

Recycling Osmium

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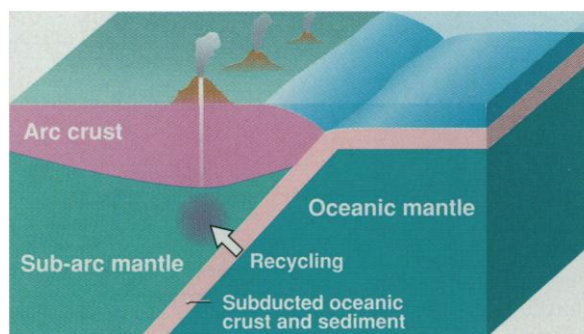
Given a new tool similar to a hammer, a carpenter will quickly learn how to use it. Learning to use an unfamiliar new tool, on the other hand, takes some time, and the user may well find some unexpected new applications. In this issue, Brandon *et al.* (1) provide a classic example of this phenomenon, using measurements of rhenium-osmium isotope ratios to show that osmium is recycled out of subducted oceanic crust into the overlying island arc mantle wedge. Osmium is not expected to do this, and their findings show that there is more to the story of mass transfer of noble metals in subduction zones than we first thought.

Measurements of the natural decay products of ^{187}Re to ^{187}Os (by β -decay with a half-life of 42 billion years) have been applied to geological and cosmochemical problems for a relatively long time (2). It provides among other things a measure of the age of the galaxy (3) and solar system (4). Applying the Re-Os isotopic system to the terrestrial crust and mantle (5) has always been a daunting technical challenge, however. Until recently, Os isotope ratios were very difficult to measure owing to the high energy required to generate Os^+ ions. The mass spectrometers required to do this, either with laser-induced resonant ionization or ion beam sputtering, are relatively expensive and rare.

Then a new technique, negative thermal ionization mass spectrometry (NTIMS), appeared on the scene. In rapid succession, NTIMS measurements of Os isotopic ratios were demonstrated (6) and their application to geology was shown (7). Compared to the old methods, this new technique allows a thousandfold decrease in sample size and a fivefold improvement in reproducibility of the isotopic ratio measurement and can be used on equipment already present in most isotopic laboratories. One laboratory reported making the required modification on a 20-year-old mass spectrometer and having a large osmium beam within hours of receiving the article describing the technique to review.

The subsequent 5 years have not shown the expected flood of new Re-Os results, however. This is partly the result of the "newness" of this isotopic system. Consider the carpentry analogy. The Sm-Nd isotopic decay system was like a new kind of ham-

mer. Introduced for use on terrestrial rocks in the late 1970s (8), its uses were easily predictable thanks to the similarity of the Sm-Nd system to the geochemically well-understood Rb-Sr isotopic system. Many of the same things that were possible with the Rb-Sr isotopic system could also be done with Sm-Nd—many of them much better—and Sm-Nd became a standard



Island arc subduction. The oceanic crust and sediments (pink) are subducted beneath the overlying island arc mantle (green). Elements extracted from the subducted crust are first recycled into the arc mantle (arrow), and then that mantle melts to form island arc volcanic rocks. Osmium was thought to remain in the subducted slab, to be carried into the deep mantle. Brandon *et al.* (1) show that at least some is instead recycled.

method of isotope geochemistry within a few years of its debut.

By contrast, relatively little still is known about the geochemistry of Re and Os. What is certain is that they are radically different in their geochemical behaviors compared with Sm, Nd, Rb, and Sr. These four elements are all more soluble in volcanic magmas than in the mantle residues that produce volcanic magmas (that is, they are incompatible), which means that all are depleted from the mantle with time and are added to the crust. Osmium, a noble metal, is nearly quantitatively retained in the mantle source during melt production (that is, it is compatible), and Re behaves in a mildly incompatible fashion. This means that large fractionations of Re from Os occur during the formation of Earth's crust, which has a very high Re/Os ratio and acquires over time an enriched $^{187}\text{Os}/^{188}\text{Os}$ ratio as a result of the decay of ^{187}Re to ^{187}Os .

It is precisely such crustal Os isotopic signatures that Brandon *et al.* (1) have observed in mantle xenoliths (inclusions in a basalt of its mantle source rock) from beneath the Cascade and Japan arcs. It has been known for some time that many elements present in the subducted slab are re-

cycled into the mantle overlying it (see figure) (9). Melting in this region of the mantle produces island arc volcanoes at the surface, and these volcanoes can entrain pieces of the island arc mantle, such as the xenoliths studied by Brandon *et al.* (1).

The surprise is that Os, as a compatible element, was not expected to be mobilized from subducted slab to sub-arc mantle. The explanation is that the fluids that accomplish this mass transfer are more oxidizing and more Cl-rich than most magmatic liquids, and thus more capable of mobilizing Os (and possibly other noble metals also, such as platinum). This additional mobilization means that all of our notions about how the platinum group elements behave during subduction require rethinking.

There have been other recent surprises as well. For instance, the Re-Os isotope system provides the long sought after means of determining the age of the sub-continental lithospheric mantle (10). Also, mid-ocean ridge basalts appear not to be in Os isotopic equilibrium with their mantle residues (11). Recently, at the largest annual meeting of geochemists (12), a huge increase in the number of Re-Os-related talks and posters compared with previous years showed that this particular geochemical tool is finally beginning to come into its own. Still, it is very likely that the

most interesting uses of this isotopic system are still to be discovered. After trying the old ways of using this new tool, we are now finding out some of the new ones.

References

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