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Different Types of Joints, Their Use in the Chronology of the Tectonic Events and Interest in Water Research. Example of the Massive Limestone and Granit Located in the Region of Skikda, North-East Algeria

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Abstract: To the North East of Algeria, between Annaba and Skikda, the Djebel Safia and Djebel Si Messaoud quarries extract very fractured limestone, useful for the Hadjar Soud cement factory and the microgranite of Djebel Filfila for the petroleum port construction in Skikda. These limestone outcrops form an anticlinal axis NW-SE, a dextral main fault with an average direction to N-165°crosses the anticline. It can be observed that a part of the joints turns with the strata, in angular linkage with the stratification, we name them: "gonioclases". Other ones are complety independents to the folding, they accompany the transverse accidents and more particularly the N-165° main fault and we name them: "neoclases". Some of the gonioclases are converging in the core of the anticline: so, they constitute a gutter able to play a part in the groundwater drainage.

Key words: Fracturation, joints, gonioclases, neoclases, groundwater Algeria

INTRODUCTION

The joints constitute the most widespread tectonic structures on the surface of the Earth. They are found in all kinds of rocks and all the contexts. The mechanisms of the joint formation are often a subject of discussion. The study of hydrogeology and fracturing in particular was at the origin of a reflexion on the relations between the underground fracturing and flows in an area where the permeability is due to the existence of fractures. A detailed attention has been studied in relation to these fractures where the purpose was to collect qualitative information on the movement of the various families of joints because the network of fractures constitutes the only way offered to subsoil water.

The goal of this note is the study of the various types of joints in the carbonated and granite rocks in the area of Skikda as well as the detailed analysis of the directions of fracturing for the water research. This analysis related to a great number of sites whose localization is primarily controlled by the quality of outcrops: careers of Djebels Safia, Si Messaoud and Filfila. The geometrical study of these outcrops ordered primarily by the tectonic history, makes it possible to analyze the fractures in three dimensions since it is possible to measure the direction and the dip of the plans of discontinuities of the rocks.

The studied careers are in the North-East Algeria, between Annaba and Skikda (Fig. 1). They careers are exploiting limestone of Djebels Safia and Si Messaoud, essential to the operation of the cement factory of Hadjar Soud and the careers located in the granites of Filfila, used for the construction the petroleum port of Skikda.

MATERIALS AND METHODS

In the laminated rocks, the mechanical joints without appreciable rejection (Fourmarier, 1949) were named diaclives by Thurmann (1856) and joints by Daubrée (1878, 1879). The joints constitute fractures perpendicular to the stratification (Daubrée, 1880; Fourmarier 1922; Dreyfuss, 1946; Aubouin, 1968; Mattauer, 1949, 1973).

However, there is also a whole group of well characterized joints which are highly oblique with the stratification and sometimes clearly independent of the joints S. str. (Cairo, 1975). The joints which form with the bedding planes well defined angles (Fig. 2a, 2b) are called Gonioclases (Gc) (of the Greek: gônio, angle and klasis, rupture). The dip of the later, although often near to 90°, can deviate from this value. The joints which do not present any angular relationship to the bedding plane are called Neoclases (Nc) (of the Greek: néos, new and klasis, rupture).

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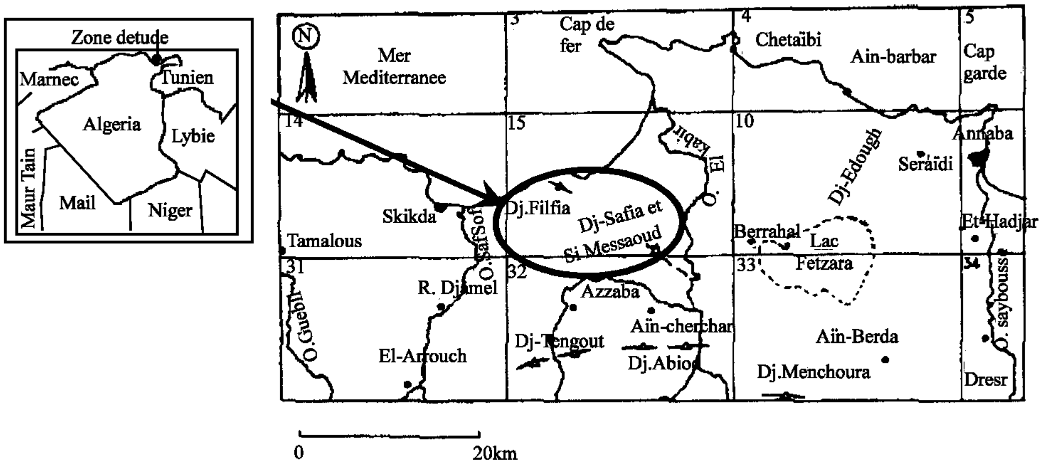

