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TECTONIC ANALYSIS OF THE CIMMERIAN CONTINENTS BETWEEN ARABIA, INDIA AND TURAN PLATES

by

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ABSTRACT

Paleomagnetic, geological, and remote sensing data (TM data) provide evidence that the Cimmerian Continent in the Iranian Plateau (C.C.I.) is actually a part of the African-Arabian continental plate. A compilation of presently available paleomagnetic pole positions from C.C.I., Pakistan, and India indicates a close similarity in paleo-pole positions. This suggests that the C.C.I. was part of the African-Arabian Continent (Gondwana), while its dissimilarity with the pole position of the Turan Plate (Eurasia), suggests that Paleotethys separated these two continents in late Paleozoic-early Mesozoic time. Analysis of the tectonic evolution of the northern margin of the C.C.I. shows that the Hercynian orogeny is not recorded to the south of the geo-suture line.

The progressive counterclockwise motion of the African-Arabian Plate, coupled with the buoyancy factor, resulted in a continent-continent collision along the MRT-MKF line, which introduced a right-lateral component to the MRT, MKF, and their southeastern extension, the Baghan-Germab fault line. The right-lateral movement along the above faults is similar to the sideways motion between the eastern Mediterranean and the Anatolian Plates.

There are fundamental differences in paleomagnetic pole position, stratigraphy, and orogenic records between the western structural domain (alpine realm) and eastern structural domain (epi-Hercynian realm) in Binalud Mountains. These structural domains are located on the west and east sides, respectively, of the Baghan-Germab right-lateral strike slip fault. The presence of rocks with older orogeny (Hercynian) in the Eastern Binalud suggests that this region is structurally related to the Turan Plate (southern part of Eurasia). It is therefore concluded that Kopeh Dagh fold belt is not a uniform continuous basin as suggested by previous workers. The eastern part belongs to a foredeep of the Turan Plate (epi-Hercynian) and the western part was connected to the Cimmerian Continents through the Western Binalud Mountains. The dynamic analysis of the Kopeh Dagh geo-suture line demonstrates a north-south trending compressional stress, which is tectonically active at the present time.

KEY WORDS

Iran, geotectonics, suture zone, Cimmerides, paleogeography.

1. INTRODUCTION

The present study is an attempt to investigate the nature and the tectonic evolution of the Paleotethys suture zone from the eastern edge of the Black Sea, eastward to the Herat-Hindu Kush lineament.

The Cimmerian Continent in the Iranian Plateau (C.C.I.) is enclosed between two marginal active fold thrust moutains belts : the Zagros fold thrust belt to the southwest, and the Kopeh Dagh fold thrust belt to the northeast (fig. 1). The Zagros fold thrust belt is enclosed between the Main Zagros Thrust (with a right-lateral strike slip component) on the north and the Precambrian Arabian Plate on the south. The Kopeh Dagh fold thrust belt is situated between the Main Kopeh Dagh reverse fault on the north and the Central Iranian microplates on the south (fig. 1).

The suture line between Eurasia and Gondwana is located in the northern part of the C.C.I. It consists of a series of northwest-southeast trending reverse faults with apparent right-lateral strike slip motions. The linear suture zone consists of : (1) the Main Range Thrust (MRT), and (2) the Main Kopeh Dagh Fault (MKF) which continues eastward into the Ashkhabad and the Baghan-Germab

