Andesites: their origin and the role in the Earth evolution

Yoshiyuki Tatsumi

Department of Earth and Planetary Sciences. Kobe University
and
Institute for Research on Earth Evolution, JAMSTEC

E-mail: tatsumi@diamond.kobe-u.ac.jp

One characteristic feature of the planet Earth is the bimodal height distribution at the surface (Fig. 1). This is caused by the difference both in density and thickness of the Earth’s crust. Two types of crusts, the oceanic and continental crusts, have been created at divergent and convergent plate boundaries, respectively, via. plate tectonics. The bulk composition of continental crust is andesitic (60 wt.% SiO_2), in marked contrast with the basaltic oceanic crust with ˜50 wt.% SiO_2. This raises the question of how intermediate continental crust forms from basaltic magmas produced in the mantle wedge of subduction zones.

The Izu-Bonin-Mariana (IBM) arc is a juvenile intra-oceanic arc and has a thick middle crust layer with *Vp* of ~6km/s, suggesting this arc to be an active site of both creation and growth of the continental crust. Petrological modeling, including remelting of the initial basaltic arc crust and magma mixing between mantle- and crust-derived melts, can successfully explain the layered crust-mantle seismic structure of the IBM. During this process, the sub-arc Moho is chemical transparent and permeable to the refractory melting residue of arc crust. This crust-mantle transformation or discharge of the ‘anti-continent’ could play the major role in the creation of intermediate continental crust.

The continental crust in detail possesses compositions typical of calc-alkalic series that often coexists with tholeiitic series in a single volcano. Resolution of the genetic relationship between these two types of andesitic magmas should, therefore, provide a better understanding of andesite genesis and arc crust evolution. Reexamination of petrographical and geochemical characteristics of these two magma series in the NE Japan arc provides a new insight into andesite genesis: (1) tholeiitic magmas are produced via anatexis of amphibolitic crust caused by underplating and/or intrusion of mantle-derived calc-alkalic basalt magmas into the arc crust, and (2) The mantle-derived calc-alkalic basalt magma mixes with crust-derived tholeiitic melts to form calc-alkalic andesite magmas.

The essential cause of operation of plate tectonics that creates both andesitic continental crust and basaltic oceanic crust and results in the bimodal height distribution is the temperature difference within the mantle and mantle convection. The upper thermal boundary layer of this convection corresponds to the lithospheric plate, but behaves naturally as a stagnant-lid, i.e., the plate should not move. The presence of liquid water at the surface, on the other hand, strongly reduces the yield strength and could cause the fracture within the stagnant-lid, triggering the plate subsidence or subduction. Parameters that govern the presence and absence of liquid water on the terrestrial planets are: the distance from the Sun and the mass of a planet. A conclusion of this consideration would be that the Earth is a shore planet because of the presence of the ocean, which seems to be a conclusion of a Zen dialog.

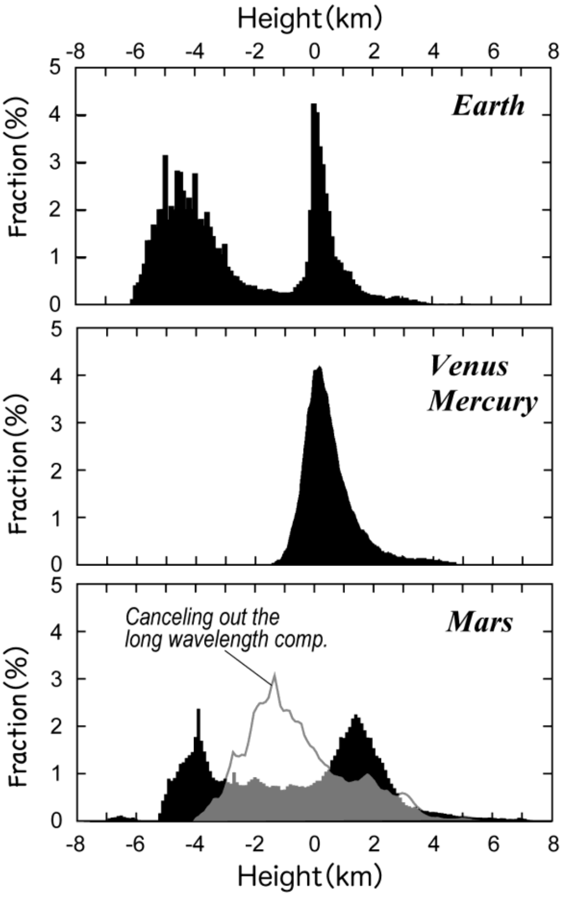

Figure 1. Hypsometry of surface tomography of the terrestrial planets.