

Modelling the joint rare gas, solid-isotope, and trace element evolution of a multi-component mantle

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We will discuss our recent progress in modelling the mantle's geochemical evolution within a paradigm of a multicomponent mantle in which mantle components have always been created and modified by present-day geological processes, but at much faster rates during the first ~2Ga of earth evolution. In this scenario, upwelling mantle is first sampled by relatively deep OIB/EMORB melt extraction that creates both OIB/EMORB melts and the residues to this melt extraction which, being buoyant, pond beneath the oceanic lithosphere until they further ascend and melt beneath a mid-ocean ridge to form MORB. Both MORB and OIB/EMORB melt extraction processes can selectively melt mantle component lithologies in chemical isolation from each other, consistent with recent melt inclusion and Re/Os observations. Important mixing can occur, but only by the pooling of the melts created within a melting column, not by diffusive homogenization within the source itself.

Here we present an overview of the results of our recent forward-model exploration of the mantle's chemical evolution within this scenario. These models mainly differ from our previously published work (Phipps Morgan and Morgan, 1999; Phipps Morgan, 1999) in including more rare-gas isotopes (Xe, Ar, Ne, He), in tracking the time-dependent evolution of recycled and primitive components (i.e. we track the individual mantle time-evolution of 'each piece' of recycled material through two stages of subsequent melting), and in incorporating the chemical consequences of slab melting and lithosphere serpentinization and deserpentinization processes at a subduction zone.

We demonstrate that many apparent paradoxes in other scenarios for the mantle's chemical evolution do not exist in this alternative scenario. In particular, the helium-heatflow, the Hf/Nd, and the several Pb-paradoxes are easy to reconcile within this paradigm of whole mantle convection in which the MORB source is a recently-derived 'complement' to recent OIB/EMORB melt extraction. Likewise, recent melt-inclusion observations in OIB and MORB exhibit the range of isotopic and trace-element heterogeneity implied by these model calculations.

(U+Th)/Noble gas dating of fluorite

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An exhaustive revision of bibliographical data of fluorite for the Ph.D. thesis of the first author indicates that many fluorites contain appreciable (i.e. measurable) amounts of U+Th. The exact location of this U+Th has not been constrained by most authors, but our current study of deposits in southern Mexico indicates unambiguously that most of the U+Th is located in minute inclusions of uraninite and other uranium-bearing minerals. Most U+Th concentrations are in the range 1-100 µg/g. Dating of fluorite has been possible by the Sm/Nd method, but many fluorites do not contain enough lanthanides for accurate dating by this method. On the other hand, production of noble gases by different interactions of the U+Th disintegration chain can range from abundant to very low, but it is usually measurable by noble gas mass spectrometry. These products can be divided into three categories: a) *radiogenic* α production from the U+Th series, i.e. the (U+Th)/⁴He method; b) *fissiogenic* production of Kr and Xe from ²³⁸U; c) *nucleogenic* production of ²²Ne from ¹⁹F after a (α ,n) β^+ reaction. The immense production of ⁴He from (U+Th) is remarkable and can theoretically permit the dating of 1 Ma fluorite with only 0.1 µg/g U. The Kr and Xe can be used to check if ⁴He concentration is concordant with the Kr and Xe age or has been lost. The Xe concentration can be used also as a dating method per se. The nucleogenic ²²Ne is a completely new dating method that takes advantage of the extraordinary abundance of ¹⁹F in fluorite and the lack of the competing ²⁵Mg, another nucleogenic ²²Ne generator. The difficulties encountered during the course of this study are related to three factors: 1) the uncertainty of values for fissiogenic and nucleogenic productions; 2) the diffusivity of noble gases in fluorite, which seems to be comparable or greater than that of apatite and 3) the discrete concentration of U+Th in minute phases and relatively low concentration in the fluorite lattice. The first problem will be solved in the near future with more dating of fluorites from age-constrained deposits. The second problem is unavoidable and is related to lattice diffusion itself, crystal imperfections (stressed also by fission tracks) and thermal history. The last problem is not as serious as supposed if U+Th bearing inclusions are homogeneously distributed and lattice imperfections are not extensive. Despite the problems pointed out, noble gas fluorite ages are probably comparable to fission track ages in apatite, and in favourable cases can give the true age of fluorite crystal growth. The possibility of a cross check of three geochronometers is an encouraging feature. The most suitable fluorites seem to be those moderately rich in U+Th (units to tens of µg/g), with intermediate colour hue, well crystallised, and millimeter sized.