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DID YOU KNOW…?

The MSA has available on its website a collection of fully open access publications. These include *Teaching Mineralogy* (Brady, Mogk, and Perkins 2011); *Mineralogy and Optical Mineralogy Laboratory Manual* (McNamee and Gunter 2014); *Guide to Thin Section Microscopy* (Raith, Raase, and Reinhardt 2012), *Carbon in Earth* (edited by Hazen, Jones, and Baross 2013, RiMG volume 75), and many more. Full-text articles from *American Mineralogist* from 1916 through 1999 are also a part of this collection. The Open Access publications are under the **Publications** pull-down menu on the www.minsocam.org home page.

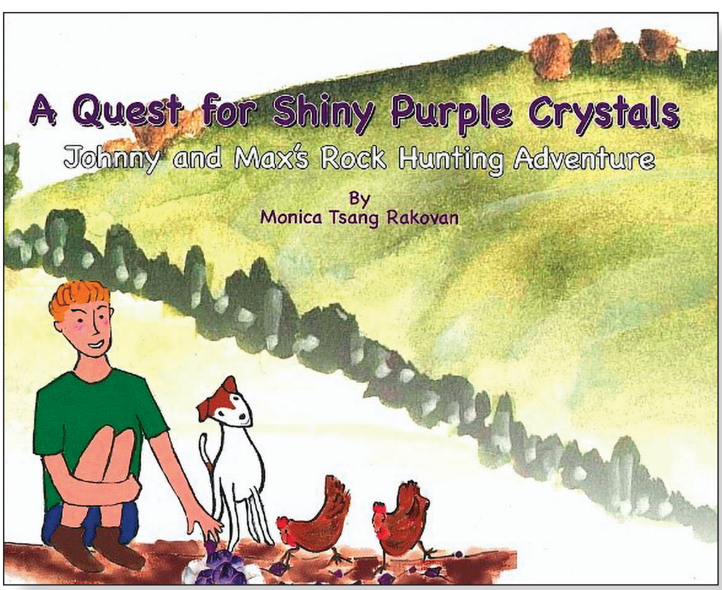
A MINERAL PUBLICATION FOR CHILDREN

***A Quest for Shiny Purple Crystals: Johnny and Max's Rock Hunting Adventure*, by Monica Rakovan, 2018, 32 pp, softcover, ISBN 978-0-9863349-1-7**

The MSA is pleased to be able to offer this exciting publication for children. In this illustrated book, Johnny and his best (furry) friend, Max, become fascinated by the rocks they are finding. To learn more, they visit a nearby rock shop, where the owner, Sal, answers many of their questions. Johnny and Max are invited to go rock collecting with Sal at a farm where the chickens are digging up purple crystals! The hunt begins for more shiny purple rocks and learning about an unusual amethyst find.

Written by Dr. Monica Rakovan, *A Quest for Shiny Purple Crystals* is a great way to teach children about collecting rocks and encourage enthusiasm for the sciences. A helpful glossary in the back helps introduce children to new words, and the colorful illustrations bring the story alive.

Description and ordering online at www.minsocam.org or contact Mineralogical Society of America, 3635 Concorde Pkwy Ste 500, Chantilly, VA 20151-1110 USA phone: +1 (703)652- 9950 fax: +1 (703) 652-9951 e-mail: business@minsocam.org. Cost is $10.



HUNTING MINERAL-CENTERED LIFE FROM THE DEEP ROCKY BIOSPHERE

The emergence of life is generally considered to have been assisted by the power of minerals (Hazen 2012). Modern organisms are equipped with biochemical machineries that might have replaced more primitive mineral parts a long time ago. Given the high energetic costs to operate such sophisticated biochemical machineries, it is speculated that mineral-centered life might have been evolutionarily preserved on modern Earth where the primordial geochemistry prevails with extreme energy starvation. One of the ideal places to hunt possible primitive life is in the deep subsurface because of its restricted supply of energy-rich photosynthetic products. Granite and basalt are geologic giants that have been representative of the continental and oceanic crusts, respectively, since ~4.0 Ga. Energy-starved deep biospheres in granitic and basaltic crusts have been potentially hosting primitive life that is not in competition with biochemically sophisticated microbes.

