GEOLOGICAL INTERPRETATION OF NEOTECTONIC ACTIVITIES FROM SOYUS MKF-6 IMAGERY IN THE PAMIR-ALAY, CENTRAL ASIA

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Abstract

Neotectonic activities of the South Tienshan-Pamir region were proved by means of remote sensing. The geological interpretation of multispectral satellite images could point out indications of vertical and horizontal fault movements at different times by analysis of relief and drainage irregularities and by displaced lineations of fault zones. Combining the data of the young movements together with strike and dip of the activ faults it was possible to deduce the probable recent stress field.

1. Introduction

The geological interpretation is based on multispectral satellite images taken with the MKF-6 camera of the GDR on Soyus-22 spacecraft (six bands; altitude: 250 km; ground solution: 10 m). Two scenes with an overlap of about 80 % were available for stereoscopic viewing to get some subtle information. Computer classifications were used for lithological evaluation and a computer program for photolineation statistics.

The area under investigation (Fig. 1) is situated in the southern part of Central Asia mountain chains in the USSR (about 40°N, 72°E). It belongs to the Palaeozoic fold belt of the South Tienshan and the northern Pamir. The image covers parts of five tectonic units (Fig. 2; 160 x 115 km) striking parallel to the latitude: 1. the Fergana basin (left upper corner, with the large delta of the Aksu river; altitude less than 1,000 m), 2. the Turkestan-Alay (ca. 3,000 m) and 3. Seravshan-Alay anticlinorium, both occupying most part of the image, 4. the Alay basin (right upper corner), and 5. the North Pamir anticlinorium (about 7,000 m; right lower corner), [1].

The region covered by the image is of high recent activity connected with seismic events. Geomorphology reflects geological processes which have caused sharp escarpments of faults, displacements, and irregularities of the drainage system. A great attention was paid to the analysis of such features.

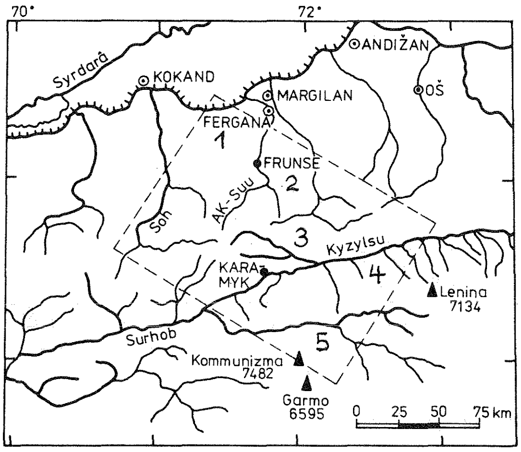
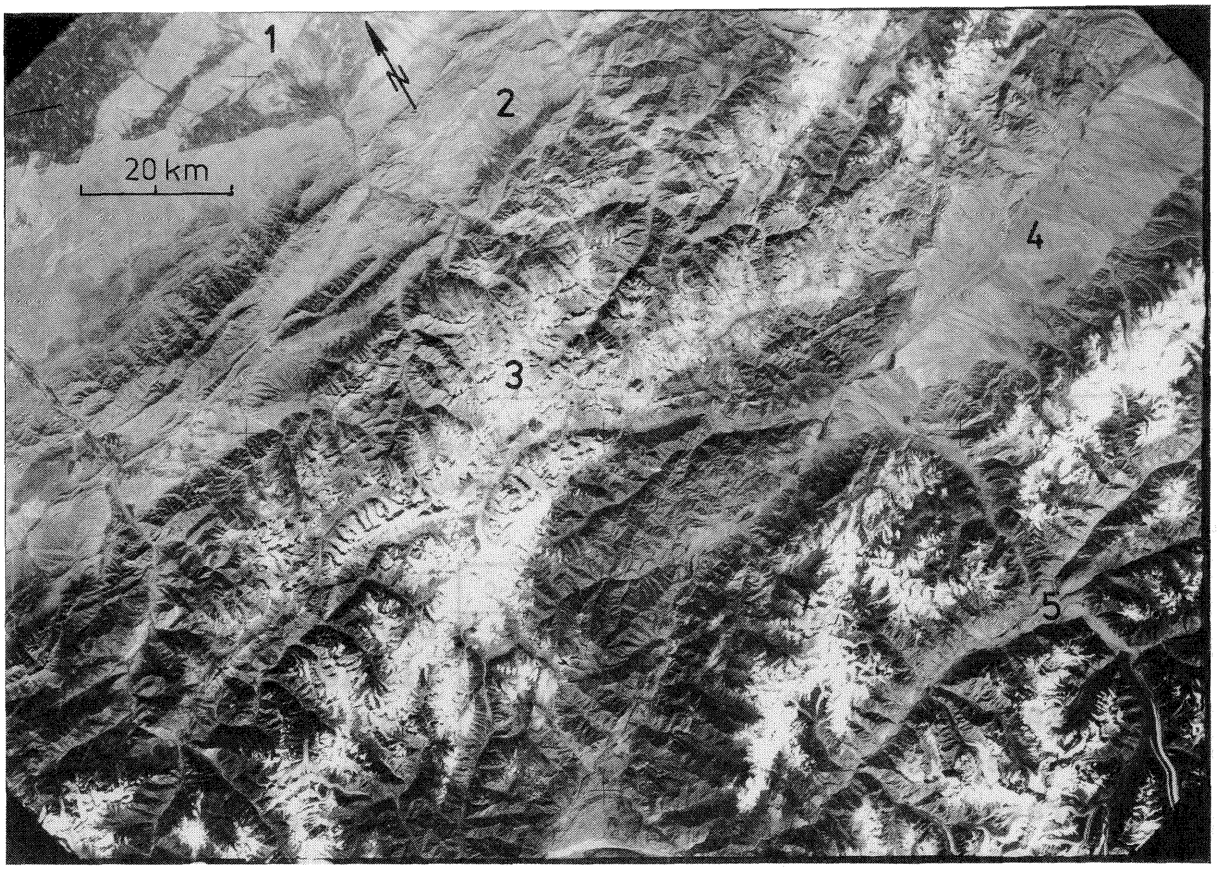


