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TEM observation of geogas-carried particles from the Changkeng concealed gold deposit, Guangdong Province, South China

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ABSTRACT

Geogas prospecting is a relatively new technique in exploration for deep-seated and concealed mineral deposits. Now, the technique is to reveal the presence of concealed ore bodies by analyzing the element concentrations of substances that are transported by geogas from concealed ore bodies to the Earth's surface. However, the element concentrations provide us with limited information about the concealed ore bodies. In our work, to investigate the category, size, shape, chemical component of geogas particles, copper grids for transmission electron microscopy measurement were directly used to capture the geogas-carried solid particles in Quaternary sediments overlying the Changkeng concealed gold deposit, Guangdong Province, South China. In the samples, we found Au, $PbSO_4$, WO_3, Fe_2O_3, SiO_2, TiO_2, and Al_2O_3 particles, etc. using a transmission electron microscopy. Of which, gold particles, and Hg-, Zn-, Pb-, W-bearing particles may originate from concealed ore bodies and can provide more direct information than those provided by element concentrations.

1. Introduction

Geogas prospecting is a relatively new technique in exploration for deep-seated and concealed mineral deposits that was jointly developed in the early 1980s by the Swedish mining and smelting company Boliden AB and the Department of Nuclear Physics, LTH, Lund University, Sweden (Kristiansson and Malmqvist, 1980). It can be used to explore for deposits at depths ranging from several hundred meters to 1 km below the surface. Geogas is defined as an ascending flow of gaseous matter such as N_2, O_2, CO_2, CO, CH_4, NH_3 (Tong and Li, 1999) originating from degassing of the upper mantle and lithosphere (Gold and Soter, 1980; Morner and Etiope 2002; Annunziatellis et al., 2003), releasing from ore mineral weathering (Wang et al., 2007), atmosphere driven by barometric pumping (Cameron et al., 2004). Geogas might be a global phenomenon, because it has been widely reported from many ore deposits worldwide (Xie et al., 1999). It can carry solid substances from concealed ore bodies or other geological bodies and transport them to the Earth's surface (Wang et al., 1997, 2007). Concealed ore bodies may be detected by capturing these geogas-carried substances in Quaternary sediments, and analyzing their extremely low element concentrations by instrumental neutron activation analysis (INAA), atomic absorption spectrometry (AAS), and particle induced X-ray emission (PIXE) (Kristiansson and Malmqvist, 1982, 1987; Malmqvist and Kristiansson, 1984; Kristiansson et al., 1990; Wang et al., 1997; Tong et al., 1998; Hirner, 1998; Xie et al., 1999; Malmqvist et al., 1999; Cao et al., 2004). However, the traditional methods for estimating the concealed ore bodies consist only of measuring the element concentrations of the geogas-carried particles using different analytical methods. In our work, to investigate the origin of geogas-carried particles TEM (Transmission Electron Microscopy) copper grids were directly placed in Quaternary sediments overlying concealed ore bodies to collect particles in ascending geogas. Using TEM, we measured the particle characteristics (the category, size, shape, chemical component and association) and discussed origin of the geogas particles.

2. Geological setting

Changkeng deposit in the Jinli town, Gaoyao City, Guangdong Province of southern China is located in the northwest margin of the Sanzhou Upper Palaeozoic faulted basin in the central Guangdong depression of the South China fold system, which hosts a large Carlin disseminated type gold deposit and a super large carbonate-hosted replacement-type silver deposit, and is a new type of deposit discovered in China in recent 20 years (Du et al., 1993, Zhang et al., 1997). Not any kind of igneous rocks has been found in the ore district (Sun et al., 2003). The exposed strata in the Changkeng area are Lower Carboniferous, Upper Triassic rocks and Quaternary sediments (Fig. 1). Lower Carboniferous Shidenzi Formation is mainly limestone and silty shale is fragmentary. Lower Carboniferous Ceshui Formation is stone, siltstone

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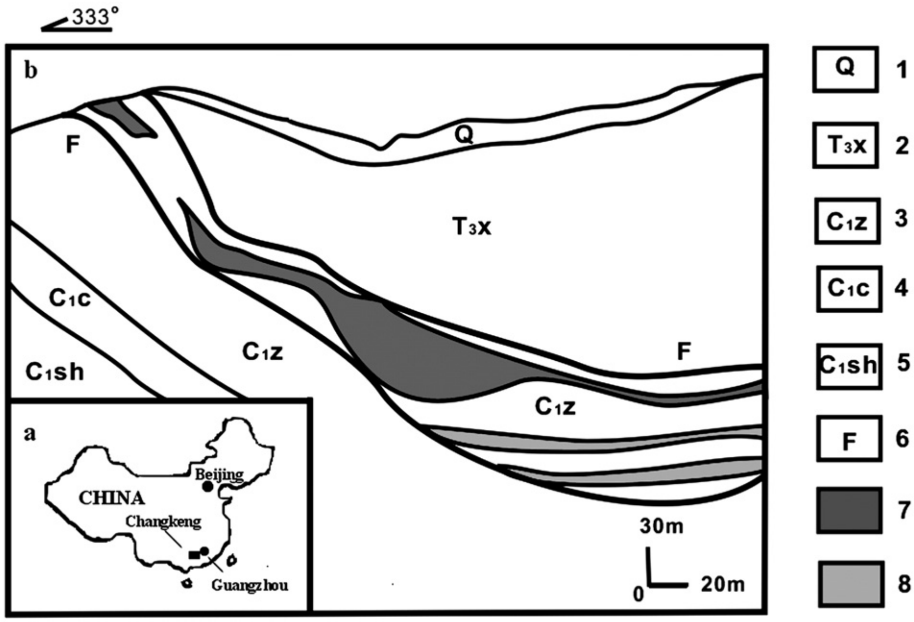

