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Structural control on the shape of intrusions in the Koktokay ore district, Chinese Altai, north western China

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ABSTRACT

The Koktokay pegmatite-type rare-metal-bearing ore district in the Altai orogen is famous for both its large scale and its diversity of rare metals. However, the emplacement mechanisms of the ore-bearing pegmatite intrusions in the Koktokay ore district are still unclear. Based on field observations, the emplacement of the ore-bearing pegmatite intrusions falls into two types. The first type is typical of the formation of dykes and sills, whereby they intruded into fan shaped, moderate dipping, joints within plutonic rocks. The second type involves the formation of a punched laccolith that was fed by a pegmatite sill. Magmatic stoping is the main mechanism of the laccolith emplacement. The peripheral faults played an important role in helping the emplacement of the laccolith. The trend of dykes and sills indicate two potential prospecting areas, which are located in the western and northern regions of the Koktokay ore district.

1. Introduction

Rare metals are important mineral resources, the strong demand for which has stimulated continuous research aimed at furthering prospecting efforts. Rare metals are usually found within granite-pegmatite intrusions and many mineralogical and geochemical studies of rare-metal-bearing granite pegmatites have been carried out over recent decades. These studies have focused mainly on petrogenesis, genetic mineralogy, the geochemical origin of granite-pegmatite melts, and the processes of rare-metal enrichment (Cerný et al., 1985; London, 1986a, 1986b, 1992, 2009; Stern et al., 1986; Cerný, 1991a, 1991b; Alfonso et al., 2003; Roda et al., 2004; Galliski and Cerný, 2006).

Analyses of the structure of magmatic intrusions provides an important way of tracing magma sources and ore bodies at depth (Jolly and Sanderson, 1995; Petford et al., 2000; Bons et al., 2001; Paquet et al., 2007), understanding mechanisms of magmatic emplacement (Brown and Solar, 1999; Burchardt, 2009; Tian and Shan, 2011), as well as vital data to unravel the tectonic evolution of these areas (Paterson et al., 1989; Henderson and Ihlen, 2004; Demartis et al., 2011; Skarmeta, 2011). In addition, structural studies on dykes and sills are essential for determining the magma flow directions as well as regional paleostress fields (Pollard, 1973; Delaney et al., 1986; Rubin, 1995; Hoek, 1991; Hou, 2012).

Although the pegmatite intrusions in the Koktokay ore district have been shown to contain rare metal (Zou et al., 1986), the mechanism of intrusion emplacement is still unclear. In addition, very little is known about where to find potential ore bodies within this ore district. Therefore, research on the structures of the Koktokay ore district is of economic importance.

The emplacement of dykes can be categorized into two ways: self-propagating dyke-fractures (Lister and Kerr, 1991; Spence and Turcotte, 1985) and dyke intrusion into previously fractured rocks (Nicholson and Pollard, 1985; Hoek, 1991; Martínez-Poza et al., 2014). Sills, on the other hand, are usually emplaced by intruding along stratifications, pre-existing planes between sedimentary or volcanic beds, or weakened planes related to foliation in metamorphic rock (Johnson and Pollard, 1973; Hyndman and Alt, 1987; Kavanagh et al., 2006; Burchardt, 2008; Galland et al., 2009; Schofield et al., 2012). We will address the mechanisms of dyke emplacement in the Koktokay district and will analyse how the sills

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formed. As well as the dykes and pegmatite sills, a pegmatite laccolith can also be found in the Koktokay district. This study pays particular attention to the question of how intrusions with different shapes formed simultaneously in the same region.

In this article, we attempt to address these questions in order to further our understanding of what factors control the structures and formation of shallow-level intrusions, as well as provide useful information to aid future resource prospecting of the deep and peripheral underground pegmatite intrusions in the Koktokay district.

2. Geological setting

2.1. The Chinese Altai orogen

The WNW–ESE trending Chinese Altai orogen, which belongs to the Central Asian Orogenic Belt, lies between the southwestern edge of the Siberia plate and the northern edge of the Kazakhstan–Junger plate (Fig. 1a; Sengör et al., 1993; Windley et a1., 2002; Xiao et al., 2004). The Chinese Altai orogen, which was produced by accretion of island arcs, oceanic islands, seamounts, accretionary wedges, oceanic plateaus, and microcontinents, formed during subduction that persisted from the Precambrian to the Devonian (Windley et a1., 2007; Xiao et al., 2004; Briggs et al., 2007). Devonian back-arc extension and subsequent collision indicated the end of the main orogenesis in the Chinese Altai (Xiao et al., 2004, 2008, 2009; Buslov et al., 2004; Wang et al., 2006; Zheng et al., 2007; Yuan et al., 2007). The intrusion of I, I-A, and A type granites, which indicate a post-collisional environment, followed the main stage of orogenesis (Li et al., 2003; Wang et al., 2006; Yuan et al., 2007; Tong et al., 2007; Wang et al., 2010). Horizontal NNE–WSW trending compressional stress ($\sigma 1$), in response to prolonged subduction and collision, facilitated the formation of WNW–ESE trending folds and faults (Fig. 1b; e.g., the Irtysh fault and Qinghe–Halong anticline; Liu et al., 2013) as well as the denudation of the geologic units (including magmatic intrusions and stratum) in the Chinese Altai orogen (Zhang and Zheng, 1993; Wang and Xia, 2005). From the Mesozoic onwards, the Chinese Altai orogen entered a relatively stable evolutionary stage (Li and Polyansky, 2001).

