Mélange-peridotite interactions in the source of arc magmas

Emmanuel Codillo, Veronique Le Roux, Mark Behn, Gray Bebout, Glenn Gaetani, and Horst Marschall

The mechanisms of material transfer from the slab to the overlying mantle in subduction zones are still highly debated. Whether material transfer primarily occurs during partial melting, fluid percolation, or detachment of solid diapirs has critical implications for the timing of elemental fractionation observed in arc magmas, the composition of the overlying arc crust, and the geodynamic processes in subduction zones.

It has been postulated that mélange rocks, which are physical mixtures of sediments, oceanic crust, ultramafic rocks formed from the mechanical and metasomatic interactions along the slab-mantle interface, could play a key role in arc magmatism. Field observations of exhumed high-pressure mélange rocks often display blocks of crustal rocks embedded in mafic to ultramafic matrices. Importantly, mélange rocks show compositional similarities with global arc lavas in terms of trace elements and isotopes, implying that some characteristic slab signatures of arc lavas may already be imprinted during the formation of mélange. However, the fate of mélange rocks along the descending slab is still rather unconstrained. Once formed, these mélange rocks may either melt along the slab-top, or rise as solid or partially molten diapirs (Fig. 1A). If favored, these diapirs could effectively deliver the compositional signatures of mélange rocks into the source of arc magmas. The goal of our project is to investigate the phase equilibria, melting properties, and densities of a variety of mélange rocks in order to constrain their physical behavior during subduction and their influence on arc magmatism.

We performed a series of piston-cylinder experiments on natural mélange rocks from several exhumed high-pressure terranes (e.g., Syros, Greece, Santa Catalina, USA) that cover the endmember compositions of global mélanges over a wide range of pressure and temperature conditions. In particular, we aim to constrain the initiation temperature of mélange melting (solidus) which allows us to assess the likelihood of mélange melting along the slab-tops at different subduction zones (Fig. 1B). We then determine the elemental compositions of melts and mineral residues for various bulk starting compositions, and quantify the density evolution of mélange rocks along the slab-top (Fig. 1C). This information will be combined with numerical modeling to determine the conditions necessary for mélange diapirs to rise from the slab with respect to the onset of mélange melting. Critical information on the effects of melting and instantaneous melt extraction on the density evolution of the melting residues will be fed into numerical model calculations to ensure that the dynamics are consistent with the compositional evolution of the mélange diapirs. Preliminary results from this study show that melting of mélange rocks along the slab-top is unlikely at low pressures (<2.5 GPa) even along a hot subducting slab. In addition, the intrinsic buoyancy of most mélange rocks relative to the overlying mantle may promote the ascent of mélange diapirs and subsequent interactions with the overlying mantle wedge. Using these experiments, we extract critical insights on the physical behavior of mélange rocks during subduction and the geochemical consequences of mélange melting. ■

References

Lambert, I.B., P.J. Wyllie (1970). Melting in the deep crust and upper mantle and the nature of the low velocity layer. Phys Earth Planet Int, 3,316-322

Liu, J., S. Bohlen, W. Ernst (1996). Stability of hydrous phases in subducting oceanic crust. Earth Planet Sci Lett, 143, 161-171

Nichols, G.T., P.J. Wyllie, C.R. Stern (1994). Subduction zone melting of pelagic sediments constrained by melting experiments. Nature, 371, 785-788

Skora, S., J. Blundy (2010). High-pressure hydrous phase relations of radiolarian clay and implications for the involvement of subducted sediment in arc magmatism. J Petrol, 51, 2211–2243

Syracuse, E.M., P.E. van Keken, G.A. Abers (2010). The global range of subduction zone thermal models. Phys Earth Planet Inter, 183, 73-90

Till, C.B., T.L. Grove, A.C. Withers (2012). The beginnings of hydrous mantle wedge melting. Contrib Mineral Petrol, 163, 669-688

