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Research Article

SOME RELATIONSHIPS BETWEEN MAJOR FEATURES OF FAULTS (CASE STUDY OF MIDDLE, SOUTHERN TIEN SHAN AND ADJACENT AREA)

***Oksana G.Tsay**
Institute of Geology and Geophysics, 49, N. Olimlar Str., Tashkent, 100041, Uzbekistan
**Author for Correspondence*

ABSTRACT
The article covers the major quantitative features of faults (length, width, depth, displacement amplitude, strike azimuth, dip angle) and the relationships between them.
Information is available from the database “Faults of the Middle, Southern Tien Shan and adjacent area (Tsay and Lordkipanidze, 2018, Tsay, 2019). The results indicate that strong relationship has been found in 3 cases: between the length and horizontal displacement amplitude, between length and width; between vertical and horizontal displacement amplitudes.

Keywords: *Faults, Features, Database*

INTRODUCTION

The issue of finding the relationship between quantitative features of faults is very significant. The major quantitative features of faults are the following: length, width, depth, vertical and horizontal displacement amplitude, which basically is used in classification of faults. The tectonophysical analysis carried out for faults of different zones (wrench, extensional and compressional) of the lithosphere showed that there is a strong relationship between features of faults (Sherman SI and Seminsky KZh, 1991, 1992; Sherman SI, 1994).

Creation of database and classifications of faults are one of the actual problems of today. It is caused by necessity of finding new relationships between major quantitative features of faults such as, length, width, depth, vertical and horizontal displacement amplitudes, strike azimuth, angle of dip, that will allow expanding possibilities of their forecast. Database has many advantages: searching, grouping, filtration, systematizing by features (or group of features), that can be used for finding of relations between features in a complex. From this point of view, the creation of a unified database of faults for their comprehensive critical analysis and summary using modern software (ACCESS, SPSS, etc.), opening up wide opportunities for the use of new knowledge of faults in geological sciences is relevant.

The article covers the major quantitative features of faults (length, width, depth, displacement amplitude, strike azimuth, dip angle) and the relationships between them.

The study area is the Middle, Southern Tien Shan and adjacent area, bordered by faults Karatau in the north and the Kopetdag in the south, Talas-Fergana in the east and by Coastline Caspian Sea in the west. Within its borders of the area are the Turan Plate and the Fergana Basin, known for the hydrocarbon deposits, the Tien Shan and Pamir-Alay mountain systems with numerous ridges and mountains, characterized by diversity and multiplicity of ore occurrences, seismicity and geological processes.

MATERIALS AND METHODS

The information on major features of faults is available from the database “Faults of the Middle, Southern Tien Shan and adjacent area”, realized in ACCESS (Lordkipanidze and Tsay, 2016a, 2016b, 2017; Tsay, 2018; Tsay and Lordkipanidze, 2018, Tsay, 2019). The database is including the following 18 tables (with attributed features): I. general characteristics (fault name, synonym, definition, location); II. morphological characteristics (length , width, depth, morphological type); III. displacement amplitude (vertical, horizontal); IV. planar feature of the beds (direction / azimuth of the strike, direction / azimuth and angle of dip); V. age (time of formation); VI. related phenomena (connections with magmatism,

mineralization, seismicity); VII. source of information (author). Total number of faults in the database exceeds 1000. By special queries (in ACCESS): electronic catalog of faults (with 18 features) has been created; the average data of features (length, width, depth, vertical and horizontal displacement amplitudes, strike azimuth, angle of dip) has been calculated for each fault. Then average data has been analyzed using SPSS for estimation of the following: statistics (frequency counts, percentages, cumulative percentages, mean, median, mode, sum, standard deviation, variance, range, minimum and maximum values, standard error of the mean); plots (histograms); summarizing transformed data; regression (model summary, parameter estimates, anova); partial correlations.
So the possibility of finding of relations between features in a complex was realized.

