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Geochemical challenges of diverse regolith-covered terrains for mineral exploration in China

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ABSTRACT

In recent years mineral exploration has concentrated on concealed deposits in regolith-covered terrains. In China, the regolith-covered landscapes mainly include desert windblown sand basins, desert peneplains, semi-arid grassland, loess plateaus, forestry land, alluvial plains and laterite terrains. These diverse regolith-covered areas represent geochemical challenges for mineral exploration in China. This paper provides an overview of recent progress on mechanisms of metal dispersion from the buried ore deposits through the transported cover to the surface and penetrating geochemical methods to detect the anomalies. Case studies show that, in arid and semi-arid desert sand-covered terrains, sampling of fine-fraction (−120 mesh, <0.125 mm) clay-rich horizon soil is cost-effective for regional geochemical surveys for sandstone-type uranium, gold, and base metal deposits. Fine-fraction sampling, selective-leaching and overburden drilling geochemical methods can effectively indicate the 210 gold ore body at Jinwozi goldfield. In alluvium-covered terrains, fine-grained soil sampling (−200 mesh, <0.074 mm) combined with selective leaching geochemistry shows clear ring-shaped anomalies of Cu and Ni over the Zhouan concealed Cu–Ni deposit. In laterite-covered terrains, the anomalies determined by the fine-fraction soils and selective leaching of absorbed metals on coatings of Fe–Mn oxides coincide well with the concealed deposit over the Yueyang ore deposits at the Zijin Au–Cu–Ag field. Nanoparticles of hexagonal crystals mainly native copper, gold and alloys of Cu–Fe, Cu–Fe–Mn, Cu–Ti, and Cu–Au were observed in gases, soils and ores using a transmission electron microscope (TEM). The findings imply that nanoparticles of gold and copper may migrate through the transported cover to the surface. Uranium is converted to uranyl ions [UO_2^{2+}] under oxidizing conditions when migrating from ore bodies to the surface. The uranyl ions are absorbed on clay minerals, because clay layers have a net negative charge, which needs to be balanced by interlayer cations. Nanoparticles of Au and Cu and ion complexes of U are more readily absorbed onto fine fractions of soils containing clays, colloids, oxides and organic matters. Thus, fine-grained soils enriched with clays, oxides and colloids are useful media for regional geochemical surveys in regolith-covered terrains and in sedimentary basins. Fine-fraction soil sampling combined with selective leaching geochemistry is effective for finding concealed ore bodies in detailed surveys. Penetrating geochemistry at surface sampling provides cost-effective mineral exploration methods for delineation of regional and local targets in transported cover terrains.

1. Introduction

Geochemical exploration has played an important role in mineral discoveries, particularly due to China's National Geochemical Mapping Program — Regional Geochemistry-National Reconnaissance (RGNR). The program is almost covering all the outcropping mountainous and hilly areas (approximately 6 million km^2) mainly using stream sediment sampling (Xie et al., 1997). However, the diverse regolith-covered terrains provide an additional geochemical challenge for mineral exploration in China. In recent years, nation-wide mineral exploration activities are now concentrating on concealed deposits in regolith-covered terrains. Particularly in the new century, interest was kindled by the discoveries of the large porphyry copper deposits and large sandstone-type uranium deposits in Gobi desert terrains extending from northern China northward into Mongolia. For example the large copper porphyry deposit located at Tuwu in the Eastern Tianshan Gobi (Fig. 1) (Wang et al., 2007a), the large copper and gold porphyry deposits located at Oyuu Tolgoi, about 80 km from the Chinese border into Mongolia (www.ivanhoe-mines.com) and large sandstone-type uranium deposits at the Turpan–Hami Basin (Quan and Li, 2002) and at Ordos Basin (Dahlkamp, 2009).

