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Recognition, genesis and evolution of manganese ore deposits in southeastern China

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ABSTRACT

Manganese ore deposits are common in the Falang Formation of Ladinian age (Middle Triassic), southeastern Yunan, China. The deposits containing manganese oxide and manganese carbonate ores are not metamorphic in origin and they commonly contain bioclasts. Concentric ring structures are clearly observed in oolitic and pisolitic manganese ores. An integrated approach using sedimentology and paleoenvironment analysis provides new insight into the genesis of these ores. Systematic research has been conducted on typical deposits (Dounan, Yanzijiao, Laowu, Tujichong) using cathodoluminescence and scanning electron microscope techniques, which allow elucidation of changes in laminated microtextures at the mm–μm scale. Preliminary results show that manganese enrichment in Triassic deposits of this region may be related to microbial activity and mineralization was a consequence of bacterially mediated diagenetic reactions. In addition, findings of biodetritus in the manganese ore indicate that manganese ore is close to the redox level. The concentration of manganese in solution and in precipitates in Triassic is controlled by bacterial oxidation and redox conditions corresponding to sea level changes during the Ladinian.

1. Introduction

The demand for manganese has increased as a result of a rapidly-developing metallurgical industry in China. The manganese deposits occur mainly in eastern China where they formed around the margins of platforms, especially the Yangtze Platform. The origin of manganese deposits in eastern China has not been well constrained, although some other deposits and their ores have been investigated by previous workers (Fan and Yang, 1994, 1999; Fan et al., 1993, 1999; Liu and Xue, 1999; Ye et al., 1988). The occurrence of these deposits also has been reviewed in some comprehensive treatises (Fan et al., 1999; Hein and Fan, 1999) produced in the late 1990s. The genesis of these deposits have been investigated by some researchers (Hou, 1994; Liu and Xue, 1999), and it has been suggested that the deposits were formed following hydrothermal alteration and metamorphism of sediments deposited by gravity flows on the lower slopes (Zheng and Zhang, 1991).

Many studies of Fe–Mn nodules have been reported from modern and ancient environmental systems (Cronan, 1997; Hein et al., 1997; Nayak et al., 2011; Salama et al., 2012; Usui and Someya, 1997; von Stackelberg, 1997). The role of bacteria in the formation of certain types of manganese ore deposits also has been investigated (Polgári et al., 2012a,b; Southam and Sanders, 2005). The present research focuses on oolitic and pisolitic microstructures, which appear to be particularly prevalent in manganese nodules, especially where cyanobacteria contributed to manganese enrichment. The aims of this study are to investigate manganese enrichment and its possible relationship to microbial activity, and to identify if the concentration of manganese in solution and as a precipitate is primarily controlled by bacterial oxidation and redox conditions. In this contribution, we offer a brief review of sedimentary environments of manganese deposits and their genesis for the southeastern part of Yunnan, China.

2. Geologic setting

In southeastern Yunnan, China, the Triassic stratigraphy indicates deposition at an active continental margin that was evolving into a passive margin (Geological Bureau of Yunnan, 1990). During the Ladinian Stage (Carnian), and possibly into the Norian, the study-area underwent two rapid late-stage spreading events due to extension of the Tethyan Ocean in the west.

Manganese deposits are mainly of platform sedimentary and supergene origins in southern China. The manganese deposits of southeastern Yunan contain high-quality manganese ore. Manganese deposits formed during the Ladinian (Middle Triassic), are found in the Falang Formation, and are widely distributed along the southeastern margin of Jianshui–Luoping (Fig. 1). The Falang Formation is composed of mudstone and siltstone, and sandstone interbedded with carbonate.

Manganese-bearing sequences of the Falang Formation are disconformably overlain by clastic rocks of the Upper Triassic Niaoge

