Recent Trends in Sedimentology

Developments until about the first half of the 20th century were mainly the outcome of individual efforts. The end of the Second World War saw a major change in this trend. Large-scale oceanographic expeditions by the major nations in the post-war period, development and deployment of submersibles, deep-toe equipment, side-scan sonar and undersea TV camera in subsea exploration, large-scale drilling operations at sea and refinement of core recovery techniques since 1950, have provided information, which was heretofore unobtainable. Much of what is known today about the siliciclastic and carbonate deposits of shallow seas has been revealed by these explorations.

Discovery of giant petroleum reserves in carbonate rocks provided impetus for the study of carbonate petrography and carbonate depositional environments. Intensive research on carbonates, initiated by the major oil companies, led to the discovery of what is known today about carbonate petrography and facies. An equally intensive investigation of the present day carbonate depositional environments in the Bahamas, Florida and the Persian Gulf also took place.

Exploration for petroleum opened up new dimensions in organic geochemistry also. Techniques were developed for working out the maturation and thermal history of sedimentary basins. Deployment of sophisticated equipment such as X-ray diffraction (XRD), X-ray fluorescence (XRF), scanning electron microscope (SEM), electron probe micro analysis (EPMA), cathodo-luminescence (CL) made investigation of fine-grained sediments and sedimentary rocks with a high degree of precision possible. Isotope studies (both stable and radio isotopes) provided clues to environmental interpretation. Application of mathematical and statistical techniques led to the investigation of subtle interdependence between lithological units and chemical constituents within stratigraphic sequences.

The ideas developed during the last few decades have been revolutionary in many ways. Information available from hundreds of thousands of boreholes drilled in search of hydrocarbon has diverted the attention of sedimentologists to the subsurface. Techniques have been developed for recognition of sedimentary facies from well logs, cores and well cuttings. Developments in the field of trace fossil study (*ichnology*) now allow interpretation of depositional environment from information which, until recently, was considered insufficient (see Chapter 6). The current emphasis is on facies modeling from both surface and subsurface data. Developments in the field of seismic exploration have introduced concepts such as *seismic and sequence stratigraphy* (see Chapter 9). New concepts such as *allostratigraphy and autostratigraphy* have also been introduced. Simultaneously, the traditional ideas on basin development are being modified from the point of view of plate tectonics.

Source

Albritton 1963 ; Dunbar and Rodgers 1957 ; Gilluly, Waters and Woodford 1975; Hubbert 1967; Mather and Mason 1939; McIntyre 1963; Miall 1978; Middleton 1973, 1978; Nelson 1985; Shea 1982; Zenger 1986.

LITERATURE ON SEDIMENTOLOGY

In the early part of the 20th century there were hardly any text and reference books on sedimentology available. Since 1950 the figure has been increasing almost exponentially.

Quartz and Feldspar as Provenance Indicators

Quartz, the most abundant derital constituent in sedimentary rocks, is often used as an indicator of provenance, but opinion differs about the specific characters of a quartz grain which are indicative of its origin. Undulatory extinction ('strain shadows'), traditionally taken to be indicative of a metamorphic source, has been found in quartz grains of plutonic origin also (Blatt and Christie 1963). Acicular inclusions, long believed to be a characteristic of quartz of granites, have also been detected in metamorphic rocks. No significant difference between shapes of quartz grains of igneous and metamorphic origin have been statistically established, although this was, at one time, believed to be an important discriminating criterion. A group of geologists at Indiana University, after a thorough review of the problem, came to the conclusion that strongly undulose and finely polycrystalline quartz grains are indicative of metamorphic source rocks, but the quartz grains of plutonic and volcanic origin are characteristically strain free (Basu 1985). The Indiana group developed a method of discriminating sedimentary rocks of plutonic, low- and high-rank metamorphic parentage by plotting the proportions of the following four parameters in a '*diamond diagram*': undulatory quartz, non-undulatory quartz, polycrystalline quartz, and the number of crystal units per polycrystalline grains (Fig. 2.4).

As it is very stable, quartz survives prolonged weathering and erosion. The ratio of quartz to feldspar (plus unstable rock fragments) can therefore be used as an index of mineralogical maturity of a sediment of mechanical origin. Comparative studies of sand populations transported under various climatic and environmental regimes have shown that a unique combination of extreme climate, relief, transportation, and rate of sedimentation is necessary for elimination of all the unstable fractions leading to a highly matured, first-cycle quartz sand. This imprint of climate, although preserved for the first 75 km of transportation in high-gradient streams, is rapidly destroyed as soon as a high-energy marine environment is reached. For this reason, palaeoclimatic interpretation from mineralogical composition is feasible only for terrigenous, first-cycle sand (Suttner *et al.*, 1981).

