Post-Triassic normal faulting and extensional structures in Central Alborz, Northern Iran

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Abstract
This paper presents structural evidence of extensional activity in Central Alborz during Mesozoic. The structural evidence of homogenous early stage stretching such as layer parallel to oblique boudinage of Permian and Triassic rocks in various portions of the study area accompanied by extensional-fibrous fractures were followed with more advanced extensional features. These extensional structures include tension gashes in brittle-ductile shear zones, large to medium scale slickensides with normal movements, distinct normal faults, assemblage of high angle faults with primary normal component of displacement, majorly in Permian to Early-Middle Jurassic rocks and large initially normal faults within the Shemshak Group. Development of later extensional structures has also influenced the former Early Cimmerian structures, where some of north-verging folds were cut and displaced by high angle transverse faults with normal components. Partial continuation of the normal faulting in the Shemshak Group is an evidence for the Jurassic timing of these normal faulting. Many of the faults that are interpreted as originally normal faults, have experienced a reactivation and inversion as reverse or strike-slip faults, during the Late Cretaceous-Early Paleocene regional compressional tectonic activity.
Keywords: *Normal faulting, Extension, Tectonic inversion, Cimmerian, Alborz, Iran.*

Introduction

Various aspects of large portions of the existing mountain chains that extend along southern Eurasia and formed during the Cimmerian events are still poorly known (Zanchi *et al.*, 2015). Three tectonic events from the Late Triassic to Jurassic have led to three significant unconformities in the region including a Late Triassic, a Middle Jurassic and a Late Jurassic (Fürsich *et al.*, 2009a). Firstly, Stille (1924) recognized a Late Triassic Early Cimmerian Orogeny and a pre-Tithonian Late Cimmerian Orogeny in Crimea, based on structural observations. Distinct of this unconformity is found around the Middle–Upper Triassic boundary. Although not an angular unconformity in most places, it can be easily recognized by the abrupt change in facies from platform carbonates to siliciclastic rocks or karst morphology and the development of lateritic soils and bauxite deposits indicative of subaerial exposure across northern and east-central Iran (Fürsich *et al.*, 2009a). This unconformity is clearly the expression of The Early Cimmerian orogenic movements affected the southern Eurasian margin from Anatolia to Tibet and was caused by the collision of several microplates detached from northern Gondwana at the end of the Paleozoic (e.g. Alavi, 1991 and 1992; Zanchi *et al.*, 2015). This event started at Carnian (Wilmsen *et al.*, 2009). Secondly, Ziegler (1975) defined a Mid-Cimmerian (Middle Jurassic) deformation phase, which can be widely recognized in northern Europe, Caucasus (e.g. Saintot *et al.*, 2006), Alborz Range (Fürsich *et al.*, 2009a; Ehteshami-Moinabadi *et al.*, 2012) and Central Iran (Kashmar-Kerman zone) where Masoodi et al. (2013) studied ductile normal shear zone with a normal activity age of 168 Ma. This latter unconformity formed around the Early–Late Bajocian boundary. Its signal a sharp change in facies, commonly associated with the formation of conglomerate layers can be documented in all areas of the former Iran Plate and beyond, from Kerman in the south to the Kopeh-Dagh in the north, and has been interpreted as tectonic in origin (Fürsich *et al.,* 2009a). Rarely, the Mid-Cimmerian unconformity is developed as an angular unconformity (e.g. Wilmsen *et al.*, 2003; Seyed-Emami *et al.*, 2004). The Mid-Cimmerian tectonic event can be documented all across the Iranian Plateau (Alborz Mountains of northern Iran, NE Iran, and east-central Iran) and the southern Koppeh Dagh (northeastern Iran) (Fürsich *et al.*, 2009a). This phase is explained as the expression of the onset of sea-floor spreading within the South Caspian Basin situated to the north of the present-day Alborz Mountains (Fürsich *et al.*, 2009a); although the rifting probably started in Toarcian (Wilmsen *et al.*, 2009).

Detailed works by Fürsich *et al.* (2009a and b) and Wilmsen *et al.* (2009a) along with other studies such as Brunet *et al.* (2003), Fürsich *et al.* (2005) and Fürsich *et al.* (2006) clarified some stratigraphic and sedimentological aspects of Mid-Cimmerian tectonic events and its relation to opening of the South Caspian Basin in the Middle Jurassic. This conclusion were subsequently stated by several other works for example Taheri *et al.* (2009), Wilmsen *et al.* (2009b), Soson *et al.* (2010), Stephenson and Schellart (2010), Ghassemi-Nejad *et al.* (2012) and Mafi *et al.* (2014). However, the studies on the structural aspects of the Mid-Cimmerian extensional system in Caucasus (McCann *et al.*, 2010) and Northern Iran are rare (e.g. Shahidi *et al.,* 2011; Ehteshami-Moinabadi *et al.,* 2012; Ehteshami-Moinabadi, 2013). Field studies during 2014 and 2015 in various portions of Central Alborz revealed evidence of extensional structures in Permian to Jurassic rocks, some of which show also evidence of positive tectonic inversion (Fig. 1). At first, this paper wants to presents the style and situation of these structures, and then provide some preliminary scenario for tectonic setting of their formation. More works on these structures including dating of shear zone deformation structures and tectonostratigraphic studies will help to provide an interpretation of them.

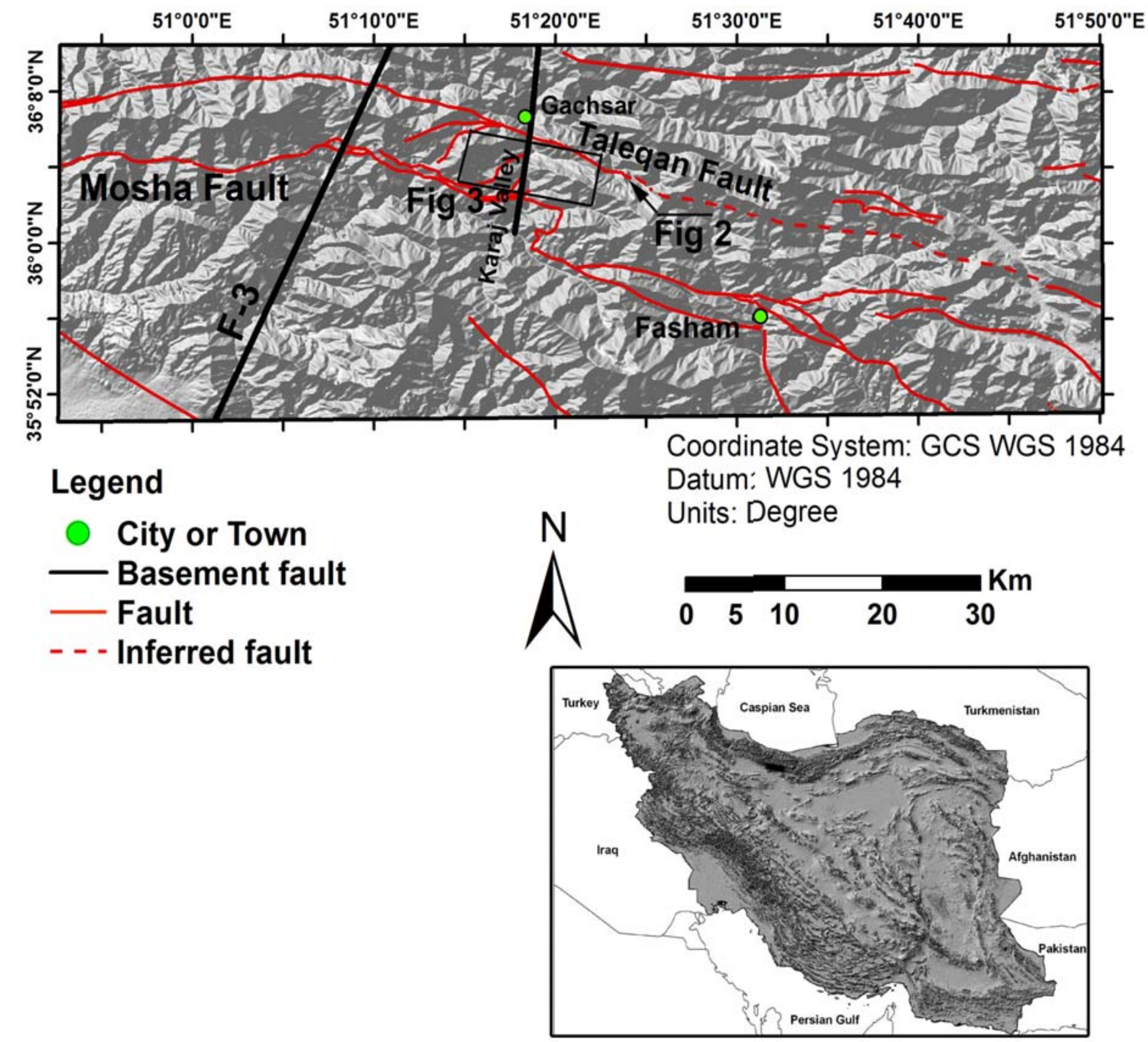

Figure 1. SRTM- shaded relief map of the portion of the Central Alborz showing the position of major faults and Figs. 2, 3 and 12. The inset map shows the location of shaded relied map in the northern Iran.

