to accommodate the observation that a "hydrostratigraphic unit may occur in one or more lithostratigraphic units." Seaber (1988) attempted to define a hydrostratigraphic unit that applied to all geological environments by focusing on the material properties of the rock or sediment.

HYDROSTRATIGRAPHY

The starting point for any regional hydrogeological characterization study is to establish the hydrostratigraphy by identifying mappable flow units and intervening aquitards.

This is done using standard subsurface and surface mapping techniques based of the principles of sequence or genetic-unit stratigraphy.

Emphasis is placed on the characterization of hydraulic properties of lithofacies within each genetic-unit on various scales using data from a wide range of sources including thin-sections, core studies, slug tests, DSTs and pump tests.



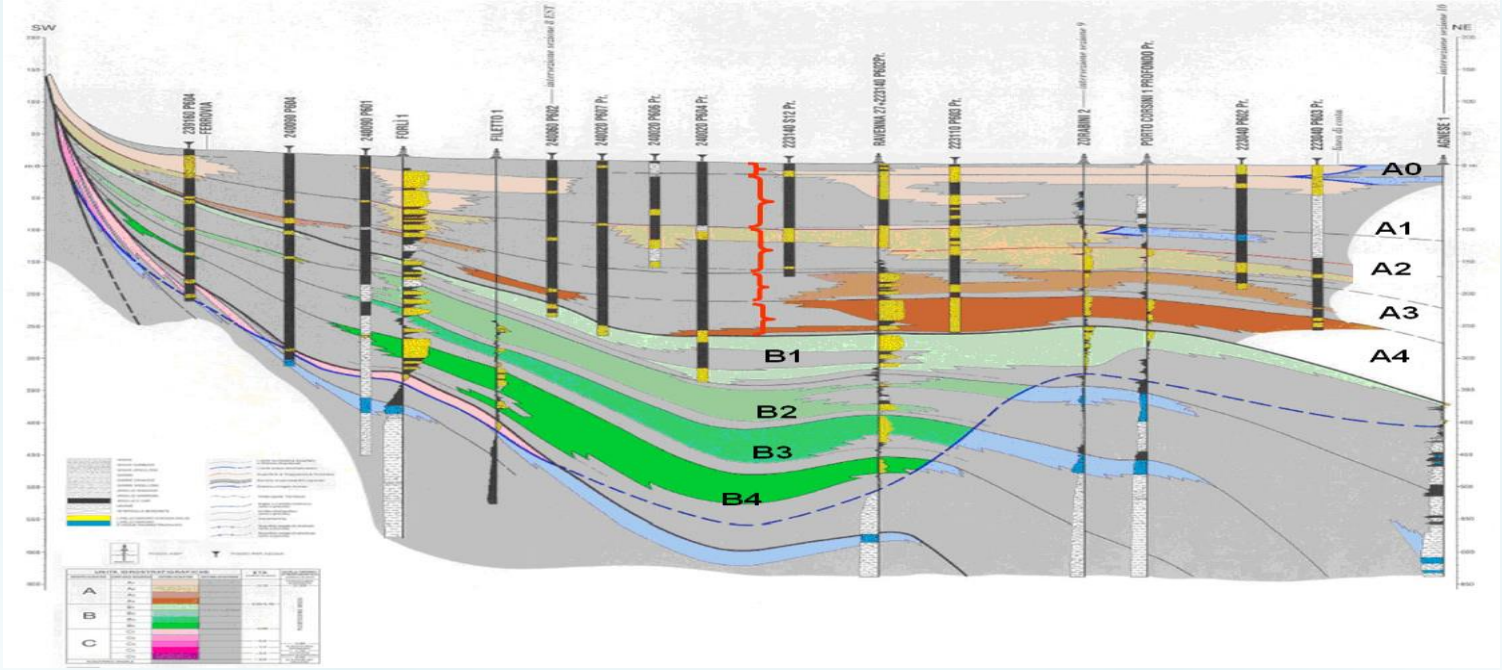
grado di permeabilità relativa	coefficienti di permeabilità	tipi di rocce
alto	$K > 10^{-2}$	ghiaie
medio	$10^{-2} > K > 10^{-4}$	sabbie
basso	$10^{-4} > K > 10^{-9}$	sabbie fini,silts
impermeabile	$10^{-9} > K$	argille

Hydrogeologists have long noted that ground water flow often does not conform to the boundaries of recognized stratigraphic units.

Two terms, “aquifer” and “hydrostratigraphic unit,” are commonly employed to subdivide the subsurface into units more relevant to groundwater hydrology.

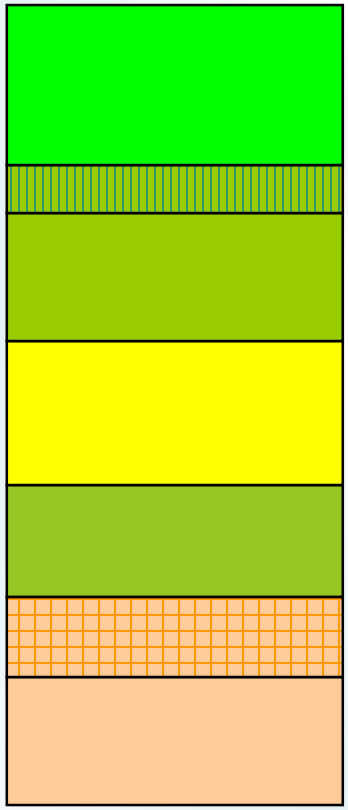
The term “aquifer” is commonly defined for water supply usage in economic terms. In many areas, “aquifer” is defined by local laws and regulations which makes it difficult to use as a technical term.