Feldspar, which ranks only next to quartz in abundance, may also act as an indicator of provenance. The chemical composition of feldspar may be useful for this purpose. Homogeneous alkali feldspars more sodic than Ab_{50} are generally of volcanic origin. Alkalic feldspars more potassic than Or_{88} are derived from plutonic and metamorphic sources (Trevena and Nash 1981). Identification of the structural states of detrital alkali feldspars may also lead to recognition of the parent rock. Detrital feldspars from metamorphic sources are mostly microcline, while those from volcanic sources are generally sanidine. Alkali feldspars with relatively higher Al/Si structural states are likely to be associated with rapidly cooling outer shell of a pluton rather than its core. This change in the degree of ordering of feldspar is reflected in the stratigraphic sequence produced out of gradual unroofing of batholiths that have served as a source of sediments (Basu 1977). A quick method for the determination of the structural states of alkali feldspars for this purpose was developed by Basu and Suttner (1975).

In the modern big rivers of the world the proportion of quartz to feldspar increases when the climate is tropical to subtropical, suggesting a lesser chance of survival of

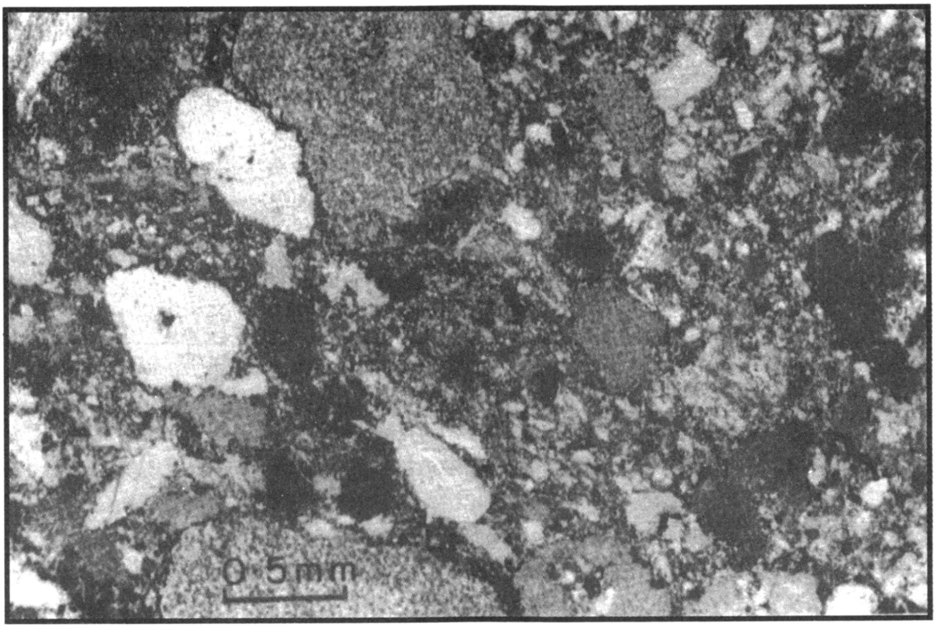

Fig. 3.13: Photomicrograph of an intrasparite. Locality unknown (thin section supplied by Hindustan Minerals & N.H.S.S. Co., Kolkata.

<table>
<tr><td colspan="5">Depositional texture recognizable</td><td rowspan="2">Texture not recognizable</td></tr>
<tr><td colspan="4">Original components not bound together during deposition</td><td rowspan="4">Original Components bound together during deposition</td></tr>
<tr><td colspan="3">Contains mud (particles less than 20 microns)</td><td>Lacks mud</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Mud-supported</td><td colspan="2">Grain-supported</td></tr>
<tr><td>grains <10%</td><td>grains >10%</td><td>mud >10%</td><td>mud <10%</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td><td>Crystalline Carbonate</td></tr>
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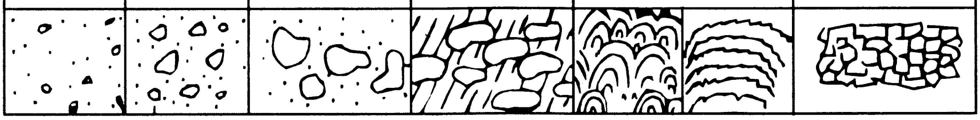

Fig. 3.14: Dunham's (1962) scheme of classification of carbonate rocks according to depositional texture (modified).