Fig. 1 Location of the study area in the southern part of Central Asia (USSR). The image includes the South Tienshan (Alay) and the northernmost Pamir. Numbers: see in the text.

Fig. 2 MKF-6 image from Soyus -22 spacecraft, band 4, 18.9.76, Pamir-Alay (see Fig.1). Explanation of numbers in the text.



2. Geological interpretation

Only a few rock outcrops with lithologic significance occur in the study area. The best examples for lithologic evaluation are the dark stripes of anticlines at the boundary of the Fergana basin, according to the geological map coal bearing beds of Devonian age, and the light stripes of Quaternary age in the Fergana basin and light areas in the Alay valley and other ones. But the white band at the northern border of the Alay valley show the highest reflectance. It belongs to Palaeogene marine sediments. The neighbouring darker stripe represents red continental sediments of Lower Cretaceous age. On the color composite

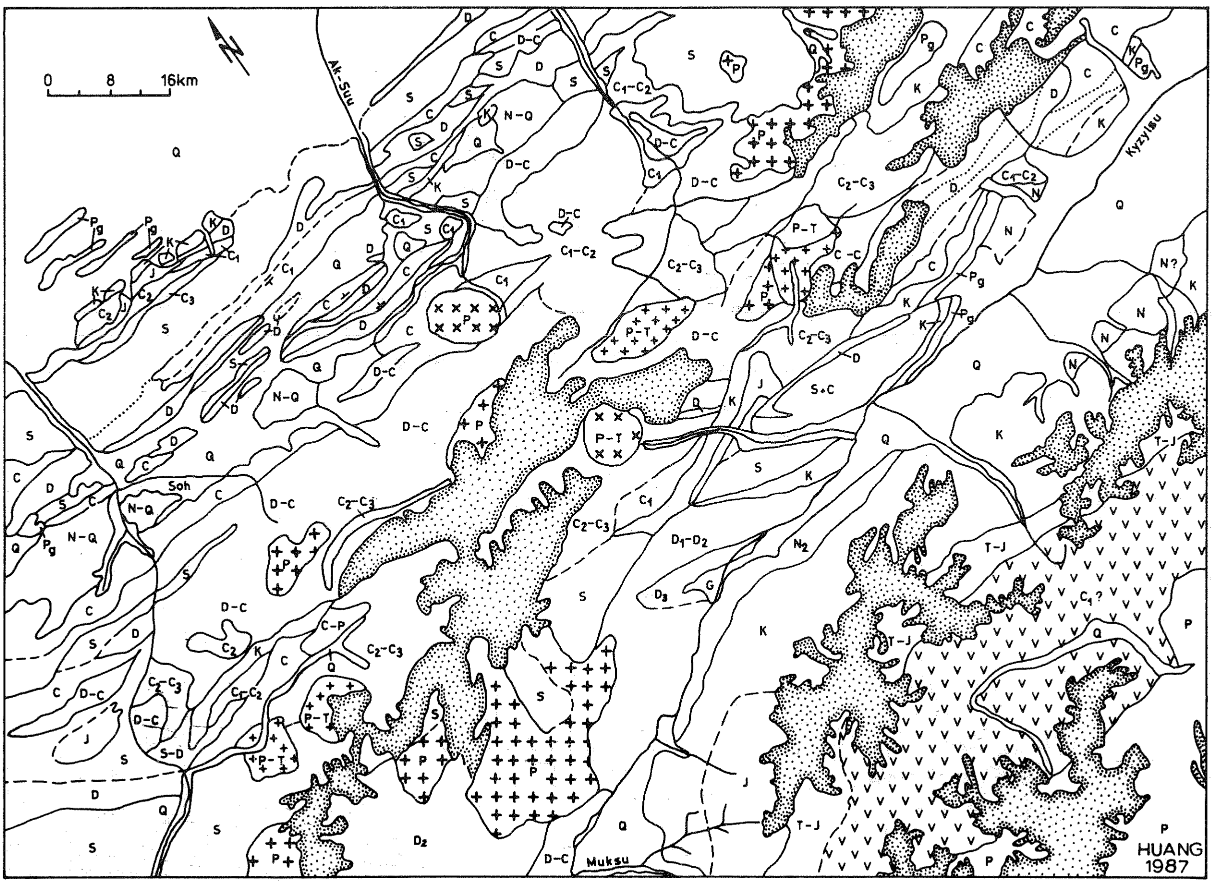


Fig. 3 Photogeological map on the base of satellite images (Fig. 2) checked by the geological map.

Legend

Q	Quaternary
N-Q	Neogene-Quaternary
N	Neogene
P_g	Palaeogene
K	Cretaceous
J	Jurassic
T-J	Triassic-Jurassic
T	Triassic
P-T	Permian-Triassic
P	Permian
C-P	Carboniferous-Permian
C	Carboniferous
C_2-C_3	Middle-Upper Carbon.
C_1-C_2	Lower-Middle Carbon.
C_1	Lower Carboniferous

D-C	Devonian-Carboniferous
D	Devonian
D_2	Middle Devonian
D_3	Upper Devonian
D_1-D_2	Lower-Middle Devonian
S	Silurian
V V V	effusive rock or tuff
+ + +	granodiorite
(dense crosses)	syenite
X X X	granite
(solid line)	lithological boundary
(dashed line)	inferred lithological boundary
(dotted line)	lithological traces
(dip symbol)	dipping
(stippled)	glacier or snow

they occur as small yellow-brown and white bands.

There were some difficulties to distinguish continental Neogene sediments from Quaternary sediments if we only use color information. But comprehensive analysis of texture and drainage pattern, and position information still provided the possibility to delineate some of them. For the other parts of the mountain area it is necessary to lay more emphasis on integrating color composite, texture pattern and other information because of the well-known dependence of the type of erosion, relief, and drainage pattern on the properties of the rocks [2,3].

The geological interpretation was checked by the geological map. Generally, both are coinciding. Some of the rock units are not suitable to be interpreted from the image. After comparing some parts were reinterpreted. The final result is shown in Fig. 3. Apart from visual interpretation a supervised and a unsupervised classification were used for lithologic evaluation. With the images of the bands 1, 2, 6 was carried out a Bayes maximum-likelihood classification (15 classes) to complete the geological interpretation.