The term “hydrostratigraphic unit” (HSU) has been defined in a variety of ways in the literature, and does not currently have a formal definition



AQUIFERS, AQUITARDS and HSUs

- An aquifer can be composed of one or more HSUs.
- Thick aquitards or aquicludes may be defined as HSUs based on their distinct groundwater flow characteristics.
- Thin aquitards or aquicludes that form significant, laterally continuous layers that limit hydraulic communication may be used to define HSU boundaries.



Unit #1: Isotropic Aquitard

Unit #2a: Anisotropic Aquitard $K_v >> K_h$

Unit #2b: Isotropic Aquitard

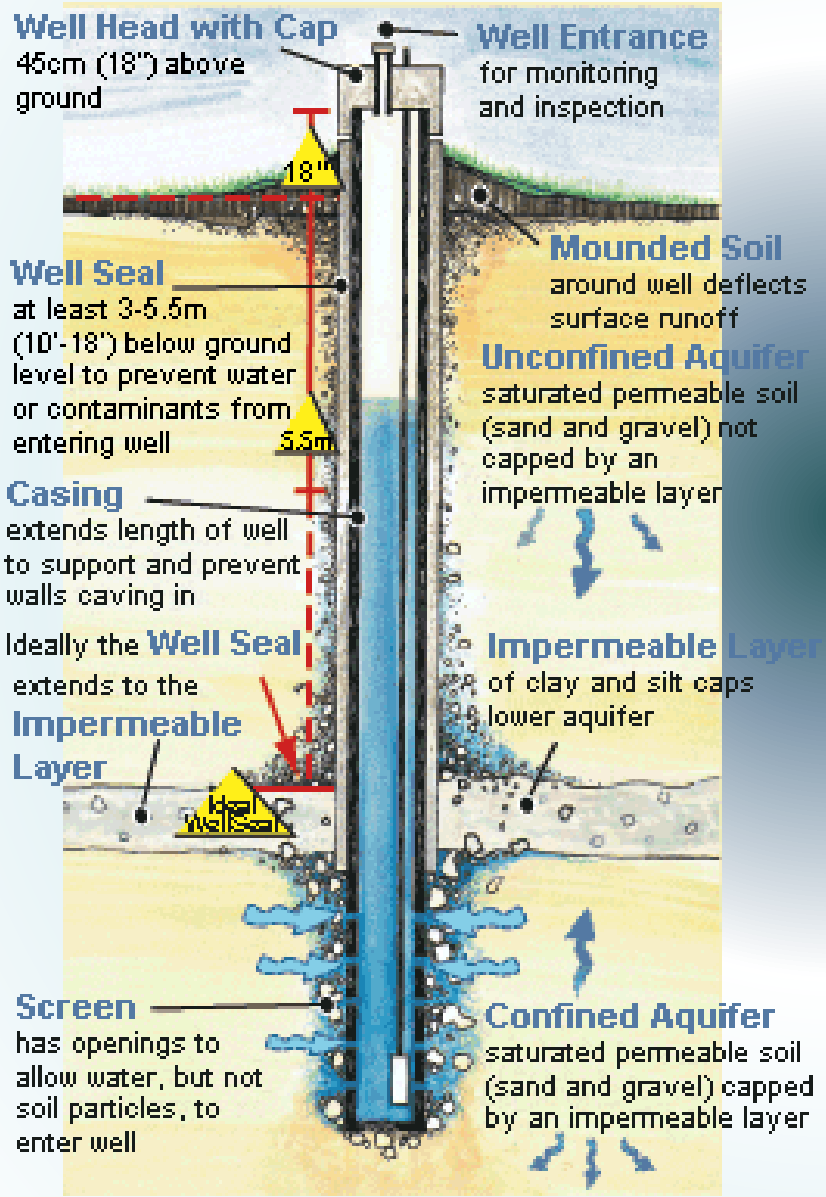
Unit #3: Isotropic Aquifer

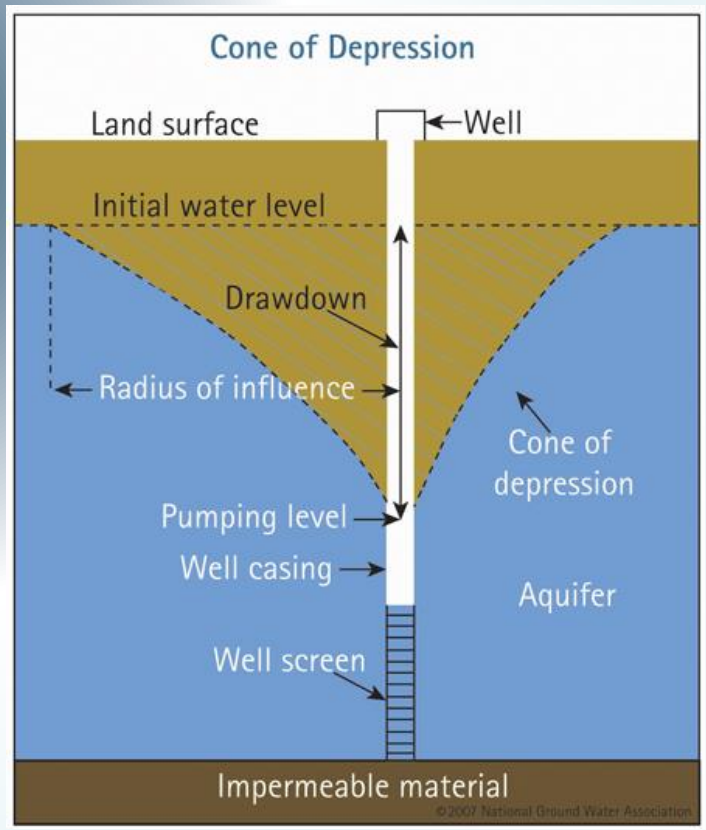