Dolomite and Dolomitization

When more than 50% of a carbonate rock is composed of the mineral dolomite ($CaCO_3.MgCO_3$), the rock is called a *dolostone* (Shrock 1948) or simply a *dolomite*. Pettijohn would name a rock dolomite only if the proportion of dolomite in it exceeds

The conditions leading to simultaneous deposition of silica and iron oxides are not fully understood but a marine or restricted marine environment of sedimentation, somewhat isolated from the open sea, is believed to be responsible for deposition of the banded iron formations of Precambrian age. A Precambrian ocean with an upper oxic layer and a bottom anoxic layer containing Fe and SiO_2 is the commonly assumed model. Large-scale precipitation of BIF followed the upwelling of deep, Fe–SiO_2–rich waters to the newly developed continental margins and shelves.

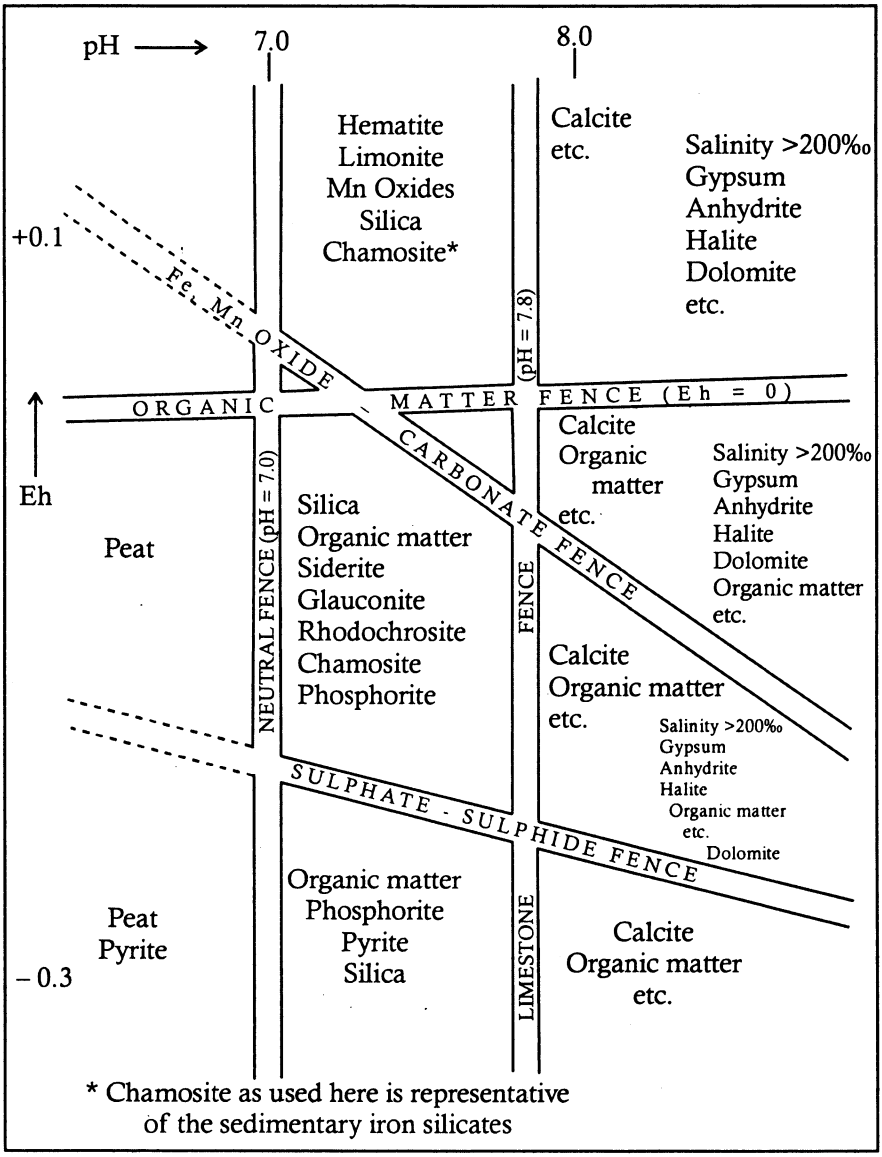

Fig. 3.19: Fence diagram illustrating influence of Eh and pH on generation of mineral assemblages in sedimentary rocks (after Krumbein and Garrels 1952).