CYCLES IN CARBONATE ROCKS

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ABSTRACT. Sedimentary cycles are readily recognized in rock sequences involving both marine and continental strata and to a lesser extent in strata that are entirely marine but include both carbonate and detrital types. In rock sequences composed entirely of carbonate rock, cycles commonly can be detected by trends in the size and abundance of terrigenous components. In carbonate formations that are largely devoid of detrital minerals, however, cycles must be established on the basis of differences in size of clastic carbonate grains which may indicate differences in turbidity but are not necessarily the results of transportation. Trends in distribution obtained from a detailed analysis of cycles, however, may indicate whether the position of various size grades has been determined by transportation or by environment.

NATURE OF SEDIMENTARY CYCLES

A cycle as applied to the sedimentary record in geologic history is described as a recurrence, repetition, or return to a starting point, repeated at more or less irregular intervals (Weller, 1930, p. 99). The significance of sedimentary cycles of various types and magnitudes was discussed many years ago in a carefully considered analysis by Barrell (1917, p. 745-904) and cycles have since been described and discussed in many papers from many different approaches.

During the 1930's studies of cyclic sedimentation dealt largely with late Paleozoic sequences commonly referred to as cyclothsens (Weller, 1931; Moore, 1931; Wanless and Shepard, 1936). These sequences are composed of comparatively thin but sharply differentiated rock units, some of marine and others of continental origin, considered to be the result of changes in relative sea level. The ultimate cause of such changes is still not generally agreed upon, but apparently it was responsible not only for many repetitions of each depositional environment, but also for very extensive developments of each. Probable depth limits of various units within the marine deposits of a Permian cyclothem have been estimated by Elias (1937) through comparison of fossil assemblages with their nearest living counterparts of known depth range.

More recently, and especially during the past decade, cyclic sedimentation has been recognized in rocks that are entirely of marine origin. The cycles are not nearly so obvious as in formations where beds of continental origin, including coal, alternate with arenaceous, argillaceous, and carbonate beds containing marine fossils; nevertheless, cyclic changes in environment are demonstrable. In southern Arizona, for instance, a marine sequence of limestone, mudstone, and some sandstone comprising the Naco group of Pennsylvanian and Permian age exhibits alternations of rock type representing cyclic development (Wanless and Patterson, 1952). These rocks are classified into textural types that can be arranged in a sequence of apparently increasing depth zones, and from them at least 70 cycles are recognized by Ziegell.1

Though less apparent, cyclic sedimentation may also be recognized in rocks entirely within carbonate sequences. The cycles are recognizable through comparison of included faunas and detrital grains. Subtle changes as repre-

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sent by differences in grain diameter (elasticity), frequency (number of quartz particles present in a given surface of thin-section), or in the abundance of particular organic components, give evidence of cyclic development. This field has been pioneered by Carozzi (1950, 1954a, 1954b) who has developed techniques for obtaining statistical measurements and for graphic representation of trends; he has demonstrated the applicability of his methods even to partly dolomitized rocks.

Where grains of quartz and other terrigeneous minerals are very scarce or locally absent in sequences of limestone, cycles may be recognized by changes in carbonate grain size. Such changes, however, unlike those among land-derived detrital particles, are not necessarily related to amount of transportation. Grains of limestone, even where clearly of clastic origin, may have been derived from nearby beds as intraformational deposits or from organisms that lived in the vicinity. Belts of sediment in the quiet waters in deeper parts of Kapingamarangi lagoon (McKee, Chronic, and Leopold, 1959) furnish an illustration of particle size that has been determined by environmental control of organic distribution rather than by current or wave transportation. In this lagoon each sedimentary belt or zone is recognized by distinctive clastic (mostly bioclastic) particles of limited size range, but the grain-size characteristics of each belt bears no relation to its bathymetric position.

**REDWALL LIMESTONE AS A CYCICAL DEPOSIT**

The Mississippian Redwall limestone of the Grand Canyon, Arizona, consists largely of massive carbonate beds that superficially seem to be uniform in texture throughout and, as shown by insoluble residue analyses, are remarkably free of noncarbonate detritus. Detailed sampling, however, has demonstrated that this formation is not uniform in texture but contains, within individual massive units, sedimentary cycles represented by differences in grain size. Grains range in size from cryptocrystalline to very coarse.

In the upper two members of the Redwall limestone very little recrystalization or dolomitization has occurred, so samples for textural analyses were taken at five-foot intervals in each of a series of eight sections. These samples, with the exception of aphanitic varieties in which grains are too small to examine petrographically, are composed of clastic particles of three principle types—bioclasts, intraclasts (defined as intraformational clastic fragments), and oolites. The clasts are largely unmixed in some rock units, but are mixed in most. Only locally has the texture been obscured through dolomitization. Grain size differences as represented in figure 1 reveal that five cycles are represented in the upper part of the Redwall; they have been recognized throughout the length of the Grand Canyon or for more than one hundred miles in an east-west direction.

Although grain size in clastic carbonate particles may bear no relation to depth or distance from shore, two features in the Redwall limestone suggest that in this formation the cycles may result from systematic changes in depth as reflected by difference in wave base. First, within each cycle, rocks of intermediate grain size complete a progression from one extreme in size to the other; the rocks do not follow a random arrangement in size grades. Second,
sections in the eastern part of the Grand Canyon contain within each cycle relatively more fine-grained clasts and do not attain the extremes in coarseness found in sections farther west (fig. 1). Thus, these cycles suggest a history of alternate changes in depth above and below wave base, probably the reflection of transgressions and regressions of a shallow sea over a broad even floor.

REFERENCES CITED