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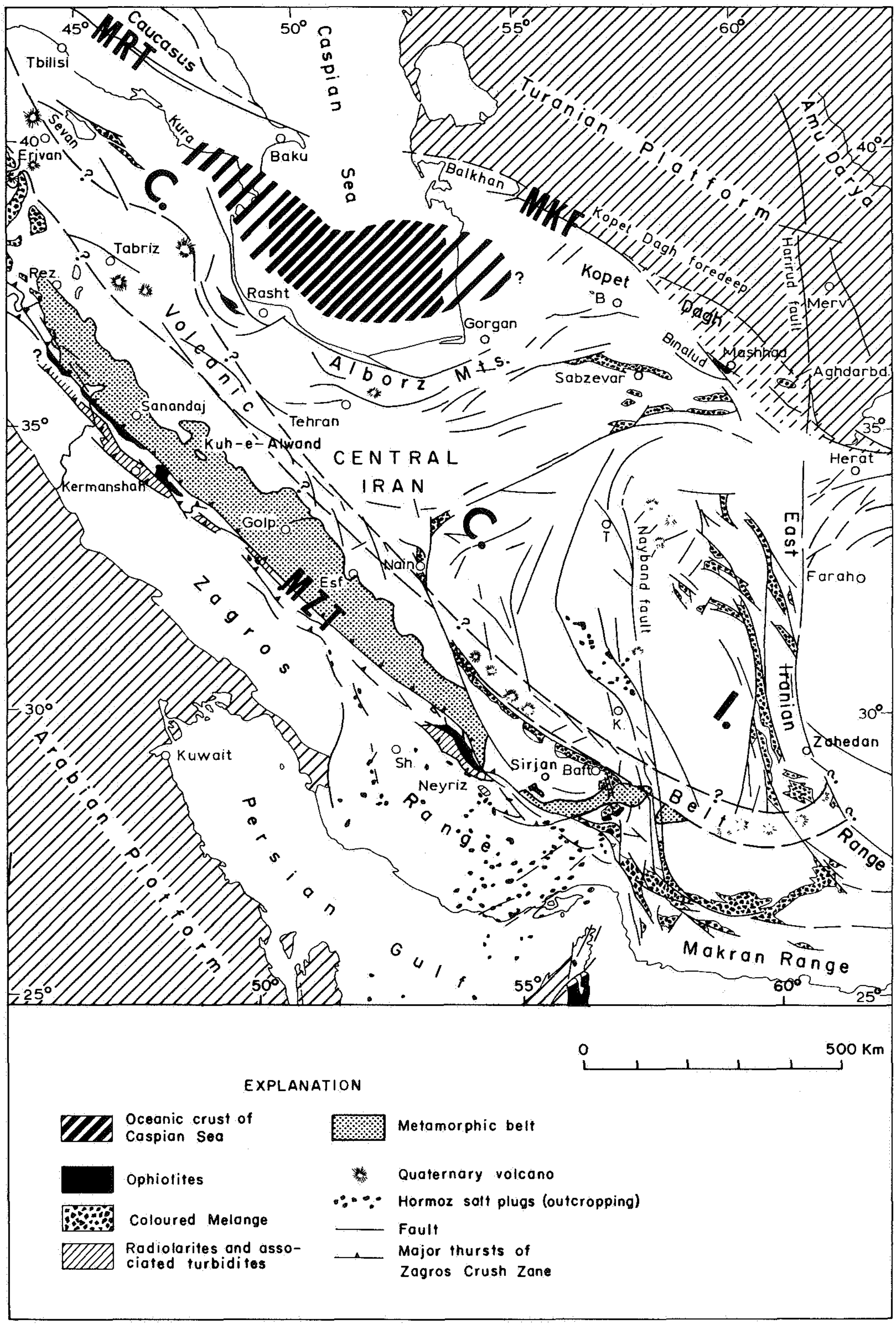

Figure 1. : Tectonic setting of the Cimmerian Continent (Central Tethyan Orogenic Belt). (Modified from Stocklin, 1968, 1977).

fault line (fig. 5) and Herat-Hindu Kush lineament in Afghanistan. The Apsheron-Balkhan fault parallels the suture zone and forms a ramp structure between the Southern Caspian Sea, with oceanic crust, and the Central Caspian, which is apparently floored with a continental lithosphere.

To analyze the tectonic evolution of the northern margin of the C.C.I., geologic, stratigraphic, and paleomagnetic data has been compiled and critically reviewed along with some lineament data (TM data), from this region. The Kopeh Dagh sedimentary accretion zone (approximately 70 km wide) was subjected to crustal shortening of about 15 % during Neogene time. The sedimentary cover consists of an approximately 10 km thickness of Mesozoic-lower Tertiary sediments. The Kopeh Dagh basin probably did not evolve into an oceanic crust as suggested by previous workers (Berberian & Berberian, 1981).

