Journal of Volcanology and Geothermal Research 285 (2014) 170–179

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Two episodes of volcanism in the Wudalianchi volcanic belt, NE China: Evidence for tectonic controls on volcanic activities

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ARTICLE INFO

Article history:
Received 31 March 2014
Accepted 11 August 2014
Available online 23 August 2014

Keywords:
Geomorphology
Geochronology
Volcanic cone alignment
Tectonic control
Wudalianchi
NE China

ABSTRACT

The NNW striking Wudalianchi Cenozoic volcanic belt (WVB) in NE China is mainly composed of volcanoes in Menlu River area, Keluo, Wudalianchi and Erkeshan. K–Ar radiometric dating suggests two episodes of volcanism in the WVB. Specifically, the Pliocene to early Pleistocene volcanism is distributed only in the northern part of WVB, whereas middle Pleistocene to Holocene volcanism occurred over the entire WVB. Geomorphological analyses further delineate four northeast-striking linear alignments of cones in the Wudalianchi and Keluo volcanic fields, probably related to magma feeding fractures with en echelon arrangement. No age progression is observed along these alignments. We propose that a NNW-trending rift may have controlled the eruption from Pliocene to early Pleistocene and a dextral transpression stress field may have influenced the volcanism from middle Pleistocene to Holocene. We suggest that the Pliocene and early Pleistocene volcanism is associated with far effect of the India–Eurasia collision, while the middle Pleistocene to Holocene volcanism in WVB may have resulted from interaction between the India–Eurasia collision and the subduction of the Pacific plate.

1. Introduction

Cenozoic intraplate volcanism produced diverse volcanoes in dispersed volcanic fields of Northeast China (Fig. 1), constituting the eastern part of the Asian tectono-magmatic province that extends from Lake Baikal, Siberia to eastern China (Barry and Kent, 1998). Among these Cenozoic volcanic fields, the Wudalianchi volcanic belt (WVB for short) in NE China, with the latest manifestation of potassic volcanism in the world (the historic eruption 1719 AD–1721 AD), has drawn more and more attention because of its unique geochemical and petrological features. The Wudalianchi volcanic rocks belong to a series of ultrabasic–intermediate, alkaline–peralkaline potassium-rich rocks (Qiu et al., 1988). Three types of volcanic rocks are identified: olivine leucitite, leucite basanite and trachybasalt (Zhang et al., 1995). The Wudalianchi volcanic rocks are characterized by strong enrichments of K, light rare earth elements (REE) and large ion lithophile elements, strongly fractionated heavy REE and EM1-like Sr–Nd–Pb–Hf isotopes (Zhang et al., 1995; Zou et al., 2003; Chu et al., 2013).

Despite intensive studies carried out the WVB, the origin of the Wudalianchi volcanoes is still a matter of considerable debate. With respect to the mantle source, both asthenosphere and sub-continental lithospheric mantle (SCLM) have been proposed as the potential sources for these unique magmas (Zhang et al., 1995; Zou et al., 2003; Chu et al., 2013; Kuritani et al., 2013). The generation of these basalts have been variously ascribed to mantle plume arising from the mantle transition zone (Qiu, 1989; Deng et al., 1998; Kuritani et al., 2013), asthenosphere upwelling as a result of subduction and stagnancy of the Pacific slab in the transition zone under the east Asian continent (Tatsumi et al., 1990; Basu et al., 1991; Zou et al., 2003; Lei and Zhao, 2005; Wang and Chen, 2005; Zou et al., 2008; Zhao and Liu, 2010); and lithospheric extension (Zhang et al., 1995; Fan et al., 1999; Shao and Zhang, 2008).

In the Wudalianchi area, geochemical studies are inevitably influenced by the complex structure of the mantle beneath the volcanic field (Chu et al., 2013). Accordingly, instead of undertaking additional geochemical analyses, here we focus on the geochronology and geomorphology of the Wudalianchi volcanic belt (WVB). The objectives of this study are (1) to define the spatial and temporal distribution of volcanoes in WVB; (2) to identify episodes of volcanism; and (3) to assess the tectonic control on volcanism.