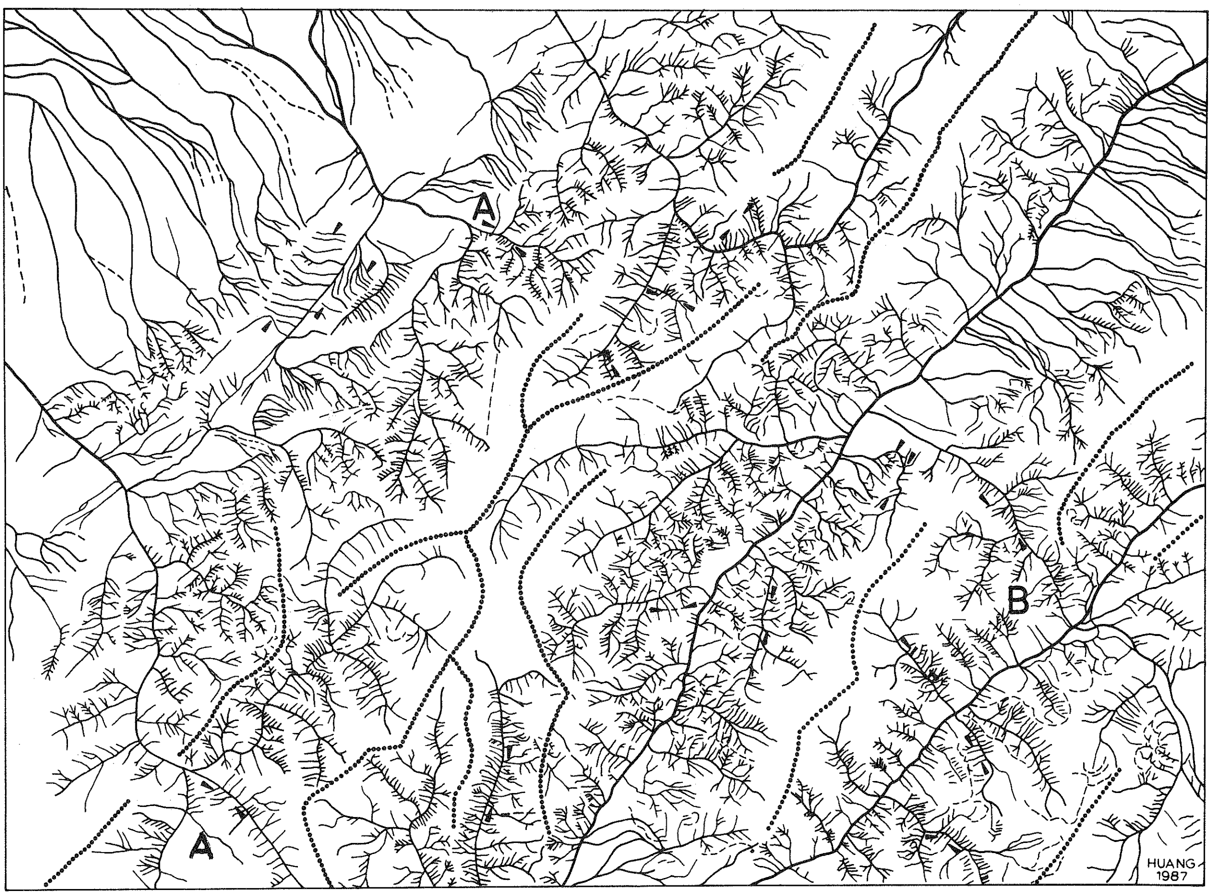


Fig. 4 Interpreted drainage map on the base of a satellite image (Fig.2). Arrows indicate faults or inferred faults.

3. Photolineations

Many photolineations are to be seen distinctly in the hard rock, mostly crossing the mountain chains oblique with a small angle, sometimes they occur parallel to the mountain crest (Fig. 2 and 5). They are forming sharp escarpments, first of all at the border to the Fergana basin (left upper part of the image) indicating neotectonic uplift of blocks.

At some places these fine lines of fault traces are running down from the mountain crest to the lower plateau crossing there the large fans on the slope. They are dominantly striking E-W and cutted by younger NW and NE faults which have produced displacements of the older E-W fault traces. The displacements amount to some hundred meters (200 to 800 m) and are mostly to be recognized in the northern part. They seem to be caused by horizontal movements, compared to it the fault escarpments point out vertical movements. The steep dipping E-W faults preparing steps in the relief are sometimes indicated by asymmetrical drainage pattern (Fig. 4). In many cases the drainage reflects fault tecto-