Table 1: Statistical characteristics of features of the faults

		L	**m**	**h**	**Displacement amplitude**		**Al**	**ά**
					Av	**Ag**		
N	Valid	144	94	25	132	45	53	118
Mean		439.99	6980.61	34.87	1193.79	41.67	144.47	68.04
Std. Error of Mean		64.75	1416.81	2.68	88.21	12.07	17.77	1.36
Median		135.00	290.83	30.00	1000.00	6.00	60.00	72.50
Mode		200.00	12500.00	30.00	1000.00	1.00	35.00	70.00
Std. Deviation		777.04	13736.52	13.38	1013.42	80.96	129.34	14.74
Variance		603798.37	188691898.08	178.95	1027028.17	6553.93	16727.67	217.13
Skewness		3.34	2.52	0.88	1.11	2.47	0.55	-1.60
Std. Error of Skewness		0.20	0.25	0.46	0.21	0.35	0.33	0.22
Kurtosis		14.40	6.09	2.21	0.98	5.87	-1.63	2.48
Std. Error of Kurtosis		0.40	0.49	0.90	0.42	0.69	0.64	0.44
Range		5498.00	59997.00	63.00	4486.00	349.90	335.00	70.25
Minimum		2.00	3.00	12.00	14.00	0.10	10.00	15.00
Maximum		5500.00	60000.00	75.00	4500.00	350.00	345.00	85.25
Sum		63359.05	656177.60	871.75	157580.43	1874.99	7657.00	8028.43
Percentiles	10	12.25	15.13	18.00	93.00	0.53	25.33	43.25
	20	20.00	35.00	22.30	263.50	1.00	35.00	60.00
	30	41.00	70.83	30.00	500.00	1.19	50.30	67.50
	40	76.00	116.00	30.00	786.67	2.22	52.50	70.00
	50	135.00	290.83	30.00	1000.00	6.00	60.00	72.50
	60	200.00	650.00	40.00	1195.00	9.60	79.50	75.00
	70	350.00	4500.00	40.00	1500.00	16.00	289.00	75.30
	80	650.00	12500.00	42.50	2000.00	56.20	308.00	80.00
	90	1225.00	23762.50	49.75	2668.17	172.33	327.00	82.05

RESULTS AND DISSCUSSION

Table 1 shows the statistical characteristics of the studied features of faults: length (L, kilometer), width (m, meter), depth (h, kilometer), vertical and horizontal displacement amplitudes (Av, meter and Ag, kilometer), strike azimuth (Al, grad), angle of dip (ά, grad). The distribution of data values in all cases (with the exception of ά) is markedly non-normal. Table 2 and Figures 1-6 shows statistical characteristics of the studied features of length, width, depth, vertical and horizontal displacement amplitudes, strike azimuth as well as frequency of features after transformation of the variables to LN.

The results indicate that strong relationship with correlation coefficient of more of than 0.60 has been found in 3 cases: between the length and horizontal displacement amplitude (r=0.85, N=28), between length and width (r=0.72, N=63); between vertical and horizontal displacement amplitudes (r=0.66, N=31) (Table 4). Less strong relationships with r>0.50 have been found between the width and the vertical displacement amplitude (r=0.58, N=53), between horizontal displacement amplitude and strike azimuth (r=0.57, N=17), between strike length and azimuth (r=0.55, N=28), between length and vertical displacement amplitude (r=0.52, N=68). In other cases, there is a weak relationship between the discussed features (r<0.50). Table 3 shows statistics characteristics of features of the faults (for 3 cases with high correlation). Table 5 shows results of ANOVA for testing the acceptability of the models (for the same cases). The general trend of dependence is seen quite well and the regression equation in all cases as power function (Table 6).

