Understanding Melt Generation Processes in Subduction Zones

T.L. GROVE[1]

[1]Dept. EAPS, M.I.T., Cambridge, MA, USA
tlgrove@mit.edu

Water (H_2O) is the indispensable ingredient in arc magma generation. Hydrous minerals in subducting oceanic lithosphere and the overlying mantle provide the source of H_2O when they become unstable and dehydrate. The H_2O released by dehydration of serpentine and chlorite triggers melting as it rises into shallower hotter overlying mantle. Melting continues as a buoyant H_2O-bearing melt ascends through the mantle wedge and interacts with the increasingly hotter and shallower surroundings. The melting process is strongly influenced by plate tectonic variables that control the location of the active volcanic arc above the subducted lithosphere. H_2O also modifies the thermodynamic and physical properties of silicate melts. The effects of H_2O on the melting behavior and melt compositions can only be understood by carrying out experiments. In the presence of excess H_2O the mantle begins to melt at 800 ºC at depths of 120 km and the solidus rises to 865 ºC at 60 km depth. This depth range spans the predicted depth of melt initiation for the global subduction zone system and is controlled by the combined tectonic effects of slab dip, convergence rate and age. Compositions of near-solidus melts have been measured at 3.2 GPa from 925 to 1050 ºC. The melt is broadly andesitic in composition and melting is peritectic with olivine + liquid produced by melting of garnet + orthopyroxene + high-Ca pyroxene. The coexisting supercritical vapor phase contains a silicate component that is rhyolitic. Extrapolation of the measured compositional variation toward the solidus implies that the first melt is SiO_2 enriched. Evidence preserved in the major and trace element compositional variation of near-primary arc magmas provides a complimentary top-down approach to understanding of the melting process. These lavas record last equilibration in the mantle at shallow, near-moho depths and range in temperature from >1350 ºC at 0 % H_2O to >1200 ºC at 4 to 8 wt. % H_2O. The hydrous melts achieve these temperature and H_2O contents by dissolving, reacting and re-equilibrating with the mantle wedge as they ascend from the slab–wedge interface. In some arcs primary mantle melts are as cool as 1100 ºC with H_2O contents of >12 wt.%. Anhydrous melts in arcs are produced by adiabatic decompression melting induced by mantle flow into the wedge corner. Geochemical modeling of trace element partitioning into arc magmas shows that >99 % of LILE and LREE come from the subducted slab and most closely resemble melts of an eclogite source.