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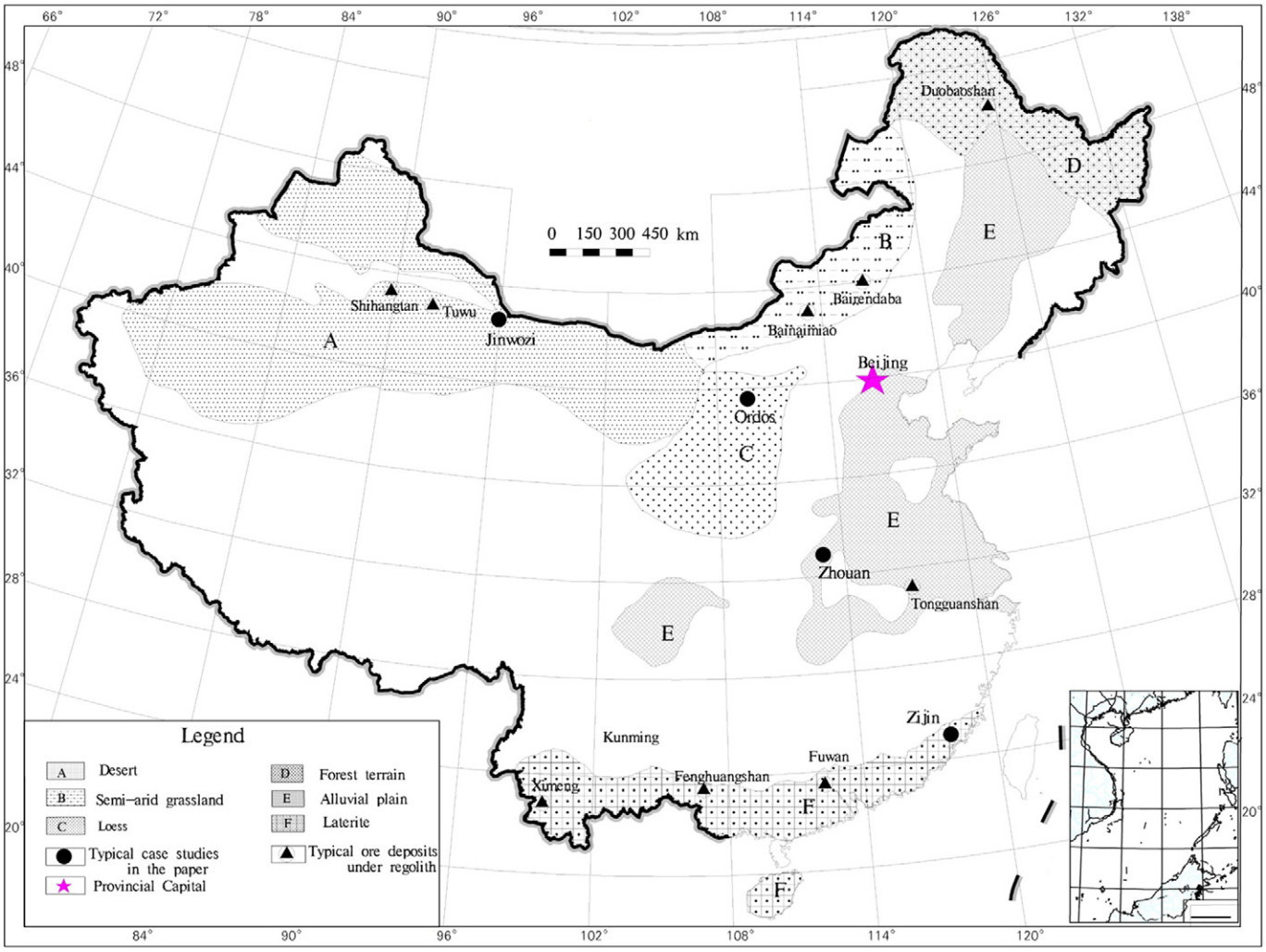

Fig. 1. Regolith-covered terrains with locations of case studies and some typical large ore deposits in Chinese covered terrains.

Table 1
Main features of different types of regolith-covered terrains.

Types of regolith	Estimated total surface (km^2)	Cover thickness range (m)	Climate & vegetation
Gobi desert (A)	1,435,000	A few meters to tens of meters at desert peneplains, more than 10 m at desert basins	i) Arid; ii) Average rainfall less than 200 mm; iii) Barren, sparse vegetation, shrub & alhagi-rich
Semi-arid grassland (B)	323,900	A few meters to tens of meters, an average of less than 10 m	i) Semi-arid continental climate; ii) Average rainfall of 300 mm; iii) Dominated by grass; iv) Chestnut soil well-developed;
Loess (C)	385,000	A few meters to more than 600 m, an average of 50–80 m	i) Semi-arid to semi-humid; ii) Average rainfall of 500 mm; iii) Broad-leaved and coniferous forests of temperate zone, farmland;
Forest terrain (D)	391,000	A few meters to tens of meters, an average of less than 10 m	i) Humid; ii) Average rainfall of 500–1000 mm; iii) Arbor-rich, humus well-developed; iv) Large areas of perpetually frozen soil; v) Broad-leaved and coniferous forests of frigid zone vi) Marsh areas widely distributed;
Alluvial plain (E)	996,200	A few meters to hundreds of meters, with a maximum of more than thousands of meters	i) Monsoon climate of medium latitudes; ii) Average rainfall of 500–1000 mm; iii) Farmland;
Laterite (F)	463,000	A few meters to tens of meters, an average of less than 10 m	i) Subtropical to tropical rain forest; ii) With average rainfall of 1800 mm; iii) Broad-leaved forest; iv) Soils enriched in iron and aluminum oxides.

A, B, C, D, E and F have the same meanings with those in Fig. 1.