THE GEOELECTROCHEMICAL EXTRACTION METHOD (CHIM) IN EXPLORATION FOR CONCEALED ORE DEPOSITS

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INTRODUCTION

In the last two decades new technical means and methods of exploring for mineral deposits have been developed based on the behavior, transformation and distribution in ore bodies and host rocks of various key elements. Among these, a geoelectrochemical extraction method (CHIM) has been developed by Russian and Chinese investigators. A series of experiments on CHIM, as developed in China, have improved the method (e.g., Fei 1984, 1992, Xu 1989) which now uses a small electrical power supply to obtain better results. Over the past two decades in China, a series of feasibility tests on CHIM in exploration for mineral deposits have demonstrated successful detection of anomalous element concentrations over known deposits covered by various thickness of overburden and including ores of copper, lead, zinc, tin, gold, silver, arsenic, uranium and antimony, and have resulted in new discoveries (Luo 1992).

METHOD

CHIM is applied to exploration for concealed orebodies by exciting and extracting metallic ions in overburden and in zones nearby orebodies using an applied electric field. Metallic ions are chiefly derived from oxidation dissolution in the shallower part of orebodies and electrochemical dissolution in deeper parts (Luo 1992). Geoelectrochemical dissolution plays an important role in the formation of metallic ion haloes and results from the variable different electrode potentials of minerals. Ryss (1986) studied the process of electrochemical dissolution of pyrite, galena, pyrrhotite and chalcopyrite and provides a theoretical explanation for the development of metallic ion haloes. He describes so-called macro-batteries (electric fields) resulting from macroscopic oxidation-reduction potential, as well as many micro-batteries due to electro-potential differences between minerals. In an orebody, electrochemical dissolution (both strong and weak) generally takes place over a large area of electrolytic activity.

Processes of electrochemical dissolution lead to elevated concentrations of metallic ions in haloes around orebodies. Under the action of the geodesic electric field, metallic ions that are not reacted or absorbed will eventually migrate upwards into loose sediment/regolith near the surface and form ion haloes in dynamic equilibrium. When an artificial electric field is applied to the medium in which ion haloes exist, halo-forming cations will migrate toward the cathode. If the artificial electric field is strengthened and the supply time increased, the ions in dynamic equilibrium migrate upwards one by one, and the space vacated by migrated ions will be filled by ions derived from nearby the ore so as to maintain dynamic equilibrium. A large ionic source (e.g., an orebody) at a depth within the range of the applied artificial electric field may continually supply cations to a cathode extractor set up at the surface and will continue to accumulate until a new dynamic equilibrium is reached. Therefore, ions gathered by the extractor are derived from both the secondary haloes near the surface and ionic haloes of the deep orebody. By analyzing ionic concentrations in the extractor, geoelectrochemical anomalies may be detected and used for targeting.

The process of halo-forming electrochemical dissolution derived from a sulfide ore-body has been demonstrated in laboratory studies (Figure 1). Experimental results show that the Zn^{2+} content at the receiver increases with the supply time (Figure 2). In the first 3 hours the Zn^{2+} content entering into the extractor was

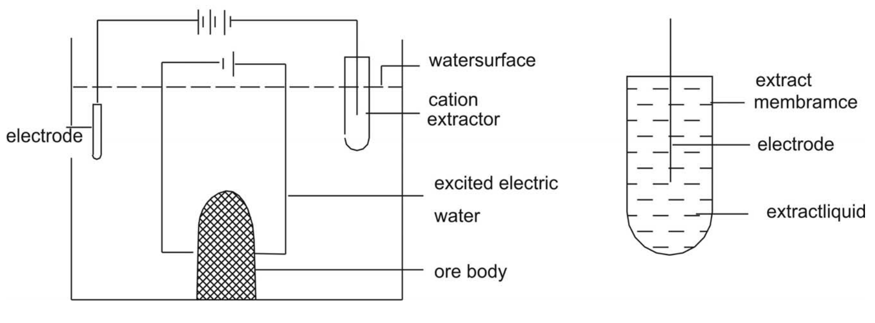

Figure 1: Diagram showing modeling device (A) and the extractor for elements (B).