Geological setting

The Alborz Range is a polyorogenic folded belt that evolved during Cimmerian and Alpine orogenies (Berberian & King, 1981; Alavi, 1992, 1996). Stampfli *et al.* (1991) suggested that the Alborz block was separated from Gondwanaland in the Ordovician and Silurian and then collided with the Eurasia plate in the Late Triassic during Early Cimmerian Orogeny (Zanchi *et al.,* 2009). The Early Cimmerian Orogeny caused inversion of originally normal faults such as the Mosha and Hasanakdar faults in the Central Alborz (Ehteshami-Moinabadi *et al.,* 2012). The Shemshak Group, composed of a thick succession of fluvial, deltaic to marine sedimentary rocks was deposited in the Late Triassic – Middle Jurassic (Aghanabati 2004; Fürsich *et al.,* 2009a, 2009b). In the Middle Jurassic, the Middle Cimmerian event initiated a rift basin (Brunet *et al.,* 2003; Wilmsen *et al.,* 2009b) in the region. The marine condition continued in the Cretaceous until the Late Cretaceous – early Paleocene, when there was a pulse of exhumation and cooling accompanied by folding in the Central Alborz (Guest *et al.,* 2006; Ehteshami-Moinabadi *et al.,* 2012) that closed the limited Cretaceous basins in the area and causing the inversion of Middle Cimmerian related normal faults (Zanchi *et al.,* 2006; Ehteshami-Moinabadi *et al.,* 2012). Deposition of Paleocene Fajan conglomerates (Alavi, 1996; Allen *et al.,* 2003) was terminated by the development of marine condition in a Neo-Tethys related back-arc basin in the western and central Alborz, in which the Eocene Ziarat carbonates and Karaj tuffs, shales, and volcanics were deposited (Lorenz, 1964; Allen *et al.,* 2003). During the Oligo-Miocene, right-lateral transpressional tectonic regime (Allen *et al.* 2003; Guest *et al.,* 2006), or oblique inversion Ehteshami-Moinabadi & Yassaghi, 2013) deformed the range. The transition from extension to Neogene compression occurred sometime in the late Eocene to early Oligocene in the case which the comparison between cooling ages from the Talesh Mountains and elsewhere across the Iranian Plateau indicates widespread plateau formation in the Oligocene, earlier than previously suggested for the northwestern plateau margin (Madanipour *et al.,* 2013).

Structural Data

Dizin area

In an outcrop near the Dizin international ski resort, a major fault bound the lower portion of the outcrop that its hanging wall includes a series of synthetic and antithetic small faults with few small scale chevron-like folds that all together developed in the inclined carbonate layers of Permian Ruteh Formation (Fig. 2a). The stereogram in the Fig. 2a shows attitudes of structures in the outcrop. In detail, there is evidence of a stretching stage more or less parallel with the bedding plane that led to boudinage and extensional fractures filled with calcite (Fig. 2c to 2f). The attitude of the fractures is is perpendicular to bedding. The boudins show an overlapping state and the small chevron-like folds exit in the outcrop that possibly shows evidence of a compression stage after the stretching.

Nesa area

Nesa area is a known district within the study area that contains thick succession of Shemshak Group deposits in the south Central Alborz with several abandoned coal mines (Ehteshami-Moinabadi *et al.,* 2012). Fig. 3 shows the local geological map of the area with newly mapped faults and structures that are described here. Outcropping geological units become younger from south to north. At south of the area, folded and faulted Paleozoic rocks are exposed at footwall and hanging wall of the Hasanakdar fossil Fault that is considered as the relict of an inverted fault during the Early Cimmerian (Figs. 3 and 4; Ehteshami-Moinabadi *et al.,* 2012). The High angle faults cut the folded Paleozoic rocks especially the Permian Doroud and Ruteh Formations as well as Triassic Elika Formation in the area (Figs. 3 and 4). The strike of these faults varies from NNW to NE (Fig. 3 and Fig. 5a). These faults have strike-slip components; however, relatively large normal separation is observable along some of them. For example, Fig. 5 shows the satellite image of some of these faults that cut and displaced the Permian to Triassic rocks. The vertical field exposure of these faults resembles a horst-graben structure (Fig. 5b and 5c). In Fig. 5a, in the left side, two faults cut a portion of the Permian Ruteh Formation and put it lower than the Triassic Elika Formation at south, showing a normal component displacement. Although, the erosion made it difficult to have a direct observation about the fault surfaces or fault zone, but the change of bedding attitude along these faults suggest some slip along them (Fig. 5d). These faults caused the truncation and displacement of folds axial surfaces that exposed at higher elevations in some places (Fig. 6).

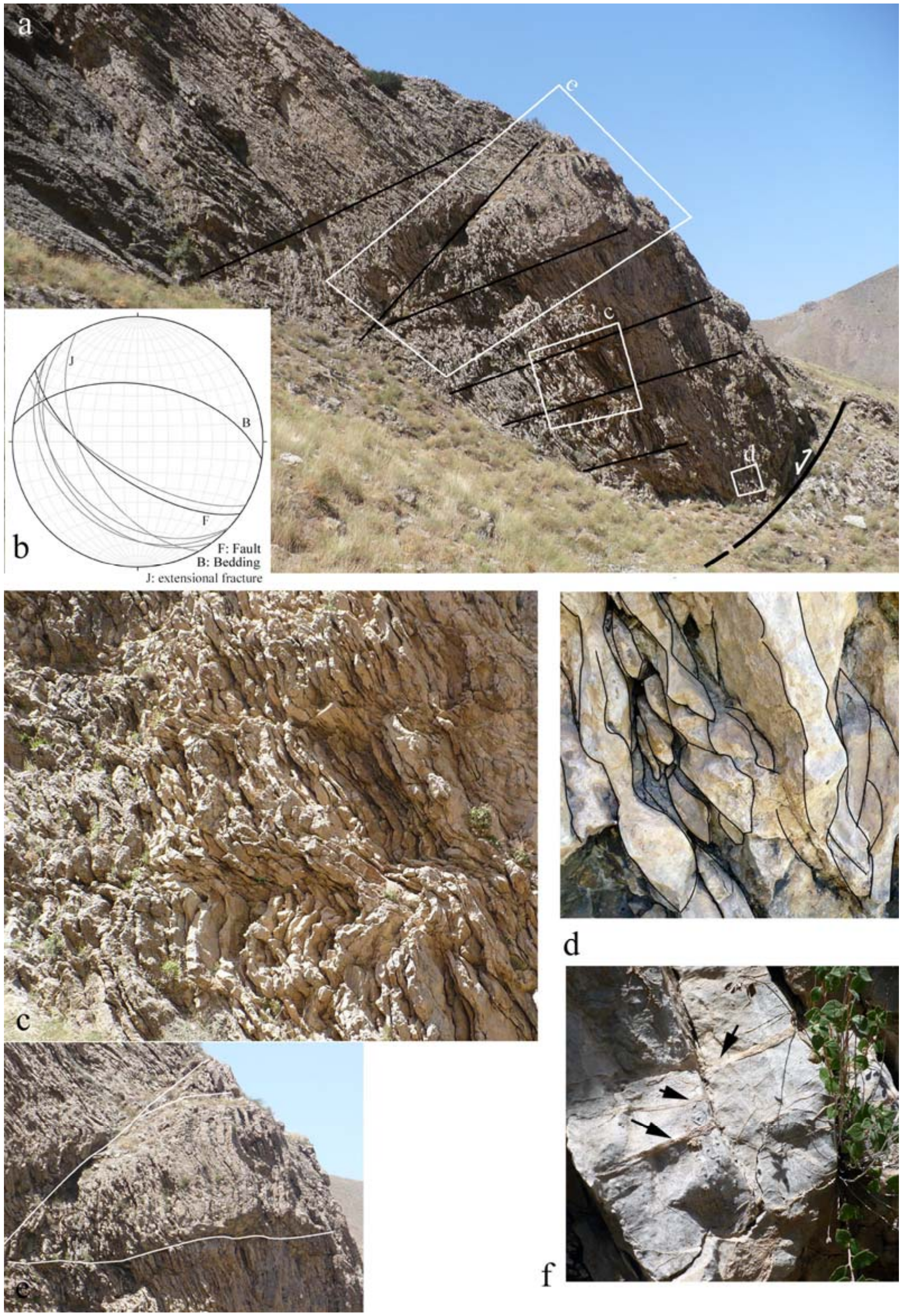

Figure 2. a: Outcrop of folded Permian Ruteh Formation in the Dizin area cut by several faults. b: The stereogram of faults, bedding and extensional fractures the F refer to the major fault shown in a. c: Enlargement of part of a, showing the small scale chevron-like folds. d: Bedding-parallel boudinage in the mentioned rocks followed by overlapping of boudin segments. e: Closer view of folded rocks bounded by to antithetic faults. f: Systematic fibrous extensional fractures. The strikes of fractures are nearly parallel with the strikes of faults. For the location of the photo a, refer to Fig. 1.

