

Deep-sea ash layers reveal evidence for large, late Pleistocene and Holocene explosive activity from Sumatra, Indonesia

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ABSTRACT

Deep-sea tephra layers sampled from sediment cores collected within, and adjacent to the Sunda trench of off-shore Sumatra reveal evidence for five previously undocumented, and apparently large (minimum volume >0.6 – 6.3 km³; volcanic explosivity index values of 4–5) explosive eruptions over the last ~31,000 years, with a presumptive source of mainland Sumatra. Chemical analysis of glass shards and ¹⁴C age constraints are used to distinguish the five tephra layers, as well as a sixth that likely correlates with the Youngest Toba tuff (YTT). The tephra layers are labeled V-1 through V-6 relative to their north-to-south positioning along the Sunda trench. The three tephra layers taken from cores west of central Sumatra (V-3, V-4, V-5) are well-constrained by ¹⁴C age determinations, whereas less reliable sedimentation-rate estimates are available for the northern (V-1, V-2) and southern (V-6) tephra layers. Deposition of the northernmost tephra, layer V-1, was likely accompanied by seismicity as two chemically indistinguishable tephras are separated by 12 cm of course-grained turbidite. Layer V-2 shows a strong chemical resemblance to the YTT and age estimates do not rule out the correlation. With the exception of a likely correlation with the YTT, no other correlations were made between the tephras analyzed in this study with the marine or terrestrial record from the published literature. The most frequent, widespread, and youngest marine tephra layers were found in the central region of the study area. Layers V-3, V-4, and V-5 were all deposited within the last 17 thousand years with minimum eruptive volumes of >0.6 to >5.2 km³. A complex depositional sequence of layer V-6 is estimated at ~27.5 ka, and may be associated with Late Pleistocene ignimbrite volcanism of southern Sumatra. The ages and suggested minimum volumes represented by the deep-sea tephra layers are consistent with an active volcanic arc, and demonstrate the need for further terrestrial studies.

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1. Introduction

The island of Sumatra, Indonesia comprises the majority of the western Sunda Arc, one of the most volcanically active regions on Earth. The Global Volcanism Program lists 35 active volcanoes on the island (average spacing of 50 km) with reported eruptive activity occurring at 13 centers during the past 100 years, in addition to fumarolic and other signs of activity at many sites (Smithsonian Institution, 2012). Consequently, much of the island's human population and infrastructure is at risk from volcanic activity. Despite the dangers, the known Holocene eruption history of Sumatra is almost entirely limited to historic eye-witness accounts of small-to-moderate explosive activity from the past few hundred years. This lack of information is partly

attributable to difficulties in accessibility, coupled with extremely high erosion rates and dense vegetation in this equatorial region. However, many of Sumatra's stratovolcanoes are steeply-sloped with only minor vegetation suggesting a youthful and frequent eruption history (e.g. Gasparon, 2005), and the overall large number of volcanoes suggests that increased knowledge of Sumatran volcanism would be valuable for volcanic hazard assessments. In this study, we take advantage of the recent availability of a set of tephra-bearing deep-sea sediment cores to document a number of large, explosive, Late Pleistocene to Holocene volcanic eruptions from the Sumatran mainland.

In 2007, workers from Oregon State University, in collaboration with the Agency for Assessment and Application of Technology, Indonesia, participated in the Paleoquakes07 research cruise that included collection of 144 deep-sea cores of shallow (<5 m) marine sediments deposited along the Sumatra–Andaman plate boundary (Fig. 1, Table 1). Turbidites within the cores, from within the Sunda trench and the adjacent continental slope, reveal at least nineteen and as many as twenty-four subduction zone earthquakes over the past 7.5 ka between ~5°N to ~2°N (Patton et al., 2010). Within the intercalated hemipelagic

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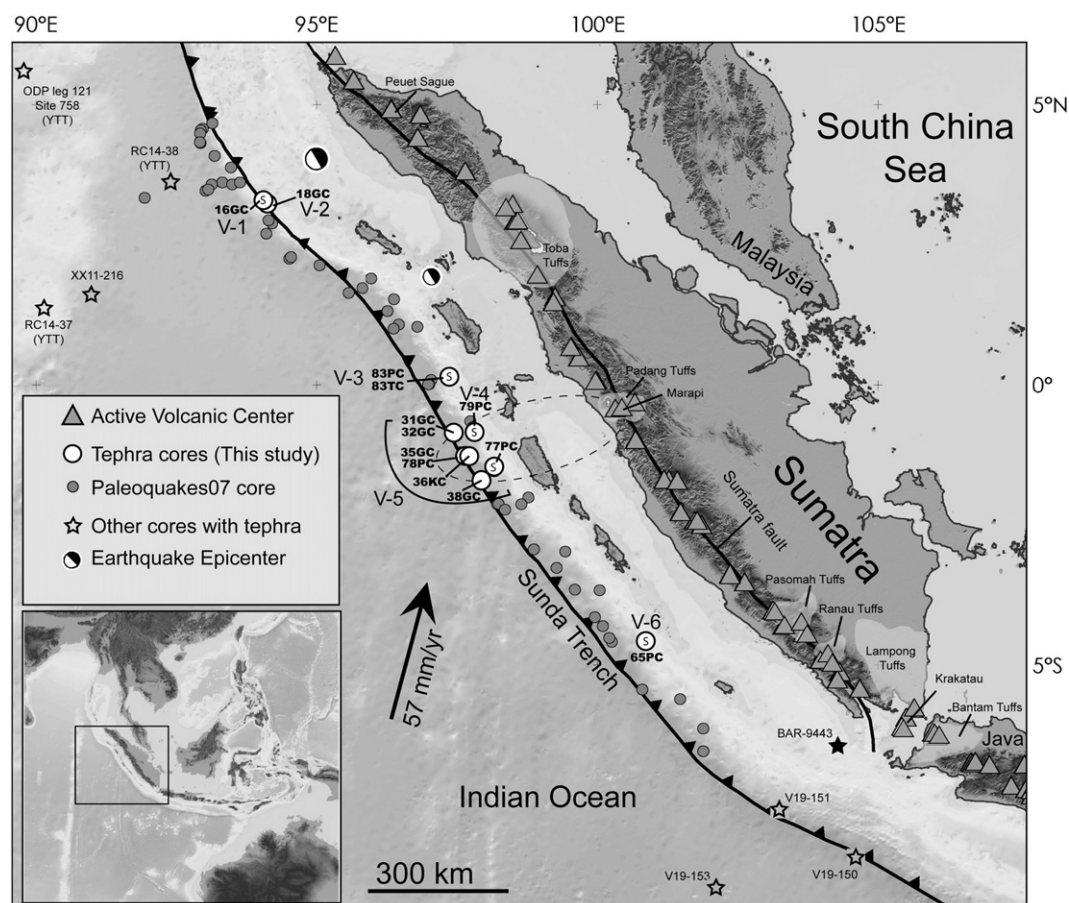


