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Tectonic and volcanic implications of a cratered seamount off Nicobar Island, Andaman Sea

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ABSTRACT

The region of the Nicobar earthquake swarm of January 2005 has been explored during a recent cruise using multibeam swath bathymetry, seafloor imaging and TV-guided sampling to decipher the seafloor morphology, nature and tectonic frame work. A seamount with well-developed crater at the summit was discovered near to the center of the Nicobar swarm. Rock samples collected by TV-guided grab from the seamount crater are dacite, rhyolite and andesite type with a veneer of ferromanganese oxide coating. The aggregates recovered from the slope consisted of manganese globules. The geochemistry of the globules suggests 66–97% Mn-oxide indicative of hydrothermal origin. The morphology of the seamount, seafloor video footage and geochemistry of the seabed samples suggest that the cratered seamount has erupted in the recent geological past and is dormant at present. This is the first documented report of submarine arc-volcanism in the Andaman Sea. This finding substantiates the prediction of a submarine volcano east of Nicobar Island. Study of the seismicity and the stress pattern in the region suggest that the earthquake swarm in the region occurred due to 2004 Sumatra–Andaman megathrust earthquake. The derived stress pattern suggests that the 2004 earthquake greatly reduced the normal stress in the region of West Andaman fault from the planes or unclamped them. Thus unclamping of the region by the 2004 Sumatra Andaman earthquake led to the initiation of the swarm through predominantly strike slip faulting. The newly discovered dormant submarine volcano indicates the volcanic nature of the region. We suggest that this submarine volcano is a link between sub-aerial volcanoes of Barren–Narcondam Islands of the Andaman Sea and the volcanoes of Sumatra.

1. Introduction

The most energetic earthquake swarm that has ever been recorded globally (Lay et al., 2005) nucleated east of Nicobar Island in the Andaman Sea during January 2005. This swarm is considered as an aftershock effect of the tsunamigenic Great Sumatra–Andaman earthquake of 26 December, 2004 of magnitude M_w 9.3 that ruptured a 1600 km-long stretch of the megathrust zone, the longest rupture zone of any recorded earthquake (Fig. 1). The swarm consisted of more than 120 individual events, all of greater than M_w 5.0 magnitude, in a time span of ~48 h (Fig. 2).

Earthquake swarms occur as a result of two broad tectonic processes (Hill et al., 2002), as an aftershock event of a great earthquake and as a consequence of or in precedence of a spurt in volcanic activity. For example, volcanic activity and lateral dike injection was found to be associated with 1998 axial seamount swarm (Dziak and Fox, 1999). Stress transfer due to crustal deformation was suggested as the likely cause of an Izu Island swarm (Toda et al., 2002). The 1996 swarm of Loihi seamount was preceded by at least one eruption and accompanied by the formation of summit crater, the Pele's pit (Garcia et al., 1998). The periodically triggered seismicity and renewed volcanism at Mount Wrangell, Alaska, a place as far as 11,000 km away from Sumatra was attributed to the aftershocks following the great Sumatra–Andaman earthquake (West et al., 2005). Based on numerical model studies, Walter and Amelung (2007) predicted that maximum sub-seafloor volumetric deformation occurred during the megathrust earthquake in December 2004 to the east of Nicobar Island and suggested possible submarine volcanic activity in the region.

We conducted multidisciplinary investigations in November 2007, using multibeam bathymetry, underwater video and seabed sampling with a TV-guided grab over the Nicobar swarm region onboard *RV Sonne*, chartered by the National Institute of Oceanography, Goa, India, to decipher the nature of the seafloor and tectonic frame work of the swarm area. We also analyzed the

