Research on Ore-controlling factors and Metallogenic Prognosis of Dongchuan Copper Mining Area, Yunnan, China

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Abstract. Dongchuan is a famous copper producing area in China, where has good geological condition to form many copper deposits with local characteristics. This article summarizes the metallogenic regularities of Dongchuan copper deposits based on the previous works, research findings and the latest research advances. The study suggests that the Dongchuan copper-ore area has a good metallogenic background and immense prospecting potential. Copper ore is mainly found in Yinmin Formation, Luoxue Formation, Heishan Formation, Daqiaodi Formation, and in the Sinian-aged basement, and its occurrence is closely related to volcanic magmatism. The discussions regarding prospecting directions of Dongchuan copper ore were conducted based on the metallogenic regularity research, the results shows that further expanding of the exploration activities from the existing ore-bodies would be carried out; the breakthrough points focus on the Pingdingshan Formation, Qinglongshan Formation, and Daqiaodi Formation strata; at the same time, more attention should be paid to the new types of deposits, such as Yanziya-type or hydrothermal deposits.

1. Introduction
The Dongchuan copper production site is located in Dongchuan, Kunming city, north Central Yunnan, which is one of the most famous copper production sites in China. There are good metallogeny conditions and complicated mineralization environment in Dongchuan area. Several deposit types and multiple ore-bearing strata have been found in this area, including Dongchuan-type, Xikuangshan-type, Lanniping-type, and Taoyuan-type deposits [1-4]. A series of geological prospecting and scientific research projects were launched in the Dongchuan area, especially in the late 1980s to 1990s. Significant results were obtained from the ore prospecting activities conducted in Dongchuan area by applying the latest metalloegeny theories and exploration techniques, revealing it as a good copper-ore prospecting targets in China with immense potential [5-7]. Hence, it is meaningful to study the ore controlling factors and the prospecting direction in this area to further increase the availability of copper resources from deeper or outer Dongchuan production area.

2. Metallogenic geological conditions and ore controlling factor analysis
The Dongchuan area is in the middle of the western margin of the Yangzi Plate, which has a complicated crustal movement evolution history [8-10].
1) Ore-bearing strata and paleogeography
Dongchuan copper ore is mainly found in Yinmin Formation, Luoxue Formation, Heishan Formation, and in the Sinian-aged basement, although copper mineralization can also be observed in Qinglongshan and Pingdingshan Formations. The Yinmin Formation contains Xikuangshan-type Cu–Fe deposits, and the edifice should be closely related to the copper-ore mineralization position and regional distribution of the deposit. A Dongchuan-type copper deposit is also found within the dolomite strata of Luoxue Formation, and it is the most important industrial deposit in this area. Most ore-bodies are distributed within the lower Luoxue Formation and the bottom impure dolomite; copper metallogeny increases with increasing thickness of the ore-bearing strata. The copper deposit in Heishan Formation is located in the bottom carbo-argillaceous dolomitic slate under redox conditions. At other locations, only pyrite is observed in Heishan Formation without the existence of copper mineralization. The weathering-deposited copper ore in the Sinian-aged basement, which is a Lanniping-type copper deposit, is a special type of deposit found in the Dongchuan area. Its deposition is related to the weathering degree, preservation conditions, and paleotopography of the ancient weathered crust possibly formed in the depressions of an unconformable surface.

Previous researchers generally considered the Qinglongshan Formation as non-Cu-bearing, although a 20-m-thick Cu-bearing bed was found in the Tuobuka old-house village. The Pingdingshan Formation contains high-potential Cu-bearing strata because of the presence of Na-rich volcanic rocks (mafic-intermediate intrusive rocks) that favor large-scale copper mineralization and also the presence of a mineable Cu-rich ore-body in the same strata as that in the Yanzhi area.

Daqiaodi Formation is a volcanism–magmatism-related copper deposit, occurring in volcanic rocks, cryptoexplosion breccia, and intrusive rocks. It is also the Cu-bearing ore bed.

