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Research paper

Textures and mineral compositions of the Xinjie layered intrusion, SW China: Implications for the origin of magnetite and fractionation process of Fe-Ti-rich basaltic magmas

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A B S T R A C T

The Xinjie layered intrusion in the Panxi region, SW China, hosts both Fe-Ti oxide and platinum-group element (PGE) sulfide mineralization. The intrusion can be divided, from the base upward, into Units I, II and III, in terms of mineral assemblages. Units I and II are mainly composed of wehrlite and clinopyroxenite, whereas Unit III is mainly composed of gabbro. PGE sulfide-rich layers mainly occur in Unit I, whereas thick Fe-Ti oxide-rich layers mainly occur in Unit III. An ilmenite-rich layer occurs at the top of Unit I. Fe-Ti oxides include magnetite and ilmenite. Small amounts of cumulus and intercumulus magnetite occur in Units I and II. Cumulus magnetite grains are commonly euhedral and enclosed within olivine and clinopyroxene. They have high Cr_2O_3 contents ranging from 6.02 to 22.5 wt.%, indicating that they are likely an early crystallized phase from magmas. Intercumulus magnetite that usually displays ilmenite exsolution occupies the interstices between cumulus olivine crystals and coexists with interstitial clinopyroxene and plagioclase. Intercumulus magnetite has Cr_2O_3 ranging from 1.65 to 6.18 wt.%, lower than cumulus magnetite. The intercumulus magnetite may have crystallized from the trapped liquid. Large amounts of magnetite in Unit III contains Cr_2O_3 (<0.28 wt.%) much lower than magnetite in Units I and II. The magnetite in Unit III is proposed to be accumulated from a Fe-Ti-rich melt. The Fe-Ti-rich melt is estimated to contain 35.9 wt.% of SiO_2, 26.9 wt.% of FeO^t, 8.2 wt.% of TiO_2, 13.2 wt.% of CaO, 8.3 wt.% of MgO, 5.5 wt.% of Al_2O_3 and 1.0 wt.% of P_2O_5. The composition is comparable with the Fe-rich melts in the Skaergaard and Sept Iles intrusions. Paired non-reactive microstructures, granophyre pockets and ilmenite-rich intergrowths, are representative of Si-rich melt and Fe-Ti-rich melt, and are the direct evidence for the existence of an immiscible Fe-Ti-rich melt that formed from an evolved ferrobasaltic magma.

1. Introduction

Layered mafic-ultramafic intrusions in the Panxi region, SW China, such as the Panzhihua, Hongge and Baima intrusions, are parts of the ~260 Ma Emeishan large igneous province (ELIP) (inset in Fig. 1) (Zhou et al., 2002, 2005, 2008). These layered intrusions are volumetrically small relative to the world-known layered intrusions such as the Bushveld Complex in South Africa, the Sept Iles intrusion in Canada, the Bjekreim-Sokndal intrusion in Norway and the Skaergaard intrusion in Greenland (Namur et al., 2010 and references therein). However, a distinct feature of the intrusions in the Panxi region is that large volumes of Fe-Ti oxide ores occur in the middle to lower parts of the intrusions. For example, massive oxide ore bodies in the basal part of the Panzhihua intrusion are up to 60 m in thickness (Zhou et al., 2005), much thicker than the laterally extensive magnetite-rich layers in the Bushveld Complex and the Sept Iles intrusion (Cawthorn and Molyneux, 1986; Lee, 1996; Higgins, 2005). How such large amounts of Fe-Ti oxides were accumulated in the layered intrusions in the Panxi region is enigmatic. Possible mechanisms proposed to explain the origin of

