Thrust fault geometry of Southern Elburz Mountains in the Northern Iran

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Abstract. A three-dimensional analysis of the geometrical position of thrust faults in the Gorg-Dare area in the south of the Elburz Mountains indicates the dominance of the thrust sheets in that area. The function of thrust sheets has resulted in the disorganization of stratigraphy and consequently in the intricacies of geology in this area. On the whole, the geometry of thrust fault in this area is based on the Imbricat design. However, each thrust fault consists of smaller geometrical forms inside it. Accurate desert measurements for drawing the geological map of this area showed that each thrust sheet is made up of certain Cylindrical structures. These Cylinder-shaped structures which are surrounded with faults have placed masses of rocks adjacent to each other. Considering the large variety of ages of the Cylindrical masses adjacent to each other, it is possible that the establishment of each Cylinder-shaped structures took place during different periods of thrust fault activities. Altogether, such systems in the southern parts of the Elburz Mountains have had a major role in the evolution of geological structures and brought about fascinating geological appearance.

Key words: Elburz Mountains., Thrust Tectonics, Structural Analysis., Fault Geometry

1. Introduction

The Elburz mountains system in northern Iran (Fig.1), extending in a sinuous manner for about 2000 km from the Lesser Caucasus of Armenia and Azerbaijan in the northwest to the mountains of northern Afghanistan to the east forms a composite poly-orogenic belt. The tectonic history of southern Elburz mountains is poorly understood, since from the upper Triassic time the area was affected by the Cimmeride and the Alpine tectonic events. Attempts to synthesize regional stratigraphy and structural features of this mountains system have been restricted to what Stocklin (1960, 1968, 1974a,b) and Stampfli (1978) presented on the basis of data which were meagre and scanty at the time, and by workers (Berberian and King, 1981; Davoudzadeh et al., 1986; Davoudzadeh and Webber-Diefenbach, 1987; Boulin, 1988; Sengor, 1990; Stampfli et al., 1991) who based their analyses almost emtirely on the same data and interpretations already presented by Stocklin and Stampfli. Detailed structural and lithostratigraphic analyses in some specific critical parts of the Elburz, as well as systematic paleontological studies along certain stratigraphic sections have resulted in a better understanding of the stratigraphy and structural geometry of this mountains system (Seyed-Emami et al., 1971; Bozorgnia, 1973; Seger, 1977; Stampfli, 1978; Hamdi and Janvier, 1981; Ahmadzadeh-Heravi, 1983; Hamdi et al., 1989; Seyed-Emami and Alavi-Naini, 1990; Golshani, 1990; Alavi, 1996).

Our work is concentrated on a relatively small (25km) part of the Gorg-Dare near Shahrod city. The fault geometry there were studied during approximately six months of field works. The principal product of which, a geologic map (Fig. 2), was constructed using a 1: 20000 aerial photographic base. This detailed map and attendant structural geology work, gave us the new pattern of thrust faulting geometry in this area.

2. Lithostratigraphy

Based stratigraphic analyses several formations may be distinguished in this area (Fig.2) each formation formed in a tectonically controlled environment and in the following paragraphs I present a brief and general description of these formations, ranging from the oldest to the youngest.

The most characteristic constituents the upper Cambrian Mila Formation are nodular limestones, in part strongly glauconitic and containing abundant trilobites, brachiopods, and hyolithids. These limestones are associated with dolomitic, marly, shaly and sandy beds. This unites considered to represent deposits of an epicontinental platform sedimentary basin that was influenced by the initial stages of extensional tectonics (Alavi, 1996). The upper Devonian-Carboniferous Geirud Formation consists of sandstones, shales, fossiliferous sandy limestones and several phosphatic layers, followed by sandstones, shales and fossiliferous limestone.

The lower Triassic to middle Triassic Elikah Formation consists of an association of limestone, party marly, rarely dolomitic, yellow to pinkish. Many beds are crowded with worm-tracks, calcaires vermicules (Stocklin, 1977).

