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PAPER 8

SOFT-SEDIMENT DEFORMATION AND HYDRAULIC FRACTURING
OF DEEP-WATER SEDIMENTS: EXAMPLES FROM THE WEST CROCKER FORMATION
(OLIGOCENE-LOWER MIocene), SABAH, MALAYSIA

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Soft-sediment deformation is a common feature of sedimentary rocks deposited under conditions of rapid burial. In the Lower Miocene West Crocker Formation, Kota Kinabalu area (West Sabah), soft-sediment deformational features occur in deep-marine sandstone, interpreted as submarine turbidites and debris flows. The structures include load moulds, flame structures, dish structures, and injection structures. Both sand and clay injectites, although mainly of mm to cm in scale, seem to be a common feature of the West Crocker Formation but have not been documented in the past. The occurrence of clastic injectites, especially of sand, in deep-marine sediment has received much attention lately because of their reservoir potential and impact on reservoir continuity.

Another interesting and distinctive feature of the West Crocker debrites is the occurrence of layer-bound, bedding-normal fractures. These thin, often “hair-line” fractures are pervasive within individual sandstone beds but terminate in the shale beds above and below. Fracture spacing ranges from a few mm to 10’s of cm. They occur more commonly in the thicker (> 1 m) debrite beds, although some have been observed in beds that are less than 0.5 m thick. In the thicker beds, they are commonly associated with water-escape “dish” structures, and in places, clay injections at the base of the sand. These fractures are also cut by later, probably tectonic, faults.

The soft-sediment deformational structures, such as load and flame structures, were evidently formed by gravitational loading of sand onto a fluidized muddy substrate, very commonly occur in the cm-thick shale partings between the massive sandstone beds. Injection structures are usually the result of instantaneous release of overpressure through the fracturing and re-mobilization of semi-consolidated sediment. The soft-sediment deformation features were formed at shallow burial depths (metres to tens of metres), when the sediment was still poorly consolidated. In contrast, the brittle deformation, however, which had led to fracturing, must have occurred after the sands had attained sufficient strength through consolidation and lithification at moderate burial depths (probably many hundreds of metres). In a compacting sedimentary basin, where the maximum principal horizontal stress (σ1) direction is essentially vertical, tensile hydraulic fractures may form at right angles to the minimum principal horizontal stress (σ3) direction, resulting in layer-bound bedding-normal fractures.

We envisage a post-depositional evolution for the West Crocker debrites as follows: (1) deposition (2) shallow burial and soft-sediment deformation (3) deep burial, sealing and overpressuring, (3) fracturing and injection.