

## **The Displacement Criteria in Fibrous Crystallized Gypsum Veins in Southern Hemrin Anticline East of Iraq**

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### **Abstract**

This paper deals with gypsum veins in Mudstone and Siltstone in the South Hemrin area (NE Muqdadia) in the eastern part of Iraq. The criteria which characterize displacements in fibrous crystallized gypsum veins have been studied and two types recognized:

1-The criteria which appear on the vein surfaces. These criteria give precisely the direction and type of displacement. The determination of the chronology of successive displacements along the veins is hindered because the effects of the last displacement usually erase features associated with the first. The types of displacement features are: cavities and convexities, tectonic tool marks, accretionary growth steps, teeth and sheet structures and wavy structure.

2-The criteria which appear in vein sections. These criteria give with some difficulty the type and direction of the displacement without precisely determining the age of deformation in relation to the inferior and posterior displacement. The types of displacement features in this case are: fibres perpendicular to vein walls, fibres oblique to vein walls, bent fibres, secondary wall-parallel fractures, conjugate shear fractures, en- echelon fractures and en- echelon veins.

**Keywords :** Displacement criteria; Tectonic tool marks; Wavy structure; Bent fibres; En- echelon veins

### **1. Introduction**

The study of displacement criteria in vein surfaces and vein sections provides significant information on the directions of extension that happened in any region. The existence of striation on vein surface indicates that the vein has suffered squeezing and shear displacement with the host rock.

Numerous authors such as [1-5] used the principle of roughness – smoothness as a practical field technique for determining the sense of the relative displacement on fault surface. The roughness and smoothness are manifested by low steps that trend at right angles to the striations, so that the displacement direction of the missing block (i.e. the block which has been detached to show the vein structure) is opposite to the direction of the gentle ridge slope.

Other authors have dealt with kinematic criteria in ductile deformation e.g. [6-16].

Deformations and shear criteria in gypsum were studied by [17]. However, in the field of brittle deformation [18-26] outlined the relationship between stylolite, tension gash and the principal stress axes.

Mattauer [27] and Angellier [28] determined the sense of slip on planar fault surfaces which produce pure and oblique dilation (vein and simple slip) or the sense of slip on non planar fault surfaces which produce pure and oblique convergence (oblique and horizontal stylolite) or openings (called lozenges) filled with fibrous or blocky minerals.

Fibrous crystallization growth in veins and in fault surfaces have been studied by [5,29, 30, 31, 32] and used in determining the vein opening trajectory; on the other hand crack-seal veins have been used as shear indicators to determine the opening history of the veins [7,31,33,34,35,36,37,38].

Machel [39] studied fibrous gypsum veins (satinspar) and fibrous anhydrite veins. He emphasized that they occur in extensional veins. The attitude of these veins is mostly horizontal and he suggests that the veins opened due to vertically-oriented tensile stress.

Gross et al [40] studied sigmoidal gypsum veins and sigmoidal fibrous gypsum veins in incompetent shale and gypsum layers and used them in measuring the extensional strain.

Taha et al [41] studied the fibrous gypsum veins in horizontal beds of mudstone and siltstone, they classified them to three groups based on the pattern and orientation of gypsum fibres between vein walls.

This study is concerned with the criteria of displacement in fibrous gypsum veins, these criteria appear on vein's surfaces and in vein's sections. Most criteria on vein surfaces depend upon the criteria proved by Angelier [28] and Petit [42] in the determination of the sense of

slip on fault surface. These criteria give precisely the direction and the type of displacement due to the existence of striation on vein surface which produced by scratching and gouging of one side of the fault by hard asperities. The determination of the chronology of successive displacements along the vein surfaces is hindered because the effects of the last displacement usually erase features associated with the first. Some of the vein section criteria depend upon the concepts of the progressive opening of extension veins [5], vein section's criteria indicate roughly the sense of displacement but they cannot accurately calculate the principal strain directions. For the vein surface criteria, it is difficult to show the surface of the vein in the field so the samples have been taken to the office, then the wall-rock has been separated from the vein, then checked the vein surface with a lens.

