

The Earth as a Planet: The Re-Os Isotope Evolution of Bulk Silicate Earth. A.J.V.Riches^{1,†}, N.W.Rogers¹, B.L.A.Charlier¹, J-L Bodinier², ¹ The Department of Earth and Environmental Sciences, The Open University, United Kingdom, ² Laboratoire de Tectonophysique, ISTEEM, Université Montpellier 2, France, [†] Present address: Planetary Geoscience Institute, University of Tennessee, Knoxville, TN

Introduction: The terrestrial planet, Earth, presents us with an opportunity to study the mechanisms that influence and perhaps characterize other bodies in our Solar system. Scientific understanding of the internal structure, composition and evolution of large terrestrial bodies is influenced by our knowledge of the processes which operate on Earth.

Earth's primitive mantle, or bulk silicate Earth (BSE), is the composition of Earth's mantle after core formation, but before the extraction of continental crust. An accurate and precise model of the chemical and isotopic composition of Earth can potentially provide information pertinent to fundamental aspects influencing the evolution of Earth; these include accretion processes during planetary formation and global-scale differentiation processes. In addition, a realistic model of BSE can also constrain the composition of present day reservoirs in the silicate Earth; for example the upper mantle and crust [1].

The Study Area: Studies of the peridotite massifs of the Eastern Pyrenees have made a significant contribution to our understanding of mantle composition and evolution on Earth. The Lherz peridotite body is considered by many as the type locality for mantle lherzolite, yet a number of competing petrogenetic models exist to explain the history of this massif. In particular, adjacent harzburgites and lherzolites have many contrasting interpretations that include; 1) variable extents of melt extraction from an original lherzolite [2,3] or, 2) refertilisation of a primary harzburgite by basaltic melt [4,5].

This study presents a comprehensive geochemical investigation of adjacent harzburgite and lherzolite bodies on the Lherz massif to determine which of these models is correct.

Field Relationships: The Lherz peridotite massif contains lherzolite with subordinate websterite-bands and tabular harzburgite bodies that form a layered sequence with penetrative foliation [4,5,6]. Field relationships indicate that this layering is the oldest feature on the massif and that it is cross-cut by two later and distinct magmatic intrusions (figure 1). Cross-cutting magmatic features include; 1) layered anhydrous pyroxenites and, 2) amphibole-pyroxenite and hornblende veins/dykes. Two sample sites (A and B), provide material across harzburgite-lherzolite contacts. Site A corresponds to section 2 of [4]. The contact between harzburgites and lherzolites is, in all observed cases, a

sharp and clearly defined compositional boundary. Both sample sites are distant from visibly exposed cross-cutting veins and dykes, but detailed petrographic observations indicate that narrow (<15mm) amphibole-pyroxenite veinlets occur along the compositional boundary between harzburgite and lherzolite bodies at site A. The presence of these late-stage melts at site A modifies incompatible element contents in a number of peridotite samples at this locality.

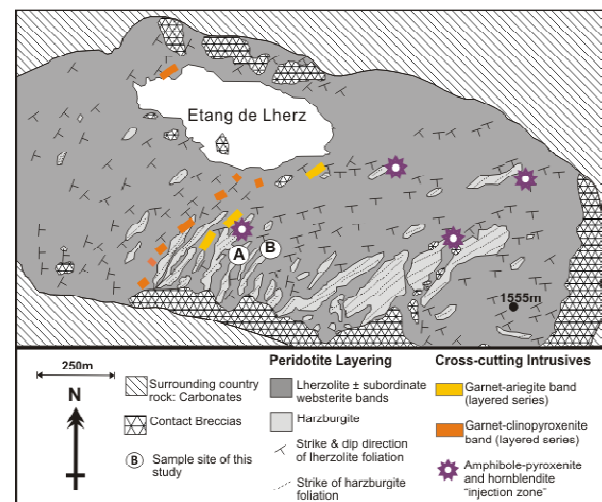


Figure 1: Geological Map of The Lherz Peridotite, after [4,6]

Results and Petrogenetic Interpretations: Major element compositions of all harzburgite samples provide evidence of a high degree of melt extraction at depths ≥ 2 GPa. In contrast to harzburgites, lherzolites may potentially result from small degrees of melt extraction. In this study, models of melt extraction cannot explain major element contents in lherzolites, nor do these lherzolites result from the addition of basaltic melt to residual harzburgites during the Variscan, instead lherzolites are interpreted as the products of pyroxene segregation.

Previous studies of several peridotite bodies within the Eastern Pyrenees group show that whole rock osmium contents and isotope values correlate well with major element contents and Mg#, whilst Re contents and isotope ratios may record small perturbations that hinder the determination of a reliable Re-Os isochron [3,7]. These authors report model ages of ~ 1.8 -2Ga that they link to melt extraction processes and Nd model ages in local crustal rocks [3,7,8].

