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Petrology and geochemistry of Silurian–Triassic sedimentary rocks in the Tongling region of Eastern China: Their roles in the genesis of large stratabound skarn ore deposits

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ABSTRACT

This paper describes the petrology and geochemistry of the Silurian–Triassic sedimentary rocks in the Tongling area in Eastern China, aiming to establish a genetic link between different stratabound skarn deposits and sedimentary lithologies. The results from this study show that some Devonian–Triassic transitional lithological units with compositions varying between siliceous rock and carbonate (especially thinly layered impure carbonate) control the distribution of some large stratabound skarn ore deposits in the Tongling region. Interlayer detachment faults in the transitional lithology rocks are particularly important, controlling the final locations of the deposits. The transitional lithological zones may have also served as source rocks, likely providing some ore-forming metals to the deposits. Gypsum evaporites in rocks from Carboniferous sources may have supplied some sulphur to the hydrothermal systems. Five of such transitional lithological units enriched in organic matter are spatially and closely associated with some large stratabound skarn ore deposits in the Tongling region, suggesting that organic matter may have served as an absorbent or reducing agent during ore formation.

1. Introduction

Stratabound skarn deposits are found globally and are of high economic value. The skarns, intrusive and altered rocks, and ores associated with stratabound skarn deposits have attracted many studies (Bouriak et al., 2003; Cao et al., 2012; Cisternas and Hermosilla, 2006; Gaspar and Inverno, 2000; Holbrook, 2001; Li and Tang, 2001; Liu et al., 2006; Lu et al., 1997; Mao et al., 2011; Paolo and Carmelina, 2007; Rieger et al., 2008; Tang et al., 2009; Xia et al., 2009; Xie et al., 2011; Zhou et al., 2011; Zhu et al., 2012). These deposits occur primarily in the contact zones between intermediate–felsic igneous rocks and selected sedimentary rocks and are commonly found as layers or stratiform-like orebodies. Previous studies on the genetic relationship between sedimentary rocks and stratabound skarn deposits focused on the source rocks formed during syndepositional mineralisation (e.g., Lu et al., 2008; Raith et al., 1995; Zeng et al., 2005; Zhai et al., 1992; Zhou et al., 2011). However, the majority of stratabound skarn deposits are not genetically linked to such source rocks (Chang et al., 1991; Cisternas and Hermosilla, 2006; Rieger et al., 2008; Tang et al., 1998). Whether the skarn deposits that are spatially associated with such source rocks can provide enough ore-forming metals is unclear (Gaspar and Inverno, 2000; Mao et al., 2006, 2011; Qiu et al., 2007; Xu et al., 2007; Yuan et al., 2012). Clearly, the genetic relationship between sedimentary rocks and stratabound skarn deposits remains a topic of debate.

Palaeozoic to Mesozoic clastic and carbonate sedimentary rocks are common in the Tongling region of Anhui Province, Eastern China. These rocks are associated with many stratabound Cu–Au skarn deposits formed in the Yanshanian period (Mesozoic), serving as an excellent natural laboratory for studying the genetic relationship between sedimentary rocks and skarn mineralisation. Many geological and geochemical studies have been performed on the skarn deposits in this region (Lai, 2007; Pan and Dong, 1999; Xu and Zhou, 2001; Yang and Lee, 2011; Yang et al., 2007), but few have focused on the role of sedimentary rocks in the formation of these deposits. Previous studies primarily focused on the formation of the deposits and the Yanshanian mineralisation events in the Tongling region. Here, we utilise petrological and geochemical data from the associated sedimentary rocks and the stratabound skarn deposits to study their genetic relationship, which may provide new clues for a better understanding of the ore-forming processes.