2.2. The Koktokay ore district

The 500 km long and 40–80 km wide Altai pegmatite belt is located in the Chinese Altai orogen. It is comprised of many isolated pegmatite fields (each field is marked with dashed circles in Fig. 1b; Zou and Li, 2006). Some of the pegmatite intrusions in the pegmatite belt, particularly the rare-metal-bearing intrusions, are rich in Li, Be, Nb, and Ta (Zou et al., 1986; Luan et al., 1995).

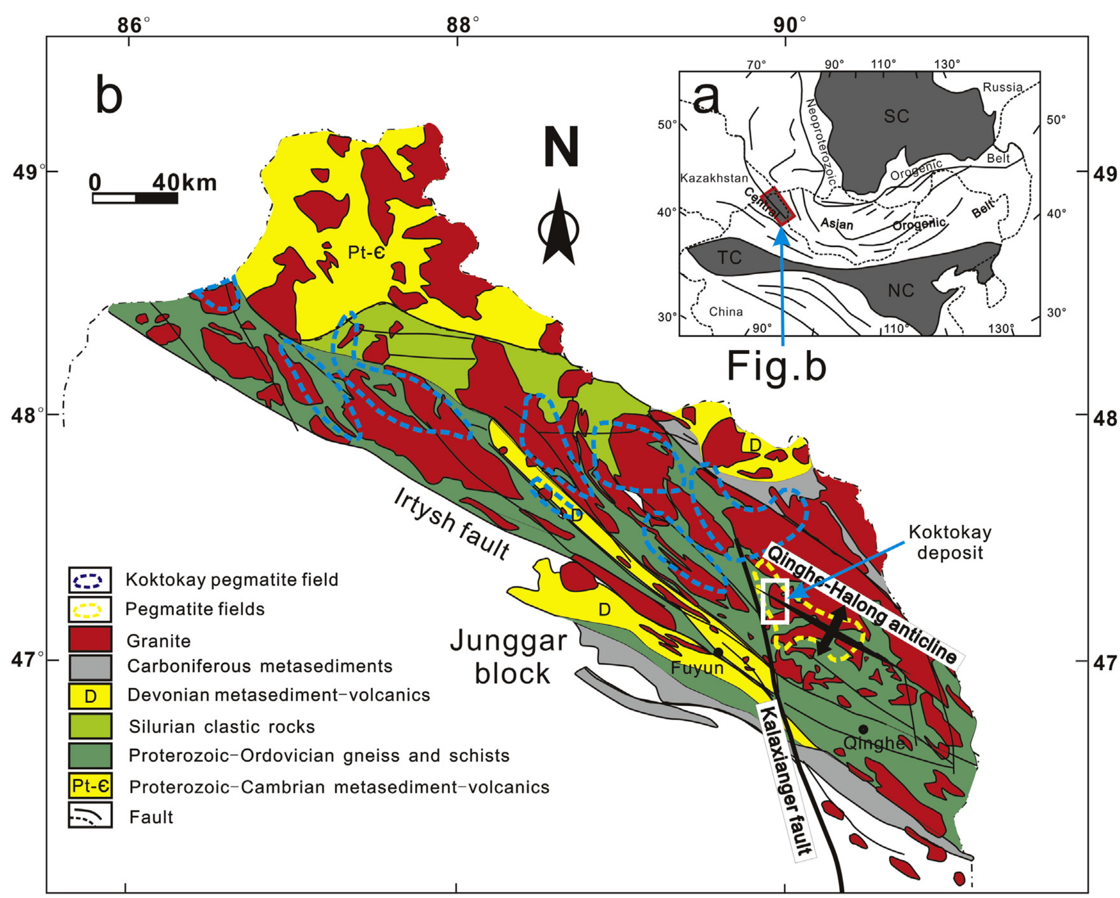

Fig. 1. a) The location of the Chinese Altai orogen within the Central Asian Orogenic Belt. b) Regional geological map with the study area highlighted. A series of NW–SE trending structures dominate the Chinese Altai orogen. Dashed circles indicate pegmatite fields of concentrated pegmatite intrusions. These fields comprise the entire Altai Pegmatite Belt. The Koktokay pegmatite field is marked with yellow dashed line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)