It is interesting to note that the horizontal amplitude of displacement (Ag) affects the correlation between the length (L) and width (m) (Table 7). In this case, the partial correlations table shows both the zero-order correlations (correlations without control of Ag) of all three variables and the partial correlation controlling of the first two variables (L and m) controlling for the effects of the third variable (Ag). The zero-order correlation between L and m is fairly high (0.74) and statistically significant (p<0.001); between m and Ag - is weak (0.46) and not statistically significant (p=0.41); between L and Ag is high (0.65) and statistically significant (p<0.001). The partial correlation controlling for L and m, are stayed high 0.66 and significant (p<0.001). The interpretation of this finding is that the observed positive linear relationship between L and m is due to underlying relationships between each of those variables and the Ag.

Table 2: Statistical characteristics of features of the faults transformed to LN

		LN(L)	LN(m)	LN(h)	LN(Av)	LN(Ag)	LN(Al)	LN(ά)
N	Valid	144	94	25	132	45	53	118
	Missing	929	979	1048	941	1028	1020	955
Mean		4.79	6.18	3.48	6.53	1.79	4.49	4.18
Std. Error of Mean		.15	.29	.081	.11	.32	.14	.028
Median		4.89	5.67	3.40	6.91	1.79	4.09	4.28
Mode		5.30a	9.43	3.40	6.91	.00	3.56	4.25
Std. Deviation		1.77	2.76	.40	1.31	2.15	1.04	.30
Variance		3.14	7.64	.16	1.72	4.61	1.07	.09
Range		7.92	9.90	1.83	5.77	8.16	3.54	1.74
Minimum		.69	1.10	2.48	2.64	-2.30	2.30	2.71
Maximum		8.61	11.00	4.32	8.41	5.86	5.84	4.45