Unit #4: Isotropic Aquitard

Unit #5a: Fractured Bedrock Aquifer

Unit #5b: Unfractured Bedrock Aquifer

WELLS for WATER PUMPING and EXTRACTION



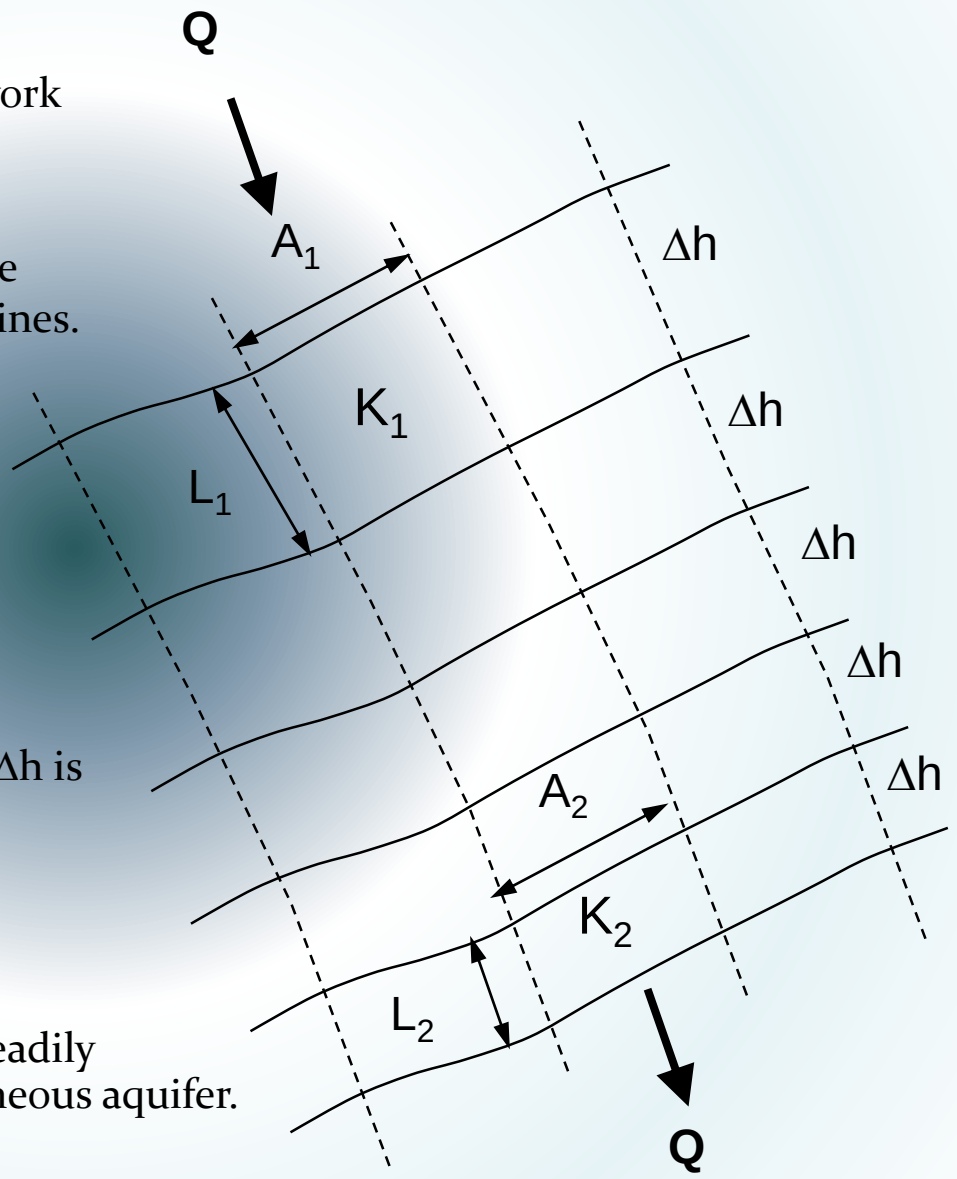


FLOW NETS

- Equipotentials and flow lines form a network called **flow net**.
- For a flow net flow all tubes carry the same flow and there is no flow normal to flow lines.
- This means:
  $Q = K_1DhA_1/L_1 = K_2DhA_2/L_2$

INTERPRETING FLOW NETS

- For a uniformly thick aquifer $A_1 = A_2$ and Δh is constant for contours at equal intervals.
- It follows that: $\underline{K_1} = \underline{L_1}$, $K_2 = L_{2, \text{etc ...}}$
- Thus if K_1 has been measured K_2 can be readily estimated for an isotropic but inhomogeneous aquifer.



