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Fracture related-fold patterns analysis and hydrogeological implications: Insight from fault-propagation fold in Northwestern of Tunisia

L. Sanai [a,*], I. Chenini [b], A. Ben Mammou [a], E. Mercier [c]

[a] Mineral Resources and Environment Laboratory, Department of Geology, Faculty of Science of Tunis, Tunis El Manar University, Tunis, Tunisia
[b] Research Unit Paleo-Environment, Geomaterials and Geological Risk (UR13ES26), Department of Geology, Faculty of Science of Tunis, Tunis El Manar University, Tunis, Tunisia
[c] Planetology and Geodynamic Laboratory (UMR 6112), Nantes University, BP 92208, 44322 Nantes Cedex 3, France

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ABSTRACT

The spatial distribution of fracturing in hard rocks is extremely related to the structural profile and traduces the kinematic evolution. The quantitative and qualitative analysis of fracturing combined to GIS techniques seem to be primordial and efficient in geometric characterization of lineament's network and to reconstruct the relative timing and interaction of the folding and fracturing histories. Also a detailed study of the area geology, lithology, tectonics, is primordial for any hydrogeological study. For that purpose we used a structural approach that consist in comparison between fracture sets before and after unfolding completed by aerospace data and DEM generated from topographic map. The above methodology applied in this study carried out in J. Rebia located in Northwestern of Tunisia demonstrated the heterogeneity of fracturing network and his relation with the fold growth throught time and his importance on groundwater flow.

1. Introduction

Geological studies of fractured rocks in folds aim to determine firstly their mechanism of formation which allows the allocation of each fracture set to a specific stress field or geological setting. Secondly to develop methods for predicting the orientation, spatial density and connectivity of fractures where outcrops are sparse or absent that provide useful tools for solving practical problems related to groundwater or hydrocarbon flow in fractured aquifers and reservoirs. In the last decades of the 20st century, Several studies on the genetic relationships between fractures and tectonic history were carried out (De Sitter, 1959; Ramsay, 1967; Price and Cosgrove, 1990; Bahat, 1999; Konon, 2004; Peacock and Azzam, 2006; Marfil et al., 2005; De Joussineau et al., 2005; Guiton, 2001; Florez-Nino et al., 2005; Bellahsen et al., 2006; Ahmadhadi et al., 2007; Wennberg et al., 2007; Frizon de Lamotte et al., 1997; Saint-Bezar et al., 2002; Louis et al., 2003; Evans et al., 2003; Amrouch, 2010; Amrouch et al., 2010a; Khan, 2011). According to Bonnet et al. (2001), all consolidated subsurface rocks are fractured to some degree with a scale ranging from microcracks to crustal rifts. Fractured reservoirs characterized by secondary porosity generated through fracturing, continue to intrigue and challenge in the same way hydrogeologists (Faybishenko et al., 2013; Narasimhan, 2005; Bodin et al., 2007; Doherty, 2011; Masciopinto and Palmiotta, 2013; Caine and Tomusiak, 2003; Herrera and Garfias, 2013) and petroleum engineer (Bazalgette et al., 2010). GIS techniques are also useful (Sander, 2007; Al Saud, 2010; Corgne et al., 2010). The motivation for the study was to characterize surface heterogeneity at different scales. Specifically, the goal of this paper is to establish the link between fractures and a fault propagation fold tectonic history in a region of North Africa (Tunisia). i.e. Discriminate between pre, syn and post-fractures; secondly find the relationship between tectonics and groundwater circulation. i.e. Highlight features that control groundwater flow in fractured limestone and constitute a potential preferential pathways based on the continuity of geologic units and inferred fracturing distribution. The present study is based on a simple but powerful structural approach that consist in comparison between fracture sets before and after unfolding to understand the distribution of the fracture network and allocate each set to a fold development episode. Though the approach is described in some books, its applicability is not proven by examples in nature. Aerial photographs are primarily used for fracture mapping to define the location of major faults, subsequently, outcrop's are investigated in detail for the quantitative and qualitative analysis of fracture patterns. The works undertaken in this area are limited to those of Ould bagga (2003) as part of a study of the geodynamic evolution of the region Fernana–Ghardimaou. This study

* Corresponding author. Tel.: +216 21789601; fax: +216 70860325.
E-mail address: sanailotfi@ymail.com (L. Sanai).

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is carried out by applying a more detailed and comprehensive study of fracturing that characterizes the structural building and influence the flow of groundwater.

2. Methodology

2.1. Used approach

The study was carried out by a multiscale approach (Fig. 1) combining data from aerospace, digital and those in the field. The use of such multiscale methodology was in order to overcome two major problems including scarcity of fracture surfaces exposed in relief and there's no sufficient mirrors faults data to conduct a detailed microtectonic study and connect fracturing to stress.

