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Geometrical classification and estimation of stresses of the joints in the ShewaSur-Chamchamal Anticline, NE Iraq

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Abstract

A classic joints survey have been executed on Shewa Sur-Chemchamal anticline seeking for geometrical classification of the joints and their causative stresses being the mentioned anticline not yet touched from structural point of view. Approximately, all type of joints in the mentioned anticline appeared:ab, bc, ac, hko1, hko2, hko3, hko4, okl, hol acute about a, hol acute about c and hol. Nearly, all estimated stress is of NE--SW trend which (Zagros type) and are comfortable with the nearby anticlines.

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Introduction

A classic method of joint study was used for execution this work. Field work was carried out in the form of isolated stations selected along lines perpendicular to Shewasur-Chem chemal anticline (study area) hinge area. In each station the joints were measured by compass and classified geometrically according to Hancook, 1985, then presented on stereonet.

It is worth to mention that joints appear only near the hinge line of the anticline.

The conjugate joints, among the measured joints, were used to estimate the paleo stress trend.

A lot of academic studies were carried out concerning joints in Iraq territory following the mentioned steps of work, Alazawi, 2010; Alkhatony, 2009; Al-Brifkani, 2008; AlSumaidaie, 2010; Al-Abdullah, 2009; Barno, 2011; Shihab, 2015. Al mentioned works illustrates that approximately all kinds of joints are existed and the estimated stress direction is nearly NE-SW.

In addition, there are many works, concerning present case study, outside of Iraq in general. Among these works are: Dyer, 1988; Lash & Engelder, 2007; McConaughy & Engelder, 2000; ZHAO and JACOBI, 1996.

The relation of joints and stress was discussed by ENOELDER & Geiser (1980), they concluded from field studies on the Appalachian Plateau that regional systematic joints reflect the principal directions of the regional stress field which gave rise to the joint.

Moreover, joints are opening-mode fractures that propagate in the plane of s 1 and s 2 and normal to s 3, and thus are sensitive indicators of the local stress eld orientation Dyer, 1988; Pollard and Aydin, 1988.

Systematic joints align parallel to the trend of the maximum horizontal stress (SH), they are used to construct regional paleo stress trajectories (Engelder and Geiser, 1980).

Furthermore, late-formed joints are often aligned parallel to the regional trend of the contemporary tectonic stress (modern-day SH), and are thus used for mapping the orientation of neotectonic stress, Engelder,1982 and Hancock, 1991 and many others.

More than 800 measurements of joints were carried out to fulfill the target of this study. The main aim of the present study is to identify various types of joints and to extract the regional paleo stress in the study area.

Location & Geologic setting

The study area is located about 70 km. NE Kirkuk city, NE Iraq. The length of the studied anticline attains 75 km., trending toward NW. Chem chamal city and Lesser Zab River located at southeastern and northwestern ends of the study area respectively, figure (1)

Tectonically, the study area lies within low folded zone of Zagros Fold-Thrust Belt ,that consists of a series of widely spaced, low amplitude gentle folds trending NW – SE but change gradually to E – W as they extend northwestwards, Buday & Jassim, 1987. This zone is characterized by the presence of regional detachment consists of Middle Miocene salt layers of Fat'ha Formation, that have caused decoupling of the surface structures from their subsurface counterparts (op cit), figure (2).

The study area is wide, gentle anticline and single plunging anticline in the southeastern end, figure (3). The lithology of rock units exposed in the study area is built up of alternating beds of gypsum, marl, claystone, sandstone and conglomerate represented by Miocene and Pliocene formations: Fat' ha (Middle Miocene, 370 m. thick) in the core of anticline, Injana (Upper Miocene, 1266 thick), Mukdadiya (Pliocene, 840m. thick)) and Bia-Hassan (Pliocene, 906.5m. thick) which form the north western part of the study area figure (3).

Geometrical classification of joints (see table 1 & 2, figure (4) (5) and figure (3) whenever necessary)

As mentioned above, the present classification depends totally to Hancook, 1988. The following joint classes were distinguishes:

-ac class: The plane of this class parallel to tectonic axes c and a and perpendicular to b. In the NE limb this class appear in station (54,43,24,20,5)with 84% while in the SW limb (50,43,24,20,5) with 4.59%.

-bc class: This class is parallel to the direction of dip. The line of intersection of this class is parallel to the bedding plane and strike of the beds. It appears in station (14, 5) with 2.3 in the NE limb while it appears in stations (15, 9) with 2.85%.

-ab class: This class includes the bedding planes and all planes that are parallel to them. The joints appear only in station (16) in the SW limb with 1.26%.

-hko class: This class is divided into two sub classes:

The first is hko acute about a: The planes of this subclass are acute about a axis. The acute angle (60) resulted from the intersection of plane of this subclass. The b anda axes bisect the acute and obtuse angles respectively.

This class has two planes:

*hko1 acute about a that appear in the NE limb in stations (28,22,16, 6,1) with 4.61% while in the SW limb, they exist in the station (50,42,41,26,17,11,10,9,4) with 11.72%.

*hko2 acute about a existing in the NE limb in stations ((52,48,47,40,36,28,22,8)with 11.53 while in the SW limb the planes of hko2 acute about a appear in station (34,19,17,15,7,3).

The second is the hko subclass acute about b (60°), a and b axes bisect the acute angle and obtuse angle of its planes respectively. This subclass comprises two planes:

* hko3 acute about b appears in stations in the NE limb(39,27,20,5,1) with 10.36%.while in the SW limb they appear in stations (49, 38,34,30,23,10).

*hko4 acute about b appear in stations (40, 32, 31, 28, 5) in the NE limb with 8.84%. While they appear in the SW limb in station (30, 23, 21,11) with 6.33%.

-okl class: The line of intersection of okl planes with bedding plane are parallel to a axis and perpendicular to fold axis. Only oklsubclass acute about c exist in the study area. The planes of this subclass make an angle 60 with bedding plane ang also make an acute angle with c axis ang obtuse angle withabout b axis.

In the NE limb this subclass appears instatio (44,40,36, 35, 18,6) with 15.19% while in the SW limb it exists in the station (53,51,49,45,41 37, 33,26, 25,21,12,2) with 17.11%.

holclass: The planes of this class are parallel to fold axis and intersect a and c axes. The line of intersections of this class are parallel to b axis. It occurs in two subclasses:

*hol acute about a: The planes of this subclass make 60 about a axis and obtuse angle about c axis.Also make 30 with bedding plane. In the NE limb they appear in stations (48,44,39,16,14) with 5.76% while in the SW limb they exist in stations (15,7)with 2.21%.

hol acute about c: The plane of this class makes an acute angle about c axis and obtuse angle with a axis, moreover it makes 60 with bedding planes. It appears in the NE limb in stations (53,51,45,38,37 33,19,13 10,9,7,4,3)with 11.92% while in the SW limbs it appears in stations (53,51,45,38,37,33,19,13,10,9,7,4,3) with18.22%.

hkl class: The planes of this class are always oblique to the tectonic axes. It appears in the NE limb in (54,52,47,36,32,31,27,24,22,8,6) with 21.34% while in the SW limb it appears in stations (46,42,41,38,37,29,25,21,17,13,4,3,2) with 20.91%.

