Metallogeny of the Maoping graphite deposit, Sichuan Province

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Abstract. There are abundant crystalline graphite resources in Panzhihua area. Large and medium-sized deposits are mainly distributed in Renhe District and Miyi County of Panzhihua City, and their genetic types are sedimentary and metamorphic. The ore-bearing rocks of graphite deposits in Renhe area are mica quartz schist of Lengzhuguan Formation of Early Proterozoic Kangding group, while the ore-bearing rocks of graphite deposits in Miyi County are sericite phyllite of the first member of Tianbaoshan Formation of Huili Group of Mesoproterozoic, with a slightly later stratigraphic age and a slightly lower metamorphic degree. Therefore, a thorough study of the genesis and metallogenic regularity of graphite deposits in Miyi area is of great guiding significance to the search for similar types of graphite deposits in Panxi area.

1. Introduction
With the rise of graphene application theory, the demand for graphite ore resources is increasing day by day, while the research level of graphite ore deposits is not high[1-2]. The Panzhihua area is rich in crystalline graphite resources, and large and medium-sized deposits are mainly distributed in Renhe district and Miyi County of Panzhihua City, with sedimentary metamorphic genetic types. The ore-bearing rock of graphite ore in Renhe district is mica quartz schist of Lengzhuqian formation of Early Proterozoic Kangding group, while that of graphite ore in Miyi County is sericite phyllite of the first member of Tianbaoshan Formation of Huili Group of Mesoproterozoic, with a slightly later stratigraphic age and a slightly lower metamorphic degree. Therefore, it is of great significance to study the genesis and metallogenic regularity of graphite ore in Miyi area for the exploration of the same type of graphite ore in Panxi area.

2. Regional geological characteristics
The mining area is located in the middle part of Kangdian basement fault uplift belt (I 1-3-2) of Kangdian foreland thrust belt (I 1-3) of the ancient Yangtze block (I-2). The metallogenic belt of the mining area is located in Mianning Panzhihua Fe-v-Ti-Cu-Ni-Pt-Pb-Zn-rare earth-metallogenic belt (IV-37), mainly distributed in magmatic V-Ti-magnetite and its associated sulfur, nickel, basic ultrabasic rock type nickel ore, stratabound hydrothermal type lead-zinc (silver) ore and its associated sulfur ore, volcanic sedimentary metamorphic rock type lead-zinc ore, sedimentary metamorphic graphite ore, magmatic platinum ore, sedimentary bauxite
ore and there are a few other types of iron ore, among which the sedimentary metamorphic graphite ore is found in this metallogenic belt. The ore-forming process of graphite deposits in this area mainly goes through three stages: (1) shallow marine sedimentary stage: carbonaceous clayey fine debris formed by weathering of Archaeozoic ancient land, deposited into carbonaceous clayey silt fine sandstone, with a sedimentary time limit of 2.4-2.9 billion years. (2) regional metamorphism stage: with the regional metamorphism of the low-pressure facies system of the middle stripe stage superposed with dynamic metamorphism, the highest metamorphism degree reaches to the amphibolite facies, and the part containing carbon metamorphoses to form carbon schist or graphite schist (carbon Muscovite quartz schist, etc.), the metamorphism time limit is 1.7-1.9 billion years. (3) migmatization: it is particularly obvious in the Kangdian basement fault uplift belt, causing the remelting of some parts of Kangding group, forming the magma upwelling, and forming the tonde diorite and Datian quartz diorite (tonalite) in a short distance, with the edge of migmatitic granite, with a time limit of > 1.7 billion years. Due to the regional metamorphism and migmatization in this period, the graphite scales were lengthened and enlarged, forming crystalline graphite deposits with industrial utilization. Most of the graphite-bearing strata are remelted, and only part of them become the "remains" of migmatite or the outer contact zone of migmatite.

3. Geological characteristics of mining area

The exposed strata in the mining area include the first sub section of the first member of the Tianbaoshan formation of the Huili Group of the Middle Proterozoic (gray gray white sericite with graphite ore, which occurs in sericite phyllite in sequence), the second sub section (gray dark gray sericite plate phyllite, with strong Silicification in some sections), the third sub section (gray light gray gray sericite with graphite ore, and the graphite ore occurs in sericite phyllite in sequence Middle) and fourth sub members (purple red sericite phyllite with grayish yellow metaquartz sandstone); second member of Tianbaoshan formation (metaquartz sandstone); quaternary system (eluvial slope deposit), etc. The magmatic rocks exposed in the mining area are mainly diorite monzogranite (η γ 3 x), biaofang black cloud monzogranite (η γ 3 B), Maoping medium grain monzogranite (η γ 3 mp) and diabase vein (β μ) in Jinning period.

The main types of metamorphism in the area are regional dynamic metamorphism and magmatic hydrothermal contact metamorphism.

(1) Regional dynamic metamorphism: the formation of Tianbaoshan formation in the end of Jinning was subjected to regional north-south compressive stress. The formation is composed of argillaceous rock with quartz silt, fine sandstone and a small amount of carbon in the upper part, and metamorphosed into grey light grey sericite phyllite with a small amount of metamorphic quartz sandstone, sericite plate phyllite, siliceous slate and cryptocrystalline graphite. The metamorphic degree of the rock is low, it is greenschist facies, and the mineral assemblage is mainly sericite and chlorite.

(2) In the later stage, with the emplacement of Jinning adamellite intrusive body and superimposition of magmatic hydrothermal contact metamorphism on the basis of the green schist facies of Tianbaoshan formation, sericite breccia, quartz sericite breccia, carbonaceous siliceous slate and so on are formed in the contact part, and the recrystallization of Aphanitic Graphite forms crystalline graphite.

