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Initial geometry and paleoflow reconstruction of the Yamansu skarn-related iron deposit of eastern Tianshan (China) from paleomagnetic and magnetic fabrics investigations

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ABSTRACT

This study aims to uses paleomagnetic and anisotropy of magnetic susceptibility (AMS) methods to recognize the initial deposit position and to track the paleoflow at the origin of an iron skarn-related deposit. The Yamansu deposit is located in eastern Tianshan. This province has a substantial mining potential for Fe–(Cu) skarn, Cu–Ni and V–Ti orthomagmatic deposits, and orogenic Au lodes. Recent publication dates the Yamansu deposit at 323 Ma, and uses this deposit to define a model of Submarine Volcanogenic Iron Oxide (SVIO) deposits (Hou et al., 2014a,b). In the proposed model the Yamansu stratoïd ore bodies formed horizontally within the central venting part of a large submarine composite volcano in a back-arc environment. However, at Yamansu the ore bodies are tilted vertically by the large scale dextral strike-slip faulting during the Permian. The Carboniferous positions are thus overprinted and unknown. Understanding the initial geometry and structures of the Yamansu deposit is then necessary to test and/or improve the proposed SVIO model. Field observations evidence an emplacement of the basalt as sill and their alteration into skarn. Magnetic mineralogy results show that the magnetic remanence and susceptibility are carried by magnetite. Paleomagnetic measurements on massive garnet skarn and basaltic sill distinguish two groups of samples. The higher coercivity samples give a mean remanence direction that is compatible with regional Late Carboniferous directions after bedding correction. This result indicates that both the basaltic sill and the massive garnet skarn were horizontal when formed. The AMS results agree with the paleomagnetic data because the magnetic foliations after bedding correction are horizontal and the well-defined magnetic lineation suggests the existence of a horizontal fluid flow during metasomatism. These results indicate that the basaltic sill horizontally intruded the Carboniferous limestones intercalated within the volcanic pile. Metasomatic iron-rich fluid probably ascended along a pre-existing fault and was injected horizontally into the limestone and sill, and then caused extensive skarnization and deposited the magnetite before tilting due to the Permian right-lateral strike-slip.

1. Introduction

As an important metallogenic province, the eastern Tianshan can be divided into four units (Fig. 1): the Dananhu arc belt, Aqishan–Yamansu belt, Middle Tianshan terrane and South Tianshan terrane. These units have been formed by the accretion–collision of arcs and microplates from the Ordovician to Carboniferous (Charvet et al., 2007, 2011; Wang et al., 2010). By the end of the Carboniferous all of the units were welded and deformed. Major dextral shearing occurred during the Permian due to the relative displacement of the Jungar and Yili blocks, below Tarim and Siberian (Wang et al., 2007, 2014). In spite of compressive Cenozoic re-activation and subsequent uplift, those different tectonic units are still delineated by large Permian strike-slip faults which accommodated the dextral movement between the Tarim and Siberian blocks.

The Carboniferous and Permian were productive periods for mineralization in the eastern Tianshan. Most mineralization correspond to skarn-related iron deposits, porphyry Cu deposits, orthomagmatic Cu–Ni and V–Ti deposits with associated mafic/ultramafic complexes, and orogenic and epithermal Au deposits. Three main metallogenic stages have been identified (Zhang et al., 2008 and references therein):

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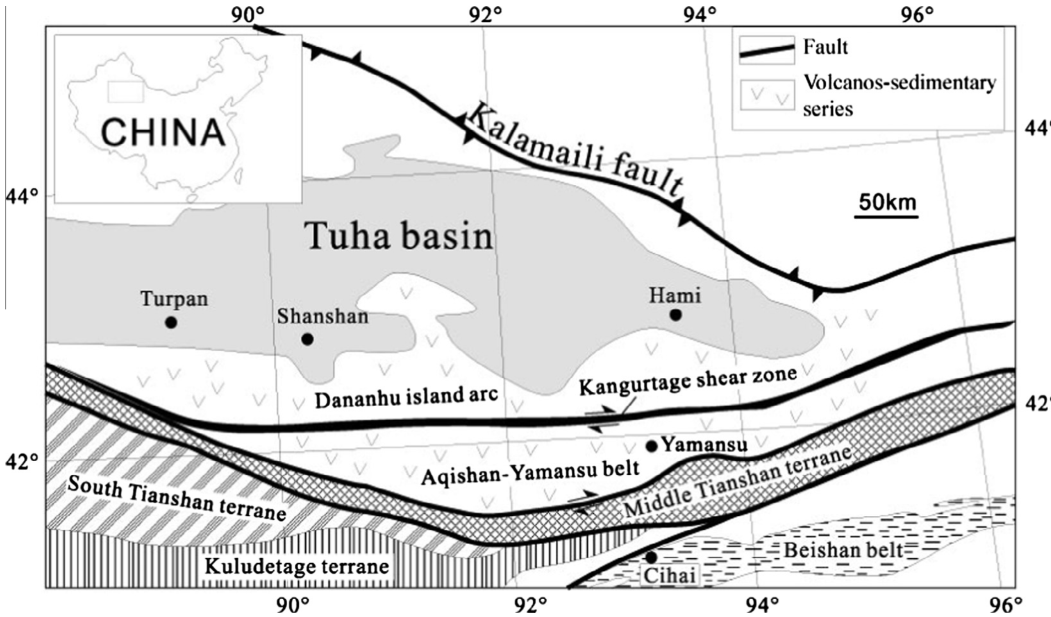

Fig. 1. Simplified location map showing for the Yamansu iron skarn deposit and the main tectonic units of eastern Tianshan (modified from Li (2004) and Gu et al. (2006)).