## **2. Aim of the study**

This study has two objectives: 1) present some new displacement criteria in fibrous gypsum veins, these criteria appear on vein's surfaces and in vein's sections, 2) apply others criteria which have been used in the literature(

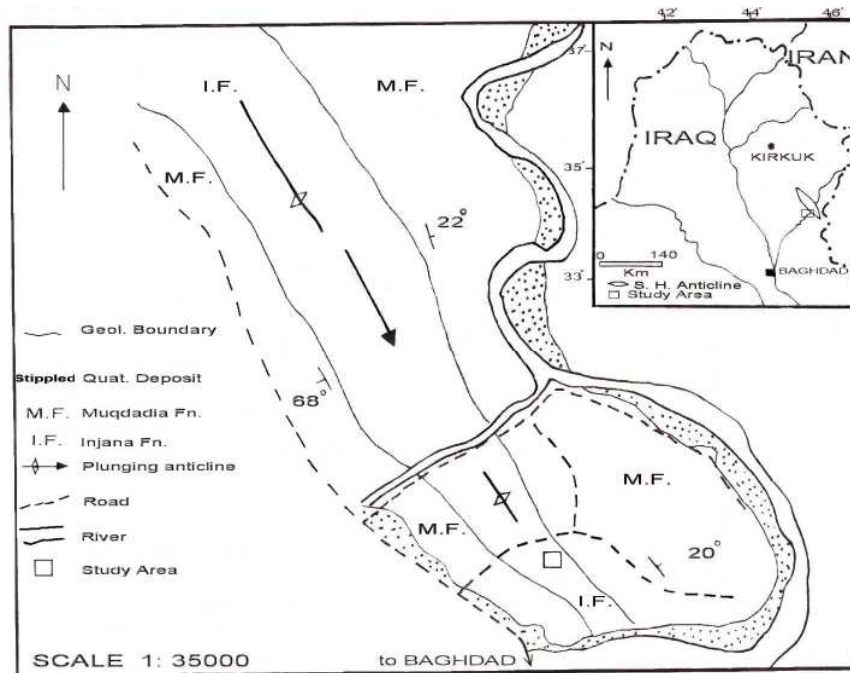
such as that used for determining the sense of slip on fault plane and that used for determining the extension direction of the progressive opening) on veins in fibrous gypsum veins .

## **3. Geological setting**

The study area is located about 125 km northeast of Baghdad in the core of the NW-SE trending Southern Hemrin Anticline in eastern Iraq (Fig. 1). The dip of the northeastern limb of this anticline is about 20° and the southwestern limb dips at about 60°.

Two formations crop out in the study area, Upper Miocene detrital sediment named locally Injana Formation which is about 600 m thick. This formation is composed of interbedded thin sandstone, marl and siltstone with fine grains in its lower part which gradually become coarser in its upper part. The sandstone layers are characterized by cross bedding structures [44-46]. Injana Formation is underlined by Fatha Formation( Middle Miocene ) and is overlain by

Muqdadia Formation of Pliocene age. The beds of the Muqdadia Formation are predominantly pebbly sandstones with lenses of marl and siltstone. The thickness of the formation is about (1200-1300) m [47,48]. Muqdadia Fn is overlain by the Bai-Hassan Formation of Upper Pliocene age. It crops out in the northeastern limb of the Southern Hemrin Anticline and is eroded from its southwestern limb ( the study area). This formation is composed of conglomerates consisting of sub-rounded pebbles, cobbles, and boulders of quartz and limestone surrounded by a fine grained matrix of sandstone and limestone. The Bai-Hassan Formation is covered by fine grain detrital sediments of Quaternary age.