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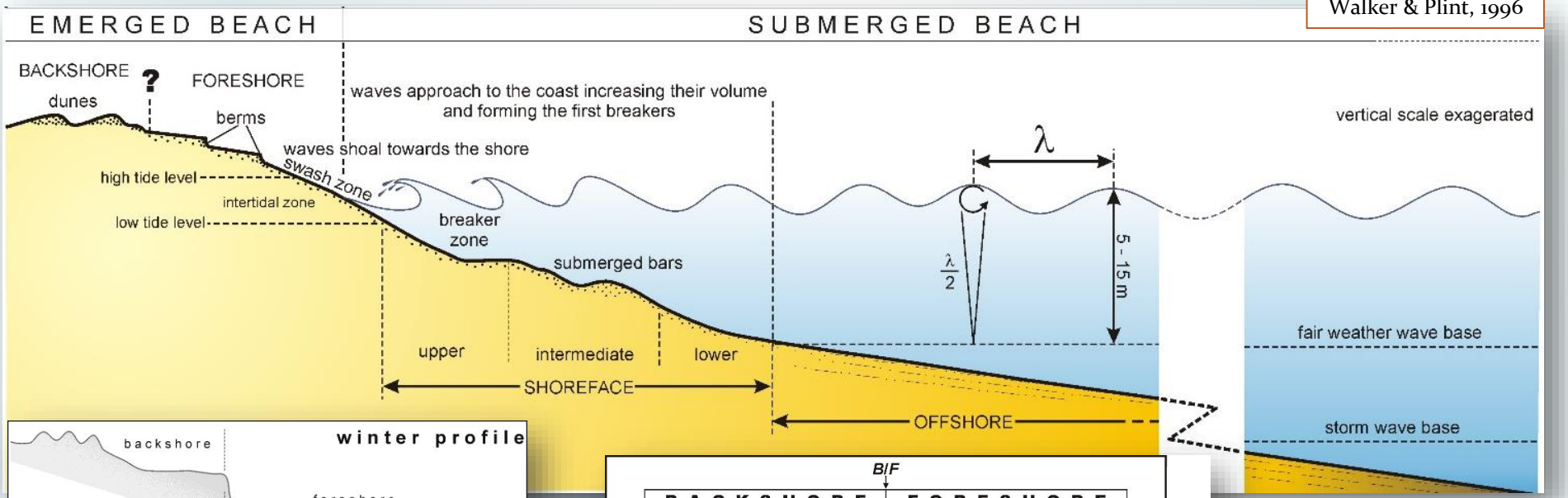
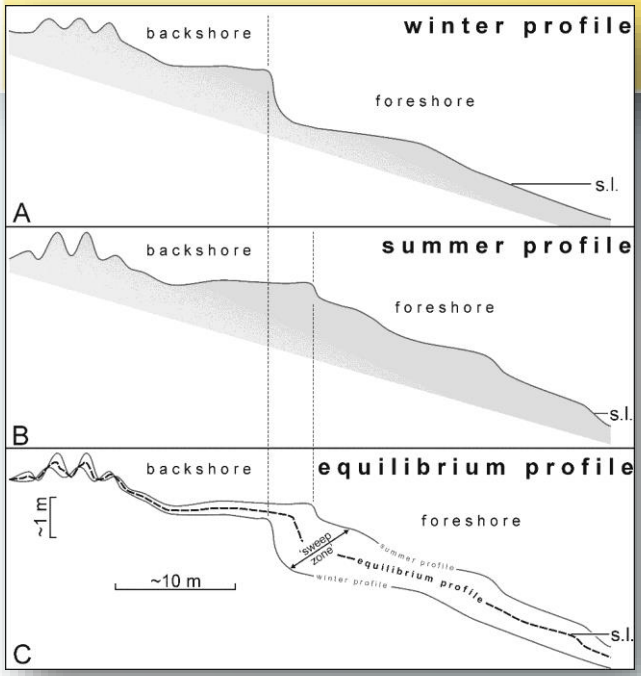
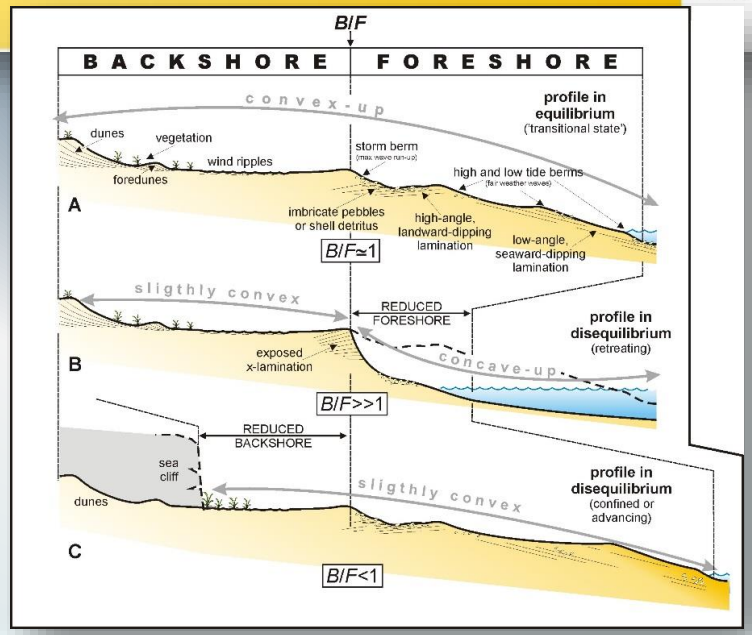
Clastic Resources and applications to problems of coastal erosion

