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Geochemical and isotopic constraints on the genesis of the Jueluotage native copper mineralized basalt, Eastern Tianshan, Northwest China

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ABSTRACT

The Jueluotage native copper mineralized basalt is located in the Jueluotage Volcanic-sedimentary Belt, Eastern Tianshan, Xinjiang Uygur Autonomous region. The basalt, amygdaloidal basalt and tuff, which host native copper mineralization, were erupted in the lower strata of the Late Carboniferous Matoutan Formation. Whole-rock geochemistry shows that the basaltic occurrences at Shilipo, Heilongfeng, Changchengshan and Dongjianfeng have fractionated chondrite-normalized REE distributions and distinctly negative primitive mantle-normalized Nb, Ta and Ti anomalies. The whole-rock strontium, neodymium and lead isotopic data indicate low $\varepsilon_{Sr}(t)$ (−7.9 to +23.6), high $\varepsilon_{Nd}(t)$ (+2.5 to +7.1), with restricted $^{206}Pb/^{204}Pb$ (18.152–18.491), $^{207}Pb/^{204}Pb$ (15.521–15.562) and $^{208}Pb/^{204}Pb$ (37.978–38.251) ranges. On the basis of these data, we report that the Cu-bearing basalt is associated with high-iron tholeiitic basalts that were sourced from depleted continental lithosphere mantle garnet-bearing peridotite. The primary magma of the Cu-bearing basalt was: (1) relatively low in silica and magnesium; and (2) underwent only slight olivine and clinopyroxene crystal fractionation during the magmatic evolution process. In the Jueluotage belt, the Shilipo basalt lavas display significant geochemical similarities to numerous mafic intrusions that are present throughout the Jueluotage belt. Those mafic lavas and intrusions probably represent successive pulses of mafic magmatism, which lasted between ca. 310 and 270 Ma.

A crucial empirical observation is that the Jueluotage volcanic-sedimentary belt is a well-known metallogenic province that contains a wide range of copper, nickel, gold, and iron mineral deposits. These mineral systems were formed at different times and are associated with radically different ore-forming processes. However, they are all within the Jueluotage belt, which is interpreted to be a suture zone between the Junggar and Tarim plates, northwestern China. We propose that the Jueluotage volcanic-sedimentary belt reflects the occurrence of a major lithospheric discontinuity that favored the emplacement of different magma types and the circulation of hydrothermal fluids over a long span of time, thus controlling the spatial clustering of a range of mineral systems.

1. Introduction

Numerous researchers have suggested that basalt-hosted native copper occurrences are related to mantle plume activity, as, for example, the Keweenaw area in North America and the Emeishan area in Southwest China (Zhu et al., 2003; White and McKenzie, 1995; Cannon and Suzanne, 1999; Ojakangas et al., 2001). This hypothesis on the genetic relationship between native copper mineralized basalt and mantle plume needs to be tested with more evidence. Since Dong et al. (2003) first documented the basalt occurrences with native copper mineralization in the Late Carboniferous Matoutan Formation of Eastern Tianshan (Northwest China), the area has attracted the attention of researchers (including Dong et al., 2003, 2005; Cui et al., 2006; Wang et al., 2008; Yuan et al., 2008, 2010). Some of the studies have focused on geological features (Dong et al., 2005; Cui et al., 2006), geochronology (Yuan et al., 2007), and whole-rock element geochemistry (Yuan et al., 2010).

The Jueluotage Volcanic-sedimentary Belt consists of Carboniferous volcano-sediment outcrop distributed between the Turpan-Hami Basin and the Middle Tianshan Block (Zhou et al., 2010), and widespread late Carboniferous–early Permian mafic magmatic rocks (Fig. 1). The Jueluotage belt includes the Cu-bearing basalt and numerous mafic intrusions hosting copper–nickel mineralization (e.g., Huangshan, Huangshandong and Tulaergen) These mafic

