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THE 1962 EARTHQUAKE AND EARLIER DEFORMATIONS ABONG THE IPAK EARTHQUAKE FAULT

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Abstract

The eastern segment of bed rock of the Ipak fault was studied in detail to define the earlier deformations and compare it with 1962 earthquake deformations. Ground displacements that accompanied the Buyin Zahra destructive earthquake coincided precisely with the pre-existing fault trace. Analysis of joints associated with the Ipak geological fault in Eocene volcanic rocks at the investigated area define four tension joint sets of which one, a persistently developed joint set and the youngest (J4), might be related to the faulting process.

Local compression direction derived from joint analysis of the youngest tension joint set shows that the post-Neogene local maximum principal stress axis acted at N56° E, which gives a sinistral movement for the geological fault (like the 1962 earthquake movement). Comparison of this compressional axis (N 56° E) with the horizontal component of the compressional axes based on the fault plane solution of the 1962 earthquake (N 40° E) shows that there was a counterclockwise rotation in the stress field from Neogene to Recent time.

1. INTRODUCTION

The Buyin Zahra earthquake and its fault (Ipak) were studied immediately after the event (Ambraseys 1962, 1963; Abdalian 1963; Mohajer and Pierce 1963; Mohajer 1964; Saraby and Foroughi 1962; Institute of Geophysics 1963, etc.) and more recently by Berberian (1971), Sobouti (1972) and others. The earlier papers analyzed the earthquake faulting and fractures formed along the part of the fault which crossed the alluvium of southern Eshtehard (Ambraseys 1963). The present note examines the fracturing through rock and compares the 1962 earthquake fractures to the fractures caused by earlier tectonic deformation.

The Buyin Zahra (Qazvin) earthquake occurred at 19h 20m 38.7s GMT (10h 55m local time) on the 1st September 1962 (10.6.2521, Saturday) in the southern Qazvin area (SW of Tehran). Its epicentre was located at 35°.6'N, 49°. 9'E (U.S.C.G.S.) with a focal depth of about 20 km, and a magnitude averaged from several determinations at 7.25. The earthquake killed 12,225 and injured 2,776 people. It damaged beyond repair 21,310 houses (294 villages) and killed 35% of the livestock in the area. The maximum intensity of the shock did not exceed IX MM (Ambraseys 1963).

The earthquake was associated with a WNW (N 100E at Ipak) surface faulting about 100m long, with upward vertical movement of the southern block and a small left lateral horizontal component. The earthquake faulting was from Ipak south of Buyin Zahra to Takhrijin, 6km west of Ab-e-Garm (on the Tehran-Hamadan road). Besides faulting, extensive non-tectonic deformations occurred. The fault plane solution of this earthquake is in good agreement with the field observation if the south dipping plane is chosen (Petrescu and Purcaru 1964; McKenzie 1972). The earthquake fault occurred along a pre-existing geological fault (Ipak fault-Berberian 1971). Ambraseys (1963 and 1965) gave two different earthquake fault maps for the Buyin Zahra earthquake, and it is not clear which of them is the more reliable and correct.

The Ipak fault is a long longitudinal geological fault which starts from the eastern part of Ipak and runs west, to the Ab-e-Garm area(Figs. 1,2 and 3). The fault cuts the older faults existing in the area. It seems that the Ipak fault is a fault which has been reactivated during various young orogenic and epeirogenic movements.South of the Ipak fault (in its western segment, Ab-e-Garm area; Bolurchi 1975) there are outcrops of Carboniferous deposits while there are no outcrops of the same deposits north of the fault (nor in the Soltanieh mountains). This may indicate that the Ipak fault was an old reactivated facies divider fault that controlled the Carboniferous sedimentation, or that after sedimentation the erosion was stronger to the north of the fault than to the south (formation of the northern horst). In the area north of the fault, Upper Guadalopian and Julfian sediments are missing, while they are completely formed at the southern part. It seems that these variations are due to reactivation of the fault. After the Permian period the area north of the fault was uplifted and underwent a stronger erosion than the southern part.