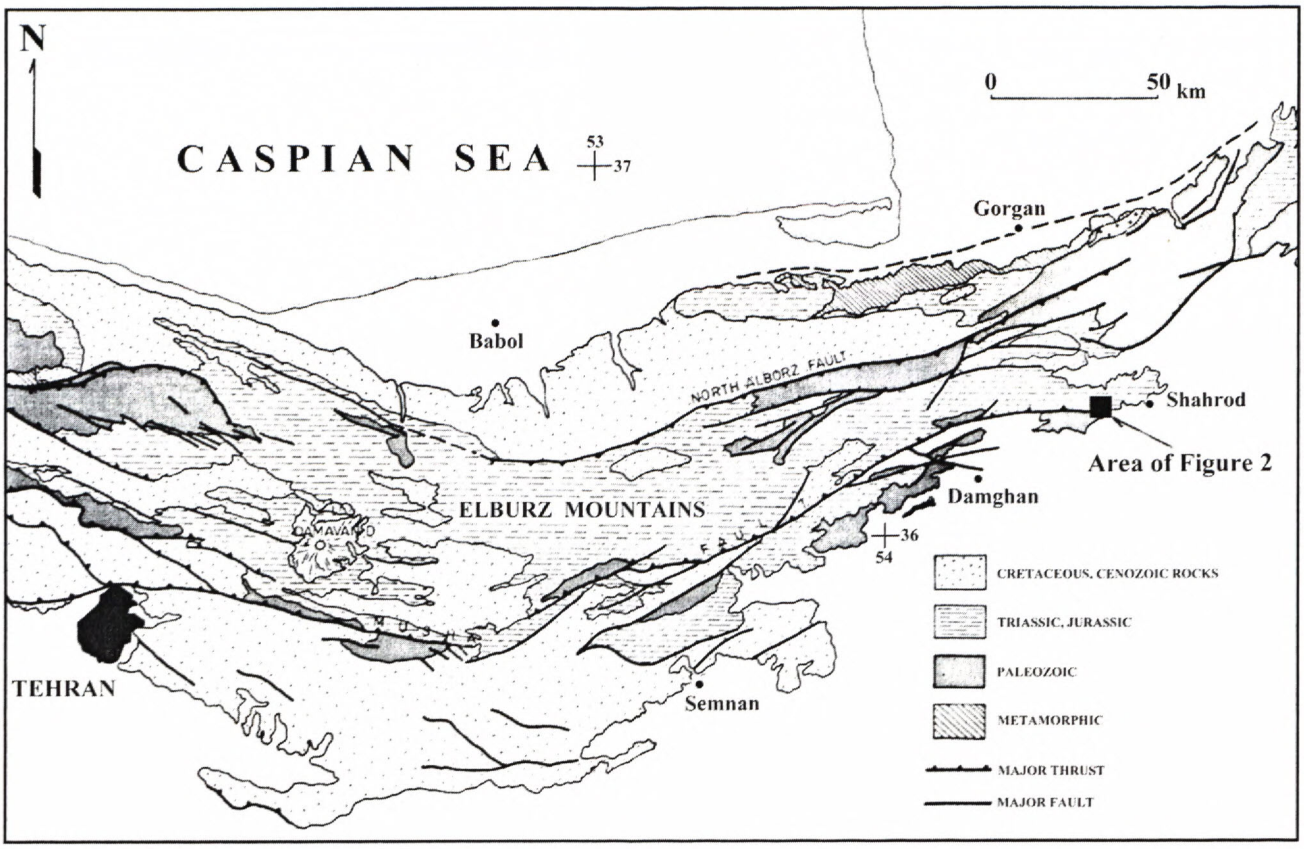

Fig. 1. Tectonic map of the Elburz system with major lithotectonic units and main structural features (Adapthed from Geological map of Iran 1:1000,000 NIOC 1973-1978; 6 sheets).

