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STRUCTURAL EVOLUTION AND CORRELATION OF TECTONIC EVENTS IN THE ALBORZ MOUNTAINS, THE ZAGROZ RANGE, AND CENTRAL IRAN.

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ABSTRACT. - There is a close stratigraphic and structural similarity between Alborz Mountains, Zagros Range and Central Iran from Late Precambrian to Early Triassic and from Late Cretaceous to Recent. From Middle Triassic to Late Cretaceous, there is no significant stratigraphic or structural correlation between Alborz Mountains and Central Iran, with that of Zagros Range. The major regional emergences in Alborz Mountains, the Zagros Range, and Central Iran accompanied erosion or non-deposition at the Middle Precambrian - Late Precambrian boundary, at the base of Middle-Upper Devonian, at the Carboniferous-Permian, Permian-Triassic, Triassic-Jurassic, and Jurassic-Cretaceous boundaries, within the Lower Cretaceus, and at the Lower-Middle Cretaceous, Cretaceous-Paleocene, Eocene-Oligocene, Miocene-Pliocene, and Pliocene-Quaternary boundaries.

The Central Iranian volcanic belt may be considered as an arc system aligned parallel to the Zagros trench zone and certainly reflects the orientation of deep-seated tensional fractures in the crust of that area.

Immediately under the Zagros trench zone where the Arabian lithosphere (oceanic crust + peridotie) began to sink, various grades of metamorphism were produced along a metamorphic front. The early granite intrusions were caused by the same tectonics that produced the metamorphic belt.

Presence of volcanic and metamorphic belts in the immediate hinterland zone of the Zagros Thrust, with distinct ophiolites, may be used for recognition of a subduction zone where the former arc probably was uplifted and incorporated in the Central Iranian continental mass. The volcanic belt presumably can be considered as a manifestation of an upward action along the subduction zone where partial melting by friction and conduction occurred, and/or of a unique deep-seated process, perhaps convection in the upper asthenosphere.

It is believed that the crustal section that underlies the major part of the Zagros Range is not continental and the asthenosphere is higher than normal under the trech zone where rifting and consequent colliding was taking place and where isostatic compensation occurred along the Zagros Thrust zone. As a result, the upper asthenosphere material rose closer to the surface, causing magmatism and metamorphism in Central Iran.

