Magmatism

Flood basalts of Siberian Traps doubled at a stroke (*July 2002*)

Erupted at the time of the Palaeozoic-Mesozoic boundary, and coinciding with the largest mass extinction during the Phanerozoic, the Siberian Traps are by far the biggest example of flood-basalt volcanism known. They blanket a huge area of the Siberian Platform. To the east of their outcrops is a large extensional downwarp, known as the West Siberian Basin, where recent deep drilling has cut through up to 1 km of flood basalts. Dating samples from 15 boreholes proves that these too are members of the Siberian Trap suite (Reichow, M.K. *et al*. 2002. $^{40}Ar/^{39}Ar$ dates from the West Siberian Basin: Siberian flood basalt province doubled. *Science*, v. **296**, p. 1846-1849; DOI: 10.1126/science.1071671). Combined, the two zones of Siberian Traps represent eruption of around 2.3 million km^3 of plume-derived magma at around 250 Ma ago, possibly within 2 or 3 Ma. Gas release from such a stupendous event is implicated in the Permian-Triassic mass extinction, either through climate change associated with CO_2 and SO_2, or toxic effects of hydrofluoric acid. Unlike the end-Triassic and K-T extinctions, no clear evidence has emerged for coincident flood volcanism and major impact at the end of the Palaeozoic Era. However, the use of tungsten isotopes as "fingerprints" for extraterrestrial debris in boundary sediments may help resolve the issue of whether an impact accompanied the Siberian Traps (see *Tungsten and Archaean heavy bombardment*, this issue)

Sea level fluctuations and large igneous provinces (*September 2002*)

On a global scale, shifts in sea level recorded by stratigraphers and on seismic profiles stem from one of two main processes: changes in land-ice volume and the volume of the ocean basins. The latter most often results from changing rates of sea-floor spreading, so that when it is rapid a greater volume of the lithosphere near spreading centres retains sufficient buoyancy to displace the oceans onto continental margins. During slow spreading, cooling of the lithosphere and an increase in its density enlarges the deep abyssal plains, so that the oceans withdraw to low levels. The mid-Cretaceous saw vast outpourings of plume-related lavas onto the floor of the West Pacific. So large, that they reduced the volume of the Pacific basin enough to result in continental flooding that was unprecedented in the Phanerozoic Eon.

On a local scale, changes in sea level recorded by the stratigraphic record include those due to local processes, generally ascribed to tectonic events at continental margins, which involved rising continental lithosphere. However, one of the greatest forces for local change in the continental freeboard is changing density of the lithosphere due to thermal effects. Anywhere once affected by major igneous events should record relative falls in sea level during the acme of magmatism, and rises when activity waned. The British Tertiary Igneous Province, a precursor to the eventual rifting of the North Atlantic under the influence of the Iceland plume is a good candidate for charting magma-sea level connections. The central volcanic complexes of the Hebrides, and their enveloping flood basalt piles formed at the start of the Palaeocene (~60 Ma). Around that time, much of the British Isles underwent several kilometres of vertical uplift and exhumation, whose effects remain today. In the surrounding marine basins, this event is recorded by Palaeogene sandstone bodies, presumable derived by erosion of the uplifted crust. Yet local Palaeogene sediments also record episodes of rising sea level. John Maclennan and Brian Lovell of the French Institut de Physique du Globe and Cambridge University have modelled the likely effect on sea levels around the British Isles by crustal underplating of magmas formed during the BTIP magmatism (Maclennan, J. & Lovell, B. 2002. Control of regional sea level by surface uplift and subsidence caused by magmatic underplating of the Earth's crust. *Geology*, v. **30**, p. 675-678; doi: 10.1130/0091-7613(2002)030<0675:CORSLB>2.0.CO;2).

Up to 8 km of mafic igneous rocks seem to have ponded at the base of the British Isles' crust while the BTIP was active. This estimate stems from the fact that the lavas of the province evidence high-pressure fractional crystallization. Calculations of the percentage of cumulates needed to generate the bulk chemistry of the BTIP lavas suggest that their volume far outweighs that of the volcanic part of the province. Given estimates of the volume of underplated cumulates, modelling boils down to examining the consequences for lithospheric density of initial heating and its subsequent relaxation. The Palaeogene sedimentary record provides good support for the model, with massive uplift from 60-56 Ma (the period when the BTIP was forming). Sudden sea-level rise at the end of this period never reached the level prior to magmatism; in fact it amounts to one half the estimated uplift. That is precisely in line with the underplating model.

