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Geochemistry and Neodymium and Strontium Isotope Systematics of the 3.7-3.8 Ga Pillow Basalts of the Isua Greenstone Belt, Southwest Greenland

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The 3.7-3.8 Ga Isua greenstone belt, southwest Greenland, consists of the World's oldest known, relatively well-preserved supracrustal lithotectonic assemblages of variably metamorphosed volcanic and sedimentary rocks. The volcanic rocks include pillow basalts and ultramafic units. The sedimentary rocks consist mainly of banded iron formations, cherts, debris flows, conglomerates, and siliciclastic turbidites. On the basis of recent mapping, the northeastern part of the belt is divided into three lithotectonic domains: northwestern, central and southeastern (Appel et al. 1998). Each lithotectonic domain is characterized by different intensity of deformation and lithologic associations.

Pillow basalts from the northwestern and central tectonic domains have well-preserved concentric core structures and rims. The concentric core structures may have resulted from repeated use of pillow tubes by a series of surges of flows, during which the pillows may have partly to completely drained and refilled several times, producing concentric chilled margins. It is likely that the pillow rims represent rapidly quenched volcanic glasses that have undergone alteration and recrystallization during sea floor hydrothermal alteration and subsequent metamorphism. The cores and rims have distinct mineral assemblages and chemical compositions. The cores are composed of hornblende + quartz + epidote + albite + calcite, whereas the rims consist mainly of hornblende + biotite + muscovite + epidote. The rims are enriched in Fe_2O_3, MgO, MnO, K_2O, Rb, Cs, V, Sn, Zn, Ni, Cr, Co, Sc, and Ga relative to the cores, whereas the cores are enriched in SiO_2, Na_2O, Pb, U, Mo, Nb, P, and LREE compared to the rims, suggesting that all these elements were mobile during alteration. In contrast, Al_2O_3, TiO_2, CaO, Th, Zr, Y, and HREE have similar concentrations in both cores and rims, suggesting that these elements were relatively immobile during sea floor alteration and subsequent metamorphism. The relative enrichment and depletion patterns of certain elements in the Isua pillow basalts are comparable to those in Phanerozoic pillow basalts, which have undergone intensive hydrothermal sea floor alteration.

On a primitive mantle-normalized trace element diagram, the Isua pillow basalts display the following significant features: (1) depleted to enriched LREE patterns (La/Sm_{pm}=0.57-1.27); (2) positively fractionated HREE patterns, generating high Gd/Yb_{pm}(1.32-2.28) ratios; (3) depletion of Nb relative to Th and La, resulting in large negative Nb (Nb/Nb*=0.38-0.81) anomalies; and (4) depletion of Ti relative to Sm and Gd, yielding negative Ti anomalies (Ti/Ti*=0.59-0.74). Collectively, the geochemical characteristics of the least altered samples are consistent with a magmatic arc geodynamic origin.

Preliminary results of Nd isotope analysis of the pillow cores suggest that samples from the central tectonic domain have systematically lower ε_{Nd}(T) (-0.34 to -0.64 vs. +0.64 to +6.32) values than their counterparts from the northwestern tectonic domain. In contrast, the ε_{Sr}(T) (+198 to + 595 vs. +191 to +225) values do not show any distinct, systematic variations between the two lithotectonic domains, suggesting that Rb and Sr have been more sensitive to the post-eruption alteration than Sm and Nd. Epsilon values were calculated on the basis of 3800 Ma emplacement age of the volcanic suites. The effects of alteration on the epsilon values is under assessment. In conclusion, the geochemical and isotopic composition of the 3.7-3.8 Ga Isua pillow basalts record a complex history of volcanism, sea floor alteration, and regional metamorphism.

Appel PWU, Fedo CM, Moorbath S & Myers JS, *Terra Nova*, **10**, 57-62, (1998).