2. Geological setting

The NE China is located between the North China Craton and the Siberia Craton. This region belongs to the eastern part of the Xingmeng Orogen, which forms the eastern part of the Central Asian Orogenic Belt or Altaid (Jahn et al., 2000). NE China is composed of three

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http://dx.doi.org/10.1016/j.jvolgeores.2014.08.016
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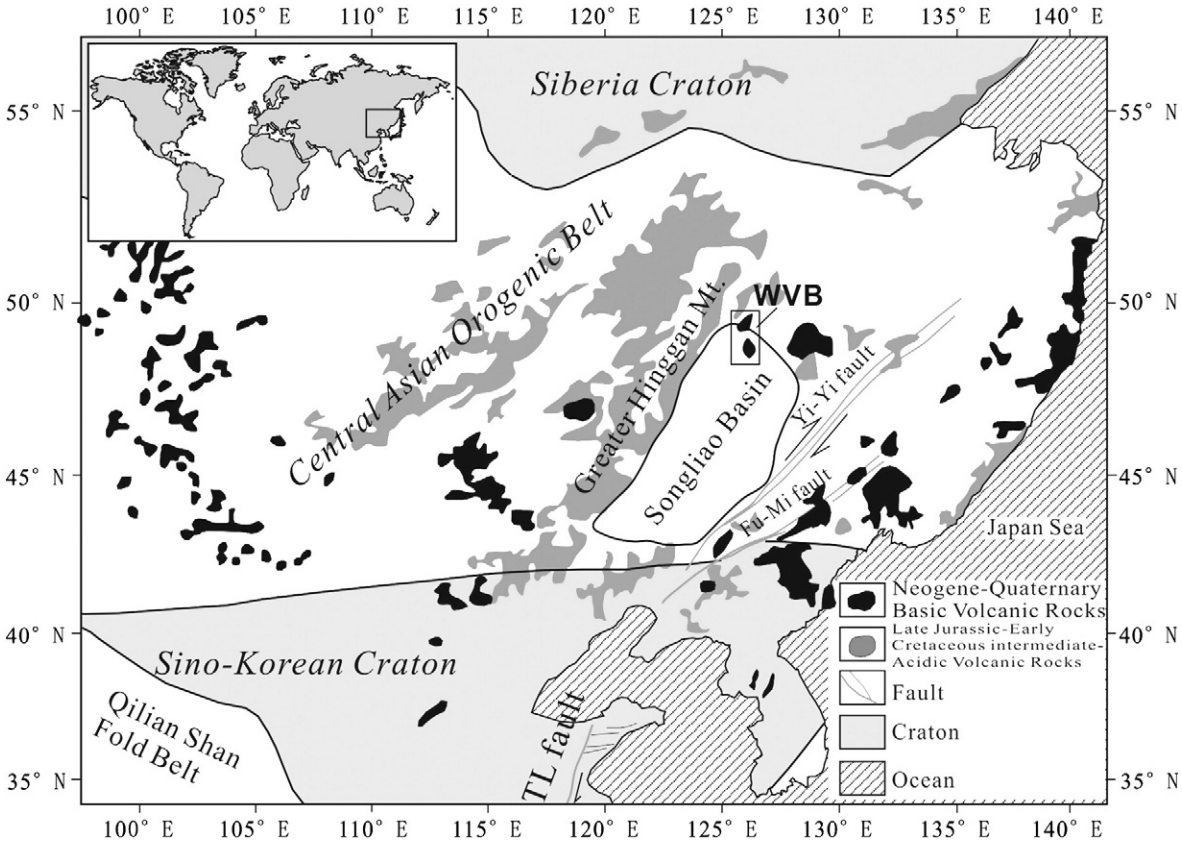