Table 1. Numerical details of the measured joints in NE limb

Classification	Obtuse angle of joint plane with bedding and obtuse bisector trend. angle,	trend/plunge	Acute angle of joint plane with bedding and acute bisector trend. angle,	trend/plunge	Orientation and plunge of intersected line with bedding trend/plunge	Average of measurement of joint cluster Strike/dipdir/dip	Station\latitude longitude\ Elevation\mean bedding plane
hko_3	96.4	109.9/43.6	83.6	293.8/46.4	111.9/ 02.0	292/202/88.222	1/35.48 44.32/470
hko_1	97.4	273.6/ 44.9	82.6	273.6/ 44.9	90/3.5	270.25/180.25/86.125	315/45/5
ac	91.9	25.8/ 47.9	88.1	219.4/43	32. /6.8	212.4/302.4/86.6	5/35.47 44.33/450
hko_3	99.1	104.8/43.4	82.7	291.1 /46.8	108.1 02.	288.28/198.28/87.14	315/47/7
hko_4	96.9	178.0/ 43.1	83.1	349.3/ 47.2	353.3, 04.43	353.2/263.2/88.6	
bc	97.9	80.8/ 44.6	82.1	271.3/ 45.9	86.2/5.3	266.5/176.5/86.75	
hkl	100.2	326.3/ 55	79.8	148.5/ 35	327/1	212.4/302.4/86.6	6/35.49 44.32/450
okl>c	150.7	6.5/ 78.4	29.3	205.9/ 12.3	7.3, 4	288.28/198.28/87.14	315/47/5
hko_1	154.1	45.9/ 76.9	25.9	247.5/ 14.1	47.1/5	353.2/263.2/88.6	
						266.5/176.5/86.75	
hol>c	133.9	110.0/60.5	46.1	296.5/ 29.6	111.6 /2.8	293.75/203.75/52.62	8/35.50 44.31/390
hkl	149.4	3.5/79.3	30.6	210.6/12	4.5/5.3	195.28/105.28/26.57	315/45/7
hko_2	96.7	8.8/ 52.2	83.3	201.1/ 38.4	13.5/ 6	194.57/284.57/79.71	
bc	100.7	132.8/ 45.4	79.3	311.1/44.6	312/9	311.87/221.87/84.25	14/35.47
hol>c	109.8	301.2/59.9	70.2	121.1/30.1	121.2/1	121.16/31.66/65.16	44.35.5/620
hol>a	161.5	126.5/75.8	18.5	304.9/ 14.2	306.4/4	305.5/215.5/23.5	302/45/5
hol>c	90	312.2/ 49.9	90	134.2/40.1	313/1	133.13/43.13/85.06	16/35.46 44.35/630
hol>a	163.7	131/76.9	16.3	307.5/13.1	310.8/8	308.85/218.85/21.28	302/47/5
hko_1	97	58.7/46	83	247.3/ 44.2	62.9/ 04.3	243.2/333.2/85.6	
okl>c	105.9	48.9/50.6	74.1	242/40.2	54.2/ 6.5	235.75/325.75/76.87	18/35.45 44.38/740
okl>c	102.7	29.6/51.3	77.3	223.8/39.6	35.2/7	216.75/126.75/77.83	302/47/7
ac	96.7	33/47.9	83.3	232.6/ 43.8	42.1/9.9	223/133/84.63	20/35.44 44.40/770
hko_3	113.2	82.8/ 48.9	66.8	274.9/ 41.7	88.1/6	269.77/179.77/74.88	305/45/10
hol>c	93.4	123.3/ 36.7	86.6	303.8/53.3	123.6/ 00.2	123.6/33.6/83.4	
hkl	137.9	161.7/ 64.9	42.1	334.2/25.3	340.3/2.9	337.57/247.57/46.28	22/35.43 44.42/755
hkl	138.1	348.3/72.7	41.9	180.5/17.7	349.4/3.5	173.85/83.85/38.42	305/47/5
hko2	95	32.5/ 47.5	85	222.5/ 42.9	37.1/5	217.5/307.5/85.16	
hko1	98.8	89.3/ 45.3	81.2	274.7/44.9	92/2.7	272.2/182.2/85.4	
ac	95	30/ 47.7	85	220/ 42.7	34.6/5.0	215/305/85	24/35.41 44.46/645
hkl	110.3	117.5/50.2	69.7	298.8/ 39.8	118.1/ 00.6	298.22/208.22/74.66	305/45/5
hkl	100.8	354.1/53.6	79.2	182.3/36.7	357/ 3.9	178/88/76.14	