2) Volcanism–magmatism and metallogeny
Kunyang Formation in the Dongchuan area underwent relatively aggressive volcanism–magmatism that created highly favorable metallogeny conditions. Deep-seated, rifting-controlled basic magma is very closely related to copper ore and is beneficial to its mineralization. Hence, areas with vigorous volcanism–magmatism activities exhibit higher mineralization potential. Volcanic rocks and intrusive rocks can also contain ore-bearing strata.

3) Distribution pattern of geological structures and ore-bearing lithology
The distribution of the ore-bearing lithology in the Dongchuan copper-ore area is structurally controlled, especially by folds. This is obvious in the Cu-bearing strata of Yinmin and Luoxue Formations; the EW and SN-strike strata are controlled by EW and SN-trend folds. Faults of smaller scales would cause displacement of the ore-body, whereas larger-scale faults would destroy or overstep the ore-bearing strata, for example, the Luoyingdongyi ore-belt is deeply overstepped, possibly because of the presence of faults.

4) Uplifting–subsidence of fault blocks and deepening of the ore-bearing lithology
The Dongchuan area was separated into several fault blocks by few regional faults and differentially uplifted or subsided because of post-depositional tectonic movements. These tectonic events produced fault blocks with different degrees of denudation, directly affecting deep-seated ore prospecting. The Shanmuqing fault block exhibits the highest degree of subsidence, whereas the ore-bearing strata are well preserved. It has great prospecting potential but is deeply buried under the Dayingpan Formation. The Tuobuka–Boka fault block exhibits the highest uplifting and significant denudation, thereby indicating that the current ore-bearing strata might be remnants of the denudation, resulting in lower prospecting potential. However, there are some relatively well-preserved localities in Tuobuka–Boka fault block, especially the syncline core and the relatively subsided area, which exhibit significant prospecting potential.

The Tangdan–Lanniping fault block is slightly uplifted but the ore-bearing strata are still preserved. Therefore, it has some prospecting potential in the deeper parts. The top cover of the Luoyin fault
block’s ore-bearing strata was recently denudated but the strata itself are slightly damaged. Yet, this area also has high deep-seated ore-prospecting potential.

Theoretically, the chance of discovering a copper deposit or a deep-seated ore-body increases when the prospect target area satisfies more prospecting criteria. All criteria may not be simultaneously met during the actual prospecting in a target area; however, this does not affect the evaluation of the target area, which depends on the main prospecting information during the process.

### 3. Metallogeny prognosis

There are two major directions of metallogeny prognosis in the Dongchuan copper-deposit area: prospecting prognosis of the known ore-body (belt); and prediction of “edge,” “deep,” and “new” areas.

1) Prospecting direction of the known ore-body (belt): This is the focus of classical prospecting. The continuous progress of geological exploration, mining, and scientific research in this direction is expected to increase the reserves and scales of the known ore-body (belt) and also improve the prospecting and exploration methods. Although the Dongchuan copper-deposit area is highly researched, it has immense prospecting potential as the area is big and contains many ore-bodies. Hence, this is an important direction for further progress.

2) “Edge,” “deep,” and “new” areas: Research and exploration in the Dongchuan area has only been concentrated until now on the known ore-body (belt); however, the surrounding areas have not been investigated. Some important geological problems and observations related to prospecting have remained unsolved for a long time because of lack of investment. Thus, strategic issues regarding the exploration of these areas outside the known ore-body (belt) have not been considered. Hence, the “edge,” “deep,” and “new” prospecting direction has been realized.

   (1) Edge: It refers to the areas that are relatively away from the current exploration and mining sites. Although the exploration degree is low and the working conditions are hard, these areas exhibit immense prospecting potential, and ore-bodies have been found in some cases till now as well. Hence, more prospecting efforts should be put into these “edge” areas, including the area from the west of Lanniping to the Jiulong area, the area from the west of Yinming to the Xiasikeshu area, the area from Renzhanshi to Wagangzhai, and the area to the north of Xintang.

   (2) Deep: This refers to the deep-seated and hidden ore-bodies. There are some areas where huge undiscovered ore-bodies may be present, such as the east-wing of the Luoyin syncline, both wings of the semi-concealed Shanmuqing syncline, the Xiaoliukou–Yinmin hidden ore-body that is covered by mixed breccia of the Daqiaodi Formation (Dashuigou- or Zhangkoudong-type), and the Potou–Buwei area located east of Tuobuka, which is also covered by mixed breccia of the Daqiaodi Formation.

