Further insights on S content and behaviour in the lithospheric mantle

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Sulphides are minor but common phases in mantle rocks. They are thought to be the main mineral host in mantle rocks for highly siderophile elements (HSE). Therefore, sulphide mineralogy and S concentration are key factors for understanding the behaviour of PGEs and the Re/Os isotopic system in the mantle. Previous studies have shown extremelly different S contents for the two main types of upper mantle samples, i.e. orogenic massifs and xenoliths. The massifs have S contents in the same order of magnitude as estimated for MORB source (~200 ppm, e.g. O'Neil, 1991) and correlated with major element contents. In contrast, peridotite xenoliths brought up by alkali basalts generally have low S contents ($\leqslant 50$ ppm), poorly correlated with fertility indexes (FI#; e.g. Al_2O_3, CaO). It has been postulated that it is the alteration of sulphides into iron hydroxides that could explain the lower S abundances (e.g. Lorand, 1990). However, this interpretation is still controversial.

Five mantle xenolith suites from eastern Australia (Au) and Southern France (Fr.) have been investigated: Mt Quincan (Atherton Province, Qld, Au), Wallabadah Rocks (Liverpool Province, NSW, Au), Allyn River (Barrington Province, NSW, Au), Mt. Gambier (Newer Volcanics Province, SA, Au) and Montferrier (Montpellier Volcanism, Fr.).

Mt Quincan xenoliths are mainly lherzolite ($7 \geqslant$ cpx% $\geqslant 19$), but a few are ol-rich (75>Ol%$\geqslant$97). Mt Gambier peridotites are more depleted, including harzbugite and cpx-poor lherzolites (0>cpx%>9); two are cpx-rich with 14 and 25% of cpx. Xenoliths from Wallabadah Rocks range from harzbugites to lherzolites (4>cpx%>15) and Allyn River samples are mainly lherzolitic (cpx%~16). Montferrier xenoliths are fertile lherzolite (11>cpx%>15) displaying highly deformed porphyroclastic microtexture and rare disseminated pargasite. Among the Montferrier xenoliths two populations can be distinguished one consist of fresh dark-green xenoliths in basaltic lava flow, the second one of altered yellowish xenoliths within a breccias.

Sulphur contents were measured using iodometric method at the Museum National d'Histoire Naturelle, Paris, Cu and trace element analysis were performed on ICP-MS at Macquarie University or at Montpellier II University.

Mt Gambier xenoliths have higher sulphide modal abundances than Mt Quincan samples. Sulphides in Mt Gambier xenoliths occur as Isolated blebs fully enclosed in olivine, spheroidal bodies up to 400 µm in diameter at spinel-silicate junctions, small droplets along fluid inclusion trails, in vermicular intergrowths at the silicate grain boundaries or in sulphide veins penetrating the silicates. Weathering is not uncommon but of very limited extent (0–30%). In contrast, Mt Quincan xenoliths contain only a few sulphide blebs (50-300 µm), generally highly weathered (30 to 90%) per polished thin section. Wallabadah peridotites have very variable sulphide habits and abundances, and the degree of weathering is variable (up to 50%). Allyn River peridotites show very unusual numerous large interstitial sulphides with angular shapes and 'jagged' rims. Montferrier xenoliths have large sulphides (up to 300 µm) with polygonal shapes in microtextural equilibrium with the neoblastic matrix. These sulphides are highly altered (50 to 80%) in breccia-hosted periotite and almost unaltered (<15%) in lava hosted-xenoliths. The common sulphide assemblage in all the xenolith suites is pentlandite, pyrrhotite, monosulphide solid solution (mss) and chalcopyrite.

