Squeezing out of the T-X box: Rheological evolution of volcanic lavas, impact lavas and cryolavas

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Volcanism on Earth is typically restricted to compositions that can be generated by partial melting of the Earth's mantle and/or crust, and through subsequent modifying processes such as magma mixing, assimilation, and fractional crystallization. This leads to the familiar range of terrestrial lava compositions, limited at the present day to foidites (e.g. Nyiragongo) at the low-SiO_2 end, and high-silica rhyolites (e.g. Obsidian Dome) at the other. Carbonatites (e.g. Oldoinyo Lengai) represent a rare departure from silicate volcanism on Earth.

Silicate volcanism has been important on most terrestrial bodies that have differentiated internally, amd continues to the present day on Io, where lavas are suspected to be much hotter than on Earth, and hence more mafic, with komatiite a popular candidate composition. Io also exhibits sulfur volcanism. At lower temperatures, cryovolcanism has been cited as a likely mechanism for the extrusion of sodium carbonate-rich material on Ceres. Sulfates, chlorides and carbonates are likely cryovolcanic materials at Europa, Enceladus, and other ocean worlds.

Impact melts are composed primarily of target material, whose composition is dictated by surface processes that extend beyond the realm of igneous petrology. Consequently they span a much wider range. On terrestrial bodies with primary crusts, such as the anorthositic lunar highlands impact melts can resemble monomineralic melts, which could never form by any other mechanism. Where impacts remelt secondary crusts, for example the lunar maria, the same magma could be reborn but at a much higher temperature than during initial formation and emplacement. These superheated sheets of lava have tremendous erosive power, both thermal and mechanical, and they can downcut into their substrate quite vigorously, until they cool below their liquidus. Conversely, their erosive potential diminishes rapidly as crystallization proceeds.

As planetary geology reaches the edges of the solar system and prepares for the leap to exoplanets, we should be ready to encounter volcanic processes occurring over a much wider range of T-X space than we are familiar with.