hko3 hkl	104.7 132	87.9/ 45.8 38.6/ 65.2	75.3 48	276.6, 44.5 238.8/26.2	92.2/4.4 42.3/7.9	272.78/182.78/82 229.125/139.125/49	27/35.40 44.48/600 305/45/8
hko_4 hko_2 hko_1	104 .6 93.4 97.1	140.7/42.6 6.3/50.9 46.2/46.1	75.4 86.6 82.5	316.1/ 47.5 205.1/ 40.7 244/45.5	318.2/2.3 14/ 9.3 55/9	318/288/85.14 195.16/285.16/83.16 236/146/86	28/35.41 44.50/605 305/50/10
hko_4 hkl	105.4 119.1	168.6/ 43.4 339.9/ 69.2	74.6 60.9	341.7/ 46.8 168.2/ 21	345/ 3.5 341/2.8	344.63/254.63/84 163.2/73.2/51.3	31/35.38 44.50/665 325/40/10
hko_4 hkl	105.4 142.6	147.7/ 45.7 115.3/65.2	74.6 37.4	327.1 44.3 303.9/25.1	327.4/ 00.3 116.8/3.3	327.35/237.35/81.64 300.28/210.28/43.71	32/35.39 44.51/640 325/43/7
okl>c okl>c	100.2 95.5	60.3/49.1 22.3/51.3	79.8 84.5	254/41.7 214.9/ 39.4	66.2/6.9 27.3/6.2	247.31/337.31/81.25 208.28/118.28/81.28	35/35.36 44.52/705 325/47/7
hkl okl>c hko_2	141.6 101.9 91.4	66/67.2 50/ 50.6 21.9/ 52.6	38.4 78.1 88.6	281.7/ 27.4 259.1/ 43.2 229.5/40.8	72.2/ 14.4 62.6/14.9 32.8/13.9	267.14/177.14/44.71 245.2/335.2/80.4 214.5/304.5/83.2	36/35.37 44.53/710 325/45/15
hko_3 hol>a hol>c	117.1 165.5 95.9	116.2/49.6 163.7/87.8 134.3/38.1	62.9 14.5 84.1	304.9/40.7 288/ 3.9 317.5/52.0	119.9/4.3 343.6/3.2 136.2/1.5	301.28/211.28/72 196/106/6 136.14/46.14/86	39/35.32 44.54/666 325/47/10
hko_2 hko_4 okl>c	92.7 100.4 98	204.8/ 42.5 167.9/ 43.7 58.8/48.2	87.3 79.6 82	13.5/48 343/46.4 252.6/ 42.7	18.6/5.6 345.3/2.4 65/6.9	198.71/288.71/88.57 345.16/255.16/86.16 245.85/335.85/83.28	40/35.34 44.56/740 325/50/7
ac hol>c	95.7 96.6	35.8/ 49.8 132.8/36.4	84.3 83.4	239.4/ 42.7 315.3/ 53.6	46.1/12.0 134.4/1.2	227.5/137.5/83.6 134.3/44.3/84.7	43/35.31 44.56/680 320/38/12
hol>a okl>c okl>c	162 104.1 98	151.9/ 84.3 41.2/52.8 18.1/ 55.8	18 75.9 82	303.3/6.5 250.7/ 41.1 226.6/37.7	331.5/3.1 52.9/15 27.9/13.9	194.5/104.5/4.5 236.37/326.37/77.12 211.2/121.2/76.8	44/35.32 44.57/773 320/47/15
hkl hko_2	139.7 91.9	156.4/65.1 11.8/ 48.9	40.3 88.1	332.8/ 25 200/41.4	335.8/1.4 15.4/4.1	334.4/244.4/45.1 195.7/285.7/85.3	47/35.29 44.57/650 320/45/5
hol>c hko_2 hol>a	133.3 90.4 168.5	121.7/ 59 199.9/40.8 159.6/88.2	46.7 89.6 11.5	307/31.1 7.1/ 49.9 283/3.2	123.1/ 02.3 12.5/6.4 339.5/ 02.7	304.81/214.81/54.36 193/283/85.6 193.6/103.6/4.8	48/35.30 44.59/680 320/45/8
hkl hkl hko_2	131.3 150.9 97.5	112/ 61 6/ 78.5 11.1/ 51.4	48.7 29.1 82.5	296.4/29 205.5/ 12.1 199.9/ 38.9	113/1.9 6.8/3.9 14.5/ 4.3	294.42/204.42/53.42 194.83/104.83/26.33 195.28/285.28/80	52/35.53 44.26/428 315/48/5
hkl ac	123.8 93.9	25.2/ 65 44.9/ 47.1	56.2 86.1	224.1/ 26.2 240.8/ 44	28.7/7.5 52.4/8	214.2/304.2/53.7 232.9/142.9/86.5	54/34.54 44.24/470 320/45/8