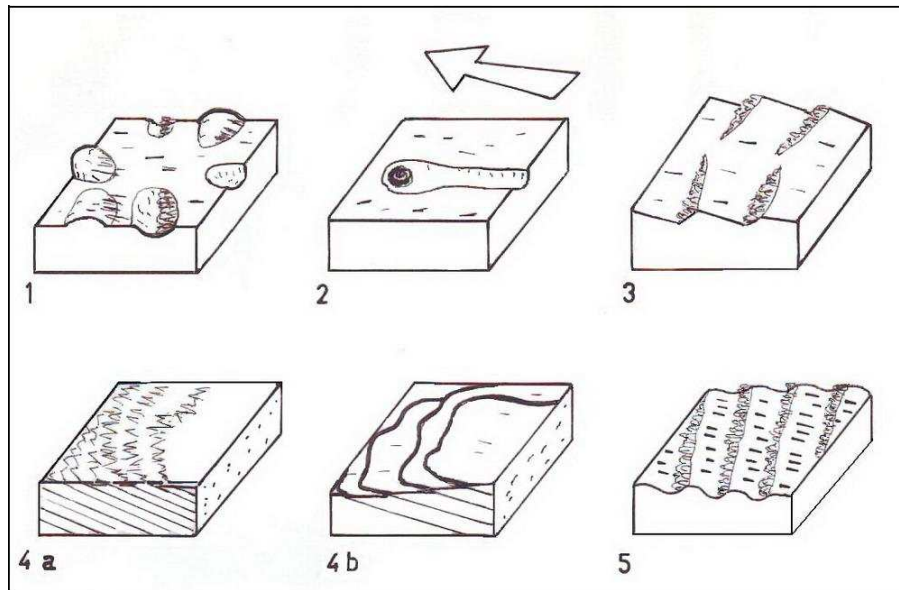
**Fig. 1. Location and geological map of the study area. The geological map is after [43].**

#### **4. Criteria on Vein surfaces**

Vein surfaces are defined here as the vein wall surfaces which separate the vein from the host rock. There is a good resemblance between criteria on fault surface stated by Angelier [28] and those on vein surface, because the two types of criteria have been produced by shear displacement. Angelier [28] used the character of friction on fault surface in determining the sense of slip, where a positive criteria (accretionary growth steps, wavy structure, teeth and sheet structures) appear with less friction in comparison with a negative criteria (tectonic tool marks, asperities). The criteria on vein surface

(Fig. 2) depend in most cases on the direction of mineral growth which indicates the slip direction. However, in some cases the tectonic tool marks develop due to the displacement of hard rocks. In any case, the criteria on vein surfaces should be considered as secondary structures which generate after the formation of the vein. The vein surface criteria can be used to deduce the sense of displacement of the missing block. One of the prime methods is to measure exactly the angle of pitch of the slickenside lineation on the vein surface.





**Fig. 2. Sketch without scale for five centimetric vein surface criteria : 1- cavities, 2- tectonic tool mark, 3- accretionary growth steps, 4- teeth and sheet structures , 5- wavy structure.**

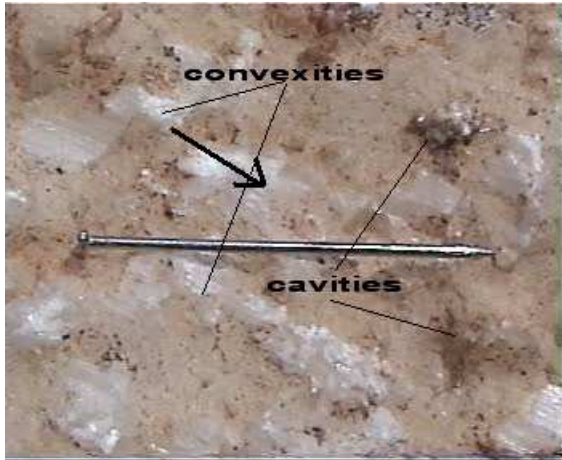
#### **4.1. Cavities and convexities:**

When the vein surfaces have a roughness as a cast of the irregular wall rock surrounding the vein, which is inhomogeneous and anisotropic [49], and then these vein surface asperities have suffered shear displacement, so the cavities undergo mineral growth and the convexities undergo crushing, frequently associated with striation (Fig. 2-1). The sense of displacement of missing block is toward the end of crystallization in the cavities, (Fig. 3).

#### **4.2. Tectonic tool marks:**

This criterion is an analogue to that occurring between fault blocks when pebbles or other hard

minerals grains are squeezed and then dragged between the fault blocks which make asymmetric grooves on a fault surface, but here they occur between the vein surface and the wall rock, its grooves are open in one side and closed in the other (Fig. 2-2), the closed side frequently contains brown to dark colour which reflects the colour of the foreign material coming from the wall rock such as sand, silt or mud, the displacement of the missing block is toward the closed side of the groove, (Fig. 4).



**Fig. 3.** Vein surface asperities have many cavities and convexities which are affected by shear slip displacement producing fibrous crystals growth and crushing ( striation) respectively ( pin length is 2.45 cm ).



**Fig. 4.** Grooves have been produced by three hard matters , arrows indicate the sense of displacement of the missing block( pin length is 21mm).