(1) An early subduction-island arc stage within the Dananhu arc (360–320 Ma) leading to the formation of the porphyry Cu deposits such as the Yangdong and Tuwu porphyry Cu deposits (Zhang et al., 2004; Han et al., 2006) and base metal volcanic massive sulfide deposits. In the Late Carboniferous, the magmatic front migrated southward to form the Aqishan–Yamansu arc during the closure of the ancient Tianshan ocean (Ma et al., 1997; Hou et al., 2006; Wu et al., 2006; Zou et al., 2006; Hou et al., 2007).

The 320–280 Ma time span corresponds to the collisional–accretionary tectonic stage between arcs and micro-plates. During this tectonic phase major thrusts, folds and co-genetic foliations developed. Except for the main 290–282 Ma ore-forming stages of the Kanggur orogenic-type gold deposit (Zhang et al., 2003), this Late Carboniferous-Early Permian period is nearly devoid of mineralizing events throughout the eastern Tianshan.

(2) A post-collisional stage (280–245 Ma) is marked by shearing along the major right-lateral Permian strike-slip faults. This stage corresponds to the formation of world-class orthomagmatic Cu–Ni–Ti–V deposits associated with mafic–ultramafic complexes (Wang et al., 2008a,b, 2009; Mao et al., 2011). Some of the ore-bearing intrusions are typical sheeted syntectonic intrusions in the Permian dextral shear zones (Branquet et al., 2012). This period also marks the peak of gold mineralization throughout eastern Tianshan. The gold deposits are either lodes of the shear-zone-type in the Permian strike-slip zones or veins of the epithermal/magmatic hydrothermal type related to the Permian volcanism and intrusions (Pirajno et al., 1997; Zhang et al., 2000; Wang et al., 2005; Zhang et al., 2008).

(3) A final Triassic stage (240–220 Ma) during which Fe–V–Ti oxide ores formed in mafic/ultramafic intrusions such as the Weiya deposit (Zhang et al., 2005).

In the eastern Tianshan, many deposits of iron, gold or silver are reported to be of the "skarn-type" (Mao et al., 2011; Zhang et al., 2008). As explained below and to avoid confusion, we will favor the more generic term "skarn-related" to qualify these iron–(copper) deposits in the following sections. The skarn-related Fe–(Cu) deposits in the Aqishan–Yamansu arc belt are reported to have been formed during the Carboniferous before Permian dextral shearing (Li et al., in press). The Yamansu skarn-related magnetite deposit is one of the most studied in the eastern Tianshan province. It is hosted in Carboniferous limestone and a basaltic formations. Recent studies (e.g. Li et al., in press; Hou et al., 2014a) show that, despite the massive calc-silicate deposition of Ca and Fe-rich garnets and pyroxenes, these deposits are not iron skarns formed by contact metamorphism as defined by Einaudi et al. (1981) and Meinert et al. (2005) because they lack cogenetic intrusions. Moreover, Li (2012) and Li et al. (in press) demonstrate different relationships between basaltic injections, skarn and mineralized sequence than those generally observed in intrusion-related iron skarns. Recently, based on detailed works of Hou et al. (2014a) on the Yamansu deposit, Hou et al. (2014b) proposed a new genetic model for the Chinese skarn-related iron deposits. This "Submarine Volcanogenic Iron Oxide (SVIO)"model involve: (i) facies variation in submarine volcanic rocks from a large central-vent composite volcano, (ii). mainly stratiform and sub-horizontal ore bodies at the deposition time; (iii) convecting aqueous chloride solution deriving from evolved-magma-fluids mixed with seawater; (iv) and consequently, a sub-contemporaneity between volcanism, skarnization and iron mineralization.

However, at Yamansu the initial dip of the stratoïd ore bodies is still questionable as Permian deformation overprints the initial structures involved in the genesis of the deposit and rotates the primary geometry. This constitutes a major pitfall for the recently proposed SVIO model, and points toward the necessity of an integration and understanding of such ore deposits within the structural framework and evolution of the eastern Tianshan orogenic segment. To constrain the initial position of the Yamansu iron deposits, the basalts and massive garnet skarns associated with ore deposition have been sampled for paleomagnetic and AMS studies. Moreover, as the AMS method is sensitive to the magnetic mineral texture (Borradaile and Tarling, 1981; Hrouda, 1982) magnetic fabrics are used to trace deformation events (Cifelli et al., 2004) and/or fluid circulation events in the primary structures (Sizaret et al., 2006a,b). All these data are finally integrated in a genetic model, starting by magmatism associate with metasomatism along a major fault during the late Carboniferous, and its tilting by the dextral strike-slip Permian deformation.