Table 2. Numerical details of the measured joints in SW limb

Classification	Obtuse angle of joint plane with bedding and obtuse bisector trend. angle,	trend/plunge	Acute angle of joint plane with bedding and acute bisector trend. angle,	trend/plunge	Orientation and plunge of intersected line with bedding trend/plunge	Average of measurement of joint cluster Strike/dipdir/dip	Station\latitude longitude Elevation\mean bedding plane
hkl okl>c hkl	124 157.29 114.52	357.4/65.2 050.6/ 48.6 075.6/ 54.5	56 22.71 65.48	187.3/25.1 240.3/ 41.9 263.9/ 35.8	359/04 054.9/ 04.8 078.4/03.9	182/092/53.142 235.6/145.6/82 260/171/68.2	2/35. 47 44 .32/460 310/220/05
hkO$_2$ hkl hol>c	90.62 135.32 96.48	055.5/ 45.3 195.6/ 64.0 191.9/43.3	89.38 42.6 82.7	252.4/ 46.0 356.9/ 27.2 358.2/ 47.5	064.1/ 08.5 011.9/ 07.6 004.6/ 06.9	255.4/345.4/87.8 365/275/48 364.4/274.4/88.5	3/35.46.44.31.36/594 315/ 225/09
hko$_1$ hol>c hkl	106.43 131.43 101.98	350.8/53.6 284.5/ 68.4 084.0/47.4	73.57 48.8 80.7	175.4/36.5 101.3/ 21.6 267.8/ 42.7	352.4/ 02.2 104.0/ 01.1 085.8/ 01.9	173/83.3/75 302/052/46 266/176/83	4/ 35.46 44.32/585 305/ 215/09
hol>c hko$_2$ hol>a	104.5 91.8 134.3	155.1/44.3 025.3/50.1 130.9/ 59.6	75.5 88.2 45.7	333.9/ 45.7 219.4/ 40.8 316.5/ 30.5	334.5/ 00.6 031.2/ 07.0 132.3/ 02.4	334.428/254.428/83.428 211.857/121.857/84.42 314.166/224.166/53.333	7/35.48 44.30 /503 330/225/08
hko$_1$ bc hol>c	92.27 94 98	008.6/ 49.0 135.4/ 41.5 134.3/ 45.0	87.73 86 82.0	195.7/ 41.2 314.7/48.5 313.7/ 45.0	011.6/03.5 315.0/00.3 314.0/ 00.3	192/102/84 128/045/87 314/224/86	9/35.50 44.28/339 310/220/04
hko$_1$ hko$_3$ hol>c	98.02 92.09 104.04	015.8/52.8 181.1/ 40.1 135.0/ 45.5	81.98 87.91 75.96	208.9/ 38.0 351.8/50.3 315.0/44.5	020.6/ 06.4 355.6/ 04.6 315.0/ 00.0	202/112/78 176/86/85 315/255/82	10/35.49 44.27/ 450 315/ 225/12
hko$_4$ hko$_1$	94.72 93.42	123.1/38.2 202.9/40.7	85.28 86.58	308.1/51.9 006.7/50.5	126.2/ 02.4 013.4/08.1	126/036/86 194/104/86	11/ 35.50 44.27/405 320/230/1
okl>c okl>c	108.99 107.46	009.7/ 59.9 046.7/ 49.6	71.01 72.54	239.8/ 42.2 273.9/ 51.4	026.4/26.5 071.1/25.9	212/302/79 255/165/82	12/ 35.49 44.25/340 317/227/28
hkl hol>c hol>c	149.5 96.18 95.71	189.6/ 71.0 030.3/ 48.4 052.0/ 47.9	30.5 83.82 84.29	219.9/ 42.1 219.9/ 42.1 241.9/ 42.5	008.4/03.7 034.6/ 04.8 056.5/ 05.0	363/273/35 215/305/85 237/147/84	13/ 35.46 44.33/566 320/230/05
bc hol>a hko$_2$	92.85 148.95 90.84	137.0/ 30.6 102.7/ 60.6 064.1/ 47.9	87.15 31.05 89.16	313.9/59.5 297.7/ 30.3 269.5/ 45.1	314.7/ 01.3 106.4/06.5 076.2, 13.0	135/045/77 315/225/45 259/349/78	15/ 35.45 44.35/532 310/220/16
hko$_1$ hko$_2$	102.31 94.62	006.7/ 53.4 061.3/ 48.6	77.69 85.38	195.7/ 36.9 250.4/ 41.8	009.9/ 04.3 065.3/ 04.5	191/101/76 246/336/81	17/ 35.45 44.36/600 310/220/10
hkl hko$_4$ okl>c	130.21 99 108.56	066.8/ 66.4 308.8/ 57.0 047.8	49.3 81 71.44	263.7/ 24.6 127.0/ 33.0 241.9/ 38.5	069.6/ 06.4 128.3/ 00.8 053.1/ 06.9	256/346/45 128/045/73 235/145/75	21/ 35.42 44.41/790 315/225/09
hko$_3$ hko$_4$ ac	93.96 92.64 93.84	319.9/ 00.6 104.4/ 39.5 028.3/ 47.0	86.04 87.36 86.16	319.9/ 00.6 290.9/ 50.7 222.0/ 43.8	319.9/ 00.6 319.9/ 00.6 319.9/ 00.6	140/050/85 108/018/85 215/305/88	23/35.40 44.45/710 315/225/07
hkl okl>c	154.22 106.81	163.7/ 68.5 055.2/48.7	25.78 73.19	328.5/ 22.2 253.5/ 42.7	341.6/ 05.3 063.4/ 09.2	334/244/35 245/155/80	25/ 35.37 44.45/745 310/220/10
ab okl>c hko$_1$	173.47 98.25 92.35	154.8/ 82.7 011.8/ 48.9 203.7/43.4	6.53 81.75 87.65	321.7/ 07.5 200.6/ 41.5 014.7/ 47.0	334.6/ 01.7 015.6/ 04.4 018.9/ 04.5	325/235/10 196/286/85 199/109/88.6	26/ 35.39 44.47/705 315/225/05
hkl	108.95	342.4/ 60.4	71.05	168.0/ 29.7	343.8/02.4	165/75.4/63.7	29/ 35.36 44.46/730 315/225/05
hko$_4$ hko$_3$	90.62 105.84	280.5/ 51.6 150.1/ 45	89.38 74.16	090.6/ 38.8 327.9/ 44.2	096.7/04.8 329.0/ 01.1	289/010/82.2 328.85/238.85/81.42	30/35.37 44.48/740 320/230 /07
okl>c hol>c	109.54 116.18	253.4 / 38.2 315.9/ 69.2	70.46 63.82	253.4/38.2 133.6/ 20.8	060.7/ 09.8 135.6/ 00.8	243.8/153.8/72.7 135.8/045/51.5	33/35.34 44.48/760 320/230/10
hko$_2$ hko$_3$	93.52 96.12	069.4/340.8 340.8/ 57.6	86.48 83.88	266.0/ 46.5 171.9/ 32.9	078.0/ 08.4 344.0/ 05.0	258.5/348.5/86.35 165.5/075.5/73.75	34/ 35.35 44.50/785 315/225/10
hol>c okl>c hkl	153.23 108.56 142.98	333.0/ 82.3 050.5/ 53.0 078.6/ 68.7	26.77 71.44 37.02	167.6/ 07.9 240.5/ 37.4 269.8/21.7	333.2/ 02.0 054.1/ 04.8 080.1/ 03.8	158.66/68.66/20 235.6/145.6/73.2 264.7/174.7/39.7	37/35.31 44.50/720 310/220/05
hkl hol>c hko$_3$	167.21 115.69 102.3	176.2/79.3 009.0/ 57.9 341.5, 55.6	13.19 63.31 77.7	338.8/ 11.2 198.2/ 32.4 166.5, 34.5	355.5/03.3 011.6/ 04.2 343.1/ 02.4	345.4/250.4/17.9 193.4/283.6/67.2 163.8/73.28/73.28	38/ 35.32 44.52/680 315/215/05
hkl okl>c hko$_1$	135 104.7 99.4	345.7/ 74.7 035.0/54.0 2.0/ 55.5	45 75.3 80.6	179.7/15.8 231.3/37.1 194.2/ 35.2	346.7/ 03.6 40.8/ 07.9 6.0/ 05.8	171.375/081.375/38 223/313/74.2 187.5/097.5/75.125	41/35.29 44.52 /670 320/227/10

hkl ac hko_1	139.96 98.18 102.81	345.4/ 75.0 039.8/49.1 002.4/ 56.0	40.04 81.82 77.19	181.8/ 15.6 235.8/ 42.0 195.9/ 34.8	346.6/ 04.2 046.8/ 08.0 006.7/ 06.3	172.14/082.14/37.14 227.42/137.42 /86.03 188.57/098.57/73.57	42/ 35.30 44.54/610 315/225/10
hol>c okl>c	145.72 118.87	336.2/ 80.3 045.7/ 59.5	34.28 61.13	173.6/ 10.2 243.5/ 31.8	336.7/ 03.0 050.5/ 08.0	152.58/073.58/27 234.87/144.87 /61.25	45/ 35.27 44.53/645 315/225/08
hkl hkl hkl	151.27 147.08 125.63	079.9/ 73.7 057.1/ 75.3 331.2/61.0	28.73 32.92 54.37	273.6/ 16.8 255.8/15.5 155.6/29.0	081.0/ 03.8 058.4/04.7 332.2/01.9	267.66/177.66/29.7 247.25/337.25/28.25 153.2/243.2/62.6	46/ 35.28 44.56/625 310/220/05
hko_3 okl>c	96.8 104.9	312.3/ 55.3 48.6/ 50.1	83.2 75.1	135.2/34.8 241.7/40.6	313.2/ 01.4 54.1/ 06.5	133.58/043.58/76.33 235.5/145.5/77.83	49/35.43 44.34/700 302/225/07
hko_1 ac	98.3 93.6	059.6/ 47.7 038.8/ 47.1	81.7 86.4	249.0/ 42.7 228.8/ 43.3	063.9/ 04.7 043.5/ 05.0	244.444/334.444/83.3 223.8/313.8/86.3	50/35.41 44.38 /770 305/225/6
hol>c okl>c	106.04 114.55	091.1/47.0 196.3/ 49.6	73.96 65.45	284.1/ 43.8 000.6/ 41.5	097.3/06.6 009.6/07.9	278.5/188.5/79.3 367.54/227.54/75.72	51/35.53 44.25/415 318/228/10
okl>c hol>c	99.22 124.01	038.1/ 50.3 316.2/75.4	80.78 55.99	247.2/ 43.6 137.5/ 14.6	050.9/14.9 316.3/ 00.3	233.2/133.2/81.6 136.6/046.6/44.2	53/35.54 44.23/440 320/225/15

