LIFE AND SEDIMENTS : AN APPROACH TO BIOSEDIMENTOLOGY.

Cl. MONTY

General sedimentological concepts relies on the assumption that sedimentary particles fall unaffected through the water column on the sea floor where they are sonner or later burried and fossilized. In fact things are much more complex, and the following considerations should be thoroughly investigated in recent sediments.

Before burial, sediment have to cross 3 main sets of bio-diagenetic barriers, beside the classical chemical one due to transhumance from fresh to marine waters. The first one comprises a complex series of plankto-nectonic barriers that will intercept clay minerals and silt-sized aggregats; these grains, rich in adsorbed organic matter and colloids are infested by microbial populations finding there substrate and food. Such bio-mineral particles are harvested by planctonic organisms (from protozoans to copepods etc...) selectively or not. During transit through the cells or guts, bio-clay aggregates, among others, are submitted not only to various enzymes and generally acid pH's, as well as to parasitic or symbiotic gut-dwelling bacteria. These multiple aggressive agents may interact with fine-grained argillaceous particles at various levels as we observed it in sediments from the Calvi shelf (Corsica). The importance of this type of bioalteration relies, among other things, on the residence time of detrital grains into the guts of preying animals. Experiments carried by Syvitski and Lewis (1980) showed that during one run through the guts of copepods, illite did not suffer much (Residence Time 2 hrs), montmorillonite was alltered to vermiculite and mica (R.T. 1hr), whereas cristallinity of fresh vermiculite was completely destroyed (R.T. 1hr). Furthermore, when excreted, these originally clays-sized particles where amalgamated by organic matter into pellets 100µm in diameter rapidly infested by bacteria. The new, food-rich, particles will soon be preyed by other organisms and so on.

Similar types of bioalteration threatens sediments travelling in bedload; indeed, as suspension load they will be intercepted by the second biodiagenetic barrier constituted by the benthos, and also abundantly recycled. Experiments concluded by Pryor (1975) showed that during ingestion by decapods or annelids, chlorite was destroyed or, at least, considerably altered, whereas illite was disordered. Furthermore, beside these biochemical alterations, feeders excrete and can induce the deposition of considerable amounts of pelloidal sediment, made of fine-grained bioaltered particles glued by organisms and colloids, in environments where turbulence would not normally allow their deposition and stabilization. Some examples will quantify the importance of such bio-deposition : the Cardium edule population of the Wadden sea induce deposition of about 10 x 10^3 Tons of clay-sized sediments per year whereas in the same time, deposition by Mytilus ranges from 25 to 175 x 10^3 T/year. In the Mississipi sound, sedimentation due to decapods (like Callianassa) may reach 12T/km^2/year. Beside the stabilisation processes reported here above, other may result from the development of microbial film on top of the sediments by cyanobacteria (oscillatoriaceans) or bacteria (like Beggiatoa) which may rapidly transform an originally non-cohesive sediment into a cohesive one able to withstand strong currents or slopes or show particular hydroplastic behaviour. Present studies show that these processes are not limited to shallow waters but may be found at any depths in the sea. Beside incorporating organic fresh matter into the sediments and hence opening the way to new biochemical alteration, microbial films may originate strong T° clines due to exothermic microbiological reactions; we, for instance, measured T° of about 55°C at the surface of microbial mats, thriving in salt ponds under 20cm of water, the surface of which yielded T° of about 20°C. Such phenomena due to exothermic biochemical reactions may considerably interfere with thermodynamical equilibrium and mineral stability.

Another important process which also affects grain production and sediment texture is bioerosion; bioerosion affects rocks (reef, crusts, cliffs) as well as individual grains; it is a widespread phenomenon bound to many organisms from microbes to vertebrates (fishes); a classical example is the sponge Clionia which may produce up to 180 T/Ha/y of grains; crabs may convert sand to silt, and microbes shells to carbonate dust, increasing considerably the overall diagenetic surface of the sediment. Furthermore bioerosion may be associated with significant bio-transportation of sediment as is for instance accomplished by fishes feeding on reef rock at given periods of the day and excreting chewed or residual grains in other sites.

