Tectonic Settings of Magmatic Sulfide Deposits in China

M.-F. Zhou[1], X.-Y. Song[1], R.R. Keays[2], and C.M. Lesher[2]
[1]Department of Earth Sciences, University of Hong Kong, Hong Kong, China
[2]Mineral Exploration Research Centre, Department of Earth Sciences,
Laurentian University, Sudbury, Ontario, Canada P3E 6B5
e-mail: mfzhou@hkucc.hku.hk

Introduction

Eurasia is a composite terrane made up of numerous continental blocks (terranes) that have been welded together since Neoproterozoic time. For example, the Precambrian North China Craton is separated from the South China Block to the south by the Palaeozoic-Mesozoic Qinling-Dabie Orogenic Belt (Fig. 1) and from the Precambrian Siberian Craton to the north by the Palaeozoic Paleo-Asian Orogenic Belt (also known as the Altaid Tectonic Collage). The Cainozoic Tibetan Plateau to the southwest was produced by collision between Eurasia and India. Major Ni-Cu-(PGE) sulfide deposits in China occur in the North China Craton, the Paleo-Asian Orogenic Belt, and the South China Block.

Magmatic deposits hosted within large layered intrusions, such as Stillwater and Bushveld, are not known in China. Instead, most of the sulfide deposits are hosted by small mafic-ultramafic bodies formed in a variety of tectonic environments. The distribution of Ni-Cu-(PGE) sulfide deposits in China is shown in Figure 1. Most of the major deposits appear to be associated with mantle plumes, but several of the minor deposits are associated with arc-related intrusions.

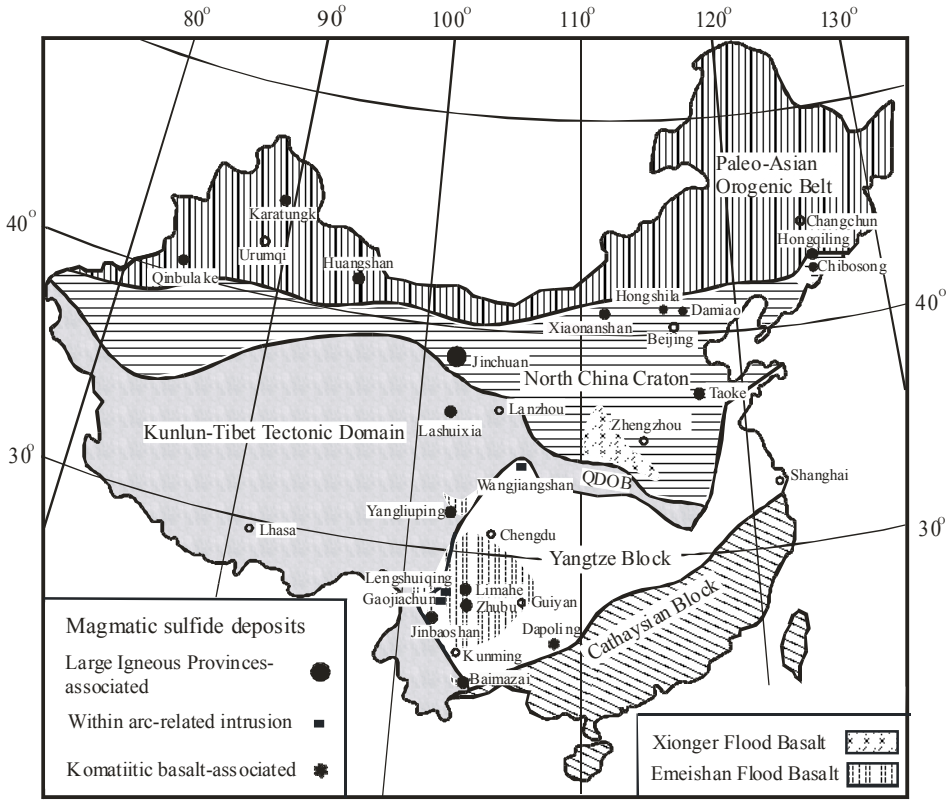

Figure 1. *Major geological blocks of China showing the distribution of Ni-Cu-(PGE) sulfide deposits (after X. Yang et al., 1993; Tang and Li, 1995; Liang et al., 1998). Note locations of 1.76 Ga Xionger volcanic succession in the North China Craton, which is part of the Xionger Large Igneous Province, and the 259 Ma Emeishan volcanic succession in SW China. QDOB = Qinling-Dabie Orogenic Belt.*

