THE CONTROLS ON DECAY AND MINERALIZATION - THE KEY TO THE FOSSILIZATION OF SOFT TISSUES

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Recent investigations of a range of fossil deposits have shown that the mineralization of labile tissues like muscle is a relatively common phenomenon. The level of detail preserved in calcium phosphate may even provide histological evidence of the affinities and functional morphology of ancient organisms. Such examples of soft-tissue preservation, however, are at odds with the normal efficiency with which organic matter is degraded in sediments. Equally paradoxical is the contention that the same microbes that drive decay are instrumental in promoting authigenic mineralization and hence the preservation of fine detail. The critical controls operate in the earliest stages following the onset of decay of the organism. The carcass forms a locus for steep chemical gradients (e.g. O_2, nitrate, S_2, pH, redox) that are created over a few microns by the activity of diverse populations of microbes. The processes involved in mineralization can only be deduced to a limited extent based on fossils. Rates, for example, are inaccessible, and critical evidence may be concealed by diagenesis. The alternative approach is to carry out experiments on soft-tissue mineralisation by microbes.

Selected tissues and whole organisms are exposed to defined chemical gradients and bacterial metabolites and/or decayed under conditions known to produce mineralisation (in calcium carbonate/calcium phosphate or pyrite) on a laboratory time scale. The muscle and other tissues of the shrimp *Crangon* can be routinely mineralized in such experiments and the carcass provides a suitable substrate for the formation of microbial veils. A computer controlled microelectrode system allows the chemical gradients (O_2, pH, sulphide) generated by the decay process to be profiled automatically on a mm to μm scale. This can be done without significantly disrupting the aqueous system, so that the dynamics of decay can be monitored through time. Changes are correlated with measurements of bacterial populations, concentrations of critical ions, and mineral formation. In addition to experiments in aqueous systems, carcasses are placed in gels which stabilize the gradients and facilitate sampling and analysis. Chemical gradients can be created in a gel prior to the introduction of a carcass, to allow particular chemical controls (e.g. phosphate concentration) on the mineralisation process to be investigated. Experiments have shown, for example, that while bacterial inocula promote decay, they also enhance the preservation of mineralized soft-tissues relative to that in carcasses where only indigenous microbes are present.

The results of experimental studies are paralleled by analyses of the matrix surrounding fossils with phosphatized soft-tissues. In the Jurassic Solnhofen Limestone, for example, where phosphatization is relatively common, levels of sedimentary phosphate within the matrix immediately adjacent (and in the same lamina) to some fossils are depleted compared to the background level. This implies that at least some of the phosphate incorporated into the mineralized soft-tissues was derived from the sediment. This conclusion is corroborated by the presence of more phosphorus in some soft-bodied fossils that is available in the tissues of their living counterparts. Such experimental and analytical approaches are the route to understanding the controls on soft-tissue preservation. [Supported by NERC grants GR3/8860 and GR3/9090.]