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ZIRCON Lu-Hf SYSTEMATICS: EVIDENCE FOR THE EPISODIC DEVELOPMENT OF ARCHEAN GREENSTONE BELTS P. E. Smith, M. Tatsumoto* and R. M. Farquhar, Dept. of Physics, Geophysics Division, University of Toronto, Canada M5S 1A7; U.S. Geological Survey*, Federal Center, MS 963, P.O. Box 25046, Lakewood, CO 80225

A combined U-Th-Pb and Lu-Hf isotopic study of zircons was undertaken in order to determine the provenance and age of an Archean granite-greenstone terrain and to test the detailed application of the Lu-Hf system in various Archean zircons.

The eastern Wawa subprovince of the Superior province consists of the low grade Michipicoten and Gamitagama greenstone belts and the granitic terrain. Earlier studies have established the structural and stratigraphic relationships of the area (1-4). The adjacent high grade Kapuskasing zone is believed to represent the lower crustal levels to the greenstone belts (5).

The rock units of this area have been the subject of extensive geochronological studies using zircon U-Pb (6, 7) and whole rock U-Th-Pb methods (Smith, et al in prep.). The three volcanic cycles recognized in the area have mean ages of 2748 My (cycle I), 2732 My (cycle II), and 2714 My (cycle III). Syntectonic granitoids which surround the supracrustal rocks date from the cessation of cycle I volcanic rocks, to the time of post-tectonic plutonism dated at 2666 $\pm$ 2 My. The oldest rocks yet dated come from a granite dated at 2888 $\pm$ My which is possibly the basement to the volcanic rocks. Zircon ages from the Kapuskasing zone appear to reflect updating during the regional metamorphism (8).

The Lu, Hf, U and Th contents of zircons from these rocks reveal patterns that may be indicative of their source regions (Fig. 1). Zircons from rocks of granitic composition appear to have distinct enrichments in U and Th relative to zircons from rocks of more intermediate composition. More striking however, is the severe depletion of Lu and Hf from the zircons from the Kapuskasing area. The lowest Hf content measured so far, 1790 ppm, is from zircons from a mafic gneiss. The elemental patterns in the lower crustal zircons suggest that Lu and Hf loss accompanies Pb loss during high grade metamorphism.

The U-Pb age corrected Hf isotopic ratios from the zircons indicate significant long-lived heterogeneity of source regions for the greenstone belts (Fig. 2). Overall the heterogeneity in the ratios may be attributed to three isotopically distinct sources: (1) a high Lu/Hf source, (2) a moderately enriched Lu/Hf source; and (3) a sub-chondritic Lu/Hf source.

The high Lu/Hf source is represented by a sub-volcanic intrusive from cycle II and two tholeiites (whole rock determinations) from the lower stratigraphic levels of cycles I and II. The epsilon Hf values range from +8.7 to +11.6 and the source is believed to represent the depleted mantle.

The second source has epsilon Hf values ranging from +1.4 to +5.9. There is an apparent alignment of dacitic volcanic rocks and their sub-volcanic equivalents from cycles I and II with the tonalitic syntectonic granitoids. It is believed that the source of these rocks was the lower crust and it can be inferred that previous intracrustal differentiation led to a high Lu/Hf lower crustal reservoir. The process which led to the enhanced Lu/Hf ratio was most likely Hf loss as attested to by the Kapuskasing zircons. A greater than chondritic Lu/Hf ratio for the lower crust may explain the apparent non-coherence of initial Nd and initial Hf ratios for an Archean tonalite reported in the literature (9, 10).

The low Lu/Hf source is represented by rhyolites capping the sequences of cycles I and III and by post-tectonic potassic granitoids. Their epsilon Hf values ranging from -1.3 to +1.4, significantly lower than the coeval dacites, are indicative of an upper crustal source.

The Hf isotopic data from the three volcanic cycles indicate that the typical lithological features of a greenstone belt cycle could be accommodated in a crustal growth model that involved decreasing depth of melting in three isotopically distinct reservoirs: mantle, lower crust and upper crust. The model age of the sources given by the intersection of the lower crustal curve with the bulk earth evolution curve (11) is about 2900 My, in good agreement with the zircon U-Pb basement age. This linear array also has a similar intersection age to that of Proterozoic carbonatite complexes studied by Bell et al (12). The general convergence of the other reservoir vectors around this age suggests that mantle depletion, crustal extraction and intracrustal differentiation were all part of the same episodic event. It is also apparent that recycling of older basement was important in the formation of many of the later greenstone belt rocks.