   (3) New: refers to the new theories, new strata, new deposit types, and new methods. Some units have shown remarkable contributions in these aspects, such as the (previously known as) China National Non-ferrous Metal Company, the Nonferrous Geological Exploration Bureau of Southwestern China, and the Dongchuan Copper Mines Administration. We should look for prospecting breakthrough in new strata such as those in Pingdingshan Formation, Qinglongshan Formation, and Daqiaodi Formation other than the ore-bearing strata of the known industrial ore-bodies. We should also look for new deposit types such as Yanziya-type and hydrothermal-type deposits.

Although a significant amount of time has passed since the discovery of the Yanziya-type copper deposit, nothing has been done regarding the prospect, ore-bearing strata, type of deposit, ore-body scale, and geological characteristics of this ore-body. A private company has currently set more focus on the Yanziya copper deposit, which is a large-scale deposit with thick and rich ore-bodies. It is clear that this Yanziya-type deposit has immense prospecting potential, requiring further prospecting to be conducted in the Dongchuan area even if the ore-body may not be located in continuous strata and the metallogeny may be complex. The author also thinks that the ore-bearing Pingdingshan Formation is parallel to the non-mineralized Pingdingshan Formation. Some copper-mineralized Pingdingshan Formation outcrops were found in Qinjialiangzi Formation and Hongmenlougou Formation in Tuobuka area. Hence, exploring the Yanziya-type copper deposit in the Dongchuan area is an important prospecting direction.
Volcanism–magmatism activities have been vigorous in the Dongchuan area. Not only massive mafic rocks but also a huge Jinningian-aged granitic body has been found in Xinchun (Dongchuan area). These magmatic activities bring along ore-forming materials and induce important mineralization. In fact, a lot of rich and hydrothermal-related ore-bodies were found in the Dongchuan area. However, owing to their small scale, they were considered as independent deposit types and did not attract much attention. The discoveries of Yanziya-type copper deposit and mixed breccia copper deposit in the Pingdingshan Formation indicate that some intrusive-related copper deposits showing hydrothermal activity may be related to copper mineralization. This should be considered during further mineralization studies and prospecting.

4. Conclusion
The Dongchuan area is an important copper-ore deposit in China and has immense prospecting potential. Several geological studies have been conducted by previous researchers. The known ore-body (belt) still remains the major target area for existing levels of prospecting; however, the exploration of remote areas needs to be reinforced. In the near future, it will be possible to achieve some breakthroughs in the strata of Pingdingshan Formation, Qinglongshan Formation, and Daqiaodi Formation. Furthermore, the exploration of new deposit types, such as Yanziya-type and hydrothermal-type deposits, should be reinforced.

References
[1] Gao H, Pei R F, Wang A J, Chao D H, Fan S J and Mei Y X 2012 Geological Bulletin of China 08 1332–51
[2] Liu J S Wu, Y Z and Duan J R 1996 Journal of Central South University of Technology 27 8–12
[3] Qiu H N, Wijbrans J R, Li X H, Zhu B Q, Zhu C L and Zeng B C 2001 Bulletin of Mineralogy, Petrology and Geochemistry 04 358–9
[4] Zhang Y F 2003 Yunnan Geology 04 360–70
[5] Nie T, Fang W X and Du Y L 2014 Z W, Qian X G and Tian M 2014 Geotectonica et Metallogenia 182 57–69
[6] Jiang J S, Li T F, Chen X S 1996 Sedimentary Geology and Tethyan Geology 02 205–19
[7] Zhao X F, Zhou M F, Li J W, Sun M, Gao J F, Sun W H and Yang J H 2010 Precambrian Research 182 57–69
[8] Huang R Q, Wu J M and Wang Z P 1999 Geology and Exploration 04 15–8
[9] Yin F G, Sun Z M, Ren G M and Wang D B 2012 Acta Geologica Sinica 12 1917–1932
[10] Wang T R, Fang W X and Zhao J J 2012 Yunnan Geology S1 272–4