Convergence of the colliding plates along the MRT-MKF suture line continued until continent-continent collision began between the two plates in

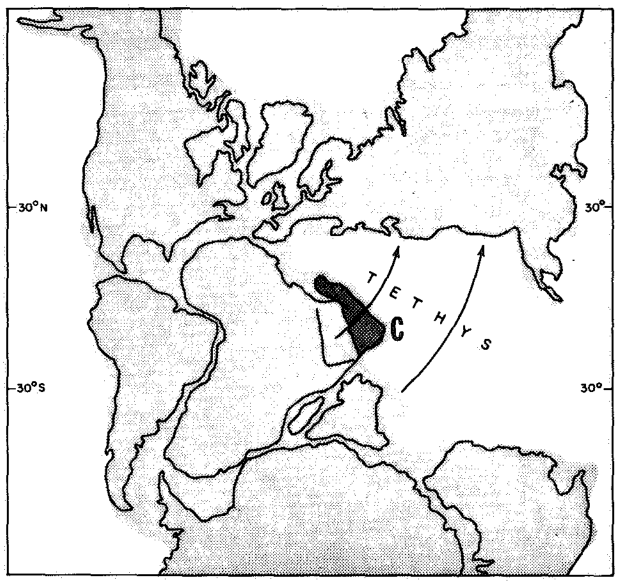

Figure 2. : Paleogeographic map showing the tentative reconstruction of the continental (stipple) and ocean crust in the early Mesozoic era. The Cimmerian Continent (C) include : Southern Turkey, Iranian Plateau, Central and Southern Afghanistan, Salt-Range Pakistan, Pamir and Tibet.

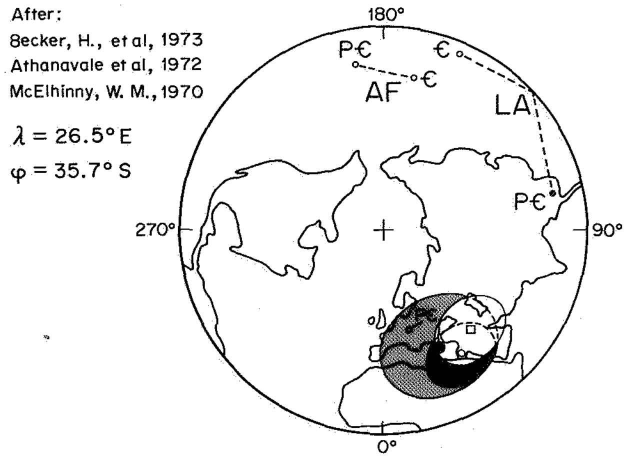

Figure 3. : Pole position and the cone of confidence of the Intra-cambrian rocks of C.C.I. (solid circle), lower Cambrian rocks from Indian Plate (square), and Pakistan (open circle). Modified from Becker *et al.* (1973), Anthanarale *et al.* (1972), and McElhinny, W.M. (1970).

the Triassic. At this stage the paleotethyan oceanic lithosphere was completely subducted and assimilated underneath the Cimmerian Continent. Afterwards, the displacement was converted into