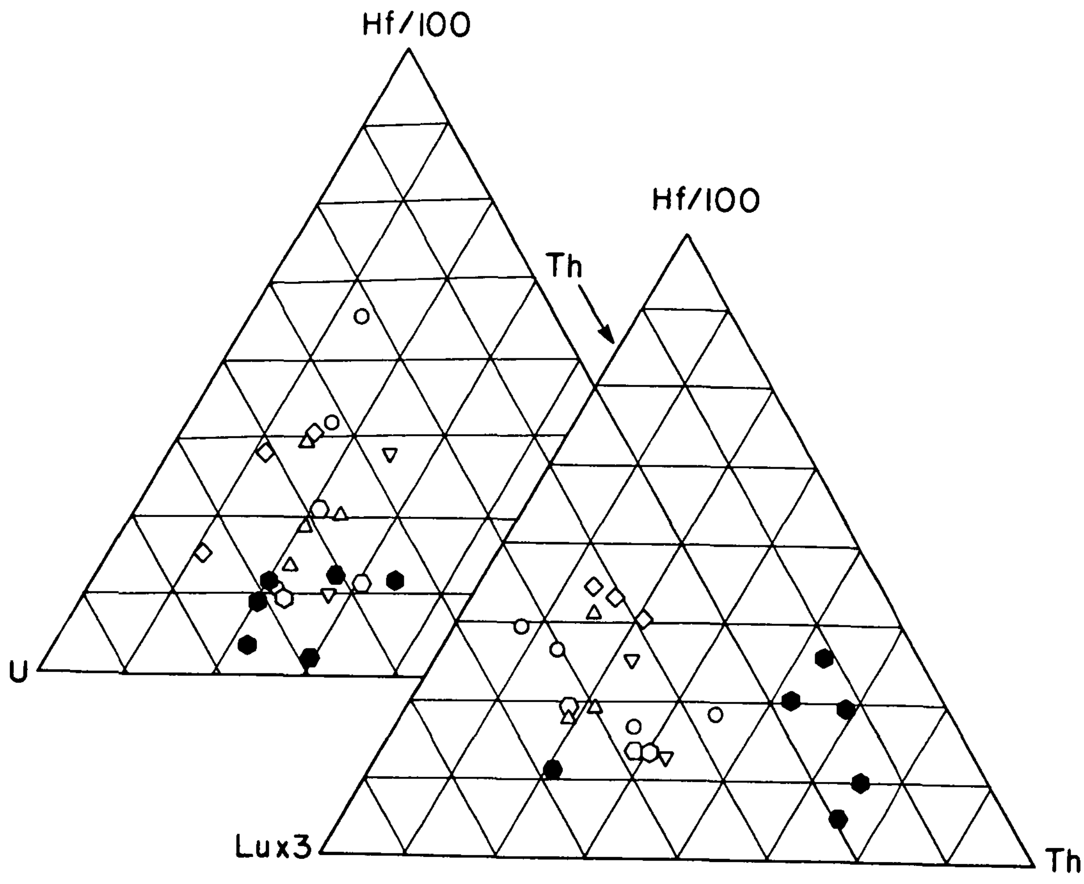

Figure 1

Relative abundances of Lu, Hf, U and Th for eastern Wawa subprovince zircons. Symbols are: △ Dacitic volcanic rocks; ▽ rhyolites; o sub-volcanic granitoids; ◇ syntectonic granitoids; ⬡ post-tectonic granitoids; **◯ basement** granite zircons; ⬢ Kapuskasing zircons; ⬢ conglomerate boulder zircons.

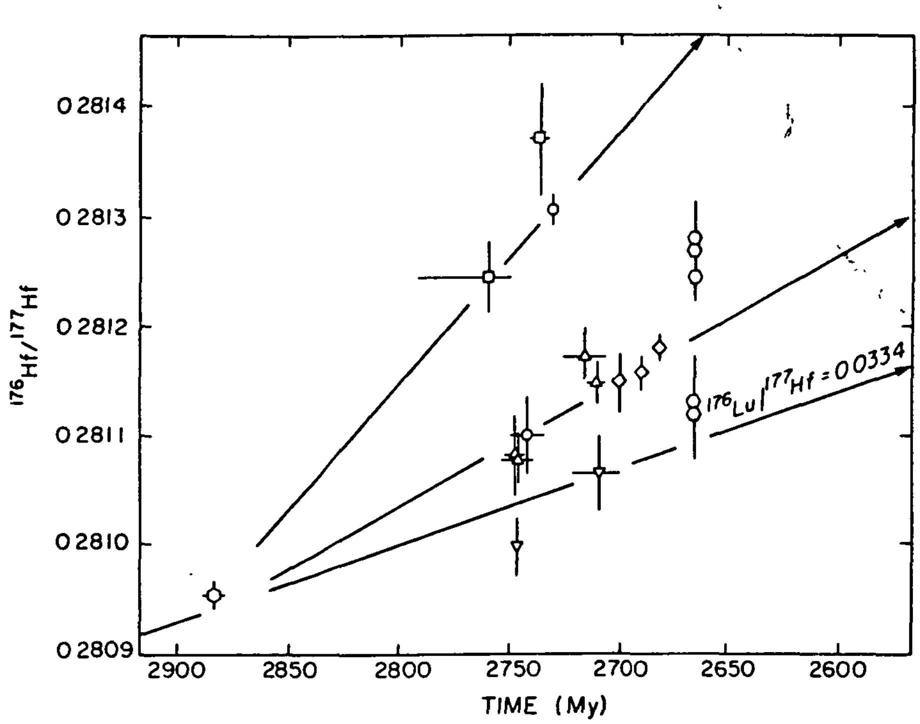

Figure 2

Initial $^{176}Hf/^{177}Hf$ vs T diagram for zircons and whole rocks (□). Symbols as in Figure 1.

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