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Structural analysis of a fractured basement reservoir, central Yemen

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The Pan-African Arabian-Nubian Shield (ANS), within which Yemen lies, formed as a result of Neoproterozoic collisional events between c. 870-550 Ma. Several subsequent phases of extension occurred, from the Mesozoic (due to the breakup of Gondwana) to the Recent (forming the Gulf of Aden and the Red Sea). These resulted in the formation of numerous horst- and-graben structures and the development of fractured basement reservoirs in the southeast part of the ANS.

Two drill cores from the Mesozoic Marib-Shabwa Basin, central Yemen, penetrated the upper part of the Pan-African basement. The cores show both a lithological and structural inhomogeneity, with variations in extension-related deformation structures such as dilatational breccias, open fractures and closed veins. At least three deformation events have been recognized:

- D1) Ductile to brittle NW-SE directed faulting during cooling of a granitic pluton. U-Pb zircon ages revealed an upper age limit for granite emplacement at 627±3.5 Ma. As these structures show evidence for ductile deformation, this event must have occurred during the Ediacaran, shortly after intrusion, since Rb/Sr and (U-Th)/He analyses show that subsequent re-heating of the basement did not take place.
- D2) The development of shallow dipping, NNE-SSW striking extensional faults that formed during the Upper Jurassic, simultaneously with the formation of the Marib-Shabwa Basin. These fractures are regularly cross-cut by D3.
- D3) Steeply dipping NNE-SSW to ENE-WSW veins that are consistent with the orientation of the opening of the Gulf of Aden. These faults are the youngest structures recognized.

The formation of ductile to brittle faults in the granite (D1) resulted in a hydrothermally altered zone ca. 30 cm wide replacing (mainly) plagioclase with predominantly chlorite, as well as kaolinite and heavy element minerals such as pyrite. The alteration- induced porosity has an average value of 20%, indicating that the altered zone is potentially a good fluid-flow pathway and also a suitable reservoir for hydrocarbons.

The youngest faults (D3) are often filled with calcite, (saddle) dolomite and pyrite that formed at temperatures between 100 and 150°C. Fluid inclusions within calcite have abundant hydrocarbon-rich components indicating that these veins formed synchronously with hydrocarbon migration. The same minerals were deposited within the ductile to brittle faults within the granite (formed during D1). This resulted in significant porosity reduction, especially in the faults themselves, reducing the fluid flow efficiency within the altered granite, locking up hydrocarbons and reducing the reservoir quality.