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Geochemical studies on Permian manganese deposits in Guichi, eastern China: Implications for their origin and formative environments

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ABSTRACT

Permian manganese ore deposits are widely distributed in southwestern and eastern China. Guichi Permian manganese district in southern Anhui Province, central eastern China, is currently the most important manganese metal producers in eastern China. Manganese ores (MnO = 18.2–45.4 wt.%) in Guichi region occur in calcareous, argillaceous and siliceous Mn-bearing sequence of the Permian Gufeng Formation. In contrast to Mn-bearing rocks, the ores have higher Mn, Fe, P, Sr (more than 1500 ppm) and Ni contents (>480 ppm), higher Mn/Fe (>5) and La_n/Ce_n (>2) values, and lower Co/Ni (<0.05) ratios. The Guichi manganese deposits also have low Co/Ni (<1) and Co/Zn ratios, low in total REE contents (mostly < 100 ppm) with negative Eu (0.46–0.75) and Ce (0.42–0.76) anomalies. The mineralogy and geochemistry of manganese deposits in the Guichi region strongly indicate hydrothermal activities, which is supported by high paleotemperatures (49–71 °C) of Permian Mn-carbonate ore and Mn-bearing carbonate. The low $Ce_{anom.}$ values (<−0.1) and high strontium contents indicate that the Guichi manganese deposits were formed in high-salinity and oxidative marine sedimentary environment. The Al_2O_3/TiO_2 (9.23–48.2) and Y/Ho (25.9–44.4) ratios, REE patterns, $\delta^{13}C_{V\text{-}PDB}$ (−10.2‰ to 5.00‰) and $\delta^{18}O_{SMOW}$ (20.7–28.0‰) characteristics of Permian manganese deposits reveal a mixed Mn source of volcanic, terrigenous and organic matter.

1. Introduction

Manganese ore deposits are widely distributed in China, which is ranked fifth in the world in terms of total Mn reserves. The sedimentary Mn deposits comprise ~70% of the total Mn reserves of China (Fan and Yang, 1999), and are primarily hosted by mud rock, black shale, carbonate rock, and chert–mudstone–limestone (Fan and Yang, 1999; Fan et al., 1999), and formed during the Proterozoic, Cambrian, Ordovician, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous and Quaternary (Fig. 1) (Fan and Yang, 1999; Fan et al., 1999; Hein et al., 1999; Liu and Xue, 1999; Tang and Liu, 1999; Xie et al., 2006; Yeh et al., 1999; Zeng and Liu, 1999). Most of the Mn reserves of China are distributed in the Neoproterozoic, Devonian and Permian periods. In contrast, Proterozoic, Devonian, Cretaceous and Oligocene Mn deposits are widely found elsewhere in the world (Fig. 1) (Brusnitsyn and Zhukov, 2012; Fitzgerald and Gillis, 2006; Jach and Dudek, 2005; Munteanu et al., 2004; Nyame, 2008; Nyame et al., 2002; Polgári et al., 2012, 2005; Roy, 2006; Salas et al., 2008; Sethumadhav et al., 2010).

Permian manganese deposits, which typically show a Si–Ca–Mn element association (Fig. 1), are mainly distributed to the south of the Yangtze River in China (Fig. 2). The main deposits are the Gexue medium-sized manganese deposit (2–20 million tonnes reserve and Mn grade >18% according to China standard) in Yunnan Province; the Shuicheng (medium), Nayong (medium) and Zunyi (large, >20 million tonnes reserve) manganese deposits in Guizhou Province; the Bayi (large), Pinglu, Lipu and Fenghuang (medium) manganese deposits in Guangxi Province; the Dongxiang (large, Qiyang-Lingling), Dongshanxia (medium) manganese deposits in Hunan Province; the Daye, Jiayu and Hongan (medium) manganese deposits in Hubei Province; and the Guichi manganese deposit (medium) in Anhui Province (Fig. 2).

The Guichi manganese district is situated in southern Anhui Province, which is currently the most important manganese metal producers in eastern China (Xie et al., 2006). Mn-ore reserve and resource of Guichi manganese district are about 2.3 million tonnes (>18% Mn) and 5.0 million tonnes, respectively (Table 1). In contrast to Mn ore deposits in northeast and southwest of China, which have been studied in detail (Fan and Yang, 1999; Fan et al., 1999; Hein et al., 1999; Liu and Xue, 1999; Liu et al., 2008; Tang and Liu, 1999; Yang et al., 2009; Zeng and Liu, 1999), the Mn deposits in eastern China has rarely been studied (Xie et al., 2006).