To explore the granite biosphere, a 69 Ma granite was drilled horizontally from a 300 m deep underground tunnel at the Mizunami Underground Research Laboratory (Tono, central Japan). Pristine groundwater samples were taken and subjected to genome-resolved metagenomic analyses in combination with geochemical and microbiological site characterizations. It was revealed that anaerobic methane-oxidizing archaea were harvesting energy from magmatic methane under energy-starved conditions (Ino et al. 2018). In addition, a diverse phylum within the candidate phyla radiation (CPR), called Parcubacteria, appears to be dominant in the deep granite biosphere. All CPR members are represented by small genomes and cell sizes with restricted metabolic capacities, which might have been inherited from an early metabolic platform for life (Hug et al. 2016).

For the oceanic crust biosphere, the *JOIDES Resolution* research vessel was used to drill into basalts of the following ages: 13 Ma, 33.5 Ma and 104 Ma. This drilling was done during Integrated Ocean Drilling Program (IODP) Expedition 329, which targeted life beneath the seafloor of the South Pacific Gyre (SPG). The South Pacific Gyre is known as an oceanic province where surface photosynthetic activity is exceedingly low (D'Hondt et al. 2015) and which might favor microbes living independent of photosynthesis in the underlying basalt.

Unlike land-based subsurface investigations, it is technically difficult to collect pristine crustal fluid from a borehole drilled from a scientific vessel. Without geochemical information from the crustal fluid, the habitability of the rocky environment remains largely unknown. To understand the nature of the rocky biosphere in oceanic crust, a new life-detection technique was successfully developed for drilled rock cores and used in combination with nanoscale mineralogical characterizations (see Yamashita et al. 2019 and Sueoka et al. 2019). Basalt fractures filled with clay minerals and calcium carbonate were associated with the formation of Fe–Mg-smectite that is compositionally and structurally similar to saponite and/or nontronite, both being indicators of low-temperature basalt–water interactions. Unexpectedly, the dense colonization of microbial cells was directly imaged to exceed ~10^{10} cells/cm^3, a range of cell density typically found in a human gut (Fig. 1) (Suzuki et al. 2020). More surprisingly, there was a dominance of heterotrophic bacteria, as demonstrated by DNA sequences and lipids, from which one can conclude that there is organic matter in the form of carbon and an energy source(s) in subseafloor basalt.

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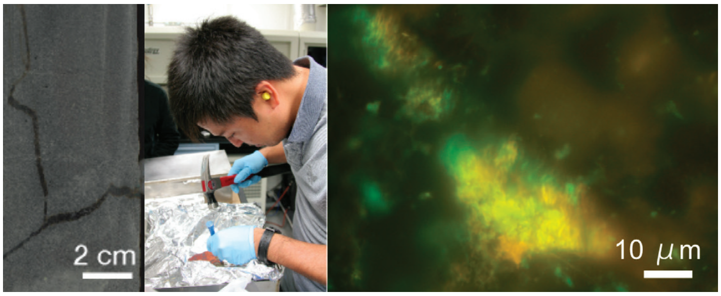

Figure 1 (LEFT) Picture of a basaltic core sample with fractures. (CENTER) A scientist subsampling a part of a rock core. (RIGHT) Fluorescence microscopy image of SYBR Green I–stained microbial cells associated with nontronite. Green and orange colors indicate the presence of microbial cells and nontronite; the yellow color indicates the enrollment of microbial cells within nontronite aggregates.

These findings change our view of the rocky biosphere where inorganic energy sources derived from rock–water interactions are generally regarded as of primary ecological importance. Given the prominence of basaltic lava and/or magmatic methane on Earth and Mars, microbial life could exist where subsurface igneous rocks interact with liquid water. It is also important to note that the presence or absence of microbial life and associated metabolic repertories will clarify poorly characterized physicochemical properties in deep igneous rocks, such as permeability and fluid and energy fluxes. Finally, the technology to hunt mineral-centered life in the deep subsurface is now ready – we are on the verge of unveiling life's story from the very beginning.

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JOURNAL OF MINERALOGICAL AND PETROLOGICAL SCIENCES

Vol. 115, No. 2, April 2020
Special Issue: Indian Continent