Fig. 1. Location of deep-sea marine cores analyzed in this study. Larger white circles represent cores in which tephra was identified and analyzed geochemically. Cores from the continental slope are identified with an "S". Smaller, light gray circles represent examined cores without identified tephra deposits. Individual volcanic units are labeled as V-1 through V-6 relative to north-to-south core location. A dashed line shows the minimum distribution ellipse used in volume calculations for unit V-5. Triangles represent active volcanoes of the west Sunda arc as identified by the Global Volcanism Program (Smithsonian Institution, 2011). Also shown are locations of deep-sea cores with tephra horizons analyzed by Ninkovich (1979) (open stars) and Beauregard (2001) (solid star). Bathymetry and topography data are from Smith and Sandwell (1997).

sediment and turbidites, tephra layers analyzed in the present study were identified in cores collected at distances of 200–300 km west of the modern Sumatran arc front.

In this study, we establish the composition, age constraints, and distribution of the newly discovered tephra layers and provide constraints on Late Pleistocene to Holocene eruptions capable of transporting

Table 1
Physical characteristics of deep-sea cores and tephra samples from Cruise RR0705.

Core Num.	Type ^a	Lat.	Long.	Seafloor depth (m)	Tephra depth (cm)	Tephra thickness (cm)	Tephra sample #	Dominant shard type ^b	Avg. shard (μm)	EMP # analyses	LA-ICP-M # analyses	Spot size (μm)	Tephra layer designation
16	GC	3.287	94.035	1911	146	4.0	SUM132	1 and 2	50	28	22	40	V-1
16	GC	3.287	94.035	1911	130	5.0	SUM134	1 and 2	50	37	21	40	V-1
18	GC	3.276	94.020	1820	222	5.0	SUM136	2	< 30	34	6	30	V-2
83	PC	0.130	97.361	3337	151	0.5	SUM049	1	90	32	27	70	V-3
83	TC	0.130	97.361	3337	203	1.3	SUM048	1	90	18	18	70	V-3
79	PC	−0.847	97.794	3833	165	3.5	SUM137	1	50	28	17	30	V-4
79	PC	−0.847	97.794	3833	303	8.0	SUM008	1	90	28	15	70	V-5
31	GC	−0.860	97.430	5420	84	2.7	SUM106	1	90	31	31	70	V-5
32	GC	−0.860	97.442	5435	43	2.3	SUM011	1	90	31	27	70	V-5
35	GC	−1.283	97.650	5455	110	3.4	SUM010	1	90	34	19	70	V-5
78	PC	−1.283	97.650	5455	243	3.9	SUM009	1	90	34	33	70	V-5
38	GC	−1.699	97.938	5511	144	1.0	SUM012	1	90	34	14	70	V-5
77	PC	−1.478	98.155	3778	120	1.5	SUM131	1	110	36	27	70	V-5
36	KC	−1.283	97.650	5455	15	1.5	SUM138	2	30	31	14	30	V-5
65	PC	−4.579	100.858	2751	436	n.d.	SUM013	1 and 2	100	13	0	n.a.	V-6
65	PC	−4.579	100.858	2751	440.5	n.d.	SUM014	1 and 2	100	12	0	n.a.	V-6
65	PC	−4.579	100.858	2751	441.7	n.d.	SUM015	1 and 2	100	6	0	n.a.	V-6
65	PC	−4.579	100.858	2751	465.5	n.d.	SUM016	1 and 2	100	43	33	70	V-6
65	PC	−4.579	100.858	2751	481.3	5.1	SUM017	1 and 2	100	7	0	n.a.	V-6
65	PC	−4.579	100.858	2751	486.3	6.1	SUM018	1 and 2	100	11	0	n.a.	V-6

^aCore type: GC = gravity core; PC = piston core; TC = trigger core; KC = kasten core.

^bShard type 1 = micropumiceous, type 2 = bubble-wall or platy.

^cn.d. = not determined, reworked sediment.

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