Geochemistry points to continents' role in mantle dynamics (*October 2002*)

Major-element chemistry of basalts provides proxies for key parameters involved in magmatism. Sodium content, normalized to an MgO content of 8%, relates to the degree of mantle melting, and similarly normalized iron content helps assess the depth of melt production. Such proxies help establish potential mantle temperatures - the temperature of magma that would erupt after rising adiabatically from different mantle depths. Low $Na_{8.0}$ suggests high potential temperature in a magma's source.

Vast repositories of basalt chemistry relate to every conceivable setting of magmatism, so $Na_{8.0}$ and $Fe_{8.0}$ numbers are useful in testing various hypotheses. One of these is that slabs of continental lithosphere affect mantle convection, by forming insulating "lids" that control surface heat flow. Eric Humler and Jean Besse, of the Université Denis Diderot in Paris, focus on the relationship between mantle potential temperature beneath ocean-ridge systems and their distance to passive continental margins (Humler, E. & Besse, J. 2002. A correlation between mid-ocean ridge basalt chemistry and distance to continents. *Nature*, v. **419**, p, 607-609; DOI: 10.1038/nature01052). Leaving out the complicating factors of continental margins that involve subduction and ridges affected by hot spots, they found that recent ridge basalts show higher potential temperatures when the ridge is close to continental lithosphere than for more distant ridges. This suggests that the mantle cools away from continents by between 0.05 to 0.1°C per kilometre. This matches the well-known increase in depth to ridges as they become further from continents. Rather than being inert passengers on modern plates, continents do play a role in the mantle's thermal structure.

The scope for synopsis of geochemical data is boosted by wider availability of existing data. How tedious it used to be, trawling paper journals for tables of analyses with which to compare ones own. It is still quite a task, but there is light on the horizon, because geochemists at the University of Mainz in Germany have made their compilations for ocean-island volcanic rocks and those from large igneous provinces (flood basalts) available on the web as the initial input to the GEOROC (**Geo**chemistry of **R**ocks of the **O**ceans and **C**ontinents) database. A similar database for ocean-floor basalts is PETDB at Columbia University in the USA (http://petdb.ldeo.columbia.edu/petdb/). Between them, the two web sites amass over 200 thousand analyses of major- and trace-elements, and isotopes, enough for even the most ardent user of MS Excel!

Detrital platinum-group grains and "plum pudding" mantle heterogeneity (*October 2002*)

Evidence for the degree and longevity of geochemical heterogeneities in the mantle has largely stemmed from studies of basalts derived by mantle melting. The great diversity of melting and fractionation processes involved in their genesis obviously complicates assessment of whether or not the mantle is a mixture of several chemical domains, even though it is suspected. Indeed it is only to be expected as a result of 4.5 billion years of mantle melting events and recycling of surface materials that find their way into subduction zones, unless, that is, long-term convection is an efficient means of mixing. A novel approach by a team from Stanford University, the University of Copenhagen and the US Geological Survey uses a combination of the rhenium-osmium radioactive decay scheme and the tendency for Re to enter melts, while Os is highly compatible to address this long-standing conundrum (Meibom, A. *et al*. 2002. Re-Os isotopic evidence for long-lived heterogeneity and equilibration processes in the Earth's upper mantle. *Nature*, v. **419**, p. 705-708; DOI: 10.1038/nature01067). The novelty lies in their use of detrital grains of platinoids in alluvium derived from the many ultramafic masses in the western USA, rather than individual basalts or peridotites themselves.

Measurements of $^{187}Os/^{188}Os$ in the grains span a wide range from extremely unradiogenic values to those signifying a high component of radiogenic ^{187}Os. The data occupy a bell-shaped (Gaussian) frequency distribution. While that probably reflects equilibration of old, unradiogenic material with radiogenic Os in melts derived from the mantle ultramafic rocks, and the destruction of any age information, it does point to mantle dotted with patches with different origins.