Lecture notes - Bill Engstrom: Instructor **Sedimentary Rocks** **GLG 101 – Physical Geology**

Now that we've reviewed the processes of weathering, we can begin to see how pre-existing rocks can be weathered and become sedimentary rocks.

Hydrologic Cycle and Sedimentary Rocks

- Weathering produces sediments or solutions.
- These materials that can be deposited or precipitated to become sedimentary rocks
- **The Process: Weathering-Erosion-Transportation-Deposition-Cementation (Know this)**

The "agents" of erosion are: Wind / Water / Ice

These agents act to create many different "depositional Environments" (e.g. streams, lakes, deep sea, glacial and deserts)

How is sediment transported by these "agents"?

Mechanisms of erosion & transportation

- **Traction** - grains roll but remain in contact with the surface
- **Saltation -** grains jostled and moved downstream/wind by collision with other grains.
    - Grains tend to move near bottom- partially in contact with the bottom.
- **Suspension** - grains moved in suspension above the bottom- muddy water.

Sorting of Detrital Sediments (detrital – e.g. sands and gravels)

Sorting - The selective transport of particles on the basis of grain size.

- Depends on the **velocity** and **viscosity** of the fluid.
- Water will move bigger particles than air at the same speed.
- Ice can move the largest particles of all.
- Fast water will move larger size particles than slow water.

Types of sorting

- Well sorted = constant or small range of energy at deposition

- Poorly sorted = erratic energy or very high energy environment (e.g. glaciers or high gravitational forces such as near mountains)

For example: Poorly sorted gravels may mean that the sediment is deposited closer to the source or in a higher energy environment.

Rounding

- Edges tend to be knocked off during transport. Also depends on velocity and viscosity of the fluid
- Angular fragments = close to source
- Rounded fragments = generally far from source but, depends on source

For example: If feldspars are abundant, the sediment may be deposited close to source since they weather more quickly and would not be present further away.

Weathering breaks minerals down into more stable material.

- Feldspars picked up at the source continue weathering during erosion and transportation.
- Rock fragments & feldspars = close to source
- Quartz = generally far from source but depends on source. Quartz does not weather quickly.

Motion from weathering site to deposition site – How things move

- Detritus – material moved as clasts or pieces
- Chemicals move as ions in solution

Deposition = Process by which materials are deposited or precipitated in an area different from where they were eroded

- **Physical dropping of detrital material -** Detrital rocks, settling
- **Preciptitation of materials (ions) in solution** - **Chemical**
    - Evaporites (Salt, calcite, gypsum)
    - Chert (silica)
    - Microcrystalline limestones (calcite)
- **Biochemical**
    - Radiolarian chert & Petrified wood (silica)
    - Fossils (calcite) & , Coquina, Chalk, Coal

Preserving Sedimentary Rocks: Subsiding Basins. As basins subside (sink) sediments are accumulated. Buried sedimentary basins are prime areas for oil and gas exploration, since they form the best environments for the formation of oil and gas. And, oil and gas typically accumulates in sandstones and fractured limestones within these basins.

Environments of deposition - Examples
(will cover more on these later)

- **Continental** Environments - Alluvial Fans, Playa Lakes, River Systems, Lakes, Glaciers, Deserts, Deltas
- **Transitional** Environments (between continents and oceans/marine) – Deltas, Tidal Flats, Beaches
- **Marine** Environments - Nearshore/shelf, Deep Ocean

The concept of "Base Level"

- **Base level** of a river or stream - **The lowest point to which it can flow.**
- For large rivers - sea level **is usually the base level.**
- For tributary streams - a large river or lake is the base level (local base level).
- All rivers and streams erode toward sea level, which is also known as the "ultimate base level."

Aggredational vs. Degradational Environments

- **Degradational** Environments – generally above sea level / capable of eroding – into the ocean
- **Aggredational Environments** – generally below sea level – accumulation occurs as basins slowly subside

How do sediments become rocks?