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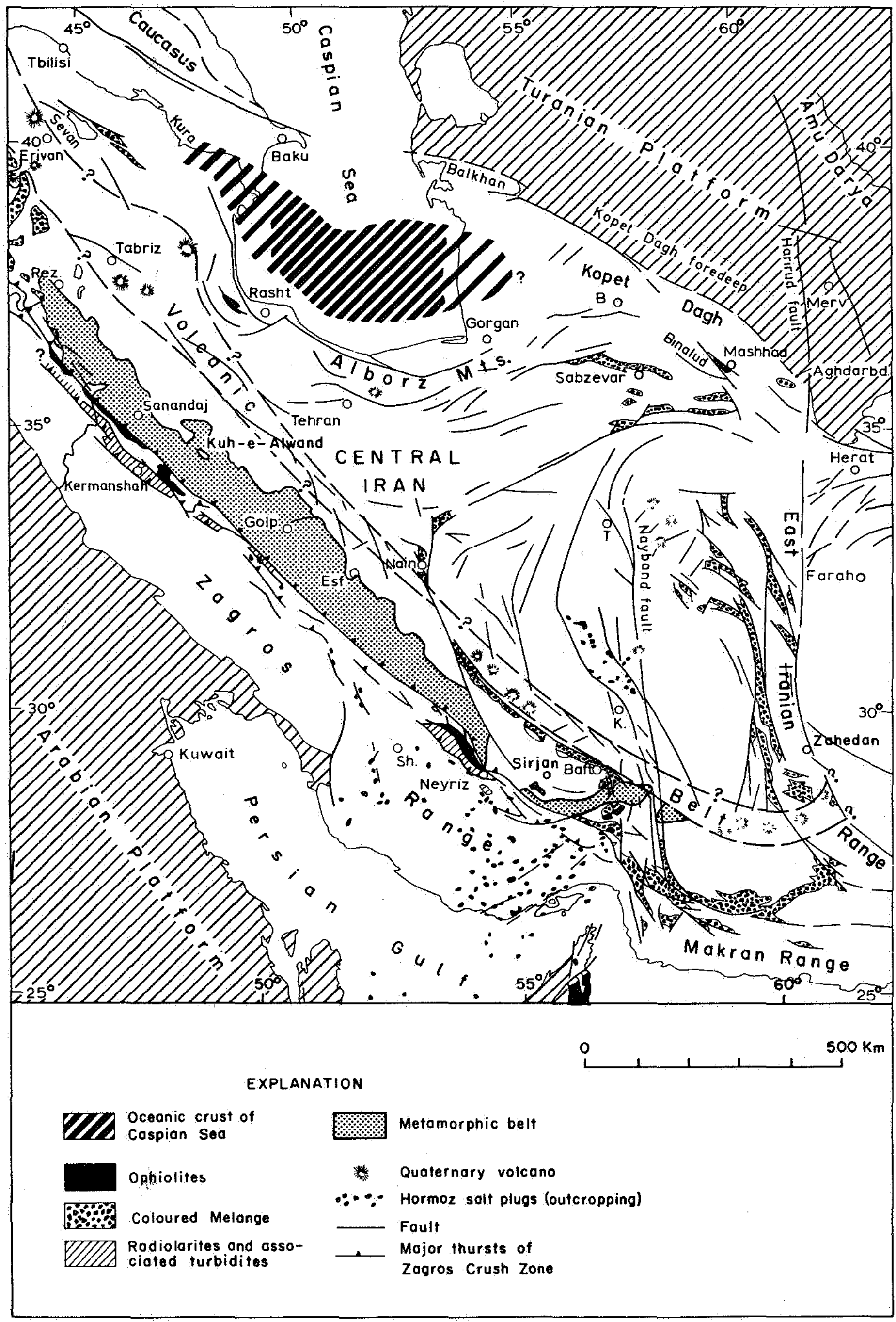

Fig. 1

Map showing major structural zones and ophiolite distribution in Iran and neighboring countries (modified from STOCKLIN, 1974).

INTRODUCTION.

The purpose of this paper is to discuss the structural evolution and correlation of tectonic events in the Alborz Mountains, the Zagros Range, and Central Iran (Fig. 1), from Precambrian through Recent time by means of a tectonic-event correlation diagram (Fig. 2) and an orogenic belt model (Fig. 3).

The Alborz Mountains and Zagros Range are part of one of the two longest mountain belts in the world (the Alpine Himalayan Orogen). They are the youngest of topographically high orogenic belts, and they are sites of Cenozoic orogeny including Pleistocene uplift. The nappe theory of deformation of the Alpine type is not compatible with the structures in Iran (Stocklin, 1968a), and the Iranian structures are strikingly different from those of Alpine type orogen.

The close stratigraphic and structural correlation between the Alborz Mountains, the Zagros Range, and Central Iran suggests that the Iranian-Arabian Platform and part of Gondwana Land were connected from Late Precambrian to Middle Triassic and from Late Cretaceous to Recent time. Absence of significant stratigraphic and structural correlation between the Alborz Mountains, the Zagros Range, and Central Iran indicates that the Zagros Basin was probably separated from the Iranian Plate in Middle Triassic time and rejoined to the Iranian Plate in Late Cretaceous.

The principal structural zones of Iran were uplifted during Late Precambrian time. The uplift is characterized by the presence of the Assyntic Unconformity. Assyntian or Baikalian refers to the basement consolidation as identified by the previous authors (STOCKLIN, 1974), (Fig. 2).