Xionger Large Igneous Province (ca. 1.76 Ga)

The 1.76 Ga Xionger Large Igneous Province (LIP) comprisesvolcanic rocks as well a mafic dyke swarm and is situated along the southern margin of the North China Craton (Fig. 1). The volcanic succession is composed of a 3-8 km-thick sequence of basaltic to rhyolitic volcanic rocks covering an area of more than 60,000 km2. The volcanic rocks contain pyroxene and plagioclase as phenocrysts and fine-grained plagioclase, pyroxene, and quartz in the matrix, but no amphibole or biotite, suggesting an anhydrous environment of crystallization. Their geochemical signature suggests derivation from a lithospheric mantle source that had become enriched through subduction of crustal materials or derivation from a more depleted mantle source followed by contamination during ascent through the crust. The 1.76 Ma mafic dyke swarms intrude Archaean granulites and amphibolites in the central parts of the craton,. The volcanic succession and the dyke swarms, together with anorthosite complexes dated at 1.75 Ma and similar aged Rapakivi granites, may have been formed by the same mantle plume. This super mantle plume may have initiated the break-up of the presumed Proterozoic super-continent, Columbia (Rogers and Santosh, 2002).

Numerous mafic-ultramafic blocks occur along major faults within the North China Craton. They vary in size and lithology, are hosted by high-grade metamorphic rocks, and have tectonic fabrics coincident with those of the wall rocks. They may represent the mafic-ultramafic parts of tectonically-disrupted layered intrusions. In the Jinchuan area north of the Qilian Mountains, for example, a northward-verging thrust fault contains numerous tectonic slices of mafic and ultramafic rocks including the Jinchuan ultramafic body, which contains world-class Ni-Cu sulfide deposits. However, it has not been established if the Jinchuan ultramafic body is related to the Xionger LIP. Elsewhere within the craton, the Gaotai and Xiaosongshan intrusions are composed of mafic and ultramafic rocks and contain stratiform chromite deposits, whereas the 1.75 Ga Damiao intrusion is composed of anorthosite and norite and contains both V-Ti magnetite deposits and Ni-Cu sulfide deposits.

Emeishan Large Igneous Province (ca. 259 Ma)

The Emeishan LIP consists of massive flood basalts and numerous contemporaneous mafic intrusions. The volcanic succession covers an area of more than 5x105 km2 (Fig. 1), with thickness ranging from several hundred meters up to 5 km. The volcanic succession overlies the early Permian Maokou Formation, which is composed of limestones, and is overlain by the late Permian Xuanwei Formation, which is composed of sandstones.

In the western part of the Emeishan LIP, the volcanic succession was strongly deformed, uplifted, and eroded as a result of the India-Eurasia collision. Several N-S-trending faults in the Yuanmuo-Xichuan region have exposed Emeishan dykes over a considerable range of crystallization depths. These intrusions have been important mineral exploration targets for the Chinese, but their origin and timing of emplacement are poorly understood. We have dated the Xinjie intrusion, which contains both Ni-Cu sulfide and magnetite deposits, using the SHRIMP U-Pb single zircon method and have obtained a crystallization age of 259 Ma, which is coincident with the end-Guadalupian mass extinction (Zhou et al., 2002c).

Several Ni-Cu-(PGE) sulfide deposits are associated with the Emeishan LIP in SW China. The major sulfide deposits are from north to south: Yangliuping, Limahe, Jinbaoshan, and Baimazai. There are also numerous, subeconomic, Ni-Cu-(PGE) sulfide deposits hosted by smaller intrusions. These deposits are poorly understood in terms of their geological settings, but their host intrusions and associated volcanic successions suggest links with mantle plumes, similar to those in the Noril'sk-Talnakh area, Siberia (Naldrett and Lightfoot, 1999).

