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Lithospheric mantle evolution above a subducting plate: Direct constraints from Antarctic Peninsula spinel peridotite xenoliths

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Our understanding of the tectono-magmatic processes in subduction zones generally relies on interpretations of the bulk-rock compositions of associated volcanic rocks. These, however, have typically undergone extensive modification in the crust (fractionation and/or contamination) and interpreting the mantle processes that have contributed to their genesis is complex. Direct evidence of the composition of the mantle beneath subduction-related volcanics is rare as mantle xenoliths are seldom brought to the surface. An exception is the Antarctic Peninsula, which consists of a series of suspect arc terranes accreted to the margin of Gondwana. Subduction occurred along a trench, off the west coast, and lasted over 200 Ma. It finally ceased after a series of ridge-trench collisions, which began at $\sim$50 Ma in the south and ended at ca. 4 Ma in the north. This was followed by extensive alkaline volcanism along the length of the Antarctic Peninsula. At several localities these post-subduction volcanics contain abundant, fresh spinel-bearing lherzolites, harzburgites and pyroxenites. The widest variety of xenoliths were collected from basanites and tephrites emplaced on Alexander Island and Rothschild Island in the accreted Western Domain. The mineral chemistry of the xenolith suite as a whole is highly varied, e.g. olivine ranges in composition from Fo_{77} to Fo_{91}, but within individual xenoliths typically only limited variation is apparent. Xenolith textures and plots of mineral chemistry suggest that the constituent mineral phases are in equilibrium and can be used to determine pressures and temperatures. PT estimates based on pyroxene compositions indicate that the lithosphere beneath the Antarctic Peninsula has a normal, unperturbed mantle geotherm and a thickness of $\sim$90 km; the base of the mechanical boundary layer is at $\sim$70 km and the xenoliths appear to have been entrained from within this region.

Preliminary modelling of incompatible-trace-element ratios of diopsides and augites in the peridotites suggests that they are not all simple residues of mantle melting. They have a wide range of $[La/Sm]_n$ ratios (0.01 to 8.56) and appear to have undergone variable degrees of modal metasomatism, which has also resulted in an increase in bulk-rock concentrations of major elements, such as Fe and Al. Variable Ti enrichment in spinels and very-high oxygen fugacities suggest that an extreme range of melt compositions may have interacted with the mantle beneath the Antarctic Peninsula and produced the diverse lithologies that we have observed in the mantle xenolith suite. These include boninites (Mg-rich, hydrous melts) and small-fraction melts. We propose that metasomatic enrichment by silicate melts may have occurred during subduction whereas carbonate metasomatism modified the lithosphere following the formation of a 'window' in the underlying slab.