



Age and geochemical characteristics of Paleogene basalts drilled from western Taiwan: Records of initial rifting at the southeastern Eurasian continental margin

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ABSTRACT

The southeastern Eurasian continental margin has been characterized by formation of rift basins associated with intraplate basaltic volcanism since early Cenozoic time. In contrast to Paleogene volcanic rocks that occur sporadically in the basins, Neogene basalts are more widespread on land as lava flows and pyroclastics in the Taiwan Strait (Penghu Islands) and northwestern Taiwan. To better understand the tectonomagmatic evolution, in particular the initial rifting record, this study reports new age, major- and trace-elemental, and Sr–Nd–Pb isotope data of volcanic rocks drilled from several locations in the Taiwan Strait and western Taiwan. ⁴⁰Ar/³⁹Ar dating results show two main episodes of volcanic activities: ~56–38 Ma (Eocene) and ~11–8 Ma (late Miocene). The volcanic rocks are composed dominantly of basalts and basaltic andesites, and subordinately of dacites and rhyolites of Eocene age. The two episodes of basaltic volcanism have distinct geochemical characteristics. Comparatively, the Eocene basalts are more depleted in basaltic components such as Ca, Fe and Ti, but have higher Al content. They are also more enriched in large ion lithophile elements (LILE) and light rare earth elements (LREE), and show depletions in high field strength elements (HFSE). Sr–Nd–Pb isotope compositions of the late Miocene basalts are relatively more uniform and unradiogenic ($\epsilon_{\text{Nd}} = +6.0$ to $+3.8$), similar to those of Miocene basalts from NW Taiwan and Penghu Islands, and broadly coeval OIB-type basalts from the South China Sea. However, the Eocene basalts have a wider range in isotope ratios (e.g., $\epsilon_{\text{Nd}} = +5.6$ to -3.2) pointing towards an enriched mantle source. The overall geochemical characteristics suggest two distinct mantle sources: (1) a more refractory mantle source metasomatized by subduction-related processes to generate the Eocene basalts and (2) a fertile but isotopically depleted mantle source for the late Miocene basalts. These two source components are proposed to reside in the lithospheric mantle and asthenosphere, respectively. The change in magma sources with time reflects the evolution of an extensional regime within the Eurasian continental margin from an initial rifting to a well-established stage accomplished by thinning of the lithosphere and associated upwelling of the asthenosphere. The Eocene bimodal volcanism entails a transition from the latest Cretaceous magmatism in the western Taiwan Strait that not only signals incipient rifting in the region, but also records geochemical inputs from the subducted Paleo-Pacific plate to the southeastern Eurasian lithospheric mantle. As the preexisting, subduction-related component had been preferentially overprinted by the Eocene magma generation, there was a magmatic quiescence in the Oligocene before the onset of Miocene basaltic volcanism that resulted essentially from decompression melting of the ascended asthenospheric mantle.

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1. Introduction

Since the Cenozoic, the continental margin of Southeast Asia was subjected to tensile stress, which is proposed to be related to passive

continental rifting initiated during the late Cretaceous (Taylor and Hayes, 1980), extrusion and rotation of Indochina in response to the India–Eurasia collision during late Cretaceous (Tapponnier et al., 1982) or an active mantle plume/hotspots (Lei et al., 2009; Wang et al., 2012; Zou and Fan, 2010). The extension of the Southeast Asian margin led to its submergence and the formation of numerous volcanic rift basins which are identified by seismic reflection and borehole data beneath the Taiwan Strait (Lin et al., 2003). The rift basin sedimentary sequences

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are characterized by a Paleogene half-graben covered with a Miocene drape sequence (Teng and Lin, 2004), indicating basin development in stages which are correlative with the regional tectonic evolution. The Neogene basalts are extensively studied and are exposed as lava flows and pyroclastics of the Penghu Islands in the Taiwan Strait and also northwestern Taiwan (Chung et al., 1994, 1995), whereas the Paleogene volcanic rocks only occur sporadically in the rift basins and are poorly studied. The spatial geochemical and isotopic variations of Miocene basalts on the Penghu Islands and northwestern Taiwan reveal that the greatest lithosphere thinning associated with asthenosphere upwelling occurred at the axial zone beneath the Penghu region. Variable degrees of decompression melting of a heterogeneous mantle source produced the volcanic rocks in the region (CLM: EM2 and EM1; Chung et al., 1994, 1995). Chung et al. (1995) further suggested that the EM2 component in the Miocene lithospheric mantle resulted from subduction-related processes during the Mesozoic. However, the subduction-related metasomatism model appears to be in contradiction with the fact that most Cenozoic basalts in SE China–Taiwan region lack arc-like geochemical features, such as Nb–Ta depletion. Chen et al. (1997) reported ages, petrology and limited geochemistry of the late Cretaceous–Paleogene (72–53 Ma) basalts from the northern Taiwan Strait and concluded

that the basalts are derived from a lithospheric mantle source. Their findings suggest subduction-related metasomatism in the lithospheric mantle may explain the origin of EM2 source as proposed by Chung et al. (1995). On the other hand, due to the depletion of high field strength elements (HFSE) in the Paleogene magmatic rocks and the occurrence of Paleogene andesites (65–63 Ma; Chen et al., 2010; Yang et al., 2008) on the Huayu islet, Penghu Islands, the tectonomagmatic origin of the Paleogene magmatic rocks around the Taiwan Strait is debated. In order to resolve the tectonomagmatic conditions, detailed studies on the Paleogene magmatic rocks, which are documented within marginal rift basins, are crucial (Fig. 1). Studies on these magmatic rocks will provide unique constraints on temporal and geochemical variations associated with the regional tectonic evolution of the South China Sea.