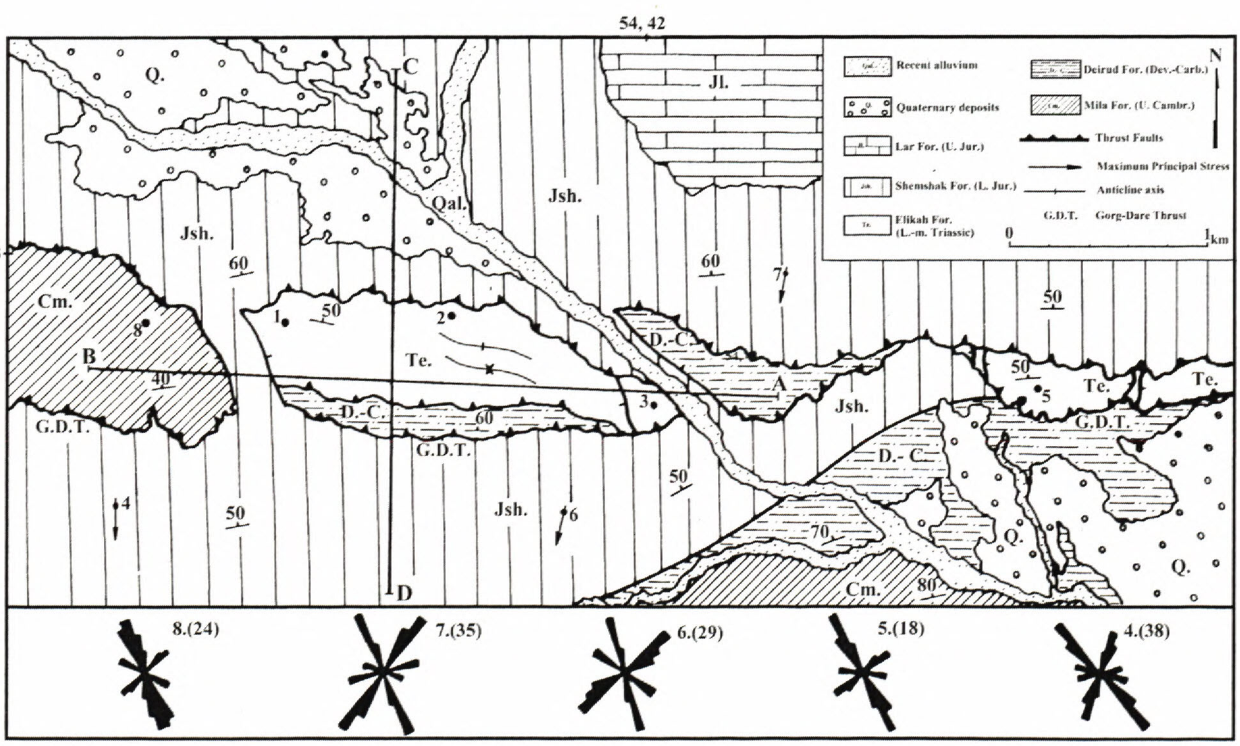

Fig. 2. Geologic map of Gorg-Dare area in southern Elburz Mountain, showing the characteristic joint patterns, illustrated by rose diagrams, and the maximum principal stress.

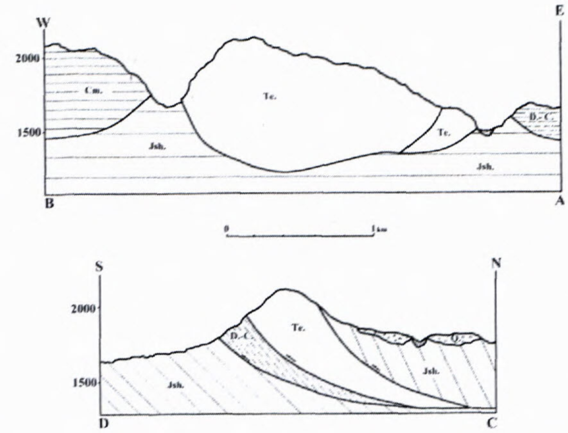

Fig. 3 Cross-section the Gorg-Dare area with major structural features. Localities shown in Figure 2.