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low, but thereafter the Zn^{2+} content in the extractor dramatically increased to around 3.8 ug/ml. This result is interpreted as during the first 3 hours, the Zn^{2+} entering the receiver came either from background content of the water, or from minor Zn^{2+} contamination released during setup of the model orebody in water. After 3 hours, the abrupt increase in Zn^{2+} is the result of electrochemical dissolution of the model orebody and chemically released Zn^{2+} ions entering into the receiver. After 4 hours, Zn^{2+} content in the receiver approaches a stable state, i.e., dynamic equilibrium. The experimental results of electrochemical dissolution of minerals indicate that under the action of natural and artificial electric fields, the processes of electrochemical dissolution of the orebody would make metallic ions continually migrate to an established receiver for accumulating elements. Thus, through geoelectrochemical extraction, ionic anomalies can be detected, with application to exploration for buried ore deposits.

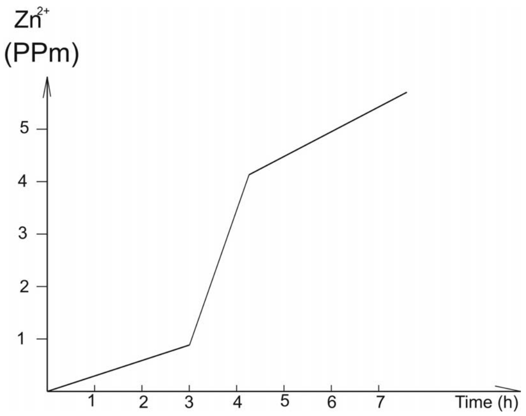

Figure 2: Time-concentration curve of the extraction of Zn^{2+}.

THE FACTORS INFLUENCING CHIM

(1) The weatherability of ores: The electrochemical dissolving and eroding capacity that produces a suitable extraction effect for prospecting deep ions around ore-bodies generally depends on the complexity of mineral compositions of the orebody, the halo-forming hydrogeological conditions and the degree and depth of the weathering zone.

(2) The ion's "pathway": the pathway of ions is an important factor in the application of the electrochemical extraction technique. Faults and fissures above ore-bodies and active groundwater systems may result in distinct electrochemical extraction anomalies. Poor hydrological connection with the orebody however, may result in detection of unclear or weak anomalies only.

CASE STUDIES

Jinwozi gold deposits, Hami, Xinjiang Autonomous Region, China

In the Jinwozi area, arid residual regolith is about 10 m thick and the orebodies are hosted in a mylonite belt at depths between 20 m and 60 m. An investigation was undertaken using a voltage of 220 V and current of 400 mA and samples were collected at a period of 12, 16 and 24 hours. Gold content of the cation absorber was analyzed by chemical spectrometry analysis. The results of electro-extraction show distinct surface anomalies over the known gold orebody at depths of 20 m to 60 m (Figure 3). Surveys in the outer area of the gold mine, using a charge time of 24 hours, outlined two new electrochemical extraction gold anomalies (Figure 4). One of three holes (ZK104) drilled to test the anomalies intersected 4.5 m of ore-grade gold mineralization at a 160 m depth.

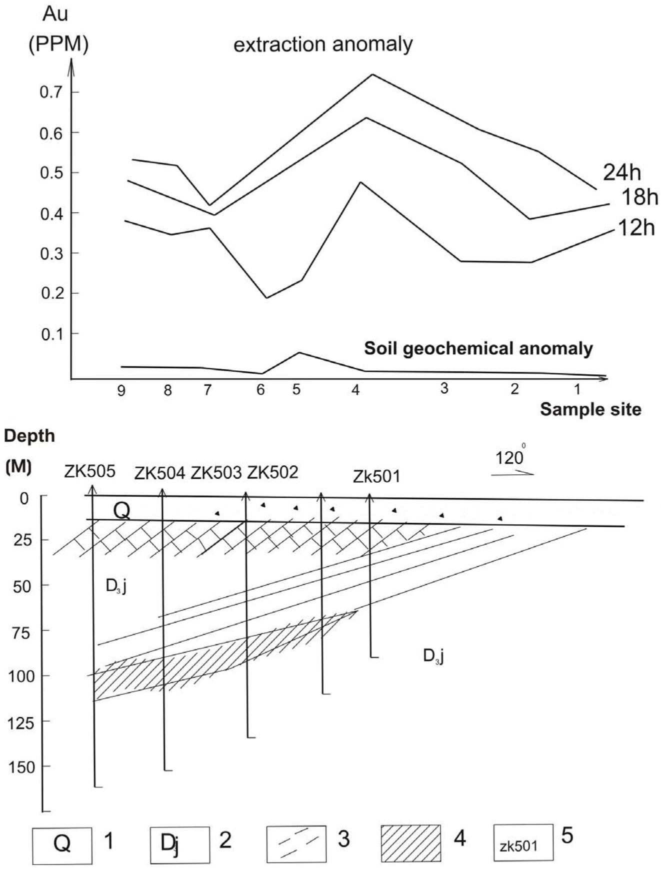

Figure 3: a) Results of electro-extraction of Line 5, Jinwozi Au deposit, Hami, Xinjiang, China; b) Cross-section of prospecting line 5, (1) Quaternary sediment (2) Jinwozi Group, Devonian sediments (3) Mylonite (4) Au orebody (5) Drillhole.

