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The Jiashan Syenite in northern Hebei: A record of lithospheric thinning in the Yanshan Intracontinental Orogenic Belt

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Abstract

The Early Cretaceous Jiashan Syenite is located in a region of late Jurassic crustal thickening. The Jiashan Syenite can be divided into three concentrically arranged units, the Jiangjiawan, Longtangou and Longtannangou units, which were intruded sequentially. Geochemically, the Jiashan Syenite has a high Ga/Al ratio (>3), is enriched in silica, alkalis, Fe, REE, Th, Ga, Nb, Zr and Hf, is depleted in Mg, Ba, Sr and Ti and in transition elements such as Cr, Co, Ni and V. The three units of the Jiashan Syenite have Ce/Pb ratios ranging from 6.12 to 13.41 and are enriched in light REE (LREE) with a moderate Eu negative anomaly. The $^{87}Sr/^{86}Sr$ initial ratios range from 0.701409 to 0.707405, with a mean of 0.70379. The $\varepsilon_{Nd}(t)$ values of −2.27 to −5.58 indicate that the magma was probably derived from enriched mantle. The Jiashan Syenite is a post-orogenic intrusion, and can be considered to be an A-type granite. It was emplaced in an environment of lithospheric extension during asthenospheric mantle upwelling. This suggests that the regional compressional shortening and crustal thickening tectonic regime in the Yanshan Orogenic Belt during the Late Jurassic (ca. 135 Ma) changed to lithospheric extension and thinning in the Early Cretaceous.
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1. Introduction

The Yanshan Intracontinental Orogenic Belt is located on the northern margin of the North China Plate and is the eastern part of the greater Yinshan Orogenic Belt, which extends westward ~1100 km from north Bohai Bay to the Baotou in Inner Mongolia, where it becomes concealed beneath the sands and gravels of the Gobi Desert along the Mongolian-Chinese border (Davis et al., 2001). The intraplate Jurassic–Cretaceous Yanshan Belt experienced folding, contractional and extensional faulting, and contemporaneous terrestrial sedimentation and magmatism (Davis et al., 1998). The tectonics of the Yanshan Orogenic Belt has been the focus of intensive study in recent years (Zhao, 1990; Bai et al., 1991, 1999; Mao and Yan, 1992; Deng et al., 1996, 2000; Liu and Shi, 1998; Yan et al., 1998; Shao et al., 1999, 2001; Xu et al., 1999; Zhu et al., 1999; Davis et al., 2001; Li et al., 2001a,b; Zhang et al., 2001a; Qian et al., 2002). Some recent authors propose that the E- to ENE-trending deformation of the Yanshan Belt, involving Archean basement rocks in contractional faulting, indicates a 'thick-skinned' tectonic style, with thrust faults steepening downwards into the basement (Bureau of Geology and Mineral Resources of Hebei Province, 1989; Zhang et al., 1996; Chen, 1998). However, near Chengde

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County in northern Hebei Province Davis et al. (1998, 2001) discovered synformally folded and thin-skinned thrust faults with large displacements.

Mesozoic magmatism and the corresponding tectonic regime in the Yanshan Belt is very complex and has attracted the attention of many geologists. Ren et al. (1980) and Cheng (1994) believed that the Yanshan Belt was a part of the Pacific active continental margin, which was formed by the interaction of the Pacific Plate with the Asia continent, and that magmatic activity occurred in a compressional tectonic setting. Yoshio et al. (1994) and Zhao et al. (1998) propose that magmatic activity was the result of low-angle subduction of the Pacific Plate. Deng et al. (1996) considered that it was due to island-arc volcanic activity formed by the convergence between the North China Craton and the Izanagi oceanic lithosphere. Most geologists (Xu, 1990; Zhao et al., 1994; Zheng et al., 2000; Zhu et al., 1999) think that the formation of the Yanshan tectonomagmatic belt is closely associated with interaction of the Pacific Plate and Eurasian Plate. Davis et al. (1998, 2001), on the other hand, propose that the collision of the Siberian and North China Plates upon closure of a Jurassic and Early Cretaceous Mongolo-Okhotsk Ocean, more than 800–1100 km to the north, may have been responsible for Yanshan north–south compression.

