Lights hidden under bushels

Geochemists are not alone in failing to make clear the elementary assumptions on which they work. The result is that what they do is under-appreciated.

GEOCHEMISTS, who have a great many achievements to boast of in the past few years, are sometimes their own worst enemies. That is what many innocent readers will conclude from a casual inspection of the rush of articles with which the geophysical literature is now spattered, and which purport to show how, for example, the measurement of neodymium isotopes in some sample of rock can shed light on the past history of the material. The articles on pages 753 and 773, singled out perhaps unfairly as representative of their kind by the mere accident that they are included in this issue, show how unforgiving of their readers' patience the geochemists have become. (If they should protest that they are not alone among specialists in making the assumption that everybody who matters knows what they intend to say, they are merely making the more dangerous assumption that only fellow specialists are likely to be interested).

The underlying difficulty is common in new fields of investigation, perhaps especially in those almost certain to become important. It is then tempting for those with new things to say to work on the principle that the assumptions with which they live day by day are widely appreciated. If indeed, with the passage of time, the novel branch of geochemistry based on the analysis of terrestrial (and other) rocks for the radioactive decay products of rare but long-lived components of the Solar System turns out to be as important as it promises, the result will be that the general readership of the literature will know what the assumptions are. This, to a large extent, is what has happened in the previously daunting field of nucleic acid chemistry, where it is no longer necessary for people to spell out the simple fact that DNA molecules are constructed from four distinct subunits, for example. But if the new geochemistry should be only of middling importance, is it destined to remain more or less a closed book?

That would be, to say the least of it, a pity, which is why, at least for a little while, geochemists should be a little less austere in the way they describe what they have done. It is not that the field is all that unfamiliar. Indeed, it resembles in many ways the pioneering work of F.W. Soddy, in the first decade of this century, in seeking to determine the age of the Earth from the radioactive decay of uranium and thorium.

The essence of that task, successfully

completed in the 1930s, is that two principal isotopes of uranium (with mass numbers 238 and 235) ultimately yield as decay products two isotopes of lead (with mass numbers of 206 and 207 respectively). Thorium-232, on the other hand, finishes up as lead-208.

What this implies is that it is possible to infer the length of time for which a rock containing uranium has been undisturbed by a sufficiently accurate measurement of the amount of, say, uranium-238 and of the abundance of lead-206 relative to that of some other isotope of lead known not to be the product of radioactive decay. (Lead-204 is the common standard.) For then the lead-206 found in a sample of the rock will represent both that formed by the decay of uranium-238 and that present at the outset. If the *primaeva* abundance of lead-206 relative to lead-204 is known (as, for example, from the analysis of rocks containing lead but no uranium), it requires merely simple subtraction to discover how much lead-206 has been formed by the decay of uranium-238.

The techniques now being exploited with such profit by the geochemists are in principle no different. Neodymium-143 is formed by the alpha-decay of samarium-147 (with a half-life of more than 100,000 million years) and strontium-87 from rubidium-87 by beta-decay (with a half-life of nearly 50,000 million years). Relative to other isotopes of neodymium and strontium, the excess amounts of the radiogenic daughter elements in some sample of rock are simply related to the amounts of the radioactive isotopes originally present and to the length of time which has elapsed. The conventional standards for comparison are the isotopes neodymium-144 and strontium-86 respectively.

Much of the confusion that attends the use of these techniques in geophysics stems from the recognition, in itself a discovery of great importance, that the elements involved, the radioactive parents and their daughters, have been repartitioned among the several components of the Earth's layer structure during geological history, not all of it Archaean. Both rubidium and strontium, as chemical elements, are more abundant in continental crust than in the mantle from which the continents were formed, but the relative concentration of rubidium is greater than that of strontium (by factors of perhaps 70 and 20 respectively). With

samarium and neodymium, by contrast, the daughter tends to be more highly concentrated than the parent.

Chemists are quick to point out that this redistribution of material is largely a function of the radii of the ions of the elements involved. (By chance, uranium and lead are concentrated in the continental crust relative to the mantle by roughly the same degree.) Whatever the mechanism of this process, what emerges is that the abundance of strontium-87 (relative to strontium-86) is greater in the continental crust than in the mantle, while the abundance of neodymium-143 (relative to neodymium-144) is less than in the mantle.

The interpretation of the ratios actually measured is complicated by the difficulty of knowing the full history of the material concerned. In attempts to infer the age of the Earth from measured abundances of uranium isotopes and the corresponding isotopes of lead, it is sufficient to search for the oldest rocks and to compare the results of abundance measurements with those obtained from meteorites. By contrast, the chief utility of the use of the newly-measurable isotopes is that they may be used to trace the comparatively recent history of the Earth's surface layers, continental crust and ocean floor alike, in which case there can be no fixed assumptions about the abundance of the isotopes in the starting material.

This does not, however, prevent practitioners from talking of "anomalies". The reference point is usually some notional composition of *primaeva* material but is hardly crucial, since only differences of abundance bear on the processes by which material has most recently been repartitioned. Eventually it should also be possible to construct a kind of historical record of the average abundance in the mantle of the isotopes involved, at least if the mantle is crudely homogeneous.

All this, of course, is commonplace among geochemists. But now and again, it would do no harm if they were to remind their readers that neodymium-143 is the product of the radioactive decay of samarium-147, or that lead-206 is the product of uranium-238. Certainly they should be more forgiving of their readers' almost certain ignorance of the importance of these isotopes as tracers of the fractionation of terrestrial material. To fail to make these concessions is to underplay an exciting field.

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