Yangcheng lead-zinc ore deposit, Hubei province.

A selected cross-section shows that the primary orebodies are located at depths of

200 m and greater in Triassic limestone, with a small shallow secondary (oxidized) ore zone near the surface (Figure 5). Voltage of 220 V, a current of 400 mA and a charging time of 25 hours were applied in the geoelectrochemical extraction test. The comparison of CHIM and conventional soil geochemical analysis shows that the electro-extraction anomalies of Pb and Zn are very distinct over the larger and deeper orebodies, while the soil geochemical anomalies only detect the shallow (secondary) mineralization.

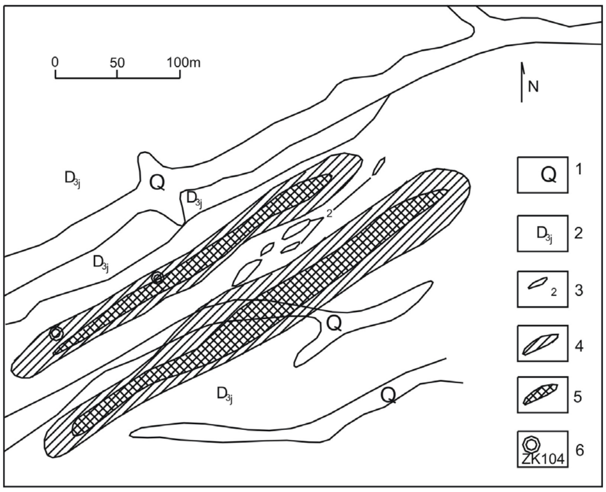

Figure 4: Map of anomalies of the electro-extraction of gold in outer area of Jinwozi gold deposit. (1) Quaternary sediment, (2) Jinwozi Group, (3) Quartz vein, (4) Au anomaly outer zone, (5) Au anomaly inner zone, (6) Drillhole.

DISCUSSION AND CONCLUSION

The extraction and analysis of elements in the form of mobile ions that can migrate over large distances makes it possible to reveal and trace concealed and overlapped orebodies. The method of diffuse extraction of metal ions under the action of electrical currents (CHIM) uses specialised synthetic sorbent collectors and successfully combines hydro-geochemical dispersion and sorption technology for use in mineral prospecting. This makes it possible to fix and accumulate the mobile form of many target elements using purpose designed ion-exchange resins, and other sorbents, for specific cations or anions. Applicability to a wide range of elements and deposit types are among the strengths of the method.

Over 10 years, studies with the geoelectrochemical extraction technology in various geochemical landscapes, including residual and transported regolith overlying copper, lead, zinc, tin, gold, silver, arsenic and antimony ore deposits, demonstrate that the geoelectrochemical extraction technique is a useful and effective technique for mineral exploration. Geoelectrochemical extraction anomalies have been detected over known concealed orebodies and resulted in the discovery of new orebodies not only in China but also in Ukraine, Russia and Canada. Experimental and field studies with the geoelectrochemical extraction method show that (a) metallic ions around an orebody are mainly derived from electrochemical dissolution and move to the collector under the action of electric field extraction, (b) The technique is well suited to exploration for a wide range of hidden ore types.

The geoelectrochemical extraction technique is also a useful and effective method for evaluating anomalies defined by conventional geophysical or geochemical methods because this technique measures directly the ions released from the target anomaly. In areas of transported overburden or deep weathering this technique may be more effective than conventional geophysical and geochemical methods; it at least can enhance any weak anomalies. The prospecting depth may be significantly greater than conventional geochemical methods because the technique activates, collects and concentrates the more mobile ions.

Due to the short history of development of CHIM however, there remain many challenges including: modeling the mechanisms of the geoelectrochemical process for particular ores; migration dynamics of various positive and negative ions in the regolith environment; and, the relationship between power supply, extraction capacity and detection depth. There is also a need for ongoing development of cheap and rapid analytical techniques that give accurate low level detection of elements compatible with ion sorbent collectors used by the electro-extraction technique.