4. Geological characteristics of the deposit

The ore-bearing stratum in the area is the first member of Tianbaoshan formation (pt 2 tb 1 ) of Huili Group of Middle Proterozoic, the ore-bearing rock is carbonaceous siliceous slate, its top and bottom plates are light gray and light gray yellow sericite phyllite, and gray dark gray sericite phyllite. Four graphite ore belts and 20 graphite ore bodies were delineated in the area, three in the middle and one in the south. The No. 1 ore belt is the main ore belt, which is located in the south wing of the great volcano back shape and delineates three graphite ore bodies;
the No.2 ore belt is located in the north wing of the great volcano back shape and delineates 12 graphite ore bodies; the No.3 ore belt, which delineates two graphite ore bodies; the No.5 ore belt is the secondary ore belt and delineates three graphite ore bodies. The ore bodies are layered and stratoid, some are lenticular, and the occurrence is consistent with the surrounding rock. The main ore body features are as follows:

1. I-1 ore body: the control ore body length is 1488.00m, the control maximum inclined depth is 488.20m, the thickness is 0.82-242.56m, the average is 88.01m, the ore grade is C solid 3.24-9.74%, the average is 6.11%. In space, the thickness of ore body tends to be thicker from west to East, and the grade tends to be richer from deep.

2. No. V-1 ore body: the control ore body is 356.00m in length, 33.03-58.31m in thickness, 43.27m in average, with the ore grade of C solid 3.58-9.84%, 7.28% in average. The ore body grade tends to become rich towards the deep.

The ore mineral in the ore is graphite with C solid content of 5.00-15.00%. Gangue minerals are mainly quartz (SiO₂ content 25.00-85.00%), sericite (content 15.00%), white mica (content 3.00%), and trace biotite (content < 0.50%). Metal minerals are mainly pyrite, pyrrhotite, limonite, rutile, hematite, chalcopyrite, sphalerite, etc. Some ore bodies are filled with late quartz vein (Fig.1 and Fig. 2). The ore structure is mainly granular and metamorphic, and the ore structure is mainly disseminated. The diameter of graphite flake is generally 1.00-64 μm, and the maximum is 128 μm. according to the analysis of graphite degree, the graphitization degree of the ore is more than 98.00%, which is crystalline graphite (Fig. 3).

Figure 1. Graphite ore in boreholes
Figure 2. Graphite filling by late quartz veins
Figure 3. Graphite ore size analysis, graphite (G arrow finger) ×1000 (reflective)
5. **Genesis of deposit**

(1) The carbonaceous clayey fine debris formed by the weathering of Archaeozoic ancient land in the sedimentary stage of shallow sea facies has been carried by water and deposited into carbonaceous clayey silt ~ fine sandstone.

(2) In the regional metamorphism stage, with the regional metamorphism of the low-pressure system of the middle stripe period superimposed with dynamic metamorphism, the fold structure in the area is nearly east-west, the highest degree of rock metamorphism is up to the amphibolite phase, and the partial metamorphism with carbon forms carbonaceous slate or graphite siliceous carbonaceous slate (carbonaceous white mica quartz schist, carbonaceous sericite phyllite, etc.).

(3) The magma intrusion of bajiaqing black cloud monzonite, Maoping medium grain monzonite and Yonglang shaoban monzonite is particularly obvious in the area, which causes the recrystallization of some strata of Tianbaoshan formation of Mesoproterozoic Huili Group. Under the thermal contact metamorphism of magma, the graphite scales are lengthened and enlarged, forming crystalline graphite deposits with industrial utilization. Most of the graphite bearing strata are recrystallized, and some of the strata or ore bodies become "residual bodies" (such as ore belt III) or in the outer contact zone (such as ore belts I, II and V) of granite.

(4) The genetic type of the deposit is sedimentary metamorphic crystalline graphite deposit.

(5) The industrial type of the deposit is crystalline graphite.

6. **Metallogenic rule**

Metamorphic deposit refers to the deposit formed in metamorphic rock area under the influence of regional metamorphism, contact metasomatism, local contact thermal metamorphism, dynamic metamorphism and migmatization[3]. When Ortega et al. studied the volcanic graphite deposits in borodale, England, according to the characteristics of carbon isotopes, it was determined that carbon came from bioorganic carbon, and its mineralization mainly occurred in a relatively short period of Ordovician magmatic activity [4].

Richard et al. studied the metallogenic geological characteristics and carbon isotopic characteristics of Mesoproterozoic graphite deposits in the New Jersey plateau, and believed that the carbon originated from primitive algae and other biological organic matters, which belonged to organic genesis [5]. According to the geochemical and carbon isotopic characteristics of Archean carbon bearing rock series in its production area, it is believed that graphite carbon comes from bioorganic matter, which belongs to organic genesis.

We concluded that: (1) Maoping Graphite Deposit is distributed in the metamorphic rock series of the first member of Tianbaoshan formation of the Middle Proterozoic Huili Group. The ore bearing rock is carbonaceous siliceous slate, and the near East-West large volcano complex back shape controls the output of the graphite ore body.

(2) There are a large number of Jinning adamellite intrusions along the dengzhanwo fault and its vicinity, which are in direct contact with the metamorphic strata or graphite ore body of the first section of Tianbaoshan formation. The emplacement of the rock body provides the magma heat source for the thermal contact metamorphism. After the thermal contact metamorphism, the ground layer and ore body recrystallize, and the cryptocrystalline graphite ore formed by the early regional dynamic metamorphism gradually forms Crystalline graphite ore.

(3) The Graphite Deposit in Maoping area is strictly controlled by the first member of Tianbaoshan formation of Huili Group of Mesoproterozoic, which is a sedimentary metamorphic crystalline graphite deposit.

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