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Mineral Resources and the biosphere: Challenges to future extraterrestrial explorationists?

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Ideas concerning the colonization of other planets envisage the extraction of essential natural resources in the same way as we see on Earth. Our ability to prospect for, identify, extract and process minerals seems to be a tacit assumption. Although mineral deposits are mentioned in some technical papers, there are very few attempts to actually evaluate the mineral potential of other planets. Earth is unique within the solar system and its evolution, including aspects of tectonic processes, has been profoundly influenced by the presence of life. The idea that Earthly deposit types – or even mineral deposits of any type – might exist on other planets such as Mars may need to be examined within this wider conceptual framework.

Some resources on Earth are clearly products of the biosphere. The most obvious are fossil fuels, which are direct or indirect derivatives of once-living organisms. Several important mineral deposit types, including iron ore, most base-metal deposits and some uranium deposits, also have strong genetic links to the biosphere. These involve bacterial mediation in metal precipitation, or oxidation-reduction reactions that can only occur in an oxygenated surface environment, itself a cumulative product of photosynthesis. Nickel-copper sulfide deposits contain mantle-derived metals, but their formation requires external (non-magmatic) sulfur, commonly provided by sulfides in sedimentary country rocks. These same sulfides form mostly through bacterial sulfate reduction, so these 'magmatic' deposits are indirectly connected to the biosphere. Magmatic-hydrothermal porphyry copper deposits may seem to be independent of the biosphere, but they require an Earthly hydrosphere, as do all hydrothermal deposits. The maintenance of liquid water on our planet depends on long-term regulation of atmospheric CO_2, which is again intricately linked to the biosphere. Plate-tectonic processes are critical in enriching many rare chemical elements (e.g., uranium, REE) so that they can form economic deposits. Similarly, orogenic processes linked to tectonics, coupled with a dynamic surface environment, constantly reorganize the outer part of the lithosphere on Earth, allowing us to explore a wide range of crustal and mantle environments at or near the planetary surface. Without lithospheric plate tectonics, the potential for incompatible element enrichment is diminished, and deposits formed in deep environments would likely remain there. Links between plate tectonics and the biosphere form a more controversial debate, but there is little doubt that the hydrosphere plays a crucial role in global plate tectonics.

It is perhaps possible that processes such as impact-related magmatism or hydrothermal systems could generate familiar or unfamiliar mineral deposits on Mars or elsewhere, but this remains very speculative. On the other hand, a conclusion that many familiar resources that we depend upon owe their very existence to the presence of life on Earth involves less speculation. The technical challenges associated with getting humanity to other worlds are enormous but hopefully will be overcome. However, this is just the first step in a giant leap, and the potential types and availability of resources to sustain such an effort also need to be considered and assessed.