Fibrous Gypsum Veins Development in Southern Himrin Mountain, East of Iraq

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ABSTRACT

Fibrous gypsum veins development in claystone host rock has been studied in southern Himrin Mountain area, northeast Miqdadiya east of Iraq. Three groups of veins have been recognized: (1) Simple fibrous veins, which contain perpendicular or inclined fibres to vein walls, their straight fibres extend between vein walls and these veins were affected by one opening direction, (2) Moderately complicated fibrous veins, which contain curving fibres either at vein walls or at vein centre. These veins were affected by two different opening directions, and (3) Complicated fibrous veins, which contain multicurved fibres in different places. These veins were affected by more than two different opening directions.

Good relationships were found between the attitude of veins in beds and the attitude of fibres in the veins which give or estimate the directions of the principal strains axes (λ 1, λ 2, & λ 3) that would indicate the vein system formation.

1

INTRODUCTION

Preface:

Crystalline materials can be deposited from solution in low pressure zone, such as a fissure, this fissure continues in opening in a direction perpendicular or oblique to fissure walls depending upon the orientation of incremental strain (Ramsay & Huber, 1983), and when the vein is filled with fibrous material like quartz, calcite and gypsum, these fibres take different forms. These forms are in accord with a direction of the incremental strain affected in an area.

Fibrous veins are classified by (Durney & Ramsay, 1973) into four types as syntaxial, antitaxial, composite and stretched. This classification was set according to the resemblance of the vein filling material with the host rock, fibrous growth beginning in vein walls and bending in vein centre or vice versa, and the continuity of fibres growth from one wall to the other which is associated with fractures.

Machel (1985) has studied the fibrous precipitation of gypsum and anhydrite in extensional veins and he suggested that:

" The attitude of the veins is mostly horizontal; the ‘main’ fibres are almost always oriented vertically ; in almost all veins of this type a fine line of division(parting) separates the fibres filling into two roughly isopachous seams, the upper seam is often thicker than the lower seam; often the fibres are bent and/ or broken indicating an overthrust- like shear along the parting; and these features suggest that the veins opened due to vertical tensile stress which may have been followed by subsequent upward buckling of the strata".

Pluijm and Marshak (1997) indicated that:" When the fibres are perpendicular to the walls of the vein, the vein opened in a direction perpendicular to the vein walls; when the vein fibres oblique to the vein walls indicate that the vein opened obliquely and there was a component of shear displacement during vein formation and when fibres are sigmoidal in shape, the extension direction rotated relative to the vein wall orientation".

Location and Geology:

The study area lies in southern Himrin Mountain (Al-Sidoor) area about 120 km northeast of Baghdad, fig (1) in the southwestern border of the Foothill (Low Folded) Zone of Iraq. Structurally, it is an asymmetrical anticline whose axis trends NW-SE. Injana Formation (Upper Miocene) is the oldest exposed stratigraphic unit and occupies the core of the anticline. It consists of alternation of fine grained sandstone strata, siltstone, claystone and marl, which form almost horizontal or slightly inclined strata in the studied site (Al-Naqib, 1959; Energoproject, 1978). The studied gypsum veins lie within claystone strata of Injana Formation.

Aims and methods of the study:

In this research we study the development of fibrous gypsum veins from simple to complicated state and we try to find a relationship between vein attitude (horizontal, vertical and inclined) and their growth fibres, and then determine the principal strain directions(λ_1,λ_2&λ_3) which reflect the extension direction that happened in the study area.

The attitudes of beds and veins have been measured in the field, and many veins samples have been studied in detail, like fibres attitude in the vein, pitch angle formed by striation or fibres growth on the outer vein surfaces, and stereographic projection of the measured data on the lower hemisphere of Schmidt net has been done in the office.

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SIMPLE FIBROUS VEINS IN NATURE AND STRAIN AXES

Three groups of veins exist in the simple fibrous veins as indicated below:

a: Veins with perpendicular fibres to vein walls

The fibres in these veins are perpendicular to vein centre and vein walls, when the vein changes its attitude, the fibres direction varies automatically, and this variation changes the directions of ($\lambda 1$, $\lambda 2$, & $\lambda 3$), fig (2-1,2,3).

In vertical veins, the fibres are horizontal fig (2-1a), and the direction of maximum strain ($\lambda 1$) should be horizontal also (which is parallel to fibres direction). The intermediate and minimum strain directions ($\lambda 2$ &$\lambda 3$), are indefinite fig (2-1b), because if one of them is horizontal and parallel to vein strike, the other should be vertical and occur in the centre of the circle. This state could be produced by normal or strike slip fault system .When the vein is horizontal fig (2-2a), the maximum principal strain ($\lambda 1$) is vertical and the others ($\lambda 2$ &$\lambda 3$) are horizontal and it is difficult to determine their positions fig (2-2b), it reveals to reverse fault system .In inclined veins fig (2-3a), ($\lambda 1$) lie on the vein pole, while($\lambda 2$ &$\lambda 3$) when one of them is horizontal and parallel to vein strike the other is inclined and lies on vein dip point fig (2-3b).

b: Veins with inclined fibres to vein walls

Oblique opening in veins will produce oblique fibrous growth which is related to the attitude of veins and fibres. There are many different cases of oblique opening we choose some of them. In fig (2-4) the fibres are inclined in vertical vein which represent an ideal case because the fibres plunge direction is perpendicular to vein strike as in fig (2-4a); ($\lambda 1$) is lying in fibres plunge position, ($\lambda 3$)in fibres pole and ($\lambda 2$) in vein strike fig (2-4b). This example represents an intermediate stage between normal and reverse fault systems. In fig (2-5a) the fibres are horizontal and deviated from the vein walls by small angle, ($\lambda 1$) is horizontal and parallel to fibres direction and ($\lambda 3$) is also horizontal and perpendicular to ($\lambda 1$), therefore ($\lambda 2$) is vertical fig (2-5b). This case represents pure strike slip system. In fig (2- 6, 7) the fibres and the vein are inclined in opposite directions in the two cases and the fibres plunge point occur in vein pole. In fig (2-6a), the fibres have small plunge angle, ($\lambda 1$) is about the horizontal, ($\lambda 3$) is about the vertical and ($\lambda 2$) is horizontal which is parallel to vein strike fig (2-6b). In fig (2-7a) the fibres have high plunge angle in which ($\lambda 1$) is about the vertical, ($\lambda 3$) is about the horizontal and ($\lambda 2$) is horizontal and parallel to vein strike fig (2-7b). The first case (2-6) represents the rapprochement of vein formation to normal fault system and in the second case (2-7) to reverse fault system.

In fig (2-8a) the inclined vein has vertical fibres in which (λ_1) is vertical, (λ_2) is horizontal and parallel to vein strike and (λ_3) is also horizontal and normal to vein strike fig (2-8b), this case represents reverse fault system. In fig (2-9a) the fibres and the vein have the same dip direction but in different amount, the fibres have small plunge angle in comparison with the vein dip angle which reflect subhorizontal (λ_1), subvertical (λ_3) and horizontal (λ_2) fig (2-9b) which indicates a system about normal fault, and in fig (2-10a) the vein is horizontal and the fibres are slightly inclined, (λ_1) occur in fibres plunge point which is subhorizontal, (λ_3) is subvertical and (λ_2) is horizontal fig (2-10b) which also indicates a case of a system about normal fault .