Table 3. Dip direction and Dip angle of acute bisector angle (stress orientation) for the conjugate joints in the NE and SW limbs in the study area

acute bisector angle	Acute angle	single measurement of conjugate joint		No. of stations in The SW limb	acute bisector angle	Acute angle	single measurement of conjugate joint		No. of stations in the NE limb
		Classification	dip dir/dip				Classification	dip dir/dip	
233.6/79.8	42.4	okl>c okl>c	302/79 165/82	12	320.8/87.5	64.9	hko_4 hho_3	198.28/87.14 263.2/ 83.6	5
226/84.4	21.9	hol>c hol>c	305/85 147/84	13	226.2/77.2	18.6	okl>c okl>c	325.75/76.87 126.75/77.83	18
218.8/77.1	54	hko_1 hko_2	101/76 336/81	17	244.9/84.7	54.5	hko_2 hko_1	307.5/85.16 182.2/85.4	22
124/84.8	31.9	hko_3 hko_4	050/85 018/85	23	215.6/84.1	41.9	hko2 hko1	285/83.14 146/86	28
308.5/81	38.6	hko_4 hko_3	010/82.2 238/81.4	30	227.8/80.7	38.6	okl>c okl>c	337.31/ 81.25 118.28/ 81.28	35
					223.8/76.7	24.5	okl>c okl>c	326.37/ 77.12 121.2/76.8	44

Fig 1. The geographical location map of the study area

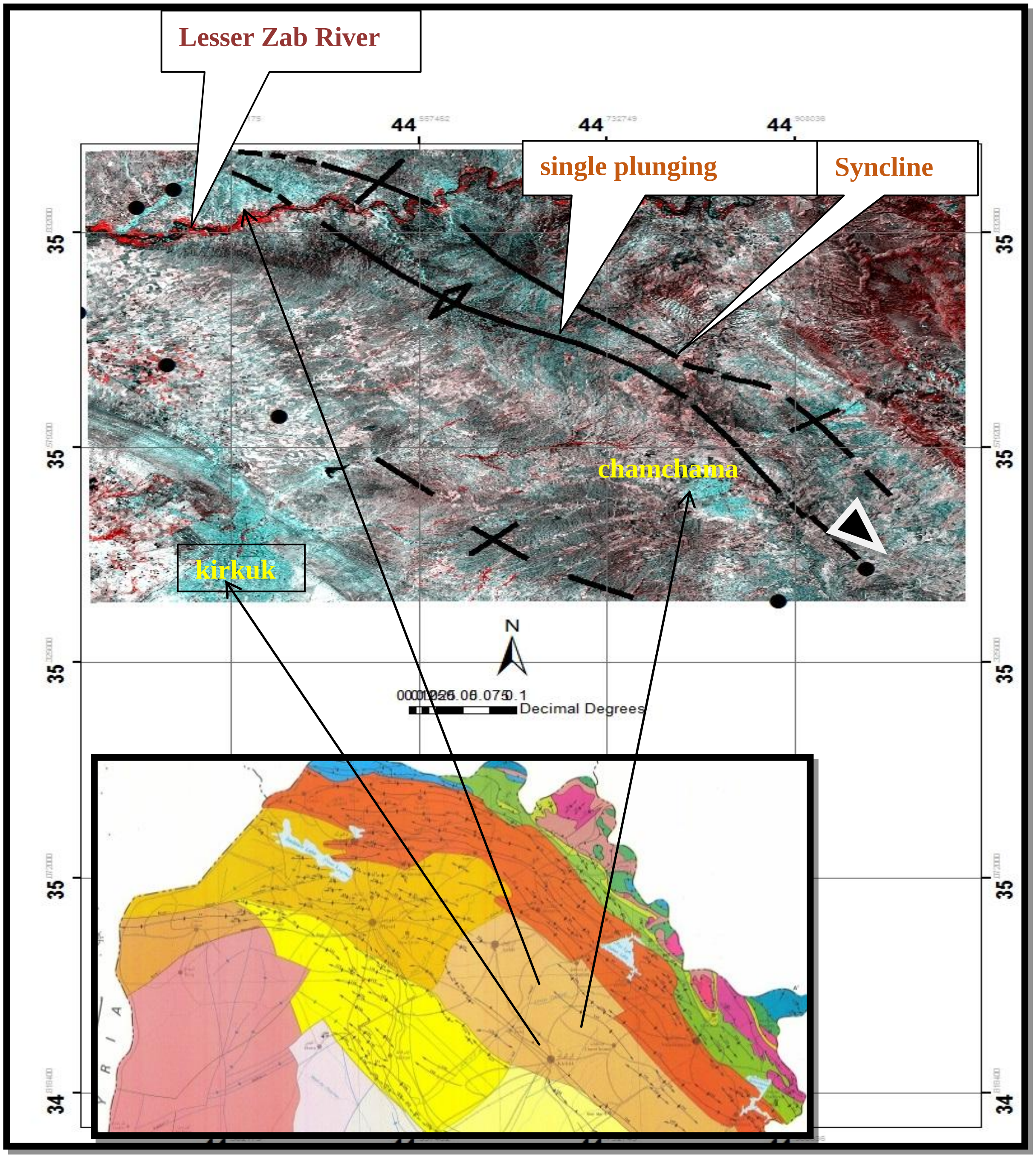


Fig 2. Tectonic map of the study area from (Al-Kadhimi, *et al.*,1996)

