CHEMICAL SEDIMENTARY ROCKS: Evaporites, Carbonates, Cherts

INTRODUCTION

Chemical Sedimentary Rocks form in association with water, either because of water evaporation (evaporites) or because of changes in the concentration of ions in solution (carbonates, cherts).
The main purpose of this lab is to learn about the most common chemical rocks, limestones, (which are calcium carbonates). Still, let's briefly review (and not forget) the other rocks.

EVAPORITES

Evaporites form in dry environments, upon water evaporation. A common misconception is that since oceans are salty, salts form in ocean water. In reality, water keeps the ions hydrated, that is, their ionic charge is neutralized by the uneven distribution of the electrical charge on a dipolar water molecule. If not enough water molecules are present, the ions get together forming a salt. So, in order for an evaporite to form, either we have more and more ions in solution or water is removed from the solution. At that point, salt is forming. In the end, salt would not form as long as there is water (in the ocean) but it requires evaporation of water (such as in a playa lake, or in basins with very limited water circulation in subtropical belts). As a consequence salts (evaporites) are not very common, and indicate a continental or a coastal environmental, never an open marine one.
There are several kinds of evaporites, but we need to mention only two of them: halite (NaCl), and gypsum ($CaSO_4$ $2H_2O$). Water in gypsum can be removed through a variety of processes and we obtain anhydrite ($CaSO_4$).

CHERTS

Cherts are made of silica (SiO_2) and typically (but not necessarily) indicate a deep marine environment. They form in a manner somehow similar to chalk (see class discussion, and below) and they are not particularly common.

CARBONATES

Carbonate minerals are compounds made with the carbonate ion (CO_3^{2-}). While many minerals can form in that way, only two are common enough in sedimentary environments and in the rock record to be worth mentioning: calcite and dolomite.
Carbonate rocks composed of calcite ($CaCO_3$) are called limestones while carbonate rocks composed of dolomite $[CaMg](CO_3)_2$ are called dolostones. These rocks form through biological and biochemical processes and through inorganic precipitation from seawater and freshwater. Carbonate rocks occur throughout the world and in every geological period beginning with the Cambrian.
Carbonate sediments can simply form inorganically on land (travertine, tufa) or in the ocean (oolitic limestones) because of water chemistry. Carbon dioxide tends to dissolve calcite, and removal of carbon dioxide favors formation of calcite in water solutions. On land, CO_2 is lost by water at springs, waterfalls, in caves and caverns, and as a consequence limestone is formed naturally. In the ocean CO_2 is lost in shallow warm waters, thus causing formation of oolites in these environments.

The great conditions that exist in shallow warm water environments for carbonate formation also favor those organisms that use $CaCO_3$ in their infrastructure (for instance, corals, certain algae, mollusks, echinoids, and many more are quite

common in carbonate rocks, and are mostly found in abundance in tropical to subtropical latitudes or from about 30º north and south latitudes).
As a consequence, most of the carbonate sediments are generated in shallow waters, and in particular in the photic zone. The photic zone is that part of the ocean waters where light penetration is enough to support photosynthesis, and it usually extends to a maximum light penetration of 100 meters in conditions of clear waters.
Carbonates can also deposit in deep waters, as long as the ocean bottom is above the CCD, or Carbonate Compensation Depth, which is at about 3500-4000 m from the surface. At that depth, high pressure and cold temperatures cause dissolution of carbonate at all times, and calcite cannot form. As consequence, carbonate (chalk) can form along the flanks of a mid-ocean ridge. When the plates move away form the ridge and start to sink, ideally calcite is dissolved, unless it is covered by cherts or red clays.
If you think in terms of changing Earth, a warmer planet would see the melting of polar caps, and a rise in sea level. The ocean is already on continental crust (the continental shelves) and more water would cause invasion of coastal flat areas. An expanded substrate, accompanied by warmer waters, would enormously increase shallow water carbonate sedimentation, as it happened for instance during the Cretaceous.

CARBONATE TEXTURES

Unlike sandstones, most carbonate grains are formed in the environment in which they are deposited (that is, most of the times they are NOT eroded, transported, deposited). Detrital grains in sandstones are in stead usually derived from outside the environment in which they were deposited. For example, sand grains usually develop through weathering and are transported to such environments as a continental shelf or a beach. Carbonate grains are usually reworked and deposited in the same depositional environment.

