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Geochemistry of vein and wallrock carbonates from the Ediacaran system in South China: Insights into the origins of depositional and post-depositional fluids

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ABSTRACT

A combined study of carbon–oxygen isotopes and major-trace elements was carried out for vein and wallrock carbonates from the Lantian Formation of the Ediacaran system in South China. The results provide geochemical constraints on the origins of depositional and post-depositional fluids with respect to recognition of the post-depositional alteration. The Lantian Formation was subdivided into the Upper and Lower carbonate units. For the Upper Unit (UU), petrographic observations indicate that wallrock carbonates only experienced limited post-depositional alteration. The wallrock exhibits $\delta^{18}O$ values of −19.2 to −13.1‰ and $\delta^{13}C$ values of −9.6 to −8. 9‰ (both relative to VPDB). The vein carbonates are divided into Groups A and B based on their $\delta^{18}O$ values and REE + Y patterns. Group A veins show nearly similar $\delta^{18}O$ and $\delta^{13}C$ ranges to, but different REE + Y patterns from, the wallrock. These data indicate that the origin of fluids for Group A veins may be similar to that of wallrock, which was probably the mixture of continental and marine glacial meltwaters. Group B veins show both different $\delta^{18}O$ values and REE + Y patterns from, but similar $\delta^{13}C$ values to, the wallrock. This indicates that post-depositional fluids are different from the depositional fluids and thus of external origin. Low $\delta^{18}O$ values −23.7 to −18.1‰ for Group B veins indicate that the post-depositional fluids were derived from continental glacial meltwater. There is no correlation between $\delta^{18}O$ and $\delta^{13}C$ values for these vein and wallrock carbonates, suggesting that the wallrock was not extensively altered by the post-depositional fluids.

For the lower unit (LU), veins exhibit different C–O isotope compositions and REE + Y patterns from wallrock carbonate, indicating that post-depositional fluids have different geochemical compositions from depositional fluids and thus are of external origin. The simultaneous changes in $\delta^{18}O$ and $\delta^{13}C$ values with different laminations in the wallrock carbonates suggest the preservation of the primary geochemical compositions. The $\delta^{18}O$ values and REE + Y patterns for the LU veins indicate that the post-depositional fluids were probably the mixtures of continental and marine glacial meltwaters. Therefore, the Lantian carbonates record the incorporation of continental glacial meltwater into the marginal sea of Ediacaran age. Nevertheless, the geochemical screening can provide constraints on the preservation of primary signatures and thus on the origins of depositional and post-depositional fluids in the Neoproterozoic marine carbonates.

1. Introduction

Ancient marine carbonates are susceptible to post-depositional alteration subsequent to their chemical precipitation from seawater. This may have changed the primary geochemical compositions and imparted secondary signals. As a consequence, the geochemical compositions of marine carbonates may no longer accurately reflect the pristine signals of ancient seawater (Holser, 1997; Jacobsen and Kaufman, 1999; Walter et al., 2007; Knauth and Kennedy, 2009). It is usually considered that Precambrian carbonates cannot preserve their primary signatures of marine precipitates (Knauth and Kennedy, 2009; Derry, 2010). Therefore, the pristine property of marine carbonates must be ensured when using them for reconstruction of seawater geochemistry (Garzione et al., 2004; Ghosh et al., 2006; Bera et al., 2010).

The post-depositional processes of marine carbonates include diagenesis subsequent to the chemical precipitation and lithification at elevated pressure (Knauth and Kennedy, 2009) and post-lithification processes (Pili et al., 2002). During the diagenesis and lithification, originally precipitated phases undergo dissolution, reprecipitation and geochemical exchange with ambient pore or external fluids (Land, 1986). During the post-lithification processes, external or internal fluids could be infiltrated into marine carbonates, leading to changes in their geochemical compositions (Pili et al., 2002). Thus, the nature of post-depositional fluids is a key to the geochemistry of marine carbonates after their deposition. However, the origin of post-depositional fluids

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and the way by which they flow through marine carbonates are poorly known. Furthermore, it is critical to distinguish the post-depositional fluids from depositional fluids in terms of geochemical composition.

The geochemical exchange between carbonate minerals and post-depositional fluids can be either internal or external processes (Wilson et al., 2000; Garzione et al., 2004; Jaffrés et al., 2007; Zhao and Zheng, 2013). When neither temperature nor the isotope composition of post-depositional fluid is different from that of depositional fluid, the origin of post-depositional fluid would be internal and the geochemical exchange between carbonate minerals and post-depositional fluid can be considered as an internal process (Wilson and Evans, 2002; Garzione et al., 2004; Jaffrés et al., 2007). However, post-depositional fluids may be derived from meteoric water or continental glacial meltwater, which are of external origins with respect to Precambrian marine carbonates (Jacobsen and Kaufman, 1999; Morrill and Koch, 2002; Knauth and Kennedy, 2009; Derry, 2010). In this case, it is important to distinguish the internal fluids from the external fluids with respect to the effect of post-depositional alteration.

