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Tectonics and volcanism in East Asia: Insights from geophysical observations

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ABSTRACT

We review geophysical and geochemical properties in the vicinity of the stagnant Pacific slab beneath northeast China, Korea and Japan to understand the origin and current state of intraplate volcanism in East Asia. East Asia has been susceptible to intensive volcanism since the Cretaceous. In particular, during the Cenozoic, Jeju Island, Korea is the most significant volcanic construct in East Asia. The generation of adakites and A-type granitoids littered throughout East Asia during the Cretaceous has been previously explained by the subduction of the Izanagi–Pacific ridge system. However, a recently revised plate reconstruction model does not comprise such a tectonic episode and consequently fails to explain adakites in arc magmatism during the Cretaceous. Thus, we propose an alternative hypothesis: temporal plume–slab interaction on the source of East Asian magmatism in order to trigger the adakites in arc magmatism without ridge subduction. In addition, we provide an overview on the tectonics and volcanism of Jeju Island during the Cenozoic in the context of the lithospheric structure from seismological constraints and recent geochemical results. The main scientific aims are to understand the consequences of mantle mixing in response to long-term subduction and subsequent changes on the stress state to determine the distribution of chemical heterogeneities, and thus define the origin and development of intraplate volcanism in East Asia. Although geophysical and geochemical data for Jeju Island are not sufficient at present, we strongly state that Jeju Island and the surrounding regions hold a key to unraveling the source of intraplate magmatism since the Cretaceous.

1. Introduction

The subduction zone process operating over much of the Earth's history induces long-term mantle mixing and chemical heterogeneity and recycles volatiles into the mantle (Stixrude and Lithgow-Bertelloni, 2012, and references therein). Arc systems may hold the key for resolving the mystery of mass and heat transport in the Earth's mantle and the composition of the Earth's interior (Schubert et al., 2001). We have examined structural and magmatic properties in the vicinity of the stagnant Pacific slab beneath northeast China, Korea and Japan (Fig. 1) to define the role of mantle mixing in the presence of current and past subduction, and to understand the origin of intraplate volcanism.

The Pacific slab penetrating down to the 410 km discontinuity and lying flat on the 660 km discontinuity beneath Japan, Korea, and China has been imaged seismically (e.g., Bijwaard et al., 1998; Huang and Zhao, 2006; Li et al., 2008; Fukao et al., 2009; Wei et al., 2012). The Pacific slab's presence in the mantle transition zone has been widely accepted in the Earth Science community. These seismic images suggest that the active intraplate volcanoes (located ~1000 km away from the Japan Trench) in East Asia do not have a hotspot origin, but might be closely related to the subduction process of the Pacific slab (e.g., Tang et al., 2014). Slower P- and S-wave velocity anomalies in the back-arc region are used to explain the source of the back-arc magmatism and to infer the convective circulation process of the mantle wedge (Zhao, 2012, and references therein). Geochemical studies also support the influence of the slab in the volcanism (Kuritani et al., 2011).

The presence of the Pacific slab in the mantle depth signifies that East Asian tectonics is in the broad deformation zone. Deep slab subduction has influenced seismic and volcanic activities in the region. However, its relationship to the magmatism in oceanic