In this lab we will learn to identify the various components of carbonate rocks, and we will also learn to classify them. Two principal classification schemes are used for limestones. One is termed Folk's classification scheme, which is named after Robert Folk, and the other Dunham's classification scheme, which is name after Robert Dunham.

Folk's classification scheme is based on the presence or absence of allochems (carbonate particles or grains), matrix (limestone clay called micrite), and the type of cement (spar is a cement composed of coarse crystals). The allochems can be bioclasts, ooids, fecal pellets, or intraclasts (see below and your notes for details). These components provide clues to the origin of the carbonate rocks.

Dunham's classification scheme is based on the texture of the rock. i.e. whether the rock contains matrix, whether the carbonate grains float in the matrix or whether they are in contact with each other, and whether the rock has any carbonate grains.

SOME CARBONATE COMPONENTS

ALLOCHEMS:

Ooids and Pisolites: Ooids are spherical grains formed by calcite precipitation around a nucleus such as a shell fragment, a quartz grain, etc. They are less than 2 mm in diameter and they typically form in shallow, warm, agitated, and carbonate-saturated waters such as those near the Bahamas.
Pisolites are ooids greater than 2mm in size

Bioclasts: these grains are broken or whole skeletal parts of organisms, such as the broken shells you would find in a Coquina.

Fecal Pellets: these grains consist of the clustered remains of whole or broken shells of microplanktonic organisms (coccolithophorids and foraminifers), undigested and expelled by organisms who fed on them. Because of the size of the pellets, which is consistently bigger than the individual organism's shell, they sink to the ocean bottom in an area that is essentially below the living environment, thus providing information on the conditions of the ocean surface at that precise spot

Intraclasts: Semi-consolidated sand- or gravel-size pieces of carbonate (limestone or dolostone) material ripped up and incorporated within the newly formed rock

CEMENT:

Sparite: Sparite, or sparry carbonate, is a clear crystalline carbonate that has been precipitated between the allochems, or clasts, of the limestone. Sparite can also be formed by recrystallization of carbonate clasts.

MATRIX:

Micrite: Micrite is fine grained (less than 4 microns) carbonate material (carbonate mud). Essentially, it is limestone clay. Contrarily to sparite, micrite is deposited together with the allochems. Like for clastic sediments, fine-grained carbonate material generally accumulates in quiet water environments from tidal flats and lagoons to the deep ocean.

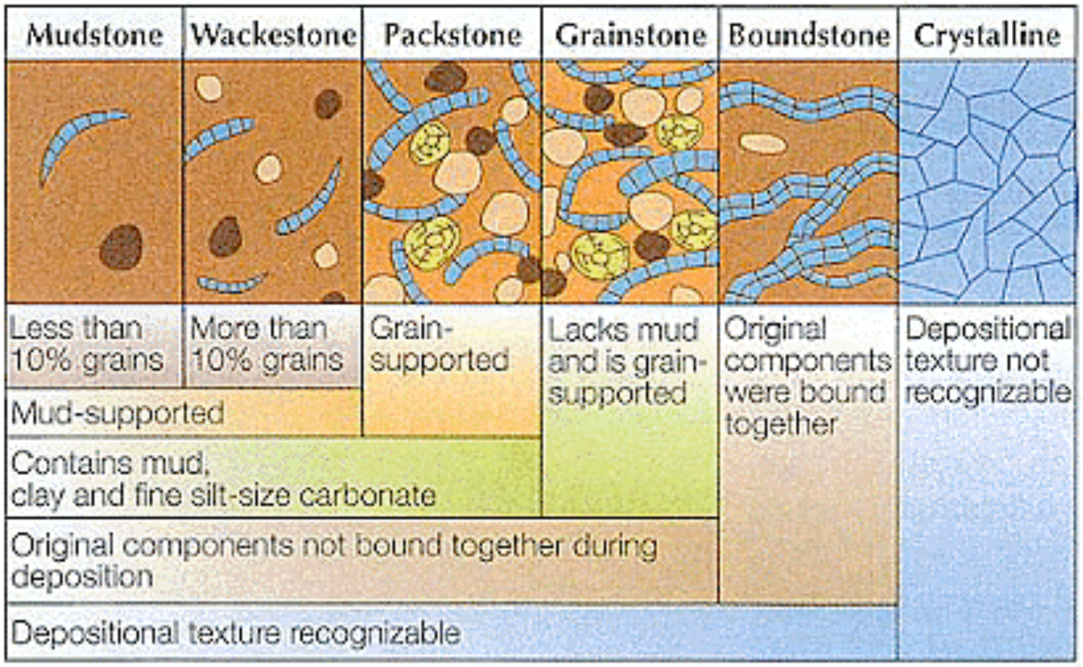
OTHER COMPONENTS:

