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Impacts of explosive volcanism on distal alluvial sedimentation: Examples from the Pliocene–Holocene volcaniclastic successions of Japan

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ABSTRACT

Volcanic activities can create cataclysmic hazards to surrounding environments and human life not only during the eruption but also by hydrologic remobilisation (lahar) processes after the cessation of eruptive activity. Although there are many studies dealing with the assessment and mitigation of volcanic hazards, these are mostly concentrated on primary eruptive processes in areas proximal to active volcanoes. However, the influence of volcaniclastic resedimentation may surpass the impacts of primary eruptive activity in terms of both extent and persistence, and can ultimately result in severe hazards in downstream areas.

Examination of the volcaniclastic successions of non-marine Pliocene–Holocene sedimentary basins in Japan has revealed hydrological volcaniclastic sedimentation in fluvial and lacustrine environments hundreds of kilometres from the inferred source volcano. Impacts on these distal and often spatially separated basins included drastic changes in depositional systems caused by sudden massive influxes of remobilised pyroclastic material. Typical volcaniclastic beds comprise centimetre- to decimetre-thick primary pyroclastic fall deposits overlain by metre- to 10s of metres-thick resedimented volcaniclastic deposits, intercalated in sedimentary successions of non-volcanic provenance. The relatively low component of primary pyroclastic fall deposits in the volcaniclastic beds suggests that: 1) potential volcanic hazards would be underestimated on the basis of primary pyroclastic fall events alone; and 2) the majority of resedimented material was likely derived from erosion of non-welded pyroclastic flow deposits in catchment areas rather than remobilisation of local fallout deposits from surrounding hillslopes.

The nature, distribution and sequence of facies developed by distal volcaniclastic sediments reflect the influence of: 1) proximity to ignimbrite, but not directly with the distance to the eruptive centre; 2) ignimbrite nature (non-welded or welded) and volume; 3) temporal changes in sediment flux from the source area; 4) the physiography and drainage patterns of the source area and the receiving basin, and any intervening areas; and 5) the formation of ephemeral dam-lakes and intra-caldera lakes whose potential catastrophic failure can impact distal areas. Models of the styles and timing of distal volcaniclastic resedimentation are thus more complicated than those developed for proximal settings of stratovolcanoes and their volcaniclastic aprons and hence present different challenges for hazard assessment and mitigation.

1. Introduction

The development of concepts of co-ignimbrite ash fallout (e.g., Sparks and Walker, 1977; Machida and Arai, 1983; Machida, 1999) and distal or co-plinian ash fallout (e.g., Fierstein and Hildreth, 1992; Kamata et al., 1997) has made a significant contribution to modern tephrostratigraphy. Such tephra beds have been correlated across geographically widespread areas, enhancing chronostratigraphic interpretations of Pliocene to Holocene sedimentary sequences (Self and Sparks, 1981; Machida, 1999; Shane, 2000; Shane and Hoverd, 2002). These non-volcanic sequences can include recognisable, discrete tephra layers deposited by atmospherically transported ash hundreds or thousands of kilometres from the source volcano. However, the resedimented (reworked) volcaniclastic deposits which often accompany and overlie these primary pyroclastic fall beds have received relatively little attention except from a sedimentological viewpoint (e.g., Smith, 1988; Shane, 1991; Nakayama and Yoshikawa, 1997; Kataoka and Nakajo, 2002; Manville, 2002; Kataoka, 2005).

Studies of volcaniclastic sediments in terms of facies, depositional processes, and environmental impacts arose during the 1980's (e.g., Vessell and Davies, 1981; Smith, 1987, 1988), in part spurred by direct observations of the aftermath of the 1980 eruption of Mount St. Helens (Pierson and Scott, 1985; Scott, 1988; Major et al., 2000; Major, 2003; Major and Mark, 2006). These studies primarily focused on

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proximal 'ring plain' or 'volcaniclastic apron' areas built near andesitic and dacitic stratovolcanoes, and emphasised the episodic nature and periodicity of eruptive activity and the ensuing influx of pyroclastic detritus. Smith (1988, 1991a) developed a conceptual facies model for volcaniclastic aprons, characterised by proximal–distal facies changes and syn- and inter-eruptive phases.

From the early 1990's to this century, a growing body of work has addressed volcaniclastic resedimentation associated with large-scale caldera/ignimbrite-forming silicic eruptions (Buesch, 1991; Smith, 1991b; Palmer, 1997), in part catalysed by the 1991 eruption of Mt. Pinatubo in the Philippines (Newhall and Punongbayan, 1996). This 5–7 km^3 DRE eruption has been confronting people with lahar hazards that extended over a wide area from the volcano and persisted since 1991 (Newhall and Punongbayan, 1996; Gran and Montgomery, 2005). Moreover, several studies have also discussed the distal environmental impacts caused by volcaniclastic resedimentation and aggradation more than 100 km from the silicic source volcano based on modern/young examples from the Taupo Volcanic Zone in New Zealand (Manville, 2002; Segschneider et al., 2002; Manville and Wilson, 2004), ancient ones from Plio-Pleistocene non-marine sediments in Japan (Nakayama and Yoshikawa, 1997; Kataoka and Nakajo, 2002; Kataoka, 2005), and the Rio Grande rift in USA (Mack et al., 1996) and others. However, conceptual discussions on impacts and triggering and controlling factors for volcaniclastic resedimentation in distal areas have not been well-addressed previously.