Fig. 1. Cross-section of Changkeng gold deposit (after Du et al., 1993). 1—Quaternary sediments; 2—Upper Triassic Xiaoping fm.; 3—Lower Carboniferous Zimenqiao fm.; 4—Lower Carboniferous Ceshui fm.; 5—Lower Carboniferous Shidenz fm.; 6—fault; 7—gold ore body; 8—silver ore body.

and limestone. Lower Carboniferous Zimenqiao Formation is bioclastic limestone and muddy limestone. The Upper Triassic Xiaoping Formation is sandstone, arkosic quartz sandstone, siltstone, and carbonaceous mudstone. Upper Triassic clastic rocks rest fault-unconformably on the Carboniferous Formations (Du et al., 1993). Quaternary slope sediments and alluvium widely distribute in the ore field. The concealed ore bodies are fault-controlled. The Au ore bodies are hosted in the brecciated siliceous rocks on the top of the Zimenqiao Formation bioclastic limestone. The Ag orebodies are located in the fractures in the Zimenqiao Formation bioclastic limestone (Du et al., 1993). The main two ore types are oxidation ore body and original ore body. The minerals in the oxidation ore body comprise quartz, illite, kaolinite, limolite, scorodite, magnetite, zircon, pyrite, native gold and other sulfides. Ore minerals in original gold ore bodies consist of pyrite, realgar, orpiment, antimonite, marcasite, cinnabar, arsenopyrite, and sphalerite. Their gangue minerals are quartz, calcite, barite, illite, dickite, fluorite, and gypsum. Ore minerals in original silver ore bodies consist of galena, sphalerite, freibergite, pyrargyrite, polybasite, andorite, miargyrite, argentite, cinnabar, and pyrite. Their gangue minerals are quartz, calcite, illite, fluorite, and kaolinite (Mao et al., 2007). Gold ore textures are brecciated and disseminated. The majority of the Au (>82%) occurs in native form. Minerals that carried this gold are quartz, illite, dickite, and pyrite. The native gold is distributed in microfractures of pyrite and quartz, or along the crystal rims of illite, dickite, pyrite, and quartz crystals. Alteration associated with the Au-mineralization is mainly silicification, decalcification, and argillization. The silver ore bodies are located 20–50 m down-section from gold ore bodies (Du et al., 1993; Liang et al., 2007).

3. Sampling and analytical method

The geogas particle collector consists of an ordinary plastic funnel equipped with a carbon-coated copper TEM grid (Fig. 2). The collectors were placed at a depth of 60–80 cm holes in soils. The plastic funnels were inverted to collect gas flow. TEM grids pressed from both nylon nets were placed just outside the end of the funnel spouts to capture the geogas-carried solid particles and protected by plastic cups to prevent contamination from the outside. After 45 days, the collectors were opened. The grids were taken up with fine pincers and put into TEM sample cell at once, which will put into a plastic seal box. The nylon nets, fine pincers, sample cell, seal box, plastic cups and funnels were clean with distilled water at first, washed with neutral detergent then, washed with high-purity water for several times again, dried for future use at last. Before carbon-coated copper grids were used, a blank check of 20% grids had been performed using TEM. Fourteen sites were sampled in an area of approximately 0.25 km^2. Each sampling cell was approximately 100 m × 350 m. Of which: Two TEM grids were put in the same collector in eight sampling sites, to test the repeatability of the experimental result. In barren area, geogas particle samples were collected using TEM grids for blank contrast analysis.

The geogas particle samples were analyzed using a transmission electron microscope (JEM-2010HR, JEOL LTD, Japan) equipped with an energy dispersive spectroscope (Energy TEM 200, OXFORD-INCA) at an accelerating voltage of 200 kV, which were carried out at the Instrument Analysis Center of Sun Yat-sen University. In the ore district, Quaternary

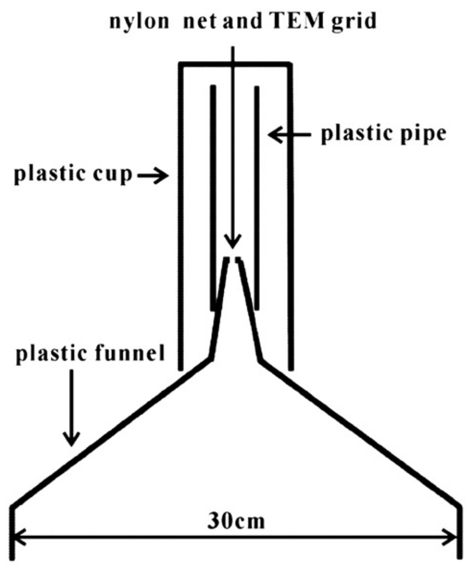

Fig. 2. Sketch of the collector for geogas particles.