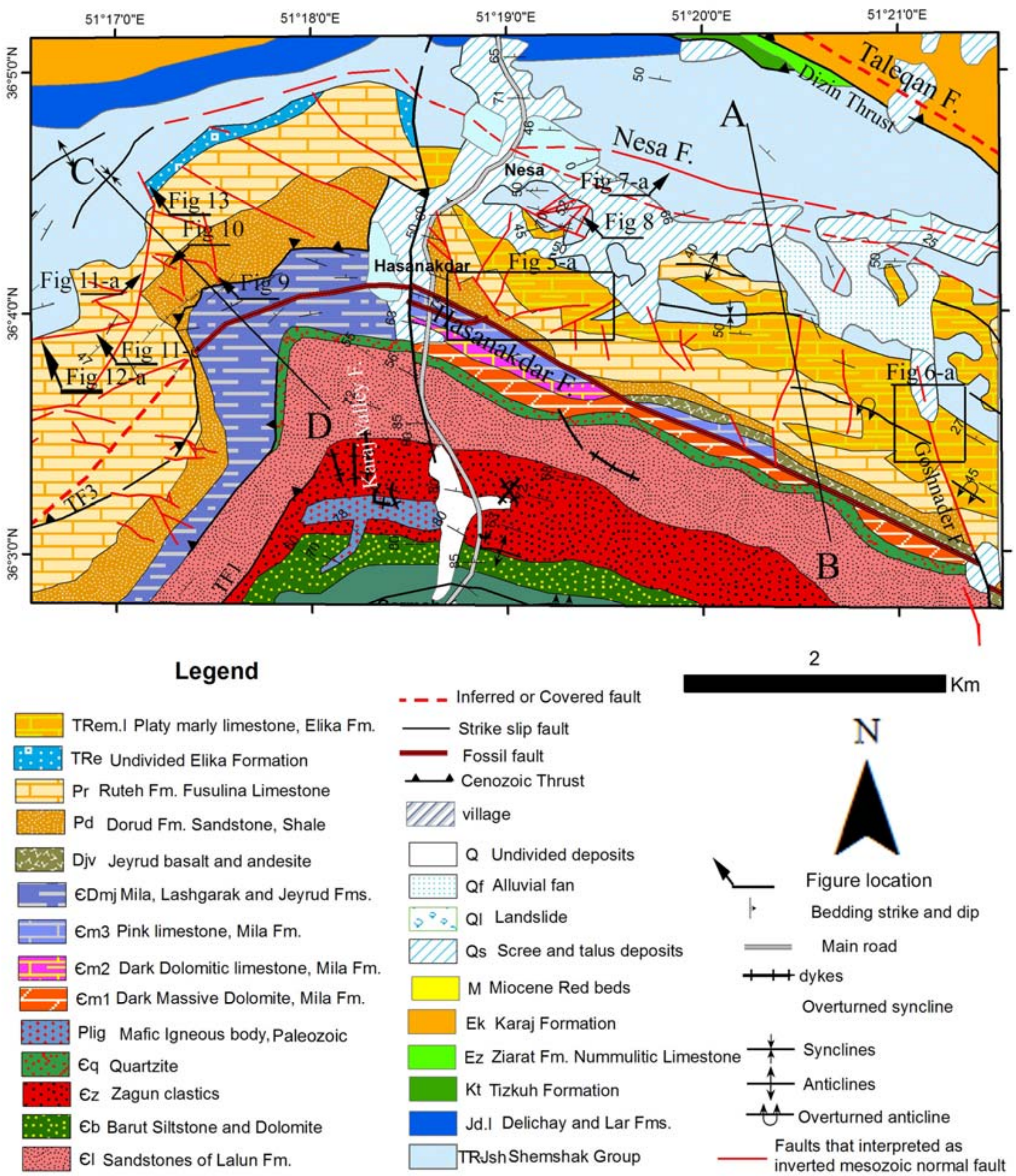

Figure 3. Geology map of the Nesa-Hasanakdar area, modified after Vahdati-Daneshmand (2001) and Ehteshami-Moinabadi (2013). Location of the map was shown on Fig. 1 by rectangle.

Fig. 6 shows a hinge zone of a large asymmetric to overturned anticline of in the Permian and Triassic rocks at the mountain crest line. The fold is cut and displaced by an NW-striking high angle fault, i.e. Goshnader fault, which dips toward NE. The Goshnader fault shows more than 250 m of right lateral offset and ~115 m normal separation based on displacement of rock unit contacts and the mentioned fold axis. Major high angle faults also exist in the Shemshak Group in the Nesa area. The largest one; i.e. the Nesa Fault, is a NW-dipping high angle fault with more than 50 m wide fault zone (Figs. 3 and 7). The fault zone includes brittle faults, S-C structure and very high angle to vertical foliation (Fig. 7a, 7b, 7d). S-C structure indicates a reverse motion along the fault zone. Also, the foliation in the fault zone emphasize on a compression component along the fault. However the structure is very high angle than the common S-C structures developed in reverse or thrust faults.

The change of attitude of foliation may be the result of reactivation of fault. There are small faults in the area that show evidence of normal activity based on the dragging of bedding plane (Fig. 7f). Assessment of other faults in the Shemshak Group in the Hasanakdar valley also shows evidence for reverse component of activity (Fig. 7e), but slickensides studied in the area preserved normal striations or normal striations interrupted by strike-slip ones (Fig. 8).

Hasanakdar Valley

Hasanakdar Valley is located to the west of Nesa area. Paleozoic to Mesozoic rocks units exposed at two sides of the valley. Detailed assessment of the rock exposure in the valley provided new information about several hundreds of meter long faults that cut especially the Permian Doroud and Ruteh and Triassic Elika Formations. The attitudes of these faults are similar with the fault observed in the Nesa area. Fig. 3 shows the mapped faults is the valley. Field studies on these faults show that most of them are high angle faults with normal comportment of activity. Fig. 9 presents examples of above-mentioned faults. Fig. 9a shows a high angle SW-dipping fault with normal component of displacement. The normal displacement is also supported by other evidences including boudinage oblique to the bedding attitude (Fig. 9b), extensional filled veins that strikes more or less parallel to the faults (Fig. 9 c and 9d), and normal striations on the slickensides (Fig. 9e, 9f).

Fig. 10 shows an example of several high angle faults cutting the entire exposure of Permian rocks in the Hasanakdar Valley. Some of these faults have up to ten cm wide fault zone. The hanging wall of the fault in Fig. 10, includes inclined small drag folds (white arrow in Fig. 10a) that may be the result of an oblique slip motion with thrusting component on the fault. But still there is evidence of an extensional activity along the fault, in addition addition evidence of Fig. 9. The outcrops of Doroud Formation along the fault contain high density of filled fractures and veins, most of which show systematic arrays of sigmoidal to complex tension gashes (Fig. 10c).

The attitude of tension gashed was used to determine the orientation of normal brittle-ductile shear zones adjacent to the main fault. Probably, the fault has a period of normal activity when it was situated in deeper levels suitable for development of brittle-ductile tension gashes.

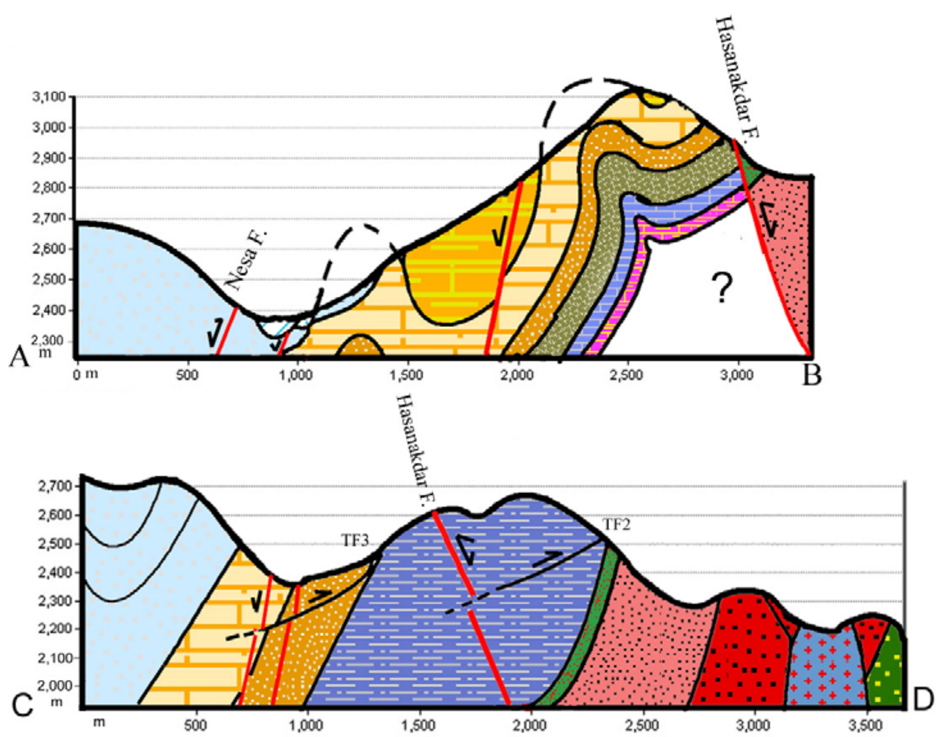

Figure 4. Two interpretive cross sections across the geology map of the Nesa-Hasanakdar area (refer to Fig. 3). Symbols like the Fig. 3.