A **beach** is a geological body, liying across the land and the sea, consisting of unconsolidated clastic sediments and subjected to a continuous dynamic change due to waves, tides and currents.

Walker & Plint, 1996

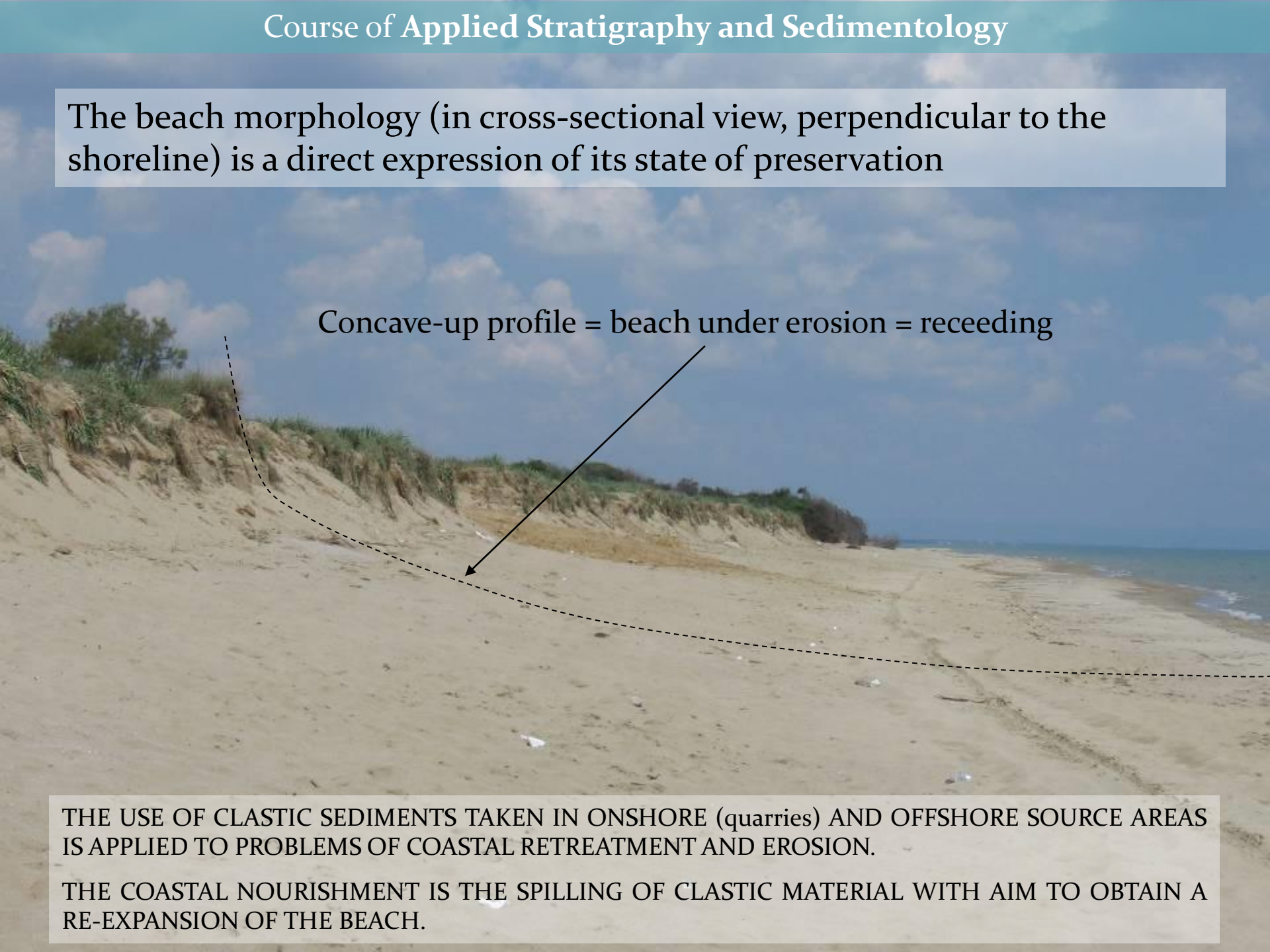






Longhitano, 2014

The beach morphology (in cross-sectional view, perpendicular to the shoreline) is a direct expression of its state of preservation



THE USE OF CLASTIC SEDIMENTS TAKEN IN ONSHORE (quarries) AND OFFSHORE SOURCE AREAS IS APPLIED TO PROBLEMS OF COASTAL RETREATMENT AND EROSION.

