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Earthquake clustering in the tectonic pattern and volcanism of the Andaman Sea region

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ABSTRACT

Seismicity pattern in the Andaman Sea region has been analysed to interpret recent dynamics of regional submarine volcanic provinces. Hypocentral determinations and focal mechanisms of available global seismological data have been used. Frequent occurrence of earthquake swarms proved to be an important characteristic of seismicity pattern in the investigated region. Epicenters of the earthquake swarms are situated almost exclusively along a narrow belt forming the easternmost limit of the epicentral area of the Andaman Sea region. The southern zone of the belt between 6° and 10.5° N is trench parallel and coincides with the northward prolongation of the Sumatra volcanic arc. The northern zone of the belt between 10.5° and 13° N is deflected by about 45° northeast and precisely follows the complicated zigzag pattern of the rift system in the middle of the Andaman Basin. Earthquake occurrence in these two zones, the northern and the southern, differs by several aspects — by shape of the epicentral zones of individual swarms, by focal mechanisms and by response to the 2004 Sumatra–Andaman great earthquake. These differences, together with available information on composition of magmas found at the seafloor, lead us to the conclusion that the swarms of the southern zone are induced by intrusions of subduction-generated calc-alkaline magmas whereas the swarms in the northern zone by intrusions of basaltic magmas associated with the seafloor spreading. Earthquake swarm occurrence defines a brittle, seismogenic layer at depths between 9 and 35 km, excludes the existence of large magma reservoirs in respective depth interval and puts their hypothetical location to a greater depth. Episodes of magma ascent from deeper reservoir to shallow magma chamber (depth <9 km) or up to the surface induce earthquake swarms. The region deserves attention of volcano seismologists through its almost continuous activity and represents an attractive area for on-site geophysical monitoring and direct seafloor observations.

1. Introduction

Andaman Sea region represents an extremely complicated tectonic environment at a convergent plate margin. The region is characterised, among other features, by a gap of 700 km between historically active island arc volcanoes. The present submarine volcanic activity along this gap is highly probable but not sufficiently studied and well understood. To contribute to a better understanding of recent dynamics of the submarine portion of the volcanic arc in the Andaman Sea region, we have utilised an easily accessible but robust geophysical tool — hypocentral parameters and focal mechanisms of teleseismically recorded earthquakes. In our former papers we have found that earthquakes are concentrated in narrow vertical domains beneath some calc-alkaline volcanoes at convergent plate margins (Špičák et al., 2004) and we have denoted such domains as seismically active columns. Later, we have shown that a thorough analysis and interpretation of seismicity pattern is capable to reveal periods of magma transport beneath volcanoes and delimitate areas with increased tectonic stress due to magma migration and ascent, sometimes probably leading to submarine eruptions (Špičák et al., 2009, forthcoming). These seismological observations are in accord with studies on the intrusions of dykes beneath volcanoes (e.g. Geshi et al., 2010).

The geological structure and tectonic evolution of the Andaman Sea region are described and explained in the monograph by Hamilton (1979) and more recent papers by Kamesh Raju et al. (2004) and Curray (2005). It is a region of highly oblique eastward subduction of the Indian plate beneath the Southeast Asian plate, influenced by the normal collision of India and Asia. The consequent tectonic stresses resulted in the development of the sliver Andaman plate, a series of extensional basins, an arc-parallel seamount chain, a SW–NE trending spreading system and several right-lateral fault systems (Fig. 1). The seismicity pattern of the Andaman Sea region was studied and interpreted particularly in relation to the 2004 Dec 26 Sumatra–Andaman great earthquake and its long-lasting aftershock sequence (Dewey et al., 2007; Engdahl et al., 2007). As a part of the aftershock sequence, the 2005 Jan 26–Feb 2 earthquake swarm, the most intensive aggregate of earthquake epicenters in the history of teleseismic observations, called Nicobar cluster, attracted attention of Indian geologists (Kamesh Raju et al., 2012; Kundu et al., 2012; Mukhopadhyay and Dasgupta, 2008; Mukhopadhyay et al., 2010). They concluded that the swarm as well as the 1983–84 and 1993 swarms beneath the Andaman Basin were generated by intruding magmatic dykes of calc-alkaline composition.

