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INTERDEPENDANCE BETWEEN SUB-RECENT CONTINENTAL ALKALINE VOLCANISM AND TECTONISM - A CASE STUDY

by Assad IRANPANAH (*) and

Farhad VAHDATI-DANESHMAND (**).

ABSTRACT. - Detailed field mapping in the Dokkan region (Northwestern Central Iran) had led to the recognition of a set of ten principal eruptive centers (volcanic cones) of post-Pleistocene age, aligned north-south and extending for a distance of about 18 km. In addition, three similar volcanic cones with the same petrological characteristics are mapped striking N30E and extending for a distance of at least 6 km in the eastern Dokhan region. These volcanic cones are composed mainly of olivine, plagioclase An50, volcanic glass and a single pyroxene-augite. Accessory minerals such as the phlogopite-biotite series and some uniformly distributed, very fine-grained magnetite are present in several samples. The phlogopite-bearing augite-olivine basalts approximately correspond to the continental alkaline-basalts reported from various localities around the world. The remarkable compatibility in age (post-Pleistocene) and the resemblance in the mineralogical characteristics between these widely scattered monogenetic volcanic cones suggests that they have probably shared a single deep-seated (40-100 km) alkaline parental magma chamber, and was erupted contemporaneously.

The tectonic environment of these Quaternary volcanism is believed to be the site of the major north-south trending normal faults originating from the basement. Stratigraphic correlation have strengthened the idea of the presence of a north-south trending horst and graben structural system in Dokhan region. This evidence is provided by the abrupt lateral variation in the facies, and the thickness of the Tertiary sediments (e. g. the thickness of the Oligocene-Miocene marine sediments vary from 700 m in the south to more than 3800 m in the north in a distance of less than 10 km). A shear-type dislocation transverse to the major trend of the normal faults, striking N30E, is assumed to be responsible for the linear extrusion of the magma in the eastern Dokhan region.

INTRODUCTION.

The Dokhan area is situated northwest of Central Iran, 75 km west of Saveh (Fig. 1). The mapping area extends between the latitude of 35° to 35°13' north and 49°28' to 49°38' east longitude, covering approximately 35 sq. km (Fig. 2).

The oldest rocks exposed in the area are shales of Jurassic age which have undergone a very low grade regional metamorphism during the Laramide Orogeny. During the Late Cimmerian tectogenesis the area was uplifted as documented by the absence of sedimentation at the base

(*) Department of Geology, University of Pittsburgh at Bradford, Bradford, Pennsylvania 16701.

(**) Geological Survey of Iran, Tehran, Iran.

of the Cretaceous. The black to brown Orbitolina limestones of Upper Barremian-Aptian age (Tizkuh Formation) unconformably overlie the older rocks.

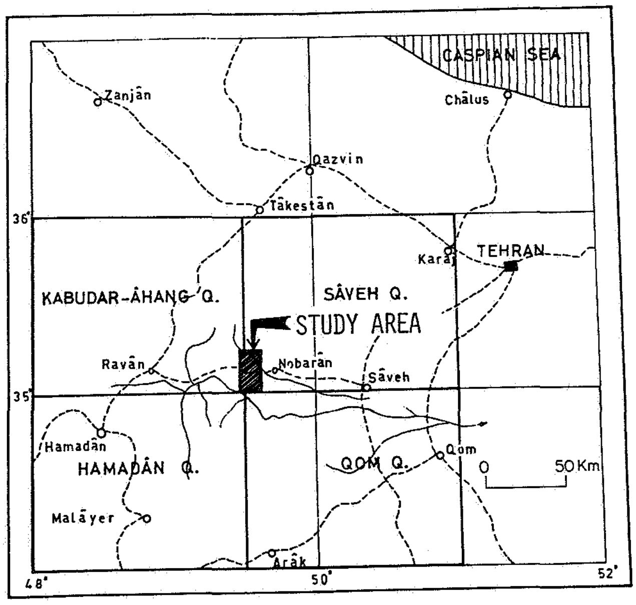


Fig. 1 - Map showing location of Dokhan region in northwestern Central Iran.