Fig. 1: Location map of the study area (Azzaba region)

Fig. 2a: Gonioclase (Gc) and Néoclase (Nc) S0 : bedding stratification plane.Dv : vertical joint (130°- 90°)

Fig. 2b: Gonioclases cutting the outcrop to diamond shaped

The neoclases are distinguished easily on the ground from the gonioclases if the layers are horizontal. However, when the layers are inclined, the gonioclases and the neoclases can't show any difference. In order to be able to distinguish the two groups in a regional scale from joints, we sought them in the granitic rocks of Djebel Filfila (Miocène higher). In these granites, the only highlighted directions are supposed to be those of the neoclases careers of Hadjar Soud (Djebels Safia and Si Messaoud), where measurements were treated on a framework to give to horizontal the bedding planes (S0) and are the subject of the lines which follow.

GEOLOGIC AND STRUCTURAL FRAMEWORKS OF THE STUDY AREA

Limestone of Djebels Safia and Si Messaoud which belong to the Kabyle domain (Durand-Delga, 1967; Bouillin *et al.*, 1984; Lahondère, 1987) appear in window in the South-East of Skikda (Fig. 3) under the kabyles aquifers where the large folds are found (Durand-Delga, 1970) (Fig. 4). This recristallized limestone studied by Raoult (1974) and then by Vila (1980) contains occasionally fossils. In spite of their scarcity, these fossils are dated as Jurassic age locally. The overlying Neocomian which comes is a good lithological reference mark to recognize the S0 planes.

Granitic rocks of Djebel Filfila of Langhian age (15,3 Millions years: Penven and Zimmermann, 1986), belong to the internal zone Maghrebides (Durand-Delga, 1967; Bouillin, 1979; Wildi, 1983) and include two small stocks from 3 to 4 km ^{2} which are lengthened according to a direction WNW-ESE, in accordance with the general orientation of the structures of the area. These two stocks

Fig. 3: Main structural elements of the limestone chain and flyschs in the center and east of the numidic chain of Djebel Safia (Durand Delga *et al*., 1970)

Fig. 4: Cross Section of the Djebel Safia region (Durand Delga *et al*., 1970)

are less eroded: Their roof plunges, in a symmetrical way, under the liasic marble slide. The zone between two stocks shows very small granitic outcrops (between 1 and 20 meters diameter) and significant metamorphism of contact (Lemoy, 1969) which supposes the existence of a deep continuity between the two intrusions.

The Filfila rock is appearing as a piled up tectonic units (Lemoy, 1969). From the bottom we distinguish (a) the Numidian aquifer (Oligocene-Miocene); (b) aquifer of kabyle maurétanean flyschs (Sénonian); (c) aquifer of the base kabyle (Oligo-Miocene kabyle); (d) the para indigenous unit of Djebel Filfila, corresponding to the cover ultra tellian of the African base.

The unit of Djebel Filfila, which arises as a tectonic window under the aquifer favoured by the anticlinorial convexity, include Jurassic and cretaceous areas: Calcareous lias (marble of Filfila, exploited in career); Pelitic dogger, with carbonated lenses (limestone and dolomites); Pelitic Malm, with small benches and sandy lenses, passing gradually to the top in Néocomian where the sandy benches take importance: A schisto-sandy Albo-Aptian where the benches are epimetamorphic (marble with actinolite) and are affected by polyphase tectonics to early tangential tectonics (synchisteous folds are overlapping the liasic marble slide) succeeds a folding in anticlinorium and synclinorium of axes WNW-ESE. The two granitic outcrops are post-tectonics, but occupy the cores of the two major anticlinorium (Lemoy, 1969; Bouabsa *et al*., 2005).

BREAKABLE TECTONICS

Gonioclases

General device: A detailed study of the gonioclases was made at careers of Djebel Safia and Si Messaoud; the gonioclases do not exist in the career of Djebel Filfila. The career of Djebel Safia shows in its central part, layers of laminated limestone where several measurements of diaclases and bedding planes (S0) were taken. In the North of the career, these layers are found under marly-limestone of the lower Cretaceous with a dip of N90°. In the South, they have a S.E direction. Thus at the top of the career, the layers plunge 20° to 30°E. The layers thus undergo a dextral rotation of 160° and the fold is a brachy-anticline with a remaining eastern part and an axis close to N130°.

In the Southern part of Djebel Si Messaoud career, the dip of the layers is of 95° SW 35° direction. This career is crossed by a great accident dextral N165°, accompanied by many secondary faults (Riedels).