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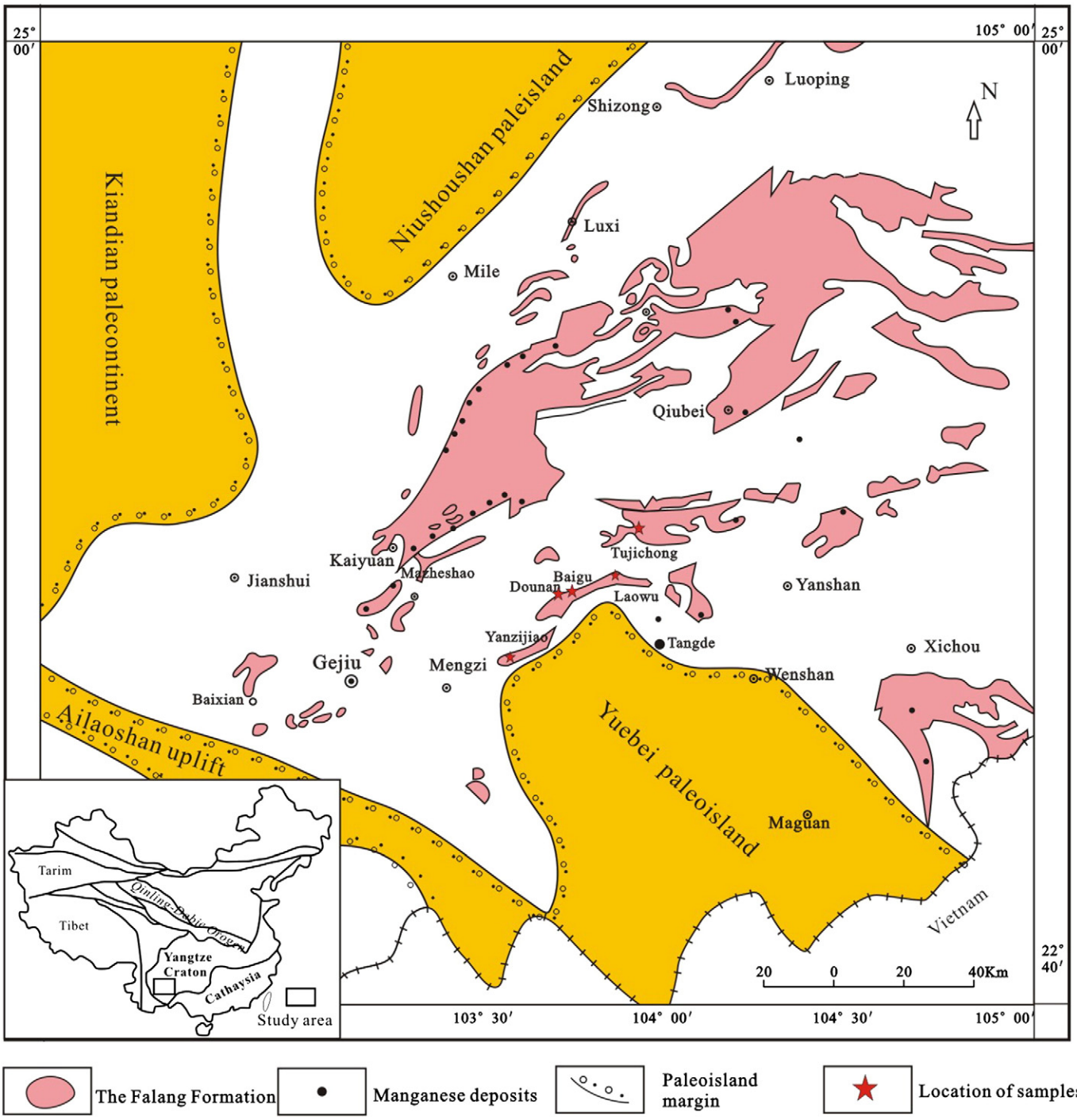

Fig. 1. The Falang Formation and manganese deposits in southeastern Yunnan.

Formation. The Falang Formation disconformably overlies the Middle Triassic Gejiu Formation limestone (Fig. 2). The Falang Formation can be divided into a lower and an upper manganese bed. Both beds are commonly found together in the Dounan deposits. Contrary to this, the Yanzijiao deposit contains the lower manganese bed, while the upper manganese bed pinches out. The Laowu deposit hosts the upper manganese layer, while the lower manganese bed pinches out.

Manganese ores in the ore-bearing strata are composed dominantly of manganese oxides (braunite in the Dounan, Yizijiao, and Laowu deposits) and manganese carbonates (rhodochrosite, Ca rhodochrosite). Cementations are composed dominantly of calcite and dolomite, quartz, and authigenic albite are secondary.

3. Samples and methods

The manganese-bearing samples investigated in this study are from five locations (Fig. 1): (1) the upper Mn-bearing series at Baigu; (2) the lower Mn-bearing series of the Dounan; (3) Laowu deposits; (4) the Yanzijiao deposit; and (5) the Tujichong deposit. All samples are from Mn-bearing sequences of the Falang Formation. Manganese ores are composed of dark gray oolitic and pisolitic limestone, with red banded and blocky ores.

Bulk oncolite rock samples (Fig. 3a, b) were collected from each of the studied deposits, and thin sections were made for textural and microfacies analyses. The precise characterization of the minerals was