**4.3. Accretionary growth steps:**

When the rock is affected by non planar preexisting discontinuities[50] and these fractures have developed to dilatational fibrous vein, the surface of the vein appears rough and contains asperities, when this vein undergoes another displacement which is shear slip, asymmetric steps on vein surfaces should be

formed (Fig. 2-3) . These steps represent the secondary fibre growth which is parallel or subparallel to vein surface, the direction of displacement of the missing block is toward the end of crystallization, (Fig. 5).

**Fig. 5.** Accretionary growth steps on vein surface formed on non-planer preexisting discontinuity, arrows show displacement of missing block ( photo width is about 6 cm ) .



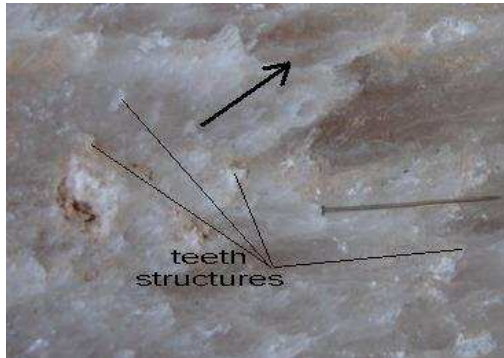
**4.4. Teeth and sheet structures:**

Teeth structure is similar to stylolite peaks in form but different in mechanism, it is developed at vein surface as a result of intersection between oblique fibres and vein walls, so the peaks are always pointed to the

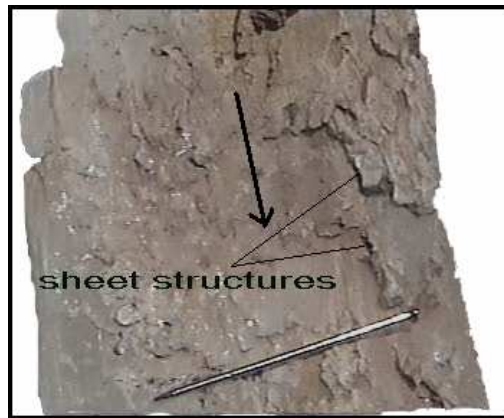
direction of displacement of the missing block (Fig. 2-4a). The length of the peaks inversely reflects the inclination angle of fibres with respect to the vein walls, so that when these teeth are long , the inclination

angle between the fibres and the vein wall is small and vice versa (Fig. 6), and when the inclination angle is so small, the fibres

become subparallel to vein walls then the teeth structure changes to sheet structure (Figs. 2-4b and 7).



**Fig. 6. Teeth structures produced by the intersection of inclined fibres with vein surface, the arrow indicates the sense of displacement of missing block ( pin length is 21mm ).**



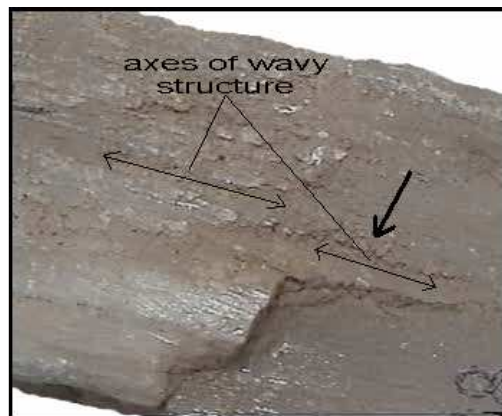
**Fig. 7. Sheet structures produced by the intersection of subhorizontal fibres( about 2°) with vein surface ( pin length is 2.45 cm ).**

#### **4.5. Wavy structure:**

When the vein surface has a wavy appearance due to its genesis as small ridges develop where the fracture plane is deflected behind a hard asperities, so ridge-in-groove lineations are formed [51] and it is affected by shear displacement normal or oblique to the axis of waves. This shear displacement

produces a striation on one side of the wave and fibrous crystallization on the other, which is due to squeezing and gaps respectively. The sense of displacement of missing block is from the striation toward the crystallization of any wave (Figs. 2-5 and 8).