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c: Veins with fibres parallel to veins walls

When the fibres become parallel to vein walls, they appear similar to simple fibrous veins in the form but different from them in genesis because they were produced by multi opening stages and the parallel fibres may represent the last stage of opening which happened due to the rotation of the principal strain axes.

To determine the directions of the principal strains in these veins we use the same previous method as follows:

In vertical veins there are two cases, one of them when the fibres are vertical fig (2-11a), (λ_1) will be vertical and parallel to the fibres, (λ_2) will be horizontal and parallel to vein strike, and (λ_3) is also horizontal which represent vein thickness (minimum extension direction) and lies in vein pole fig (2-11b), this case represents reverse fault system, the other case when the fibres are horizontal so λ_1 and λ_3 become horizontal and λ_2 vertical, this case represents strike slip fault system. In inclined veins fig (2-(12, 13) a), (λ_1) is inclined and occurs in veins dip point, (λ_2) is horizontal and parallel to veins strike and λ_3 is inclined and lie in veins pole fig (2-(12, 13) b). These cases represent approaches of vein formation to reverse or normal fault system dependding upon veins inclination degree, and in horizontal vein fig (2-14a), (λ_1& λ_2) are horizontal and (λ_3) is vertical fig (2-14b) which represents a pure normal fault system fig (2-14).

RESULTS

All the cases explained above represent some of the cases that exist in nature but in our study area there are some of them, we use the same method for determining the directions of extension happened in it.

From many field samples and office works (λ 1, λ 2 & λ 3) directions were concluded as below: Three fibrous vein categories are recognized in the study area; these are

I- Simple fibrous vein, **II-** Moderately complicated fibrous veins, **III-** Complicated fibrous veins.

I-SIMPLE FIBROUS VEINS

This group is characterized by the continuity of extension in only one direction, which forms straight fibres perpendicular or oblique to vein centre and vein walls fig (2). The directions of the principal strain axes are changing with respect to the attitude of fibres in the vein.

1- Sample No 1: Inclined vein has strike and dip 135/53˚ NE, and its thickness is about 1 cm, its fibres are perpendicular to vein walls plate (1) and fig (4), the sample is situated in horizontal beds of marl and sandstone. Stereographic projection on lower hemisphere gives the direction of λ_1 (225/37˚) and that of λ_2 (135/00˚) which is horizontal and parallel to vein strike and λ_3 (045/53˚) which is inclined and has the vein dip angle fig (3-1). The formation of this vein was by one of two probabilities, the first is similar to normal fault system where (λ_3) approaches the vertical more than (λ_1),and (λ_2) will be horizontal, the second probability is similar to strike slip system where (λ_2) lies in vein inclination point and (λ_3) in vein strike. The perpendicularity of fibres to vein wall indicate the existence of pure dilation only, normal to vein walls, therefore the first probability is the nearest to truth ,so this sample is like the case in fig (2-3) .

2-Sample No 2: Inclined vein has strike and dip 115/55˚NE and its thickness is about (12mm) plate (2) and fig (5), its fibres are plunging in the direction 230 by an angle equal to 28˚. In vertical cross section, the fibres seem perpendicular to vein walls. Stereographic projection fig (3-2) gives (λ_1) direction 230/ 28˚ and (λ_2& λ_3) one of them is horizontal 140/00˚ the other is inclined 050/62˚. It is difficult to distinguish between λ_2 and λ_3, but because of the high angle between the fibers and the vein walls(62˚), the case resembles normal fault system more than strike slip system.

3-Sample No 3: Subvertical vein has strike and dip 125 /83˚ NE and thickness is (2cm). It has horizontal fibres, slightly deviated from vein strike, their direction is 132, plate (3) and fig (6). Blès & Feuga(1986), consider the fibres in similar vein as shear fracture (f_1) along which the displacement occurs, the vein strike represents the mean plane of left handed displacement (F) which (f_1) makes with it an angle equal to (07˚) in clock wise direction, and second fracture which is extension fracture (f_2) make an angle equal to (23˚) with (F) in anti clock wise direction. The angle between (f_1) and the maximum principal stress (σ_1) is between about (15˚-60˚), so the direction of σ_1 in this sample is between about (072-117) its means value is in the direction 094 and the direction of σ_3 (dilation direction) is horizontal and equal to 035 which is perpendicular to F direction; this is according to the authors above. But we suggest that the position of (λ_1) is perpendicular to the mean value of (σ_1) which is horizontal and in the direction 004. In this case (λ_1) is not parallel to fibres direction but it make an angle equal to (52˚) with them. There is no doubt about the positions of (λ_2) and (λ_3) fig (3-3), because the displacement is pure horizontal which is produced by sinistral strike slip fault system, so λ_2 is vertical and λ_3 is horizontal, this example represents a vein produced by strike slip displacement on non-planar discontinuities.

II - MODERATELY COMPLICATED FIBROUS VEINS

This group includes the veins which were affected by second opening different in direction from the primary opening, in these veins the fibers curve either in vein centre or in vein wall forming syntaxial or antitaxial veins respectively.

Most veins of this group in the study area have curved fibres at vein walls, and the material forming the vein fibres is different from that forming the rockbeds, so they are considered as antitaxial veins (Durney and Ramsay 1973).

Veins of curved fibres could be vertical, horizontal and inclined as the first group which gives many and different cases. Two field samples represent this group as follows:

4- Sample No 4: Oblique fibrous vein has strike and dip 102 / 65˚ NE and thickness is about (12-15 mm) plate (4) and fig (7). The fibres are perpendicular to vein centre and curved at vein walls, in vein centre the fibres plunge by an angle equal to 25˚ in the direction 192 and at vein walls they plunge by an angle 60˚ in the same direction. Stereographic projection for the first stage of opening, fig (3-4) gives (λ_1) in (192/25˚) and (λ_2, λ_3) one of them is (102/00) the other is (012/65) which is before fibres curvature, (λ_1) is more close to the horizontal than the vertical, and (λ_3) is more close to the vertical than the horizontal and because of the perpendicularity of the fibres to vein walls which indicates that the first opening was produced by normal fault system more than strike slip system .

The projection for second stage of opening after fibres curvature gives (λ_1) (192/60˚), (λ_2) (102/00˚) and (λ_3) (012/ 30˚). These directions indicate that (λ_1) becomes closer to vertical than (λ_3). We can conclude that the second stage of deformation reveals reverse fault system.

5- Sample No 5: Oblique fibrous vein, has strike and dip (145/ 52˚ NE) and thickness about (6-7) mm, their fibres are plunged in the centre of the vein by an angle about 20˚ toward the direction 265 and at the walls by an angle about 05˚ toward the direction 120 plate (5) and fig (8).

