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Geology, geochemistry, and geochronology of the Dunde iron–zinc ore deposit in western Tianshan, China

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ABSTRACT

The Dunde iron–zinc deposit (185 Mt at 35% Fe), located in the Tianshan orogenic belt, Xinjiang, northwest China, is hosted in late Carboniferous volcanic–volcaniclastic rocks characterized by prograde skarn formation and retrograde alteration, but the ore lacks any clear spatial link with intrusive rocks. Four stages of skarn formation and ore development can be recognized: (1) a prograde skarn stage that formed grossularitic garnet ($Gr_{39–80}$; $Ad_{15–58}$) and diposidic pyroxene ($Di_{63–97}$); (2) a retrograde skarn stage dominated by the formation of magnetite with minor epidote, ferropargasite, apatite, hematite, and trace amounts of titanite and spinel; (3) a sulfide stage dominated by the formation of arsenide (loellingite and arsenopyrite) and sulfide minerals (sphalerite, pyrrhotite, pyrite, chalcopyrite, and minor galena), calcite, and traces of quartz; and (4) a chlorite–calcite stage mainly characterized by the formation of chlorite, calcite, and traces of sericite. Exsolution of droplet-like and patchy chalcopyrite is developed within sphalerite of the sulfide stage, indicating an exsolution temperature of 350–400 °C. As such, the crystallization temperature of early stage magnetite may have been >400 °C. Abundant fluid inclusions occur in calcite, which include daughter-mineral-bearing H_2O, H_2O, and pure H_2O inclusions. The H_2O inclusions have a wide range of homogenization temperatures from 147 °C to 367 °C with salinities of 2.4–23.4 wt.% NaCl equivalent. The daughter-mineral-bearing H_2O inclusions have homogenization temperatures from 172 °C to 347 °C with salinities of 31.9–33.0 wt.% NaCl equivalent. Using the chlorite geothermometer, the temperature of chlorite formation is constrained to be between 152 °C and 222 °C (average = 194 °C). Sulfur isotope compositions of pyrrhotite, sphalerite, pyrite, and loellingite have a narrow range of $\delta^{34}S$ values from 3.8‰ to 8.1‰ (average $\delta^{34}S$ = 6.8‰), suggesting that the sulfur was magmatic-derived. Zircon LA–ICP-MS U–Pb dating of wall rock dacite yields a weighted mean $^{206}Pb/^{238}U$ age of 316.0 ± 1.7 Ma. Combined with previous dating results of magnetite-mineralized diorite stocks, diorite dikes, and garnet skarn, it can be inferred that the Dunde iron–zinc deposit formed in the late Carboniferous after 316 Ma and is genetically related to deep dioritic intrusions. During the late Carboniferous, the tectonic setting of this region changed from subduction–collision to extension, accompanied by mantle-derived magma underplating in deep. After the formation of the iron–zinc ore deposit, the Dunde district was intruded by an early Permian K-feldspar granite that yields a zircon LA–ICP-MS U–Pb age of 295.75 ± 0.71 Ma.

1. Introduction

The Central Asian Orogenic Belt (CAOB) is the world's largest Phanerozoic accretionary orogen and crustal growth region (Fig. 1a) (Gao et al., 2009a,b; Jahn et al., 2000; Mao et al., 2004, 2005, 2008; Sengör, 1993; Windley et al., 2007; Xiao et al., 2008), and is also an ideal region for studying mineralization related to accretionary processes (Xiao et al., 2009; Zhang et al., 2012b). Marine volcanic-hosted iron ore deposits are one of the most important mineralization types of the CAOB (Chen et al., 2008; Yang et al., 2012, 2013; Zhang et al., 2012b), such as the Kachar and Davydovo in Turgay (Belevtsev, 1982); Anzas, Mengku and Abagong in Altai-Sayan (Belevtsev, 1982; Chai et al., 2013; Xu et al., 2010; Yang et al., 2012); Chagangnuoer, Zhibo and Yamansu in Chinese Tianshan (Hong et al., 2012a, 2012b, 2012c; Hou et al., 2013; Jiang et al., 2012a, 2012b; Zhang et al., 2012b, 2012c). Lots of marine volcanic-hosted iron deposits and occurrences were discovered in the 1970s in the Chinese Tianshan along the southwestern margin of the CAOB (Chen et al., 2008; D.H. Wang et al., 2006, 2007). Since then, iron ore exploration in the Chinese Tianshan has experienced a

