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Research paper

Submarine landslide deposits of the historical lateral collapse of Ritter Island, Papua New Guinea

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ABSTRACT

The March 13th 1888 collapse of Ritter Island in Papua New Guinea is the largest known sector collapse of an island volcano in historical times. One single event removed most of the island and its western submarine flank, and produced a landslide deposit that extends at least 70 km from the headwall of the collapse scar. We have mapped and described the deposits of the debris avalanche left by the collapse using full-coverage multibeam bathymetry, side-scan sonar backscatter intensity mapping, chirp seismic-reflection profiles, TowCam photographs of the seafloor and samples from a single dredge. Applying concepts originally developed on the 1980 Mount St. Helens collapse landslide deposits, we find that the Ritter landslide deposits show three distinct morphological facies: large block debris avalanche, matrix-rich debris avalanche and distal debris flow facies. Restoring the island's land and submarine topography we obtained a volume of 4.2 km^3 for the initial collapse, about 75% of which is now forming the large block facies at distances less than 12 km from the collapse scar. The matrix-rich facies volume is unknown, but large scale erosion of the marine sediment substrate yielded a minimum total volume of 6.4 km^3 in the distal debris flow and/or turbidite deposits, highlighting the efficiency of substrate erosion during the later history of the landslide movement. Although studying submarine landslide deposits we can never have the same confidence that subaerial observations provide, our analysis shows that well-exposed submarine landslide deposits can be interpreted in a similar way to subaerial volcano collapse deposits, and that they can in turn be used to interpret older, incompletely exposed submarine landslide deposits. Studying the deposits from a facies perspective provides the basis for reconstructing the kinematics of a collapse event landslide; understanding the mechanisms involved in its movement and deposition; and so providing key inputs to tsunami models.

1. Introduction

Lateral collapses is a nearly ubiquitous feature of volcanoes in almost all volcanic island arcs. Numerous collapse generated landslide deposits with volumes of cubic kilometers to tens of cubic kilometers occur both in volcanic island arcs such as the Lesser Antilles (Deplus et al., 2001; Le Friant et al., 2003) and Kermadec arcs (Wright et al., 2006), and in back arc settings such as the Sea of Japan (Satake and Kato, 2001). The available data (Table 1 and references therein) suggest that island or coastal volcano lateral collapses with volumes of 1 or more cubic kilometers and maximum thicknesses of 500 m or more occur at a global frequency of the order of ~1 per 100 years. Smaller landslides removing summit dome complexes or thin layers from the volcano flanks (e.g., 2002 Stromboli; Bonaccorso et al., 2003) occur more frequently. Significantly, the events in Table 1 indicate a broad correlation between the size of the collapse event and the size of the tsunami produced, as most of the deep-seated collapses of Table 1 produced large destructive tsunamis.

The March 13th 1888 Ritter Island collapse is the largest ocean-entering volcano lateral collapse, in volcanic arc settings, for which we have written accounts of both the collapses and the resulting

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Table 1
Historical lateral collapses and large landslides at island and coastal volcanoes in volcanic arcs for which written descriptions of both the source events and the resulting tsunamis are available. **A**. Large, deep-seated lateral collapses. **B**. Small-volume, shallow-seated volcano flank landslides that produced damaging tsunamis. Note the recent dates of these events, the historical record may be incomplete for the period prior to 1900, compared to the record of lateral collapses.

Date	Volcano	Landslide volume, if known	Maximum local tsunami runup	Distant tsunami runups (examples)	Landslide type	References
A						
1640	Komagatake, Hokkaido, Japan	0.3 km^3	>8 m		Ocean entry by landslide from subaerial volcano lateral collapse	Katsui et al. (1975)
1741	Oshima–Oshima, Sea of Japan.	2.4 km^3 (large block facies of deposit); 2.5 km^3 (collapse scar)	34 m ?; certainly >15 m (on coasts 60–80 km distant)	3 m – 4 m on Korean coast, 1200 km distant	Partly submarine volcano lateral collapse	Kato (1997) and Satake and Kato (2001)
1792	Unzen, Japan	0.34 km^3 (collapse scar volume)	>10 m	none: collapse into enclosed bay.	Ocean entry by landslide from subaerial volcano lateral collapse	Geographical Survey Institute (1982)
1883	Augustine, Alaska	~0.5 km^3	>19 m?	6 m–8 m, ~100 km distant	Ocean entry by landslide from subaerial volcano lateral collapse	Beget and Kowalik (2006) and Kienle et al. (1987)
1888	**Ritter Island, Papua New Guinea**	**~4 to 5 km^3** (Johnson (1987)); **4.2 km^3 (our estimate)**	**>15 m (on coasts up to 50 km distant)**	**8 m at Hatzfeldhafen, 370 km distant; 4.5 m at Rabaul, 540 km distant**	**Partly submarine volcano lateral collapse**	Cooke (1981) and Johnson (1987)
1933	Harimkotan, Kuriles	~1 km^3 (collapse scar volume)	20 m	Significant damage on adjacent islands	Ocean entry by landslide from subaerial volcano lateral collapse	Gorshkov (1970)
B						
1928	Paluweh, Indonesia	Volume poorly known due to eruption	3 waves, from 5 to 10 m		Ocean entry by subaerial landslide at start of large explosive eruption	Neumann van Padang (1929)
1966	Tinakula, Solomon Islands	<0.01 km^3	Small local waves only		Ocean entry by landslide from small failure near summit	Latter (1981) and Johnson, R.W. and Workshop Organizing Committee (1999)
1979	Ili Werung, Indonesia	0.05 km^3	9 m		Ocean entry by subaerial landslide	Pararas-Caryannis (1979)
2002	Stromboli, Italy	0.02 km^3	10 m	2 m (140 km distant)	Two thin slope – parallel landslides, one subaerial and one submarine	Bonaccorso et al. (2003) and Tinti et al. (2006)