THE COASTAL NOURISHMENT IS THE SPILLING OF CLASTIC MATERIAL WITH AIM TO OBTAIN A RE-EXPANSION OF THE BEACH.

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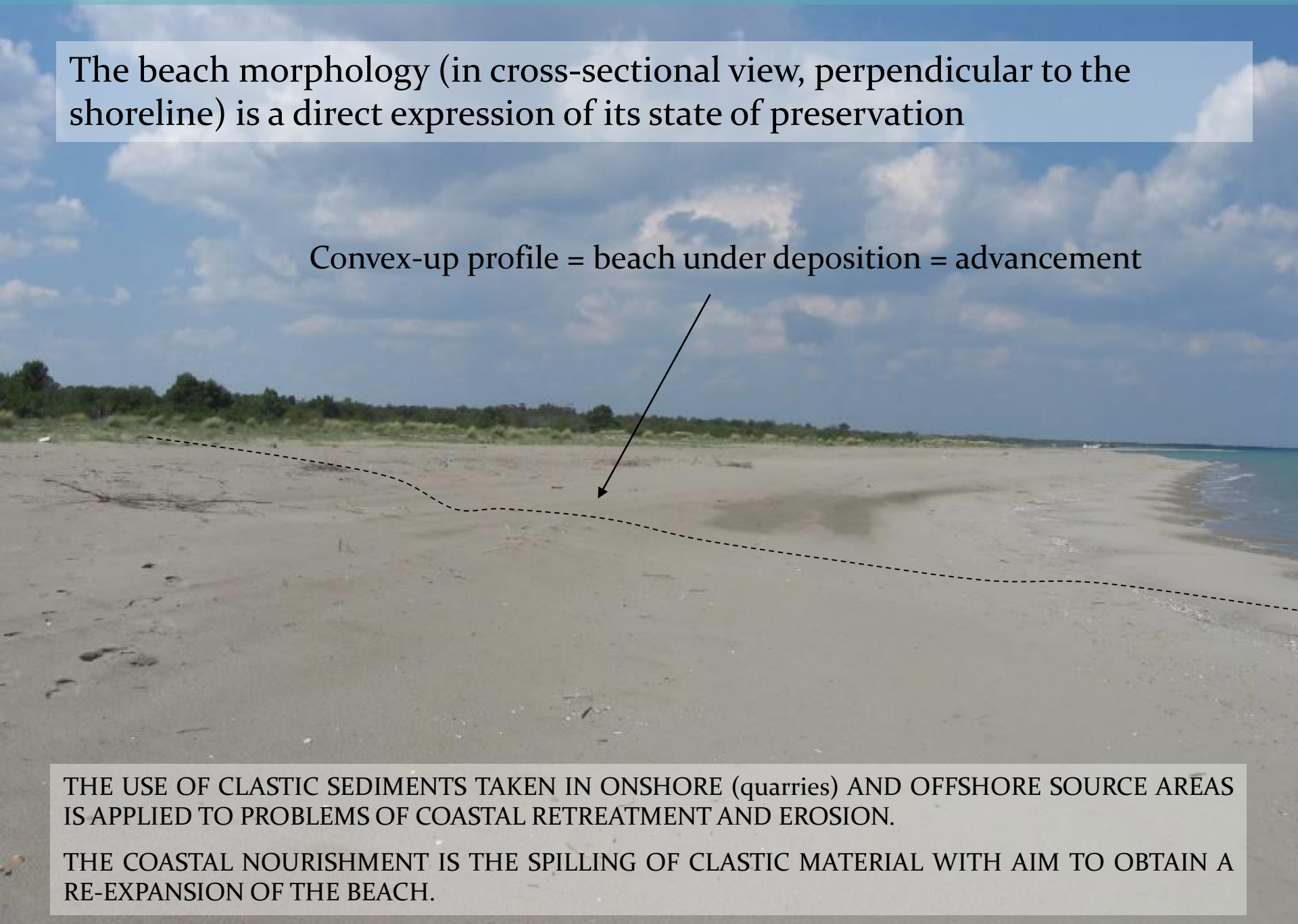