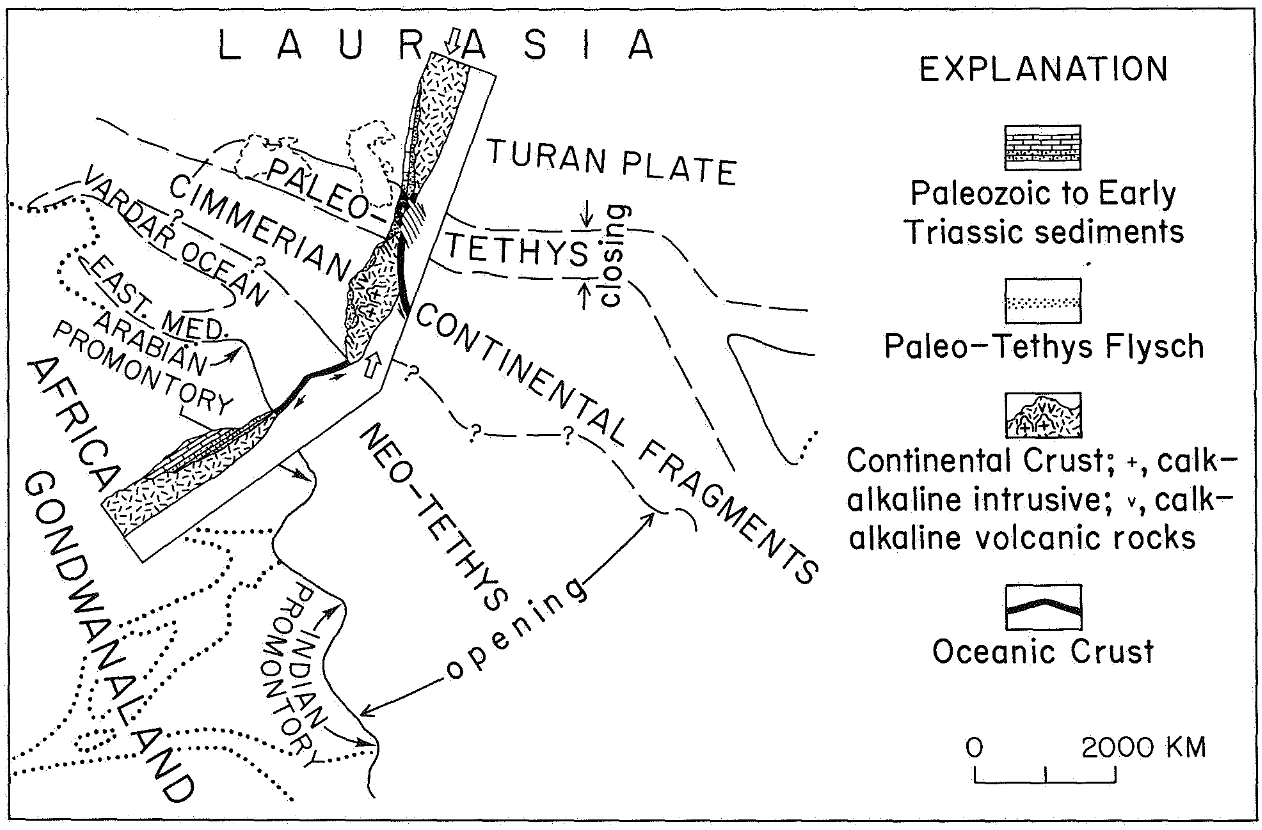

Figure 4. : Paleogeographic reconstruction of the Cimmerian Continent, and its relation to the paleotethys and the Neotethys Sea. Opening along the Neotethys Sea was probably contemporaneous with closing of the Paleotethys during the late Permian - early Triassic time. (Modified from Sengor, 1979).

intracontinental deformation. Argand (1924) described a similar situation from the Himalayas and the Tibetan Plateau, as the Indian subcontinent subducted underneath Eurasia, causing an intracontinental compressional deformation in the overriding platforms. Argand's model disregards the buoyancy factor as suggested by McKenzie (1969). Intracontinental shortening and thickening of the continental lithosphere in the Kopeh Dagh fold thrust belt have provided an avenue for sideways motion (right-lateral) along the suture zone, a situation similar to the plastic rigid indentation, continental collision model suggested by Molnar and Tapponnier (1975). The Cimmerian Continent was thickened by : (1) extensive magmatism and regional metamorphism, and (2) by compressional deformation resulting in folding and reverse faulting. Crustal thickening to an average of 15 km has also been observed in the oceanic lithosphere of the Caspian Sea (Berberian, 1983).

Hercynian intrusive rocks are exposed to the north of the suture zone (Khain, 1976). To the east of Mashhad, Hercynian ultrabasic rocks are associated with granitic and granodioritic intrusive bodies along the southeastern extension of the Baghan-Germab right-lateral strike slip fault (fig. 5). Some questionable exposures of Hercynian intrusive rocks have been reported from the Cimmerian-Continent. These rocks are associated with pre-Permian metamorphic rocks, on the Iranian Plateau southwest of Sirjan (Sabzehei *et al.*, 1970 ; Ricou, 1974).

The Bojnurd-Mashhad depression separates the gently-folded Kopeh Dagh fold thrust belt from the tightly-folded and thrusted Alborz Moutains. The fold axes of the Kopeh Dagh diverge in the west against the Caspian Sea oceanic block ; in the north they are delimited of the MKF on the Kopeh Dagh foredeep, which is the marginal depression of the Turan Plate in Central Asia. The Turan Plate is defined as an epi-Hercynian platform where the folded Hercynian substratum is covered whith younger sediments of Triassic age (Volvosky *et al.*, 1966). The Hercynian orogenic activity is characterized by several unconformable surfaces in the Carboniferous-Permian sequence and by extensive pyroclastic deposits. The suture zone defined along the north edge of the Cimmerian Continent marks an ancient continental margin (Paleotethys suture zone), between Eurasia to the north (Hercynian realm) ; and Gondwana to the south (Alpine realm). The juncture between the Turan Plate and the C.C.I. extends eastward along the Herat-Hindu Kush lineament. The magmatic belt and the ophiolite occurrences at Mashhad, marks this tectonically important boundary between Eurasia and Gondwana (figs. 1 and 5).