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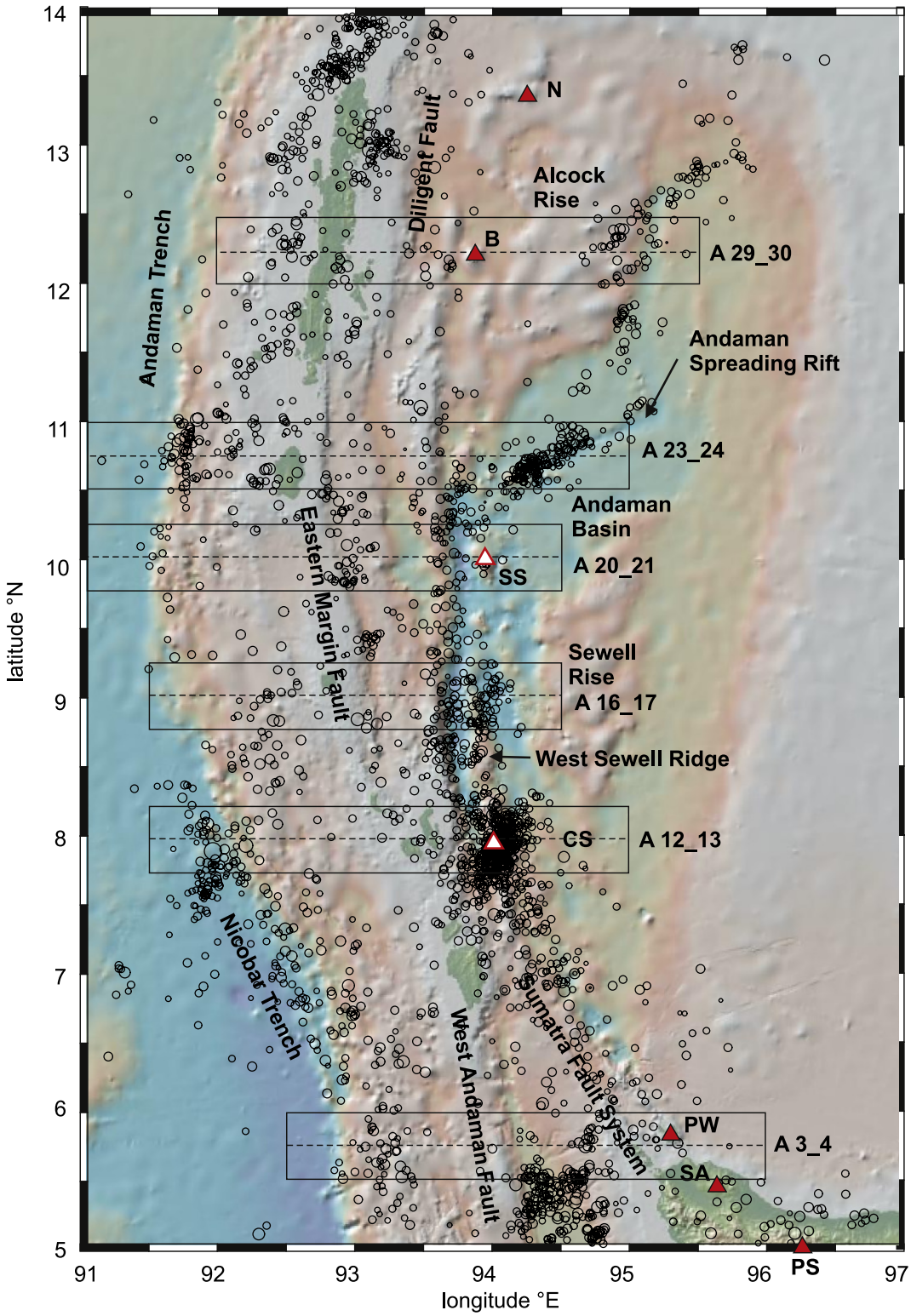

Fig. 1. Epicentral map 1960 to Jan 2013 (open circles) of the Andaman Sea region with the bathymetry of the sea floor and main tectonic units. Size of circles is proportional to body wave magnitude m_b. The swaths imaged as vertical sections in Fig. 2 are denoted by E–W elongated rectangles. Image created using GeoMapApp (www.geomapapp.org). Red triangles denote active volcanoes: N — Narcondam, B — Barren, PW — Pulau Weh, SA — Seulawah Agam, PS — Peuet Sague; open triangles denote volcanic seamounts: SS — Southern Seamount, CS — Cratered Seamount.

2. Data and method

Recent dynamics of the Andaman Sea region have been studied by means of the time/space analysis of global seismological data and their correlation with available volcanic, tectonic and bathymetry information. We have used the EHB (Engdahl, van der Hilst, Buland) database (http://www.isc.ac.uk/ehbbulletin/) of earthquake parameters derived from hypocentral determinations published by the