During epi-Baikalian time through the Paleozoic Era, the Iranian Plateau was a rather stable platform, and only epirogenic movements occurred trhoughout the area (STOCKLIN, 1968a). A regional paraconformity, present in both the Alborz Mountains and Central Iran, is locally characterized by a zone of phosphate or fire-clays in the Alborz Mountains. A regional disconformity is present at the base of the Permian in the Alborz Mountains, Central Iran, and the Zagros Range (Fig. 2).

From early Mesozoic through Cenozoic time the Iranian Plate was differentiated into several structural provinces (Fig. 2). The Zagros Basin developed by rifting and openings of the Neo-Tethys Sea (STOCKLIN, 1974), approximately along the present location of the Zagros Thrust in Middle Triassic time. Iranian-Arabien plates rejoined contemporaneously with sea-floor spreading of the Atlantic Ocean and moved the African-Arabian Plate to the north in the Early Maestrichtian epoch.

According to ARGAND's interpretation (1924), the Iranian Plate belonged to the realm of the Tethys. But after TAKIN (1972) introduced the concept of sea-floor spreading and continental drift to Iranian geology, the new concept of evolution for the Iranian Plate has been considered increasingly. However, TAKIN's approach for explaining the Central Iranian volcanism needs more independant facts to be proved. FARHUDI and KARIG (1977) have indicated the Makran of Iran and Pakistan as an active arc system. In the present study the volcanic belt of Central Iran and the metamorphic belt northeast of the Zagros Thrust are explained in the light of plate tectonic theories.

The term metamorphic belt used in this paper refers to the Sanandaj-Sirjan-Ranges (STOCKLIN, 1968a; HUBER, 1978), to the Rezaiyeh-Esfandagheh Orogenic Belt (TAKIN, 1972), or to the Stable Block (Haynes and McQuillan, 1974). As this region is regarded as the metamorphic front for the subduction zone of Zagros, we feel that the term metamorphic belt is more suitable. The metamorphism and granite intrusion in Central Iran might have occurred anytime between Jurassic and Early Tertiary (STOCKLIN, 1968a). It follows that the acid-rock intrusion (early granite intrusion in Figure 3) could have been caused by the same movements that produced the metamorphic belt.

TAKIN's (1972) geologic model was based on large scale continental drift theories (the type of movements suggested by Ricou, 1968, 1970). Alternative ideas were suggested by FALCON (1967,1969), STOCKLIN (1974), SHEARMAN (1976), and KASHFI (1976). However, KASHFI's approach is completely different from those of new concepts of plate tectonics. According to this interpretation the Zagros Range can be interpreted as being the final product of a typical geosynclinal cycle, originally a mobile geosyncline of predominantly compressional nature. He has rejected the idea of plate movements in this area. HAYNES and McQUILLAN (1974) prepared a model for the movements between the Iranian and Arabian plates.

Structurally, Central Iran is an area of desert depressions and ridges. Associated with these structures are northwest-southeast-, north-south- and some northeast-southwest-trending faults, folds, intrusions and volcanic eruptions. It is believed that the Central Iranian volcanic belt was an active arc system trending northwest-southeast (Figs. 1 and 3).

The style of tectonics in the Alborz region is manifested by continental movements having more symmetrical structures and a folding and thrusting trend approximately east-west, associated with some local gravity sliding.

The tectonic structures along the strike of the orogenic belt of the Zagros Range are expressed by asymmetrical folding and thrusting movements. Folding and thrusting were apparently associated with lateral shifting of miogeosynclinal sediments in the form of a décollement over the Precambrian Hormoz Salt and some collapse structures caused by the movement and evacuation of the salt. The collisional impingements producing ophiolite obduction are present in the Zagros Range, Central Iran,and some in the Alborz Mountains.

