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Research Advances

LA-ICP-MS U-Pb Age, Clumped and Stable Isotope Constraints on the Origin of Middle Permian Coarse-Crystalline Dolomite Reservoirs in Northwest Sichuan Basin, Southwest China

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Objective

The recent discovery of commercial natural gas accumulations in the Middle Permian coarse-crystalline dolomites in the northwest Sichuan Basin has attracted attention to the formation mechanism of these deep-burial carbonate reservoirs. Due to their temporal relationship to the flooded basalts that represent the end-Middle-Permian Emeishan Large Igneous Province (ELIP), the Middle Permian dolomites were previously thought to be products of hydrothermal dolomitization related to the ELIP magmatism. Field and core observations, however, show that the occurrence and distribution of these dolomites are not controlled by faults, the supposed conduits for hydrothermal fluids. Conversely, they are somewhat strata-bound. Hence, the objective of this study, by employing LA-ICP-MS U-Pb dating, clumped isotope thermometry (Δ_{47}) and routine stable isotope geochemistry (C carbon, O oxygen and Sr strontium isotopes), is to re-evaluate the genesis of these dolomite reservoirs, with special attention focusing on the diagenetic environment and timing of dolomitization, and the attributes of dolomitizing fluids.

Methods

Approximately 80 carbonate samples, including both Middle Permian dolomite and limestone, were collected from the Chejiaba outcrop and Well K2 close to the Longmenshan fold-thrust belt in the northwest Sichuan Basin. The samples were prepared into double-polished thin sections and then subjected to both optical and cathodoluminescence (CL) microscopic analysis. Carbon, oxygen and strontium isotope analyses were completed at the Key Laboratory of Carbonate Reservoirs, China National Petroleum Corporation, using a DELTA V Advantage mass spectrometer and a Triton Plus thermal ionization mass spectrometer, respectively. LA-ICP-MS U-Pb dating of four dolomite samples was done at the Radiogenic Isotope Facility, University of Queensland. Clumped isotope thermometry was done on four samples at the University of California, Los Angeles.

Results

Petrographic observation shows that these dolomitized rocks, composed of both euhedral and anhedral dolomites (Fig. 1a), resulted from fabric-destructive dolomitization of skeletal grainstones, packstones and wackestones. The dolomite crystals exhibit moderate CL, implying their crystallization takes place at considerable burial depth, i.e., below the redox interface that favors the incorporation of divalent manganese into dolomite crystal lattices. The euhedral and anhedral dolomite samples have similar LA-ICP-MS U-Pb ages, ranging from 235 to 233 Ma (Fig. 1b and c), suggesting a Late Triassic dolomitization event that significantly postdated the termination age of the ELIP (259.1 ± 0.5Ma). The U-Pb ages of the dolomite samples, therefore, imply that the genesis of the dolomites is not likely related to the ELIP. Instead, the dolomitization chronologically coincided with the Late Triassic compression event of the northern Longmenshan fold-thrust belt.

Relatively higher $^{87}Sr/^{86}Sr$ values of the dolomite samples (Fig. 1d) compared with those of the carbonates precipitated in equilibrium with Middle Permian seawater (Veizer et al., 1999) also argue against the link between the dolomitization and the ELIP because magmatic (mantle) fluids are commonly ^{87}Sr-depleted. Instead, the fluid responsible for the dolomitization of the Middle Permian carbonates could have been a basinal brine, which is consistent with the high $^{87}Sr/^{86}Sr$, high Δ_{47} temperatures (about 100 to 120° C) and high $d^{18}O_{fluid}$ values of the dolomite samples (Fig. 1e).

