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Enigmatic Pb-isotope arrays (Galerays): A genetic approach to mantle taxonomy

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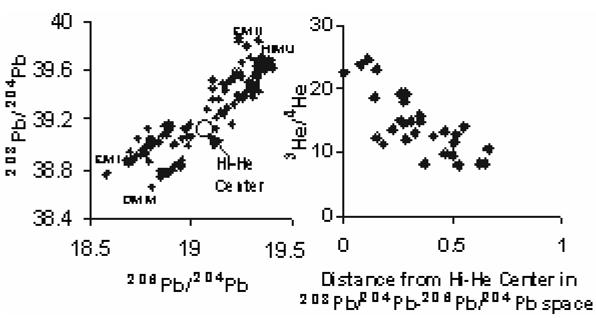
Precise Pb-isotope compositions of Samoan basalts exhibit 4 linear arrays in $^{208}Pb/^{204}Pb$ – $^{206}Pb/^{204}Pb$ isotope space. The 4 arrays intersect at a common point, forming the shape of a "chromosome" with 4 arms (Left Fig.). This point marks the most primitive, undegassed mantle source in Samoa, previously known as PHEM (Farley, Natland and Craig, 1982). $^3He/^4He$ values decrease monotonically along the arrays away from the point of intersection in $^{208}Pb/^{204}Pb$ – $^{206}Pb/^{204}Pb$ isotope space (Right Fig.). The isotope topology created by He and Pb isotopes suggests that the 4 arrays are binary mixtures of PHEM with 4 lower $^3He/^4He$ components: DMM, HIMU, EMII and a 4th component (EMI?). The trace element patterns of each arm of the Pb-isotope chromosome exhibit the characteristics that we associate with the 4 mantle endmembers. The EMI and EMII arrays are the most trace element enriched. The highest (U+Th)/Pb values are located in the HIMU array. The DMM array is neither trace element enriched nor elevated in (U+Th)/Pb.



We observe a similar isotope topology in the Pb-isotope arrays from the HSDP 2 drill core (Eisele, Abouchami, Galer and Hofmann, 2003). In $^{208}Pb/^{204}Pb$ – $^{206}Pb/^{204}Pb$ isotope space, $^3He/^4He$ values of the DSDP-2 lavas decrease monotonically away from the highest $^3He/^4He$ value reported.

The undegassed components in Samoa and Hawaii play a central role in defining the isotope topology of their respective mantle reservoirs. If the observed isotope topology of He and Pb in Samoa and Hawaii is a general feature in the mantle, it will have important implications for determining the origin and evolution of the undegassed component and its relationship with the degassed components.

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Deep subduction of the mantle wedge and the origin of OIB

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Recycled oceanic lithosphere is believed to be an important source for oceanic basalts, potentially as ascending mantle plumes. Various chemical and isotopic features of oceanic basalts are consistent with recycled, hydrothermally-affected, oceanic lithosphere (basaltic crust + gabbros) and pelagic sediments contributing to volcanism. However, little attention has been paid to the ultimate fate of the subduction mantle wedge, which will be variably depleted and enriched due to extraction of arc magmas and introduction of fluids and melts from the dehydrating oceanic lithosphere and subducted sediment. Many of the chemical effects attributed to the oceanic lithosphere could, indeed, be features of residue mantle wedge material where the introduction of fluids can affect oxygen (and other light stable) isotope ratios, significantly fractionate Th-U-Pb and subsequently generate fine-scale Pb isotopic hetereogeneities, and introduce Sr excesses. Moreover, if the wedge material is subducted into the deep mantle, remains isolated, and then ascends as a mantle plume it might be expected to have generally less depleted Hf-Nd isotope ratios than the (older) upper mantle tapped by mid-ocean ridges. Given the possibility that the mantle wedge may be an important source for oceanic basalts and mantle plumes, we have modeled the subduction system with a 2-D finite-element code to explore: (1) how much wedge material is subducted with the downgoing slab, and (2) how long such material remains with the slab. We tested three different viscosity laws - pure temperature dependence, temperature and stress dependence, and a low-viscosity mantle wedge due to the presence of volatiles. While the various rheological laws produce different flow field, both on the large scale and especially within the mantle wedge, the results concerning the subduction of mantle wedge material are surprisingly robust. The thickness of the subducted layer of material that has passed through the mantle wedge ranges from 25km at a subduction rate of 10cm/yr to 35km at 2.5cm/yr, and is largely independent of the rheology. The subducted slab can only be followed over some 20-1000 Ma until it leaves the model domain at 660km depth, but at this point the mantle wedge layer always continues to be an integral part of the slab. With the mantle wedge layer constituting 20% of the entire slab, we suggest that recycled mantle wedge material may be a hitherto unrecognised source for oceanic basalts.