The origin of the fold and thrust structure of the Alborz Mountains, the Zagros Range, and Central Iran can be explained by a horizontal compression of the earth's crust in the boundary of these areas. Throughout the Iranian Plate this compression still exists.

Although many of the conclusions reached have been previously expressed or implied by STOCKLIN (1968a, b, and 1974), HAYNES and McQUILLAN (1974), TAKIN (1972) and other previous workers, the tectonic-event correlation of the Alborz Mountains, the Zagros Range, and Central Iran and the mechanics of development of the metamorphic and volcanic belts in Central Iran have not been stressed.

STRUCTURAL EVOLUTION AND CORRELATION OF TECTONIC EVENTS.

The tectonic setting of the Alborz Mountains, the Zagros Range, and Central Iran was established by a complex sequence of geologic events which can be summarized and compared as below (Fig. 2) :

1. The Assyntic Orogeny, late in Precambrian time, was an intensive orogenic event associated with general metamorphism throughout the Iranian Plate.

   Precambrian igneous activity was associated with the Assyntian tectonic movement and produced diorite-granodiorite intrusion into the Precambrian metamorphic and sedimentary complexes in Central Iran (HUBER, 1978). During Precambrian time and the Paleozoic Era, the present area of the Alborz Mountains, the Zagros Range, and Central Iran constitued a platform on which marine clastic sediments were deposited in a shelf environment.

   The oldest rock unit in the Zagros region is the Precambrian Hormoz Formation. Precambrian basement rocks may be present at the base of the Hormoz Formation, but because the tectonic