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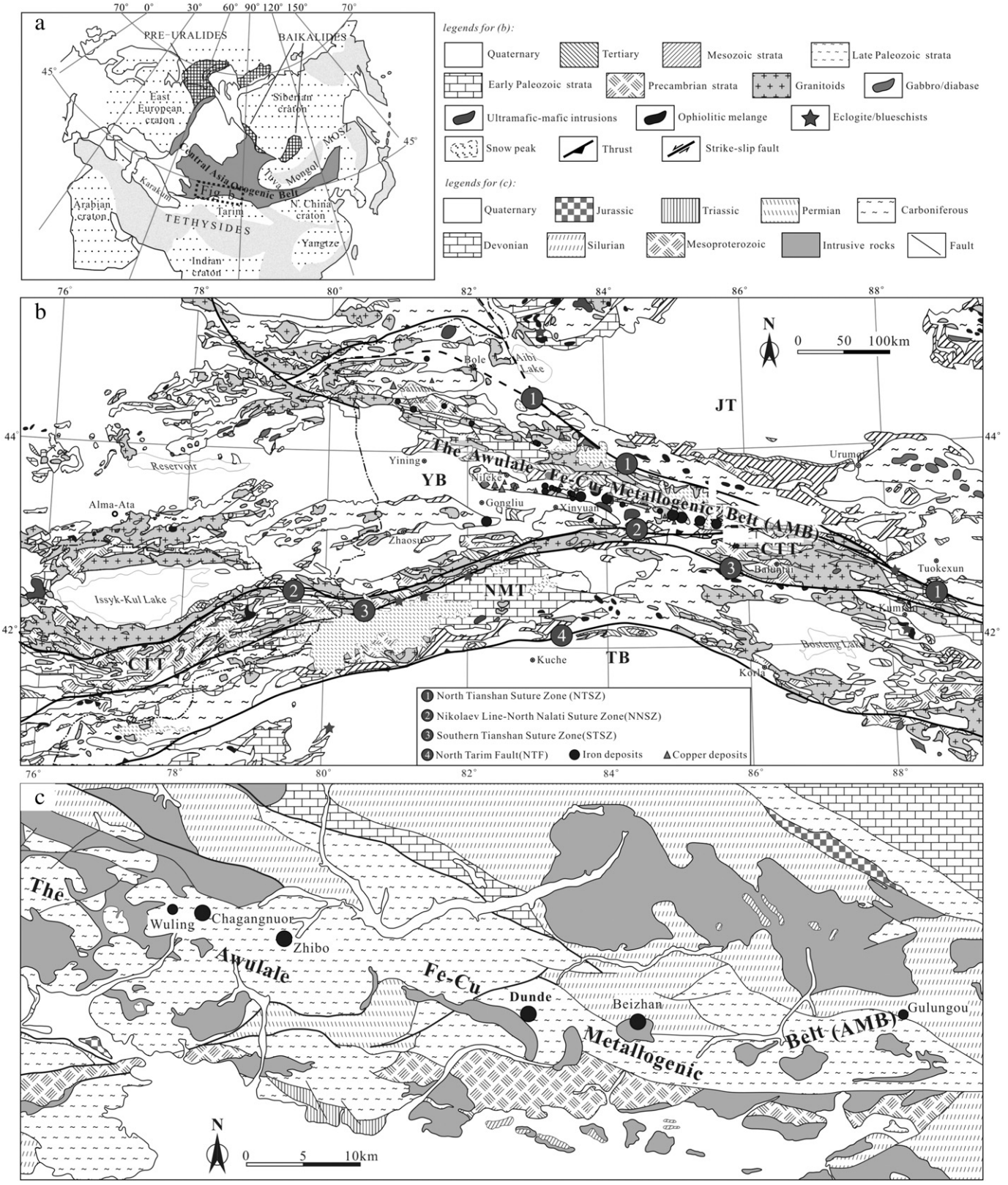

Fig. 1. (a) Simplified Central Asia Orogenic collage and adjacent structures (modified after Yakubchuk, 2004). (b) Geological map of the Chinese western Tianshan and adjacent region (modified after Gao et al., 2009a). (c) Geological map of the eastern segment of the Awulale Metallogenetic Belt showing the locality of iron deposits (modified after Zhang et al., 2012b).

resurgence with the beginning of a new phase of iron prospecting in 2004. This recent exploration has resulted in the discovery of the Songhu iron deposit in 2005, the Zhibo iron deposit in 2006, the Dunde iron–zinc deposit in 2007, and the Wuling iron deposit in 2008, all in the Awulale iron metallogenic belt (AIMB) in western Tianshan Mountains (Fig. 1b). Many prominent magnetic anomalies were