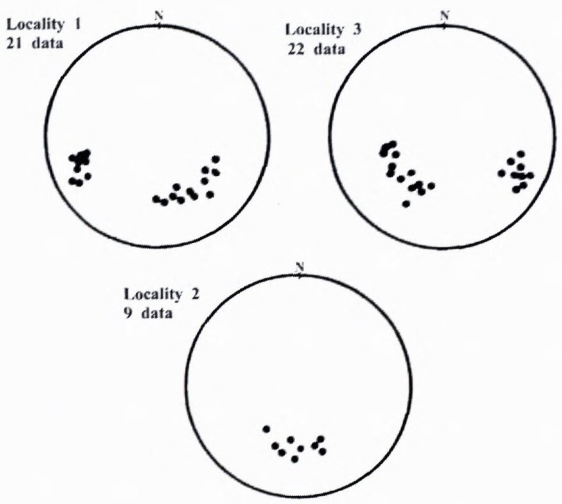

Fig. 4 The measurements conducted on the surrounding faults of a cylinder-shaped structure. Localities shown in Figure 2.

The lower Jurassic Shemshak Formation consists of an association of sandstones, siltstones, shales and claystones, that have coal seams up to 1.5m thick as a characteristic feature (Assereto, 1966). The lower part of the Shemshak Formation is characterized by cross-bedding and ripple marks are numerous and indicate a very shallow-water to lagoonal environment of sedimentation. The upper parts contain features characteristic of deltaic environment (Stocklin, 1968, 1977). The lower part of rocks may have formed the Shemshak Formation is characterized by plant fragments which are of central Asiatic type. Cross-bedding and ripple-marks are numerous and indicate a very shallow water to lagoonal environment of sedimentation. The upper parts contain features characteristic of deltaic environment. Regional structural considerations coupled with the sedimentary characteristics of this unit, with distinctive lateral variations, strongly suggest that these in a foreland basin in front of the tectonically active, south-verging, blocks uplifted during the Cimmeride orogeny, which later became covered by marine transgression strata (Alavi, 1996).

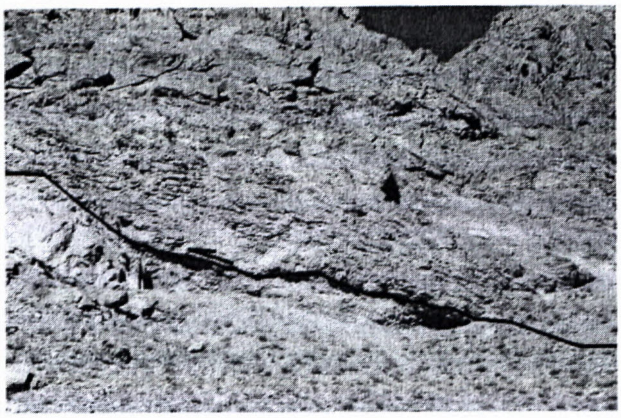

Fig. 5 Development mylonites at surface Gorg-Dare Thrust fault.

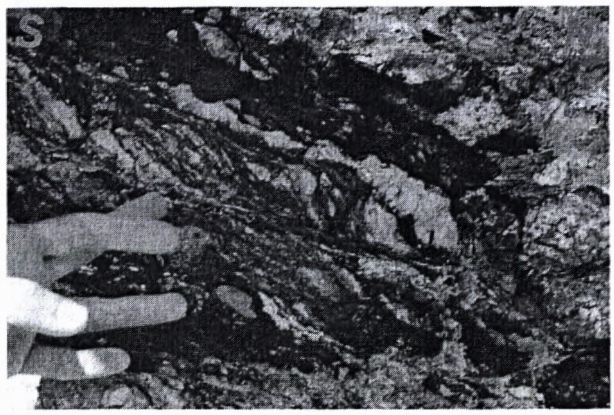

Fig. 6. C-type shear band cleavage in surface Gorg-Dare thrust fault.