During the Early Kimmerian orogeny, in the area south of the fault, Triassic deposits are not present, while they are well developed in the southern part. This is further evidence of the reactivation of the fault. The absence of Triassic sediments in the northern part should be due either to the uplifting before deposition or uplifting after deposition and undergoing of strong erosion. The fault has been reactivated during younger phases and even during Quaternary. The Buyin Zahra destructive earthquake of 1st September 1962 originated along the Ipak geological fault.

2. STRUCTURAL ANALYSIS

The aim of this paper is to study structural sections on both sides of the Ipak active fault in order to determine whether a part of the complex joints observed in the Eocene volcanics around the fault could have originated entirely due to stresses operative during faulting. In this way it is hoped to give a picture of rock deformation along the fault.

The investigated area lies half way between Ipak and Yengijeh villages (Fig. 2) near the Ipak active fault. Six structural sections were surveyed. Care was taken to choose sections on both sides of the fault and also near the fault, in order to ensure a comprehensive view of the joints and stress pattern. Thus three sections were on the northern side of the fault and three on the southern side. The position of the sections is given in Figure 4.

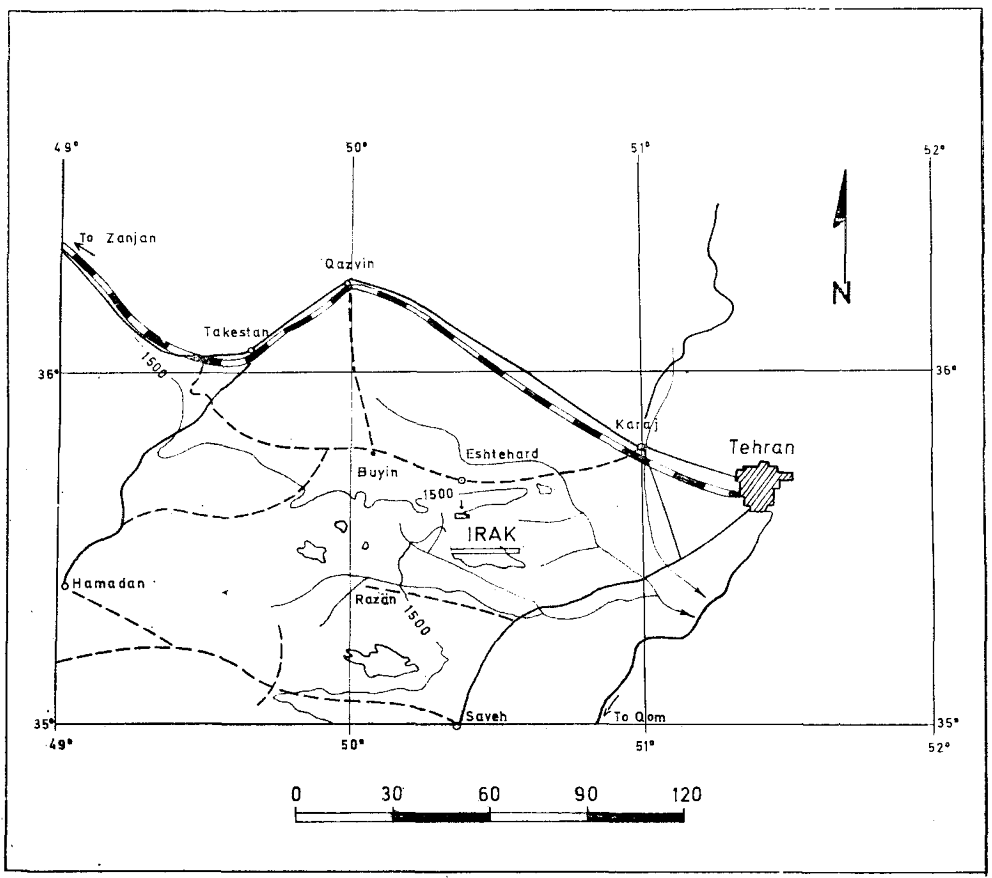

Fig. 1. Locality map of the Ipak and Buyin area.