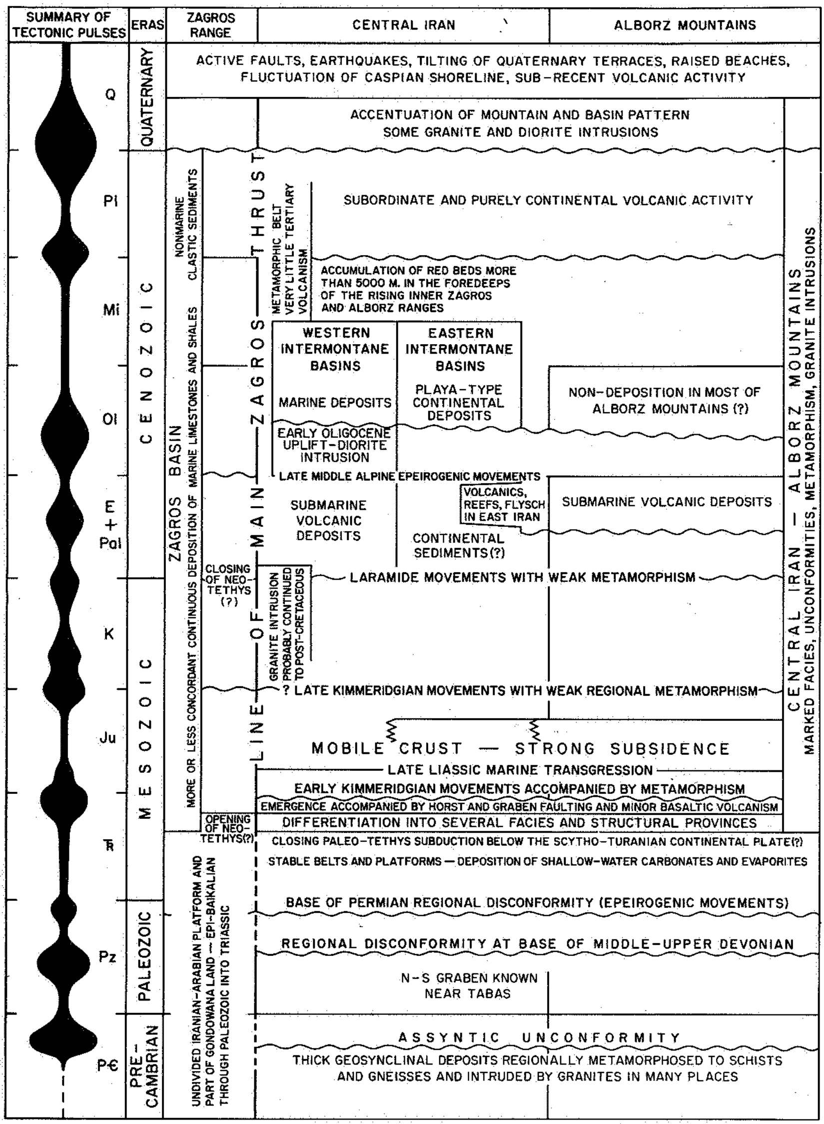

Fig. 2

Chart showing correlation of tectonic events in the Alborz Mountains, the Zagros Range, and Central Iran (compiled from STOCKLIN, 1968a, and 1974 and other sources).

movements at depth are related to décollement in most places in the Hormoz Salt the basement is concealed.

However, in Lurestan (northwestern part of the Zagros Range) there is no Hormoz diapir, and both thrust surfaces lubricated by salt and decollement folding are unknown. This is probably due to the fact that the thickness of salt was not adequate to become mobile. HARRISON (1931) calculated that the salt requirements of the Persian plugs would be met by a bed 50-100 m. thick. Based on observations on young, high plugs, PLAYER (1969) has suggested a maximum probable thickness of about 1670 m. for the Hormoz saline series. Hormoz Salt probably extends across the Kerman (designated as K in Fig. 1) region to the Oman Line (STOCKLIN, 1968b). Whether the Hormoz Salt extended to the Pakistan Salt Range is not clear (PINFOLD, 1944).

2. During the Paleozoic Era, Middle Late Devonian and Permian epeirogenic movements occurred in the Alborz Mountains, the Zagros Range, and Central Iran. They are characterized by a series of sedimentary cycles deposited under stable shelf conditions and were followed by epicontinental or nonmarine sedimentation. The Cambrian-Ordovician rocks are exposed in the fault zones of the Zagros Range and they show close resemblance to the time-equivalent rocks of the Alborz Mountains and Central Iran.

The oldest rock unit exposed in the Zagros Range is of Triassic age, and the Permian-Carboniferous sediments are known in well sections from the Lurestan region. They were deposited transgressively over the eroded lower Paleozoic rocks. The Permian carbonate sequences indicate marine sedimentation in the Zagros Basin. The boundary between the Permian and Triassic rocks is characterized by an emergence accompanied by erosion or non-deposition in the Zagros Basin.

3. Two unconformities are accompanied by emergences at the base and top of the Triassic sediments in the Zagros Range (SETUDEHNIA,1978). During Middle Triassic time, the Iranian-Arabian Plate, which was part of Gondwana Land, separated along the present Zagros Thrust, and the Neo-Tethys Sea was formed, extending from the Major Caucasus to the Zagros Basin. An intense tectogenic event with folding, faulting, and metamorphism occurred in the Alborz region, the Zagros Basin, and Central Iran during Late Triassic time (Early Kimmeridgian movements) and consequent general emergence of positive areas such as that in the northern edge of the Alborz region occurred (ASSERETO et al, 1966), (Fig. 2). This was contemporaneous with the initial and early stages of Alpine Orogeny, when a certain distension and thinning of the crust took place in the subsiding geosynclinal through. A rift somewhat similar to that in the Red Sea probably developed between the Iranian and Arabian plates during Middle Triassic time, drifting the Iranian and Arabian plates to the northeast and southwest respectively and developing a new oceanic crust in Late Triassic time (STOCKLIN, 1974). The northeastward compression of the Arabian Plate produced a trench zone (Fig. 3) and caused folding and faulting in the Alborz region and Central Iran, closing most of the Paleo-Tethys Sea in the later stages of development.