Individual sand grains lying on or near the sea floor keep on suffering significant bioimpacts. We shall concentrate here on carbonate grains as observations are much easier than on clay minerals. Beside surface interactions described above, the inner parts of these grains may show intense microbial activity. An important part of it results from microborers like cyanobacteria and fungi; they may be accompanied by bacteria feeding on their by-products and mucilages. Consumption of organic matter, reduction of sulfates (from ambiant water, but also from sulfate radicals of muccopolysaccharides), may originate reducing microenvironments where iron accumulates as amorphous or framboïdal pyrite (Monty, 1981); the biological control on pyrite precipitation may be so strong that we found occurrences where pyritic framboids were strictly limited to fructifications of mycetes. This microbiological concentration of sulfides, imparting a dark grey to black colour to initial grains, is furthermore accompanied by concentration of various elements (Cr, Au, Sb, Sc, Th, U and various RE. Monty 1981; Roelandts and Monty, 1986 in preparation). In other borings one finds concentration of glauconite or chamoisite replacing and fossilizing original microbes.

Other bio-impacts are bound to microbial cavity-life in primary (abandonned forams chambers, cells and conceptacles of rhodophytes) or secondary cavities (growth cavities in reefs, etc...) and concerns the precipitation of carbonates (aragonite needles and fine grained Mg-calcitic crystals). Although generally considered as an essentially physico-chemical process, appropriate treatment and observation of samples in our lab. revealed that these carbonate cements did grow among, or around microbes (bacteria, mycete, chrysophytes) and associated mucilages, that is, in rich and actively living nannoecosystems (Tassin, 1984). In other words they do not precipitate by supersaturation of free water filling cavities, but in mucilagenous, microbiologically active environments.

The third important biodiagenetical barrier is the redoxcline which, abruptedly or more progressively, separates oxygen rich from oxygen poor or reducing overall environments. This barrier was born in early Proterozoic time when oxygen accumulated in the biosphere. Depending on sediment texture and granularity, content in organic matter and physical stability of the deposit, the chemocline may occur just below the surface of the sedimentary floor or deeper. The level of the chemocline may furthermore show nocthemeral up and down displacements following daily photosynthetic and respiration of bottom organisms, such daily migrations may contribute to concentrations in separate layers of chemical elements according to their greater or lesser Eh-bound solubility (Mn, Fe, etc...).

The upper cm to decimeters of sediment may also be variously bioturbated by animals seeking food, shelter, etc... Some of them may extend their activity into the reduced sediment. Other types of bioturbations are induced by bacterial gases. Animal bioturbation destroys or alters depositionnal sedimentary structures and change sediment properties (content in organic matter, Eh, pH, texture, cohesivity, etc...).

During burial, sedimentary deposits and their cavities will keep on suffering bacterial activity. We have personally observed microbial life bounded to precipitation or recycling of carbonates, iron oxydes, sulfides, sulfates, organic matter, etc... down to depths of 2500 below the sea floor; depending on pressure, this may well be far from a maximum depth.

Conclusions : to my view, the punctual and simple situations briefly reported here are sufficient to show that, without life on earth, the sedimentary processes and products would be and would have been completely different from the points of view of patterns, rates, abundance, diversity, chemical and physical properties, succession through space and time, diagenesis, erosion, etc...

BIBLIOGRAPHIE

MONTY, C.L.V., 1981 : Observations pétrographiques et chimiques sur l'éodiagenèse des carbonates du précontinent calvais (Corse). Bull. Soc. Roy. Sces Liège, Nos 11-12, pp.470-482.

PRYOR, W.A., 1975 : Biogenic sedimentation and alteration of argillaceous sediments in shallow marine environments. Geol. Soc. of Amer. Bull., 86, pp.1244-1254.

SYVITSKI, J.P.M., & LEWIS, A.G., 1980 : Sediment ingestion by Tigryopus californicus and other zooplankton : mineral transformation and sedimentological considerations. Journ. Sed. Petr., 50, n°3, pp.869-880.

TASSIN, D., 1983 : Observations sur les ciments carbonatés récents d'eau tempérée (Calvi). Thèse inédite, 70pp., 50pls - C.A.P.S., Liège Univ.