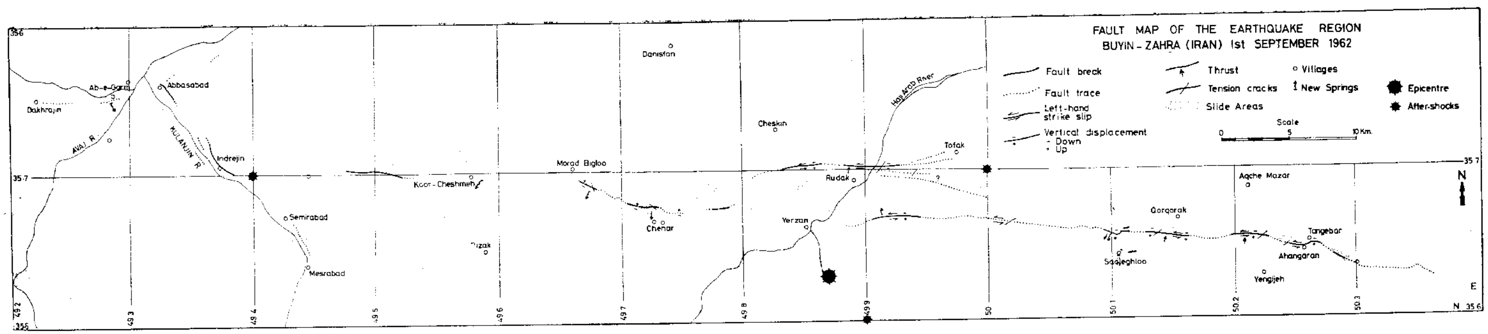

Fig. 2. Fault map of the Buyin Zahra earthquake of 1st September 1962 (after Ambraseys 1963).

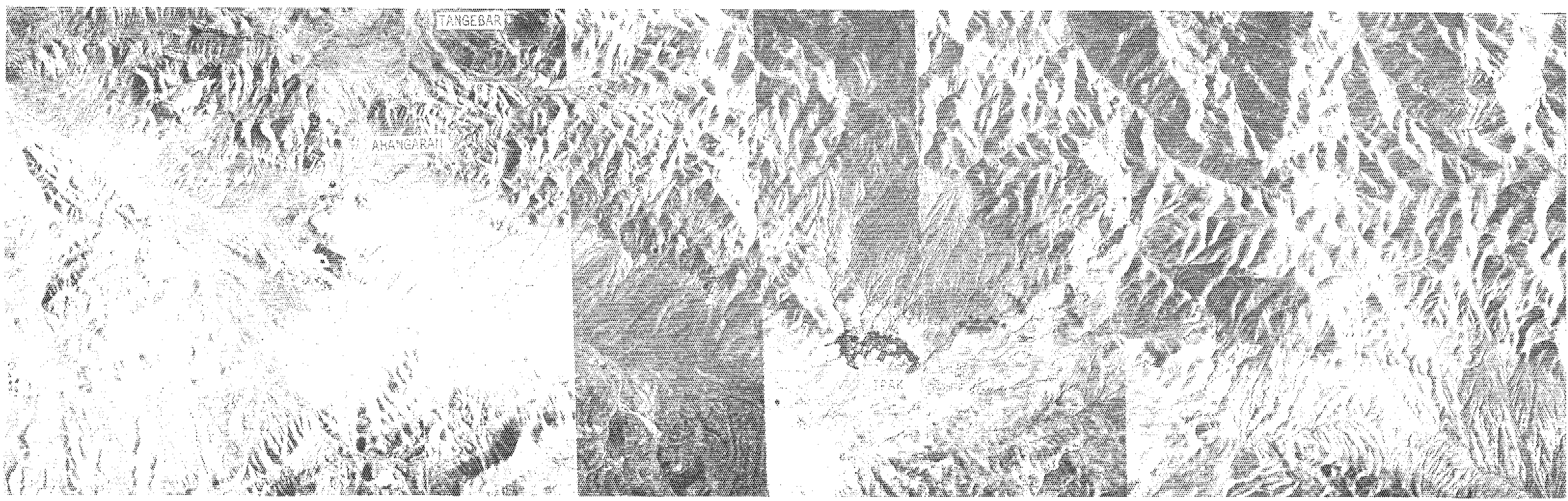

Fig 3 (P. 422A)

To initiate research, about 1503 joints, faults, and slickensides were measured. In order to determine the relationships between the joints and Ipak active fault, the joint configurations were analyzed geometrically by plotting the orientations on stereonets. Maximum concentrations were selected from each diagram of the units to represent dominant joint sets at their respective sections. In order to determine the principal stress orientations represented during geological faulting, the tension joints and slickensides were selected.