2. DISCUSSION

This paper is aimed at : (1) elucidating the relationships among the major tectonic features of the MRT and MKF ; (2) determining the structural evolution of the suture zone between the Turan Plate (Eurasia) and the C.C.I. (Gondwana) (fig. 1) ; (3) interpreting the paleotectonic setting for precollisional time (fig. 4) ; and (4) relating the Cimmerian Continent to Africa-Arabia (Gondwana).

The Paleotethys suture zone is a fault-bounded linear structural feature which consists of two very different tectonic units : the Kopeh Dagh fold belt in the south with a Mesozoic substratum, and the Turan Plate with a Hercynian substratum in the north. The Caspian oceanic crust is a unique compressional crust which probably comprises a relict of the Paleotethys Sea (fig. 4).

The contour map of the Moho surface in the Kopeh Dagh fold belt (Peive & Yanshin, 1979) demonstrates a 45 km thick crust in northern Kopeh Dagh. The depth to the Moho increases to the south, reaching to approximately 50 km where the belt adjoins the central Iranian Plateau, along several reverse faults.

During the late Permian, the Cimmerian Continent was detached from the African-Arabian plate along the Neotethys divergent boundary by continental rifting and alkali volcanism, which was followed by sea-floor spreading during late Triassic time (figs. 2 and 4).

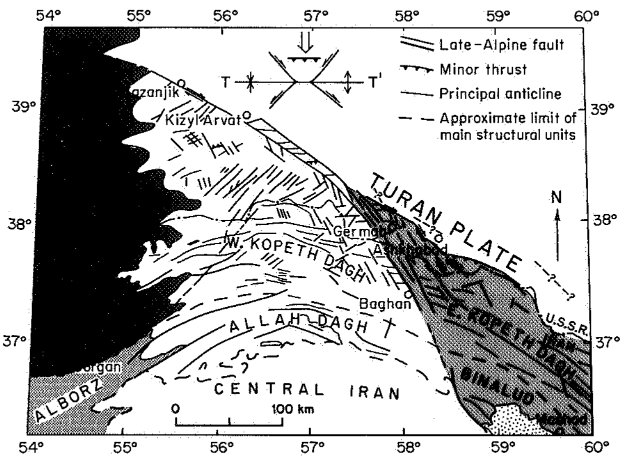

Figure 5. : Tectonic map of Kopeh Dagh, showing the main Kopeh Dagh (Kopeth Dagh in this figure) geo-suture zone, and the major structural domains : Eastern and Western Kopeh Dagh and the Caspian depression in the northern margin of the Central Cimmerian Continent.

The Cimmerian Continent collided the Eurasia (Turan Plate) along the MKF convergent boundary in late Triassic time (figs. 1 and 5). The northwestward movement of the Cimmerian Continent was associated with an approximately 40° counterclockwise rotation. As a result of this continent-continent collision and rotation, a right-lateral motion was introduced to the MKF and MRT. The Neotethys began closing in the late Cretaceous-early Paleocene, and final closure was completed during the late Miocene-early Pliocene (fig. 4). The nature of this geo-suture zone cannot be identified without a more detailed study of the thick post-Paleozoic sediments along the Herat-Hindu Kush lineament.

Surface, subsurface, and paleomagnetic evidence (fig. 3) suggests that during the Paleozoic, the central Cimmerian Continent was a northern extension of the epi-Baikalian continental plate of Arabia, a part of Gondwana. The Eurasia continental plate margin during the Paleozoic was north of the MRT and MKF line. The Paleotethys was closed by southward subduction of the oceanic crust underneath the Cimmerian Continent. This lead to Hercynian deformation of this plate, and continent-continent collision between Eurasia and Gondwana (fig. 5).

