Re–Os isotope evidence for a mid-Archaean age of diamondiferous eclogite xenoliths from the Udachnaya kimberlite, Siberia : constraints on eclogite petrogenesis. and Archaean tectonics

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Introduction

The origin and significance of mantle-derived eclogite xenoliths in kimberlites remains a controversial topic in mantle geochemistry. In particular, eclogite xenoliths from Siberia have been proposed to represent vestiges of differentiation processes that occurred in the early Earth, prior to 4 Ga ago (Snyder, *et al.*, 1993) while other workers have proposed an origin as the products of oceanic crustal recycling in the Archaean (Jerde *et al.*, 1993; Jacob *et al.*, in press; Ireland *et al.*, submitted). A major difficulty with determining the petrogenetic history of Siberian eclogites is a lack of definitive age constraints. Sm/Nd systematics in these rocks are highly complex and difficult to interpret). With this in mind we have used the Re-Os isotope system to constrain the age of a well-characterised suite of eclogites from the Udachnaya kimberlite pipe, in Yakutia, Siberia.

Seven eclogite xenoliths from the Undachnaya kimberlite pipe were studied, of which 6 were known to contain diamond, 5 of the samples were bi-mineralic but two (U1/79 and U25/84) contain kyanite. Wholerock powders were digested in Carius tubes (Shirey and Walker, 1994) and analysed for Re-Os isotopes by NTIMS.

Re-Os systematics

Re and Os contents of the eclogite suite vary from 0.087 to 1.6 ppb and 0.028 to 0.346 ppb respectively, within the range of basaltic magmas. $^{187}Re/^{188}Os$ vary from ~ 12 to >200 and span the range of oceanic basalts. $^{187}Os/^{188}Os$ for the Udachnaya eclogites varies from 0.8296 to 9.808 (γ_{Os} 503 to 6790 at the time of kimberlite eruption; 350 Ma).

Age constraints

Calculated whole-rock Nd_{CHUR} model ages in the Udachnaya eclogites vary from 0.8 to 3.0 Ga. Snyder *et al.*, (1993) propose that the complex Sm-Nd isotope systematics in these and other Siberian eclogites indicate protolith differentiation very early in Earth history (>4 Ga) followed by subsequent (Early Proterozoic) eclogite crystallisation from at least two different sources. The highly radiogenic nature of the eclogites require longterm isolation from the convecting mantle in high Re/Os environments. Re-Os model ages for the eclogite suite vary from 1.2 Ga to greater than the age of the Earth. The two most aberrant samples are both kyanite-bearing (1.2 and 6.7 Ga model ages). Model ages for the remaining samples group between 2.8 and 3.5 Ga with 4 in the range 3.2 to 3.5 Ga. If the kyanite-free samples are plotted on a Re-Os isochron diagram they define an array with a slope equivalent to an 'age' of 2.94 ± 0.38 Ga. and $\gamma_{Os_i} = 100 \pm 11$. Despite the uncertainty in the initial Os isotopic composition this data and the Re-Os model ages clearly indicate a Late to Mid-Archaean age for the eclogites. A Mid-Archaean formation age for the Udachnaya eclogites agrees well with the oldest Re depletion model age of 3.2 ± 0.3 Ga for a suite of peridotite xenoliths from Udachnaya. These data, together with the diamondiferous nature of the eclogites indicates the presence of a thick (>150 km) lithospheric mantle beneath this part of the

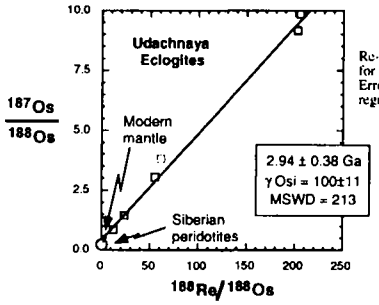

Fig. 1
Re-Os isochron diagram for kyanite-free eclogites. Error on age is 2s error on regression * √MSWD.

FIG. 1. Re–Os isochron diagram for kyanite-free eclogites. Error on age is 2s error on regression $^{*}\sqrt{}$MSWD.

Siberian craton by the Mid-Archaean.

Origin

The large fractionation of Re from Os during mantle melting will dominate the eclogite Re-Os model ages. The spread in model ages of the kyanite-free samples overlaps the Re-Os isochron age but there is not sufficient precision to say whether the ages represent the same event, e.g., mantle melting, or separate events, e.g., mantle melting to form oceanic crust followed by subduction. A subducted origin for the Udachnaya eclogites is neither at variance with, nor explicitly required by the Re-Os data. Trace elements, oxygen isotopes and phase equilibria strongly implicate a subducted origin for *some* Udachnaya eclogites (Jerde *et al.*, 1993; Jacob *et al.*, in press; Ireland *et al.*, submitted). The very large fractionation of Re from Os during formation of oceanic crust means that this event will dominate the Os isotope evolution of the rock and its model age will be dominated by the parent-daughter fractionation produced at this time. If little Re-Os fractionation takes place during subduction, or the time from oceanic crust generation to subduction is very short (e.g., < 50 Ma), as may be likely for the Archaean, then the isochron age will closely agree with the model ages. At present we cannot differentiate between these alternatives and it may be that the eclogites have a variety of origins including derivation from subducted oceanic crustal protoliths (Jerde *et al.*, 1993). The different behaviour of the kyanite-bearing samples may be due to open system behaviour during kyanite exsolution from a hyperaluminous pyroxene.

Eclogites with extremely radiogenic Os and peridotites with very unradiogenic Os isotope compositions document the ancient (Archaean) origin and extreme Os isotopic diversity of the Siberian lithospheric mantle. A Mid-Archaean age for some eclogites that appear to be high-pressure melting residues of subducted oceanic crust suggests that deep subduction was taking place in the Archaean.

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