Hyaloclastite beds of shelf and seamount: roles of exsolution, entrapment and entrainment at Lookout Bluff and Seamount Six

Submarine eruptions of basaltic magma range from highly to mildly explosive eruptions and include passive quenching and quiet lava effusions. Explosivity, increasingly suppressed by hydrostatic pressure, is driven by rapid exsolution of magmatic volatiles and steam explosions during interaction with external water. To assess the limits of phreatomagmatic processes and especially the role of steam at different depth levels, and the change of predominance of fragmentation processes, a shallow marine and a deep marine volcaniclastic rock sequence were studied. Clast characteristics and sedimentary features of the deposits were examined for information on fragmentation and ensuing primary sedimentation processes of the volcaniclastic debris in both settings.

At Lookout Bluff, Otago, New Zealand, well bedded, vesicular pyroclastic breccias, lapillistones and tuffs of Eocene - Oligocene age are exposed. The rocks are interbedded with continental shelf siltstones, and are inferred to have been erupted and deposited in a shallow marine setting. Growth of three or more separate monogenetic volcanoes, substantially separated in time, is recorded at Lookout Bluff. Each of the volcanoes produced subaqueous fall and eruption-fed density current deposits, some of which have been modified by resedimentation events. Initial eruptions from each vent were of small volume and clast characteristics suggest that initially hydroclastic fragmentation was predominant. During the last recorded eruption, producing voluminous deposits, magmatic fragmentation became dominant.

Deep-marine volaniclastic rocks from Seamount Six, a Pacific seamount on the Cocos plate, were studied with a submersible. The rocks consist of thin, well-bedded sheets of hyaloclastite and occur highly localized on topographic heights and flattish benches on the upper flanks of the seamount at ca. 2000 to 1600 m below sealevel. Earlier studies of these rocks propose a submarine fire-fountaining model with small magma jets from a central vent, fragmentation by steam explosivity and quench granulation, and emplacement by lateral density currents. However, observations during this study do not fit this model.

Non-vesicular angular blocky and splinter shard shapes indicate hydroclastic fragmentation. A critical role of steam is demonstated by the occurrence of puzzle shards and limu (Limu O'Pelee are beetle-wing like, broken fragments of lava bubbles stretched by trapped water expanding into steam). In this study, (a) detailed consideration of limu formation, including magma-water heat transfer, thermodynamics of seawater and various styles of water entrapment within lava, as well as (b) recognition of several hyaloclastite facies associations and (c) analysis of depositional characteristics of hyaloclastite shards are used to develop an integrated, multi-component model for the origin and deposition of deep-sea hyaloclastites.

In conclusion it can be said that processes of violent steam and magmatic explosivity are suppressed at depth of Seamount Six, whereas the processes of limu and sheet hyaloclastite formation, dominant at that depth, are not recognized in the shallow marine setting of Lookout Bluff. Small volume fluxes, a forced, confined style of magma-water interaction combined with minimal exsolution of magmatic volatiles seem to be the controlling factors to generate limu and hyaloclastites studied at Seamount Six, whereas open-vent eruptions and abundant degassing favour surtseyan style eruptions studied at Lookout Bluff.