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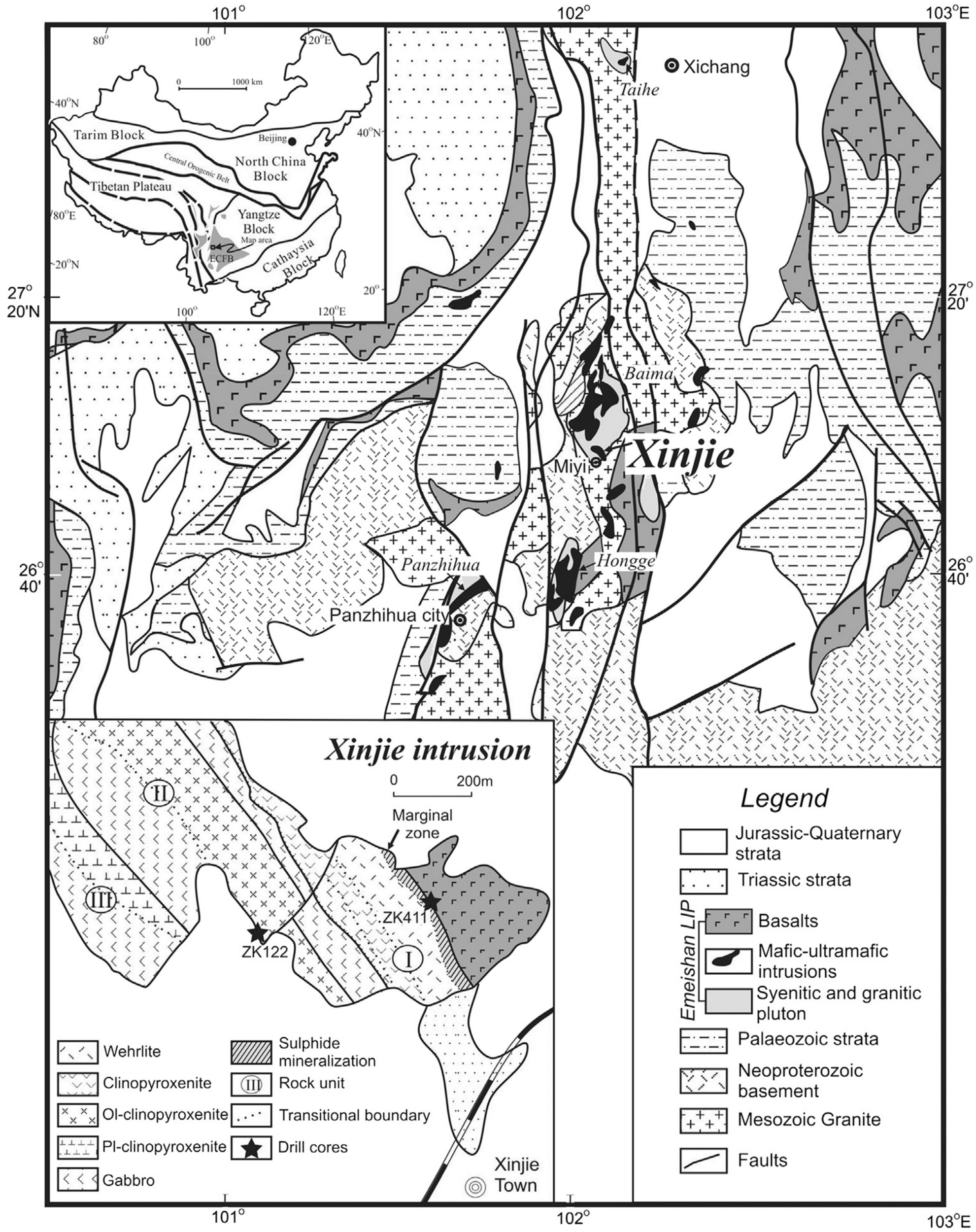

Figure 1. Geological map showing the distribution of the Xinjie intrusion in the Panxi region, SW China (after Zhou et al., 2002; Zhong et al., 2004). Inset on the top left corner showing the location of the Emeishan large igneous province and inset on bottom left corner showing the sequence of the Xinjie intrusion (after Zhou et al., 2002) and the locations of drill cores ZK411 and ZK122 (modified after PXGT, 1981).

the Fe-Ti oxide ore bodies in the Panzhihua intrusion include the formation of immiscible oxide melt in silicate magmas (Zhou et al., 2005), and settling and sorting of early cumulus Fe-Ti oxides (Pang et al., 2008a). In recent studies, liquid immiscibility in the evolved tholeiitic magmas is proposed to explain the formation of Fe-Ti-rich liquids in the Sept Iles and Skaergaard intrusions (Veksler et al., 2007; Charlier et al., 2011; Holness et al., 2011; Namur et al., 2012). A main issue that is debated for the origin of the layered intrusions in the Panxi region is the composition of Fe-Ti-rich melt for individual intrusion if an immiscible Fe-rich melt is applicable for these intrusions.

Unlike the Panzhihua intrusion, the Hongge and Xinjie intrusions in the Panxi region contain an ultramafic portion with minor amounts of Fe-Ti oxides in the lower part of the intrusion and a gabbro portion with large amounts of Fe-Ti oxides in the upper part. Cumulus magnetite enclosed in olivine and clinopyroxene in the ultramafic portion of the Xinjie intrusion contains very high Cr_2O_3 (up to 28 wt.%) and was interpreted as an early crystallized phase (Wang et al., 2008). The occurrence of Fe-Ti oxide-rich layers in the gabbro portion of the Xinjie intrusion is comparable with the main Fe-Ti oxide ore bodies at the basal part of the Panzhihua intrusion although the Xinjie intrusion contains lower amounts of Fe-Ti oxides. Thus, the fractionation processes of magmas that led to the formation of the large amounts of Fe-Ti oxides in the upper part of the Xinjie intrusion may throw some light on the formation of massive ore bodies in the basal part of the Panzhihua intrusion.

Previous studies proposed that the Xinjie intrusion may have formed by multiple pulses of magma replenishment due to the presence of rhythmic modal layers (Zhong et al., 2004, 2011).