



Microscopic Characteristics of Deformation Band in Porous Sandstone and Its Characterization of Deformation Mechanism

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Abstracts: Deformation bands in porous sandstones refer to thin strain localizations developed in porous rocks (porosity greater than 15%) or particulate sediments with incomplete cementation, which are mostly small and fault-like structures. Compared with general faults, they lack independent and continuous slip surfaces (Aydin et al., 2006; Fossen et al., 2007; Braathen et al., 2009). In clastic reservoirs, deformation bands may occur hierarchically as individual bands, as clusters, or in fault damage zones. The porosity and permeability of the deformation band are usually much lower than those of host rocks during the formation and development of the deformation band. Therefore, deformation bands in porous sandstones may change the physical properties of reservoirs and possibly affect hydrocarbon migration and accumulation. The study area of Yuanqian basin is a secondary graben structure in the northwest part of Jiangnan basin and the Upper Cretaceous Honghuatao Formation is composed of brown-red massive lithic quartz sandstone with conglomerate, siltstone and mudstone, with a thickness of 400–800 m, high porosity and good permeability (Qiao et al., 2011). Taking the densely developed deformation bands in Honghuatao Formation as the research object, according to the large-scale casting thin section, the types of deformation bands and their microscopic characteristics are analyzed in detail. The results show that the deformation band in the study area has the characteristics of shallow-middle burial depth, and mainly develops disaggregation band and cataclastic band, among which cataclastic band is the most common type. The characteristics and deformation mechanism of different types of deformation bands are different. The number of disaggregation bands in the study area is few in the field, the development scale is small, the width is narrow (mostly 1–3 mm), and most of them are single and not clustered. The rib protrusion is not obvious in appearance and the color is slightly lighter than the host rock (Fig. 1a). Under single polarized light, it can be observed that the grains in the disaggregation band did not break up obviously, but showed a certain directional arrangement, and the grain size did not decrease significantly, and then there is also no obvious change in porosity and permeability compared with host rock (Fig. 1b). All of the above reflect the characteristics of typical granular flow movement in shallow burial and weak diagenetic stage. A large number of cataclastic bands can be formed by cataclasis or cataclastic flow, and their deformation degree is different. Two-

stage cataclastic bands were obviously developed in the Honghuatao Formation according to the intersection relationship, and the degree of grain fracture in the cataclastic bands formed at different stages are different. The most common mode of grain fracture is multi-point contact and complete fragmentation. The first stage cataclastic band mainly formed by cataclasis, compressive stress is dominant, with medium grains fracture, and is truncated and staggered by the second stage cataclastic band and the displacement is about 1 mm. The second stage cataclastic band has a narrower bandwidth and the grains are completely crushed, which is formed by the cataclastic flow, indicating a strong left-lateral shear stress (Fig. 1c). The microscopic characteristics of single cataclastic bands and deformation-band clusters are good characterization of the formation mechanism of deformation bands. It can be divided into several aspects: uneven deformation along the strike of a single deformation band, relative homogeneous deformation perpendicular to the strike within a narrow single deformation band, intensification of the deformation band caused by cataclasis to cataclastic flow, heterogeneity within the deformation-band clusters formed by strain hardening. All these reflect the time evolution sequence of the deformation bands in the process of formation. When the porous rocks with middle or shallow burial depth (buried depth < 3 km) are subjected to stress, the granular flow and cataclasis occur in the larger pore space. Under the action of regional stress, many densely distributed “cataclastic cores” will be formed along the same direction which is characterized by a wide grain-size distribution and high matrix content because of grain-size reduction, angular grains and a distinct absence of pore space. When these adjacent “cataclastic cores” gradually develop and connect together, a deformation band will be formed. Granular cataclasis is relatively strong at each cataclastic core, while the cataclasis of grains between cataclastic cores is slightly weak. Thus it is easy for a single deformation band to show the alternation of granular cataclasis and pore reduction along its direction of extension (Figs. 1d, 1e). The grains are strongly crushed when the evolution degree of deformation band is strengthened, and the inhomogeneity along the direction of deformation band will be weakened. However, compared with the obvious heterogeneous deformation along the extension direction, the degree of cataclastic deformation at each cataclastic core is similar, thus forming a relatively homogeneous feature perpendicular to the strike of the cataclastic band. When