Lithification = Process by which deposited material becomes rock.

- **Lithification involves <u>compaction and cementation</u>**

Main agents of cementation

- calcite, silica, hematite, limonite
- Red = oxidizing environments - at or near surface, not in oceans (Red – oxidized sediments including hematite, limonite etc.)

How do we classify Sedimentary Rocks?

The classification is based on…. **(Figure 5.3)**

- **Mechanism of deposition (detrital or chemical), Clast size & Composition**

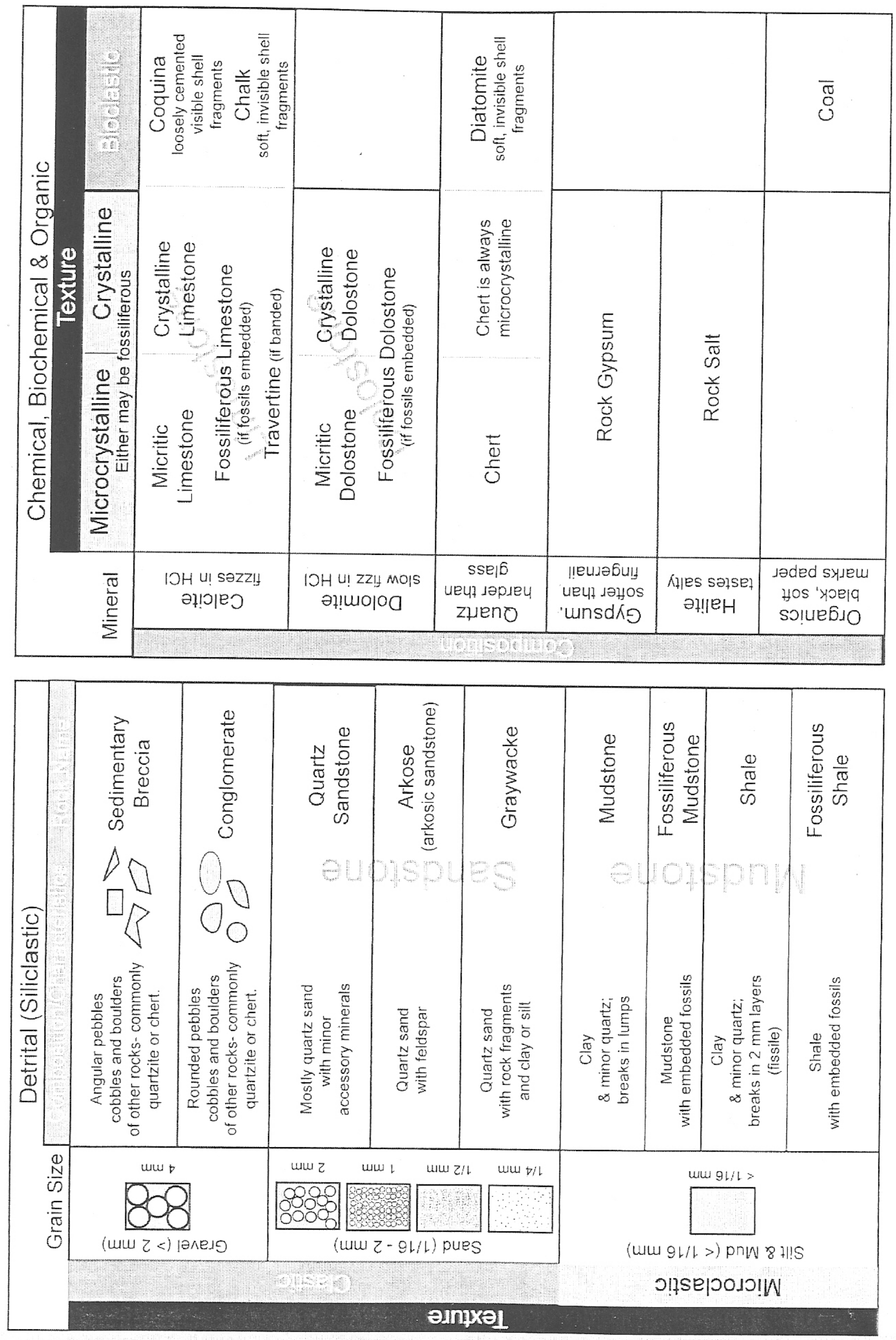

Figure 5.3: Sedimentary Rocks Classification

Detrital Rocks

- **Detrital Sedimentary Rocks -** material mainly classified on grain size & composition in the sandstones

Examples:

Conglomerate (rounded gravels/poorly sorted with gravels to clays etc.)-can indicate steep slopes, strong currents or glacial origin

Sedimentary Breccia(angular gravels/poorly sorted)-indicates that material did not travel far from source

Sandstone(sand size grains)- sorting, angularity, comp. etc. implies how it was deposited

Quartz Sandstone(predominant mineral – quartz)

Arkose Sandstone(>25% feldspar/some mica/gen. poor sorting/angular) - can indicate short transport distance and dry climate

Graywacke Sandstone(rock frags., qtz, feldspar/poor sorting, >15% matrix)can ind. short trans. distance/poss. submarine dep.

Shale(silt/clay – poorly cemented/lithified)- can indicate gradual settling in a quiet environment

Fissility in Shale - shale compacted tightly – water is forced out and rock becomes “fissile” and layers split apart easily.

Chemical, Biochemical and Organic Rocks

Examples:

Limestones - Biological or chemical precipitation of calcite ($CaCO_3$) ; can also occur as evaporite deposit commonly as stalactites or stalagmites in caves (chemical)

- Bioclastic (coquinas and chalk) vs. Crystalline (coarse or micritic) limestones

Dolostones $CaMg(CO_3)_2$ **-** Biological or chemical precipitation of dolomite; or chemical alteration of limestone to dolostone

Origins of Sediment- Chemical Precipitation from Evaporation