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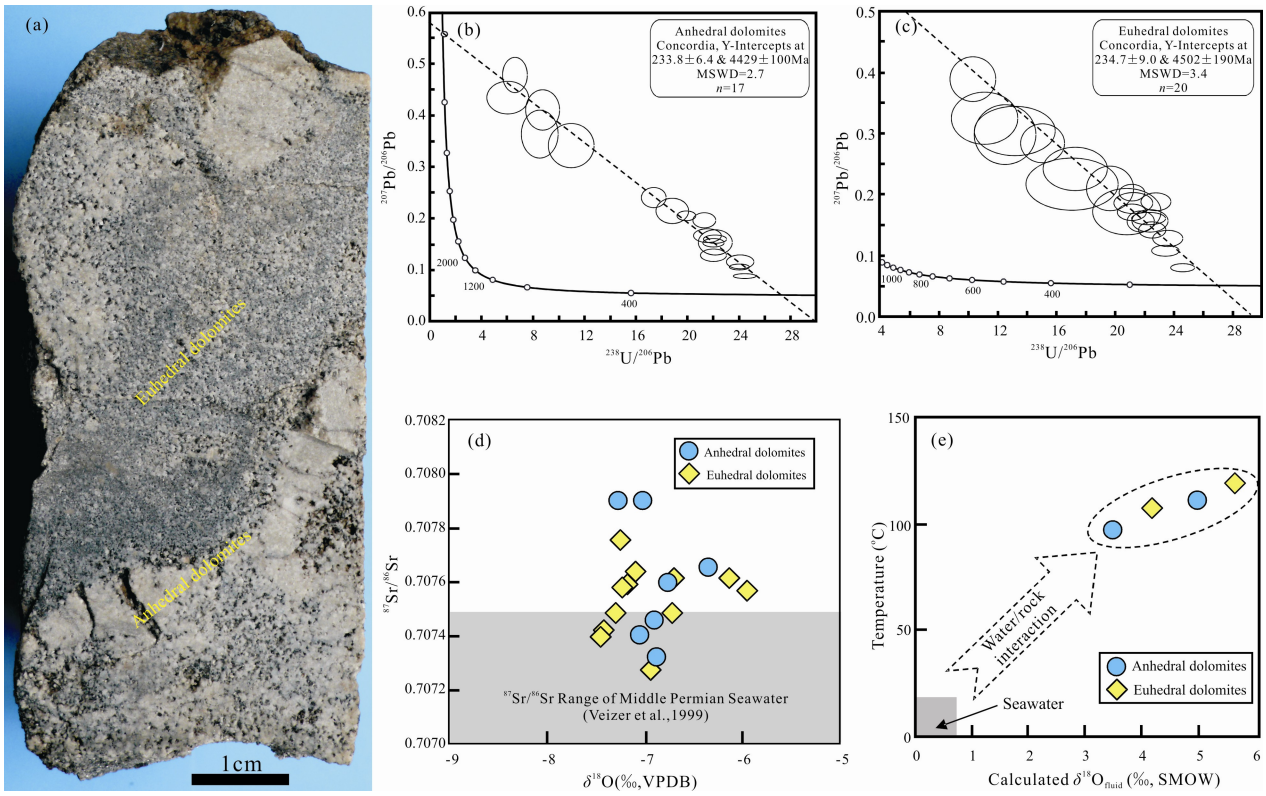

Fig.1. Petrography, U-Pb ages, and stable and clumped isotopes of Middle Permian dolomites

(a) Photograph of a sample composed of both euhedral and anhedral dolomites; (b) Tera-Wasserburg plot displaying $^{238}U/^{206}Pb$ versus $^{207}Pb/^{206}Pb$ for anhedral dolomites; (c) Tera-Wasserburg plot displaying $^{238}U/^{206}Pb$ versus $^{207}Pb/^{206}Pb$ for euhedral dolomites; (d) $\delta^{18}O$ versus $^{87}Sr/^{86}Sr$ plot; (e) Temperature and $\delta^{18}O$ (H_2O) recorded by Δ_{47} and $\delta^{18}O$ of dolomites.

Conclusions

Evidence from LA-ICP-MS U-Pb ages, and clumped and stable isotopes shows that the formation of the Middle Permian coarse-crystalline dolomites in the northwest Sichuan Basin is not linked to the ELIP at the end of the Middle Permian. Instead, these dolomites were formed from a basinal brine in the compressional setting during the Late Triassic.

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