Opening-mode fracturing and cementation during hydrocarbon generation in mudrocks: an example from the Barnett Shale, West Texas

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Natural fractures in mudrocks are common and develop due to different mechanisms operating at different times during the burial history. Knowledge on the mechanisms and timing of fracture opening and cementation is desirable because natural fractures can contribute to permeability if open, and can interact with hydraulic fracture treatments of shale hydrocarbon reservoirs whether open or sealed.

Analysis of fracture-filling cements in three fracture sets in core from the Barnett Shale in the Delaware Basin, West Texas is combined with a burial history model and data from fluid inclusion microthermometry and Raman spectroscopy to determine fracture timing, and to obtain insights into the mechanism of fracture formation. An early fracture set that was folded during shale compaction is mostly sealed with dolomite cement, but retains small pores lined with barite. A second set includes horizontal (bedding-parallel), low angle, and irregular subvertical fractures that are sealed with fibrous barite. The barite contains coexisting primary, liquid-rich hydrocarbon (oil) and aqueous fluid inclusions trapped at temperature and pressure (P-T) conditions of ~110°C, and ~55 MPa, respectively. We interpret the primary inclusions as forming during rapid burial when compaction disequilibrium combined with cracking of type II kerogen to oil caused an overpressure, thus providing a mechanism for fracturing. In addition, this set of fractures contains secondary, vapor-rich hydrocarbon (methane dominated) inclusions with condensate rims, trapped along planes that cross-cut the barite fibers. We interpret these secondary inclusions as having formed during secondary gas generation from oil (bitumen). A third set of fractures, which are partly open, contains quartz cement bridges with crack-seal structure indicative of quartz cementation during episodic fracture opening. Quartz cementation continued after opening had ceased, overgrowing the crack-seal structure. Methane saturated aqueous inclusions in the quartz bridges formed at P-T conditions of ~110°C and 35-45 MPa in the crack-seal quartz, and ~128°C and ~35 MPa in quartz overgrowths. Correlation with a burial history model suggests this set opened concurrently with, or soon after, the fractures with fibrous barite, but prior to secondary gas generation. The heterogeneous distribution of inclusions may reflect heterogeneous trapping of the two-phase hydrocarbon/aqueous fluid system in the reservoir. All three fracture events may have formed during the burial phase, although elements of the third set may have developed during the first uplift event associated with Laramide deformation.

Evaluating the provenance study methodology of using detrital zircon U-Pb ages in the Changjiang drainage basin

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High-resolution provenance study has been highly expected since the availability of single-grain dating methods, especially after the wide application of LA-ICPMS on the microanalyses of zircon grains. Large volumes of zircon dating data have been published in the last two decades in China. Data of crystalline zircon U-Pb ages and εHf(t) values have been extensively collected in the Changjiang drainage basin from over 100 journal papers, which were majorly published in the last decade. They were systematically analyzed, together with statistics on the outcropped area of igneous rocks, to explore the possibility to fingerprint provenance in such a wide and complex drainage basin.

Some major findings are summarized. (1) Some vast tectonic provinces, like the Yangtze Block extending from the upper reach to the lower reach, should be subdivided into several parts for the high spatial resolution of provenance study. (2) Only a few groups of zircon ages, including <50 Ma, 250~270 Ma and >3000 Ma, can be used directly to fingerprint their source from the Changdu Block, the northern and the western subdivisions of the Yangtze Block, respectively. (3) Some zircon ages are indicative of their specified sources based on the different peak ages of single individual tectonic events in the varied tectonic blocks (subdivisions). (4) The effectiveness of provenance distinguishing can be significantly improved by application of the scatter plotting of zircon U-Pb ages and εHf(t) values, while some groups of zircon ages are still unable to assign to any certain source. (5) The intrusion of the recycled zircons cannot be excluded, and sometimes they make a significant contribution to the fluvial zircons, like those from the widely distributed Triassic turbidites in the Songpan-Garze Massif. (6) The frequency based on counting the available dated zircon grains in each tectonic units are not necessarily the abundance of different aged zircons, usually quite different from the area statistics of the outcropped igneous rocks of the corresponding ages, so the high-resolution provenance study should take both into consideration.