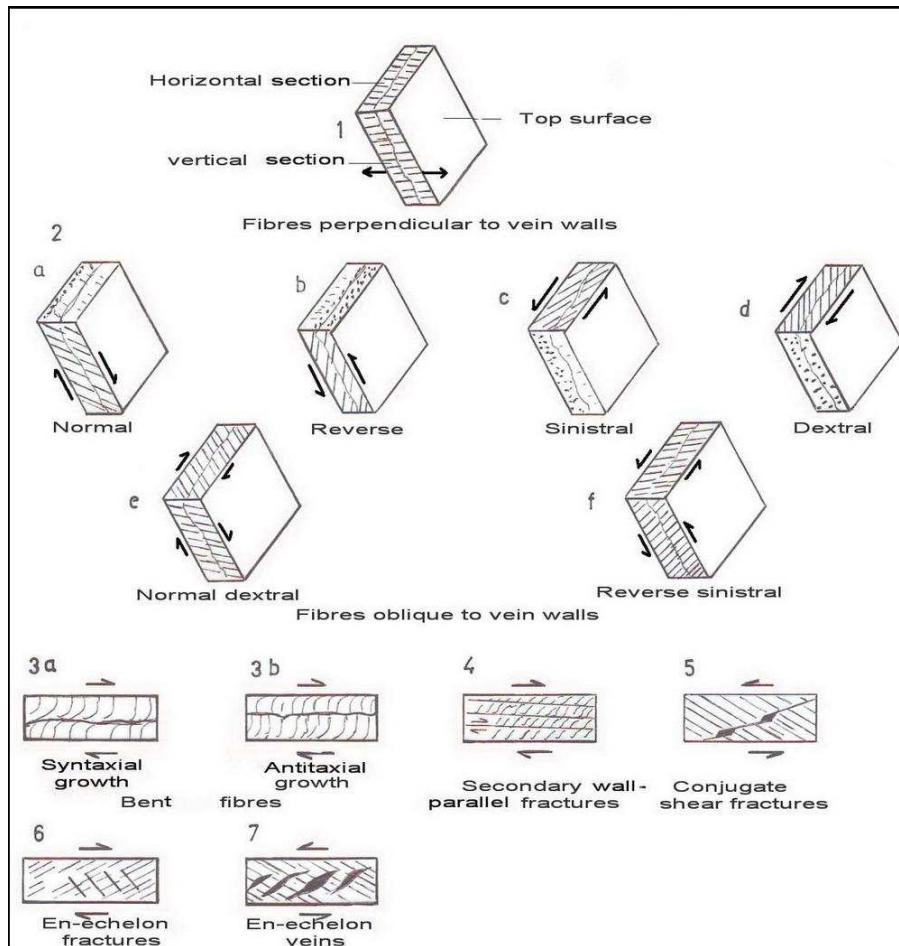
**Fig. 8. Wavy structures affected by shear displacement normal to the axis of wave which produces striation and fibres growth in each convex wave. The arrow points to the direction of displacement of the missing block (sample width is 3 cm).**



**5. Criteria in vein sections**

Vein sections are surfaces that cut the vein thickness between their two walls in any direction. Vein sections have been represented here by two type of planes, the first type is horizontal plane, which cuts horizontally the vertical or inclined veins and the second type is vertical plane, which cuts vertically the horizontal, vertical and inclined veins. From these sections we can see; the crystallization from the beginning to the end; the changes in

growth direction; and the secondary effects happened in the vein, which could be formed by some criteria. In this type of criteria we can determine the type of displacement happened in the vein, but we cannot exactly determine the direction of displacement especially in only one section because the dip of the shear displacement appears in vein section may not show the true dip (Fig. 9).



**Fig. 9. Sketches without scale of seven vein sections criteria. See explanation in the text.**

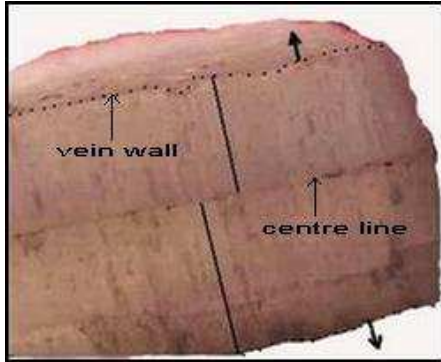
**5.1. Fibres perpendicular to vein walls:**

The vein filling fibres in this type of veins are perpendicular to vein walls and vein centre (Fig. 9-1) which indicates that the vein has been formed by a pure dilation, so the direction of opening is parallel to crystal fibres growth, this case may represent the first stage of veins

opening indicating that the vein has not undergone any shear displacement (Fig. 10).

