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Structural analysis of an outcropping granite (Proterozoic basement of Yémen): faults and fractures distributions and scaling properties.

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Numerous deep fractured reservoirs in basement have risen in recent years for oil or geothermal production. Such reservoirs are often badly-known because of a lack of direct information. Indeed, structural models proposed are mostly based on 1D borehole data, and conventional geophysical methods like seismic profiles are not so good techniques to image basement structures. Therefore, understanding the effects of scale in the organization of fracture system is a key problem in modelling geometry of deep fractured reservoir. The aim of this study is to present a detailed structural analysis of an outcropping granite at different scales and to contribute to comprehension of scaling properties of faults systems.

Multi-scale structural maps were produced by remote sensing techniques and field approaches in the granitic Proterozoic basement of Al-Mukalla (Yémen). This region, located at the Southern boundary of the Arabian Plate, has a Pan-African tectonic signature and then has undergone two phases of continental extension since Mesozoic times: Jurassic-Cretaceous and Oligo-Miocene rifting (i.e. Gulf of Aden opening). In a first time, very high resolution satellite imagery (QUICKBIRD) was used to construct map of structural lineaments from regional scale to micro-block scale ($\sim$1 km x 1 km). In a second time, field observations and fractures measurements performed at outcrop scale allow us to confirm suitability of satellite picking. Finally, description of the various structures existing in Burum's granite and characterization of geometrical and morphological features of faults, fractured corridors and joints enable us to interpret structural lineaments with better accuracy.

Major faults strike N090°E and N120°E, whereas secondary structures strike N000°E and N040°E and are interpreted as minor faults, fractured corridors or joints. Consequently, brittle deformation is mainly characterised by structural blocks with parallelogram shaped with fault segments presenting curved shaped and a tendency to curve into alignment at intersection zones. The smallest structural block individualised have major bounding faults spaced by 700-800 metres. These faults have width of 1-10 metres for fault cores and 25-50 metres for damaged zones. Influence of major faults is also observed inside micro-block and is characterised by fractured corridors that can propagate for 100-150 metres toward the few deforms central part of micro-block.

Structural maps obtained have been used to investigate both scaling properties of fault systems and regional tectonics.

Statistical analysis of fault patterns was performed by line-sample (1D) and map (2D). These datasets were used in order to consider orientation, length and spacing distribution of faults and fractures systems. Multi-scale results were compared and then confronted with published data.

Confrontation of results obtained during this study with regional tectonic settings reveals that structural pattern was strongly controlled by discontinuities inherited from Pan-African orogeny and Mesozoic rifting. Comparison of basement and cover structural patterns suggests different tectonic styles and the presence of a decoupling layer at cover-basement interface.