2. Geological setting

The Tongling region is located in the middle region of the Lower Yangtze River magmatic–metallogenic belt. Palaeozoic to Mesozoic sedimentary rocks are widely distributed in this region. These rocks

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include marine clastic, carbonate, terrigenous clastic and volcanic rocks. Three groups of NE trending S-shaped folds (Fig. 1) are present in the region, with thrust faults in the core and detachment faults in the limbs (Deng et al., 2007). A few NW trending faults cut across the NE folds. Many small plutons with surface exposures measuring 0.15–5.00 km^2 (Fig. 1) occur as composite stocks, dikes and sills in this region. The plutons are composed of quartz monzonite, porphyritic pyroxene diorite and granodiorite and were emplaced during the Late Jurassic to Early Cretaceous periods (Guo et al., 2013; Qu et al., 2012; Wu et al., 2010; Yang et al., 2011).

Cu–Au stratabound skarn deposits commonly occur in the Tongling region. The orebodies occur as layers or stratiform-like bodies within the Devonian to Triassic sedimentary sequences. Individual orebodies are in close contact with the hosting sedimentary rocks. The shapes of the orebodies vary with the geometry of the associated anticlines and faults. Available data (The 321 Geological Team, 1995; Chu, 2003) show that several large-sized stratabound skarn deposits (e.g., the Dongguashan, Xinqiao, and Tongguanshan deposits) are associated with the Devonian–Carboniferous Wutong and Huanglong Formations. These deposits together account for nearly 70% of the total ore reserves in the region. Several small- to medium-sized stratabound skarn deposits have also been identified within the Permian–Triassic sedimentary rocks, which collectively contribute to approximately 20% of the total ore reserves in the Tongling district. The remaining 10% of the total ore reserves of stratabound skarn deposits are small.

3. Lithologies

Field investigation shows that the oldest exposed rocks in the region are of Silurian age. The Upper Palaeozoic to Lower Mesozoic sedimentary rocks are well exposed, except for the Middle–Lower Devonian and Lower Carboniferous sedimentary rocks (Fig. 2). The stratabound skarn deposits in this region are spatially and closely associated with the Devonian to Triassic rocks.

The Silurian sedimentary rocks are divided between the Middle Silurian Fentou and Upper Silurian Maoshan Formations, both of which are dominated by siltstone intercalated with poorly consolidated sandstone, shale, and mudstone. A deposition gap occurs between the Upper Silurian and Upper Devonian Formations.

The Upper Devonian clastic sedimentary sequence is dominated by quartz sandstone intercalated with siltstone and shale. The Carboniferous sedimentary sequence is subdivided into the Upper Carboniferous Huanglong and Chuanshan Formations. The Huanglong Formation is further divided into two parts: the lower dolomite-dominated unit and upper micritic, microspar, and calcsilicate mineral-rich limestone unit. The lower dolomite-dominated unit of the Huanglong Formation contains thinly colloidal micrite with bryozoans and bivalves with a relatively high abundance of organic matter (Fig. 3a), which decreases significantly in the dolomite adjacent to the skarn deposits (Fig. 3b). This formation also contains pebble-like and colloform pyrite (Fig. 3c–d), siderite, and gypsum evaporite (Fig. 3e). The pyrite is characterised by a concentric colloform texture, indicating a sedimentary origin (Erik, 2004). The upper unit of the Huanglong Formation is composed of micrite limestone, microspar limestone and calcsilicate mineral-rich limestone. The Chuanshan Formation is composed of dark grey, medium-bedded bioclastic and microspar algal limestone.

The exposed Middle Permian sedimentary rocks in the region are divided into the Qixia and Gufeng Formations, and the Upper Permian sedimentary sequence consists of the Longtan and Dalong Formations. The Lower Qixia Formation is dominated by dark grey medium-thickness bituminous limestone. The Upper Qixia Formation contains dark grey medium-thickness microspar and bioclastic limestone with chert. The Lower Gufeng Formation is made up of dark grey calcareous chert and carbonaceous siliceous rock. The Upper Gufeng Formation has thin bioclastic limestone, dolomite and siliceous rocks. The Lower Longtan Formation is composed of grey biogenic siliceous shale intercalated with siliceous rock. The Upper Longtan Formation is composed of siltstones and silty shale. The uppermost part of the Longtan Formation is composed of shale interbedded with fine layers of dolomite. The Dalong Formation is dominated by dark siliceous rocks and muddy and siliceous shale.