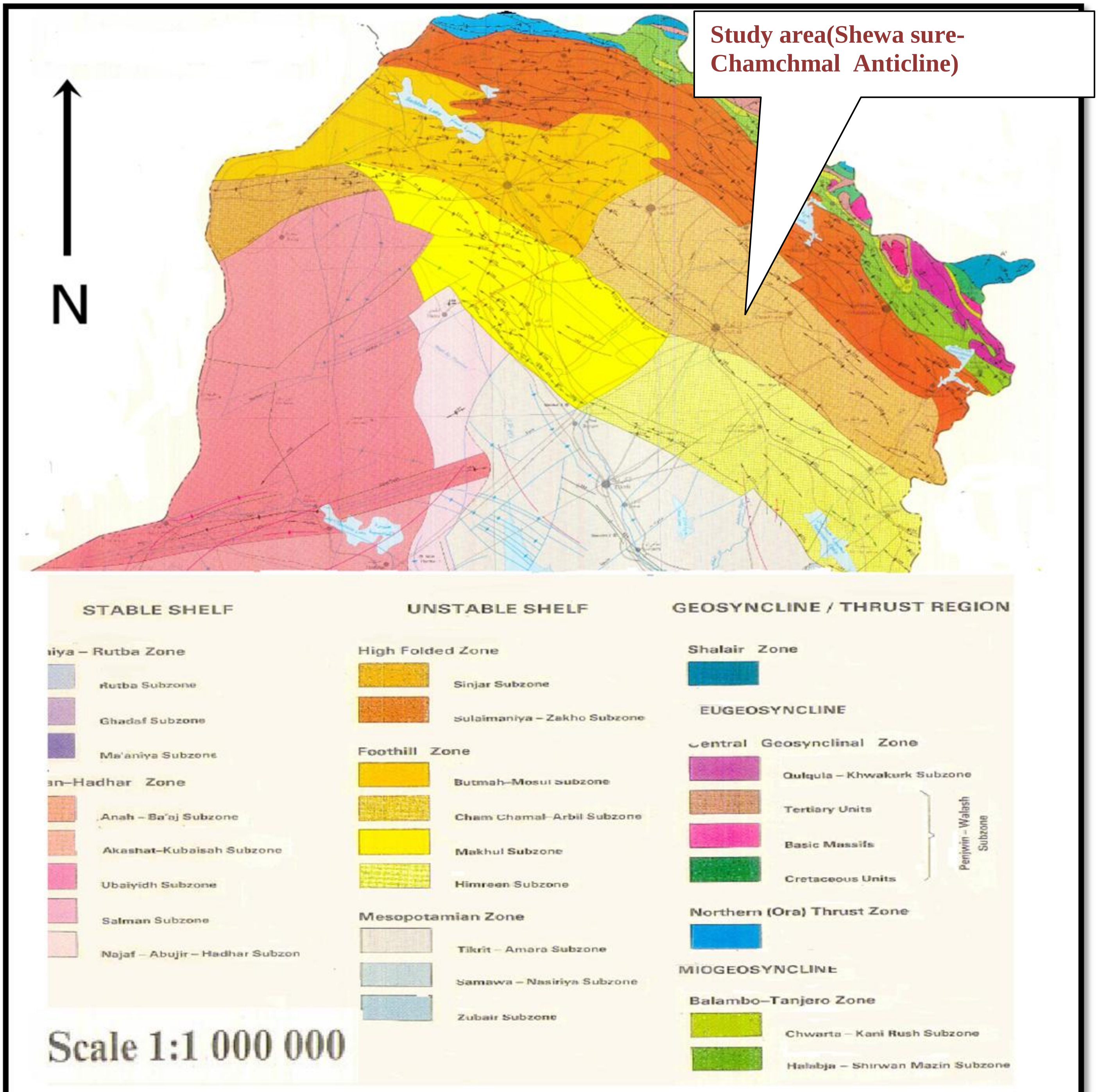


Fig 3. Geologic map of the study area from (Sissakian, 1993) showing the joints stations

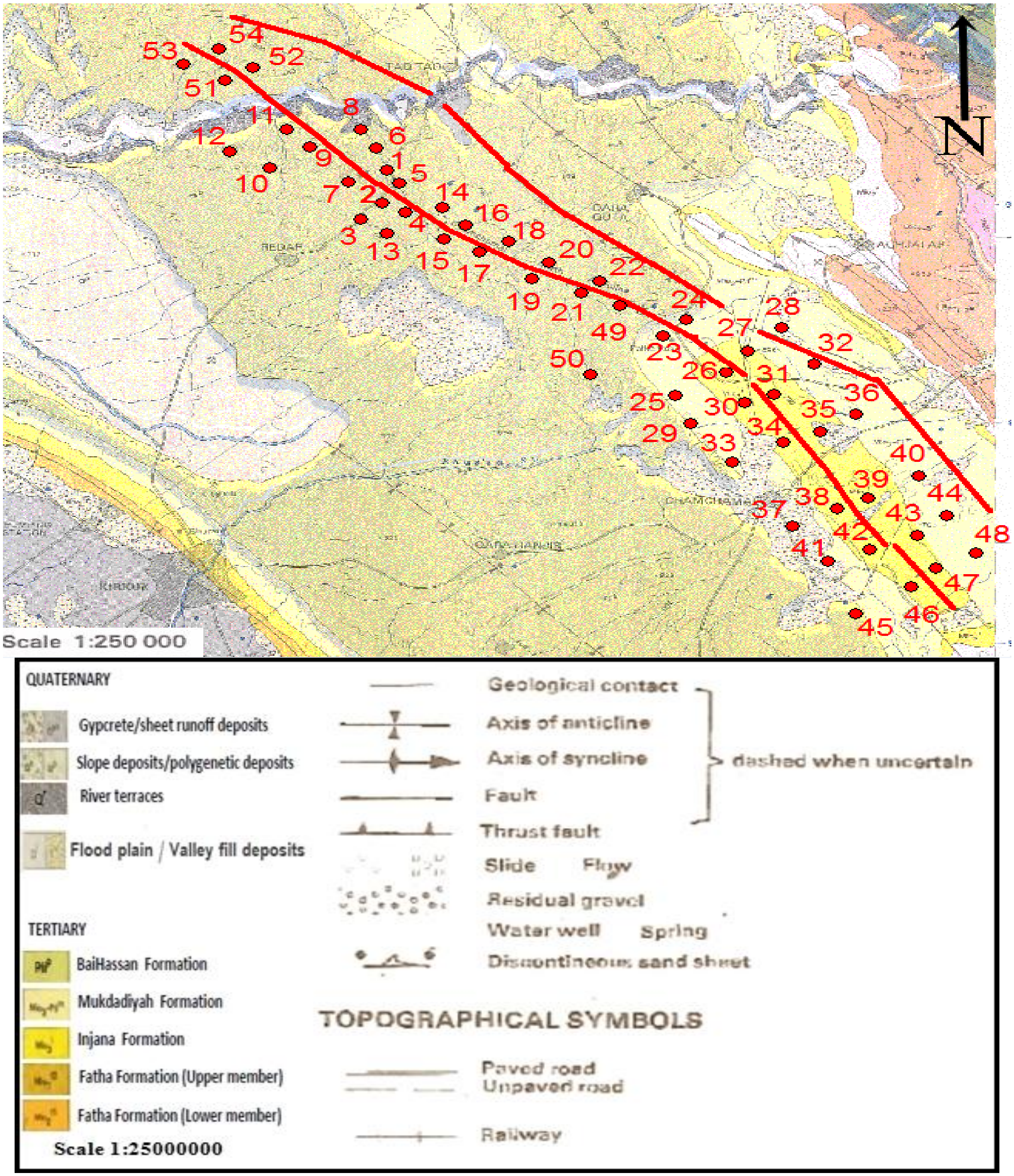


Fig 4. Stereographic projection (lower hemisphere of the measured joints,numbers represent numbers of the station

