Insight into crust-mantle coupling from anomalous $\Delta^{33}S$ of sulfide inclusions in diamonds

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Sulfur isotope compositions of 26 sulfide inclusions from diamonds have been measured with the Cameca IMS 1270 ion microprobe at UCLA. Inclusions were extracted from 12 diamonds from the Orapa kimberlite pipe, Kaapvaal-Zimbabwe craton, Botswana. In-house reference standards were analyzed between every 3 analyses, and estimated (2σ) uncertainty for $\Delta^{33}S$ is ±0.14‰ - adequate to document that inclusion populations from 4 diamonds have anomalous $\Delta^{33}S$ (0.55‰, 0.24‰, 0.41‰, 0.62‰). Inclusions from the other 8 diamonds yielded $\Delta^{33}S = 0.04 \pm 0.10‰$ (2σ). Preliminary EPMA analyses indicate these have an eclogite affinity.

$\Delta^{33}S$ is an excellent geochemical tracer of Archean crust-mantle interactions because it is invariant during geological processes and in bulk meteorites (Farquhar et al. 2000a). Observation of anomalous $\Delta^{33}S$ of inclusions in diamond confirms earlier assertions that some diamond sulfur derives from the surface (Chaussidon et al., 1987; Eldridge et al., 1991) and also provides new ways to study coupling between Archean mantle, crust and atmosphere. Our measurements of peridotite xenolith sulfur yield near zero $\Delta^{33}S$ (0.03±0.06‰ (2σ)). Mean and median of whole rock $\Delta^{33}S$ measurements for Archean sulfide (Farquhar et al. 2000b) are 0.6 and 0.3‰, respectively. Regardless of whether these $\Delta^{33}S$ values reflect average Archean crust and mantle compositions, they form a framework that can be used in combination with $\Delta^{33}S$ for sulfide from diamonds to place limits on the proportions of mantle and crustal sulfur prior to trapping in diamond. This approach can be extended to the atmospheric subcycle since we attribute $\Delta^{33}S$ variations in Archean samples to 193 nm SO_2 photolysis which produces S^o with $\Delta^{33}S = 65±4‰$ (Farquhar et al., 2001). In this context, our data indicate that all of the sulfur in these inclusions may represent subducted, but undiluted crustal sulfur and that up to 1% of the sulfur for sulfide inclusions was processed through the Archean atmosphere.

References

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Crystallisation of plate spinifex texture at 1 atm. pressure in a thermal gradient

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The spinifex zone in a komatiite flow consists of a thin upper layer of fine, randomly oriented olivine grains underlain by a thicker layer (30 cm to several metres) made up large plates of olivine oriented perpendicular to the flow top. Random spinifex is readily synthesized in dynamic cooling experiments that reproduce conditions during rapid cooling at the flow top. The coarse-grained spinifex is more problematic because the morphology of the olivine plates resembles those of dendritic crystals that grow experimentally only at high cooling rates, 50 to 100ºC/hr. Cooling rates 1-3 m beneath the komatiite flow top, in contrast, are calculated to be <5ºC/hr. This paradox has led to the suggestion that komatiites are hydrous magmas that crystallized in mid-crustal intrusions; a suggestion refuted by field studies that demonstrate clearly that most komatiites are extrusive.

To help resolve the problem we undertook a series of experiments in which synthetic Fe-free charges (51.9 wt. % SiO_2, 17.4 wt. % MgO, 13.2 wt. % Al_2O_3, 17.3 wt. % CaO) were slowly crystallized in a temperature gradient, such as exists at the top of a komatiite flow. The charges were confined in 5-cm-long graphite capsules in the upper part of a 1-atm vertical furnace (argon atmosphere) where the gradient is ~20ºC/cm, like that during cooling of a komatiite flow top. At cooling rates between 2 and 5ºC/hr, we grew long parallel dendritic olivines whose morphologies resemble those of crystals that grow only at cooling rates >50ºC/hr in experiments on the same starting material but without a thermal gradient. Plumose spinifex-like pyroxenes grow between the olivine crystals. These experiments demonstrate that plate spinifex texture forms naturally during cooling of ultramafic lava flows. The presence of water is not required to explain the texture.