

Chapter 2

Regional Geology

2.1 Geological Background

The CAOB is a well-known Phanerozoic juvenile orogenic belt (Zonenshain et al. 1990; Sengör et al. 1993), composed of fragments of Precambrian microcontinents, Paleozoic island arcs, ophiolites, and successions of volcanic rocks (Jahn et al. 2000, 2004; Xiao et al. 2004, 2009; Windley et al. 2007; Sun et al. 2008). The Tarim Basin, located to the south of the CAOB (Fig. 2.1a), is bounded by the Tianshan Mountains to the north and west, and the West Kunlun and Altun Mountains to the south. A Precambrian basement composed of Archean and Proterozoic crystalline rocks is overlain by a thick sedimentary sequence (BGMRXUAR 1993). Drilling activities in the Tarim Basin have revealed that the basin is underlain by Permian basalts at a depth of about 200 m. The basalts occupy a minimum area of 200,000 km² and have tens to hundreds of meters of thickness (Yang et al. 2005; Chen et al. 2006). It is worthy to note that the defined basalt field represents the minimum distribution in the basin. Some mafic dikes, mainly syenites, occur on the margins of the basin, such as Bachu and Yingmai intrusions (Chen et al. 1999; Zhang et al. 2008a, 2010; Zhou et al. 2009). The detailed descriptions of the volcanic and intrusive rocks in the Tarim Basin are available elsewhere (e.g., Chen et al. 2006; Yang et al. 2007; Li et al. 2008; Zhang et al. 2008a; Zhou et al. 2009; Tian et al. 2010).

2.2 Eastern Tianshan and Mafic-ultramafic Intrusions

The Eastern Tianshan is situated along the southern margin of the CAOB (Fig. 2.1b) and is one of the most important Ni–Cu metallogenic provinces in China (Qin et al. 2003, 2009). It encompasses Bogeda-Haerlike Mountains in the north, Jueluotage Tectonic Belt in the center and Middle Tianshan (named ‘Central Tianshan’ in some literatures) Terrane in the south, all of which are separated by several major faults (Fig. 2.2). Many subsidiary faults are also well developed

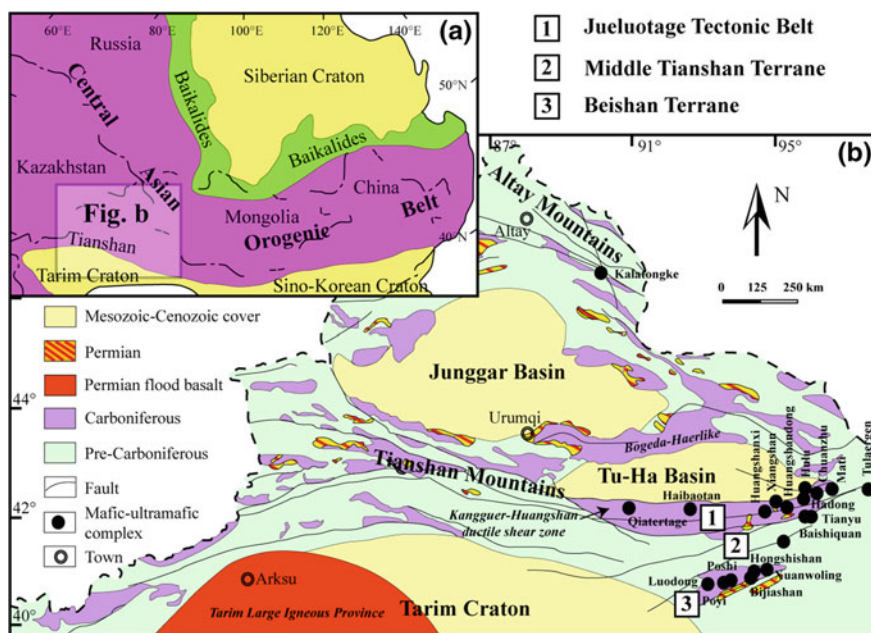


Fig. 2.1 **a** Geologic map of the study area, showing the location of the Siberian, Tarim and Sino-Korean Cratons in relation to the Central Asian Orogenic Belt (modified after Jahn et al. 2000). **b** Regional geological map showing the distribution of mafic-ultramafic intrusions in NW China (modified after Qin et al. 2002, 2003; Xu et al. 2009). Note that many unnamed intrusions are not shown on the map

within each tectonic unit, along which Late Paleozoic mafic-ultramafic intrusions are commonly distributed. The Bogeda-Haerlike Belt is made up of well developed Ordovician-Carboniferous volcanic rocks, granites and mafic-ultramafic complexes (BGMRXUAR 1993; Fang 1993; Gu et al. 2001; Li 2004; Li et al. 2006a, b). Located in the southeastern margin of the Bogeda-Haerlike Belt is the Heishanxia mafic-ultramafic complex (Fig. 2.2), which consists of peridotite, olivine/plagioclase pyroxenite, gabbro and diorite.