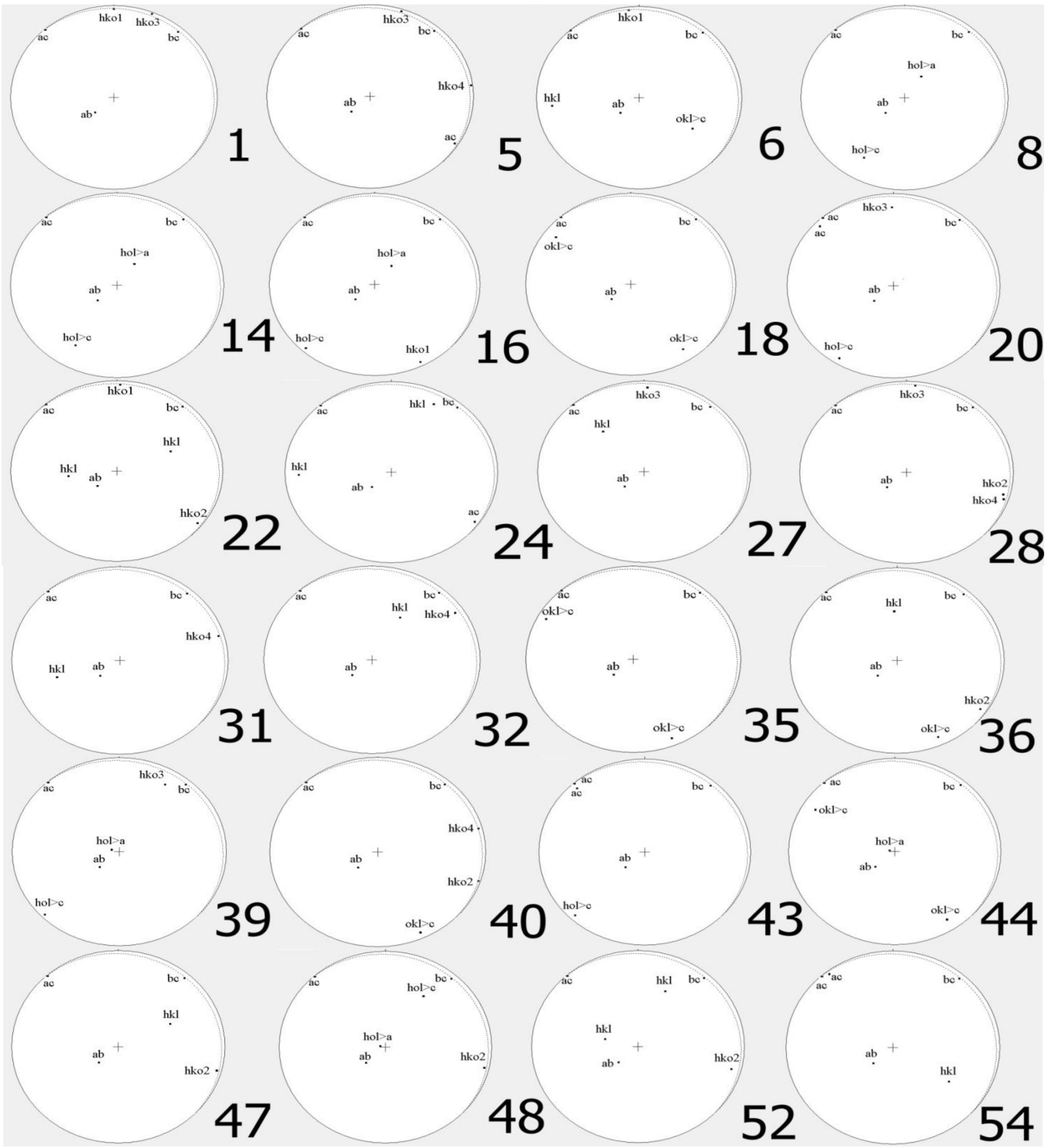
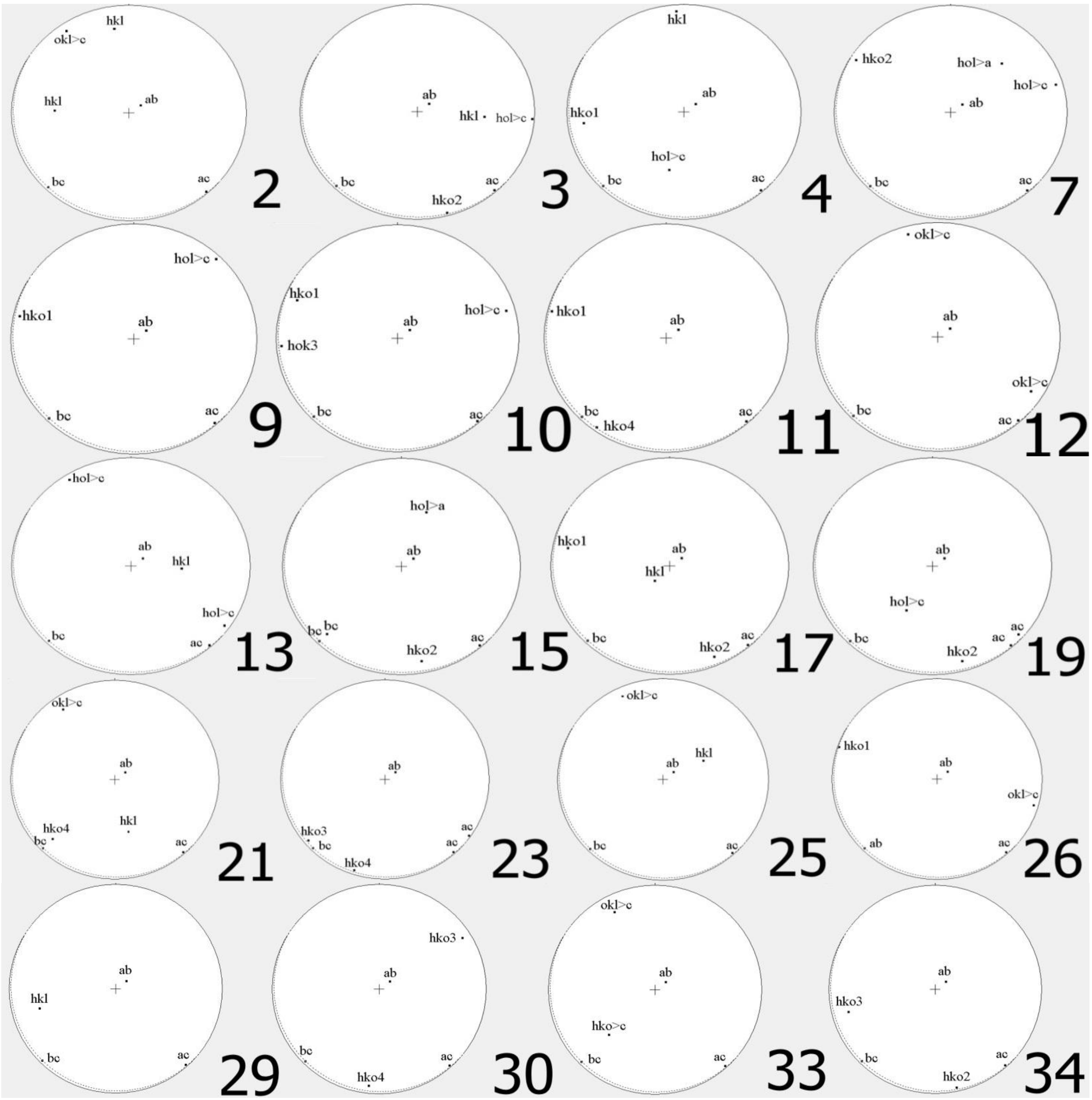
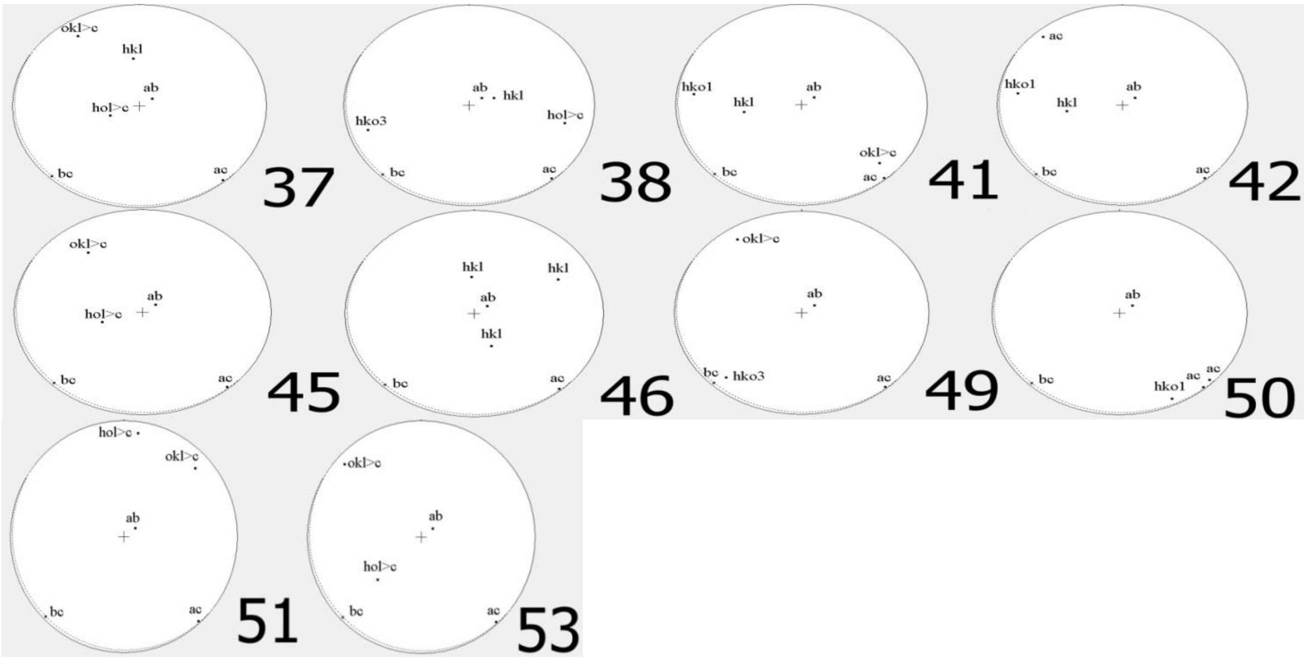