Not all the stereographic projections of the investigated sections are interpretable because of dispersion of the poles on some nets, thus some sections do not reveal a recognizable pattern. The dispersion may be due to mixing of the two major joint sets: 1) Tectonic joints, 2) Contraction joints of volcanics. The investigated area is mainly composed of volcanic rocks and, in volcanics, after cooling and contraction of lava, some joints are formed. In this paper only the best sections and nets have been chosen.

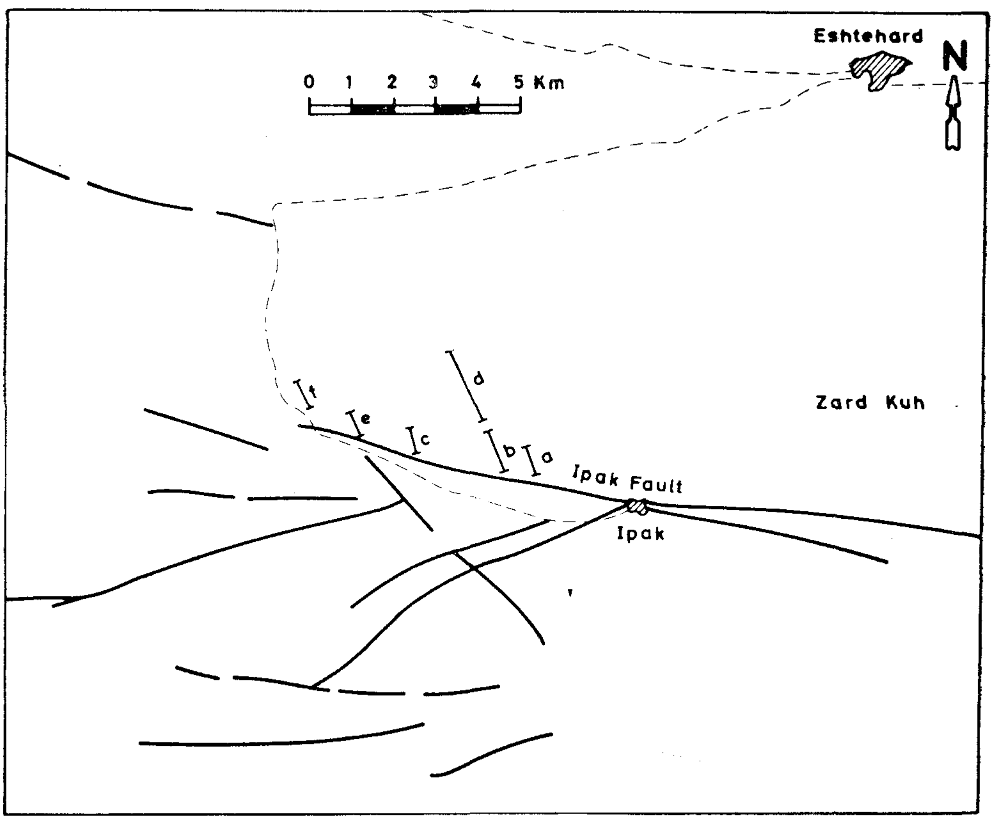

Fig. 4. Position of structural sections near Ipak (faults after Soder, 1958).

Fig 3. (Facing page). Photo-mosaic of Ipak. For definition see figure 2.

