associated carbon, their results agreed with those of previous analyses.

What is missing is an understanding of why the apatite should act as a safe-deposit vault. Until that is known, other questions will claim attention. First, why are the $^{13}C/^{12}C$ ratios so variable and, in half of the cases, so low? Biological fractionation is usually very consistent, and ratios like those in the lower half of the present distribution do not appear for more than a billion years, when they are thought to be produced by methane-consuming bacteria. These organisms require oxygen, which fits well with other indicators of increasing oxygenation 2.7 Gyr ago, but not 3.85 Gyr ago. Second, is there a plausible non-biological cause for the fractionation, either an isotope effect associated with one of the infinite number of uninvestigated prebiotic chemical reactions, or some obscure post-depositional effect peculiar to microscopic inclusions in apatite? These are worries and long-shots. It's most likely that the new results are indeed evidence for life 3.85 billion years ago.

The use of an ion microprobe to measure carbon isotopes is new. The probe works by firing caesium-ion bullets into a polished chip to break up crystals and molecules at its surface. Negative ions (C^- in this case) are extracted and accelerated, and the isotopes are electromagnetically separated by a mass spectrometer. It is assumed that any instrumental effects biasing the ratio observed from the thin films of carbon within the mineral matrices can be removed by comparison with a reference sample of pure graphite. Tests indicating consistency with results of conventional analyses are impressive, but more documentation of the probe's suitability for carbon-isotope analyses will be welcomed. As soon as that is available, curators of collections of martian meteorites and of ancient microfossils should start getting in line. ☐

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1. Nutman, A. P., McGregor, V. R., Friend, C. L. R., Bennett, V. C. & Kinny, P. D. *Precambr. Res.* **78,** 1–39 (1996).
2. Mojzsis, S. J. *et al. Nature* **384,** 55–59 (1996).
3. Hayes, J. M. in *Early Life on Earth* (ed. Bengtson, S.) 220–236 (Columbia Univ. Press, New York, 1994).
4. Maher, K. A. & Stevenson, D. J. *Nature* **331,** 612–614 (1988).
5. Sleep, N. H., Zahnle, K. J., Kasting, J. F. & Morowitz, H. J. *Nature* **342,** 139–142 (1989).
6. Hayes, J. M., Kaplan, I. R. & Wedeking, K. W. in *The Earth's Earliest Biosphere: Its Origin and Evolution* (ed. Schopf, J. W.) 93–134 (Princeton Univ. Press, 1983).
7. Wedeking, K. W. & Hayes, J. M. in *Advances in Organic Geochemistry* (ed. Bjoroy, M.) 546–553 (Wiley, New York, 1983).
8. Schidlowski, M. & Aharon, P. in *Early Organic Evolution* (eds Schidlowski, M., Golubic, S., Kimberley, M. M., McKirdy, D. M. & Trudinger, P. A.) 147–175 (Springer, Berlin, 1992).

OPTICS

X-ray lenses near reality

Jerome Hastings

X-RAY sources have already evolved from the original sealed vacuum tubes into sophisticated electron-storage rings, and free-electron X-ray lasers may be just beyond the horizon. These advances promise intense, highly parallel and tuneable photon beams. To focus and manipulate this radiation, a variety of X-ray optical devices have been developed, ranging from concentrators, in the form of tapered capillaries[1], to Fresnel zone plates[2]. But a dream of X-ray opticians for some time has been to make a *refractive* lens, the X-ray equivalent of conventional optics for visible light. On page 49 of this issue[3], Anatoly Snigirev and colleagues describe the first significant step towards that goal. This should allow us to reach a submicrometre focus with much greater efficiency than before.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

ESRF

The European Synchrotron Radiation Facility in Grenoble, France. Compound refractive lenses may soon make its intense X-ray beams much more effective.

The desire in a multitude of scientific disciplines for intense submicrometre X-ray beams has driven the construction of new electron-storage-ring X-ray sources in Europe (the European Synchrotron Radiation Facility in Grenoble, France), the United States (the Advanced Photon Source in Argonne, Illinois) and Japan (the Spring-8 Project in Harima). The objective is to perform the various 'standard' X-ray analytical techniques of diffraction and spectroscopy on individual particles or grains.

These measurements could provide information about the atomic and electronic structure of systems of chemical, biological and technological interest, ranging from the characterization of an individual grain in a commercial catalyst to measuring the strain in the metallic interconnections of large integrated circuits. But the limited ability of available X-ray optics to focus the X-ray beams prohibits such applications.

The existing optics fall into a few categories: reflecting optics such as grazing-incidence X-ray mirrors; tapered capillaries; and various types of Fresnel zone plates. Refractive lenses, routinely used in visible-light optics, had been thought to be impractical at X-ray wavelengths. In the X-ray regime, the difference in the index of refraction between air and ordinary materials is tiny — typically of the order of 10^{-6} — which appeared to present an insurmountable problem. To maximize the effect, heavy-element materials were proposed, but they have high absorption. Light elements do not, but with their low refractive-index decrement they would have long focal length and thus provide little practical focusing of the X-ray source.

Snigirev and colleagues[3] have now proposed and demonstrated a compound refractive lens for hard (14 keV) X-rays that overcomes the difficulties of earlier schemes. A series of N refractive lenses has a focal length shorter than a single lens by a factor of N, and, in aluminium, absorption is slight for X-ray wavelengths below one ångström, so a series of tens to hundreds of lenses can be used. The authors made their lens by simply drilling small round holes in an aluminium block (see Figs 1 and 3 on pages 49 and 50, respectively).

This 'crude' technology permitted a demonstration of their ideas and showed the potential for future optics. With more sophisticated fabrication techniques, one can imagine extending these lenses from cylinders to spheres to provide focusing in two dimensions. Such lenses should then be commonplace at synchrotron sources, and the full potential of the X-ray beams already available will be realized. This development bodes well for the future of synchrotron-based microanalytical techniques that are impossible today but should be standard in the future. ☐

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1. Bilderback, D. H. & Thiel, D. J. *Rev. Sci. Instrum.* **66,** 2059–2063 (1995).
2. Lai, B. *et al. Rev. Sci. Instrum.* **66,** 2287–2289 (1995).
3. Snigirev, A., Kohn, V., Snigireva, I. & Lengeler, B. *Nature* **384,** 49–51 (1996).