The folds in the Western Kopeh Dagh fold belt are asymmetrical. The northern flanks dip gently northward whereas the southern flanks are thrusted and dip steeply. The folds in the Eastern Kopeh Dagh fold belt are symmetrical. These folds are cut by several transverse conjugate strike slip faults, e.g., the Baghan-Germab right-lateral strike slip fault (fig. 5), which delimits the eastern boundary of the Cimmerian Continent in this area (Huber, 1978).

The Baghan-Germab fault is an active right-lateral strike slip fault which separates the Eastern Binalud Mountains from the Western. An average rate of right-lateral displacement of 4-5 cm/yr has been suggested by Tchalenko (1975) and Afshar-Harb (1979), comprising a total transverse offset of 9 km across the fold axes.

The writer believes that the Western Binalud (fig. 5) belongs to the C.C.I. which was part of the African-Arabian plate (Gondwana) during pre-Permian time, whereas the Eastern Binalud Mountains (Mashhad and the Ashkhabad regions) belong to the southern part of the Turan Plate (Eurasia). They did not join together until the Permian period (fig. 4). The Devonian-Carboniferous sequences present here, have counterparts in northern Afghanistan, north of the Herat-Hindu Kush lineament. The Eastern Binalud represents a marginal strip of the Hercynian realm of central Asia (Turan Plate), which was overprinted by the Alpine realm.

The comparison of the paleo-pole position for the C.C.I., India, Arabia, and Pakistan shows a close correlation between these continents (fig. 3). During early Triassic time, the Paleotethys closed as the Neotethys opened along the Main Zagros Thrust (fig. 1). It has been suggested by Wells (1969) that collision of the Arabian plate with the Cimmerian Continents and closing of the Neotethys along the MZT was related to the opening of the Red Sea during the early Miocene and continued into the late Miocene and Pliocene.

Landsat 5 Thematic Mapper analysis of the Main Range Thrust and the Main Kopeh Dagh Fault provides significant information regarding the structural evolution and timing of deformation of the exposed and buried portions of the Paleotethys geo-suture zone. The linear Paleotethys geo-sutre zone displays two thrust faults and a distinct right-lateral strike slip fault striking northwest-southeast. From west to east these are : (1) the Main Range Thrust ; (2) the Main Kopeh Dagh Fault ; and (3) the Baghan-Germab right-lateral strike slip fault. The elongated asymmetrical folds that are almost parallel to the exposed thrust faults have apparent right-lateral movements. The fold axes are cut by strike slip faults that run obliquely to the thrust faults. Detailed analysis of the imagery provides additional structural information. For example, the exposed faults (Main Range Thrust and Main Kopeh Dagh Fault) to the west and east of the Caspian Sea are on trend with a topographic feature in the Caspian Sea which separates the Southern Caspian from the Central part of the sea (the Aspheron Balkhan Fault line). These northwest-southeast trending fault lines are associated with continent-continent collisional deformation.

In addition, several linear topographic features that have not been mapped previously were identified on the imagery. The most obvious ones are northeast-trending lineaments transverse to the fold axes (fig. 5). A deformational model constructed for dynamic analysis of the structures present in the area, suggests a north-south compression, which is compatible with the inferred collision event and continued crustal shortening (fig. 5).

CONCLUSIONS:

This study has shown that the Main Range Thrust-Main Kopeh Dagh-Baghan-Germab faults delineate a distinct linear feature which is located at a juncture between the Turan Plate (Eurasia) and the Cimmerian Continent (Gondwana).

Recently obtained lineament information (TM data) shows that the Hercynian realm on the north, and the Alpine realm on the south are joined along a densely-fractured zone (geo-suture) trending northwest-southeast. In the Iranian Plateau this geo-suture marks the location of an oblique convergence between the Cimmerian Continent and the Turan Plate as the Paleotethys closed during late Paleozoic-early Mesozoic time. The geo-suture is manifested by transverse and compressive displacements. The direction of transport has changed from southwest-northeast to south-north, a 40° counterclockwise rotation introducing a chip-off type faulting.

The available geologic and seismic data seem to justify the interpretation that the collision zone along the geo-suture zone is tectonically alive and that active shortening is taking place at the present time. The dynamic analysis of the structures present in the area, postulates a north-south compression, which is consistent with the presumed collision event and continued crustal shortening.