Chemical Precipitation – A crystalline texture resulting from precipitation

Examples:

Limestone (Travertine)- Lehmann Cave, NV - stalactites and stalagmites

Limestone (Tufa) - Mono Lake California - evaporite deposits

Origins of Sediment- Biochemical/Chemical Precipitation

Examples:

Biochemical Formation of Limestone (e.g. Fossiliferous Limestone & coquina [almost all larger shells-marine/reef origin])

Chalk (specimen) & Diatomite - accumulation of microscopic marine organisms

Chert = Biological or chemical precipitation of Silica ($Si0_2$) - microcrystalline

- If biologically produced by radiolaria these are called radiolarian cherts.
- Chert often occurs as inclusions or nodules in limestones (silica dissolves, migrates and precipitates as nodules). Variations: flint, jasper, agate, chert

Rock Salt (NaCl) and Rock Gypsum($CaS0_4$ = calcium sulfate)

- **U**sually chemically precipitated by evaporation of saline water.
- Sometimes called evaporite minerals

Coal - Formed by the alteration of organic material (biochemical formation). In swamp environments, when plant material is buried and compacted coal can be formed.

Oil & Natural Gas – Formed by the alteration of organic material (biochemical). Kerogen forms from partially decayed buried remains of sea organisms. The kerogen is converted to hydrocarbons and migrates. Oil and gas accumulates as ist is trapped in permeable/porous and fractured sedimentary rocks.

Economic Significance of Sedimentary Rocks

Resources and Uses

Coal – heating/energy (electrical) generation

Oil – gasoline and other petrochemical products (e.g. plastics), and energy generation

Natural Gas – heating and energy generation

Cement (limestone)

Drywall (gypsum)

Glass Making (quartz/silica)

Reading sedimentary rocks

Information we get from sedimentary rocks indicate how the sediments were deposited (ancient environments of deposition [aka depositional environments] and paleogeographies). These indicators are "clues" to past environments.