The upper Jurassic Lar Formation is composed of light gray, compact and thin bedded to massive partly reef limestone 250 to 350 meters thick and containing characters-tic nodules and bands of white or violet chert. The limestone overlies conformably the Shemshak Formation.

3. Structural Geology

The tectonics of the Elburz system are dominated by thrust faults. Stocklin (1968), synthesized a generalized tectonic framework for the Elburz Mountains as a large, E-w trending, deep-seated synclinal structure whose southern and northern limbs were imbricated by several south-verging and north-verging thrust faults.

3.1. The Gorg-Dare Region

The Gorg-Dare region, north west of shahrod (Fig. 2), studied in this area, thrusts are the dominant structural features. They are all north dipping and mostly associated with mylonites (Fig. 5). Mylonites can be recognized in the field by their small grain size and strongly developed, unusually regular and planar folia-

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tion and straight lineation. Mylonites commonly contain two or even three foliations, inclined to each other at small angles, that is thought to have developed contemporaneously (Passchier and Trouw, 1998). Foliation in mylonite is locally subject to tight or isoclinal folding. In most cases, the axial planar foliation in these folds cannot be distinguished from the main foliation in the mylonite. Some of these folds are sheath folds, that is they have a tubular shape parallel to the mylonite lineation. Study C-type shear bands in this mylonites display a north-to-south movement direction (Fig. 6). Thrusting was propagated sequentially southward from the interior of the Elburz mountains toward its southern foreland.

The Gorg-Dare area is affected by thin-skinned tectonics. The thrust sheets comprising various stratigraphic units, including, Mila Formation, Geirud Formation, Elikah Formation and Shemshak Formation. Fig. 2 and the cross-section in Fig. 3 reveal the general geometry of the thrust faults exposed in the Gorg-Dare area. Geometrically, generations of thrusts, all south-verging, from imbricate fans, composed of several single sheets and a number of internal thrust sheets Cylinder form. These are restricted to the structural sheets and are bounded by the thrust boundaries (Fig. 7). It is clear that the Cylinder forms are genetically related to the thrust movements.

The measurements of the position of the three-dimensional geometry of thrust faults in this area indicates that there are certain forms of Cylinder-shaped geometry in thrust sheets. These Cylinder-shaped structures which make up a thrust sheet altogether have unnaturally placed different formations adjacent to each other. In appearance a mass of Cylinder-shaped rock is surrounded with a group of thrusts in all directions. Moreover, the existing lineations with a radial design on these thrusts can be observed in different parts of the Cylindrical structure. The most appropriate place for the observation of such a structure is where there are two Cylinder-shaped connections. Here, the geometrical form of Cylinder-shaped thrusts are easily observable. Based on desert measurements and observations, attempts are made to display the three-dimensional geometry of such structures in Figures 7 and 8. Among the other interesting structures present in each of the Cylinder-shaped masses are the existence of conjugate thrusts (Fig. 9). Such thrusts can be observed as a group of parallel thrusts with a slope of 90 degrees in every Cylinder-shaped mass. These thrusts are usually formed crisscross along with the displacement of strike slip. The collection of crisscross thrusts was formed in the course of the displacement and establishment of thrust sheets in the masses of Cylinder-shaped rocks.

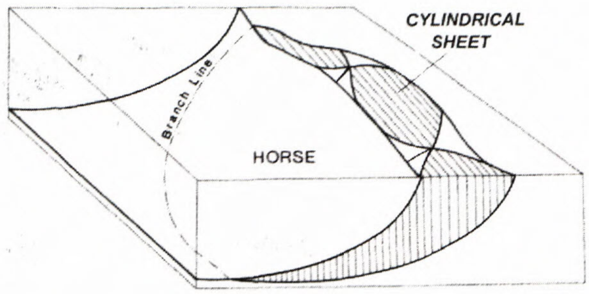

Fig. 7. Block diagram showing horse in a volume of rock surrounded by fault surfaces, formed three cylindrical sheets.