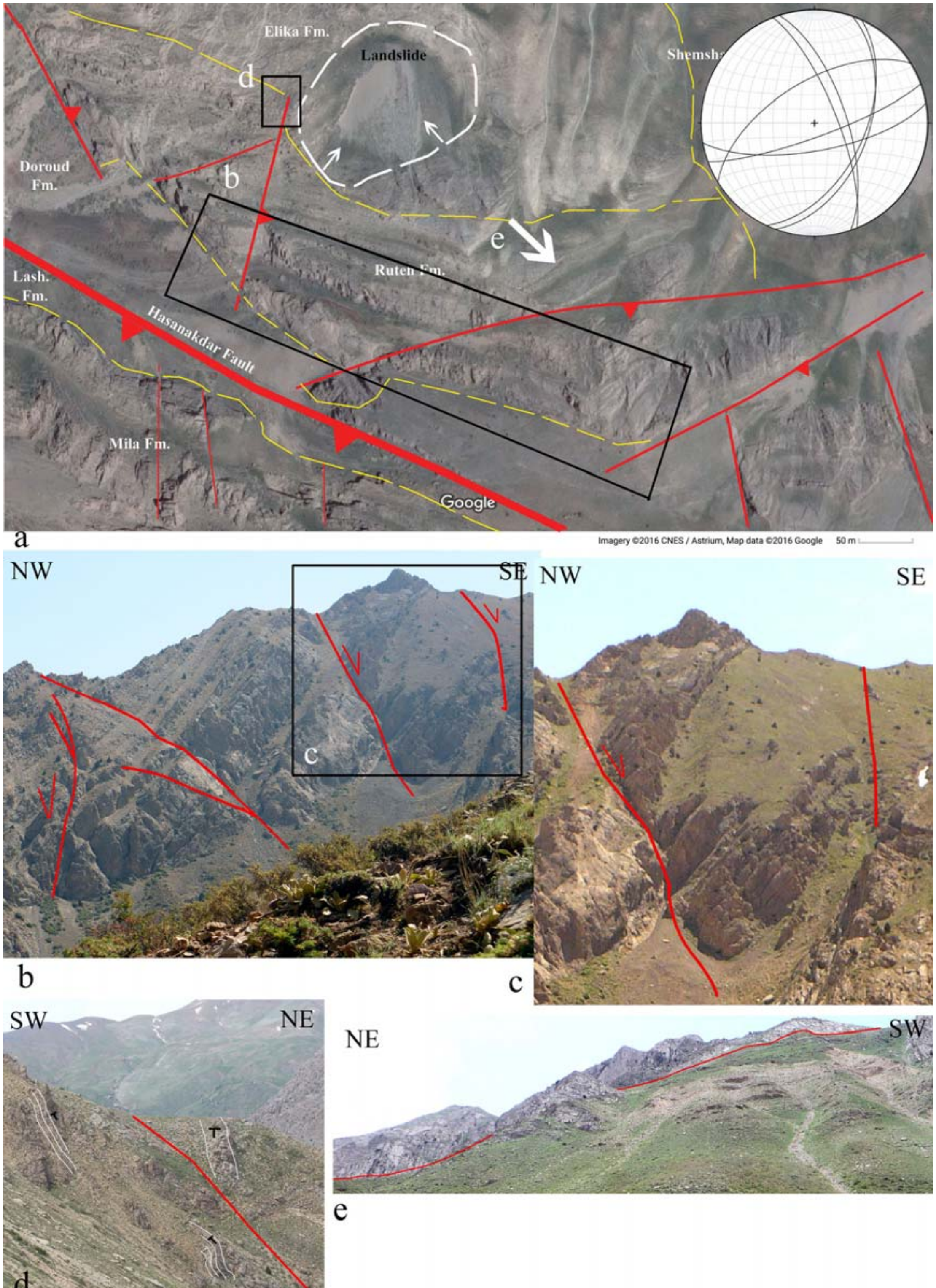

Figure 5. a: Satellite image of Paleozoic-Triassic rocks in the Nesa area, showing the mapped faults in this study. The stereogram shows the attitudes of faults. b: The vertical view of some mapped faults is a (large black box). The two left faults have considerable normal displacement and bound a wedged shape block of Permian Ruteh Formation between the same rocks nd the Triassic Elika (a and c). d: Shows the clear activity of fault and change of bedding attitude in both sides of the fault. The location of photo is shown on the a by a small black box. e: Shows the surficial trace of fault. The location of satellite image was shown on the Fig. 3.

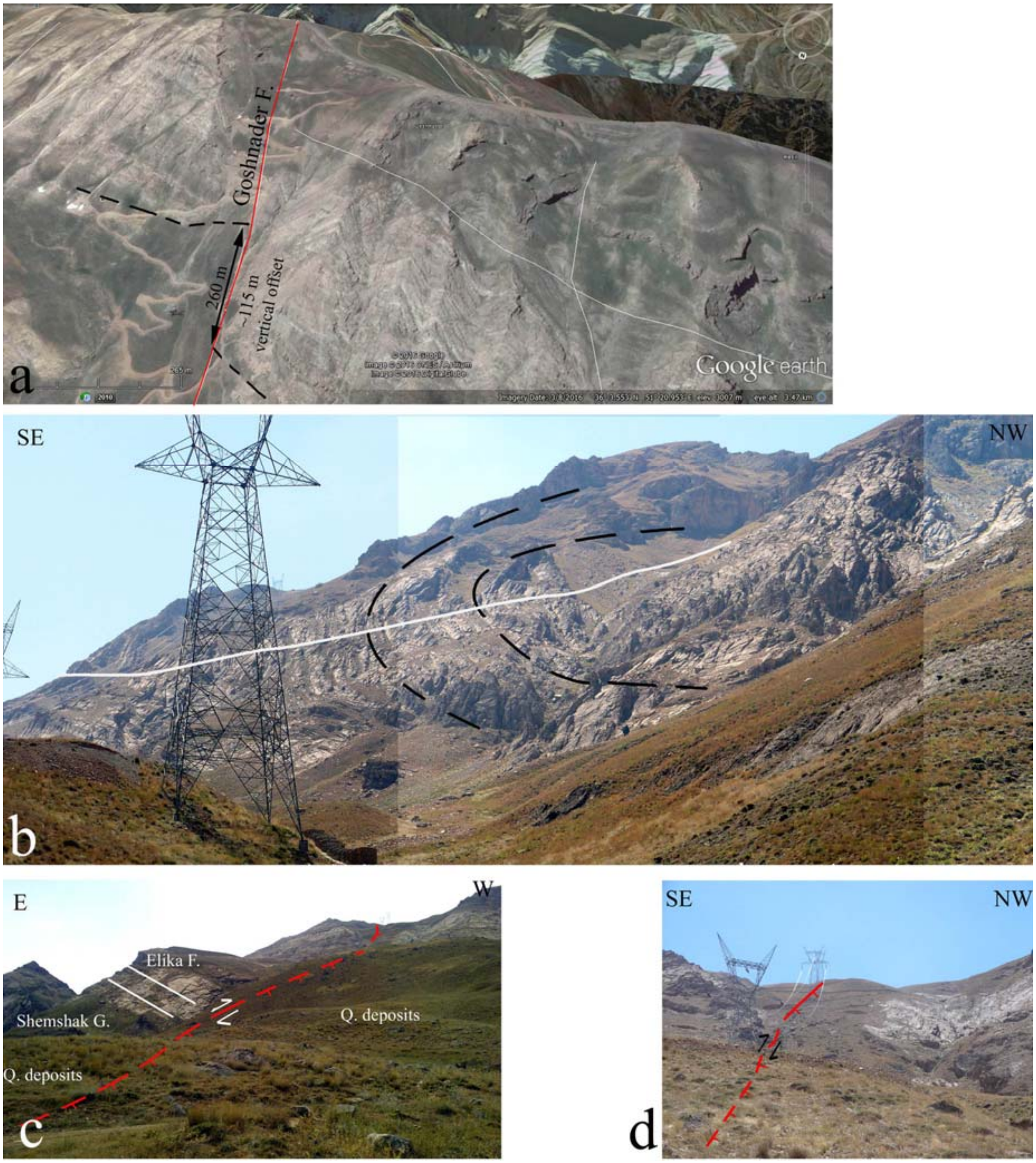

Figure 6. a: Satellite image (Google Earth) of folded Permian Ruteh and Triassic Elika For-mations where the fold axis is cut and displaced by Goshnader fault. The fault has about 260 m strike slip component and ~115 m vertical offset. b: Shows the field view of the fold. c and d: Surficial trace of the fault. For the location of photograph, please refer to the Fig. 3.

