LABORATORY-INDUCED COMPACTION BANDS IN QUARTZ-RICH POROUS SANDSTONES

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Laboratory drilling experiments reveal a new borehole failure mechanism, initiated by the apparent development of a compaction band. This mechanism is common to quartz-rich porous sandstones, which typically have subrounded grains bonded by weak contact suturing, with very little or no cementation. The experiments are conducted on 150x150x230 mm sandstone blocks subjected to three unequal mutually-perpendicular compressive loads that simulate in situ stress conditions in the earth's crust. A 20 mm central borehole is then drilled along the long (vertical) axis of the specimen. As soon as the hole is drilled, a high stress concentration ensues at the borehole wall along the least horizontal stress (σ_h) springline, decaying rapidly with distance. Beyond some critical far-field stress magnitudes borehole failure occurs along the σ_h springline, but the type of failure is dramatically different from the dilatant microcracking leading to wide and shallow "dog eared" breakouts observed in crystalline and other clastic rocks. Failure in quartz-rich porous sandstones takes the form of tabular (long and very narrow) slot-like breakouts. Back-scatter SEM images show that ahead of the slot-breakout tip a long narrow zone of reduced porosity develops. The amount of grain cracking in the zone varies from none to severe, depending on grain angularity and the stress level. We infer that the high stress concentration along the immediate vicinity of the σ_h springline and the weak suturing combine to loosen grain contacts, allowing the grains to repack and reduce porosity without noticeable shear. The long and narrow zone matches the description of field compaction bands. The loosened grains at the borehole wall are flushed off, aided by the drilling circulating water, creating a slot-like breakout, similar in width to the reduced porosity zone, and can therefore be described as an 'emptied compaction band'.

Extensive testing of six quartz-rich sandstones yielded similar results in terms of the failure mechanism inception by compaction band formation. Of particular interest to us was the behavior of the Aztec sandstone, which outcrops in the Valley of Fire, Nevada and in which natural compaction bands are exposed and can be readily examined [1]. Specimens removed from that outcrop have a 2D porosity of 25%. SEM study of a natural compaction band in the Aztec showed largely intact grains, with some slightly cracked, and a sharply reduced 8% 2D porosity. SEM images of the zone ahead of the breakout tip in our experiments revealed a narrow band of compacted intact and slightly cracked grains also resulting in reduced porosity (to 17%.). Considering the very short duration of our tests, the difference in porosity reduction is not surprising. Otherwise, the close resemblance between the zone ahead of the breakout tip and the natural compaction band is strong evidence that slot-like breakouts are themselves emptied stress-induced compaction bands.

References

[1] K.R. Sternloff , J.R. Chapin, D.D. Pollard, and L.J. Durlofsky, "Permeability effects of deformation band arrays in sandstone", AAPG Bulletin, **88**, 1315-1329, 2004.

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