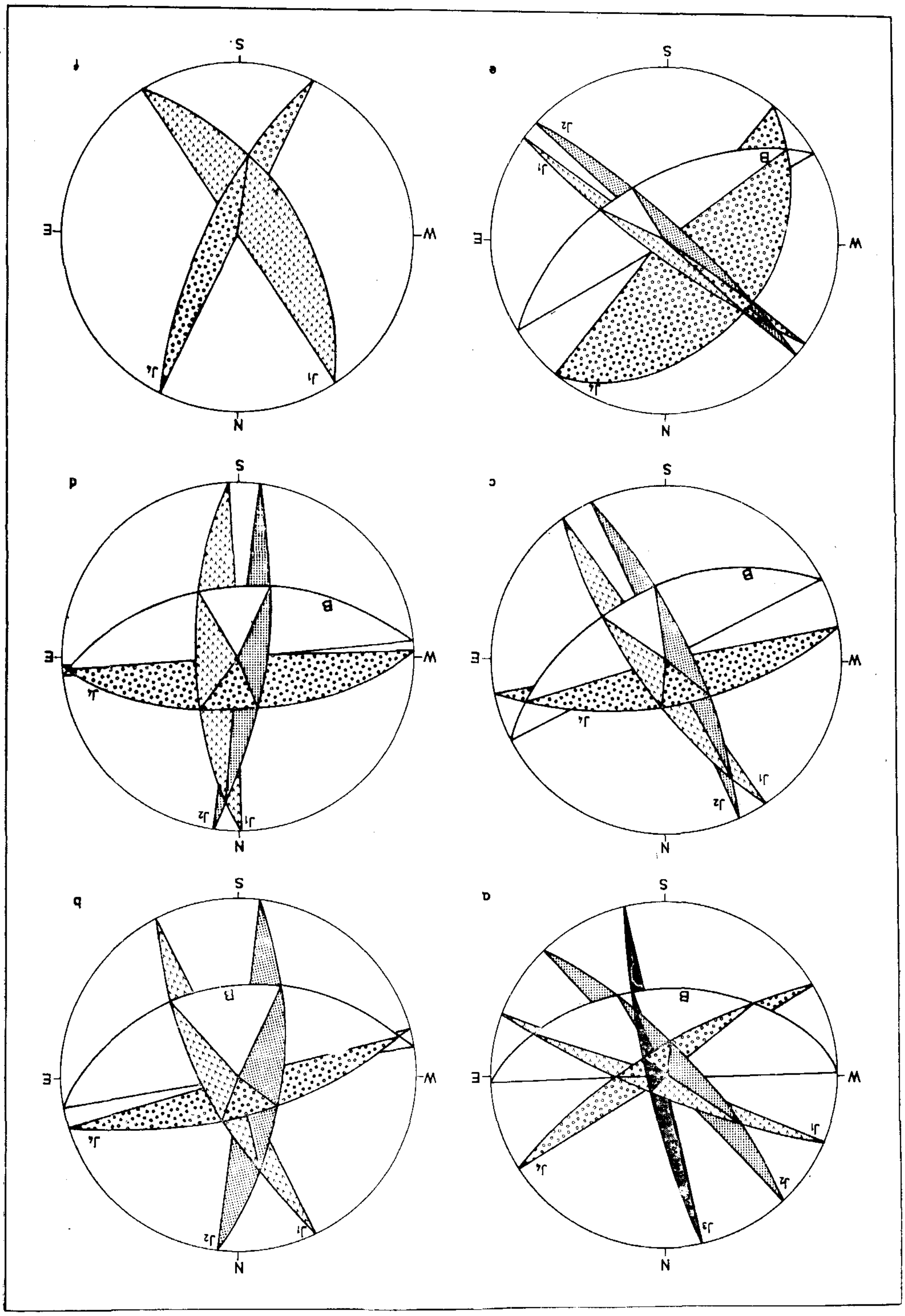

Fig. 5. Stereographic representation of preferred orientations of joints in different structural sections along Ipak fault. J1,J2,J3 and J4 are different joint sets of which J4 is the youngest tension joint set. B is bedding. Upper hemisphere of Wulf stereonet.