The Yanshan Belt was later overprinted by a magmatic regime related to the westward subduction of the Pacific Plate beneath the North China Plate. Furthermore, Fan and Guo (2005) suggested a new tectonic model, which emphasized that the Yanshan Belt was affected by the interaction of several tectonic plates, including the paleo-Pacific Plate, the Siberian Plate, the Tethyan tectonic domain and the Indo-China Block. These interactions triggered lithospheric extension, asthenospheric upwelling and decompressional melting of enriched mantle sources, and the extensive emplacement of Late Mesozoic magmas. In contrast, Shao et al. (2001), Li et al. (2001a) and Zhang et al. (2001a) suggest that the formation and evolution of Mesozoic magmas was related to underplating by intraplate basaltic magma and was not related to subduction of the Pacific Plate.

Although in previous studies Huang et al. (1977), Ren et al. (1980) and Davis et al. (1998) have suggested that compressional shortening and crustal thickening occurred during Jurassic time in the Yanshan area, during the Cretaceous lithospheric extension and crustal thinning became dominant. When did the tectonic regime change from N–S compression to E–W extension? What is the evidence provided by magmatic activity during this change? These questions are of great interest to the geological community and studies of igneous systems that are associated with lithospheric extension may be important to cast light on these issues.

The Jiashan Syenitic Pluton is close to the Late Jurassic Chengde Thrust Fault, which has a displacement of at least 40–45 km (Zheng et al., 2000; Davis et al., 2001). The Jiashan Syenite with a composition similar to A-type granites was emplaced in a late-orogenic lithospheric extensional environment. It provides an early geological record of lithospheric thinning in the Yanshan Intracontinental Orogenic Belt. Therefore, the study of the Jianshan Syenite Pluton can provide important clues for understanding regional extension and lithospheric thinning processes. Based on detailed field surveys and systematic sampling, combined with petrographic, mineralogical and geochemical studies. In this paper we present the geology and geochemistry of the Jianshan Syenite intrusion and discuss the implications for Early Cretaceous regional lithospheric thinning, post-orogenic extension and the emplacement of A-type granitoids.

2. Geological setting

The Yanshan Belt is an extensive region in eastern Asia on the northern margin of the North China Craton, underlain by 3.8–2.5 Ga Archean basement rocks (Liu et al., 1992). The Archean basement is composed of gneiss, granulite and quartzite and is overlain by a Middle–Late Proterozoic (ca. 1850–800 Ma) shallow-water marine succession with a thickness of up to 10 km. The Phanerozoic rocks in the region comprise Cambrian–Middle Ordovician shallow-marine carbonates; Upper Carboniferous–Lower Permian carbonates and coal-bearing clastics, Upper Permian–Triassic red beds and conglomerates. Jurassic coal-bearing clastics and continental volcano-sedimentary units overlie older units unconformably (Davis et al., 2001). The Cretaceous consists of terrestrial volcanic rocks, volcaniclastic and clastic rocks.

Magmatic activity in the Yanshan Orogenic Belt began ca. 195–185 Ma (Early Jurassic; Bureau of Geology and Mineral Resources of Hebei Province, 1989; Xu, 1990), with most of the granitic plutons being Cretaceous in age (ca. 138–113 Ma, Davis et al., 2001). A few plutons are Late Jurassic and Jurassic–Cretaceous in age (ca. 159–141 Ma, Bureau of Geology and Mineral Resources of Hebei Province, 1989; Xu, 1990; Davis et al., 2001). Mesozoic terrestrial sedimentation, magmatism and deformation, including multiple phases of folding, and strike-slip faulting, characterize the Yanshan fold-and-thrust belt (Davis et al., 2001). The studies by Davis et al. (2001) indicate that Late Jurassic and Early Cretaceous compressional deformation in the Yanshan Belt was much more intense than is generally believed. Five orogenic episodes in the Yanshan Belt are recognised (Deng et al., 2004): 1. Pre- and initial orogenic (Early Jurassic); 2. Early orogenic (Middle Jurassic); 3. Peak orogenic (Late Jurassic); 4. Late orogenic (early Early Cretaceous); and 5. Post-orogenic.

Jurassic tectonic deformation formed the framework for the E–W-trending Yanshan Fold-Thrust Belt (Zhao et al., 2004). Late Jurassic–Early Cretaceous intermediate-felsic volcanic rocks and intrusive rocks have geochemical features typical of adakite in the Yanshan-Liaoning area (Li et al., 2001a; Zhang et al., 2001a,b). Jurassic thrust tectonics and molasse sedimentation are widespread, indi-

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