IAS POSTGRADUATE GRANT SCHEME

Report from Laura K. Adams

Microbial Iron Reduction: From Bacteria to Cement

Expenditure

The grant received from the IAS was used to help fund a trip to the Western Isles of Scotland. Specifically the money paid for transport to the islands (car hire and ferry) as well as the accommodation for the duration of the field trip. The remainder contributed towards the food budget. The purpose of this trip was to collect sediment samples from South Uist and Benbecula. These sediments were then used to investigate iron reduction within a recent brackish water setting.

Background to study

Microbial iron reduction is an important early diagenetic process. It leads to the precipitation of iron-rich sulphide (e.g. pyrite) and carbonate cements (e.g. siderite). All cementation leads to the destruction of porosity and therefore, permeability. This study proposes to concentrate on mud and mudstones where initial porosity is high.

In fresh water systems iron-reducing bacteria are responsible for the prevalence of iron carbonate cements. Marine waters contain a greater concentration of sulphate than fresh waters. Here, iron will preferentially react within biogenic sulphide, produced by sulphate-reducing bacteria, to form pyrite.

Although commonly considered to be anomalous, early iron carbonate cements may dominate under certain conditions within the marine realm. Iron-reducing bacteria are able to extract more energy from an organic carbon source than sulphate-reducing bacteria. Therefore, in systems where the quality and/or quantity of organic matter are low iron-reducing bacteria are able to out-compete the sulphate reducers for this substrate. This starves sulphate-reducing bacteria of their reducing power to generate sulphide, and hence pyrite. In waters where the organic matter is insufficient to support a community dominated by sulphate reducing bacteria, an iron carbonate should be precipitated.

Shell beds form where there is a break in the supply of clastic sediment hence, they are commonly associated with stratal surfaces. In such situations organic matter is normally degraded by the respiratory activities of surface microbes. This renders it incapable of supporting a community of sulphate-reducing bacteria and so where iron is present in such environments siderite would be expected to precipitate at the expense of pyrite. Siderite formation within this setting has received relatively little attention.

Results

The Mid-Jurassic aged Rutland Formation exposed at Ketton, UK was deposited in marginal marine conditions. Field-scale observations show a series of brightly coloured clays separated by shell beds and coals. A more detailed study conducted using both optical and electron optical microscopy has shown siderite cements within shell beds in association with rootlets.

The controls on siderite precipitation in this ancient sediment system could not be investigated easily. An analogous recent environment was needed to clarify the processes that had occurred in ancient sediments.

The Machair is a specialised shell bed and peat-forming habitat geographically restricted to the northwest coast of Scotland and west Northern Ireland. It is commonly studied for its floral and faunal richness and for its archaeological remains but its sediments and stratigraphy are less well known.

The Machair is situated between beaches and lochs and so receives both fresh and marine water. Geochemical analyses have shown that these sediments contain sources of both organic carbon and iron. Given that sedimentation within these deposits is episodic it seems likely that siderite may precipitate within such an environment.

Sediment samples taken from these deposits were placed in laboratory cultures containing surplus iron (III) and organic carbon. Within 2 weeks all of the additional iron (III) had been reduced. This indicated that iron reducing bacteria were present and in abundance. Bacterial counts for these samples are in excess of 4500 iron-reducing bacteria per 10ml of culture. Experiments were conducted to enrich for these bacteria, at the bases of these tubes a white chalky precipitate formed. XRD analysis proved this to be siderite. DNA sequencing of an enrichment culture revealed no previously characterised iron-reducing bacteria.

Conclusions

The rock record at Ketton demonstrates the presence of siderite within a marginal marine setting. Within marine sedimentary successions a dominance of early siderite cements (as opposed to pyrite) maybe used to indicate an area where the quality and/or quality of organic matter were low. In association with other evidence this may be used to identify breaks in sedimentation. Bacterial cultures enriched from Machair sediments have produced siderite rapidly under laboratory conditions when additional sources of both electron acceptor and donor were provided. Whilst we accept the artificial nature of our experiments and their limitations, it is still reasonable to postulate that given time these bacteria may be able to perform a similar function in their natural environment. It is also justified to assume that the processes operating within the Machair may simulate those occurring during the deposition of ancient siderite within the Rutland Formation at Ketton.