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Geographical environment determinism for discovery of mineral deposits

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ABSTRACT

The spatial distribution of metallic mineral deposits discovered in China during 1901 to 2007 shows that nearly 85% of the total 2906 metallic mineral deposits with the magnitude greater than medium-size are located on the southeastern side of the famous Heihe-Tengchong "geo-demographic demarcation line". This spatial pattern is consistent with the population distribution of China, indicating that the spatial distribution of discovered mineral deposits may be related to exploration level that is strongly restricted by the geographic environments. We found that the number of discovered deposits per unit area in explored regions increases with the exploration level, following a power-law model. From this model, if the geological, geochemical and geophysical exploration in the NW region of the geo-demographic demarcation line reaches the same level as that in the SE region of the line, about 2000 metallic mineral deposits with magnitudes greater than medium-size remain to be discovered in the NW region of China.

1. Introduction

According to the standards for classification of the scales of mineral resource reserves in China (Ministry of Land and Resources of the People's Republic of China, 2000), during the period from 1901 to 2007, totally 2906 metallic mineral deposits with magnitudes greater than medium-size were found in China (National geological archives of China, 2007), of which those productively mined deposits have been the main domestic metallic mineral resource suppliers for Chinese economic development in the last 100 years.

About 85% of the total 2906 metallic mineral deposits are distributed at the southeastern side of the famous Heihe-Tengchong "geo-demographic demarcation line" (Figs.1 and 2A), which is basically consistent with the distributional pattern of population in the country since 1930s (comparing Fig. 1 and Fig. 3). The geo-demographic demarcation line is also called Huanyong Hu Line (HH Line) in the literature. In 1930s, the population in China totaled 458 million, of which about 96% were concentrated in the SE side of the HH Line, and merely 4% in the NW side (Hu, 1935). After 70 years, Chinese population increased to 1.3 billion, but the population distribution is still consistent with that revealed by the HH Line (comparing Fig. 3 A and B). The data of 2000 China census show that the proportional distribution of the population at the two sides of the line was 94.1% to 5.9% (Ge and Feng, 2008).

As we all know, the geographic environments such as landforms and climate on both sides of the HH Line are greatly different, thus the difference in the population distribution between the two regions separated by the line since 1930s mainly can be attributed to the differences in economic and societal developments resulted from different geographic environments between the two regions. An important similarity between the spatial distribution of discovered mineral deposits and the distributional pattern of population in China is noteworthy, which implies that geographical environments such as landforms and climate have an important control on the regional discovery frequency of mineral deposits. Although the different styles of mineralization are not randomly distributed, either in time or in space (Robb, 2005), and the formation of certain types of mineral deposits and their distribution in any given region depend on the crustal evolution and tectonic setting of that region, the chances of discovering mineral deposits, especially deposits under cover, will depend on geographical environments as well as economic and political factors under a given technological progress. Geographical environments have a great impact on the coverage and intensity of geological, geochemical and geophysical surveys for mineral resources, thereby the spatial distribution of discovered mineral deposits can be considered as a function of the geological exploration level.

A key function of many quantitative mineral resource assessments is estimating the number of undiscovered deposits (Singer et al., 2001). Allais (1957) used the Poisson distribution to estimate the number of deposits per square kilometer in a relatively unexplored area from several explored areas. Most resource assessments

