Using U-Pb and Lu-Hf Isotopes in Zircon to Constrain the Tectonic Provenance of the Himalayan Metamorphic Core, Garhwal Region, India

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We report the U-Pb and Lu-Hf isotopes in zircon from the highly metamorphosed core of the Himalaya in the Garhwal Region of India: the ortho- and paragneiss units of the Greater Himalayan Sequence (oGHS and pGHS, respectively) and the Lesser Himalayan Crystalline Sequence (LHCS). Our data confirm the geochemical distinction of the older LHCS and the younger GHS. Zircons from the Paleoproterozoic metasediments of the LHCS (n=92) yield U-Pb crystallization ages from 1614±14 Ma to 2679±14 Ma with a single distinct peak at 1870 Ma. εHf values from zircon in the LHCS (n=24) range from 1 to -8. Zircons from the Neoproterozoic metasediments of the pGHS (n=146) yield U-Pb crystallization ages from 481±10 Ma to 2560±8 Ma with a single distinct peak at 860 Ma. εHf values from zircon in the metasediments of the pGHS (n=43) range from 13 to -21. Zircons from the oGHS (n=139) yield U-Pb crystallization ages from 416±2 Ma to 2740±2 Ma with a single distinct peak at 472 Ma. These zircons often exhibited older inherited cores ranging from ~800 Ma to ~2740 Ma with Cambro-Ordovician rims (416 Ma to 510 Ma). εHf values from zircon in the oGHS (n=22) have two distinct modes: the inherited zircon cores have similar values to the ~860 Ma zircons from the pGHS (13 to -21), while the ~480 Ma rims range from -7 to -11.

Assuming the deposition of the pGHS was synchronous across the northern margin of India circa 800-480 Ma (Myrow et al., 2010) we compare our U-Pb data from the Garhwal region together with a compiled dataset of U-Pb ages from the literature to the pGHS in Nepal and Bhutan (data compiled from Gehrels et al., in review; McQuarrie et al., 2008; Long et al., 2010). The detrital zircon U-Pb age spectra from the pGHS in various parts of the range show significant variation, which indicates varying provenance for the various regions of deposition (Figure 1).

To further characterise the potential source regions from which the metasediments were initially derived we compare the U-Pb and Lu-Hf data from the Garhwal region to various Gondwana crustal terranes (Figure 2) using the Gondwana reconstructions of Myrow et al. (2010) and Torsvik and Cocks (2009). Using the compiled U-Pb and Lu-Hf data, the εHf values of the LHCS overlap entirely with those of the Aravalli shield of India (Kaur et al., 2011) and partially with those of the Yilgarn Craton of Australia (Griffin et al., 2004). The most juvenile εHf values of the pGHS overlap with the Arabian Nubian Shield (ANS) in Israel (Morag et al., 2011); however, the ANS in Israel is associated with island arc volcanism with little crustal contamination at ~800 Ma, while the detritus from the pGHS have an arc signature with significant crustal contamination ~860 Ma. Other older and younger Gondwana sources (older: Albany Fraser, Eastern Ghats, Prince Charles Mountains; younger: Delamerian, Ross, Kuunga, and East African orogenies) have similar Hf isotopic signatures but do not have overlapping ages (Griffin et al., 2004; Flowerdew et al., 2007; Veevers et al., 2009; Dhuime et al., 2011; Glen et al., 2011; Kirkland et al., 2011). The oGHS have εHf values indicative of a crustal melt sourced from the pGHS. The average $^{176}Hf/^{177}Hf$ evolution trend of the most juvenile and evolved zircons in the pGHS produce match those of the oGHS. Furthermore, the inherited cores of the oGHS zircons have the same U-Pb and Hf values as the pGHS. These evidences indicate the pGHS was a likely source for the oGHS. Low U/Th ratios (<10), magmatic zoning, and euhedral zircons also support an igneous (rather than detrital) source. While the nature of this Cambro-Ordovician igneous event is still poorly understood, it is clear that the Hf isotopes can provide further insight into the petrogenesis of the magmatic rocks associated therewith.

Further Lu-Hf isotopic work is needed both in the detrital rocks as well as the potential source regions to better characterise the source regions and tectonic provenance of the lithotectonic units that make up the Himalayan mountains.

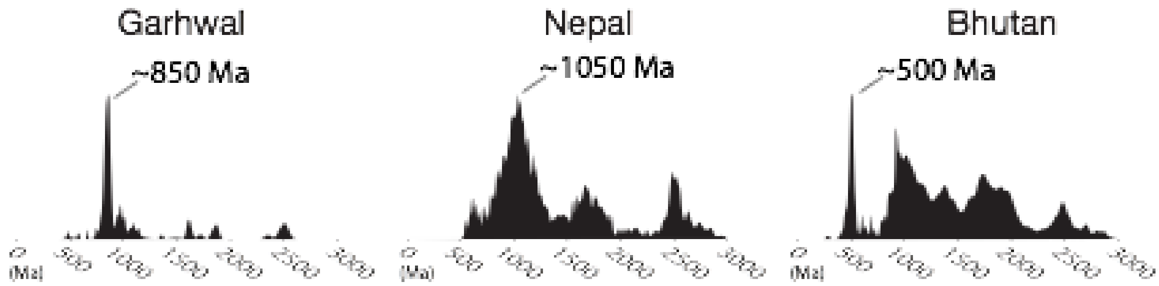

Figure 1. Normalized probability plots for the Greater Himalayan Sequence from the Garhwal region of India, Nepal, and Bhutan (data compiled from Gehrels et al., in review; McQuarrie et al., 2008; Long et al., 2010).

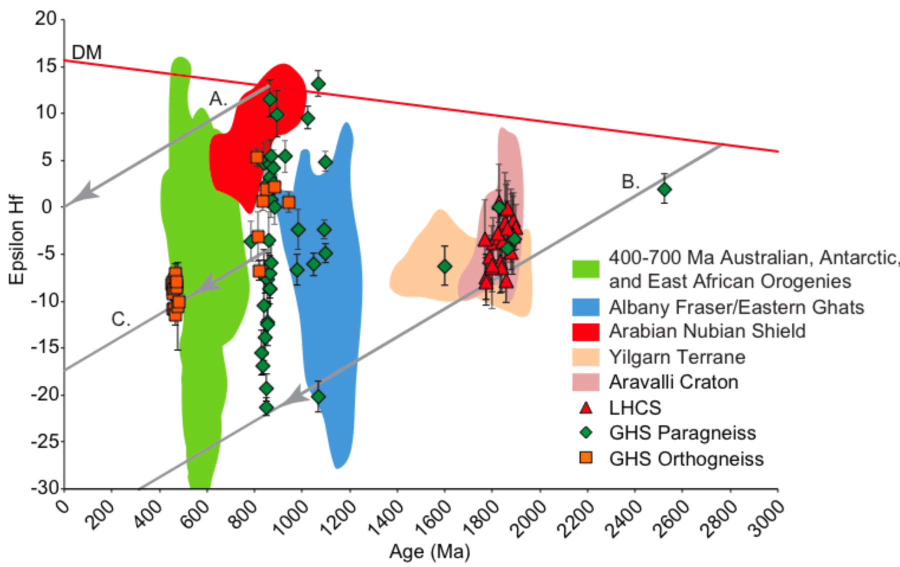

Figure 2. Plots of epsilon Hf vs age for the metamorphic core of the Himalaya and various potential source regions (see text for references). Line A represents the Lu-Hf decay path of the most juvenile zircons from the pGHS; line B represents the decay path of the most evolved pGHS zircons, and line C is the average of paths A and B, which represents a probable decay path of the oGHS.

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