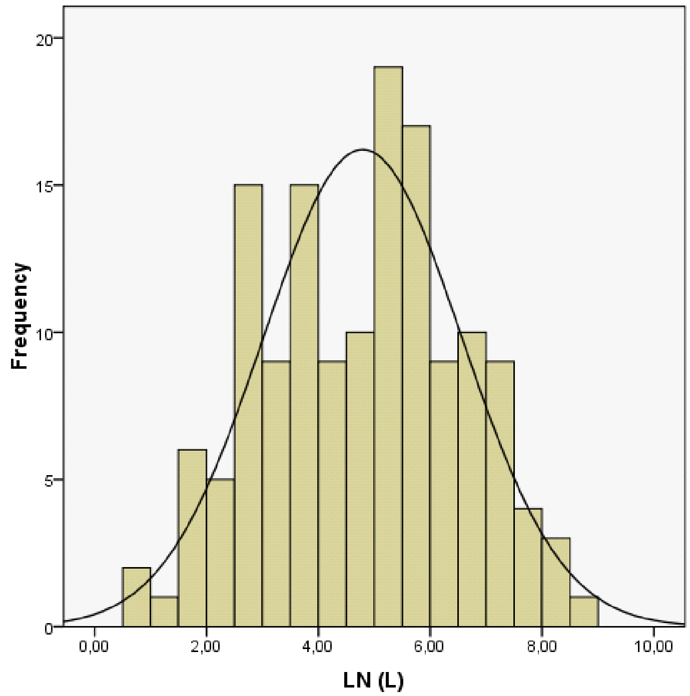

Figure 1: Histogram of Log normal distribution of length

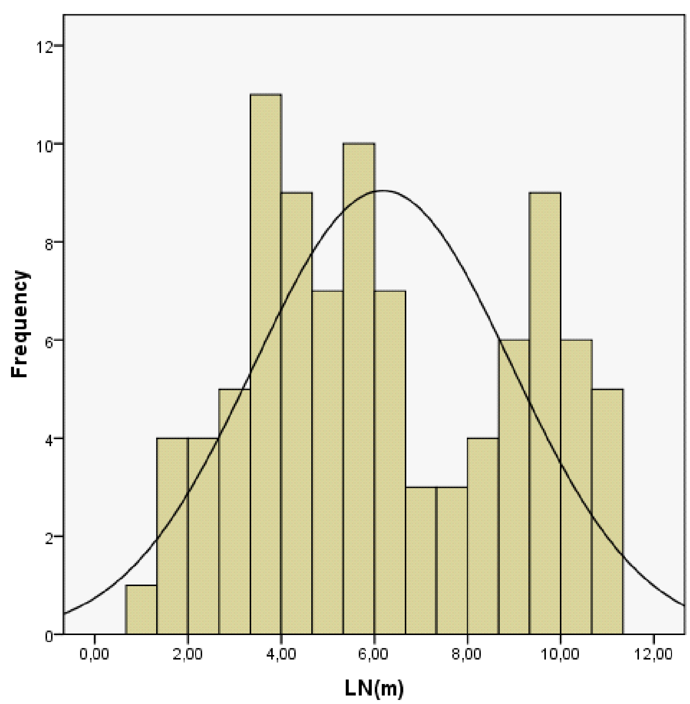

Figure 2: Histogram of Log normal distribution of width

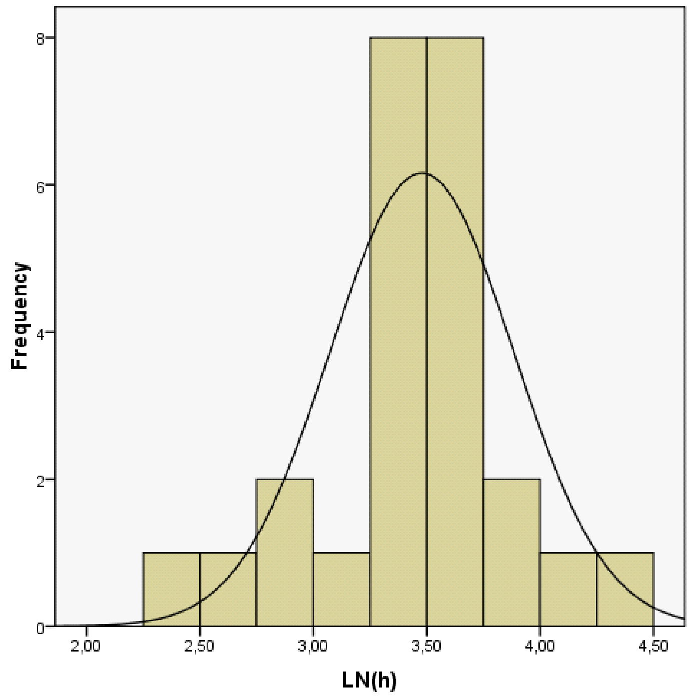

Figure 3: Histogram of Log normal distribution of depth

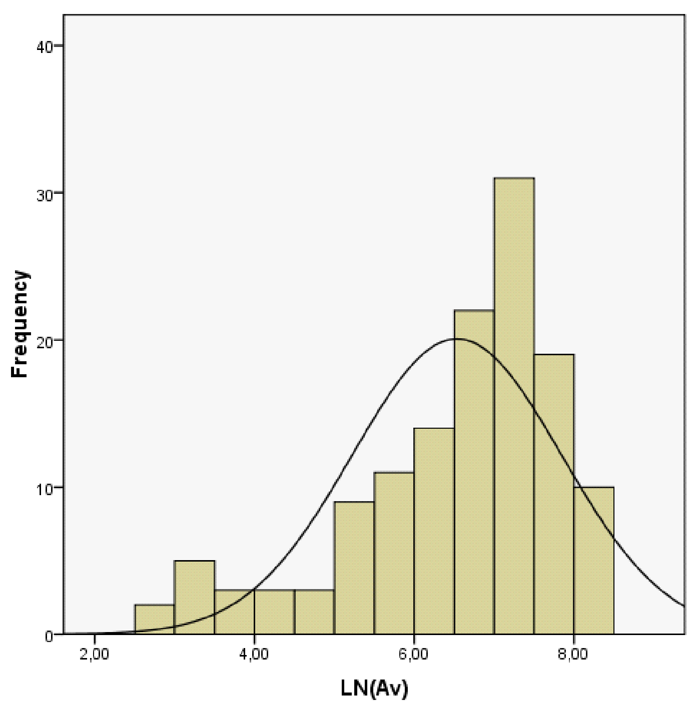

Figure 4: Histogram of Log normal distribution of vertical amplitude