**5.2. Fibres oblique to vein walls:** When the fibres grow obliquely to vein walls they indicate that the vein opening is produced by shear displacement accompanied with dilation

component, the angle made by the fibres with the vein walls denotes the genesis mechanism of the vein, so small angle means that the vein has been formed by shear displacement more than dilation and vice versa, so that one must look for the acute angle made by the intersection of the fibres with the upper vein wall (Fig. 11). In vertical section, if the acute angle is toward the vein dip direction, the opening is produced by



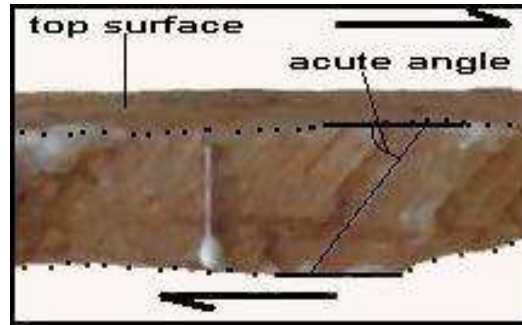
**Fig. 10. Vein section containing fibres perpendicular to vein walls and vein centre line . This indicates that the opening was engender by pure dilation only as arrows show ( black lines are parallel to fibres, dotted line is upper and lower vein walls, vein thickness is 1cm).**

### **5.3. Bent fibres:**

Normally curved fibres are seen at the walls and at the median surface of the vein (antitaxial and syntaxial growth respectively); these curvatures are due to progressive deformation [5]. The orientation of the fibres is parallel to the principal incremental elongation and the fibres suffer bending due to shear movement after pure dilation either in the vein centre (Fig. 9-3a) or at the vein walls (Fig. 9-3b) [5]. In vertical sections of horizontal and vertical veins, the bending fibres indicate that the vein has undergone horizontal shear displacement or vertical shear displacement respectively, they happened certainly after pure dilation, but if the vein is inclined, the bending fibres indicate normal (Fig. 12) or reverse displacement happened also after pure dilation. So the normal displacement is characterized by downward curving fibres and the reverse displacement is characterized by upward curving fibres and in

normal displacement (Fig. 9-2a) and if it is opposite to dip direction, the opening is produced by reverse displacement (Fig. 9-2b).

In horizontal section, if the acute angle in the right side points away from the reader, the vein has suffered left lateral displacement (Fig. 9-2c) and if it points toward the reader, the vein has suffered right lateral displacement (Fig. 9-2d).

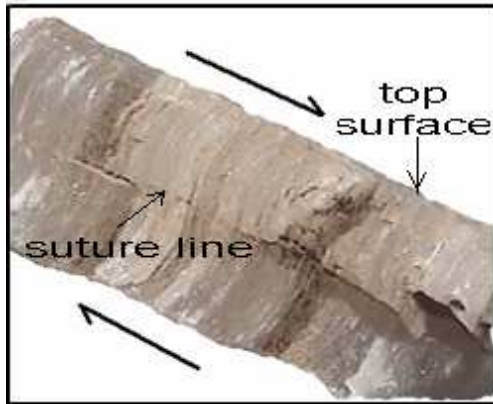


**Fig. 11. Vein contains fibres oblique to vein walls indicating that the opening was produced by shear accompanied with dilatants component (pin length is 1cm).**

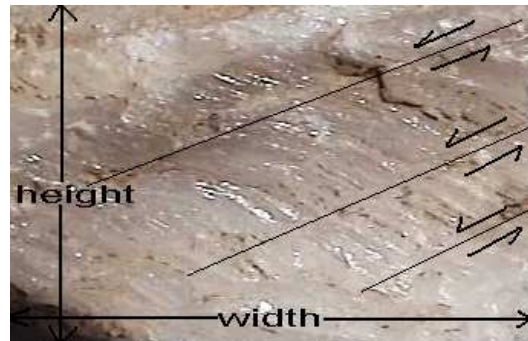
the horizontal sections of inclined or vertical veins the bending of the fibres should indicate right lateral or left lateral displacement.