Stereographic projection of the fibres in vein centre (first stage of opening) fig (3-5) gives the direction of (λ_1), (265/20˚) and (λ_2, λ_3) are (085/70˚) (355/05˚). From fibres observation in the vein which is not perpendicular to vein walls, we can conclude that the formation of oblique fibres is due to shear movement, so the direction of (λ_2) may be (085/ 70˚) and that of (λ_3) is 355/05˚ and from the stereographic projection of the curved fibres located at vein walls(second stage of opening) (λ_1) becomes 120/05˚ which is subhorizontal, (λ_2) 270/85˚ which becomes subvertical and (λ_3) is horizontal 030/05˚. This indicates that this state of deformation is due to dextral strike slip fault system.

III / COMPLECATED FIBROUS VEINS

This group includes veins formed by more than two different stages of opening in which the growth fibres may turn from perpendicular to parallel to vein walls, the crystallization either begins in vein walls or in vein centre. The variation in fibres direction reflects the change in extension direction happened in the vein.

Two samples have been studied which are :

6-Sample No 6: Horizontal fibrous vein, its thickness is about (3-5) cm plate (6) and fig (9). The fibers change their inclination in a traverse from the top surface toward the centre. They are plunged by angle about (47˚) toward the direction (320), then they are plunged (20˚) toward the direction (260), then they become subhorizontal whose inclination about (5˚) toward the direction (220) plate (7).

In the central zone there is irregular growth with some inclusion material (marly sandstone) which separates the two symmetric parts.

From these observations, we can conclude that the vein is affected by many stages of opening fig (3-6):

The first stage is inclined opening 320/47˚ which resembles reverse fault system. This fault has intermediate dip angle. The second stage is represented by thrust fault 260/20˚ and the third stage is subhorizontal 220/05˚ which is represented by over thrust fault system with elongated fibres. The last stage represents the fibres in growth stage which have irregular form that link the upper and the lower part of the vein.

7-Sample No 7: An oblique fibrous vein has thickness of about(4-5)cm, strike and dip 123 /43˚ NE plate (8). On the upper surface, there is fibrous crystalline growth that coincides with upper vein surface; these fibres resemble the slickenside on fault plane. Two groups of fibrous growth are observed on the upper surface; the first has 10˚ SE as pitch angle which seems to be produced by dextral strike slip and the second has 26˚ NW which seems to be produced by normal sinistral fault, the second group appears to be under the first group. In transformation in vein section from the top toward the bottom, we observe crystalline fibres which have (3mm) thickness they bend at upper vein surface only and become parallel to it. But in small limited zone, the fibres thickness increases and become (11 mm) and the fibres form has changed to become parallel to vein walls in the upper and lower parts, in the zone between them , the fibers are inclined by an angle (25˚) toward the direction 220. The fibres in the lower part of this zone continue in its parallelism to the vein walls until they occupy about 2.5 cm thick and they have interpenetration between marl inclusion and fibers crystallization. Under this zone of interpenetration there are other crystallized fibers zone which have varied thickness (0.5-2) cm these fibres connected with the upper fibers which is parallel to vein walls and have small inclination angle about (5˚) toward the direction 220, and then they bended at lower vein surface to from fibres growth parallel to lower vein surface with (50˚ SE) as pitch angle.

In this vein we can conclude many stage of opening without distinguishing the chronology of them fig (3-7). These are (from the upper surface) : Dextral strike slip fault, sinistral – normal strike slip fault , normal fault represent by fibres subperpendicular to vein wall , intermediate stage between normal and reverse fault represented by parallel fibers to vein walls, normal fault represented by subhorizontal fibers, and finally normal fault represented by slickenside on the bottom surface plate (8).

We can not consider this vein as antitaxial vein because it contains fibers parallel to vein wall in vein centre and it is not syntaxial because there is anon crystallized material inclusion (marly sandstone) different in composition with crystallized mineral fibres which occupies an important part in vein centre and it is not composite for the same raison above, so it is complicated.

From these previous fibrous vein samples, there are three extension directions, NE-SW direction with mean direction 215/35˚ this direction is represented by veins No (1, 2,4,6_3,7_3,7_4,7_5) which is due to normal fault system . The second is shear extension (NW-SE) with mean direction 300/10°, this extension has been produced by horizontal displacement occurring on vein surface, this direction is represented by veins No ($3,5,6_1,7_1,7_2$) and the (E-W) extension, its mean direction is 270/45° which is represented by vein No($5_1,6_2,7_6$) which represent the intermediate stage between normal and reverse fault system fig(10).

7

<u>Conclusions</u>

Fibrous gypsum veins in horizontal beds of mudstone or siltstone in Injana Formation in South Himrin (A1 sidoor area)East of Iraq have been studied and classified to three groups based on the pattern and orientation of gypsum fibres between vein walls, and the number and location of fibres bends within the vein.

Three groups of veins are recognized:

1- Simple fibrous veins: This group includes veins which have straight fibres extending between vein walls without curvature; their fibres could be perpendicular or oblique to vein walls, they reflect one opening direction.

2-Moderately complicated fibrous veins: This group includes veins which have either perpendicular fibres at the vein walls and curved fibres at the vein centre or vice versa. These veins were affected by two different opening directions.

3-Complicated fibrous veins: This group includes veins with multicurved fibres. These veins were affected by more than two opening directions.

The attitude of fibers in the vein reflects the positions of the principal strain axes (λ_1, λ_2, &λ_3) the fibers are parallel to the maximum strain axis (λ_1) in all the cases except when the vein produce on non-planner discontinuity by strike slip displacement, but the determination of intermediate and minimum strain directions (λ_2, &λ_3) are very easy in some cases and difficult in others, this depends on the attitude of the vein which contains the fibers.

<u>It is easy when</u>:

- The fibers are parallel to vein walls in any vein attitude fig (2-11, 12,13,14)
- inclined fibres in vertical vein fig (2-4, 5)
- inclined fibres in inclined vein and in horizontal vein fig (2-6, 7, 9,10)
- horizontal or vertical fibers in inclined vein fig (2- 8)

<u>And it is difficult when</u>:

- fibers perpendicular to vein walls in any vein attitude (vertical , horizontal and inclined) fig (2-1,2,3)

When the fibers approach the perpendicular to vein wall, it becomes difficult to distinguish between the position of (λ_2) and (λ_3), but when they approach the parallel to vein wall, it becomes very easy to make that distinction.

The determination of (λ_1, $\lambda 2$, &λ_3) directions makes it possible to know the type of deformation that happened due to normal, reverse, or strike slip fault system.