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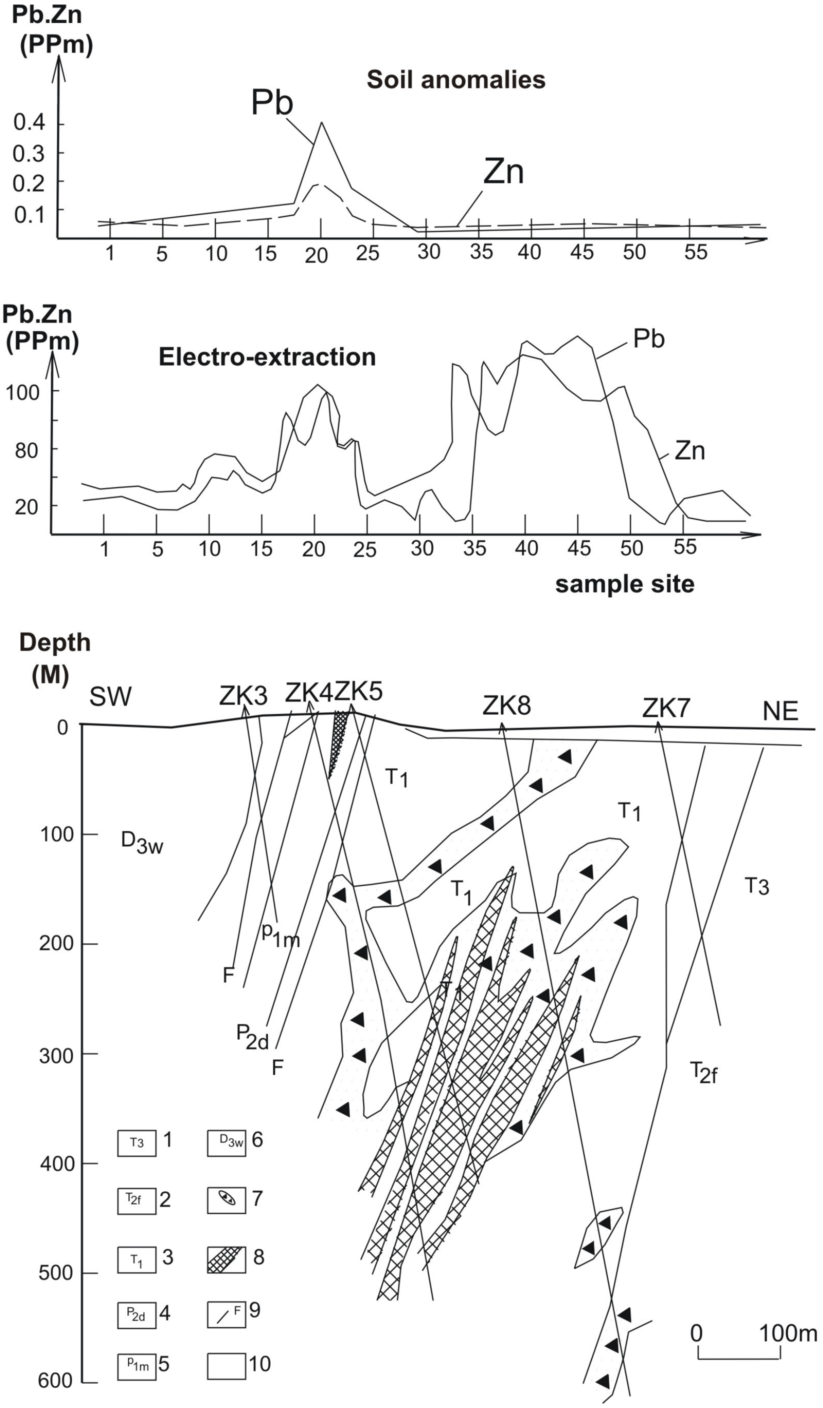

Figure 5: Results of electro-extraction at line 7 in Yangchong lead-zinc deposit. (1) Triassic limestone, (2) Fenglishan team dolomite, (3) Daye Team dolomite, (4) Dalong Team limestone, (5) Maokou Team limestone, (6) Wutong Team sandstone, (7) Karst breccias, (8) Pb-Zn orebody, (9) Fault, (10) Drillhole.

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