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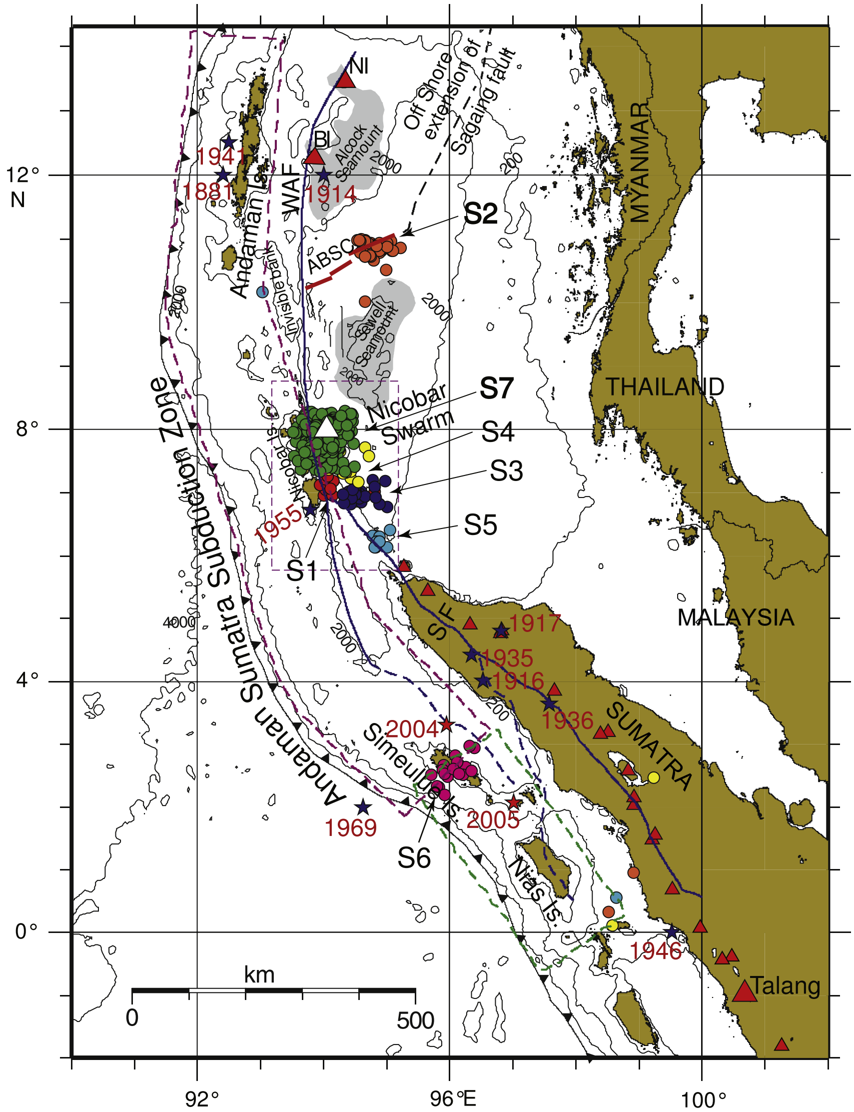

Fig. 1. Tectonic map of the study area along with seismicity data from the NEIC. The tectonic elements in the Andaman Sea depict major features (Ammon et al., 2005; Sieh and Natawidjaja, 2000; Kamesh Raju et al., 2004, 2007). The documented earthquake swarms, S1 to S7, and the volcanoes represented by triangles (http://www.ngdc.noaa.gov/) are shown, SF denotes the Sumatra Fault. The red and green dashed boxes represent the rupture zones of 2004 Sumatra–Andaman earthquake and the Nias earthquake of 2005 respectively.

seismicity and the stress pattern in the region to investigate the mechanism of the earthquake swarm and to find out probable reasons for the occurrence of the swarm at this preferred location.

2. Geodynamic setting

The general physiographic features of the Andaman Basin were well described by Rudolfo (1969). The convergence between the Indian and Southeast Asian plates in the Andaman Sea is characterized by varying degree of obliquity and rate of subduction (Sieh and Natawidjaja, 2000). Oblique subduction, the initiation of Andaman back arc spreading (Kamesh Raju et al., 2004; Curray, 2005), and the volcanic arc consisting of Barren–Narcondam Island volcanoes are the important tectonic elements in the Andaman Sea (Fig. 1). Furthermore, the major fault systems connecting the Sagaing Fault in Myanmar to the Sumatra fault (e.g., Sieh and Natawidjaja, 2000; Vigny et al., 2003; Kamesh Raju et al., 2004, 2007), the joining of Sumatra Fault (SF) with the West Andaman Fault (WAF) are also influencing the geodynamics, and modulate the stress regime (Fig. 1) in this area. The motion along the major fault-systems (viz. Sagaing Fault, Sumatra Fault and West Andaman Fault) is predominantly strike-slip. The principal stress directions are in general consistent with the coseismic displacement of the two recent major earthquake events of December 2004 and March 2005 and the direction of convergence derived from the GPS measurements in the interseismic period (Gahalaut and Gahalaut, 2007).

Barren Island is the only known active volcano in the northern Andaman Sea (Sheth et al., 2009, 2010, 2011). Based on the known volcanoes in the region, there is a distinct gap in active volcanoes from 06°N to 12°N. Subduction of the base of the Ninety-east ridge was suggested as one of the possible reasons for this gap in volcanic activity (Subrahmanyam et al., 2008). It is interesting to note the occurrence of several earthquake swarms (S1–S7, Fig. 1) at frequent intervals in different parts of the Andaman Sea. These swarms have occurred along the back arc spreading center (S2 in 1984), near the Nicobar Island (S1, S3, S4 and S7 during 1982, 1986, 1998 and 2005 respectively), along the off-shore extension of the Sumatra fault (S5 in 2001) and near Simeulue Island (S6 in 2002). All the earthquake swarms documented so far appear as minor events compared to the January, 2005 swarm located off