Fig. 1. Distribution of Cenozoic volcanic rocks in NE Asia.
Modified from Ren et al., 2002.

microcontinental blocks, including the Jiamusi block, the Songliao block and the Xing'an block (Wu et al., 2001). The Xing'an (Hinggan) block and the Songliao block are separated by the Nenjiang faults. The basement rocks in the study area are composed of sandstone, mudstone and biotite granites. The Cretaceous sedimentary formation is composed of interbeded mudstone, shale, and sandstone of lacustrine origin. The upper Paleogene alluvial and lacustrine formation includes mudstone, sandstone, and conglomerate (Feng and Whitford-Stark, 1986). The biotite granites were emplaced as small intrusions during the Yanshan orogenic episode.

The Late Mesozoic–Cenozoic volcanism in NE China can be grouped into 4 episodes: 86–39 Ma, 28–16 Ma, 16–7 Ma, and 4.5 Ma–present (Liu et al., 2001). During the first episode (86–39 Ma), N–S extension created by Pacific plate subduction beneath Eurasian continent may produce E–W fault belt and volcanism in the southern Songliao graben. During the second episode (28–16 Ma), alkali basalts dominate the eruptions in Yi–Yi and Fu–Mi faults (the north part of Tan-Lu fault system), which is very likely induced by India-Eurasia collision. During the third episode (16–7 Ma), intensive alkalic volcanism occurred around the east, west and northeast flanks of the Songliao basin, which may be related to cessation of Japanese Sea spreading. During the last episode (4.5 Ma to present), volcanism is widespread in small-sized locations. Tholeiitic eruptions mainly occurred in river valleys whereas olivine basalts and basanite erupted in the mountainous areas. Specifically in the Quaternary, volcanism in NE China varied with different volcanic fields. In Tianchi volcano of Changbai Mountain (i.e., Changbaishan volcano), bimodal volcanism generated basalts and pantellerite which constructed a giant stratovolcano (Liu et al., 1998; Zou et al., 2010, 2014). However, other Quaternary volcanic fields from NE China, including the Wudalianchi volcanic field, are dominated by alkaline-basaltic monogenetic volcanism (Wei et al., 1999, 2003; Chen et al., 2003; Zhao et al., 2013).

The volcanoes in the Wudalianchi region form a NNW-trending potassic volcanic belt (Wudalianchi volcanic belt, abbreviated as WVB in this paper). The WVB consists of four main volcanic fields (Wudalianchi, Keluo, Erkeshan, and Menlu River) and two isolated volcanoes (Jianshanzi volcano and Jianshan volcano) (Fig. 2). The WVB is located in the north edge of the Songliao basin, an intra-continental rift-depression developed during the late Jurassic to early Cenozoic (Heilongjiang Bureau of Geology and Mineral Resources, 1993). To the west, the WVB is bounded by the Nenjiang fault and Greater Hinggan Mts. To the east, the WVB belt is bounded by the early Cretaceous–middle Cenozoic Sunwu graben where NE-striking normal faults and fractures were developed (Heilongjiang Bureau of Geology and Mineral Resources, 1993).

More than 80% of the volcanic cones in the WVB are distributed in Wudalianchi and Keluo fields. The Wudalianchi volcanic field (125°45′–126°30 in longitude and 48°30′–48°50′ in latitude) is located at the north bank of Nemuoer River, and consists of twenty volcanoes with volcanic rocks covering an area of about 800 km^2 near the city of Wudalianchi (Fig. 3). The Keluo volcanic field (125°30′–126°15′in longitude, 49°10′–49°30′ in latitude) is located near the Keluo River in the Nenjiang County. Sixteen volcanoes have been identified in this field which covers an area of about 350 km^2 (Fig. 4). The volcanic rocks in different fields of the WVB exhibit similar petrological and geochemical characteristics, indicating that these volcanoes shared a common mantle source and experienced similar extents of magma evolution (Zhang et al., 1995; Chu et al., 2013).