This paper reviews Pliocene to Holocene volcaniclastic sequences, facies and sedimentation in 'distal' fluvial and lacustrine settings in Japan. Such studies of prehistoric and ancient successions can improve our understanding and awareness of volcaniclastic resedimentation and yield information on the nature of the primary volcanic eruption that may not be preserved in proximal areas. The present paper also proposes potential controlling and triggering factors for distal resedimentation, which will aid in the interpretation of distal resedimented/reworked volcaniclastic deposits in alluvial successions, and assist in the prevention and mitigation of volcano-hydrologic hazards.

2. Japanese Pliocene to Holocene volcaniclastic successions

The Japanese Islands are located in an active arc setting where the Eurasia Plate, North America Plate, Pacific Plate, and Philippine Sea Plate meet and the latter two subduct to form the arc system. The islands contain 108 active volcanoes and numerous Quaternary volcanic edifices. Previous studies on tephrostratigraphy in this country succeeded in extra-basinal correlation of widespread Pliocene

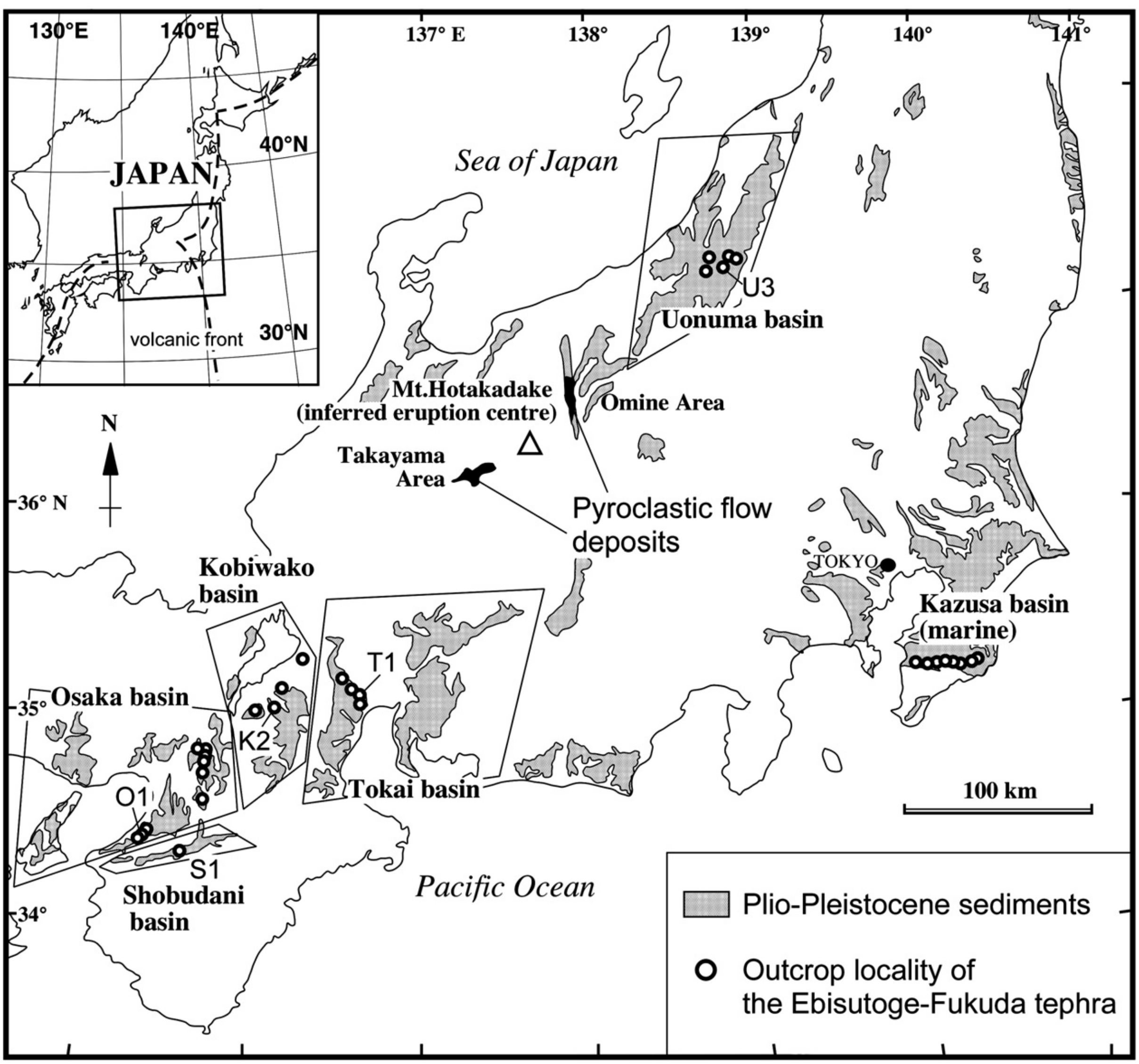

Fig. 1. Distribution of Plio-Pleistocene sediments and localities where the 1.75 Ma Ebisutoge–Fukuda tephra is exposed in central Honshu, Japan, and the location of the inferred eruption center, Mount Hotakadake (open triangle).