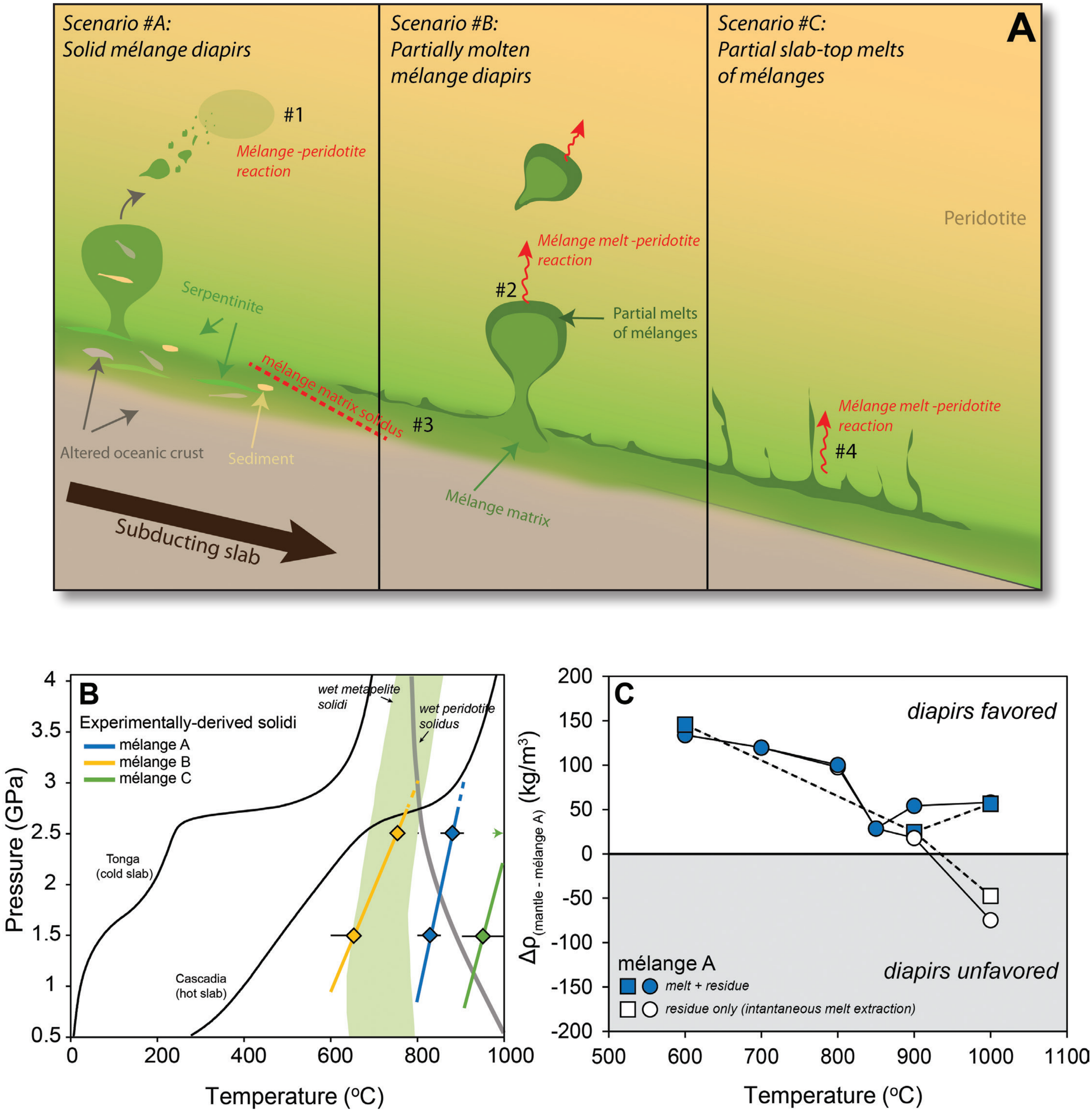

Figure 1. A. Schematic illustration of three possible end-member scenarios for the fate of mélange rocks along the slab-mantle interface; B. Experimentally-derived solidi of different mélange rocks plotted along with other solidi of different bulk compositions relevant to subduction zone melting (Literature data: Lambert and Wyllie, 1970; Liu et al., 1996; Nichols et al., 1994; Skora and Blundy, 2010; Till et al., 2012), and representative global slab-top P-T paths (Syracuse et al., 2010); C. Calculated bulk density difference between mélange rocks and overlying peridotite mantle at similar P-T conditions. Circle and square symbols represent experiments at 1.5 and 2.5 GPa, respectively.