In this study, a complete suite of Tertiary magmatic rocks, including those recovered from land-based deep boreholes drilled by CPC Corporation in southwestern Taiwan, Penghu Islands, ocean-based drilling in the Taiwan Strait and those from outcrops at the Huayu islet of Penghu Islands have been geochemically investigated. We present new geochronological and geochemical data in order to decipher their origins and regional geotectonic implications.

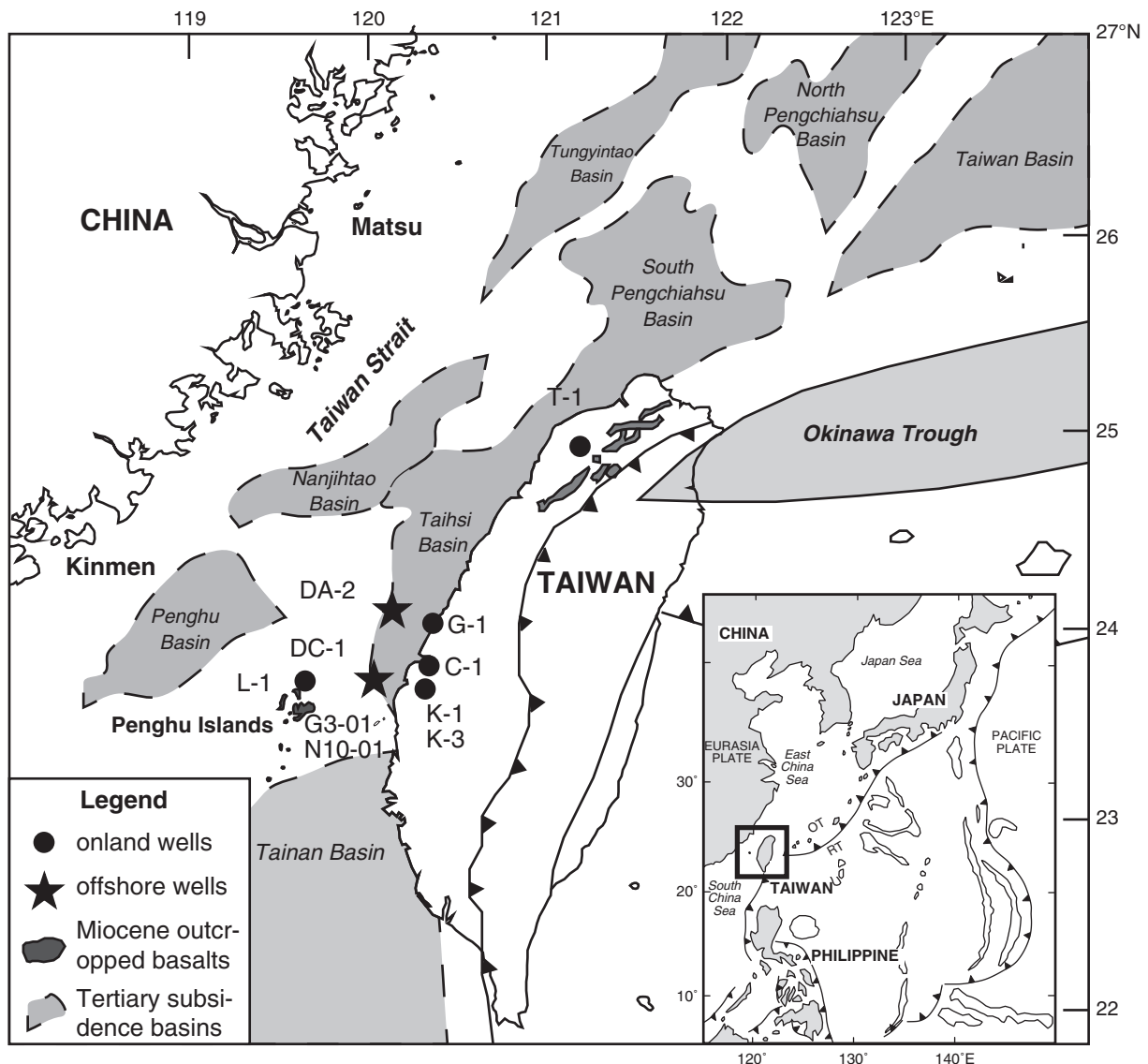


Fig. 1. Map showing localities of wells where volcanic rocks derived from in this study. Exposed Miocene basalts on NW Taiwan and Penghu Islands are also indicated (Chung et al., 1994, 1995). Lower right inset: Tectonic setting of Taiwan.

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