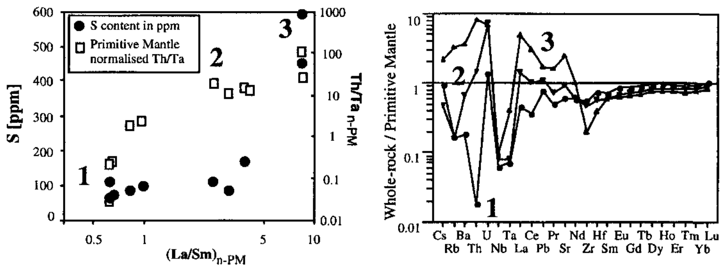

FIG. 1. Montferrier xenoliths (Southern France). Numbers in the right diagram refer to trace element spider types, defined in the left diagram.

Whole-rock sulphur contents are consistent with petrographic observations. Mt Quincan xenoliths are extremely S-poor. Their S concentration range is very narrow (10 to 28 ppm) and uncorrelated with the large range of FI# ($1.0<Al_2O_3<4.0$ wt.%) In contrast Wallabadah peridotites show S contents ranging from 10 to 131 ppm and display a good correlation with FI# (line of best fit yielding a R%=85). Some contents as high as 344 ppm are found in Allyn River peridotites. Montferrier xenoliths display S contents ranging from 7 to 592 ppm irrespective of FI#. Breccia-hosted xenoliths show values between 7 and 130 ppm, while lava-hosted xenoliths have values between 89 to 592 ppm. Cu content ranges from 5 to 36 ppm and in all the xenoliths and is correlated with FI#.

The low S contents and the lack of correlation between S and FI# in Mt. Quincan and Montferrier breccia-hosted peridotites are typical of sub-continental xenoliths (Lorand, 1990). As Cu is still correlated with FI#, and given the weathering features observed, it has been suspected that the low and/or scattered S distribution could be ascribed to post-entrainment processes. This hypothesis is strongly supported by the inverse correlation found between whole rock S content and the average degree of sulphide alteration (Luguet and Lorand, 1998 and this work). However, we emphasise that some of the lowest S abundances occur in ol-rich xenoliths. Chemistry of the silicate phases (e.g. low ol mg#) and trace elements suggest that the ol-rich mineralogy is due to percolation of basaltic magma. Low S contents of poikilitic ol-rich peridotites have been previously observed (Lorand, 1990) and ascribed to a physical extraction of the sulphides, triggered by percolation at high melt/rock ratio (Lorand and Alard, 1998).

On the other hand, the correlation between S contents and FI# (extrapolated to Al_2O_3 = 4. 2 wt.%) for the Mt Gambier and Wallabadah suites yields S estimates in the lowermost range of the Primitive Upper Mantle (~150 ppm), which is 50 to 100 ppm lower that the other estimates (e.g. O'Neil, 1991). The unusually high S of Allyn River and Montferrier lava-hosted peridotites is more problematic, as their S contents are even higher than earlier estimates for the PUM value; therefore this suggests that S has been added. Montferrier whole rock trace element patterns indicate evolution from a depleted MORB mantle to a *LREE* enriched mantle. This *LREE* enrichment, is accompagnied by large ion lithophile element (e.g. U, Th, Ba) enrichment. However the high field strength elements (Nb, Ta, Zr and Hf) display large negative anomalies (Fig. 1). Such features have been previously ascribed by many authors to an infiltration of a carbonated and/or volatile-rich small volume melt. Note that Allyn River cpxs display the same kind of trace element patterns. The plot of S content versus La/Sm and Th/Ta for Montferrier xenoliths clearly shows a positive correlation suggesting that S has been added by metasomatism probably involving a volatile-rich small volume melt. Therefore metasomatism by volatile rich fluid may be a potential process for S enrichment into the lithospheric mantle.

These five xenolith suites provide the opportunity to assess the effect of several processes (melting, sulphide extraction, metasomatism, weathering) upon HSE and to try to answer questions such as: are the lower and more variable PGE contents of mantle xenoliths due to the perturbed S contents of the xenoliths, or do they reflect large-scale differences within the subcontinental mantle?

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