8

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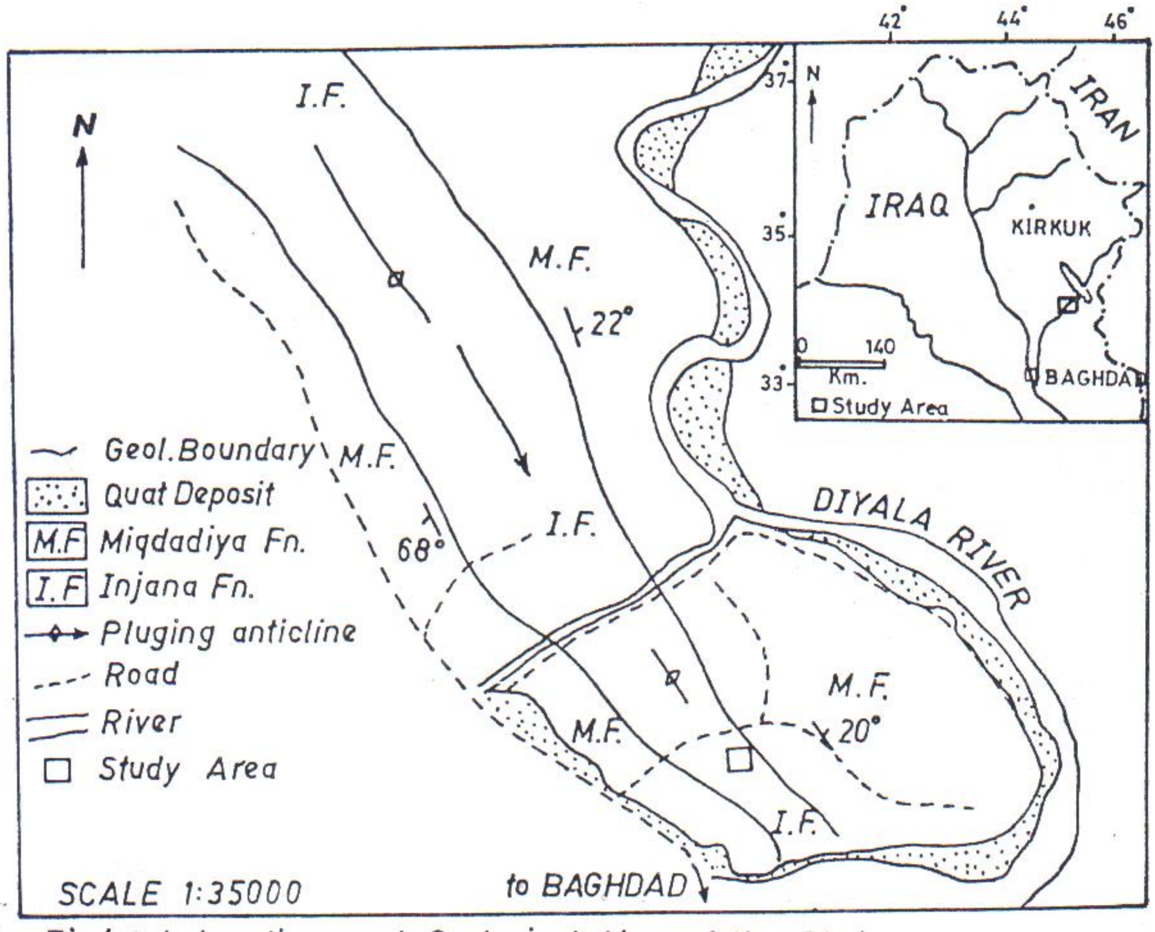


Fig (1) Location and