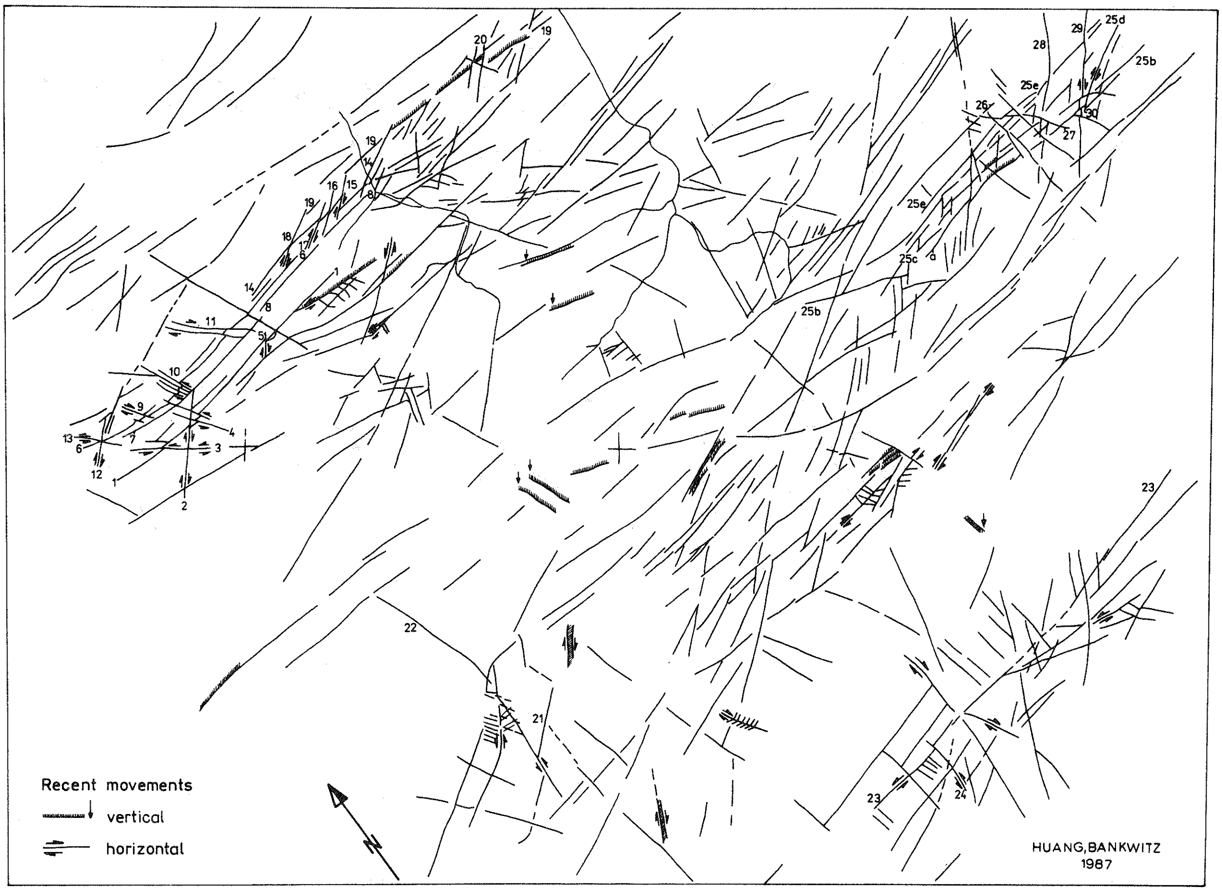


Fig. 5 Simplified lineation map of Pamir-Alay area.
Arrows: supposed movement direction.

nics, but other deformations, too. For instance, the drainage in the conjunction area of the Seravshan-Alay, Alay valley and northern Pamir is very intense and superimposed by different directions of tributaries and lineations (Fig. 4, middle to the right hand). Such pattern usually indicates manifold deformation [2] and probably thick-layered metamorphic rocks [4].

The photolineations belong to two systems: 1. E--W/N--S, 2. NE/NW. They coincide with the main faults of the geologic map, but there are many additional lineations reflecting unknown faults. Some of them seems to be of geological significance. Direction rose diagrams for each tectonic unit and for the whole studied area obtained by a computer program demonstrate the dominance of the E--W lineations (Fig. 6). Their extension vary from 20 up to 150 kms. Different parameters characterizing the behaviour of fault lineations are listed in Table 1.