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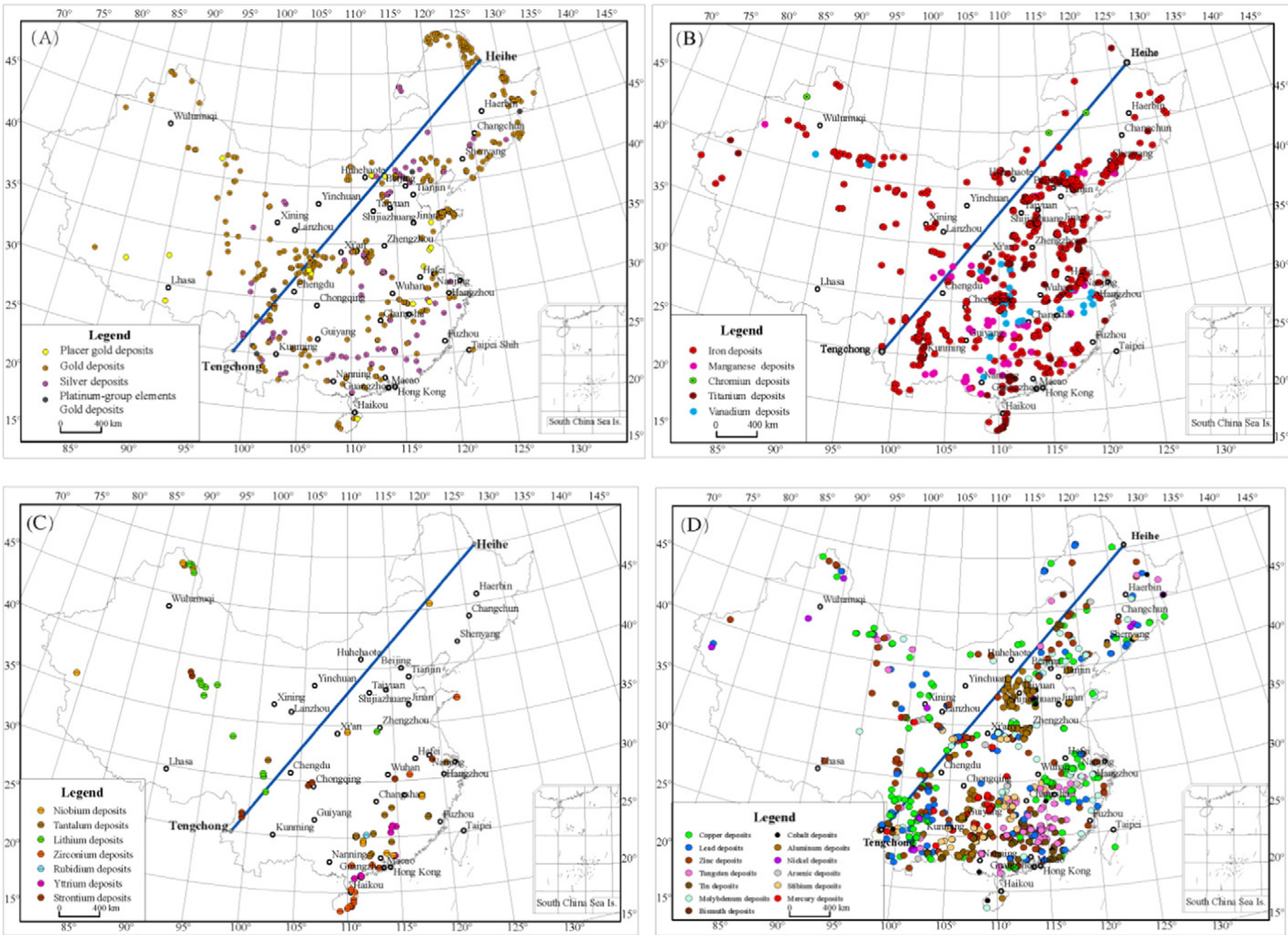

Fig. 1. Distributions of discovered 2906 metallic mineral deposits with magnitudes greater than medium-size in China during the period from 1901 to 2007 (compiled after National Geological Archives of China, 2007; Institute of Mineral Resources of Chinese Academy of Geological Sciences, 2009). (A) gold, silver and platinum-group element deposits; (B) iron, manganese, chromium, titanium and vanadium deposits; (C) niobium, tantalum, lithium, zirconium, rubidium, yttrium and strontium deposits; and (D) copper, lead, zinc, tungsten, tin, molybdenum, bismuth, cobalt, aluminum, nickel, arsenic, antimony and mercury deposits. The blue line is the HH Line.

used multivariate statistical or numerical-statistical methods to estimate the number of undiscovered deposits (Singer et al., 2001). In addition, a discrete lognormal distribution that is close to the power-law model was recommended for estimating the densities of mineral deposits that could be used for probabilistic estimates of the number of undiscovered deposits and their total tonnages in permissive tracts (Singer, 2008; Singer and Kouda, 2011; Singer, 2013). Many studies have suggested that the spatial distribution of mineral deposits follows power-law (fractal) distributions (e.g., Carlson, 1991; Agterberg et al., 1993; Li et al., 1999, 2002, 2003; Raines, 2008; Deng et al., 2009; Ma et al., 2014). If the spatial distribution of mineral deposits follows statistically power-law (fractal) distributions, the number of undiscovered deposits should be estimated with a power-law (fractal) model rather than using the Poisson or discrete lognormal distribution assumption.

This study derived a power–law relationship between the number of discovered mineral deposits per unit area and the exploration level for mineral resources based on the data of the coverage and intensity of geological, geochemical and geophysical exploration for mineral resources during the period 1901 to 2007 in China and mineral deposits discovered in the country in that period, and the derived the power-law (fractal) relation is applied to estimating the number of deposits undiscovered in the northwestern region of the HH Line.

2. Data used in this study

The data on the deposits and the exploration level used in this analysis were acquired from the 1:5,000,000 mineral resources map database of China (National Geological Archives of China, 2007), the Atlas of Geological Exploration Degree in China from 1901 to 2000 (China Geological Survey, 2004), and the 1:5,000,000 map of geological exploration degree for non-energy mineral resources (Institute of Mineral Resources of Chinese Academy of Geological Sciences, 2009). In about 100 years' geological exploration from the early 1900s to 2007, 2906 metallic mineral deposits with magnitudes greater than medium-size have been found in China (Taiwan Province is not included in the statistics), including 570 precious metal deposits (gold, silver and platinum-group metals deposits), 689 ferrous metal deposits (iron, manganese, chromium, titanium and vanadium deposits), 96 rare-metal deposits (niobium, tantalum, lithium, zirconium, rubidium, yttrium and strontium deposits), and 1371 nonferrous metal deposits (copper, lead, zinc, tungsten, tin, molybdenum, bismuth, cobalt, aluminum, nickel, arsenic, antimony and mercury deposits). The distributions of these deposits are shown in Fig. 1. The detailed description of the types of these deposits and their metallogenic and geologic settings can be found in Chen et al. (2007) and Xu et al. (2008).

According to exploration workload per unit area (including geological, geochemical and geophysical surveys at various scales as well as