The Origin of Breccias in the Miocene Green Tuff Belt, Japan: Implications for Submarine Explosive Volcanism

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Coastal exposures of Miocene submarine volcanic successions of the Green Tuff Belt of southwestern Hokkaido, and outcrop and drill core from the Hokuroko Basin of northern Honshu, Japan, are dominated by coherent basaltic to rhyolitic lavas and syn-volcanic high level intrusions, and a variety of volcaniclastic facies. The volcaniclastic facies include coarse dense clast breccias, and pumice-lithic breccias variably called "tuff breccias" in the literature. The ambient facies are foraminiferal mudstones and although there is significant difference of opinion on water depth significance, Japanese micropalaeontolgists favour depths of <2.5 kms.

In the coastal exposures of southwestern Hokkaido the volcaniclastics include dense clast breccias which vary from jigsaw-fit to clast-rotated breccias gradational into coherent lavas and intrusions. Jigsaw breccias are attributed to in-situ quench fragmentation, and are termed in situ hyaloclastite. Clast-rotated breccias indicate a degree of clast movement after quench fragmentation. Clasts have planar to curviplanar surfaces, and sometimes have radial microjointing around the margins. Bedded breccias, often dominated by angular monomictic clasts also occur and are variously interpreted as syn-eruptive, resedimented hyaloclastite breccias, dome/lava pile gravitational collapse, and even debris avalanche collapse breccias resulting from dome or cone collapse. Basaltic examples often have fragments of pillows. All appear to represent submarine talus aprons around lava domes, shields or other edifices. Lack of rounded clasts is consistent with largely submarine eruption and resedimentation. The non-vesicular character is consistent with non-explosive origins. The volumes of volcanic breccias resulting from non-explosive fragmentation are surprisingly large. Polymictic breccias and conglomerates also occur and suggest post-eruptive mixing and resedimentation. Conglomerates indicate derivation from a shoreline. Clasts in all of these are overwhelmingly volcanic in composition; older basement clasts are rare and indicate eruption and sedimentation away from a substantial continental landmass, although the conglomerates indicate the existence of emergent volcanic islands in the environs of the basin system. Isolated occurrences of graded bedded pumiceous mass flow deposits testify to explosive eruptions in the basin or basin margins and contemporaneous resedimentation. The vent locations and water depths, if subaqueous, are unknown. Isolated occurrences of variably bedded, spatter clast breccias, sometimes associated with feeder dykes indicate subaqueous fire fountaining of fluidal magmas.

Host rock successions to VHMS mineralisation ("Kuroko deposits") in the Hokuroko Basin also include the above facies. However, pumice-lithic deposits (tuff breccias) are also common and include pumiceous hyaloclastite as well as magmatic or phreatomagmatic pyroclastic deposits. Isopach patterns and textural and mineralogical similarities between the pumice lithic breccias and associated lava domes, indicate that the pyroclastic deposits are derived from dome complexes in the basin . The pyroclastic deposits that occur below or enclose the kuroko ore deposits originate from vents at the sites of the kuroko ores. These pyroclastic deposits occur mainly within a radius of 2 to 3 km from the ores, but some distal outlfow deposits occur where basin and volcanic topography allowed escape of the pyroclastically generated mass flows into deeper parts of the basin. The largest syn-ore pyroclastic unit documented in this study is about 7 û 8 km3. Some workers have suggested that the kuroko ores are located within submarine pyroclastic calderas. Ahowever, the kuroko volcanoes examined in this study are essentially dome-tuff cone/shield volcanoes with little evidence for eruption-related syn-volcanic subsidence. The larger pyroclastic deposits in the Hokuroko Basin occur in the hanging wall sequence to the ores and at least some of these units are derived from craters/small calderas within the basin; They are related to similar dome complexes which are slightly younger and at potentially slightly shallower water than those at the time of formation of the ores.

Most of the pumice-lithic breccias in the Hokuroko district that correspond to the deeper water eruptions (units stratigraphically close to the kuroko ores) are single, normal graded beds or amalgamated ("double graded") sequences. Each unit is generally composed of pumice to pumiceous-perlitic dome clasts that are identical to the source lava dome. The normal grading is interpreted to indicate that most if not all units were essentially water suported mass flows. Near vent, some flows may have been gas-supported flows but there is no specific evidence of this in the Hokuroko Basin succession. The amount of compaction of pumice compaction and fiamme formation is related to stratigraphic level with higher units generally being less compacted. Style of alterationalso plays a role with clay-altered pumices in medial to ore positions showing and fiamme, interpreted to have resulted from diagenetic compaction, whereas silicified pumices close to ore are uncompacted.

1000-2000 m (?) water depths probably retarded pyroclastic volcanism (there are no 100 km3 size pyroclastic units) but the more gas-rich magmas erupted initially explosively. After initial explosive degassing, magma oozed up to form domes and cryptodomes. Such cycles were repeated in places. These interpretations are consistent with recent accounts of significant explosive events associated with moderate depth felsic eruptions at Myojinsho volcano (Fiske et al, 1998), Myojin Knoll Volcano(Fiske et al., 2001) and Healy Caldera (I. Wright et al., 2001).

In conclusion, although substantial explosive events can occur at considerable water depths, it appears that by comparison with subaerial settings, the effects are less intense, being suppressed by hydrostatic pressure. High volatile felsic magmas are capable of substantial explosive events even at considerable water depths. Many coarse volcaniclastic successions in deep water however result from non-explosive fragmentation and resedimentation.