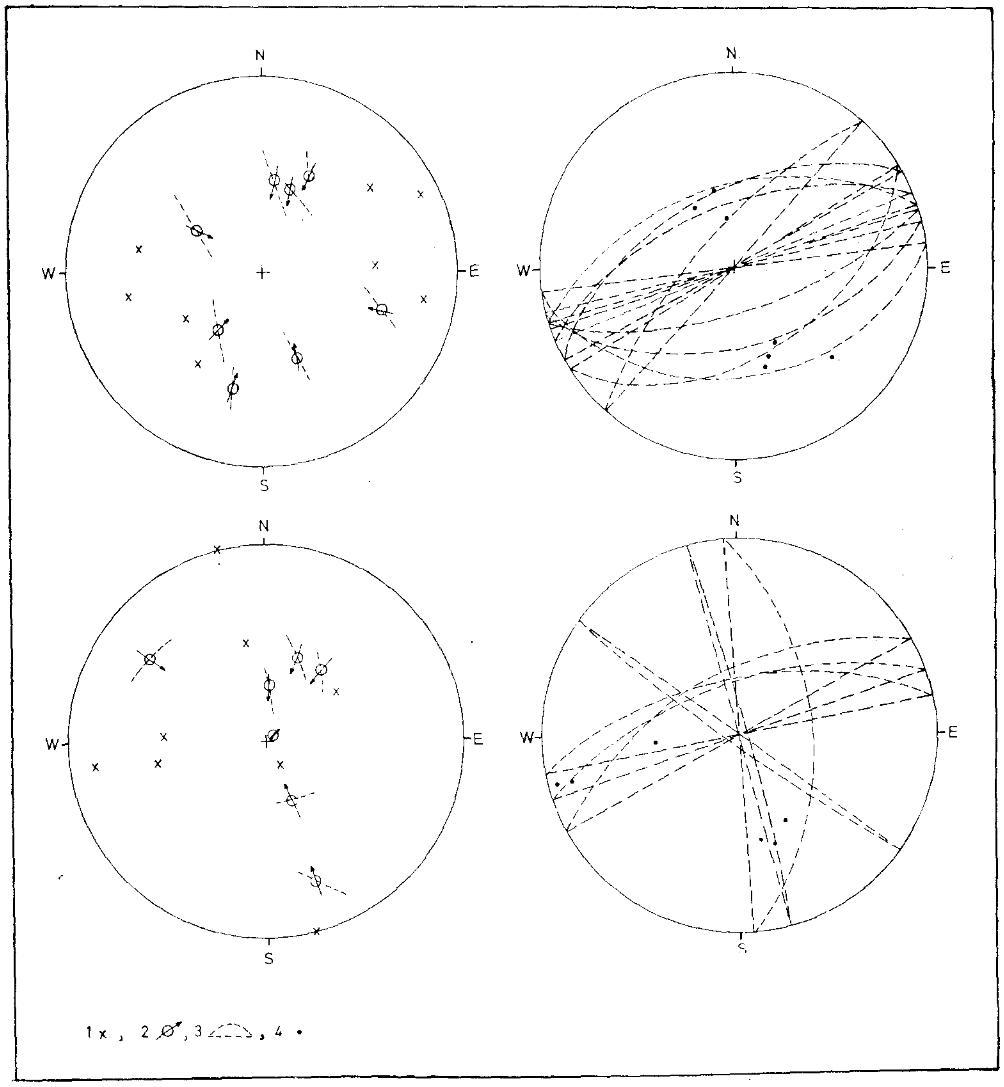

Fig. 6. Stereographic representation of preferred orientations of faults and slickensides along Ipak active fault. 1. fault, 2. plunge of slickenside and direction of the movement of hanging wall, 3. movement plane. 4. pole of movement plane.

The stereographic projection of the varying orientations in different sections are given in Figs. 5 and 6. Comparison of these projections of identified major tension joints (Fig. 5) shows that there are four developed joint sets: J1, J2, J3, and J4. The bedding is indicated in most cases. The J4 and J1 - J2 tension joint sets are the best developed tension joint sets, dominating all the sections along the Ipak active fault. Joint analysis in the field clearly showed that the J1, J2 and J3 joint sets are cut and in some places displaced by the J4 set, and it is therefore evident that the youngest tension joint set along the Ipak fault is J4 (post Pliocene).

The J4 tension joint set which dominates all the structural sections has a variable trend from N 28°E to N 86°E; thus the average trend of the J4 set is N56°E, while the major local stress direction it indicates has the same orientation, perpendicular to its plane.