### **5.4. Secondary wall-parallel fractures:**

Very thin fractures have been seen in the sections of vein, which are parallel or subparallel to vein walls. The fibres which are curved between any adjacent fractures have a sigmoidal shape (Fig. 9-4). If this curvature happened in vertical section it would indicate normal or reversed displacement and if it happens in horizontal section it will indicate right lateral or left lateral displacement. The sense of displacement of each fracture is the same as the general shear sense. So we can deduce the sense of displacement of the vein from the mechanism of only one fracture (Fig. 13).



**Fig. 12.** Vertical section in inclined vein where the fibres have been bended at the walls( antitaxial vein) and subperpendicular at the vein centre which indicate that the missing blocks( the wall rocks surrounding the vein) have undergone normal slip after nearly pure dilation ( vein thickness is 1.5cm ).



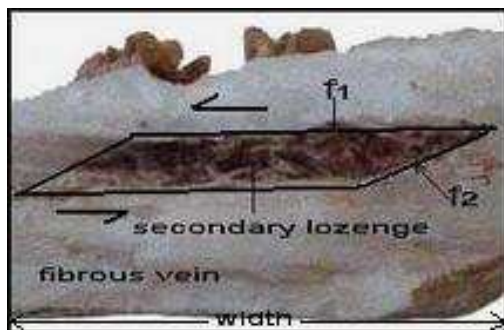
**Fig. 13.** Three wall-parallel fractures which bend the fibres between them indicating that the fibres have been affected by sinistral strike slip displacement ( photo height is about 3cm ).

**5.5. Conjugate shear fractures:**

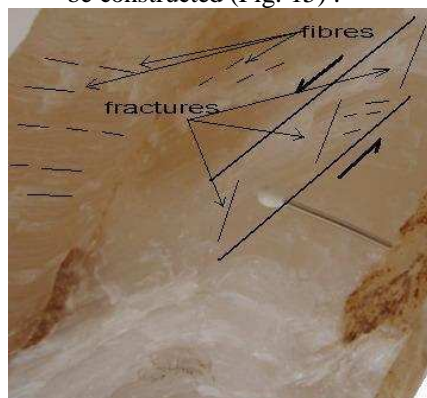
When the fibrous vein has been fractured by conjugate shear fractures (f1 and f2 Riedel's fractures) and then extension on one fracture such as on f2 is accompanied by shear on the other f1, it takes place with strike slip displacement. Opening will be created on extension fracture f2 and slipping on shear fracture f1. This opening will be filled by material different in composition and colour from that of the original fibrous vein (Fig. 9-5), so it can be seen easily and its sense of

displacement as secondary stage of displacement can be deduced (Fig. 14).

**5.6. En-echelon fractures:** Very thin and short en-echelon fractures appear in vein's sections in crystalline fibrous veins. The sense of displacement can be easily deduced in the same manner as that for the fractures in the rocks (Fig. 9-6), so the sense of the shear slip of the en-echelons fractures can be determined and then the displacements producing the vein can be constructed (Fig. 15) .



**Fig. 14.** Conjugate shear fractures in the middle of the fibrous vein( f1 and f2 ) have been developed to lozenge form filled by material different in colour and composition from the fibrous vein, the top part move to the left by left lateral displacement( the width of the photo is 5.5cm ).



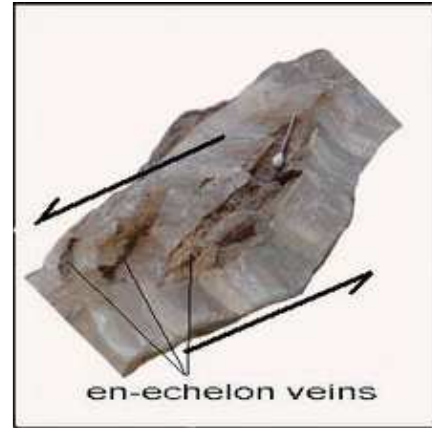
**Fig. 15.** Set of very thin en-echelon fractures indicating normal displacement. Thin lines are parallel to the fractures and dashed are parallel to the fibres ( pin length is 1cm).

### **5.7. En-echelon veins:**

Frequently small en-echelon secondary veins in crystalline fibrous original vein can be seen. These secondary veins may consist of material different in composition and colour from that of the original fibrous vein which is coming from the wall rock. For determining the sense of

displacement the same manner as that in rock fractures can be used (Fig. 9-7). These en-echelon veins could be developed from the en-echelon fractures when the deformation increases and followed by precipitation of foreign material (Fig. 16).