Our plate tectonic model for the evolutionary development of the structure of the Zagros Range, the metamorphic belt, and Central Iran is based on the assumption that the major part of the Zagros Range is not underlain by a continental crust. NOWROOZI (1972) has explained a plane about 60 km thick (probably of lithosphere) with a dip of 20°NE beneath the Persian Gulf. Association of basalt and gabbro with intruded salt plugs in the Zagros Range suggests that a basement of oceanic crust older than Late Precambrian is probably present beneath the Zagros Range and the Persian Gulf (HAYNES and MacQUILLAN, 1974).

4. Rheto-Liassic coal-bearing sandstones and shales were deposited on an unstable shelf and are overlain generally by marine transgressive sediments, which were deposited during Middle Jurassic time in the Alborz region and Central Iran. This marine environment was accompanied by a strong crustal subsidence and persisted trhough Late Jurassic time. The Triassic-Jurassic boundary in the Zagros Basin shows a regional emergence with erosional or non-depositional characteristics. In the Zagros Basin, Early Jurassic time is generally represented by the shallow water carbonates and silty shales which were deposited unconformably over the Triassic rocks. The Upper Jurassic successions in the Zagros Basin consist mainly of shallow-water carbonates.
The passage from Jurassic into Cretaceous time is represented by an unconformity in the Alborz Mountains, the Zagros Range and Central Iran.

5. Late Kimmeridgian tectogenesis (Late Jurassic movements) was characterized by weak regional metamorphism in both the Alborz region and Central Iran. The gently folded sediments were uplifted. They emerged but were subsequently covered by Cretaceous marine sediments with an angular unconformity. The Cretaceous sedimentation in the Alborz region and Central Iran was interrupted by several marine tectogenic pulses (Fig. 2).
The Laramide Orogeny (Late Cretaceous movements) was a very intense tectogenic event in the Alborz region, the Zagros Basin, and Central Iran. During the Laramide Orogeny, the present-day fundamental structural framework of Iranian geology developed.
The effect of the Early Jurassic to recent expansion of the Atlantic Ocean has been to reduce the Neo-Tethys Sea progressively. The South Caspian Basin is characterized by positive gravity anomalies (MILANOVSKII and KHAIN, 1964) and is probably the remnant of the Paleo-Tethys Sea.
Closing of the Neo-Tethys Sea can be related to northward drifting of the African-Arabian Plate, which was active during Late Jurassic anc Cretaceous time when the Atlantic Ocean was spreading. As a result of this drift, the Neo-Tethys Sea was closed in Late Cretaceous time and the Arabian Plate collided with the Iranian Plate (assuming fixed Iranian Plate) along the present Zagros Thrust (Fig. 3).
When the Arabian and Iranian Plates converged, the oceanic edge of the Arabian Plate was thrust below Central Iran, was carried into the asthenosphere, and and eventually melted. Continued convergence led to ensialic splintering and presentday complex deformation and seismicity over a wide zone of Central Iran (McKENZIE, 1970; NOWROOZI, 1972). During this process, the continental crust of the Arabian Plate in the Zagros region was folded independently from the basement in the form of décollement over the Hormz Salt (Fig. 3). The oceanic crust was consumed as the Arabian Plate subducted below Central Iran into the upper asthenosphere (Fig. 3).
Both the volcanic and the metamorphic belts of Central Iran, as well as the ophiolites and the oceanic crust remnants in the Zagros region, can be explained logically by such activities as accreting, transforming and consuming plate margins.
The volcanic belt of Central Iran is believed to be an active arc system which crosses Central Iran in a 2255 km-long belt extending from Turkey to Pakistan. During Early Tertiary time, tensional forces predominated (TAKIN, 1972), with consequent similitaries in eruptive plutons, mainly form fissures and mostly andesite and tholeitic basalt magma (Fig. 3). This belt is parallel to and roughly 150 km. inland from the Zagros Thrust. During Tertiary time, the volcanic belt of Iran appears to have occupied a position similar to present day volcanic belts of Indonesia and Central America (WALKER and BOOTH, 1976), which are

