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Source of radiogenic He in the mantle wedge: Constraints from Italian Plio-Quaternary volcanism

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In order to quantify the delivery of radiogenic He to the mantle by subduction we have undertaken a systematic study of the He and Sr isotopic composition of basaltic rocks from the Plio-Quaternary subduction-related volcanism of Italy (Roman Magmatic Province, Aeolian islands, Ustica, Etna). The $^3He/^4He$ of the olivine phenocrysts ranges to the lowest values recorded for mantle-derived rocks (6.8 – 0.44 R_a), although in many cases co-genetic pyroxene is slightly lower. The absence of any relation between $^3He/^4He$ and Mg content, and a strongly linear co-variation with $^{87}Sr/^{86}Sr$ ($R^2 > 0.9$) rules out significant magma-crust interaction. The strong co-variation between He and Sr isotopes displays a clear geographic trend as the radiogenic He and Sr generally increase northward from Eolian islands to Latium. The startlingly coherent He-Sr isotope relationship can be most simply explained as a mix between asthenosphere mantle with young HIMU affinities (as previously identified by Sr-Pb isotopes), and a radiogenic end-member, which is best explained as resulting from mantle enriched by subduction of the Ionian/Adriatic plate. The most primitive signatures in He and Sr isotopes are found at Alicudi (Eolian Islands), Ustica and Etna.

Radiogenic He in the mantle can be generated by direct addition of crustal He by fluids dehydrated from the subducting crust or by post-metasomatic radiogenic He ingrowth from U and Th decay in the mantle wedge. Only if the He concentration of the asthenospheric mantle is two orders of magnitude lower than MORB-source mantle is slab-derived radiogenic He unnecessary to explain the observed He-Sr isotope correlation. If the Sr isotopic composition of the enriched mantle is 0.715-0.72, as suggested by the geochemistry of Tuscan magmatism, the linear He-Sr isotope correlation cannot be a simple mixing relationship. The increase in the $(He/Sr)_{EM}/(He/Sr)_{yHIMU}$ with increasing $^{87}Sr/^{86}Sr$ required to explain the data can be accommodated, or volatile depletion prior to enrichment.

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HIMU-OIB magmatism in subduction zones: An example from the Italian south-eastern Alps

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The geochemical features of the SE Alps volcanics (SEAV, Tertiary age) are comparable to the numerous volcanic eruptions of Tertiary-Quaternary age from the western Mediterranean area for which a plume-related origin has been assessed, and contrast to the widespread calc-alkaline magmatism which developed northwestwards along the Periadriatic Lineament.

The occurrence of a HIMU component, which is the hallmark of hotspot basalts, in a collision environment (the Tertiary convergence of Europe and Africa plates) is here explained in terms of slab breakoff. Evidence for the European slab breakoff comes from seismic tomography which shows that the present-day fast velocity material, interpreted as the European slab subducted below the Alpine chain, is shorter by about 300 km than the total length of the subducted slab estimated by paleotectonic reconstructions.

Other piece of evidence comes from a kinematical model consisting in evaluating the time evolution of buoyancy of oceanic and continental lithosphere during subduction with both constant and time-varying convergence rates. If the subducted slab intercepts a rising plume from below the corresponding part of the slab is heated and therefore softened. The softening effect is enhanced if the slab includes continental material. The combination of changes in negative buoyancy caused by continental subduction, and softening of a part of the slab caused by slab-plume interaction, may act as a regulator for the time of slab breakoff and consequently for the time and type variations of magmatism in the overriding lithosphere above a subduction zone. In the Alpine region, we assume that the plume material interacted with the subducting slab causing its heating, softening, and finally its detachment. Ensuing upwelling of plume material through the resulting plate window is supposed to be the responsible for partial melting in the lithospheric mantle wedge and/or decompression melting of the ascending plume material.

On the basis of geological, geophysical and geochemical data we conclude that both magmatic suites originated from a common and primary deep mantle plume the root of which was located beneath the Cape Verde-Madeira-Canary Islands region, while the head was dragged and frayed by the northeastward motion of the Eurasian plate.