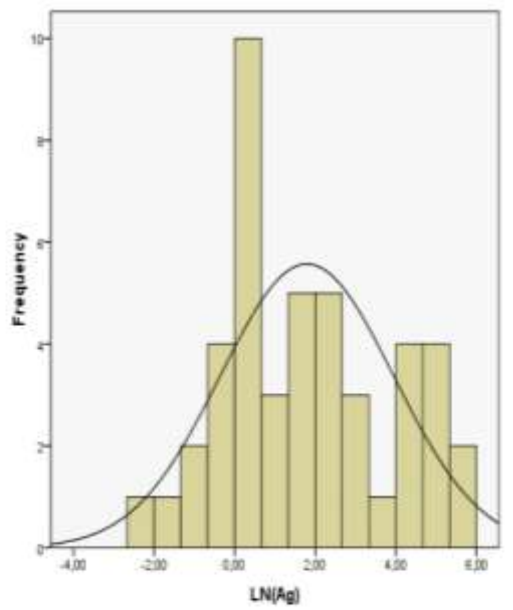

Figure 5: Histogram of Log normal distribution of horizontal amplitude

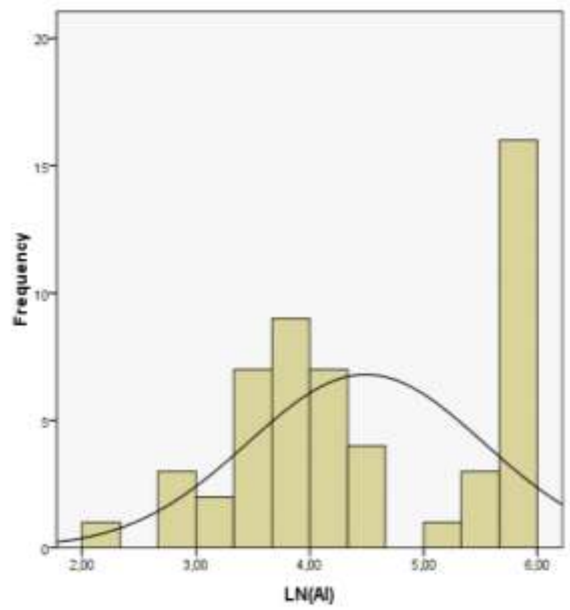

Figure 6: Histogram of Log normal distribution of strike azimuth

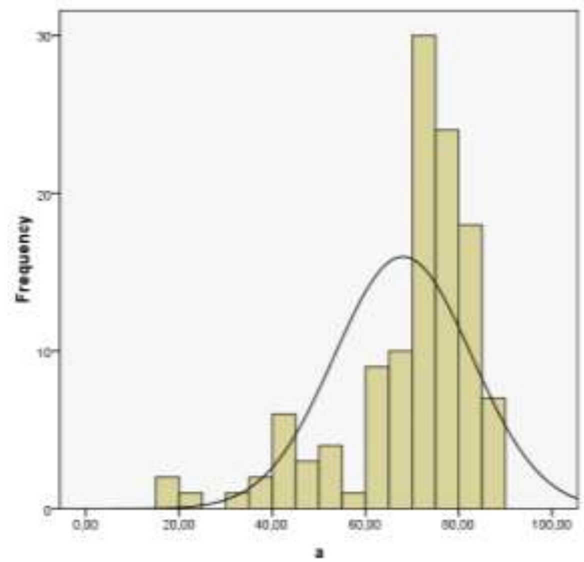

Figure 7: Histogram of normal distribution ά angle of dip

Table 3: Statistics characteristics of features of the faults (for 3 cases with high correlation)