Vein and cement carbonates occur widely in marine limestones and their geochemical compositions are commonly used to provide constraints on the origin of post-depositional fluids (Suchy et al., 2002; Hood et al., 2003; Wanas, 2008; Suchý et al., 2010; Wang et al., 2010; Zhao and Zheng, 2013). While the wallrock carbonate records the composition of depositional fluids, the vein carbonate records the composition of post-depositional fluids. In addition, the timing of externally post-depositional fluids can be determined by the geochemical proxy of components that formed in different stages of diagenesis (Brigaud et al., 2009; Harwood et al., 2013). Thus, different occurrences of carbonates, such as vein, cement and wallrock, can provide important information on the nature of fluids in different phases (Lee et al., 1996; Zhao and Zheng, 2013). This issue is very important in the geochemistry of sedimentary rocks and thus merits investigation in detail. For this purpose, we present a combined study of carbon–oxygen isotopes and major-trace elements in veins and wallrock carbonates from the Lantian limestone of the Ediacaran system in South China.

2. Geological setting

South China consists of the Yangtze and Cathaysia Blocks that were converged along the Jiangnan Orogen (Zheng et al., 2013). Subduction of oceanic crust during the Late Mesoproterozoic to Early Neoproterozoic is commonly assumed for arc magmatism and subsequent amalgamation between the two blocks, with the closure of backarc basins and arc–continent collision in the early Neoproterozoic between them (Zhang and Zheng, 2013). The Ediacaran Lantian carbonates are located in southern Anhui (Fig. 1), which is situated in the eastern part of the Jiangnan Orogen and at the southeastern margin of the Yangtze Block.

The Middle to Late Neoproterozoic sedimentary succession in southern Anhui is mainly composed of siliciclastic rocks, glaciagenic diamictite, carbonates and turbidites that were deposited on passive margin environments (Zhou et al., 2001; Jiang et al., 2006). These sediments are widespread in the eastern part of the Jiangnan Orogen and unconformably overlie the Middle Neoproterozoic Shangxi Group. In ascending order, the Middle to Late Neoproterozoic succession in southern Anhui consists of the Jingtan, Xiuning, Leigongwu, Lantian and Piyuancun Formations. They are comparable with Cryogenian to Ediacaran sequences elsewhere in South China (Jiang et al., 2006; Zhu et al., 2007). Four unconformity/disconformity-bounded sequences subdivide the Neoproterozoic strata of South China (Zhu et al., 2007), but only the second and forth sequences occur in southern Anhui. The Jingtan and Xiuning Formations belong to the second sequence, and the Leigongwu, Lantian and Piyuancun Formations comprise the forth sequence (Wang and Li, 2003).

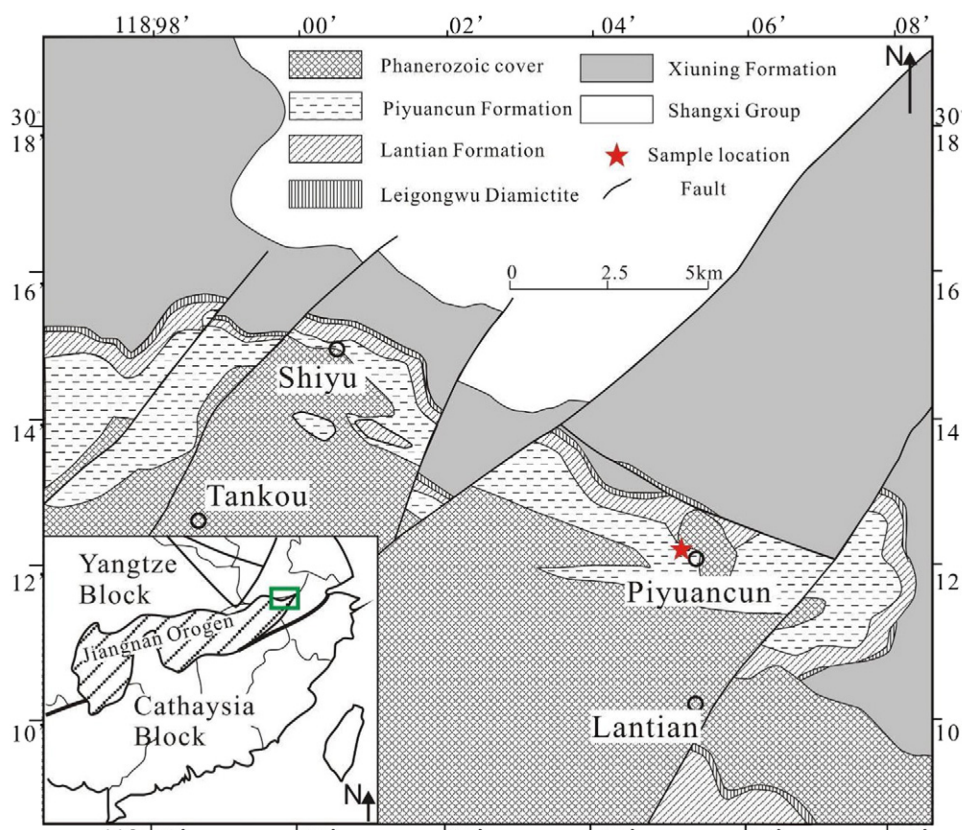

Fig. 1. Simplified geological map showing the sample locality at the Piyuancun section and the occurrence of Late Neoproterozoic sedimentary rocks in southern Anhui between the Yangtze and Cathaysia Blocks (insert) in South China (modified after Zhao et al., 2009). Asterisk denotes the sample locality.