Physics of Explosive Magma-Water Interactions at High Confining Pressures

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Because observable explosive magma-water interactions produce vast amountsof steam, many researchers conclude that in deep subaqueous conditionswhere hydrostatic pressure is in excess of water's critical pressure, steamis not produced during magma-mater interaction, precluding explosivebehavior. This conclusion is supported by the apparent paucity ofhydroclastic material in samples recovered from deep marine environments.Review of magma-water interaction physics, however, indicates thatexplosive interaction is indeed possible at supercritical pressures.Physical phenomena that must be addressed are: (1) the pressure- andtemperature-dependent rates of heat exchange between magma and water, basedon the heat capacities and conductivities of magma and water; (2) thethermodynamic behavior of water at high pressure and temperatures and itsrapid variability near the critical point; (3) the hydrodynamic behavior ofsupercritical water in response to pressure fluctuations; and (4) the roleof "detonation" physics in explosive vaporization. Thermodynamicpredictions show that the conversion of thermal to mechanical energy isonly high enough to support explosive behavior for a narrow range ofwater-to-magma mass ratios. In subaqueous conditions, apparent mass ratiosare too high for explosive behavior, but true mass ratios, involved duringinteraction, depends upon characteristic times, determined by local watersound speed and interface geometry. An important concept is the interfacecontact temperature of the film of water at the interface with magma; it ispredicted to exceed 800 K (for basaltic magmas). At supercriticalpressures, this temperature causes the film (a supercritical fluid) toexpand in volume by greater than an order of magnitude. With expansion, thefilm cools and collapses back to the interface, imparting kinetic energyinto the magma, causing magma fragmentation. Magma fragmentation is alsopromoted by quench contraction as magma rapidly looses its heat. Withfragmentation more magma surface area is exposed to water, andsupercritical film growth/collapse is repeated on a millisecond (or less)interval as an escalating process. The film becomes hydrodynamicallyunstable and prone to detonation, especially if perturbed by some externalpressure wave, such as that produced by volcanic seismicity. There arenumerous factors that prevent this system from attaining detonation, but ifit does, the expansion wave that follows the detonation wave allows steamto be generated at explosive rates.