Depositional Environments

***Here are some general* Environmental Indicators (e.g. Grain size, composition, rounding, sorting, color)**

Grain Size

- Fine grain size = low energy mechanisms (e.g. standing water)
- Course grain size = higher energy mechanisms (running water or wave action).

Sorting

- Well sorted = constant or small range of energy at deposition
- Poorly sorted = erratic energy or very high energy environment (e.g. glaciers or high gravitational forces such as near mountains)

Rounding

- Angular fragments = close to source
- Rounded fragments = generally far from source but, depends on source

Composition

- Rock fragments & feldspars = close to source
- Quartz = generally far from source but depends on source itself

Color

Red = oxidizing environments- at or near surface (terrestrial - <u>not in oceans)</u>.

***Here are some special* Environmental Indicators**

- **Sedimentary Structures - Examples**
  - Bedding & lateral continuity (e.g. is it continuous or discontinuous laterally).

- Ripple marks, Mudcracks, Scours. For example, ripple marks can indicate beach environments, desert dune or river channel deposits depending on the type. Mudcracks can indicate wet/dry cycles.
- Cross-bedding, graded bedding. The type of cross-bedding can indicate the type of environment (e.g. sand dunes vs. beach vs. river). And, certain types of graded bedding can indicate deep sea "turbidite" deposits.
- Rip-ups – These can indicate high energy deposits.
- **Fossils -** the remains or traces (coprolites) of once living organisms. Different species can indicate the environments where they live (example: fish – live in water)

Here are some more examples of these indicators and what they mean.

- Symmetric Ripples - back & forth currents (e.g. at the beach)
- Asymmetric Ripples - Current in one direction (e.g. stream deposits)
- Cross Bedding is formed from changes in ripple movement (e.g. changes in flow/direction)
    - Dune Cross Bedding – Large Scale Cross Beds. Stream Cross Beds are smaller than dune cross beds
- Leaf fossils in shale – Deposition on Land
- Dinosaur Footprint in sedimentary rocks – Deposition on Land

Interpretation of Ancient Depositional Environments from sedimentary rocks

The following summaries describe general indicators as they relate to more specific depositional environments, including the major types on continents, oceans and transitional areas. You should KNOW as much of these as possible so that, if you are given a few key indicators, you can determine the depositional environments.

Continental (polar) Environments

Glacial Till: *Extremely poorly sorted* (clay to boulders), *angular* and semi-rounded clasts, polished and *grooved (striated) rock surfaces*; very poorly bedded. Net rock types are essentially *sedimentary breccias* (tillites) glacial lake deposits.

Glacial Lakes: Thin *continuously bedded layers* of *mudstone/shale* with **varves** (alternating dark & light layers from seasonal deposition - light=summer-sand-silt dep./dark=winter-fine clay). **Dropstones** may be present (dropped by stones "rafted" by icebergs)

Continental (Arid) Environments

Alluvial Fans: *Poorly sorted gravels and sands; large, angular clasts*. Lacks fine clays characteristic of glacial deposits. Net rock type is *sedimentary breccia* grading into arkosic sandstones near margins. Discontinuous layers to faint bedding.

Playa Lakes: Thin *continuously bedded layers* of *mudstone/shale*, and *evaporites* (rock salt, rock gypsum, and occasionally limestone). *Mudcracks* are common, as are terrestrial trace fossils (e.g. footprints).

Deserts: *well-sorted, well-rounded, fine sandstones* with *huge crossbeds* (>10'), occasional asymmetric ripple marks and terrestrial trace fossils (e.g. footprints).

Desert Dune Deposition - well-sorted, well-rounded, fine sandstones with **huge crossbeds (>10')**, occasional asymmetric ripple marks and terrestrial trace fossils (e.g. footprints).

Continental (Normal) Environments

River Systems: *discontinuous layers of conglomerates, sandstones, and mudstones/shales*.