Geological Map of the Study area.

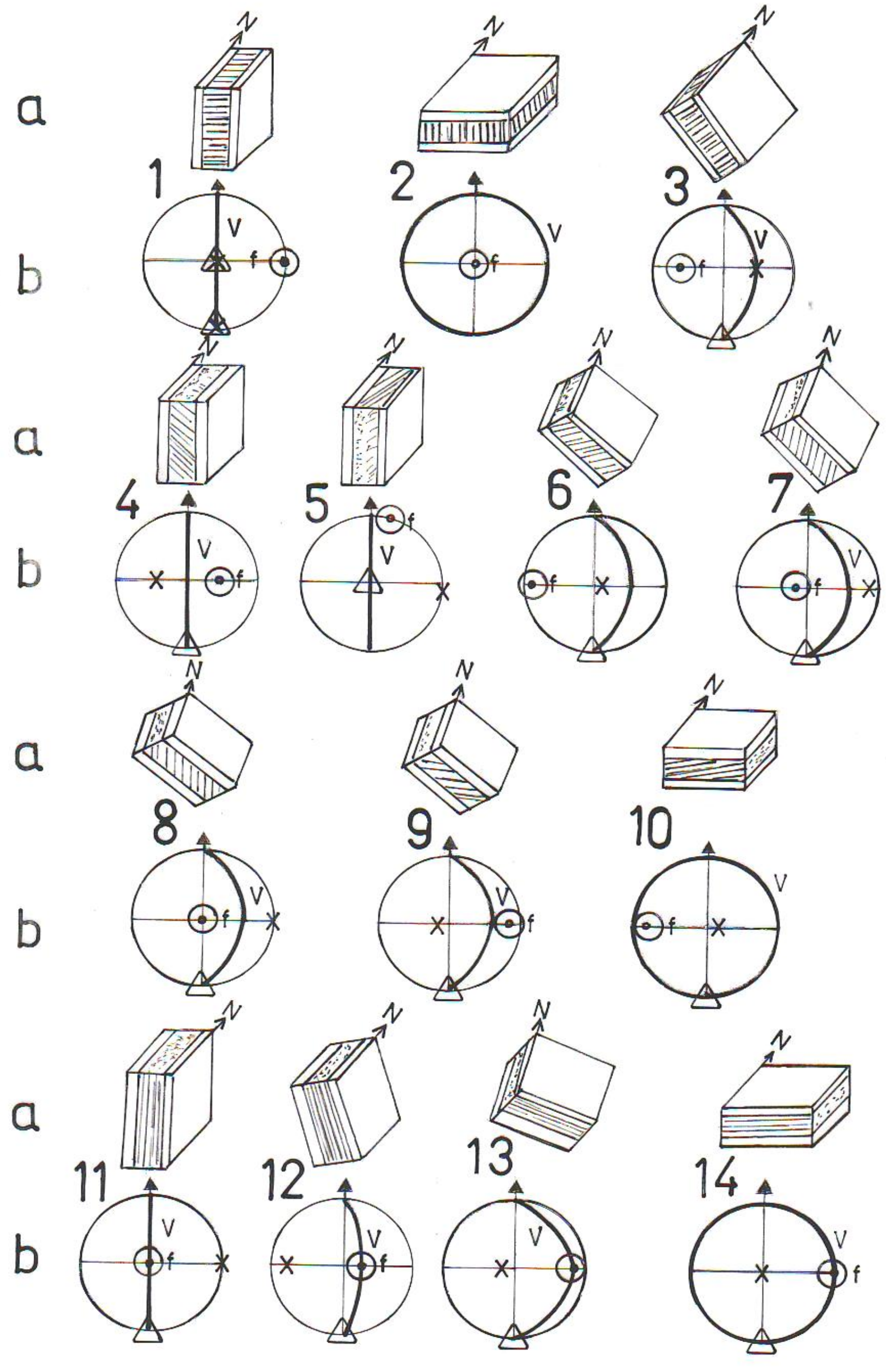
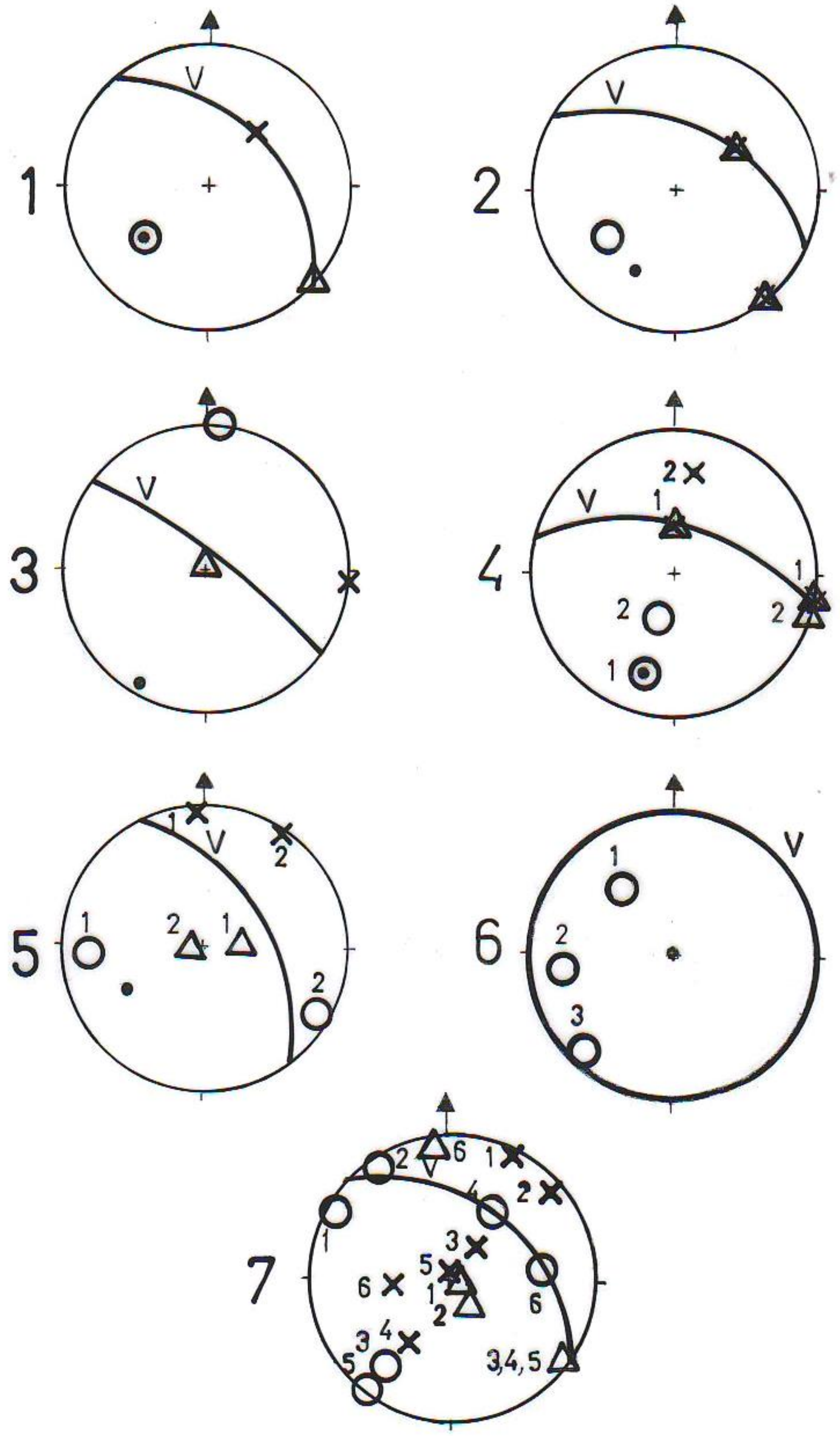