The Jueluotage Belt is characterized by Middle Paleozoic volcanic and sedimentary strata, including subaerial volcanics, sandstones and pelitic slates with inter-layered limestones, mudstones, siltstones and conglomerates. The belt can be subdivided, from north to south, into Wutongwozi-Xiaorequanzi intra-arc basin, Dananhu-Tousuquan island arc, Kangguer-Huangshan ductile shear zone and Yamansu backarc basin (Fig. 2.2; Qin et al. 2002). The Carboniferous strata along the Kangguer-Huangshan ductile shear zone were subjected to low grade metamorphism and exhibit cleavage-like layering planes. Carboniferous-Permian magmatism was active in this zone and resulted in the emplacement of copper- and gold-rich, high-potassium, relatively oxidized, calc-alkaline to alkali magmas (BGMRXUAR 1993; Qin et al. 2002, 2003; Xu et al. 2009). Abundant mafic-

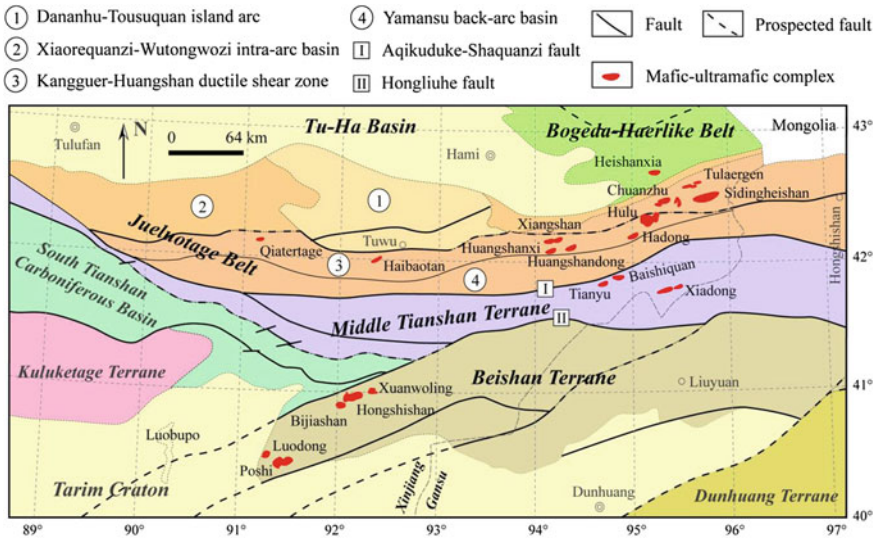


Fig. 2.2 Geological map of the Eastern Tianshan and Beishan showing the tectonic units and distribution of mafic-ultramafic intrusions (modified after Xu et al. 2009)

ultramafic complexes are distributed mainly along deep fractures in the Kangguer-Huangshan ductile shear zone (Fig. 2.2), and are mostly explored for magmatic Ni-Cu sulfide deposits. They generally occur as east-west trending sills or dykes with areal extent of less than 3 km². The Sidingheishan complex, situated in the eastern part of the Jueluotage Belt, is relatively large in area (5 km²) and has been interpreted to be a layered intrusion (Xu et al. 2006). These mafic-ultramafic complexes have rock assemblage of mainly amphibole/pyroxene peridotite, olivine/amphibole pyroxenite, hornblende/olivine gabbro, and diorite. These complexes are variably altered, usually containing hydrous minerals such as hornblende and biotite (Zhou et al. 2004; Chai et al. 2008; Sun et al. 2007; Tang et al. 2009, 2011, 2012). In particular, the Xiangshan complex contains outcrops of ilmenite-mineralized gabbros, associated with Ni-Cu sulfide deposit (Wang et al. 2009; Xiao et al. 2010). Nickel-Cu sulfide ore bodies are mostly hosted by ultramafic units and occur as massive, densely disseminated, and sparsely disseminated textures (Mao et al. 2008; Qin et al. 2002). Re-Os dating of the sulfide ores and zircon U-Pb dating indicate that the mafic-ultramafic intrusions were formed at 270–298 Ma (Han et al. 2010; Qin et al. 2011).

