Modeling impact volcanism as a possible origin for the Ontong Java Plateau

Adrian P. Jones
Earth Sciences, University College London, WC1E 6BT, UK
Kai Wünemann
Earth Sciences and Engineering, Imperial College London, London SW7 2AZ, UK
G. David Price
Earth Sciences, University College London, WC1E 6BT, UK

ABSTRACT

We have conducted hydrocode simulations to test whether impact volcanism is a viable process to explain the origin of the Ontong Java Plateau (OJP), currently recognized as the largest oceanic large igneous province (LIP) on Earth. First we demonstrate that the particular hydrocode we utilize (SALE-3MAT; e.g., Wünnemann et al., 2005) can produce the same results as the hydrocode SALEB used by Ivanov and Melosh (2003b), who claim that impacts do not trigger volcanism. We find their model to be accurate and obtain similar results after introducing a different method for estimating the amount of melt. Having also previously demonstrated that the thermal and physical state of the target lithosphere is critical to melt production (Jones et al., 2002), we use the dry lherzolite melting parameterization of Katz et al. (2003), and a hot geotherm appropriate for 20- to 10-Ma oceanic crust at the onset of the OJP at ca. 120 Ma (Ingle and Coffin, 2004). For the model with the largest amount of melt, we used a dunite projectile of diameter 30 km and velocity 20 km/s with vertical incidence. If the same projectile struck cold continental lithosphere, it would produce a ~300-km diameter impact crater, probably similar to the maximum estimates of the size of the largest impact crater preserved on Earth (Vredefort), where a central uplift of >10 km has been recognized. In our simulation, the effect of changing the target to hot oceanic lithosphere is quite dramatic, and produces massive melting both by heating and decompression. The melt is distributed predominantly as a giant subhorizontal disc with a diameter in excess of 600 km down to >150 km in depth in the upper mantle within ~10 min of the impact, although most of the initial melt is shallower than ~100 km. The total volume of mostly ultramafic melt, is ~2.5 3 10^6 km^3, ranging from superheated liquid (100% melt, >500 ∞C above solidus) within 100 km of ground zero, to varying degrees of nonequilibrium partial melt with depth and distance. This melt volume would take up to tens of thousands of years to solidify. The total volume of melt produced would be approximately three times as much, yielding ~7.5 3 10^6 km^3 of basalt, if the heat were distributed to produce 20–30% partial melting of the mantle. Larger melt volumes can easily be simulated by increasing projectile mass and/or by adopting hotter mantle, or nonanhydrous conditions. There is no upper limit on the volume of melt that can be generated in this way, although impact events become statistically less likely with increasing impactor size. We suggest that much of this melt would be buoyant and erupt rapidly, and that it would be followed by an extended secondary period of additional melting (which we have not modeled here) that would occur at greater depths (e.g., Elkins-Tanton et al., 2004). These results are sufficiently similar to the OJP to warrant serious multidisciplinary investigation, as suggested by Ingle and Coffin (2003a,b), including mantle convection modeling.