RESULTS

A study of the diaclases was carried out by Djebel Chettaba in the West of Constantine (Lahondère, new, 1992) concerning the carbonated formations (neritic formations of Constantine) it is possible to define several families of gonioclases according to their orientation. In the following table we compare the data gathered with Djebel Chettaba and those of Djebel Safia.

Values close (15° and 20°) to these orientations were often recognized. One especially finds them in the families C and D. These new values will constitute the families C' (34° and 45°) and D' (09° and 17°). It probably acts in certain cases of riedels.

These are the orientations that we find in carbonates of Djebel Safia. Most frequent is the families D, B, C and C'. Moreover some values are observed between 140° and 160° (family A).

We note that these values are superimposed, that supposes that we have only one system of joints in all the area.

We are more particularly interested here in the angles Go/S0 between the planes of joints (Go) and the layers (S0). The results are as follows (Fig. 5).

- With regard to the family D, these angles vary between 60° and 70°. The plans are plunging towards the West (00° W 65°).
- In the family B, the angles vary between 75° and 90°, and the planes plunge towards the North (90° N 82°).
- In the family C and C', the angles turn around the vertical (55°-90°).

Some values are grouped around NW 70° (?).

We have represented the poles of these planes on a framework (lower hemisphere). We have there, a mean of

Table 1: The data gathered with djebel chettaba and those of djebel safia

Family	Djebel chettaba	Djebel safia
A	N 150° à 158°	Some values 140° SW 160°
B	N 85°à 95° (1 value à75°)	90° N 70° (75° à 98°)
B'	N 104° à 105 (rare)	1 value à 105°
C	N 50° à 60°	Moy. 60° NW 80° (52° à 68°)
C'	N 34° à 45°	Moy. 38° - 90° (36° à 40°)
D	N 172° à 05°	Moy. O° W 60° (enter 168° et 07°)
D'	N 09° à 17°	Rare 10°-90°

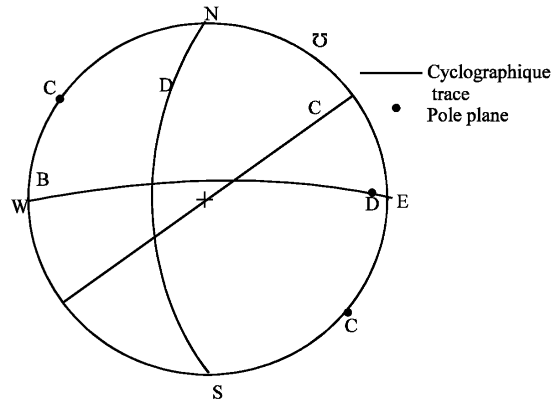

Fig.5: Pole plane, cyclographique trace and gonioclase B, C, D family of Djebels Safia

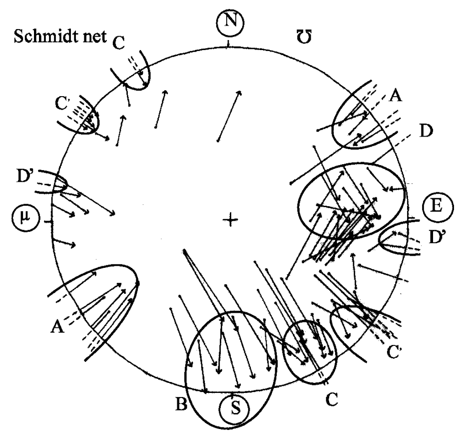

Fig.6: Gonioclase pole plane of Djebels Safia and Si Messaoud regrouped on the horizontal plane

controlling we have gonioclases. Indeed, the poles of the planes dispersed on the framework are regrouped after their handing-over with the horizontal position (Fig. 6).

Family A present, which is generally guided by the accident N 165°, functions as a pre-existent discontinuity and is found in the fault planes in particular with Djebel Si Messaoud.

In the careers of Djebel Safia, we meet several families of gonioclases which turn around 0° W 70° (family D), 90° N 80° (family B) and 40° with 65° NW / SE 90° (families C and C'). These values are also found in carbonates of Djebel Chettaba (neritic formations of Constantine).

Neoclases

Results (Fig. 7): The planes are slightly more vertical (80 with 90°) and without considering the value of the

BnS family it seems that we have a less has significant rotation of the joints taking into account the lack of data in Djebel Safia (some measurements of neoclases per family).