Additionally, Fig. 11a displays another example of large normal fault that its location. The fault has a high angle NW-dipping fault zone that is about a meter wide. As shown on Fig. 3, the fault goes across the Ruteh Formation, cuts the Triassic Elika Formation and finally continues into the Shemshak Group. It seems that the fault is sealed by portion of the Shemshak Group. Large scale slickenside (Fig. 11a and d) and adjacent fault plane (Fig. 11c) were used to propose a normal displacement with strike-slip component on this fault. Other examples of the large faults with striation features that die out inside the Shemshak Formation show an oblique slip motion with normal component (Fig. 11e).

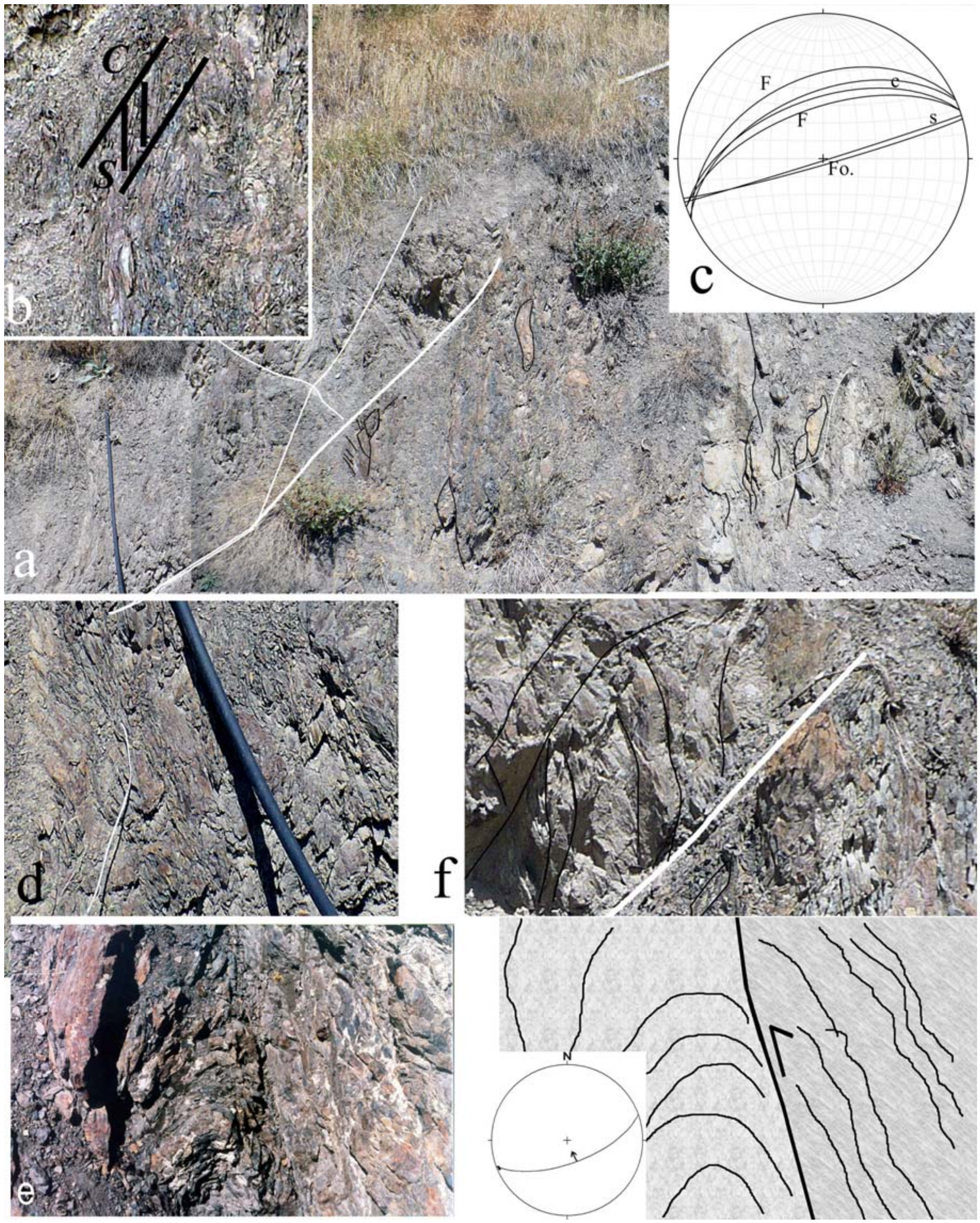

Figure 7. a: The Nesa fault zone in the Shemshak Group in the Nesa area is one of two major faults in this group with more than 50 m fault zone includes fractured rocks and high angle to vertical foliations. A clear fault branch dips toward NW. b: S-C structure is some portions show a reverse motion. c: The stereogram shows the attitude of major faults and S-C structure and foliations. d: The NE-dipping foliation slightly changes to vertical foliation in some places due to rotation or fault action. e: Evidence of reverse activity along a fault zone in the Shemshak Group associated with development of foliation. f: Evidence of a normal displacement in the fault zone based of the small drags in the bedding. For the location of photograph a, please refer to the Fig. 3.

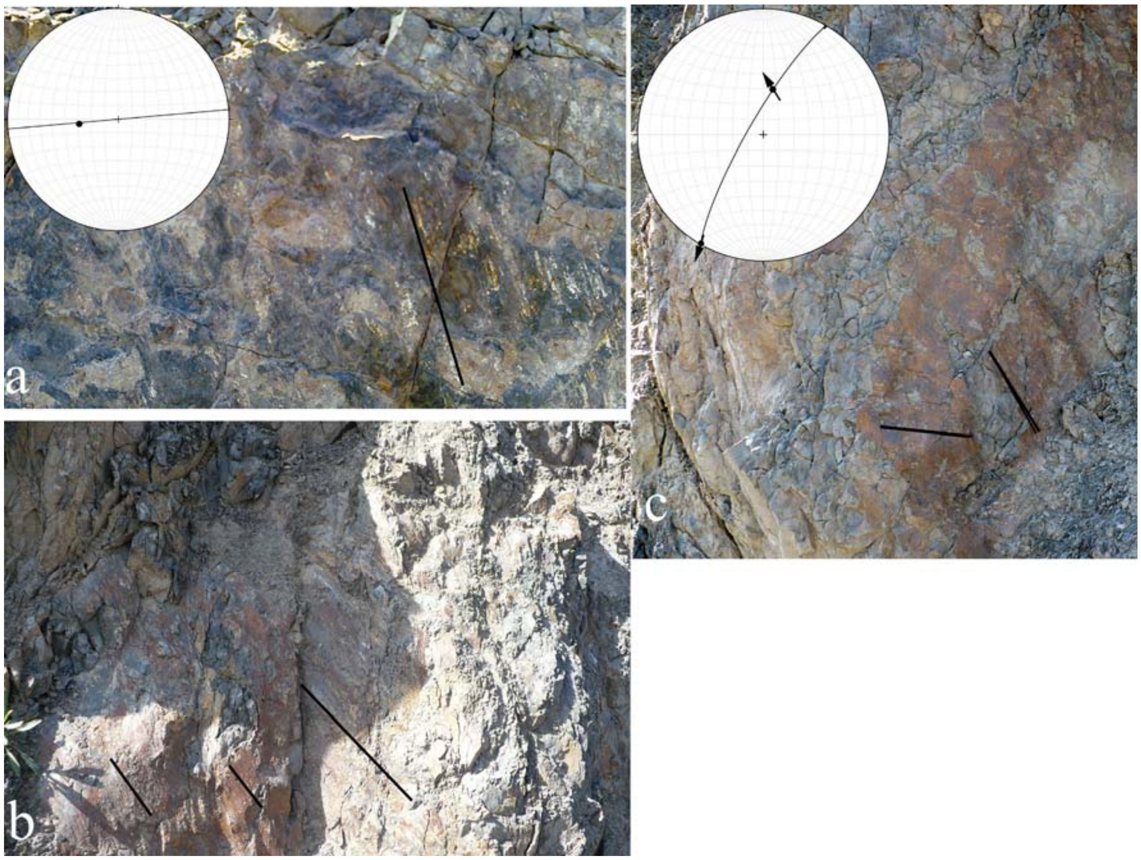

Figure 8. a and b: Examples of slickensides with normal of oblique striations c: Example of a slickenside with two sets of striations, a primary normal and a secondary strike slip striation. For the location of photographs, please refer to the Fig. 3.