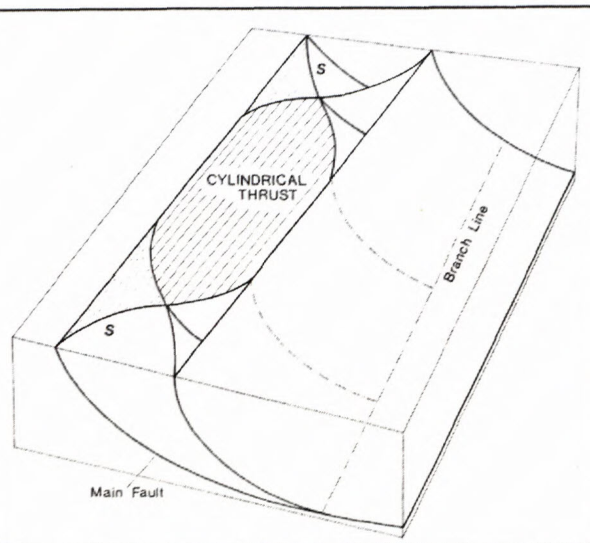

Fig. 8 Block diagram showing cylindrical sheet, which has two major faults, with connecting splay (S) and one branch line depth.

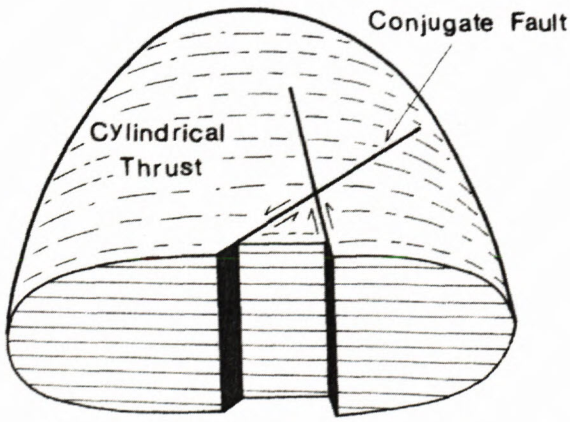

Fig. 9. Three-dimensional view of conjugate fault system, internal cylindrical sheet.

3.2. Structural Analysis

In order to describe the three-dimensional geometry of cylinder-shaped structures, structural parameters such as faults and fractures found in the region under study have been extensively measured. These measured data have been the main foundation of detailed interpretation on the structural model of the region. Statistical analyses carried out on the conjugate faults indicate that direction of maximum principal stress generally has on N10E orientation. The measurements conducted on the surrounding faults of a cylinder-shaped structure indicate that every section of this structure follows a particular geometrical pattern. In Figure 4, geometrical situation of faults in various parts of a cylinder-shaped structure has been illustrated by the stereonet. This set of measured faults shows this structure in a three-dimensional pattern. Striations on the surface of faults covering a cylinder-shaped structure have a radial pattern. Therefore, by approaching the end of this structure, the angle of striation pitch will be smaller.

4. Conclusions

According to the geometrical indices of thrust faults in the Gorg-Dare area in the south of the Elburz Mountains the following results are presented.

1. As a major system, the thrust faults dominate the changes of forms in the southern part of the Elburz.

2. The results of the study of C-type shear bands on the surface of thrust faults indicates the displacement of thrust sheets from the north to the south.

3. The position of the three-dimensional geometry of thrust faults in this area is redolent of the existence of Cylindrical forms in thrust sheets.

4. Cylinder-shaped masses have placed stratigraphic units adjacent to each other and have caused structural intricacies.

5. During the displacement and establishment of Cylinder-shaped masses, conjugate thrusts were formed as a collection of parallel thrusts with a slope of 90 degrees in the masses of rocks.

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