The mantle lithosphere beneath the Canadian Cordillera: constraints from Re-Os, Sm-Nd and Lu-Hf systematics of xenoliths

A. K. Peslier
L. Reisberg
J. Ludden
C.R.P.G.-C.N.R.S., 54501 Vandoeuvre-lès-Nancy, France

D. Francis
Earth and Planetary Sciences Department, McGill University, H3A 2A7 Montreal, Quebec, Canada

C. Chauvel
Géosciences, Université Rennes 1, 35042 Rennes, France

The Canadian Cordillera spans more than 1000 km north-south along the edge of the North American craton and includes more than a dozen Late-Tertiary to Recent volcanic centers containing abundant fresh mantle xenoliths. This orogenic belt is composed of numerous tectonostratigraphic terranes often with oceanic-island arc affinities, that were accreted to the stable margin of North America from the Jurassic to the early Tertiary. Mantle xenolith samples were collected from alkaline volcanic centers in several of these terranes. The modal composition of these peridotites define two main types of suites: (1) bimodal suites comprising both lherzolites and harzburgites; (2) unimodal suites composed almost solely of lherzolites, with only minor harzburgites. The bimodal suites are situated above a region of anomalous hot mantle detected by teleseismic studies (Frederiksen *et al.*, 1998). Major element trends of all peridotites reflect various degrees of partial melting. The harzburgite clinopyroxenes of the bimodal suites are more enriched in incompatible elements than are those of the lherzolites (Shi *et al.*, 1997).

The great advantage of the Re-Os isotopic system over the other isotopic systems used to study mantle rocks is that Os behaves compatibly and Re moderately incompatibly during melting processes. Consequently, the Os budget of a mantle rock is generally assumed to be insensitive to percolating melts and fluids, in contrast to the behaviour of other isotopic systems such as Rb-Sr, Pb-Pb and Sm-Nd. The Re-Os isotopic system is thus a powerful tool for constraining the timing of the lithospheric mantle evolution. We have thus used the Re-Os system to constrain the age of the lithospheric mantle beneath the accreted terrains of the Canadian Cordillera, and to examine its relationship with the overlying crust.

Os isotopes provide evidence for a striking difference between lherzolite and harzburgite xenoliths of the Canadian Cordillera. The $^{187}Os/^{188}Os$ ratios of the lherzolites show a regional correlation with Al_2O_3 and heavy rare earth elements (*HREE*) which appears to be independent of tectonic terrane (Fig. 1). This correlation probably reflects Re/Os fractionation during various degrees of mantle melting under the Canadian Cordillera, followed by a long period of radiogenic ingrowth. The slope and intercept of the correlation (Reisberg and Lorand, 1995) suggest a lithospheric mantle model age on the order of 1 Ga. If we group the samples on the basis of orogenic belt, tectonic terrane or Northern versus Southern Cordillera region, the Os isotopic ratio-Al_2O_3 or *HREE* correlations obtained still imply an age of 1 Ga. In contrast, crustal Nd model ages on sediments and granitoids from tectonic terranes which formed far away from any North American cratonic influence, are less than 1 Ga (Patchett *et al.*, 1997). This suggest mantle-crust decoupling during Canadian Cordillera evolution, i.e. 1) the mantle underlying the terranes does not represent the mantle from which those terranes were derived; 2) while accreting to the margin of the North American craton, the tectonic terranes did not "carry along" their mantle roots; 3) Proterozoic mantle extends laterally far beyond the limits of the cratonic crustal rocks.

Harzburgite Os isotopic ratios plot markedly above the regional correlation of the lherzolites and appear to record a younger magmatic event coupled with the ingress of low-Os metasomatic fluids/melts. These fluids enriched the incompatible trace element content of these refractory rocks (Shi *et al.*, 1997). .These fluids/melts could either be subduction

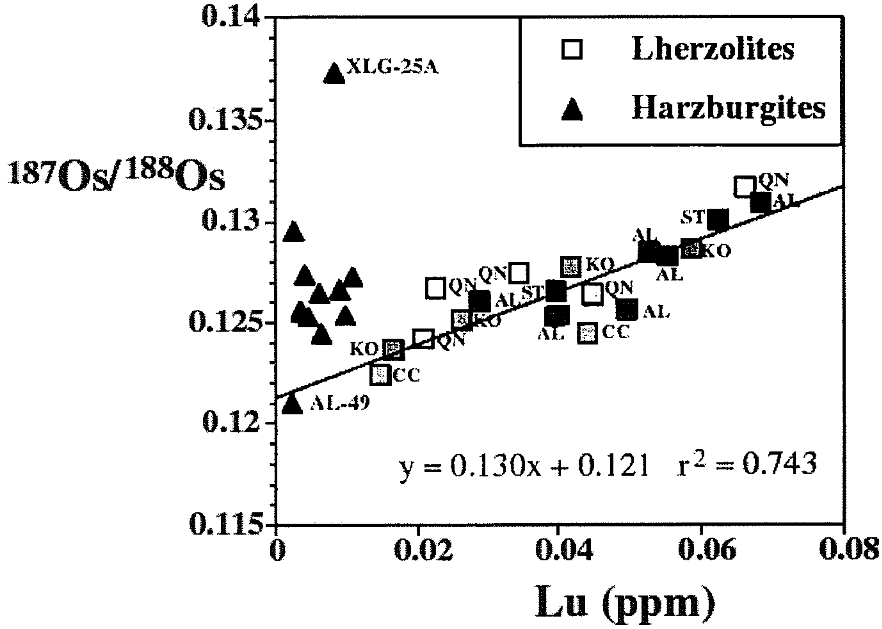

FIG. 1. Os isotopic ratios *vs* Lu. KO, QN, ST, CC = tectonic terranes; AL = xenolith site AL, situated on the Coast Belt.

related, such as found elsewhere (Brandon *et al.*, 1996) or come from the asthenosphere. The correspondence between geophysical and petrological observations in the northern part of the Canadian Cordillera favours a model in which the genesis of the bimodal suites is linked to the presence of the asthenospheric thermal anomaly (Shi *et al.*, 1997). Our Os data indicate, however, that the rare harzburgites from unimodal suites located far from the mantle anomaly, record similar Re-Os systematics to those associated with the anomaly. The increased number of harzburgite xenoliths at the sites overlying the anomaly suggest that the phenomenon responsible for harzburgite formation was more intense above the anomaly than elsewhere in the Canadian Cordillera.

Another isotopic system of great interest in mantle studies is Lu-Hf. Because of the influence of garnet in Lu-Hf fractionation, the Lu-Hf isotopic system can serve as a depth monitor for igneous processes. Until recently, analytical dificulties have severely limited the application of the Lu-Hf system to mantle rocks (Salters and Zindler, 1995). Lu-Hf and Sm-Nd analyses of whole-rocks and clinopyroxene separates are currently under way on xenoliths from the bimodal suite of the Alligator Lake site. Lu-Hf data potentially could distinguish between a shallow melt removal for the Canadian Cordillera lithosphere samples and more deep-seated melt removal from asthenospheric mantle. The Re-Os, the Sm-Nd and the Lu-Hf isotopic systems will allow a better control on the timing, the metasomatic processes and the original depth respectively of these xenoliths . This will allow better constraints to be placed on the geochemical characteristics and mechanisms of formation of the lithospheric mantle and its relation to the overlying crust.

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