Discussion

The Mesozoic evolution of Northern Iran is under influence of Cimmerian events. As noted earlier, the the Middle Cimmerian extensional tectonic in the northern Iran has occurred in Middle Jurassic. The new interpretation of the Shemshak Group was made by Fürsich *et al.,* (2009b) that is now thought to document not only post-collisional, but also synorogenic, sedimentation of the Cimmerian Orogeny and the onset of Neotethyan back-arc rifting in northern Iran. By this interpretation the Upper Triassic part of the succession represents synorogenic deposits in a peripheral foreland basin after initial coupling of the Iran and Turan plates (i.e. the onset of the Cimmerian Orogeny), and the development of the Early Cimmerian unconformity. The main exhumation of the Cimmerides, associated with the transition from the syn- to the early Liassic post-orogenic (molasse) stage, occurred around the Triassic–Jurassic boundary that is marked by conglomerates of the Javaherdeh and coarse arkosic sandstones of the lower Alasht Formations and also the Kalariz-Javaherdeh angular unconformity in some areas (Fürsich *et al.*, 2009b). From the Toarcian onwards (equivalent to the upper portion of Alasht Formation, Filzamin and Shirindasht formation), increasing subsidence rates in the southern Alborz indicate extension in northern Iran, interpreted as an eastwards-progressive opening of a Neotethys back-arc rift-basin and the Bajocian event represents the break-up unconformity of this back-arc rift basin (Fürsich *et al.*, 2009b). That means that the first stages of extensional tectonic started in a time before Bajocian, but not recorded as an unconformity. Currently, there is not sufficient information about early stage sys-rift structures of the Middle Cimmerian event within the Shemshak Group. Some authors such as Shahidi *et al.* (2008, 2011) introduced examples of E-W to SE-NW striking normal faults in the Shemshak Group, somewhere interpreted as syn-sedimentray (e.g. in Tazareh) or pre-folding. For example Shahidi *et al.* (2008) presented evidences of these faults showing that they are small faults that their origin is not well-defined.

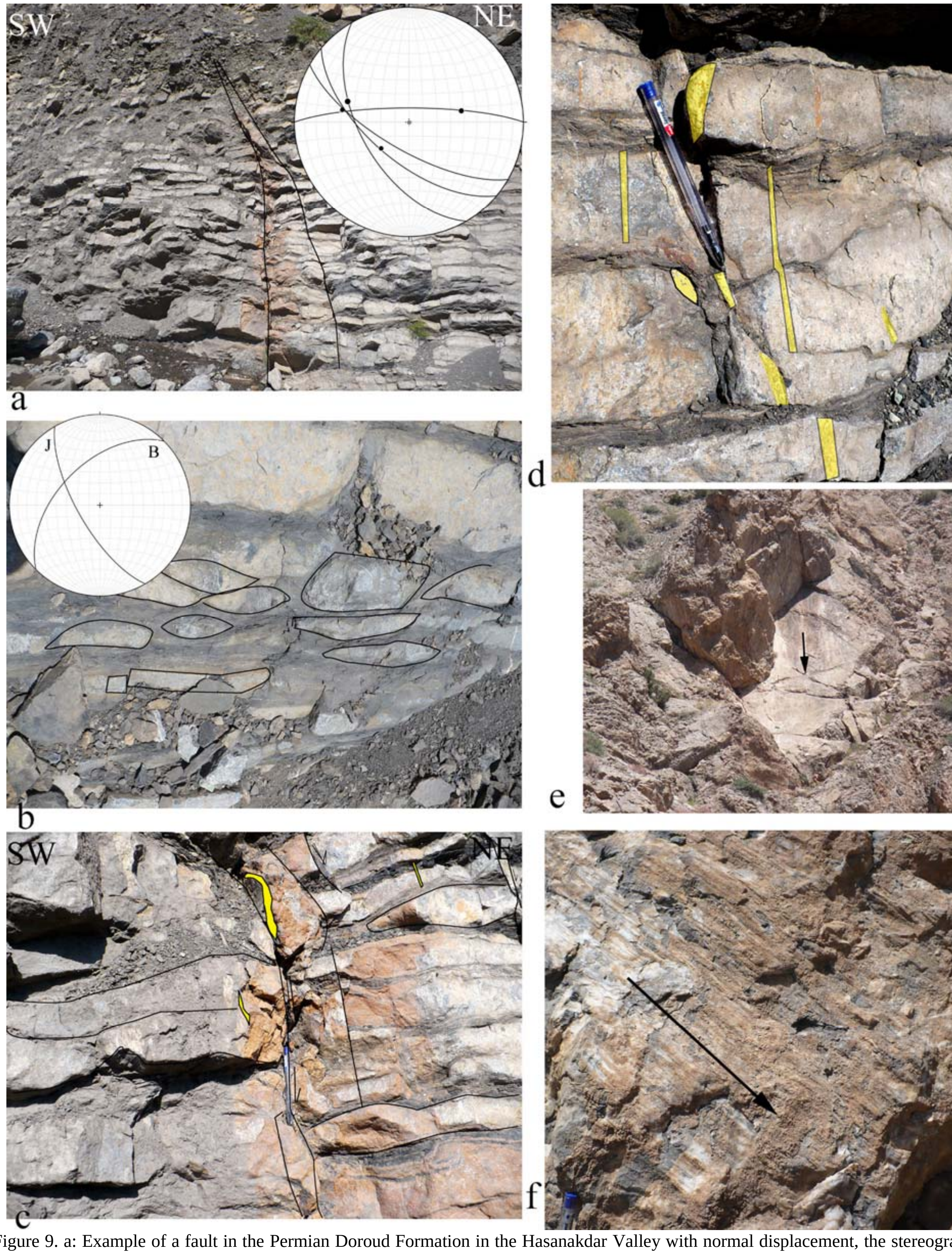

Figure 9. a: Example of a fault in the Permian Doroud Formation in the Hasanakdar Valley with normal displacement, the stereogram shows the attitudes of some faults with their normal striations marked by black dots. b: Boudinage oblique to the bedding attitude in Doroud Formation. c and d: Examples of faults with normal component of displacement that are ac-companied with extensional filled veins (yellow polygons). e and f- slickensides with normal slickenlines. For the location of photographs, please refer to the Fig. 3.

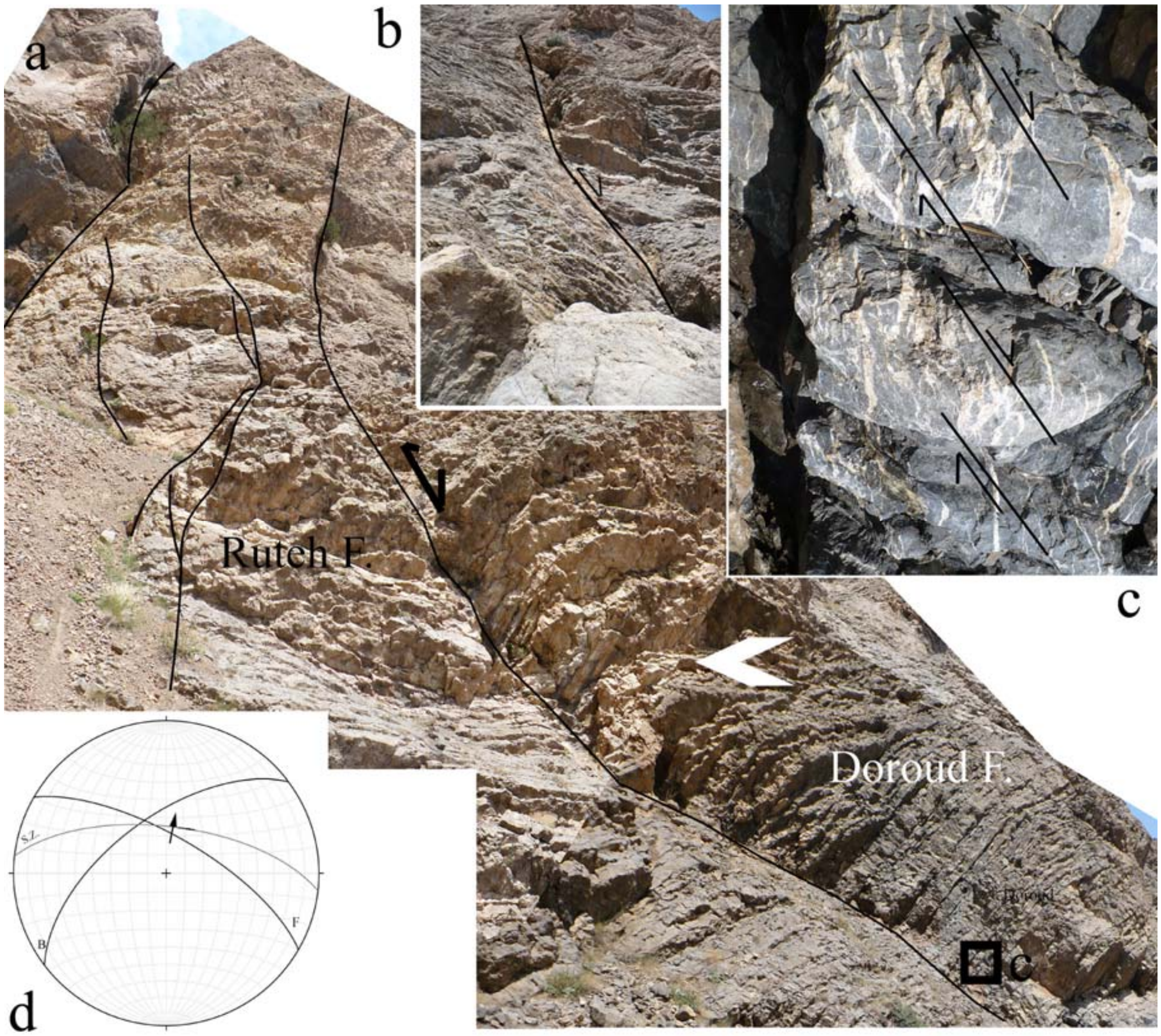

Figure 10. a and b: Interpreted large initially normal fault cutting throughout outcrop of Per-mian Doroud and Ruteh formations. The oblique drag folds (marked by white arrow) may conclude a final kinematics of strike-slip with thrusting component on the fault. View toward NW. c: Arrays of tension gashes filled with calcite in the Doroud Formation showing the ini-tial normal faulting along the above-mentioned fault. The position of photo was shown on the a by black box. d: The stereogram showing the attitude of fault (F), bedding (b) and brittle-ductile shear zone (S.Z.) with tension gashed. For the location of photograph, please refer to the Fig. 3.

