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Reactive Melt Flow as the Origin of Residual Mantle Lithologies and Basalt Chemistries in Mid-Ocean Ridges

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A reactive flow geochemical model using pMELTS thermodynamic calculations explains the observed modal, major, and trace element variations in the Red Hills peridotite, New Zealand. The model also reproduces the major and trace element chemical variation in the mid-ocean ridge basalts (MORBs) observed in the present day spreading ridges. The Red Hills peridotite is thought to originate in paleo-MOR magmatic processes in the mantle-MOHO transition zone. The peridotite body consists of a harzburgite matrix and dunite channels. The harzburgite forms the Lower Unit and the harzburgite is intruded by the replacive dunite channels in the Upper Unit. This lithology gradually turns into a massive dunite zone in which disseminated to lenticular clinopyroxene aggregates are present. The rare earth element (REE) compositions of peridotite samples vary greatly depending on their lithologies. In the Lower Unit, REEs are extremely depleted, whereas in the Upper Unit they are relatively fertile, in contradiction to their depleted lithologies. Our model consists of two-stages. The first-stage assumes melting of a depleted MORB source mantle in the garnet stability field, and the second assumes reactions between residual solids and the melts from the first-stage in the spinel stability field in an open system. The model explains the formation of depleted harzburgite and the formation of dunite channels in the harzburgite matrix well. The major and trace element compositions of the melts calculated by the model vary from ultra-depleted MOR melts in harzburgite to normal MORBs in dunite, suggesting that these lithologies are residues of a paleo-MOR. The model also explains the origins of the local and global geochemical trends found in MORBs and the geochemical variation in the abyssal peridotite samples. Our model confirms the important role of reactive flow in the mantle-MOHO transition zone beneath MORs.

Keywords: Ocean ridges, Mantle, MORB, Ophiolite, Melt