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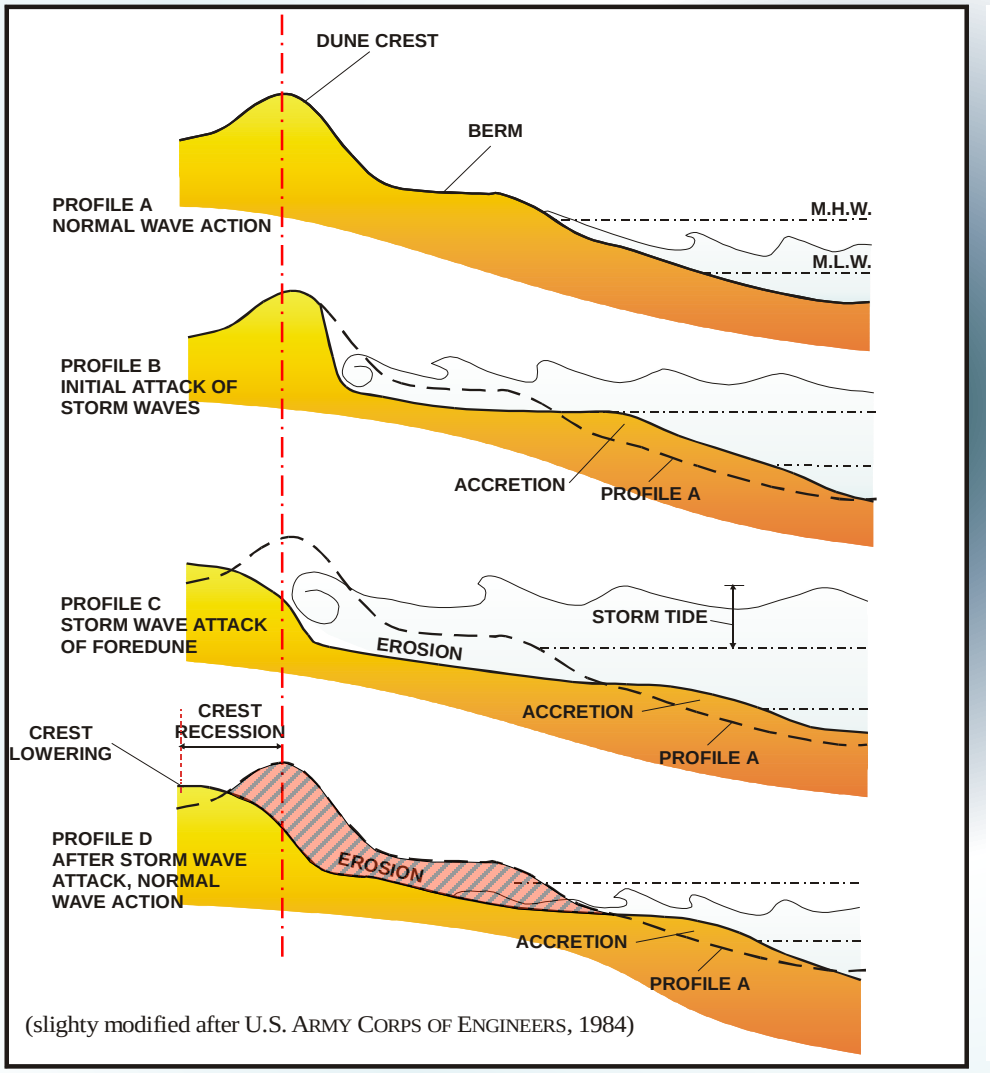
COASTAL EROSION and RETREATMENT:

Sediment lost because of removed by waves and currents (erosion)



(slighty modified after U.S. ARMY CORPS OF ENGINEERS, 1984)

Stage 1

State of preservation of a sandy beach under 'normal' (fairweather) wave activity.

Stage 2

Storm waves and erosion of the beach.

Stage 3

Coastal retreatment due to the erosion of sand and remobilization from currents.

Stage 4

Restoring of fairweather wave conditions onto the eroded beach.

Clastic resources are represented by successions cropping out or buried, which can be exploited through the excavation in quarries and extraction of 'inert' for use for coating materials, for production of cements or for interventions of beach nourishment along eroding coastlines.