		L	**Ag**
n	Valid	28	28
Mean		433.12	43.11
Std. Error of Mean		133.87	14.00
Median		135.00	6.96
Mode		7.00	1.00
Std. Deviation		708.35	74.07
Variance		501763.60	5485.81
Range		2998.00	299.59
Minimum		2.00	0.41
Maximum		3000.00	300.00
		L	**m**
N	Valid	63	63
Mean		503.18	8891.93
Std. Error of Mean		102.74	2004.84
Median		130.00	300.00
Mode		1000.00	100.00
Std. Deviation		815.49	15912.94
Variance		665018.19	253221650.82
Range		2998	59997
Minimum		2	3
Maximum		3000	60000
Sum		31700	560191
		Av	**Ag**
N	Valid	31	31
Mean		1054	15
Std. Error of Mean		166	7
Median		800	3
Mode		1000	1
Std. Deviation		925	37
Variance		855666	1357
Range		4073	183
Minimum		90	0
Maximum		4163	183

Table 4: Model summary (Power)

	R	R Square	Adjusted R Square	Std. Error of the Estimate
The independent variable is L; dependent is Ag				
	0.85	0.73	0.71	1.06
The independent variable is L; dependent is m				
	0.72	0.52	0.51	2.04
The independent variable is Av; dependent is Ag				
	0.66	0.44	0.42	1.34

Table 5: ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
The independent variable is L; dependent is Ag					
Regression	77.45	1	77.45	68.59	.000
Residual	29.36	26	1.13		
Total	106.81	27			
The independent variable is L; dependent is m					
Regression	275.06	1	275.06	65.9	.000
Residual	254.70	61	4.18		
Total	529.75	62			
The independent variable is Av; dependent is Ag					
Regression	40,00	1	40,00	22,40	.000
Residual	51,78	29	1,79		
Total	91,78	30			

Table 6: Coefficients of power relationships

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
The independent variable is ln(L); dependent is ln(Ag)					
	0.85	0.10	0.85	8.28	.000
(Constant)	0.15	0.08		1.91	.067
The independent variable is ln(L); dependent is ln(m)					
	1.09	0.13	0.72	8.12	.000
(Constant)	3.35	2.31		1.45	0.15
The independent variable is ln(Av); dependent is ln(Ag)					
	1.20	0.25	0.66	4.73	.000
(Constant)	.001	.002		0.60	0.56

Table 7: Affect of displacement (Ag) on correlation between the length (L) and width (m)

Control Variables			**L**	**m**	**Ag**
-none-a	L	Correlation	1.00	0.74	0.65
		Significance (2-tailed)	.	0.00	0.00
		df	0.00	18.00	18.00
	M	Correlation	0.74	1.00	0.46
		Significance (2-tailed)	0.00	.	0.41
		df	18.00	0.00	18.00
	Ag	Correlation	0.65	0.46	1.00
		Significance (2-tailed)	0.00	0.04	.
		df	18.00	18.00	0.00
Ag	L	Correlation	1.00	0.66	
		Significance (2-tailed)	.	0.00	
		df	0.00	17.00	
	m	Correlation	0.66	1.00	
		Significance (2-tailed)	0.00	.	
		df	17.00	0.00	

CONCLUSION

The results indicate that strong relationship has been found in 3 cases: between the length and horizontal displacement amplitude, between length and width; between vertical and horizontal displacement amplitudes. The general trends of these dependences are seen quite well and the regression equation in all cases as power functions. The results of the partial correlation shows affect of displacement (Ag) on correlation between the length (L) and width (m).

So, study shows the importance of the further development of the database for finding new relationships between quantitative features, but also for qualitative features of faults as magmatism, mineralization, seismicity that will allow to carry out their forecast.

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