Fig (2) Illusturates theoretical cases of simple fibrous veins in different attitudes containing fibres crystallized in different inclination angles (a) block diagrams showing attitudes of veins and fibres, (b) stereographic projection for each case above on lower hemisphere circle.

○ maximum principal strain axis(λ_1), Δ intermediate principal strain axis(λ_2), x minimum principal strain axis(λ_3), v vein great circle, f fibre projection, • pole to vein.



Fig(3) Stereographic projection on lower hemisphere , showing the directions of extension deduced from vein samples. Stereograms of samples Nos (1, 2&3) represent simple fibrous veins, Nos (4 &5)represent moderately complicated veins, and Nos (6 & 7) represent complicated veins. Numbers inside the stereogram indicate stage of opening, • = pole of vein, ○ = λ_1 = maximum principal strain, Δ = λ_2 = intermediate principal strain, x = λ_3 = minimum principal strain.

Plate(1) shows a vein containing perpendicular fibres to vein walls. (vein thickness 1 cm)

Plate(2) shows a vein containing inclined fibres . (pin length 2.54 cm)

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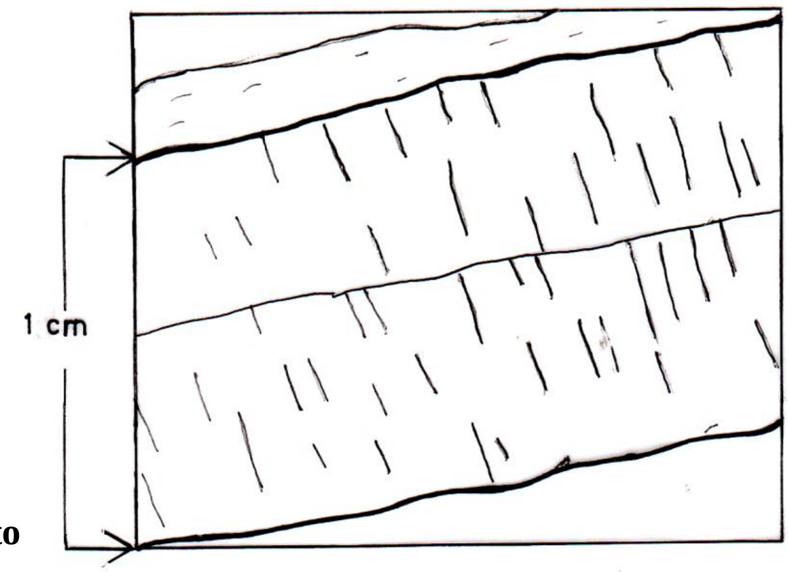
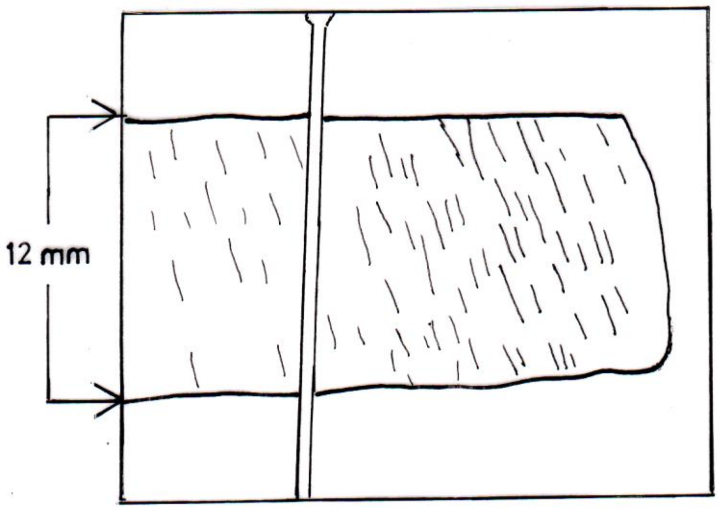
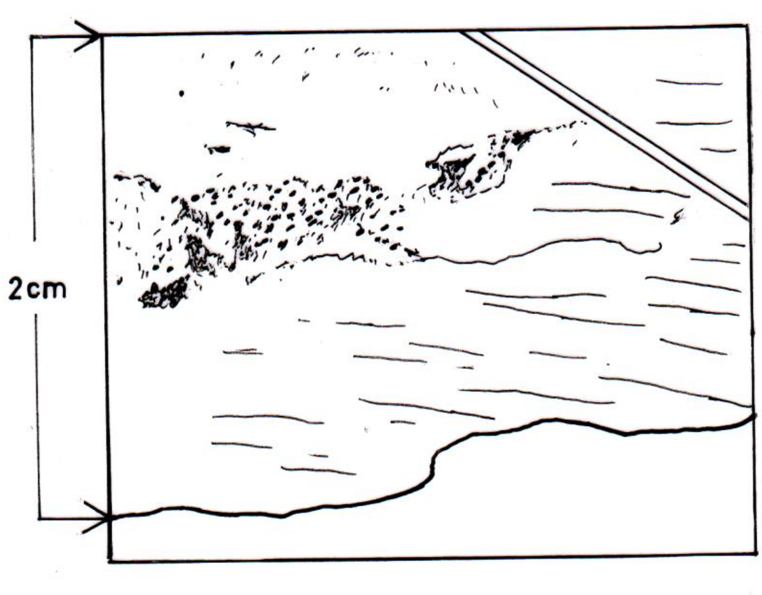


Fig(4) sketch of plate(1) showing perpendicular fibres to vein walls and vein centre line.



Fig(5) sketch of plate(2) showing inclined fibres to vein walls.



Fig(6) sketch of plate(3) showing the fibres in horizontal section which are slightly deviated from vein walls.

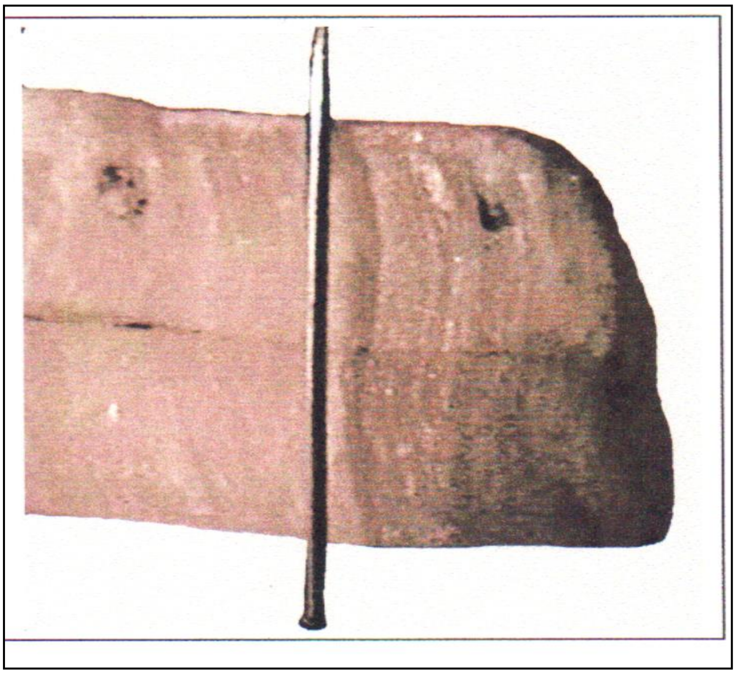
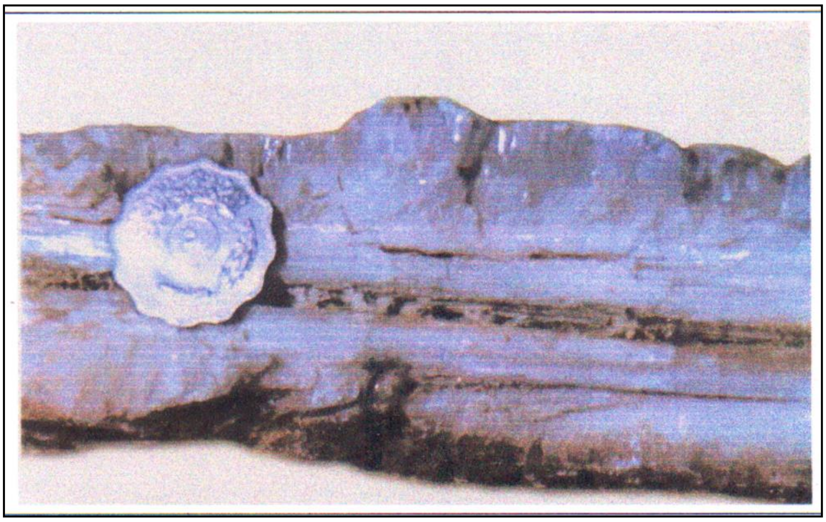
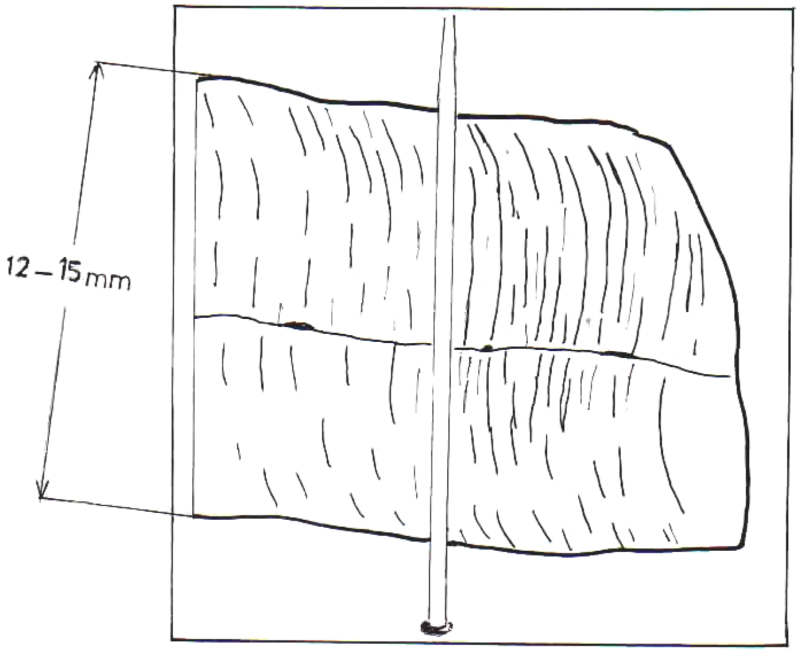