Fig 5. Stereographic projection (lower hemisphere of the measured joints,numbers represent numbers of the station in the SW limb in the study area





Conjugate joints and stress

The conjugate joints exist in the study area in station (5,18,22,28,35,44) in the NE limb and in station (12,13,17,23,30) in the SW.

The conjugate joint measurement provided to stereonet software and it is possible to determine the orientation and dip plunge of the acute bisector which represents the orientation of stress Table (3)

Results and Discussion

The authors classified the measured joints into tension joints and shear joints.

The shear joint in the study area are in the form of hko, hol and okl while tension joints are in the form of a ax and bc joints.

From tables (3) one can find that the acute bisected orientation (stress orientation) in the NE limb oscillate from 215 to 320 and 124 to 308 in the SW limb. Two measurement in the same mentioned limb in station 5 and 28 are nearly run with fold axis orientation see table (3). The stress orientation is nearly parallel to fold axis. In the SW limb a single measurement of conjugate joint run nearly with fold axis.

From above the main stress orientation is NE-SW which coincides with Zagros stress trend.

The mentioned orientation is responsible for fold development in north and NE Iraq as the previous works clarify. Thus the studied fold is formed as the folds formed in NE Iraq.

Conclusion and recommendation

1-The calculated stress orientation is run comfortable with Zagros stress and the adjacent calculated stress.

2-The present study illustrates that other orientation of stress runs with fold axis. This could be of tension along type.

3-The existence of high percent of hkl joints could be due to gypsum and anhydride beds within Fatha Formation.

4- The fold takes the present shape during Pliocene or may be post Pliocene. This is guided by the presence Pliocene sediments exposures of Mukdadiya and Bia-Hassan Formations.

It is worth to mentioned that more structural studies are needed to support the present work especially if we know that the study area is virgins from structural studies.

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