associated with active seismic (BENIOFF) zone and lie 160-325 km. inland from deep oceanic trenches to which they are parallel. It is believed that andesites probably have resulted from partial fusion of the lithosphere plate of Arabia in the Upper asthenosphere under pressure and temperature conditions associated with the Benioff zone and lie 160-325 km inland from deep oceanic trenches to which they are parallel. It is believed that andesites probably have resulted from partial fusion of the lithosphere plate of Arabia in the upper asthenosphere under pressure and temperature conditions associated with the Benioff Zone. DICKINSON and HATHERTON, (1967) have established a relationship between the potash content of an andesite volcano and the depth of the Benioff zone below that volcano. According to this study the composition parameter for andesite (K_2O content in lavas with 55 and 60% SiO_2) changes regularly with distance from foredeep trench of the volcanic arc and hence with depth along the Benioff zone. Future geochemical investigation of this parameter (from southwest to northeast on the volcanic belt) may clarify the relation of Central Iranian volcanism to the descending lithospheric plate of Arabia, beneath the Iranian Plate.

In particular, the water in the sediments overlying the oceanic plate of Arabia (Zagros Miogeosyncline) is believed to provide a hydrous zone in the asthenosphere, in which a basalt veneer partly melts, providing the abundant andesite volcanism and resulting in formation of serpentine (Fig. 3). The interacting of radioactive heating, phase changes, adiabatic compression and frictional heating along the sliding surface of the plate have probably caused partial melting and heat transfer movement of molten material. The temperature variations in the neighborhood of the descending crust of the Neo-Tethys Sea created basalt, andesite flow, and granite intrusions and formation of the metamorphic front of the Central Iran, the metamorphic belt.

6. Paleogene time in the Alborz region and Central Iran is characterized by an unconformity between Cretaceous and Tertiary rocks, indicating a Middle Alpine tectonic phase. The renewed movements in Oligocene time were succeeded by subsidence, as indicated by the transgression of the Neogene sea.

   During Paleocene and Eocene time, the Zagros Thrust developed, and syntectonic and post-tectonic coarse-grained land-derived sediments were deposited in the Zagros Basin. In Early Paleocene time there was an emergence in Alborz and Central Iran. During Late Paleocene and Early Eocene, more than 3000 m. of submarine volcanic pyroclasts (mostly welded green tuffs) were deposited in the Alborz region and most of Central Iran.

7. Intrusion of granite and diorite accompanied copper lead, and zinc mineralization in the Alborz region and Central Iran and was followed by an Early Oligocene tectogenic event. During this event, most of the Alborz region was emergent, and erosion or non-deposition occurred on the Djahrom-Shahbazan platform in the Zagros Basin.

8. Emergence of the Alborz Mountains, Central Iranian Mountains, and the Zagros Range took place after the Pliocene tectogenic phase. The orogenic events were characterized by strong folding, high-angle reverse faulting and subordinate continental volcanic activities.

9. The Late Pliocene and Quaternary tectogenic event was characterized by the accentuation of previously existing mountains and basins. Some granite, diorite, and ultramafic magmatic rocks were intruded following the rejuvenation of the pre-existing faults.