Stream Depositional Environments

- **Channel deposits** - conglomerates represent channel deposits (well-rounded and moderately sorted).
- **Bar deposits** - medium to coarse sandstones (with small crossbedding and asymmetric ripples) represent bar deposits.
- **Braided streams** - Arkose sandstones are common in braided streams near feldspar-bearing source rocks (like granites).
- **Floodplains** - The mudstones/shales (thin beds with terrestrial trace and plant fossils occasionally coal bearing if associated with swamps) represent the floodplain deposits.

Lakes

- *Thin, continuous beds of mudstone/shale* and, in larger lakes, limestones ± evaporite deposits near the lake margins.
- *Freshwater fossils*, symmetric ripples and mudcracks near shore environments.

Transitional Environments

Deltas: similar to stream deposits *discontinuous layers of conglomerates, sandstones, and mudstones/shales*.

- **Channel deposits**: The conglomerates represent channel deposits (well-rounded and moderately sorted).
- **Bar deposits**: Medium to coarse sandstones (with small crossbedding and asymmetric ripples) represent bar deposits
- **Offshore delta**: Mudstones/shales (thin beds with freshwater or marine fossils) represent the offshore portion of the delta.
- **Reverse graded bedding = The main difference between delta and stream deposits** - the delta will often grade from mud near the bottom of the deposit to sandstone/conglomerates near the top (this is called *reverse graded bedding*).

Swamps: like lakes, the swamps typically *have thin continuous beds of mudstone/shale and often <u>coal</u>* . This is a good environment for preserving terrestrial *fossils including trees* (the Petrified Forest deposits for example).

Marine Environments (Marine fossils are excellent indicators of these environments)

Beaches

- Medium to coarse well-sorted, well-rounded, sandstones or *coquinas* (if beach is made up of shell fragments e.g. Florida).
- Swash (herringbone) crossbedding and trace and hard *marine fossils* (usually abraided).
- Occasional *symmetric ripple* marks.

Offshore Depositional Environments

Tidal Flat/Estuary

- Thin beds of symmetrically rippled mudstone/shale disrupted by occasional tidal channel sands (also symmetric ripples).
- Marine fossils are common.
- Occasional mudcracks.

Nearshore & Shelf

- Usually continuous beds of fossiliferous mudstone/shales and limestones.
- Typically lacks ripples or mudcrack structure.
- Very continuous beds.
- Fossils indicate shallow water.

Deep Ocean

- Usually continuous beds of microfossiliferous mudstone/shales and limestones.
- Typically lacks ripples or mudcrack structure.
- Very continuous beds. *Fossils indicate deep water*. In some environments, long *continuous beds of chert* are formed from radiolarians and diatoms.
- Occasionally interrupted by *turbidite deposits* (sediment landslides from nearby continental shelves). Turbidite sequences are typically graded beds of sand (near bottom) to mud (near top).

Case Example- The Grand Canyon. A discussion of the Grand Canyon would be too lengthy to include in these notes. Examples will be discussed in class, and you can follow-up with your own research about the Grand Canyon in texts and on-line. I will briefly cover the Grand Canyon in class as a general example of:

- Rock formations
- **Sedimentary facies**- *a body of rock with a specified characteristic - reflecting conditions of depositional environment.*
- Stratigraphy and depositional environments

The rise and fall of sea level AND **Transgressive vs. Regressive environments**

- **Transgressive – water level rises.** When water level rises, the sea is transgressing inland (moving further inland).
- **Regressive – water level falls**. When water level falls, the sea is regressing (moving further offshore).
- **If you are trying to interpret if the water level rose or fell from the rock record, you would need to determine which sedimentary environments each rock type was deposited in**. For example, if you are looking at a cliff face, and there is a marine limestone formation at the bottom, and a sandstone (desert dune environment) at the top, with a tidal flat deposit in between, the water levels must have decreased through time. That means that you are looking at a regressive environment.

A number of different transgressive /regressive environments are represented in the Grand Canyon.

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