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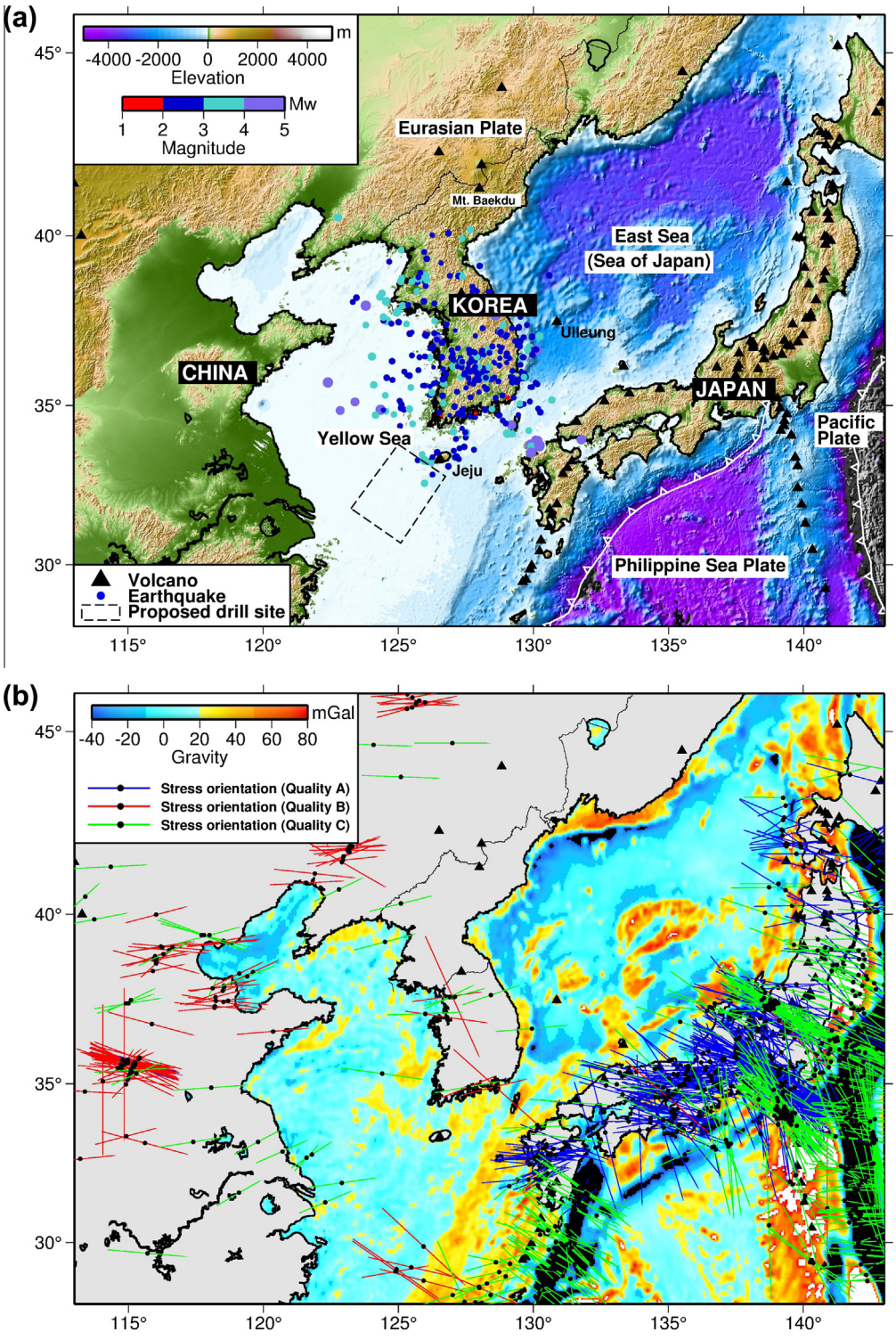

Fig. 1. Geophysical datasets probing East Asia. Locations of volcanoes are shown as black triangles in all panels (a and b). (a) Topographic-bathymetric map showing the region of study and regional seismic activities (colored circles) between 2001 and 2007. The size of the circles is proportional to the magnitude of the earthquake. (b) Gravity anomaly (Sandwell and Smith, 2009; Sandwell et al., 2013, 2014) and tectonic stress orientation in East Asia (Heidbach et al., 2008). Higher quality estimates (qualities A–C) on the stress vector are plotted. 'A' quality means that the orientation of maximum horizontal compressional stress (S_H) is accurate within ±15°. 'B' quality is accurate within ±20°. 'C' quality is accurate within ±25°. Negative gravity anomalies are observed along the Japan Trench (shown as a white line with triangles in (a)). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

islands (Jeju and Ulleung; Fig. 1a) of Korea, coupled with an opening of the back-arc, remains unclear. Furthermore, physical mechanisms that have produced crustal extension, cratonic rejuvenation, and lithospheric thinning across parts of northeastern China and their relationship to the subducted slab remain poorly understood.

Recent three-dimensional waveform modeling results from large-scale, high-density seismic arrays in northeastern China