The study of fracturing begins by harvesting Data supplied and their treatment in a quantitative and qualitative aspect. The fissure system was studied in outcrops located on the hinge, the northern flank and the two endings Periclinal.

2.2. Data collection and treatment

The method used for data acquisition of fracturing as described in many studies (Singhal and Gupta, 1999); is to find representative structural surfaces for the characterization of fracturing (medium and minor fractures) and then counting joints and major paraclases observed. For each station fracturing, an imaginary line (scan line) is drawn perpendicular to the direction of each of fractures. Then any fracture intersecting this line is included in the sample. The attitude (strike and dip) of each surface observation is noted. Of each fracture, the different parameters measured and/or observed are dipping direction filling opening and inter-fractural distance. In light of the record sheets set fractures, directional rose diagrams by families of 10° were made with stereographic projections software (GEOrient software).

Fractures striking either perpendicular or parallel to bedding strike are not affected by rotation of bedding to remove the dip and may be interpreted as occurring during any stage of fold growth. The fracture data were unfolded using the rotation necessary to bring the average bedding back to a horizontal attitude. Diagrams of 'folded' and 'unfolded' fracture sets will be presented in order to discuss their chronological relationship with folding. Relative timing of multiple fracture sets was assessed by using cutting/abutting relationships at the outcrop (Potts and Reddy, 1999).

The different parameters of harvested land fractures represent their current state (post tectonics) and unfolding rose diagrams obtained according to the fold axis (N40°) (Fig. 8) allowed us to classify fractures related the kinematics of the fold into pre, syn and post fractures. Indeed, the fractures that have kept the same direction before and after unfolding are post folding while those who changed direction following the unfolding are pre-or syn-folding fractures.

Aerial photographs dating from 1961 and 1998s, August, at scale (1/25,000) (Fig. 8) were analyzed in 3-D with a stereoscope and the Digital Elevation Model (Fig. 5) interpretation was completed using the different structures and textures. The interpretation of these sensing images, using a stereoscope, has to recognize and map the structural lineaments of the study area (Fig. 8). Validation is performed by field surveys. Therefore, the interpretation of aerial photographs allowed us to have an overview of the structure and faults.

A critical analysis combining all results (Fig. 8), i.e. photo-interpretation of DEM (Fig. 3) and aerial photographs, and geological elements (already known from maps and new ones identified in the field) was made.

3. Location and geologic setting of study area

The study area is located in the Northwestern part of Tunisia (Fig. 2). Its a well individualized fold belt that axis trending in the same atlases' strike (NE–SW). Geologically this area is extremely interesting since it outcrops in a transitional zone between a stable and autochthonous domain materialized by the Jurassic

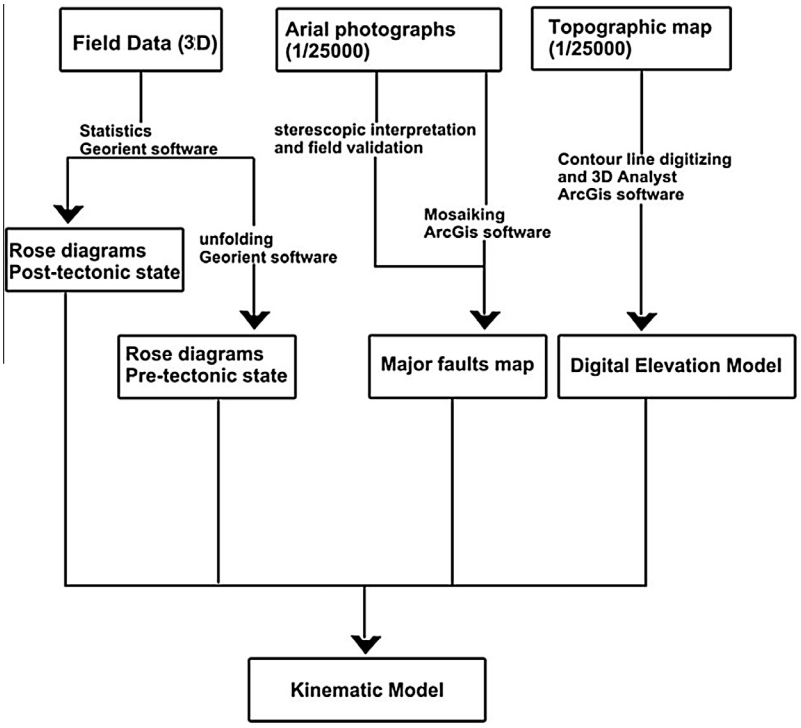

Fig. 1. Flow chart showing the used methodology.