Biological processes form iron pisoliths in the critical zone

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Iron pisoliths are small, yellow-brown spheroids that are widespread worldwide and abundant in a variety of environments, ranging from soils (where they are commonly called pea gravel) and old river courses (paleochannels) to highly weathered rock. Similar pisoliths have even been found on the surface of Mars. Pisoliths range in age from recent to over 20 million years old. Many pisoliths have a surprisingly complex internal structure composed of concentric rings of variably coloured iron oxides, aluminum rich minerals and microorganisms (Figure 1A). Iron-rich pisoliths are highly significant due to their economic potential as a geochemical sampling medium for detecting ore bodies and may even form a significant portion of an auriferous ore deposit. Despite the abundance of iron pisoliths there are many questions around how and why they develop.

Iron pisoliths form in the surface soil environment and are therefore surrounded by many different types of micro- and macro-organisms that potentially play a role in their formation. To determine which organisms are present, a process called 16s rRNA analysis was used to extract and identify specific marker genes that enable identification. This process helped to identify the micoroorganism communities within pisoliths and their role in pisolith formation. The bacteria identified are genetically similar to communities found in extreme environments such as deserts and caves, reflecting the nutrient poor environments inside the pisoliths. Analysis of pisoliths by a variety of microscopy techniques also indicates the presence of fungal hyphae of significantly different sizes and shapes. Abundant vegetation provides extensive networks of soil roots, which are an important food supply for soil microbes such as fungi. Fungal hyphae and bacteria can be preserved within pisoliths and act as a template for the precipitation of minerals such as iron oxides and gibbsite. Metals and minerals bearing a net positive charge are attracted to the negatively charged cell wall functional groups of bacteria. Metals nucleate on the cell wall and this site becomes the focus of continued precipitation, leading to the preservation of the microorganisms structure ('microfossils' Figure 1B).

The role microorganisms play in the pisoliths from ancient paleochannels is less clear because although organisms are preserved, no DNA remains as these pisoliths formed over 20 million years ago. A cyclic process of continued wetting and drying has led to mobilisation and accretion of iron oxides around a nucleus, which is commonly composed of ferruginised wood. This process coincided with a period of warmer and wetter climate in the past than is experienced by Western Australia today.

Our morphological observations and DNA analysis led to the conclusion that the formation of pisoliths in soil environments is aided by a consortium of fungi and bacteria. This new understanding may be used to refine exploration strategies for the understanding and discovery of ore deposits. Furthermore, if the pisoliths were indeed precipitated through microbial processes, there may be implications for bioremediation of trace metals with a strong affinity for Fe oxides. If we can cultivate Fe-precipitating fungi, a living barrier for contaminant remediation may be possible.

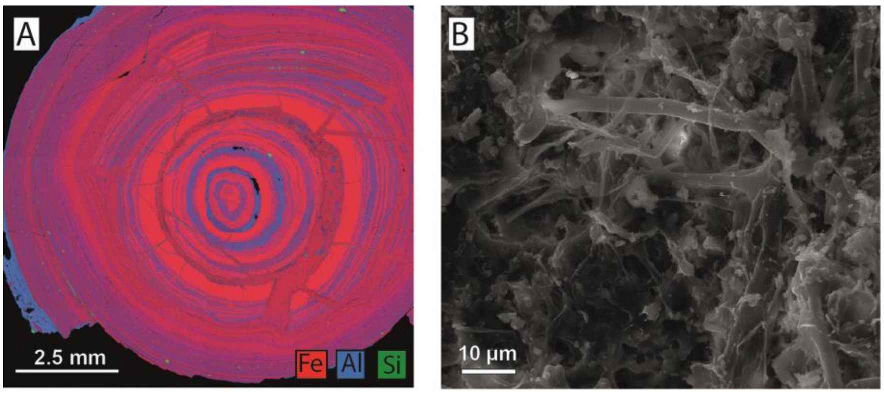

Figure 1. A. Internal structure of an iron pisoliths from an old paleochannel located in Western Australia. Each ring represents small changes in the environment of formation, with variations in iron (red), aluminum (Blue) and silica (green). B. Fungal hyphae within pisoliths act as a template for mineral precipitation.