COLUMNAR JOINTING IN ACTIVE HAWAIIAN LAVA LAKES AND IN ANCIENT LAVA FLOWS

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Inter-crystalline glass is ubiquitous in basalt, the common volcanic rock of earth's ocean basins and oceanic islands. In Hawaii, eruption temperatures are in the 1190 – 1150 °C range and the solidus is reached at about 1000 – 980 °C. Inter-crystalline super cooled melt reaches the glass transition, T_g, at 750 °C, and subsequent cooling occurs in a high temperature mix of crystals and glass: a rheological, 'sand-and-molasses' mixture. Strong temperature gradients and 'zero-displacement' lateral boundary conditions conspire to set up thermal stresses in the cooling mass. The result is stress relief via elastic-plastic crack growth that is incremental and cyclic in time and space. This cyclic fatigue fracture is defined by abrupt elastic crack growth increments in the crystal + glass domain, and plastic crack tip blunting in the crystal + super cooled melt domain. The overall increment is preserved on the crack face as a fatigue striation. As the crack advances orthogonal to the isotherms, it (and neighboring cracks) collectively define polygonal columns in three dimensions. Under conditions of maximum local equilibrium, such polygons are hexagonal in plan form with faces meeting at 120 degree triple junctions. In forming the polygons, Nature strikes a balance between the maximum reduction in the thermally-induced elastic strain energy per unit volume and the creation of the minimum fracture surface area per unit volume. This (thermodynamic) balance occurs via cyclic fatigue fracture at the elastic-plastic interface.

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