Quadrant II – Transcript and Related Materials

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Notes

Evaporites

Introduction

- Evaporites are mainly chemical sediments that have been precipitated from water following the evaporative concentration of dissolved salts.
- The principal evaporite minerals are gypsum ($CaSO_4.2H_2O$), anhydrite ($CaSO_4$) and halite (NaCl).
- There are many other naturally occurring evaporite minerals and of these the potassium and magnesium salts are important constituents of some marine salt deposits.
- Evaporites are of great economic importance and have a wide range of uses and applications.
- Evaporite beds are an essential component of many oilfields of the world, commonly being the cap rocks to carbonate reservoir rocks or effecting structural traps through salt diapirism.
- Geologically, evaporites are useful in the studies of palaeo-climatology because generally they are restricted to arid areas of low latitude , where temperatures are very high, relative humidity is low and evaporation far exceeds any rainfall.
- Evaporite deposits and depositional environments
- Thick evaporite successions, in some cases reaching 1000m or more, fill many of the world’s large intra-cratonic sedimentary basins.
- Other evaporite formations interdigitate with non-evaporitic sediments, limestones and marls especially, and occur on stable platforms and shelves and in subsiding basins.
- Evaporites deposited in lakes or marine embayments may be located in pull-apart basins, intra-cratonic rifts and extensional basins.
- Evaporite deposits are commonly cyclic. Some consist of numerous thin evaporite beds, typically of gypsum–anhydrite with little or no halite, alternating with limestone and marl.

Two principal modes of evaporite deposition are recognized:

1] subaqueous precipitation, from a shallow- to deepwater body, on a small (lake/lagoon) to large (intra-cratonic/rift basin) scale;

2] sub-aerial precipitation, taking place within sediment (sabkhas) or in very shallow to desiccated saline pans.

Gypsum and anhydrite

- Rocks of gypsum–anhydrite possess distinctive structures and textures and are susceptible to replacement, recrystallization and dissolution .
- Geological evidence and present-day occurrences show that both gypsum and anhydrite may be precipitated at the Earth's surface, subaqueously in shallow and deep water, and sub-aerially in coastal and inland sabkhas.
- On burial to depths greater than several hundred metres, however, all $CaSO4$ is present as anhydrite, and on uplift anhydrite is normally converted to gypsum (secondary gypsum).
- The many studies of gypsum– anhydrite have shown that the stable phase is determined by the activity of water (related to salinity) and temperature.
- Gypsum has low relief and weak birefringence and belongs to the monoclinic crystal system; anhydrite has moderate birefringence, higher relief and is orthorhombic. Both may show a prominent cleavage.
- The textures of gypsum–anhydrite vary considerably, depending on their precipitational environment and diagenetic history.
- Rock gypsum varies from coarsely crystalline to fine granular.
- Gypsum may show distinct bedding planes or it may occur as a compact body lacking both bedding and joints.
- Anhydrite is commonly finely granular, although fibrous and coarsely crystalline masses are also known.
- In some places crystals of gypsum are scattered throughout the anhydrite, thereby giving the rock a porphyritic appearance.
- Gypsum commonly appears to be formed by hydration of anhydrite. The process involves an increase in volume of 30 to 50%.
- The resultant swelling produces notable effects, such as the enterolithic folding of thin anhydrite layers enclosed in rock salt or other beds.
- Gypsum veins are common in rock gypsum and also in associated strata. These veins commonly show cross fibres and may exhibit cone-in-cone structure. Large gypsum euhedra and rosettes also occur in some muds and shales.

Halite

- Halite is the major component of large evaporite-basin fills, and it is the main evaporite mineral of modern salt lakes and saline pans.
- There is much variation in the textural and bedding features of halite, depending largely on the environment of deposition, whether it formed subaqueously in a near-permanent water body, or in a saline pan subject to repeated flooding–desiccation cycles.
- Halite deposited in relatively deep water (below wave-base) is typically well bedded and laminated.
- Schubel & Lowenstein (1997) have recognized three stages to the saline pan cycle: flooding, evaporative concentration and desiccation.

- Evaporation of the shallow water leads to the formation of thin halite rafts on the water surface and bottom nucleation of halite crystals on the settled-out rafts.
- These crystals grow most rapidly from their coigns, so developing a chevron texture.
- The NaCl for most halite deposits is derived from the evaporation of seawater, which contains a vast reserve of NaCl.
- NaCl also can be concentrated from fresh continental waters, as in many salt lakes, or derived from the dissolution and recycling of older evaporites.
- The bromine content of halite provides useful information on the evaporation–replenishment pattern in an evaporite basin, and indicates whether the waters were marine or continental.
- Bromine does not form its own minerals during the crystallization of salt from seawater; instead it substitutes for chlorine in halite, and the other chloride minerals.
- One major feature of thick halite deposits is that commonly they are involved in subsurface mass flow to generate salt domes or diapirs.
- These structures generally are thought to be the result of buoyancy effects, but there are other factors involved.
- Below a depth of around 900–1200m, halite has a lower density than other sediments and the overburden pressure is sufficient to cause the salt to flow.
- Salt domes are important in generating hydrocarbon traps, and they also can improve the reservoir qualities of overlying rocks by fracturing.

Other evaporite minerals

- Evaporation of seawater can yield other minerals, which are rarely found in large amounts but can be economically important.
- In particular, potassium chloride, sylvite (KCl), is an important source of industrial potash that occurs associated with halite and is interpreted as the product of extreme evaporation of marine waters.
- However, evaporation of modern waters results in a number of different magnesium sulphate (MgSO4) minerals rather than sylvite, and this has led to suggestions that the chemical composition of sea water has not been constant over hundreds of millions of years.
- Variations in the relative importance of meteoric waters (run-off from land) and hydrothermal waters (from mid-ocean ridge vents) are thought to be the reason for these variations in water chemistry, which either favour KCl or MgSO4 precipitation at different times.

Origin of evaporites

- All salt deposits are formed by the evaporation of brine.
- The ultimate source of such brines is generally sea water.
- The brine may be formed directly from sea water by evaporation in a semi-isolated or wholly isolated arm of the sea in an arid regions.
- Brines may also form in interior basins of arid regions into which waters flow that derived their salt either from connate waters of marine sediments, from dissolution of older salt beds, or, as now thought by some, by airborne salt particles derived from ocean spray transported into the continental interior by the atmosphere.
- Modern evaporite deposits accumulate in a variety of subaerial and shallow subaqueous environments

- Subaerial environments include both coastal and continental sabkhas, or salt flats, and interdune environ-ments.
- Shallow subaqueous environments are present mainly in saline coastal lakes called salinas.
- With the possible exception of the Dead Sea in the Middle East, no modern examples of a deep-water evaporite basin exists; however, geologists believe that many of the thick, laterally extensive ancient evaporite deposits did accumulate in deep-water basins.