Stromatolites: Stromatolites are laminated carbonate sediments composed of mats of blue-green algae and layers of sediment. The algae forming the mats are photosynthetic and require sunlight to survive. Therefore, stromatolites generally form in warm shallow waters (within the photic zone). The algae are "sticky" and grow filaments. This sticky, filamentous algae trap sediment brought in by currents and waves. Consequently, after a layer of algae forms it is then covered by a layer of sediment on its top. Subsequently, the algae grow through the sediment to form another mat and the cycle begins again. Ultimately, a layered rock composed of alternating algal mats and sediments is produced. Stromatolites today form in quiet, hypersaline waters with little animal life which would destroy the mats.

Oncolites: Oncolites are stromatolites rolled in a ball.

Corals: Corals have a symbiotic relationship with dinoflagellate algae called zooxanthellae. These algae are like plants. Therefore, in order for corals to survive they generally have to be within the photic zone (the zone of maximum light penetration in the ocean). In the process of photosynthesis, oxygen is produced and CO_2 removed from the atmosphere. Corals are major reef formers, both today and in the past. However, some corals do occur in deeper and/or colder waters.

Dunham Classification Scheme for Limestones



Folk Classification Scheme for Limestones

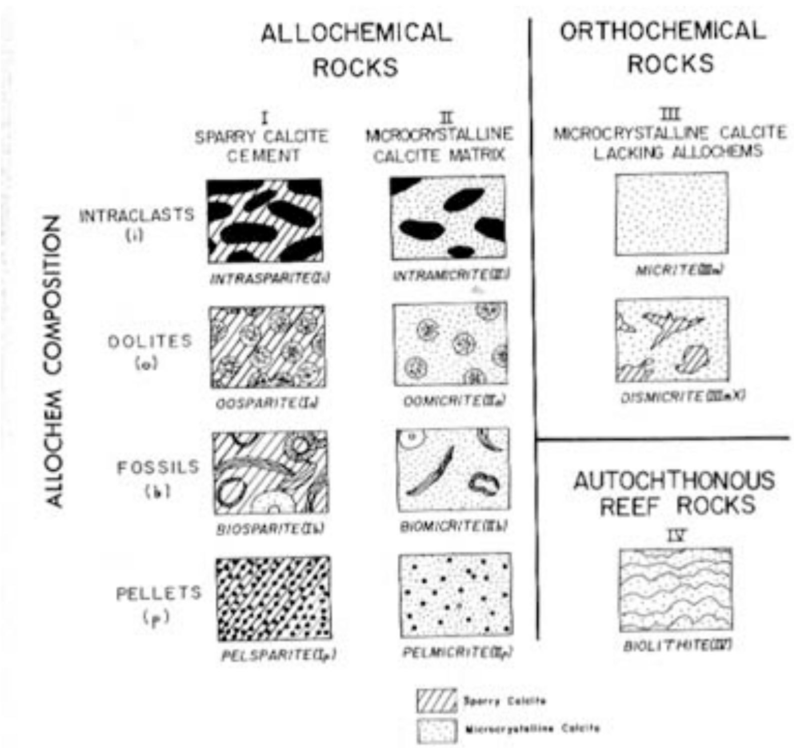


FIG. 3. Graphic classification table of limestones. For determining composition see Fig. 2; for full details of of classification, including method of denoting grain size and dolomite content, see Table I.