Fig. 6

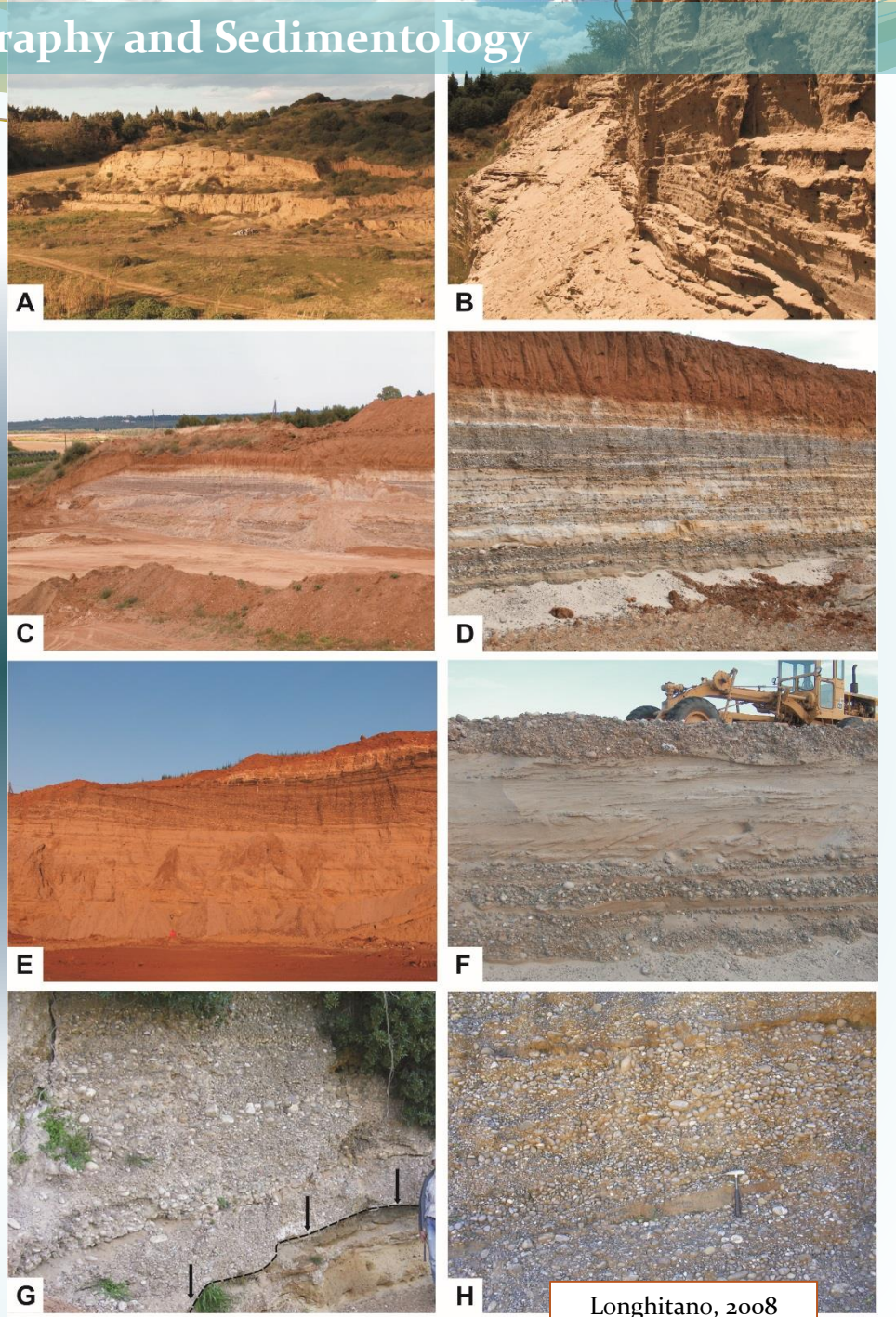


Fig. 7

Longhitano, 2008

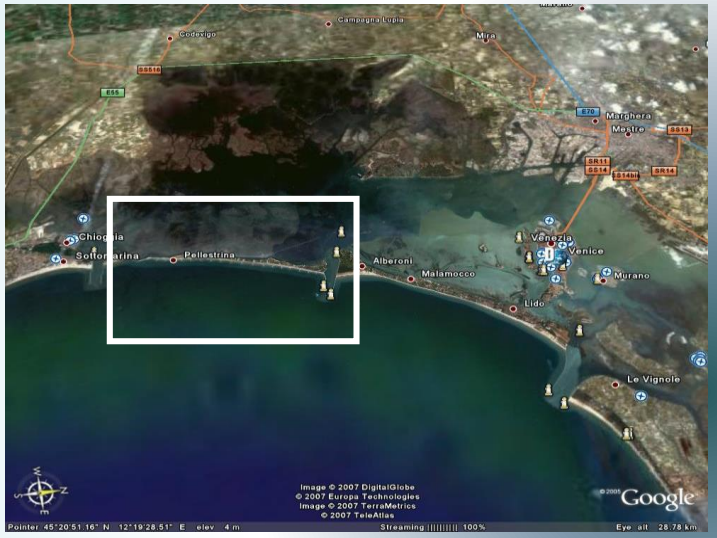
NOURISHMENT OPERATIONS WERE ALREADY CARRIED ON IN THE SEVENTIES FROM USA, WHERE MILLION CUBIC METERS OF OFFSHORE SEDIMENTS COLLECTED ALONG THE PLEISTOCENE CONTINENTAL SHELF WERE POURED TO RESTORE THE FLORIDA BEACH FOR MORE THAN 50 KM OF VERY TOURISTIC-PRONE COASTLINE.

Miami Beach (Florida, USA)

before

after

ONE OF THE MOST COMPLEX AND EXPANSIVE PROJECT WAS MADE DURING THE LAST YEARS ALONG THE VENETIAN COAST OF ITALY. THE SEDIMENTARY NOURISHMENT WAS BUILT BY BUILDING EMBANKMENTS ALONG THE COASTLINE, WITH SUBMERGED (FLOODED) PARALLEL AND PERPENDICULAR WALLS AND THE CONSTRUCTION OF COASTAL 'CELLS'.



EVEN ALONG THE METAPONTO COASTLINE, IN BASILICATA, MANY PLAN NOURISHMENTS HAVE BEEN IMPLEMENTED IN RECENT YEARS, EVEN IF THE EFFECTIVENESS OF SUCH MEASURES HAS REVEALED SCARCELY USEFUL OR USELESS!

THE IMPORTANCE IN IDENTIFYING AND SELECTING SOURCE AREAS FOR COASTAL NOURISHMENT PROJECTS PLAYS A PRIMARY ROLE, BECAUSE ANY TEXTURAL INCOMPATIBILITIES BETWEEN THE SELECTED CLASTIC SEDIMENT AND THE RECEIVING COASTS CAN CAUSE ENVIRONMENTAL PROBLEMS, INCLUDING CLOUDING OF THE MARINE WATERS OR IMPRATICABILITY OF THE BEACH.