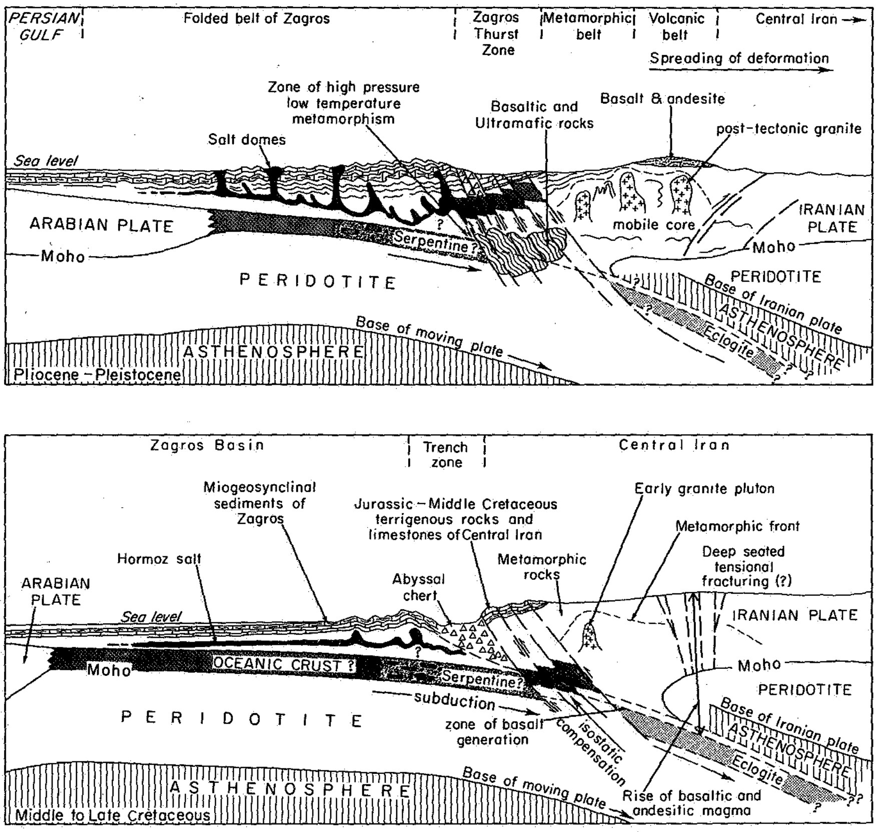

Fig. 3

Schematic model showing development of the Zagros Range and the Central Iranian metamorphic and volcanic belts, from southwest (left) to northeast (right) in Middle to Late Cretaceous time and Pliocene-Pleistocene time. The Iranian plate is held fixed (modified from HAYNES and McQUILLAN, 1974).

The Quaternary beach terraces of the Caspian Sea were tilted, and near-Recent and Recent earthquakes occurred in many parts of the Alborz Mountains, Central Iran, and the Zagros Range, indicating that the Iranian Plate is still tectonically active (NOWROOZI, 1972), and the Alpine Orogeny is still in effect in this part of the world.

CONCLUSIONS.

The undivided Iranian-Arabian Plate was part of Gondwana Land from epi-Baikalian time through the Paleozoic Era and into the Triassic Period. The Zagros Basin and the Arabian Plate were separated from the Iranian Plate in Middle Triassic time and rejoined the Iranian Plate in Late Cretaceous time, as documented by the correlation of the stratigraphic and structural characteristics of the Alborz Mountains, the Zagros Range, and Central Iran (Fig. 2).

The metamorphic belt of western Central Iran is related to the pressure-temperature and convection resulting from continental collision and subduction of the Arabian Plate below the Iranian Plate along the present Zagros Thrust. The metamorphic front developed as basaltic, ultramafic, and some early granite plutons moved upward in Late Jurassic time (Fig. 3).

The volcanic belt of Central Iran can be considered as an arc system of the Zagros subduction zone, where basaltic and andesitic magmas were generated and ascended along the deep-seated tensional fractures in post-Cretaceous time.

It is believed that the crustal sections that underlie the major part of the Zagros Range are not continental and that the asthenosphere is higher than normal under the trench zone, where rifting and consequent colliding of the Iranian-Arabian Plates were taking place, where isostatic adjustment occurred along the Zagros Thrust as the upper asthenosphere material rose closer to the surface, resulting in magmatism and metamorphism in Central Iran.

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