The Middle Tianshan Terrane is comprised of Precambrian crystalline basement including metamorphic granites, granitic gneisses and biotite schists of the Mesoproterozoic Xingxingxia and Kawabulak formations (BGMRXUAR 1993; Qin et al. 2002), and bounded by the Aqikekuduke-Shaquanzi fault in the north and the Hongliuhe fault in the south (Fig. 2.2). Permian mafic-ultramafic complexes, including the Tianyu, Baishiquan and other mafic bodies, are distributed along the northern margin of the Middle Tianshan Terrane (Fig. 2.2). These

complexes are very similar to those in the Jueluotage Belt with respect to petrology, mineralogy and mineralization, and usually display strong alteration in their Ni–Cu sulfide ore-bearing rocks (Mao et al. 2006, 2008; Chai et al. 2008; Tang et al. 2009, 2011, 2012). The rock types present in the intrusions are mainly peridotite, olivine pyroxenite, gabbro and diorite, and all these rocks contain biotite and hornblende. Both peridotite and olivine pyroxenite are the host rocks of the Ni–Cu sulfide ores (Chai et al. 2008; Tang et al. 2009; Song et al. 2011). The Tianyu ore deposit is currently being mined, and exploration work is ongoing on the Baishiquan intrusion.

2.3 Beishan Terrane and Mafic-ultramafic Intrusions

The Beishan Terrane, a junction between the Tarim Basin and the Eastern Tianshan, is located northeast of the Tarim Basin and bounded by the Dunhuang and Middle Tianshan terranes (Fig. 2.2; BGMRXUAR 1993; Xu et al. 2009). Fault-related uplifts and sags are well developed in the rift, and the contact between each pair of strata from Precambrian to Permian is separated by faults (Xu et al. 2009). The Permian mafic–ultramafic complexes discovered so far are mainly distributed in the western part of the terrane, and intrude the Proterozoic and Carboniferous strata (BGMRXUAR 1993; Jiang et al. 2006; Xu et al. 2009). Their country rocks mainly include marble, biotite-quartz schist and pyroclastic rocks. In recent years, the active exploration works revealed that the Ni–Cu mineralization potential is promising. These intrusions have outcropping area of less than 15 km², and are markedly fresh, characterized by the presence of troctolite and low/no modal abundance of hydrous minerals, and are the sib of active exploration for Ni–Cu sulfide deposits (Jiang et al. 2006; Ao et al. 2010). They commonly have rock assemblage of plagioclase-bearing peridotite, troctolite, olivine pyroxenite, olivine gabbro, gabbro and diorite (Jiang et al. 2006; Ao et al. 2010), and are usually associated with coeval felsic rocks such as rhyolites and granites. Zircon U–Pb dating of the Beishan mafic–ultramafic intrusions gave an age range of 279–286 Ma (except 261 Ma for Xuanwoling; see the following chapters), which is consistent with the formation ages (270–298 Ma) of the intrusions in the Eastern Tianshan. In this thesis, our work are focused on the petrology, mineralogy, geochronology, geochemistry and mineralization of five intrusions in the Beishan Terrane including Hongshishan, Xuanwoling, Poshi, Bi-jia Shan and Luodong intrusions.

2.4 Kalatongke Intrusion in Southern Altay

The Altay and Tianshan form complex orogens, characterized by many strike-slip faults and suture zones, which merge in the eastern part of the Tianshan (Fig. 2.1b). The Kalatongke mafic–ultramafic intrusion outcrops on the southern

side of the regional Irtysh fault zone and intrudes Lower Carboniferous sedimentary and volcanic rocks (Ran and Xiao 1994; Zhang et al. 2009). Zircon U–Pb dating of the intrusion yielded an age of 287 ± 3 Ma (Han et al. 2004), and Re–Os dating of chalcopyrite and pyrrhotite in the ores gave an age of 285 ± 17 Ma (Zhang et al. 2008b). The main Kalatongke intrusion is funnel-shaped. It consists of biotite-hornblende gabbro enclosing biotite-hornblende diorite, biotite hornblende norite and olivine norite. The three intrusive bodies hosting the sulfide ores consist of biotite diorite, biotite-hornblende norite, biotite-hornblende-olivine norite, and biotite-hornblende diabase, which exhibit gradational boundaries and are well differentiated and strongly mineralized (Zhang et al. 2003, 2009; Han et al. 2006; Jiang et al. 2009; Gao et al. 2012). The Ni–Cu sulfide ore bodies are mainly characterized by disseminated, banded and massive textures and have been mined for many years (Han et al. 2006; Pirajno et al. 2008). The Kalatongke intrusion together with the intrusions in the Eastern Tianshan is present as comparisons with the Beishan intrusions.

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