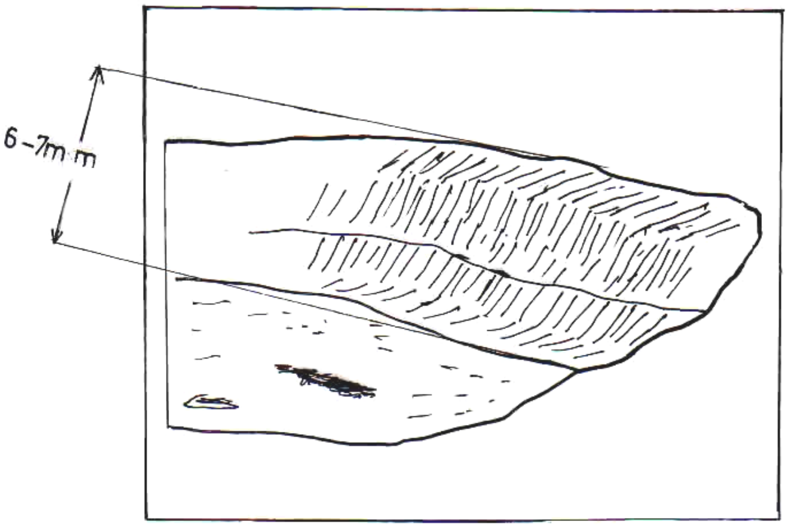
Plate (4) shows vein with fibres curved at vein walls, and perpendicular to vein centre line (the pin is2.54cm long)

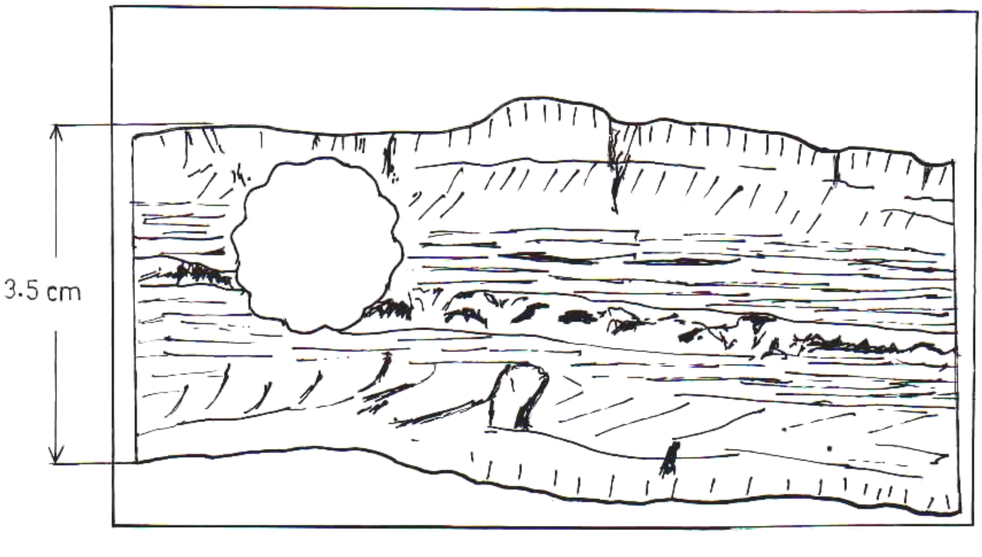
Plate (5) shows a vein with curved fibres, inclined (20°) at vein centre in the direction 265, and (5°) at vein walls in the direction(120°).

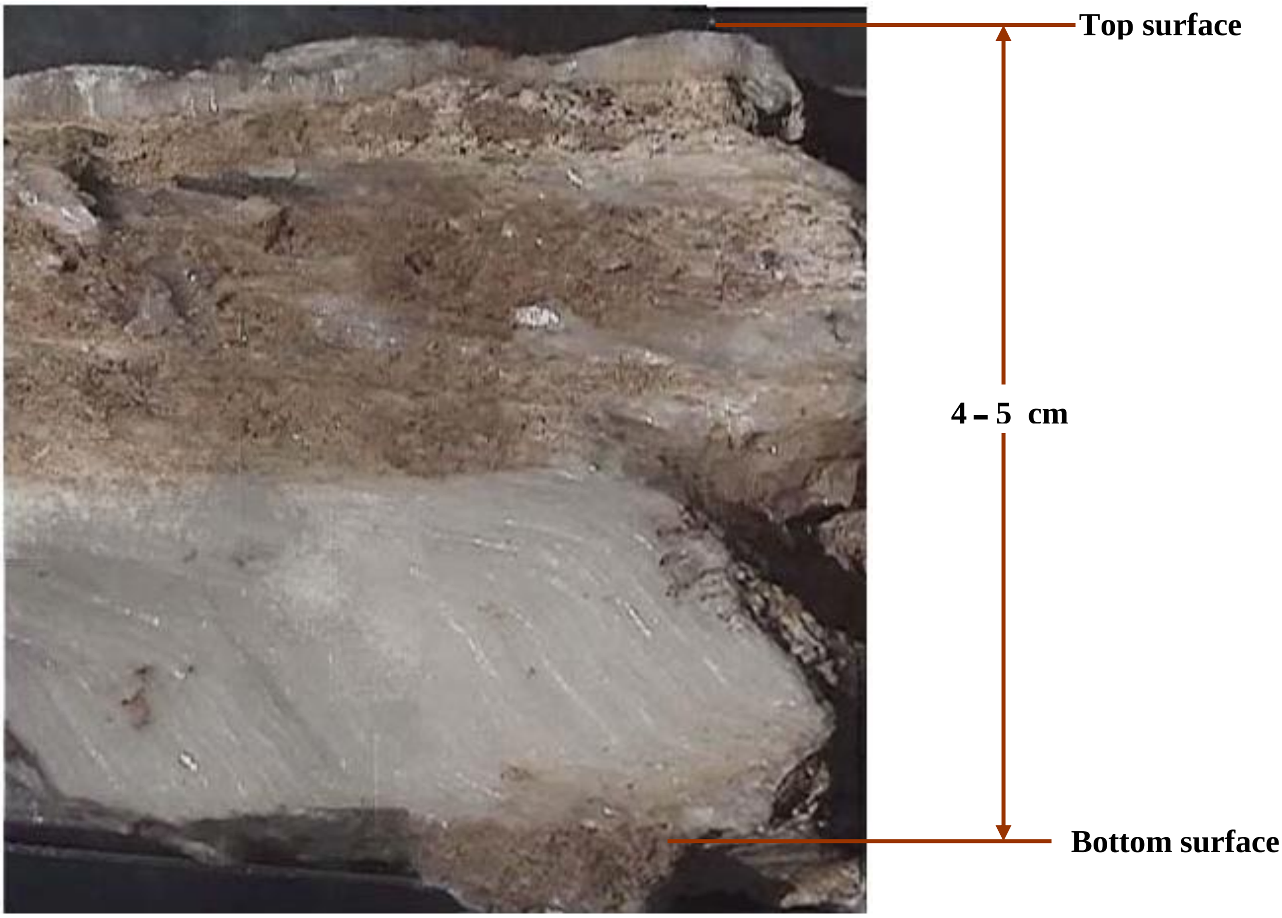
Plate(6) shows NE-SW section in horizontal vein with multibend fibres . (coin diameter 2 cm)



