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Explosive destruction of a Pliocene hot lava dome underwater: Dogashima (Japan)

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ABSTRACT

Transition from effusive to explosive volcanism is common during subaerial eruptions, and here we demonstrate that this behavior is also possible underwater. The pyroclastic facies produced underwater are distinctive and can be used to distinguish subaqueous from subaerial eruptions and depositional settings. The Pliocene Dogashima Formation (Izu Peninsula, Japan) is a pumice-rich succession originally deposited in an open-marine, below wave-base setting (Jutzeler et al., 2014a). A thick, clast-supported, gray andesite breccia composed of very coarse, dense andesite clasts with quenched margins was sourced from disintegration of an active lava dome. Overall, the gray andesite breccia is gradationally to sharply overlain by thick, graded, clast-supported white pumice breccia chiefly composed of angular pumice clasts and free broken crystals. Regional setting and distinctive facies show that this succession was produced by a fully underwater, magmatic volatile-driven, pumice-forming explosive eruption. The gradational contact between the two breccias, compositional similarities, rare mingled clasts, and fluidal textures in the gray andesite clasts suggest that the explosive eruption destroyed a hot lava dome and generated an eruption-fed, high-concentration density current. In most places, the coarsest hot lava dome fragments were deposited first, followed by the lower density white pumice clasts. The low amount of fine (<2 mm) components, well-developed hydraulically controlled grading and sorting, clast angularity, and very coarse dome-derived clasts, some including well-defined quenched margins and common fluidal textures, distinguish the products of subaqueous effusive-to-explosive eruptions from their subaerial counterparts.

1. Introduction

Subaqueous volcanic eruptions, especially explosive eruptions, are poorly understood and the spectrum of evolved eruption mechanisms and depositional processes existing underwater is incompletely known (e.g. Kano, 1996, 2003; White et al., 2003; Allen and McPhie, 2009; Allen et al., 2010; Barker et al., 2012; Carey et al., 2014; Jutzeler et al., 2014a; Rotella et al., 2015). Here we describe a Pliocene andesitic volcanic succession generated by explosive destruction of a hot submarine dome, and consider how eruptive column behavior, and transport and depositional mechanisms are complicated by the subaqueous setting. Deposits derived from underwater dome destruction by volcanic explosion have been recognized (Cas et al., 1990; Kano, 1996; Schmidt and Schmincke, 2002), although evidence of the hot state of the lava dome and of destruction from the arrival of a new vesiculating magma could not be established. On land, active lava domes are frequently destroyed by open-vent explosive, pumice-forming eruptions (e.g. Matthews et al., 1997; Sparks, 1997; Fiske et al., 1998; Robertson et al., 1998; Rosi et al., 2004; Martel and Poussineau, 2007; Platz et al., 2007; Williamson et al., 2010), but such events have not previously been identified in fully underwater settings. We define the volcaniclastic facies indicative of subaqueous effusive-to-explosive eruptions. In addition, the facies characteristics are distinctive and can be used to discriminate between submarine and subaerial depositional environments.

This study is based on detailed facies analysis of the 4.55 ± 0.87 Ma (Jutzeler et al., 2014a) Dogashima Formation (Cashman and Fiske, 1991; Tamura et al., 1991; Jutzeler et al., 2014a) in the Izu Peninsula (Japan), which is part of the 5.5–1.7 Ma (Tani et al., 2011) volcanogenic Shirahama Group. The Shirahama Group records rear-arc volcanism (Tani et al., 2011) in the northern extension of the Izu–Bonin arc and was uplifted at ~1 Ma. The presence of planktonic foraminifera species (e.g. Ibaraki, 1976), hyaloclastite and pillow lavas (Tamura, 1994), and overall absence of subaerially sourced components (e.g. rounded clasts, shallow water shells, wood) in facies that enclose the Dogashima Formation suggest that it formed in an open-marine basin of unknown water depth (Jutzeler et al., 2014a). The presence of extremely large clasts, channels, and extensive cross-bedded structures suggests deposition at the break-in-slope of a submarine volcano (Jutzeler et al., 2014a). The volcanic seamount that produced the Dogashima Formation appears to have been entirely submerged.

The Dogashima Formation was recognized as the product of subaqueous explosive eruptions (Fiske, 1969; Cashman and Fiske, 1991;

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Jutzeler et al., 2014a). It is exposed in >1.5 km^2 of mostly coastal cliff outcrops, is 5 to >80 m thick, and includes four main subdivisions (Fiske, 1969; Tamura, 1994; Jutzeler et al., 2014a), with the Kamegoiwa, Dogashima 1 (D1), Dogashima 2 (D2), and Dogashima 3, up stratigraphy. The basal part of Dogashima 2 is the focus of this study. The juvenile components in Dogashima 2 have a uniform andesitic composition but are strongly bimodal in terms of vesicularity. The overall dominance of angular white pumice lapilli reflects open-vent explosive fragmentation of magmatic foam. Less abundant non-vesicular, commonly coarse, gray andesite clasts, some of them with quenched margins and fluidal textures, were deposited hot (Tamura et al., 1991; Jutzeler et al., 2014a) and reflect the former presence of an active lava dome under water.