This study presents new whole rock Re-Os isotope data for the Lherz peridotite. $^{187}\text{Os}/^{188}\text{Os}$ values define a broad positive correlation with $^{187}\text{Re}/^{188}\text{Os}$ (figure 2), indices of melt depletion (Al_2O_3 and S), and indicators of mechanical segregation (MgO/SiO_2). $^{187}\text{Os}/^{188}\text{Os}$ and $1/\text{Os}$ (ppt^{-1}) values cannot be explained by mixing processes, and instead reflect a range of time-integrated Re/Os ratios in whole rocks. This new evidence improves our understanding of the relationship between whole rock major element contents and osmium isotope ratios suggesting that the peridotites on the Lherz massif experienced an ancient melt extraction event linked in time with pyroxene segregation. Re-Os isotope systematics alone define an age of $\sim 1.7\text{Ga}$ and yield an initial osmium isotope value of ~ 0.117 .

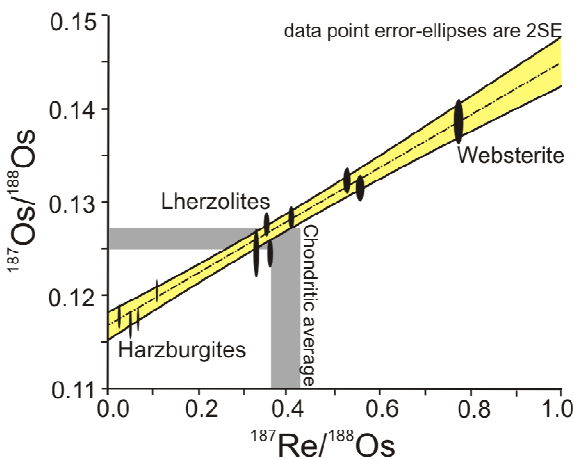


Figure 2: Isochron plot of the Re-Os isotope systematics in the Lherz peridotite body.

It is clear that mantle peridotites may remain isolated from Earth's convecting mantle for prolonged time periods and that a number of peridotite suites in both oceanic and continental settings preserve heterogeneities of similar age [9,10,11].

The Re-Os isotope Evolution of Bulk Silicate Earth: The Re-Os isotope evolution of Earth's mantle can be constrained by samples that preserve a signature of Earth's mantle after the core formation, but before the extraction of continental crust, in this context studies of global peridotite suites often focus on obtaining an isochron of age significance. With this approach, the initial value of $^{187}\text{Os}/^{188}\text{Os}$ and the isochron age can be used to constrain the composition of the mantle source that may be considered pristine and therefore relates directly to the composition of BSE at a given point in time. Alternatively, samples with major and trace element compositions similar to estimates of BSE [1] may be of relatively pristine character in terms of Os-isotope composition and may provide a

direct estimate of present day BSE $^{187}\text{Os}/^{188}\text{Os}$ composition [12,13].

Re, Os and highly siderophile elements (HSE) occur at $\sim 1\%$ chondritic abundances and in chondritic relative proportions in Earth's mantle (e.g. [14]), this is inconsistent with experimental knowledge of silicate/metal partitioning for PGE and has led to the proposal of the addition of HSEs during a "late veneer" following Earth's core formation [15].

Summary: This study provides an estimate of BSE Re-Os isotope evolution that is derived from a combination of published data with the osmium isotope systematics determined here. A broad linear relationship relates available reference points, indicating a common Re-Os component in the mantle source across several Proterozoic mantle domains on Earth. These reference points may reflect the composition of relatively pristine mantle and thus provide an osmium isotope evolution line for BSE. This work provides an estimate of the present BSE Re-Os isotope composition that is broadly chondritic, with a $^{187}\text{Os}/^{188}\text{Os}$ value of ~ 0.129 . The calculated value and range of BSE Re/Os isotope composition is within error of the estimate given by [12,13] and the average value(s) of chondritic meteorites [16].

References: [1] McDonough and Sun, (1995) *Chem. Geol.* 120, 223-253. [2] Bodinier et al., (1988) *GCA*, 52, 2893-2907. [3] Burnham et al., (1998) *GCA*, 62(13), 2293-2310. [4] Le Roux et al., (2007) *EPSL*, 259(3-4), 599-612. [5] Le Roux et al., (2008) *EPSL*, 274(1-3), 401-413. [6] Conqu r  and Fabri s, (1984) *In Kimberlites II: The Mantle and Crust-Mantle Relationships*. [7] Reisberg and Lorand (1995) *Nature*, 376, 493-571. [8] Liew and Hofmann, (1988) *CM,P* 98(2), 129-138 [9] Harvey et al., (2006) *EPSL*, 244, 606-621. [10] Liu et al, (2008), *Nature*, 452, 311-316. [11] Reisberg et al., (1991) *EPSL*, 105, 196-213 [12] Meisel et al, (1996) *Nature*, 301, 229-231. [13] Meisel et al, (2001) *GCA*, 65(8), 1311-132. [14] Lorand et al., (1999) *JOP*, 40(6), 957-981. [15] Chou, (1978) *In the 9th LPSC abstracts* [16] Walker et al., (2002) *GCA*, 66(23), 4187-4201.