**Fig. 16. Three en-echelon veins filled by silt associated with secondary fibrous material. These veins are different in colour from the original fibrous vein, they have been opened by right lateral displacement ( pin length is 1cm).**



### **6. Discussion**

Criteria have been used in determining the extension directions in quartz, calcite, and chlorite fibrous veins, can also be applied in fibrous gypsum veins, so when the opening of the vein was perpendicular to vein walls, pure dilation is produced and the fibres grow perpendicularly to the vein walls, and when the vein dilation is succeeded by shear displacement, the fibres lose their perpendicular relationship and become curved either in vein walls or in vein centre [29]. The existence of striations, grooves and steps of minerals growth on vein surfaces indicates that the vein has been undergone shear displacement, these displacement commonly happened after the pure dilation, and are parallel to vein walls. At that time the fibres in vein section appear curved and become parallel or subparallel to vein walls

either in vein centre or in vein walls. After the opening of the vein by pure dilation, the fibres related to this dilation could be affected by many section criteria such as, secondary wall-parallel fractures, conjugate shear fractures, en-echelon fractures, and en-echelon veins, these criteria commonly cut the ancient fibres and displace them. The sense of shear engenders by the section criteria is the same as the general shear sense observed on vein surface.

So we can use the two types of criteria( surfaces and sections criteria ) together for precisely determining the directions and the magnitude of extensions happened in any vein sample and then apply that to many veins samples for calculating the direction and the magnitude of deformation that happened in any area.

### **7. Conclusions**

Based on this study, the following conclusions were reached:

- On vein surfaces, some vein surface criteria have a secondary mineral crystallization such as cavities and convexities, accretionary growth steps, and wavy structures. The end of such crystallization refers to the displacement direction of the missing block. In hard matter groove, the closed side refers also to the

displacement direction of the missing block, and in the teeth and sheet structures, the peaks of the teeth and the outcrop of the sheet refer to the displacement direction of the missing block.

- In vein section, some criteria such as perpendicular fibres to vein walls and oblique fibres to vein walls prove the primary vein opening either by pure dilation for perpendicular fibres, or by the association of dilation and shear

displacement for oblique fibres. In oblique fibre veins, we look for the acute angle made by the intersection of the fibres with the upper vein wall, in vertical section it indicates normal or reverse displacement and in horizontal section it indicates left lateral or right lateral displacement.

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• Other section criteria such as bent fibres, secondary wall-parallel fractures, conjugate fractures, en-echelon fractures, and en-echelon veins prove the secondary vein displacement that occurs after the vein formation.

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## دلائل الإزاحة في العروق البلورية الجبسية الليفية في طية حميرين الجنوبي المحدبة / شرق العراق

### الخلاصة

اهتم البحث بالعروق الجبسية في الصخور الطينية والصلصالية في منطقة حميرين الجنوبي ( شمال المقدادية ) في الجزء الشرقي من العراق حيث تم دراسة دلائل الإزاحة في العروق الجبسية الليفية المتبلورة وتم تمييزها في نوعين:

1- الدلائل التي تظهر على أسطح العروق، و تعطي هذه الدلائل بدقة اتجاه الإزاحة الحاصلة ونوعها. يصعب تحديد التتابع العمري للإزاحات الحاصلة على سطح العروق الواحد وذلك لأن تأثير الإزاحة الأخيرة يحو عادة المظاهر المصاحبة للإزاحة الأولى. وكان أنواع مظاهر الإزاحات هي: التجاوبف والتحدبات و علامات الدلالة التكتونية و تدرجات النمو التزايدى و التراكيب المسننة والصفائحية و التركيب المتموج.

2- الدلائل التي تظهر في مقاطع العروق، تعطي هذه الدلائل بصعوبة نوع الإزاحة الحاصلة واتجاهها دون تحديد زمن التشوه الدقيق نسبة للإزاحات السابقة واللاحقة. أنواع مظاهر الإزاحات هي: الألياف العمودية على جدران العروق و الألياف المائلة على جدران العروق و الألياف المنحنية و التكرسات الثانوية الموازية لجدران العروق و التكرسات القصية المزدوجة و التكرسات المتداخلة، و العروق المتداخلة.