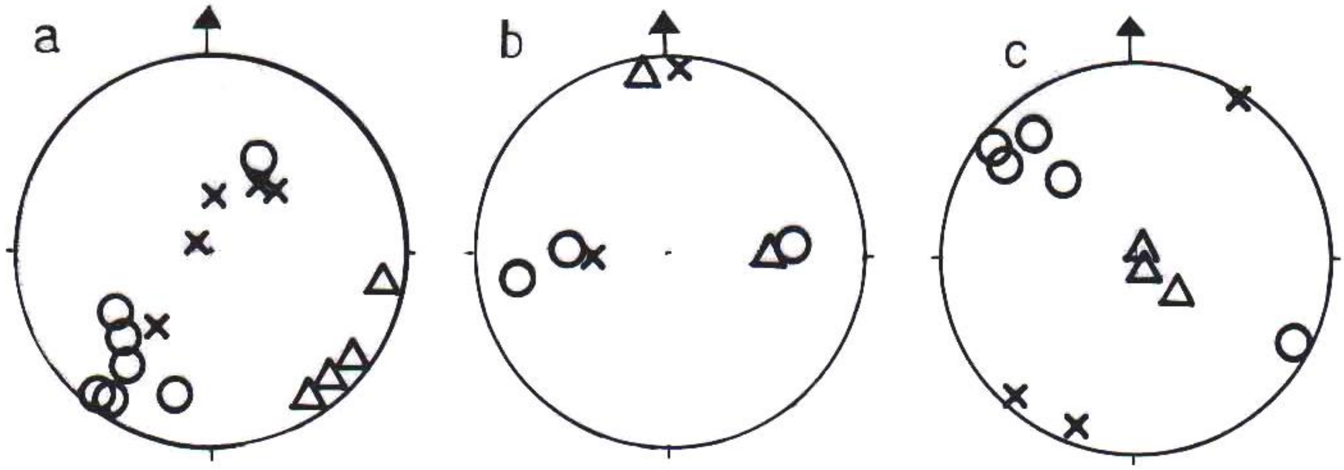

12 – 15mm


6 –7m m


3.5 cm

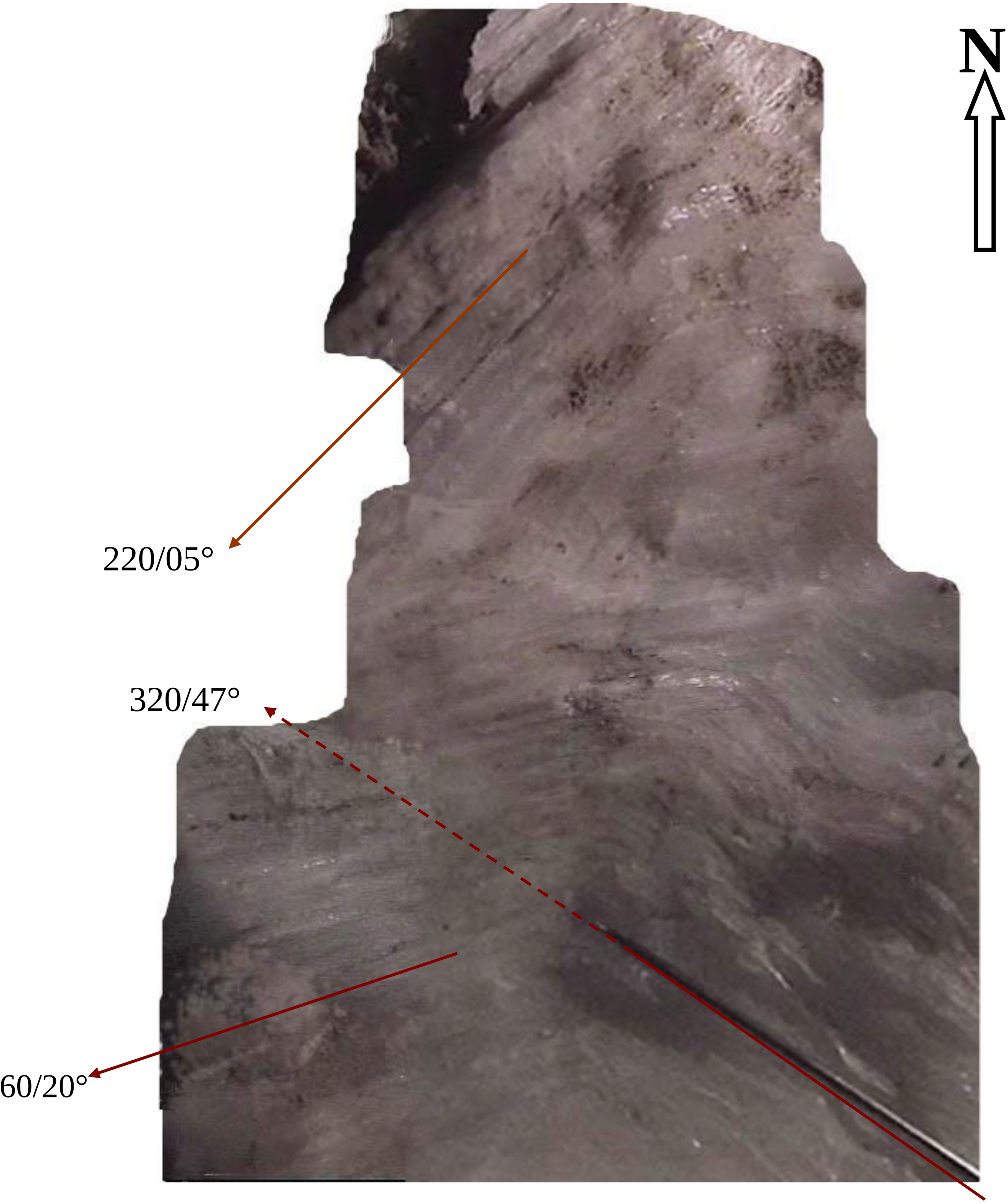


Plate(8) shows an inclined vein containing multibend fibres.



Fig(10)shows the directions of extension in the study area deduced from seven veins

a) NE-SW direction, b) E-W direction, c)NW-SE direction.


N
220/05°
320/47°
60/20°

Plate(7)show the top surface of the vein in plate(6) with three fibres directions from the top surface: 320/ 47° in the right bottom of the plate , 260/ 20° in the centre , and 220/05° in the top of the plate (pin length 2.54 cm).