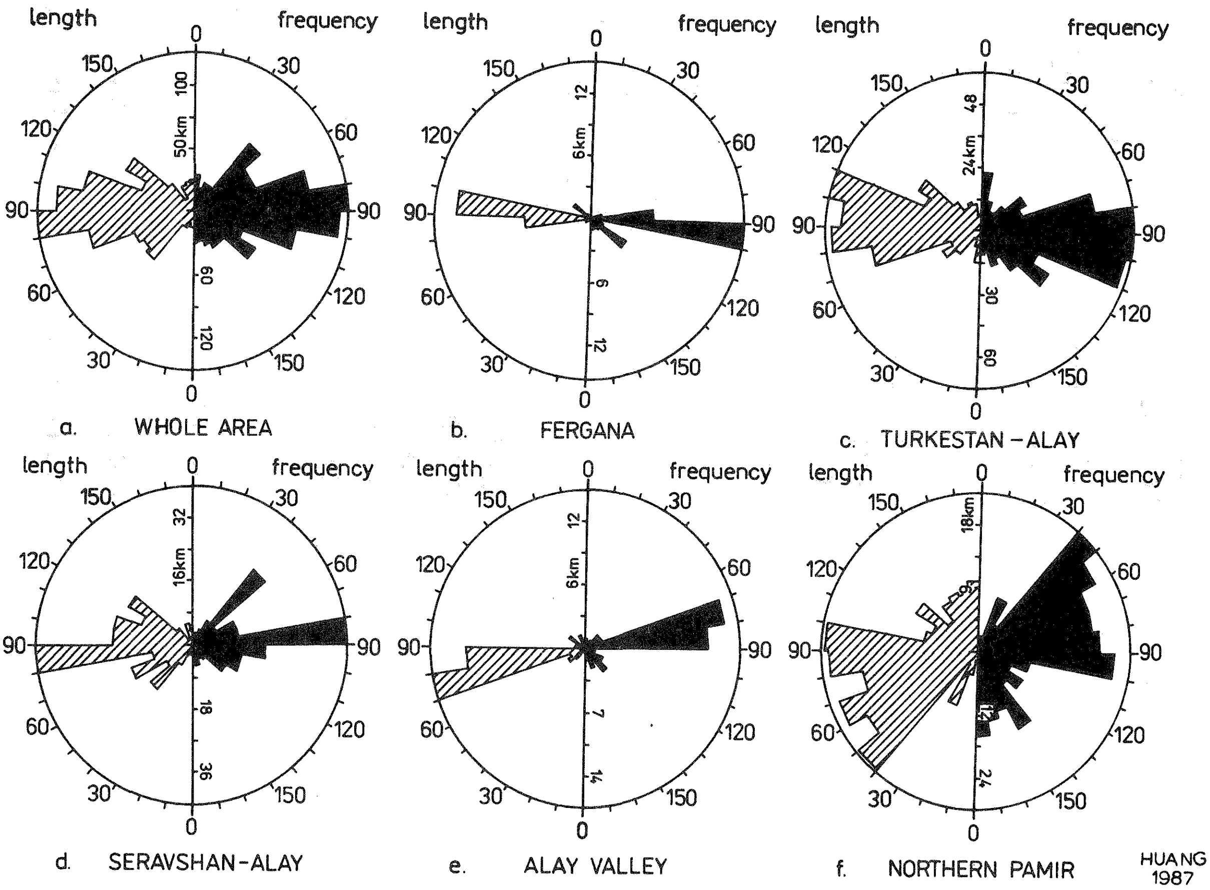


Fig. 6 Rose diagrams of the Pamir-Alay area. Lengths and frequencies in 10° intervals.

no.[x]	direction	length (km)	type of movement[xx]	relief indication	displacement amount (m)	single or complex lineation	shape of the zone	relation (older/ younger)
F 1	85°	40	V	fault trace scarp	5 displace.: 800 F 3 400 F 2 600x2 F 4 300 F 5	single	slight curve	1 / 2,3,4,5
F 2	40°	14	H	displacement of scarps		single	straight	
F 3	125°	10	H			single	straight	
F 4	145°	8+7	H			2 parts	straight	
F 5	40°	3	H			single	straight	
F 6	85°	38	V	fault trace scarp	9 displace.: 500x2 F 11 800 F 10 400x2 F 9 500 F 12 500 F 13	3 parts	straight	6,(7,8?)/ 9,10,11, 12,13
F 7	85°	24	V	fault trace scarp				
F 8	80°	20	V	fault trace scarp				
F 9	142°	4+2	H	displacement of scarps		2 parts	straight	
F 10	155°	4+4	H			4 parts	straight	
F 11	130°	12+10	H			2 parts	straight	

Table 1 Parameters of selected recent active faults in the Pamir-Alay.