In this case the related local tension trend is predominantly N 146°E. As a corollary to this conclusion the compression direction of N 56°E should give a sinistral movement to the Ipak active fault, which has a N 100°E direction. In support of the result of this joint analysis, it should be remarked that Bolurchi (1975) found a five kilometre left lateral displacement in the basal Eocene conglomerate bed along the western segment of the Ipak fault. The age of this displacement is roughly late Alpine.

Figure 5 shows the stereographic projection of the post-Pliocene slickensides along the minor faults near the Ipak fault. It shows that the orientation of the plane of movement is predominantly in a NE-SW direction.

The post-Pliocene sinistral movement of the Ipak active fault due to the N 56°E compression, identified by interpretation of the J4 tension joint, is similar to the 1962 earthquake fault movement. Comparison of the post-Pliocene compression direction (N 56° E) and the horizontal component of the compressional axes based on the focal mechanism solution of the 1962 earthquake, which is about N 40°E, shows that there is a slight (?) counter-clockwise rotation in the compressional direction from post-Pliocene time (N 56°E) to recent time (N 40°E). The overall trend of the compression direction, however, remained constant in a NE-SW direction during the specified periods. In this respect the 1962 earthquake deformations were similar to earlier deformations, and it seems probable that the fault has been subject to left-lateral movement throughout its history from Pliocene to 1962.

Finally, it must be noted that the concentration in this brief paper upon lateral movement of the fault should not be taken as imputing greater significance to lateral than to vertical movements.

REFERENCES

ABDALIAN, S., 1963. Le séisme du premier September 1962; l' histoire geologique et tectonique. In Report on the great Buyin Zahra earthquake of 1st September 1962. *Inst. Geophys. Tehran Univ.*, **15**.

AMBRASEYS, N.N., 1962. On the regional conditions and damage during the earthquake of 1st September 1962 in Iran. Preliminary report to the *UNESCO*,NS, 92p Paris.

AMBRASEYS, N.N., 1962. On the regional conditions and damage during the Buyin Zara (Iran) earthquake of 1st September 1962. Final report to the *UNESCO*, N.S Paris.

AMBRASEYS,N.N., 1963. The Buyin Zara (Iran) earthquake of September 1962: a field report. *Bull. Seism. Soc. Am.*, **53** (4), p. 705–740.

AMBRASEYS, N. N., 1965. An earthquake engineering study of Buyin Zara earthquake of Septenber 1st 1962 in Iran. *Proc. 3rd World Conf. Earthq. Engs.*, New Zealand III. p. 7–26

BERBERIAN, M., 1971., Preliminary report on the structural analysis of Ipak active fault. *Geol. Surv. Iran*, Int. Rep.

BOLURCHI, M.H.,1975. Etude géologique de la région d'Avaj (NW de l'Iran)-stratigraphic et tectonique. *T.,esis, Grenoble.*

INST. GEOPHYS., TEHRAN UNIV., 1963. Report on the great Buyin Zahra earthquake of 1st September 1962. *Inst. Geophys., Tehran Univ.*, **15**, 78p.

McKENZIE, D., 1972. Active tectonics of the Mediterranean region. *Geophys. J.R. Astr. Soc.*, **30** p. 109–185.

MOHAJER, G.A., PIERCE, G.R., 1963. Qazvin, Iran earthquake. *Bull. Am. Assoc. Petrol. Geol.*, **47** (10), p. 1878–1883.

MOHAJER, G.A., 1964. Qazvin earthquake. *Bull. Iran Petrol. Inst.*, **15**, 428–429 (in Farsi).

PETRESCU, G., PURCARU, G., 1964. The mechanism and stress pattern at the focus of the September 1, 1962, Buyin Zahra (Iran) earthquake. *Ann. Geoph.*, **20**, p. 242–247.

SARABY, F., FOROGHI, B., 1962. A survey of the Qazvin earthquake. *Geol. Surv. Iran*, Int. Rep.

SOBOUTI, M., 1972. A statistical study on the amplitude distribution of aftershocks of two great earthquakes of Iran: a) Buyin Zahra earthquake of September 1st, 1962, b) Dasht-e-Bayaz earthquake of August 3rd 1968. *J. Earth space Physics, Inst. Geophys.*, Tehran Univ., **1** (1).