We find three families with mean values:

Table 2: Mean values of the area of djebel safia

AnS (family A of neoclases of Djebel Safia)	074° N 88°
BnS (family B of neoclases of Djebel Safia)	120° N 85°
CnS (family C of neoclases of Djebel Safia)	009° E 88°

Table 3: Mean values of the area of djebel si messaoud

AnM (family A of neoclases of Djebel Si Messaoud)	017° W 86°
BnM (family B of neoclases of Djebel Si Messaoud)	105° S 78°
CnM (family C of neoclases of Djebel Si Messaoud)	156° W 84°

Table 4: Three families were highlighted with the following mean values

AnF (family A of neoclases of Djebel Filfila)	060° N 86°
BnF (family B of neoclases of Djebel Filfila)	122° N 83°
CnF (family C of neoclases of Djebel Filfila)	176° E 84°

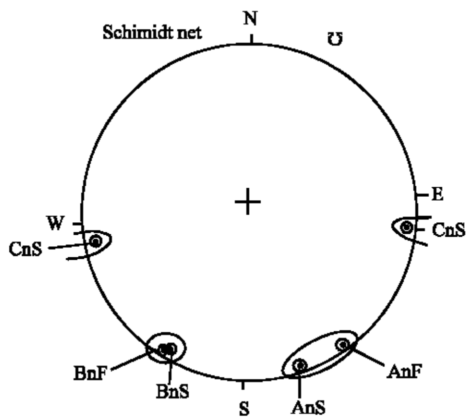

Fig. 7: Neoclase A,B,C family of Djebel Safia respectively regrouped with the one of Djebel Filfila

The results appear to us that they are distorted by the operation of a fault belonging to the CnM family. This fault, accompanied by secondary faults, seems, partly related to the reactivation of some gonioclases of family A (Fig. 8).

The BnM family could be represented by three measurements with 105° S 78°. These values are related to the operation of a dextral fault from N165° direction. Values around 140°-170° would be of Riedels and it would be the same for the values between 5° and 30°. Only the values of 105°would be connected to the neoclases of Djebels Safia and Filfila.

The area of djebel filfila: The selected careers are those which exploit the granite of Djebel Filfila in the East of Skikda. The installation of these granites is posterior to the principal orogenetic events of Eocene age and lower Miocène, and thus with the deformations which have affected limestone of Djebel Safia. The granites constitute two batholiths which are lengthened. Around an aureole of metamorphism in a carbonated series found in its lower part and a schisto-sandy formation developed above (Semroud and Fabriés, 1997).

The joints are close to the vertical. They can sometimes deviate from this position but seldom from an angle higher than 20°. They cut the granitic core and its aureole. Three families were highlighted with the following mean values:

DISCUSSION

The gonioclases, related angularly to the bedding plane are former to the plicated deformation which affects carbonates of the careers. They thus follow the rotation

Fig. 8: Reactivated joint on fault N 20°W 50°, located in sheltered zone, the compartment that we see is overlied, the movement is senester. The grooves (calcite almost subvertical)

of the layers (that is observed in the family D which presents a significant slope of 65°). On the other hand, the neoclases independent of the bedding planes are posterior with this deformation. They are also posterior with the installation of the granite of Djebel Filfila which they recut. The age of the installation of this granite is 15,3 Millions years (Penven and Zimmermann, 1986). At that time the principal structures, that are observed today in Eastern Algeria, are in place. Thus, they are recut by the neoclases.

Thus it is, reasonable to consider that the gonioclases, of a early or contemporary age to the great deformations of lower Miocene that affected the area. The neoclases would appear after the installation of the granites and are thus relatively recent. A chronology of these neoclases is possible. Indeed, very often we observe a slight displacement (millimetre to centimetric length) of the fracture lips when they are recut.

CONCLUSION

The joints, which are relatively recent or older, are by far the accidents which one most frequently meets in the qualified rocks. They are in particular more abundant than the faults. These joints which fissure the qualified rocks contribute largely to make them more permeable. The rules whereby appear to be more precised today.

In a fractured rock area, the two basic functions which defines Hydrogeology: the flow and the storage are ensured by the fractures and cracks which recut the solid mass. The fractures which guide the infiltration and routing of in-depth water (vertical transfer) undergo a widening by dissolution and thus support the formation of the cavities. The dip of the layers guides the water run-off between the deposits limestone (horizontal transfer). It arises clearly that the fractures and the morphostructural disposition of limestone favour the development of voids according to the direction of the circulation of subsoil water.

For the Djebels Safia and Si Messaoud anticline, we note that the joints of family D converge downwards and can constitute, in the core of the anticline a gutter and it is in this deep part (sub-surface) that the deformation is most intense with probable appearance of opposite microfaults and phenomena of dissolution. This gutter intersection of gonioclases D observed in Safia and Si Messaoud plunges with an angle of few degrees towards the West (88° W 6°).

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