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CONTRASTS BETWEEN RECENT WARM- AND COLD-WATER SHELF CARBONATES : SIGNIFICANCE IN THE INTERPRETATION OF ANCIENT LIMESTONES

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RÉSUMÉ

Deux associations principales de grains bioclastiques peuvent être décelées sur les shelfs actuels : l'association « foramol » (composée notamment de foraminifères benthiques, de mollusques, de *rhodophycées* calcaires, de coraux ahermatypiques, etc.), association qui, en première approximation, caractérise les eaux tempérées, et l'association « chlorozoan » des régions intertropicales, qui renferme entre autres des *chlorophycées* calcaires et des coraux hermatypiques. Certains grains calcaires non bioclastiques (pellets, grapestones, ooïdes, etc.) présentent, eux aussi, une distribution caractéristique.

La température de l'eau ne semble cependant pas être le seul facteur contrôlant la distribution de ces associations, car l'influence de la salinité est, elle aussi, appréciable.

La grande distribution des carbonates d'eau froide dans la nature actuelle nous oblige à revoir quelque peu le modèle classique d'interprétation des carbonates anciens généralement considérés comme déposés en eau chaude.

ABSTRACT

Two main associations of skeletal grains are recorded on Recent shelves : the « foramol association » (benthonic foraminifera, molluscs, calcareous *red* algae, ahermatypic corals...) which is found well outside the tropics, and the intertropical « chlorozoan association » characterized, among other things, by the presence of calcareous *green* algae and hermatypic corals. Further differences are found in the distribution of non skeletal grains (pellets, grapestones, ooids, etc.). Temperature does not appear, however, to be the only controlling factor as salinity also plays a significant rôle in the distribution pattern of the two associations.

The widespread occurrence of Recent cool water carbonates means that we have to revise the traditional « warm water » interpretative model for ancient limestones.

As more and more information becomes available regarding the nature of the sediments on the continental shelves, it is clear that Recent sediments rich in carbonates are *not* restricted to tropical regions. Considerable spreads of such sediments exist in temperate regions where the mean sea temperatures fall well below 18^{o} C. The « temperate-water » carbonates have, at first sight, a number of characters in common which distinguish them from their well-known « warm-water » relatives.

GRAIN ASSOCIATIONS

In order to confirm the existence of two distinct sediment types, Lees & Bul-

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ler (1972) collated the available information on the sand-sized (or larger) carbonate fraction of Recent shelf sediments. They recognised two associations of skeletal grains. The first, the foramol association, is characteristic of those carbonates forming well outside the tropics. The main organism groups represented are molluscs, foraminiferas (benthonic), echinoderms, bryozoans, barnacles, ostracods, sponges (calcareous spicules), worms (tubes), ahermatypic corals and calcareous *red* algae. Not all of the constituents are necessarily present in any one deposit, but molluscs and forams are almost always present. Depending on local conditions the dominant grain type may be the debris of molluscs, forams, bryozoans, barnacles or calcareous red algae.

The second skeletal grain association, which was named chlorozoan (*op. cit.*) may contain any of the above-mentioned components but contains, in addition, significant amounts of coral (presumably hermatypic) and/or calcareous *green* algae. Barnacles are rare and bryozoans are usually no more than a minor component. Coral (hermatypic)/algal reefs are restricted to areas of chlorozoan sediments.

The non-skeletal grains, where present, also appear to form natural groups. Pellets generally occur in areas with the chlorozoan association, but they may also be present with the foramol association in areas near the foramol/chlorozoan boundary. The other non-skeletal grains such as ooids and aggregates (e.g. « grapestone ») are much more restricted in occurrence and are seemingly limited to certain areas with chlorozoan sediments. Any given area of carbonate sedimentation may thus be classified as one of three types with respect to non-skeletal grains : (1) non-skeletal grains absent, (2) pellets only, (3) pellets with ooids and/or aggregates.

Aragonite muds (whatever their origin) appear to be limited to areas with the chlorozoan association.

FACTORS INFLUENCING THE DEVELOPMENT OF THE GRAIN ASSOCIATIONS

(a) *Skeletal associations*

Lees & Buller (*op. cit.*) showed that water temperature is significant in determining the position of the boundary between the foramol and chlorozoan associations. The chlorozoan association only develops in those areas where minimum temperatures exceed 14° C and mean temperatures exceed 18° C. However, temperature is not the only controlling factor : foramol sediments occur in a number of areas where, on the basis of water temperature, the chlorozoan type would be expected.

Such anomalies can be explained if salinity is taken into account. When the salinity falls below a certain value, (for example : mean salinity of $< 34\ ^{0}/_{00}$ in an area where minimum temperature is 25° C) the foramol association develops even though the water temperature is high enough to support the chlorozoan association. Conversely, in areas of unusually high salinity, the chlorozoan association appears to be able to tolerate water temperatures lower than usual.

In reality the situation is rather more complex than this : to account for the distribution of the two skeletal associations it is necessary to consider the minima and maxima of temperature and salinity, not just the mean values.

(b) *Non-skeletal associations*

The development of the non-skeletal grain associations also seems to be influenced by temperature and salinity. Indeed, the effect of salinity seems to be more marked than in the case of the skeletal associations. If one considers temperature alone, the non-skeletal grains are limited to areas where the minimum temperature exceeds about 14° C and the mean temperature exceeds 18° C. However, temperature appears to have little influence on the nature of the non-skeletal grains which are developed : salinity (or some factor related to salinity) is seemingly critical.

SIGNIFICANCE IN THE INTERPRETATION OF ANCIENT LIMESTONES

These findings, unfortunately, complicate the task of interpreting ancient limestones in terms of depositional environments — although at the same time they provide a possible means of making more accurate interpretations.

Carbonate sediments certainly form in cool seas today, and perhaps formed in similar situations in the past. This in itself means that we have to revise the traditional interpretative « model » for limestones which tends to suppose that all are « warm water » deposits whose compositional variations can largely be ascribed to environmental energy conditions. Such a model, although useful, is too simple and is incomplete (Lees, 1973). But the problem is not solved by regarding « temperate » and « tropical » carbonates as separate, temperature-dependent classes. Because of the salinity effect, some present-day carbonates from tropical regions have the grain association characteristics normally found in temperate regions.

Interpreting ancient limestones in terms of salinity and temperature regimes will not be simple because there are two variables to consider. Independent determination of one of the variables (e.g. palaeotemperature) would clearly help in the determination of the other. However, even without this it may be possible to establish the major salinity and temperature regimes. To do this, the stratigraphic interval considered should be as small as possible, and the areal scale as large as possible (preferably world-wide). The aim would be to map out the distribution of grain associations analagous to those which exist today. The skeletal associations clearly pose a number of problems in this respect. For example, because of natural evolution it cannot be assumed that the fossil members of a group responded to salinity and temperature in the same way as their modern counterparts. However, the non-skeletal associations are not subject to such evolution. It is possible, therefore, that global distribution maps of the various non-skeletal associations could be interpreted more or less directly, particularly in respect of salinity. Within such a framework the interpretation of the skeletal associations may be feasible.

In order to maintain the possibility of reference to something reasonably well-understood, it would probably be best to study the relatively recent sediments first and then work down the stratigraphic column. One of the first problems which might be tackled is that of the sub-Recent ooids which are sometimes common on shelves well outside the areas of present-day ooid formation. Because it appears that above-average salinities (rather than high temperatures) are necessary before ooid formation begins, it is worth considering that their presence is related to increased oceanic salinity (increase of 1 ‰ possible) resulting from the formation of the continental ice sheets.

REFERENCES

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