For this Parting Shots, I have been ordered by Managing Editor Pierrette Tremblay to break with tradition and show some illustrations from my own research which seem appropriate for this issue. All are secondary electron SEM images of (001) crystal surfaces taken by my long-time and very skilful collaborator, Martin Lee, when we were investigating the complicated character of the surfaces of moderately weathered alkali feldspars. Although the surfaces appear smooth to the unaided eye, at the micrometre scale they are covered by all manner of tiny nooks and crannies\(^1\) that are potential homes for microbes. These defects are not intriguing rarities, but commonplace, albeit sub-optical, features of Earth’s surface. Alkali feldspar is the third most abundant mineral in the continental crust, and crystals originating in granitic rocks almost always develop similar complex surfaces when they enter the weathering zone.

**FIGURE 1** encapsulates the riot of crystal-structural and chemical processes that leads to nook and cranny formation. The original, centimetre-sized crystal grew from granitic magma 394 million years (Ma) ago at ~750°C as a homogeneous alkali feldspar solid solution with a composition near Na\(_{0.3}\)K\(_{0.7}\)Al\(_{2}\)Si\(_3\)O\(_8\). Na\(^+\) and K\(^+\) have very different ionic radii, and this imposed severe local distortions on the feldspar’s Al–Si–O framework. In response, at ~670°C the crystal began to unmix, by solid-state diffusion, forming a lamellar intergrowth (known as film perthite) of Na-rich albite in a matrix of K-rich orthoclase. It is these film lamellae that give the pronounced E–W lineation on the micrograph.

For nearly 400 million years, the crystal lurked beneath the surface, at a maximum depth of ~3 km, replete with its inventory of residual elastic strains and energy in the cores of dislocations. Uplift began at ~65 Ma. Some 20,000 years ago, northern Britain was beneath a kilometre of ice, but rapid global warming 15,000 years ago led to fast retreat. Excavated by ice, our feldspar emerged into the light. Great forests developed, to be cut down by Neolithic men beginning 5000 years ago. Peat soils developed, with acid pore waters, currently with a pH of 3.4. The water rapidly became nearly saturated in feldspar components, and dissolution of our feldspar occurred preferentially, at sites of high strain or down dislocation cores, allowing fluid access to crystal interiors. At low temperatures, whenever both Na- and K-rich feldspars are present (as in these perthitic intergrowths), aqueous solutions with which they are in equilibrium are strongly enriched in Na and have fixed compositions that do not depend on the proportions of the two feldspars. So, in our feldspar (Fig. 1), albite has dissolved preferentially, leading to the E–W slots. A residual ‘toast-rack’ of orthoclase remains, flaking off in places to reveal striations where dislocations once occurred.

For well-understood crystallographic reasons, the long axes of the lens-shaped dislocation loops develop in two orientations, one approximately normal to (001), as shown in these micrographs, the other at right angles, parallel to the b-axis. Impregnation in vacuo using a runny type of resin, followed by dissolution of the silicate in HF, showed that the weathered feldspars contain extraordinary, deep, organized honeycombs of etch tubes penetrating many tens of micrometres beneath the surface (Fig. 3). Soil bacteria and other microbes demonstrably inhabit these natural labyrinths, and the tubes and cells are remarkably similar in size (Fig. 4). Aqueous fluids in the tubes will have high Na:K ratios, just like the extracellular fluids in your body, dear reader, while your cellular fluids are relatively rich in potassium. Encouraged by the late J. V. Smith (see Elements 1:151-156), we and others have suggested that these myriad self-organized, cell-sized nooks and crannies may have provided protective containers for the prebiotic reactions that led to the first self-replicating molecules and the emergence of life.

---

\(^1\) These strange English words may be unfamiliar to some of our international readers. The Concise Oxford Dictionary defines a nook to be ‘a corner or recess; a secluded place’. A cranny is ‘a chink, a crevice, a crack’. It is perhaps worth mentioning that the word nooky is U.K. slang for sexual activity, perhaps because it is usually enjoyed in a secluded place.

---

**Figure 1** A natural, uncleaned (001) cleavage surface of an alkali feldspar fragment originally from a granite, collected with care from an acid peat soil (width of image 60 µm)

**Figure 2** A freshly produced (001) cleavage surface that has been etched for a few seconds in HF vapour (width 10 µm)

**Figure 3** This strangely biological-looking network is a resin cast of natural etch-tubes formed on dislocations running in two directions at right angles. After impregnation most of the feldspar was completely dissolved away in HF, allowing the soft resin sheets to flop over onto the remaining feldspar surface (width 20 µm)

**Figure 4** False-coloured image of soil microbes (in pink) inhabiting a weathered feldspar surface (width 20 µm)
Sub-micron Analysis of Isotopes & Trace Elements in Terrestrial Biogeochemistry

NanoSIMS 50L
CAMECA’s Ion Microprobe for Ultra Fine Feature Analysis
- Trace element mapping down to 50nm lateral resolution
- Reproducibility of stable isotope measurements in the low sub-permil range
- Parallel detection of up to 7 masses

Uranium fixation with bacteria
G. Sulfurreducens from a biofilm incorporated 13C-labeled acetic acid and reduced U6+ to U4+, which was precipitated as uraninite on the surfaces of the bacteria. NanoSIMS can be used in combination with HR-TEM to track the uptake of radionuclides and identify the bioprecipitated mineral phases.

Study of Biogenic Nanoparticles
The composite C, N, and S mapping of a biofilm with NanoSIMS demonstrates that microbially derived extracellular proteins can limit the dispersal of nanoparticulate metal-bearing phases, such as the mineral products of bioremediation.
Red regions represent relatively pure Sulphur (as ZnS),
Orange & Yellow: increased levels of Nitrogen in presence of ZnS,
Light blue: presence of both C and N, with little to no S (no ZnS).
From: Extracellular proteins limit the dispersal of biogenic nanoparticles,
John W. Moreau et al., SCIENCE, vol 316 (2007)

Also in our Geoscience Product Line:
- IMS 71-GEO Small geometry SIMS
- IMS 1280-HR Ultra-high resolution SIMS
- SXFiveFE Field Emission EPMA
A hypothetical question of course! But even if we could ask them, the SPECTRO MS makes the question redundant. This novel ICP mass spectrometer analyzes the entire relevant mass spectrum completely simultaneously; faster and more precisely to boot.

**SPECTRO MS**
- Double focusing sector field mass spectrometer with newly developed ion optic and pioneering detector technology
- Simultaneous measurement of more than 75 elements with 210 isotopes for improved precision together with highest sample throughput
- Fast fingerprinting, internal standardization in real time and the measurement of transient signals, isotope ratios and isotope dilution
- Compatible with EPA, FDA, CLP and 21 CFR Part 11 as well as additional standards and guidelines

Do You Think Ions Like Queuing Up?

Find out more about the new SPECTRO MS at  
spectro.info@ametek.com  
Tel +49.2821.892-2102  
http://ms.spectro.com
We put bugs in our software. The Geochemist’s Workbench traces microbial respiration and fermentation, population growth and decay, mixed communities, enzymes, catalysts, and surface complexation. Save now on new release.