The Carbonate Veins Documenting the Tectonic Evolution of the South China Sea Continental Margin from Early Cretaceous to Early Cenozoic

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Abstract

The transition from active to passive continental margin of the South China Sea (SCS) is usually inferred to occur in the Late Mesozoic to Early Cenozoic. However, it is less known about the tectonic characteristics of active continental margins before the Late Mesozoic, which hampers the recognition of integral evolution of the SCS. The International Ocean Discovery Program (IODP) site U1504 has sampled greenschist facies mylonite from the basement in the Outer Margin High of the northern SCS continental margin, which potentially record the Mesozoic and Cenozoic tectonic evolution of the SCS region. The microstructure has identified two episodes of deformation in the mylonite, namely early ductile and late brittle deformation, but without age constraints. Here, we further identify three episodes of carbonate veins (pre-mylonite, syn-mylonite and post-mylonite) in the greenschist facies mylonite according to the intersecting relationship between the veins and the mylonite foliation. Then we select 10 carbonate samples for in situ U-Pb dating, and obtain three accurate ages. The pre-mylonite carbonate veins are dated to 210 ± 20 Ma and 195 ± 32 Ma, respectively, which might denote the age of the protolith clast. The age of the syn-mylonite carbonate vein is 135 ± 12 Ma. But for the post-mylonite carbonate veins, no effective age was obtained using U-Pb dating method. Post-mylonite carbonate veins and late brittle fractures were formed at the same time, and the formation environment is similar to the overlying Late Eocene bioclastic limestone. Therefore, combining the microstructure, geochemistry and seismic profile, we speculate that the post-mylonite carbonate veins and brittle fractures may be formed during the Early Cenozoic rifting. These dating ages of the three episodes of carbonate veins suggest that the mylonite records at least two main periods of continental extension in the SCS region since the Early Cretaceous. In reference to the Mesozoic tectonic settings, we infer that, due to the slab rollback of the subducting paleo-Pacific, the SCS continental margin started significant extension during the Early Cretaceous as shown by the ductile deformation of the mylonite. In the Early Cenozoic, the mylonite was exhumated to the seafloor along with further continental extension, and weak brittle deformation occurred in the mylonite. Therefore, the Early Cretaceous extension of the SCS active continental margin may have a certain promotion effect on the rupture of the passive continental margin in the Cenozoic. Keywords: Greenschist facies mylonite; Carbonate U-Pb dating; Continental margin of the SCS; Early Cretaceous; IODP 368

Multi-stage carbonate veins at IODP Site U1504 document Early Cretaceous to early Cenozoic extensional events on the South China Sea margin

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Abstract

Recognition of the pre-spreading tectonic characteristics of the South China Sea (SCS) continental margin is key to understanding how the SCS opened. However, information on this subject is extremely scarce because of the lack of direct chronological constraints on deformation events. The International Ocean Discovery Program sampled greenschist-facies mylonite from the basement of the Outer Margin High at site U1504 in the SCS, which could provide information on the pre-spreading history. The microstructure analysis revealed that two episodes of extension had affected the mylonites, namely early ductile and late brittle deformation. Pre-mylonite, syn-mylonite and post-mylonite carbonate veins were identified on the basis of the intersecting relationships with the mylonite foliation. The pre-mylonite carbonate veins yielded U–Pb ages of 210 ± 20 and 195 ± 32 Ma, which might represent the age of the protolith. The age of the syn-mylonite carbonate vein is 135 ± 12 Ma. No effective ages were obtained for the post-mylonite carbonate veins using U–Pb dating. The $\delta^{13}C$, $\delta^{18}O$ and$^{87}Sr/^{86}Sr$ compositions of the post-mylonite carbonate veins suggest that they were formed by hydrothermal fluid precipitation dominated by seawater. Considering the extensively developed marine environment in the northern continental margin after the late Eocene, the post-mylonite carbonate veins at site U1504 likely formed in the Eocene or later. Combining the microstructure, geochemistry and seismic profile, we hypothesize that post-mylonite carbonate veins were formed during early Cenozoic rifting. In reference to the geological background, we conclude that the basement of the SCS margin experienced at least two stages of extension before spreading: the first stage occurred during the Early Cretaceous and was caused by rollback of the Paleo-Pacific plate; the second occurred in the early Cenozoic because of passive rifting. These multiple extensional events of the active continental margin and of the passive margin collectively resulted in thinning the SCS continental margin.

Keywords: Continental margin of the South China Sea; Pre-spreading tectonics; International Ocean Discovery Program 368; Greenschist-facies mylonite; Carbonate U–Pb dating

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