Considering the interpretation made by Shahidi *et al.* (2008) and (2011), Zanchi *et al.* (2006) and Fürsich *et al.* (2009a, 2009b), so far several scenario presented for the Late Triassic-Jurassic evolution of the Alborz Range: Late Triassic-Early Bajocian syn-sedimentary extension that led to Mid-Late Jurassic proto-Caspian oceanic basin (Shahidi *et al.*, 2008, 2011); late Triassic-Early Jurassic extension due to peripheral bulging of the stable area located south of the main collision zone (Zanchi *et al.*, 2006); onset of rifting in Central Alborz started in Early Toarcian (Early Jurassic) followed by increasing subsidence in Alanian and finally onset of sea floor spreading in Bajocian (Fürsich *et al.*, 2009a, 2009b; Wilmsen *et al.*, 2009). Currently, it is difficult to propose which of these scenarios or any other substitution may provide a better picture for geodynamics of the Central Alborz during the Late Triassic-Jurassic. The Early Cimmerian orogeny led to positive inversion of inherited faults such as Mosha and Hasanakdar in the study area, north-verging tight folds and foliation exposed in portions of the south Central Alborz (Ehteshami-Moinabadi *et al.*, 2012; Ehteshami-Moinabadi, 2013, 2014). Some of these folds are cut and displaced by high angle transverse faults with normal components (e.g. Figs. 4 and 6).

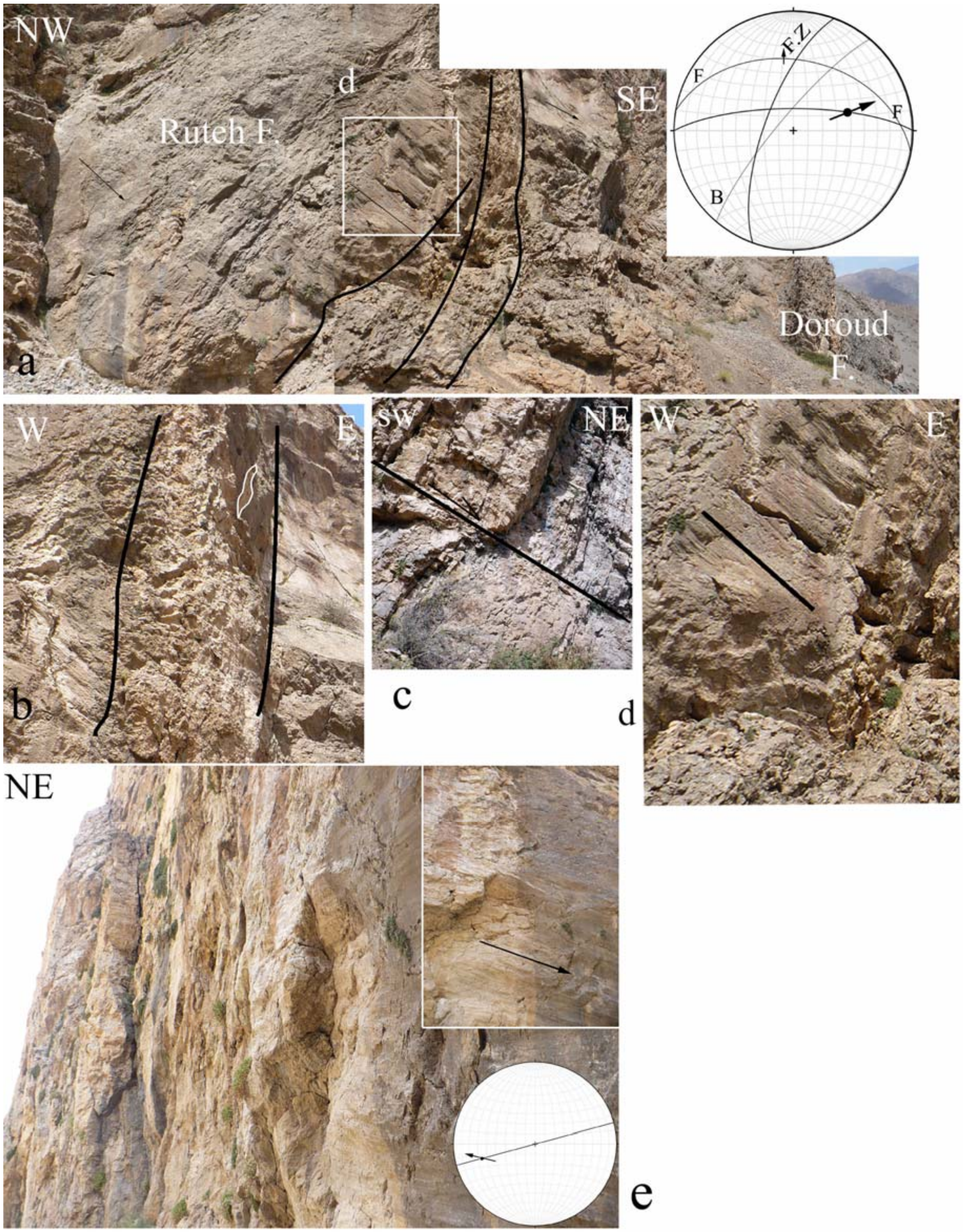

Figure 11. a: A look of a fault showing its >1 meter wide fault zone. The fault cut the Permian Ruteh Formation. Fault zone consists of fault breccias (b). Slickenside faults (a and d) and nearby normal faults (c) show a normal component of activity along the fault. e: A large slick-enside vertical fault with striation that exposed due to erosion in one of fault blocks along a large cliff (with more than 50 m height) in the Permian Ruteh Formation. The fault goes con-tinues westward utile it die out in the Shemshak Group. The striation on the fault surface shows a strike slip motion with normal component for the fault. For the location of photo-graphs, please refer to the Fig. 3.

