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Pyritisation of Plant Axes from the London Clay: Pyrite Textures and Their Importance to Understanding the Mechanism of Fossilisation

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Introduction

The importance of pyrite textures in understanding the process of fossilisation of plant axes from the Eocene London Clay has been discussed previously by Canfield and Raiswell (1991). However, in light of recent advances in understanding pyrite formation pathways (Rickard 1997), a study of pyrites plant axes from the Eocene London Clay presents new insights into the process of fossilisation and illustrates how in anoxic environments, pyrite is an ideal medium for preservation of delicate anatomical features.

Methodology

120 specimens, which include pinaceous stems, dicotyledonous roots and stems and monocotyledonous axes, were collected from the shoreline of Warden Point on the Isle of Sheppy, England (NGR 021724). Each specimen was fractured to give fresh radial and tangential surfaces, gold coated, and examined using a Leica/Cambridge Instrument S360 SEM-EDX system.

Results

Three principal pyrite textures are commonly associated with pyrites plant axes (Fig. 1). Micro-crystalline pyrite is found in both the lumina of xylem vessels and parenchyma cells in three different locations; (1) upon the inner surface of cell walls, (2) in the middle lamella between cell walls, (3) within primary and secondary cell walls. The pyrite crystals are generally anhedral in form, < 0.25μm in size and display disordered packing. However, where the crystals are outlining anatomical features such as bordered pits they are more euhedral and display ordered alignment. Framboidal pyrite is generally associated with radial and massive polycrystalline overgrowths, both within the lumina of xylem vessels and also infilling parenchyma cells. The framboids range in size from ~2μm to ~20μm in diameter. The microcrysts of individual framboids are typically uniform in size and range in size from ~0.5μm to ~2μm. The microcrysts typically display disordered packing, however, linear, radial and concentric microarchitectures are also observed. Massive polycrystalline pyrite is also present infilling the lumina of xylem vessels and parenchyma cells. There is clear textural evidence indicating that nucleation occurred on either the micro-crystalline pyrite lining the inner surface of the cell wall or on the external microcrysts of framboids. In both cases crystal growth usually leads to a complete infilling of the cell with interlocking crystals.

Discussion and Conclusions:

The Eocene London Clay is a sequence of marine clays, silts and sands reaching a thickness of >150 m in south east England (King 1981). The environment appears to have involved a reduced, anoxic sediment underlying oxic waters. Pyrite was formed within the plant axes through the oxidation of $FeS_{(aq)}$ by H_2S generated by microbial sulphate reduction. The importance of $FeS_{(aq)}$, which has been found in modern day estuarine environments (Rickard et al. 1999), is that it behaves as a dissolved species and is able to penetrate the plant axes. Initial pyrite formation occurred in an environment close to the sulphate - sulphide redox boundary. In this environment, high pyrite supersaturation values are readily reached and the small amounts of O_2 resulted in the rapid pyrite nucleation, at the expense of crystal growth. However, Schoonen and Barnes (1989) showed that the reluctance of pyrite to nucleate is a major kinetic barrier to pyrite formation and that nucleation is catalysed by an active surface. Biological surfaces provide active sites for nucleation (Donald and Southam 1999) and therefore resulted in the early rapid formation of micro-crystalline pyrite upon the inner surface of cell walls, in the middle lamella between cell walls and within cell walls. Near contemporaneous framboidal pyrite formation also occurred within the cell interior, probably upon detached micro-crystalline nuclei from the cell wall. As the plant axes were buried in the sediment, O_2 was removed by microbial activity and lower pyrite supersaturation values developed. In these environments, pyrite crystal growth upon the existing micro-crystalline and framboidal pyrite generally exceeded the rate of nucleation and polycrystalline pyrite developed and infilled the remaining open spaces within cells. This paragenetic sequence of micro-crystalline - framboidal - polycrystalline pyrite generation can be conveniently summarised on an Eh-pH diagram. The initial micro-crystalline pyrite precipitation, followed by rapid infill by framboidal and polycrystalline pyrite, appears to be the critical factor in achieving excellent preservation as it forms internal and external casts of cells, preserving delicate anatomical features.

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