[x] see Fig. 5; [xx] V - vertical movement, H - horizontal movement.

no.[x]	direction	length (km)	type of movement[xx]	relief indication	displacement amount (m)	single or complex lineation	shape of the zone	relation (older/ younger)
F 12	45°	6	H	displacements of scarps		single	straight	
F 13	138°	6	H			single	straight	
F 14	85°	20	V	fault trace scarp	4 displace.: 2000 F 15, 400 F 16, 500 F 17, 400 F 18	single	slight curve	14/15,16, 17,18
F 15	48°	6	H	displacements		single (double?)	straight	
F 16	48°	5	H	of		single	straight	
F 17	55°	6	H	scarps		single	straight	
F 18	55°	8	H			single	straight	
F 19	90°	46	V	fault trace scarp	6 displace.: 500 F 20	single	straight	19 / 20
F 20	45°	6+5	H	displacement of scarp		2 parts (?)	double straight lines	
F 21	48°	15	H		2000 F 22	single	straight	21 / 22
F 22	0°	36	H			single	slight curve	
F 23	95°	22+26	H	valley	400 F 24	2 parts	straight	23 / 24

Table 1 Parameters of selected recent active faults in the Pamir-Alay.
[x] see Fig. 5; [xx] V-vertical movement, H-horizontal movement

4. Analysis of Neotectonic Activities

The satellite image contains many information of different nature about recent and neotectonic endogenous activities reflected by the landscape features. The high erosion rate together with the high young relief imply the lasting uplift of the Alay and Pamir mountains. Large fans with erosion debris at the footwall of the fault escarpments cover sometimes the whole slope and the steplike plateaus parallel to the faults, because there is no water enough to transport the debris down to the lowland (Fig. 2). That means, the mountaneous landscape is to be drowned in its own debris, caused by the permanent uplift of the mountain chains.

In the conjunction area of the Pamir and the Seravshan-Alay to the west of the Alay valley arêtes, horns, cirques, and tarns are to be recognized beyond the snow line. But such phenomena could not been found in other part of the image. This might indicate the continual subsidence of this part in recent time and the area may be a prolongation of the subsided zone of the Alay valley.

Neotectonic activities have a strong correlation with geomorphological processes and appearance in the study area proved by the steep dipping fault scarps of the left upper part of the image (Fig. 2). They are notable image features clearly displaced by oblique younger faults with horizontal movements. Because there is a strong physical weathering in the area [3], so this features prove that the dip-slip faults are active recently. That means uplifting is going on otherwise the steep relief must be reduced.

River valleys in this area are immature, so some drainage pattern anomalies indicate neotectonic activites by the asymmetric position of the drainage tributaries (Fig. 4,A). Such pattern is an indication of the occurrence of horizontal sliding parallel to the main valley [1]. The direction of the tributaries does not follow the natural flow direction. They are shifted to the higher terrain against the gravity, and they point out influence of acting faults.

The transcurrent faults and fault scarps give the possibility to measure or estimate some parameters of neotectonic activity (Fig. 5, Table 1). On the base of these results it is to suggest that there are two recent active fault system in this area. Vertical movement is significant for E--W striking faults, while horizontal movement characterize the NE-SW striking faults (left-handed shearing) and the NW-SE faults right-handed shearing. A horizontal compression in north-south direction should have existed in this area during the neotectonic development up to recent time. This stress field deduced from the remote sensing interpretation correspond to the northward overthrusting Pamir, and to several focal plane solutions of seismic events in this region [1].

5. Conclusions

The studied area is characterized by complex geological structures and varied geomorphology. For such area, the high spectral and spatial resolution of Soyus MKF-6 imagery is favourable for geological interpretation. Available stereoscopic pair images also sharpen ability of interpretation.

In such area characterized by strong physical weathering, erosion patterns with strong correlation to rock properties provide vital information. Integrating direct image information as geometric features, color, texture, and drainage pattern enable additional indirect geological information in regard to delimitation of units and different rocks, and kinematic analysis.

The area under investigation is of high recent activity proved by seismic events. Many indications of neotectonic activities have been interpreted or inferred from images based on interpretation of geological features, lineations and drainage pattern. Some parameters of neotectonic activity have been measured or estimated. Vertical movement for E-W striking faults and horizontal movement for NE-SE and NW-SE striking faults were derived by analysis of kinematic indications. It is to suppose that recent horizontal compression in north-south direction exists in the area and the superordinate stress field can be derived corresponding with the interpretation of seismic events.

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