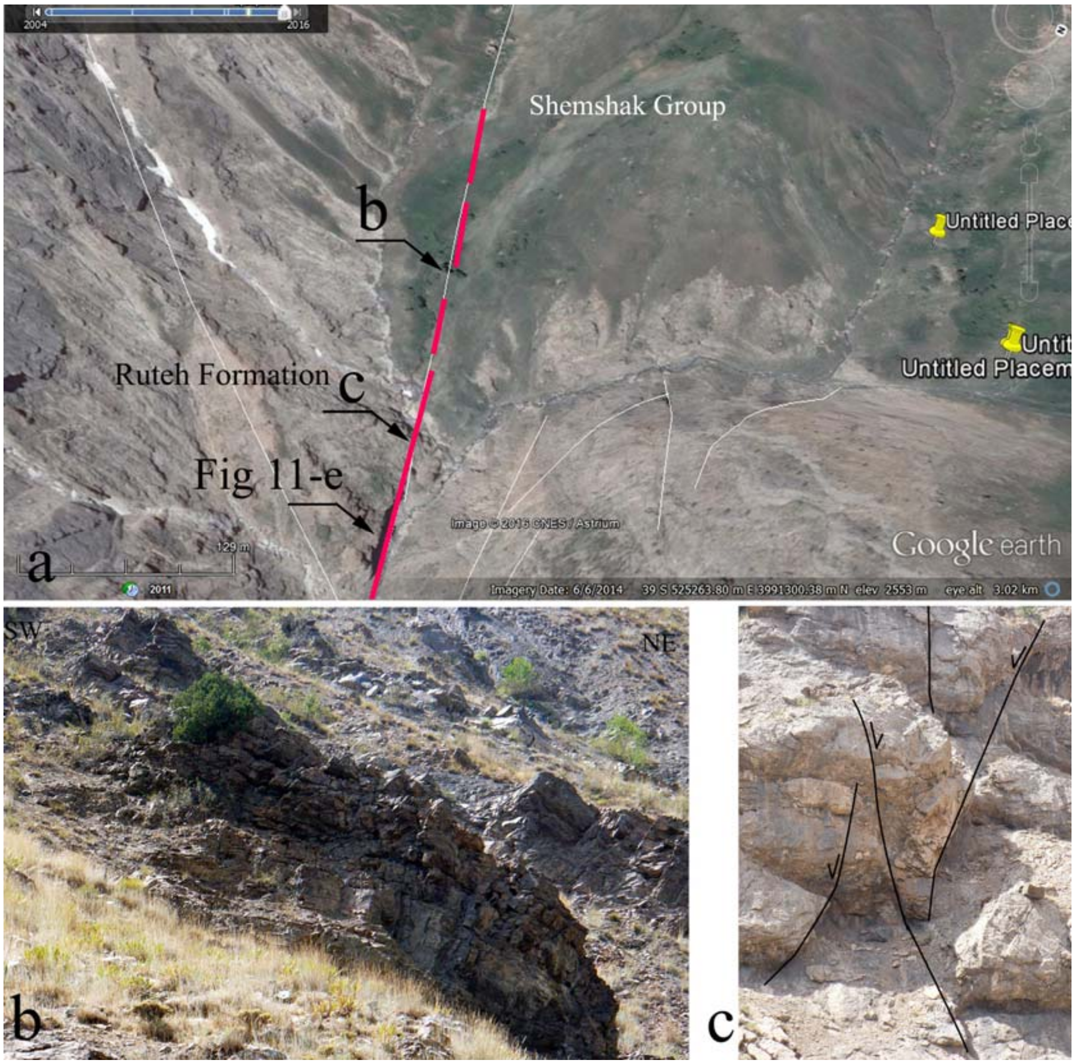

Figure 12. a: Satellite image (Google Earth, 2016) showing the westward continuation of large fault introduced in Fig. 11e. Continuation of the fault in the Shemshak Group is not clear, be-cause of regular exposure of rocks (b), while the fault has a clear fault zone within the Permian Ruteh Formation (c). For the location of photographs please refer to Fig. 3.

The evidence of layer-parallel to oblique stretching that led to boudinage of Permian and Triassic rock beds is widespread in various portions of the study area from Dizin (Fig. 2), Hasanakdar (Fig. 9) and also other portions of the region, most of which show an overlapping setting of boudin segments. However, this evidence may be a local structure or due to sedimentary loading, if it is not supported by other contemporary extensional structures in same rock units such as large to medium sized slickensides with normal striations (e.g. Figs. 8 to 11), extensional fractures and veins (Figs. 2 and 9), distinct normal faults (Figs. 9a, 10, 11e). Assemblage of extensional structures and high angle faults with sign of early normal component of displacement (Figs. 2, 3, 5, 9, 10) in Permian to lower Jurassic rocks of Hasanakdar and Dizin areas more emphasize on a regional extensional activity after Triassic. The problem is the time of formation of presented structures. Additionally, the existence of large high angle faults showing slight reverse motion in the Nesa area (e.g. Nesa Fault) and many smaller faults with primary normal displacements in the Shemshak Group may confirm the proposition of normal faulting during the Jurassic in the study area where the Taleqan and Nesa faults are examples of large originally normal faults formed during this event (Ehteshami-Moinabadi, 2013). These extensional structures experienced tectonic inversion in the Late Cretaceous-Early Paleocene that could change the attitude of them. Rotation of originally normal faults is a known consequence of inversion from analogue modeling and natural examples (.g. McClay, 1989; McClay & Buchnan, 1992; Sibson, 1995). The Jurassic timing of these normal faulting in the Nesa and Hasanakdar area is proposed by this fact that these fault continues in the portions of the Shemshak Group and die out without a clear continuation within the younger rocks of Cretaceous. For example, Fig. 12a shows the satellite image of the large fault introduced in Fig. 11e. The fault continues form this point toward west in the Permian Ruteh Formation with clear interruption of rock units (Fig. 12c), but its continuation within the Shemshak Group has no clear evidence where the bedding has an orderly situation (Fig. 12b). In another case, the Fig. 13 displays the field and satellite view of the large originally normal fault explained in Fig. 11a and b, where its northern termination slightly has entered in the Shemshak Group, but is covered by regular beds of the group toward north.

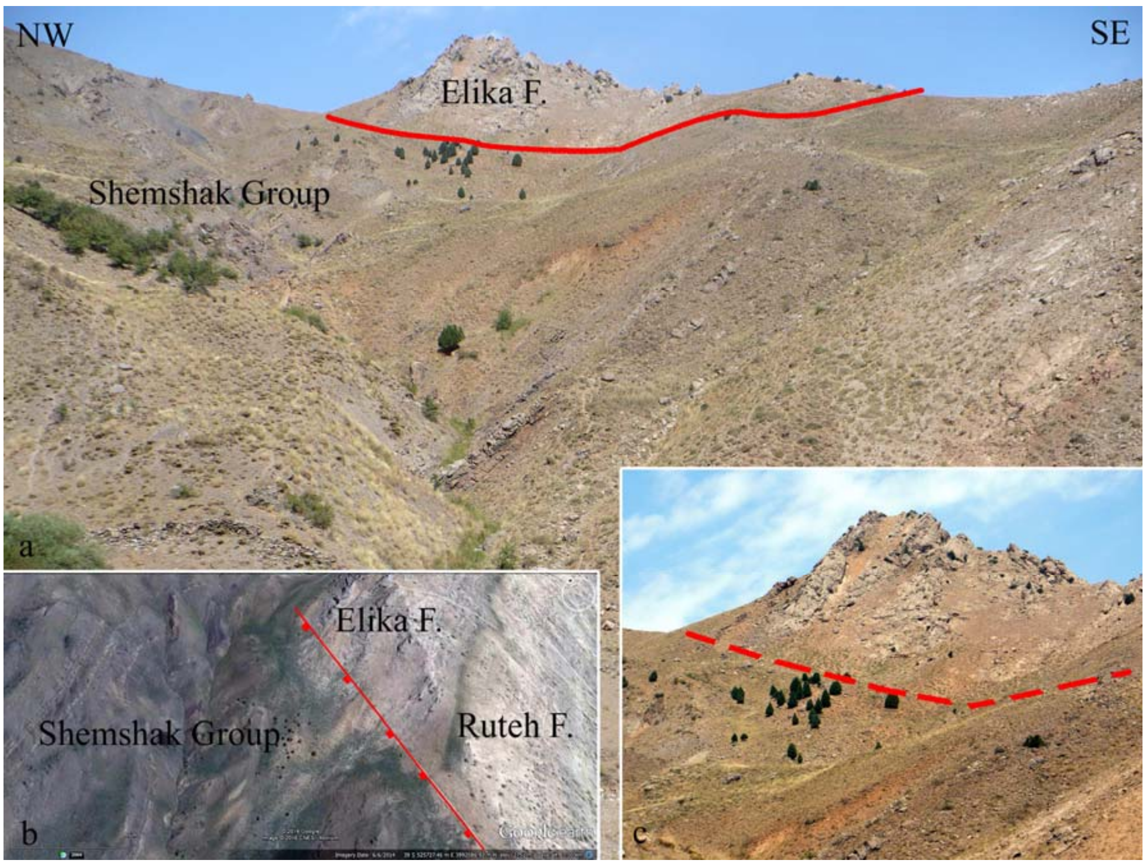

Figure 13. Field (a and c) and satellite images (b) (Google Earth, 2016) of the originally normal fault introduced in Fig. 11a and 11b where it is sealed by regular succession of the Shemshak Group. For the location of photographs please refer to Fig. 3.

The study on Mesozoic geodynamic of the Alborz Range is important from other aspects. For example, SEDEX-type ore deposits related to the Middle Cimmerian exists and studied in surrounding regions such as Caucasus, Azerbaijan (e.g. Filizchai deposit; Laznika, 1981; Goodfellow, 2004; Seravkin & Snachev, 2012). Similarly, recent investigations report that Pb derivation from the source(s) in Pb-Zn ore deposits in the Alborz Range and Central Iran is related to orogenic activities that occurred during the Mesozoic to Cenozoic. In the SEDEX type ore deposits the (normal) faults served as fluid conduits that focused hydrothermal brines from underlying strata onto the sea floor to form the deposits (Emsbo, 2009).

Conclusions

The Mesozoic evolution of Northern Iran is under influence of Cimmerian events. The documented extensional structures in the Permian to Early and Middle Jurassic rocks of the Central Alborz include high angle transverse faults with normal components that cut north-verging folds formed in the Early Cimmerian, homogenous early stage stretching such as layer-parallel to oblique boudinage of Permian and Triassic rocks in various portions of the study area accompanying with extensional-fibrous fractures, tension gashes in brittle-ductile shear zones, large to medium scale slickensides with normal striations and distinct normal faults. Assemblage of high angle faults with sign of early normal component of displacement in the Permian and to Early and Middle Jurassic more emphasize on a regional extensional activity after Triassic. Continuation of the normal faults in the Shemshak Group and their sealing with upper beds of the Group may be an evidence for the Jurassic timing of these normal faulting. Many of faults have have experienced a positive inversion, possibly during the Late Cretaceous-Early Paleocene. This tectonic inversion could change the attitude of original extensional structures. Study on various aspects of Mesozoic geodynamic of the Alborz Range, especially the Middle Cimmerian is important to infer the extension direction and also for mineral resource studies.

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