Minor Igneous Activity, possibly Associated with Late Permian Mantle Plumes

There are several clusters of Late Permian mafic intrusions within the Paleo-Asian orogenic belt in Northern China. They form three Ni-Cu-(PGE) ore districts: the Karatungk district in Northern Xinjiang, the Huangshan district in Eastern Xinjiang, and the Hongqiling district in Jilin.

Mafic-ultramafic complexes are intruded into the Devonian and Carboniferous carbonaceous slates and volcanic tuffs. Although an extensive exploration program has been conducted for sulfide mineralisation in this region, the timing and origin of the host intrusions are poorly understood. We have dated zircons in the Huangshan intrusion using the SHRIMP U-Pb single zircon method at 268 Ma. Permian volcanism is known in north China, but few detailed studies have been completed. Thus, it is unknown whether there are any contemporaneous volcanic rocks associated with these intrusions. However, the widespread I-

type granites across the Paleo-Asian Orogenic Belt have been interpreted to be products of mafic magma underplating (Jahn et al., 2000), possibly related to the mantle plume that produced the mafic intrusions.

Besides the Karatungk, Huangshan, and Hongqiling Ni-Cu-(PGE) sulfide deposits, the Lashuixia sulfide deposit in the Qilian Mountain district of Gansu is also associated with late Permian igneous activity in Northern China, but occurs in the Qilian Palaeozoic Orogenic Belt of the Kunlun-Tibet tectonic domain (Fig. 1). In addition, the Qinbulake Ni-Cu-(PGE) sulfide deposits in Western Xinjiang also occur in the Paleo-Asian Orogenic Belt.

Neoproterozoic Arc-Related Mafic Magmatism (740 to 860 Ma)

There is extensive Neoproterozoic (750 to 860 Ma) igneous activity in South China, which is referred to as the Jinningian orogeny (Zhou et al., 2002b). It is represented in the southern part of Shaanxi on the northernmost margin of the Yangtze Block by several large layered mafic intrusions hosted by supracrustal rocks of the Xixiang Group. The Xixiang sequence in this area is over 4 km thick and consists of tholeiites, andesites, dacites, pyroclastic rocks, graywackes, conglomerates, and arkoses that appear to have developed in an arc environment. The Wangjiangshan and Bijigou mafic intrusions have recently been dated at 780 and 820 Ma using SHRIMP U-Pb single zircon methods (Zhou et al., 2002a). All of the intrusive rocks and volcanic rocks are considered to be co-magmatic and the volcanic-intrusive magmatism is interpreted to be part of a continental arc built on the northern margin of the Yangtze Block (Zhou et al., 2002b).

Several Neoproterozoic arc-related mafic intrusions in the northernmost part of the Yangtze Block, including the Wangjiangshan and Bijigou layered intrusions, contain magnetite and Ni-Cu-(PGE) sulfide deposits. The Gaojiachun and Lengshuiji Ni-Cu-(PGE) sulfide deposits are hosted by layered mafic intrusions possibly representing part of the Neoproterozoic arc along the western margin of the Yangtze Block (Fig. 1).

Summary

All of the major Chinese magmatic sulfide deposits appear to be associated with major thermal events, which are interpreted to occur in a variety of tectonic settings. For example, the Jinbaoshan, and Yangliuping deposits in the Yangtze Block are interpreted to have formed in a continental rift-related tectonic settings associated with mantle plume, a setting similar to that envisioned for the Kambalda (Western Australia), Duluth (Minnesota), and Noril'sk-Talnakh (Siberia) deposits. The Jinchuan, Huangshan, Karatungk, and Hongqiling deposits are interpreted to have formed in rifted continental margins, a setting similar to that envisioned for the Raglan (northern Québec) and Thompson (Manitoba) deposits. The deposits associated with the Wangjiangshan intrusions in the northern margin of South China are interpreted to have possibly formed in a rifted arc a setting similar to that envisioned for the Perseverance (Western Australia) and Alexo-Dundonald and Langmuir-Redstone (Canada) deposits.

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