2. Lithofacies of Dogashima 2

Dogashima 2 is 15–30 m thick and composed of eight strikingly different stratigraphic units (Jutzeler et al., 2014a) partly deposited in a submarine channel carved into beds of the units below. This study focuses on the three basal units of Dogashima 2 (D2-1, D2-2, and D2-3). Dogashima 2 is a relatively coarse, clast-supported succession dominated by angular white pumice, crystal fragments, and non-vesicular, gray andesite clasts (Fig. 1). The white pumice and gray andesite clasts occur in both units; however, the moderate to strong grading by clast density occurs through the units (Fig. 2). The basal part of Dogashima 2 (D2-1 and D2-2) is chiefly made of gray andesite clasts (>90 vol.%), whereas white pumice clasts and crystal fragments are dominant (>60 vol.%) in the upper part (D2-3).

2.1. Clasts in Dogashima 2

The white pumice clasts have a slight yellowish hue, and their grain size modes are between 4 and 16 mm (Jutzeler et al., 2014a). Pumice clasts are overall angular, but rounded in D2-1 and D2-2, and the coarsest pumice clasts (up to 30 cm) in D2-3 have curviplanar surfaces, and some have quenched margins (Fig. 3). White pumice clasts are >60 vol.% vesicular and contain <40% of phenocrysts (about 20 vol.% if considered as dense rock equivalent, where plagioclase is dominant over two pyroxenes and opaque phases. Gray andesite clasts are gray to dark gray, chiefly 10–50 cm of diameter, and equant and angular in shape, although fluidal clasts and ovoid large clasts (up to 10 m of diameter) with devitrified quenched rims and internal radial joints occur (Fig. 3). A thermoremanent temperature of 450 °C was determined on several rims of coarse gray andesite clasts (Tamura et al., 1991) in D2-2. Gray andesite clasts are non-vesicular, and their mineralogy is identical to white pumice clasts, with 15–20 vol.% phenocrysts; feldspar microlites occur as trachytic texture, and ovoid porphyritic inclusions are present. In both clast types, plagioclase composition (An_{48-70}) defines a single trend (Jutzeler et al., 2014a). Very rare clasts show mingling of an elongate blob of gray andesite with round edges within a white pumice clast (Fig. 3d), attesting of the contemporaneity of the two phases in a probable semi-molten state.

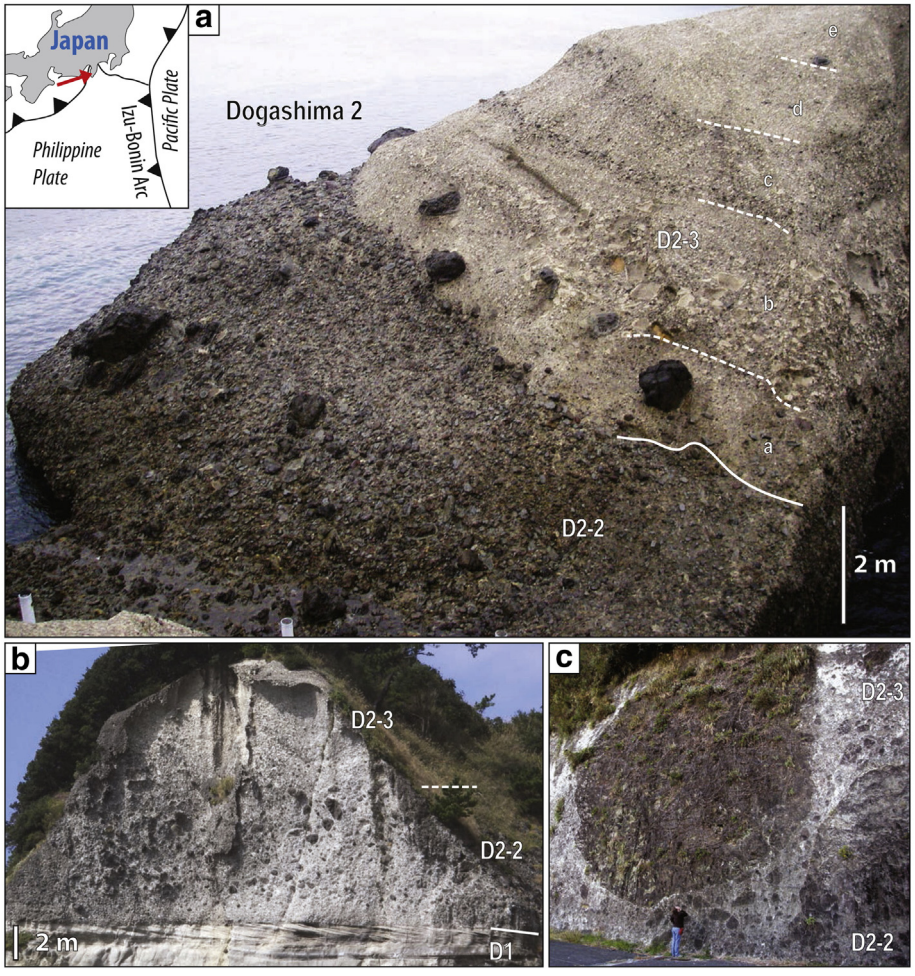

Fig. 1. Dogashima 2 outcrops in the Dogashima Formation (Dogashima town, Izu Peninsula, Japan). *a*, Dogashima 2 at the rim of the submarine channel at locality G-east. Coarse gray andesite breccia (D2-2) is overlain by several beds (a–e) of white pumice breccia (D2-3). Note the sharp contact between D2-2 and D2-3, although the units have mixed componentry; D2-3 is well stratified. Tectonic map in insert, red arrow shows location. *b*, Dogashima 2 in the submarine channel. D2-2 and D2-3 are in fully gradational contact. D2-2 overlies Dogashima 1 (D1) with a sharp contact. *c*, Giant blocks of gray andesite in D2-2 in the middle of the paleo channel. Contact between D2-2 and D2-3 is indistinct; person for scale.