REFERENCESS

AFSHAR-HARB, A., 1979 - The stratigraphy, tectonics and petroleum geology of Kopeh Dagh region, northern Iran. Ph. D. Thesis.

Petroleum Geology Section, Royal School of Mines, Imperial College, London.

ARGRAND, E., 1924 - La tectonique de l'Asie. *C.R. XIIIème Congr. Géol. Intern.*, 1922 Liège, 171-372.

ATHANAVALE, R.N., HANSRAJ, ASHA & VERMA, R.K., 1972 - Paleomagnetism and Age of Bhandar and Rewa Sandstones from India. *Geophys. J.*, ***28***: 499-599.

BECKER, H., FORSTER, J. & SOFFEL, H., 1973 - Central Iran, a former part of Gondwanaland ? Paleomagnetic evidence from Infra-Cambrian rocks and iron ore of the Bafq Area, Central Iran. Z. *Geophysics*, ***39***: 953-963.

BERBERIAN, M., 1983 - The Southern Caspian : a compressional depression floor by a modified oceanic crust. *Can. J. Earth Sci.*

BERBERIAN, F. & BERBERIAN, M., 1981 - Tectono-Plutonic Episodes in Iran. Zagros-Hindu Kush-Himalaya Geodynamic Evolution. *Amer. Geophysical Union, Geodynamic Ser.*, *3*: 5-32.

HUBER, H., 1978 - Geological map of Iran, 1:1 000 000 with explanatory note. *NIOC, Expl. & Prod. Affairs*, Tehran.

KHAIN, V.E., 1976 - The new international tectonic map of Europe and some problems of structure and tectonic history of the continent. *In* : Europe from Crust to Core, Ed. D.V. Ager & M. Brooks, Wiley, London.

McELHINNY, W.M., 1970 - Paleomagnetism of the Cambrian Purple Sandstone from Salt Range, West Pakistan. *Earth Planet. Sci. Letters*, ***8***: 149-156.

McKENZIE, D.P., 1969 - Speculations on the consequences and causes of plate motions. *Geophys. J.R. astr. Soc.*, ***18***: 1-32.

MOLNAR, P. & TAPPONNIER, R., 1975 - Cenozoic tectonics of Asia : effects of a continental collision. *Science*, ***189(4201)***: 419-426.

PEIVE, A.V. & YANSHIN, A.L., Eds., 1979 - Scheme of distribution of continental crusts of various ages in northern Eurasia and relief of the Moho surface scale 1:5 000 000, *Geological Inst.*, USSR.

RICOU, L.E., 1974 - L'évolution géologique de la région de Neyriz (Zagros iranien) et l'évolution structurale des Zagrides. Thèse, *Univ. Orsay*, n° AD, 1269.

SABZEHEI, M., MAJIDI, B., ALAVI-TEHRANI, N. & ETMINAN, H., 1970 - (compiled by W.A. Watters & M. Sabzehei). Preliminary report, geology and petrography of the metamorphic and igneous complex of the Central part of Neyriz Quadrangle. *Geol. Surv. Iran*, Int. Rep.

SENGOR, A.M.C., 1979 - Mid-Mesozoic closure of Permo-Triassic Tethys and its implications. *Nature*, ***279***: 590-593.

STOCKLIN, J., 1968 - Structural history and tectonics of Iran - a review. *Am. Ass. Petr. Geol. Bull.*, ***52/7***: 1229-1258.

STOCKLIN, J., 1977 - Structural correlation of the Alpine ranges between Iran and Central Asia. *Mém. h. sér. Soc. Géol. France*, ***8***: 333-353.

TCHALENKO, J.S., 1975 - Seismicity and structure of Kopeh Dagh (Iran, USRR). *Phil. Trans. Roy. Soc. London*, ***278/1275***: 1-25.

VOLVOVSKY, I.S., GARETZKY, R.G., SHLEZINGER, A.E. & SHREIBMAN, V.I., 1966 - Tectonics of the Turanian plate. *Tr. Geol. Inst. Aka. Nauk SSSR*, Moscow, ***165***, 287 p. (in Russian).

WELLS, A.J., 1969 - The Crush Zone of the Iranian Zagros Mountains and its implications. *Geol. Mag.*, ***106***: 385-394