Triassic sedimentary rocks include the Lower Yinkeng, Helongshan and Nanlinghu Formations. The Yinkeng Formation is composed of thin muddy microspar limestone, calcareous chert and muddy shale.

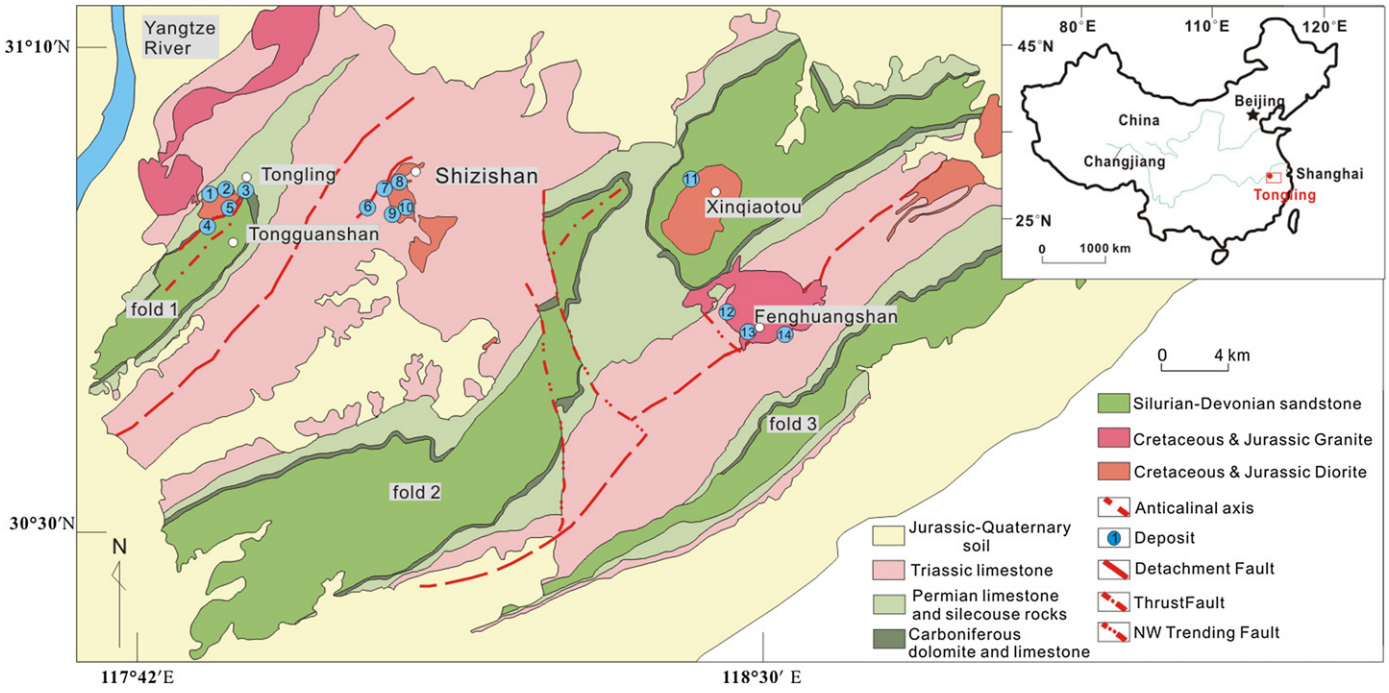

Fig. 1. Simplified geological map of the Tongling area (modified after Deng et al., 2007; Guo et al., 2009) and its location (inset). 1 Luojiacun Cu deposit; 2 Bishan Cu deposit; 3 Tianebaodanshan Au deposit; 4 Baoshan Cu deposit; 5 Xiaotongguanshan Cu deposit; 6 Laoyaling Cu deposit; 7 Dongguashan Cu deposit; 8 Shizishan Cu deposit; 9 Huashupo Cu deposit; 10 Datuanshan Cu deposit; 11 Xinqiao Cu deposit; 12 Fenghuangshan Cu deposit; 13 Jiangjiachong Cu deposit; 14 Xiangsishu Cu deposit.