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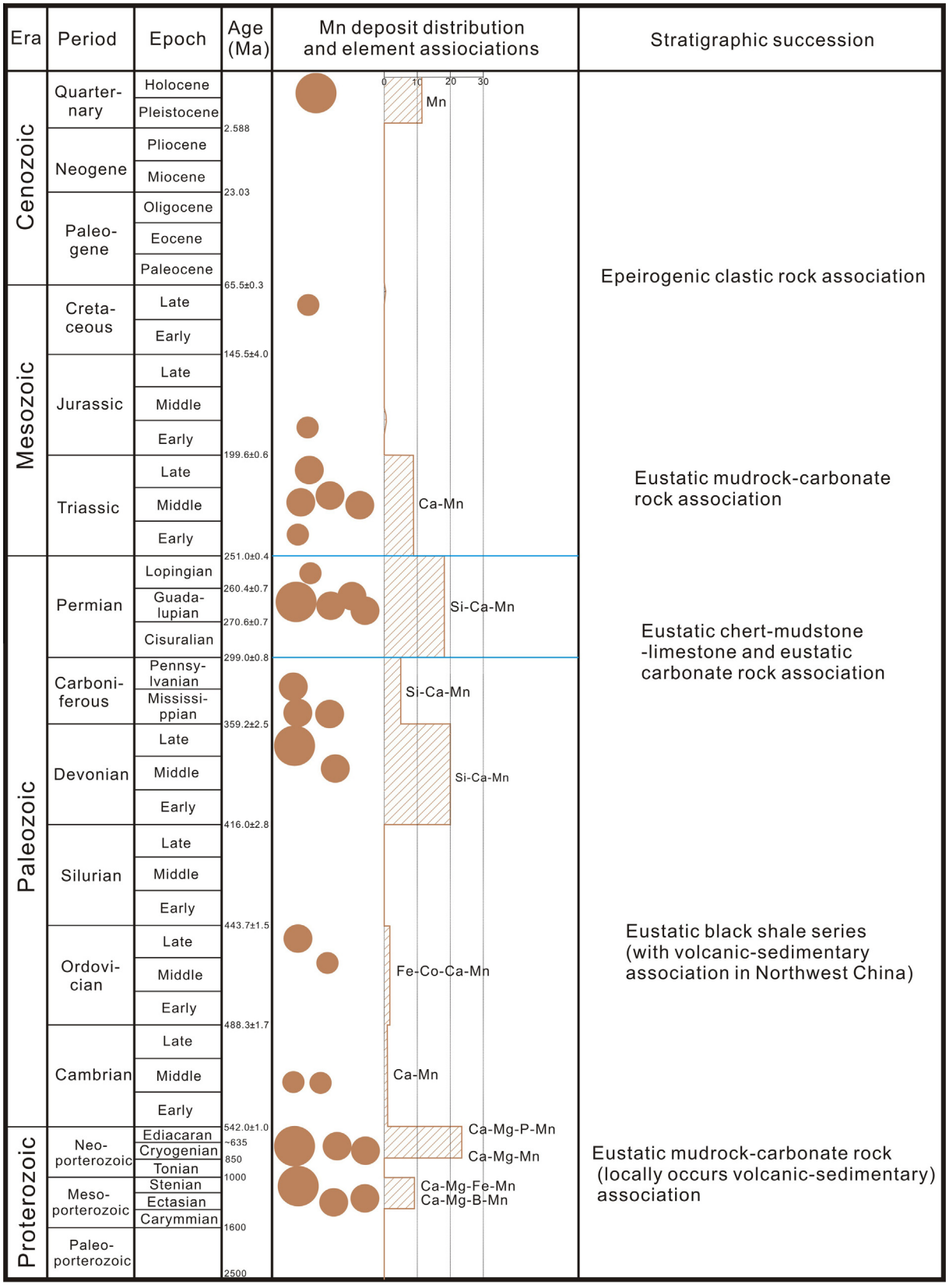

Fig. 1. Temporal–stratigraphic distribution and element associations of manganese deposits in China (modified from Fan and Yang, 1999). Brown solid circles of different sizes stand for large (>20 million tonnes reserve), medium (2–20 million tonnes reserve) and small (<2 million tonnes reserve) of manganese ore deposits, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)