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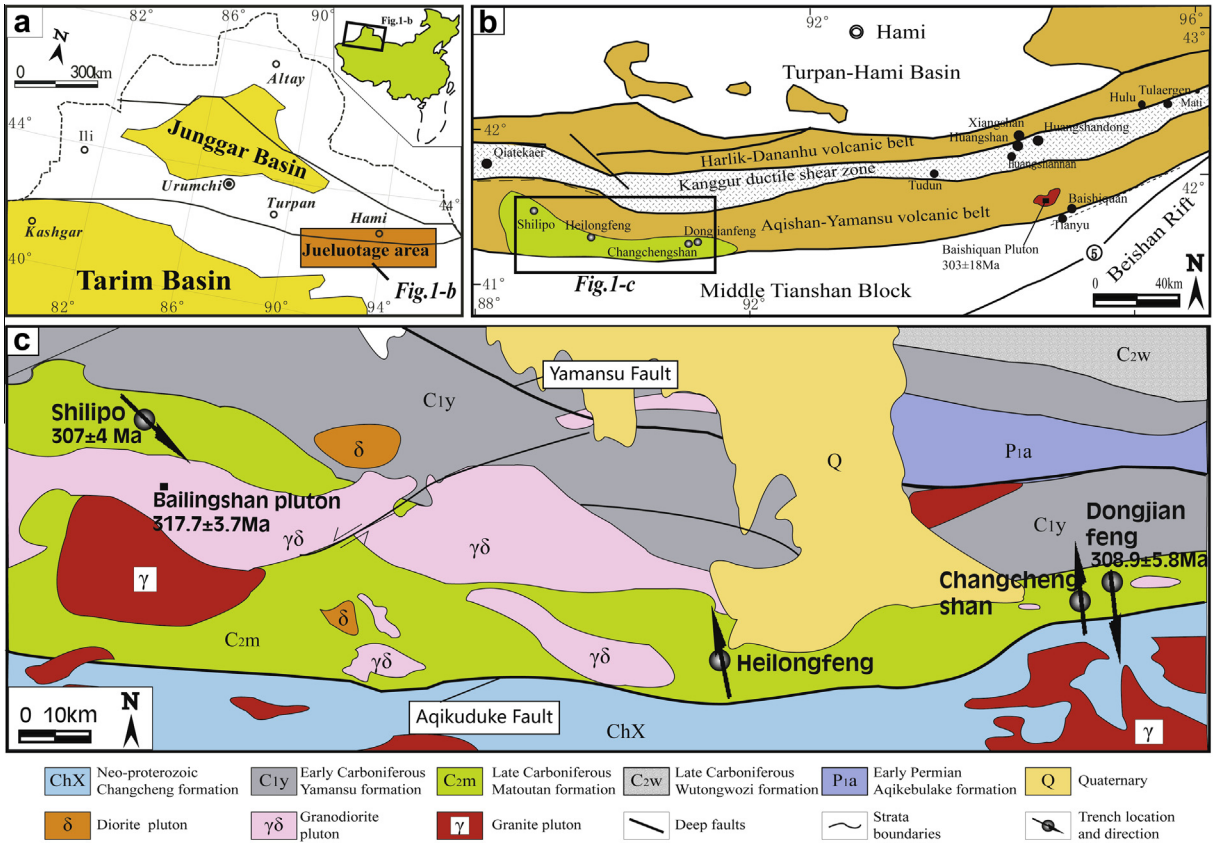

Fig. 1. Sketch map of the study area: (a) location of North Xinjiang area; (b) sketch map of Northern Xinjiang area (modified after Wang and Xu (2006)); and (c) structural and geological map of Jueluotage Volcanic-sedimentary Belt with native Cu and Cu–Ni mineralization distribution (modified after Bureau of Geology and Mineral Resources of Xinjiang Uygur Autonomous Region (1993)).

intrusions have been proposed to have formed under various tectonic settings, including ocean plate subduction (Han et al., 2010; Xiao et al., 2010), mantle plume magmatism (Xia et al., 2008; Su et al., 2011; Zhang et al., 2008), and post-collisional lithosphere delamination (Gu et al., 2006; Song et al., 2011). Some researchers (Wang et al., 2008; Yuan et al., 2008, 2010) suggest that the Cu-bearing basalt could be genetically and geochronologically related to the copper–nickel mineralized mafic intrusions in the Jueluotage belt.

The genesis of native copper mineralized basalt in the Jueluotage belt has so far been poorly documented. Specifically, no isotopic and geochemical evidence is available to constrain magmatic sources and the tectonic setting, and the petrogenetic and geochronological relationship between the Cu-bearing basalt and Cu–Ni mineralized mafic intrusions is poorly understood. This study addresses the existing knowledge gap and focuses on the four basaltic occurrences located in the Shilipo, Heilongfeng, Changchengshan and Dongjianfeng districts of eastern Tianshan. Eleven samples from these four localities were examined petrographically and mineralogically as part of this study. New high-precision whole-rock Sr–Nd–Pb isotopes of the Cu-bearing basaltic samples were combined with the corresponding whole-rock major and trace element data recently published by Yuan et al. (2010). To better understand the petrogenesis of the basaltic magmatism, another eight whole-rock major and trace element samples without corresponding Sr–Nd–Pb isotopes are collated (six from Yuan et al. (2010) and two from Dong et al. (2005)). The Bailingshan diorite and Baishiquan granites were also analyzed for whole-rock geochemical and Sr–Nd isotopes.

After detailed geological observation and geochemical analysis focused on the native copper mineralized basalt, this paper further constrains: (1) the petrogenesis of Cu-bearing basaltic magmatism; (2) the origin and evolution of the basaltic magmas in the area; and (3) the geodynamic setting and the relationship between the Cu-bearing basalt and the Cu–Ni mineralized mafic intrusions in Jueluotage belt, Northwest China.

2. Geology

2.1. Regional geology

The native copper mineralized basalts analyzed in this study are located in the Jueluotage volcano-sedimentary belt, North Xinjiang, Northwest China (Fig. 1a). The Jueluotage belt occupies an area of approximately 62,000 km^2, between 89°00′–96°00′ East and 41°40′–42°40′ North. The Jueluotage belt is bounded by the Turpan-Hami Basin to the north, the Middle Tianshan Terrane to the south (Fig. 1b), and is commonly considered be a collisional zone between the Junggar and Tarim plates (Li et al., 2006; Xiao et al., 2010). The Jueluotage belt can be subdivided into the Haerlik-Dananhu volcanic belt in the north, the Kangguertag-Huangshan ductile shear zone in the middle, and the Aqishan-Yamansu volcanic belt in the south (Fig. 1b).

Rock types in the Jueluotage belt mainly comprise Carboniferous mafic to felsic volcanic rocks and marine sedimentary rocks, together with scattered outcrops of Silurian, Devonian, Permian and Mesozoic to Cenozoic sedimentary rocks. Late Paleozoic mafic to felsic volcanics and intrusions are widely distributed in the belt (Wang and Xu, 2006; Zhou et al., 2010). The Jueluotage belt is a