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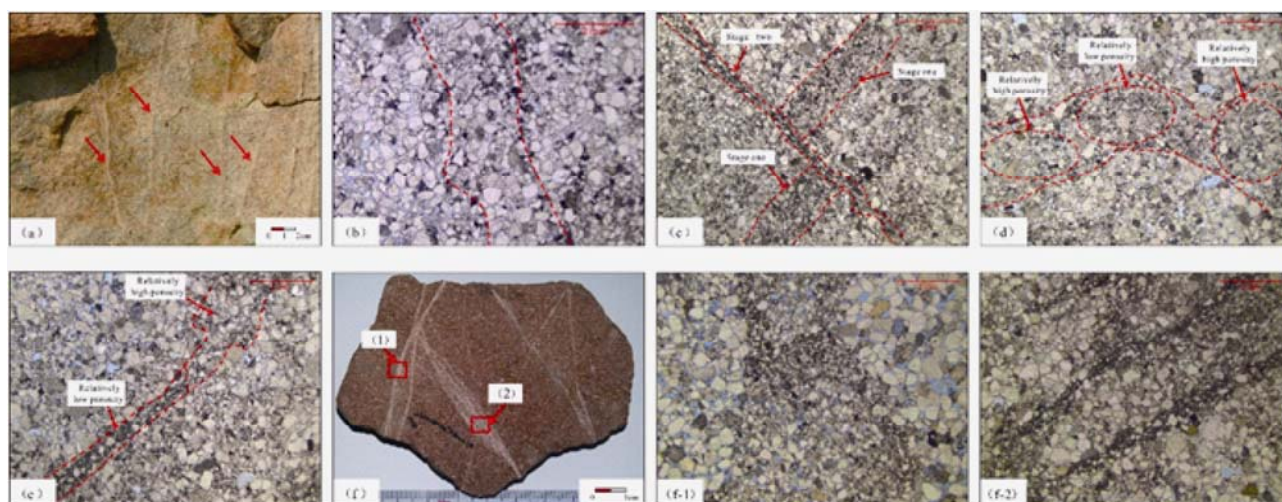


Fig. 1. Macroscopic and Microscopic Characteristics of deformation bands

(a) Disaggregation bands in field; (b) Microscopic characteristics of disaggregation bands; (c) Two-stage of cataclastic bands; (d,e) Inhomogeneous deformation in a single cataclastic band; (f) Macroscopic characteristics of deformation-band clusters; (f-1) A microscopic magnification of the box area (1) in the figure (f) microscopic characteristics of deformation-band clusters; (f-2) A microscopic magnification of the box area (2) in the figure (f) cataclasis and cataclastic flow in the deformation-band clusters

the burial depth of strata increases or the tectonic force acts quickly on the cataclastic band again, the pre-existing cataclasis will continue to increase, and the change from cataclasis to cataclastic flow will take place. The fractured grains with multi-point contact will continue to be fine-grained, forming argillaceous fragments, wrapping a small amount of larger grains in them, and directionally arranged under the strong compression-shear stress, showing the characteristics of cataclastic flow, thus forming cataclastic bands with lower porosity and permeability. Deformation-band clusters will be formed further because of strain hardening between these single deformation bands. The cluster of bands extend tens to hundreds of meters in length, and the width vary greatly along their strike which can occur in millimeters to centimeters, and generally larger than that of a single deformation band (Fig. 1f). It can be seen that every cataclastic band are moderately-completely crushed microscopically, the transition zones are formed between each individual cataclastic band, and the grains in the transition zones are also fragmented because of the cataclasis. However, the grain size is larger than that of the cataclastic bands, which is different from that of the cataclastic bands in terms of the weak degree of grain crushing (Fig. 1f-1, f-2). The complete evolutionary sequence of deformation band follows the formation order of disaggregation band, cataclastic cores, cataclastic band with medium degree of grain crushing, strengthening cataclastic band with complete crushed grains, clusters of cataclastic band and finally, a sliding surface is formed. Different types of deformation bands formed in different diagenetic stages can coexist and superimpose in different parts of a sandstone layer. Porosity and permeability in the cataclastic band decrease seriously compared with the host rock, and deformation-band clusters with completely grain crushing are likely to have a greater impact on fluid flow.

Keywords: porous sandstone, deformation band, cataclastic band, microscopic characteristics, deformation mechanism

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