During Late Albian time, the Austrian Orogeny was probably responsible for the uplift of the area. Upper Cretaceous sediments (Cenomanian) have not been found in this area.

The Laramide Orogeny has caused folding and slight metamorphism in the area and Nummulitic limestones (Ziarat Formation) of Lower Ypresian-Upper Lutetian age overlie the underlying formations with angular unconformity. These rocks are followed uncoformably by dark-red conglomerate of the Lower Red Formation (L. R. F.) of Oligocene age (IRANPANAH, 1968). The conglomerate sequence has been deposited in continental conditions during the Middle Alpine Orogeny. The conglomerate covers the older sediments unconformably which is in turn covered by Qom Formation disconformably (GANSSER, 1955).

There are abrupt changes both in facies and thickness in Tertairy rocks exposed in the area in a short lateral distance. These variations may be a reflection of rugged topography in the sedimentary basin (i. e., features like horsts and grabens on the sea floor) prior to, or contemporaneous with deposition. For instance, in the southern part of the map area, the Upper Oligocene - Lower Miocene marls and organodetrital limestones of the Qom Formation, more than 3800 m thick in the north, are reduced to only 700 m in a distance of less than 10 km to the south (Fig. 5).

Tectonic movements in Pliocene-Pleistocene time are responsible for fairly strong folding and faulting in the area. The directions of the principal lateral compressions had been mainly north-northeast (IRANPANAH, 1979b).

The most significant features mapped in Dokhan region are ten principal eruptive centers (volcanic cones) of post-Pleistocene age in the western part of the area. These volcanic cones are lined up in a north-south trend. Three volcanic cones with the same characteristics are also present in the east of Dokhan region striking northeast-southwest. The interdependence between these young continental alkaline eruptions and tectonics is the subject of this discussion.

A number of dormant or recently extinct volcanoes have been recorded from several localities in Iran : Azarbayejan, Eurmeyeh-Dokhtar (RIOU, 1979; DIDON & GERMAIN, 1976), Kuh-e Bazman and Kuh-e Taftan (WALKER, et al., 1976), the Lut depression and Central Alborz Mountains (STOCKLIN et al., 1972, ALLENBACH, 1966).

The linear orientation of the volcanic cones in the study area does not follow the Dokhan and the Zagros structural axis (northwest-southeast), and is assumed to have resulted from rejuvenation of Precambrian horst and graben structural system (STOCKLIN, 1968).

The volcanic cones are composed mainly of augite-olivine basalts of post-Pleistocene age which were erupted in a continental environment occupying the higher topography in the region. The extrusive rocks cut across the Quaternary alluvial deposits in the southeast of Ebrahimabad.

These volcanic cones are monogenetic, that is they are erupted only once in contrast with other young polygenetic volcanoes such as Kuh-e Bazman and Kuh-e Taftan in the southeastern Central Iran (WALKER et al., 1976) and the Damnavand in the Alborz Mountains (ALLENBACH, 1966).

In the norm system CIPW these continental alkaline basalts approximately match the "critical phase of silica undersaturation" of YODER and TILLEY (1962) The preliminary source of the continental alkaline-basalts has been investigated on crystal- melt equilibrium (LEEMAN and ROGERS, 1970). They have been assumed a depth of 40-100 km for the source of these magmas.

Close similarity of the mineralogical characteristics and the contemporaneous extrusion of the alkaline basaltic magma in these post-Pleistocene volcanic cones suggest that they have probably been drawn from a single deep-seated parental magma chamber.

STRATIGRAPHY.

The oldest rocks exposed in the Dokhan region consist of slightly metamorphosed black to dark brownish gray and dark red shales of Jurassic age. These rocks are exposed in the northeastern part of the region with a limited extension. The thickness increases

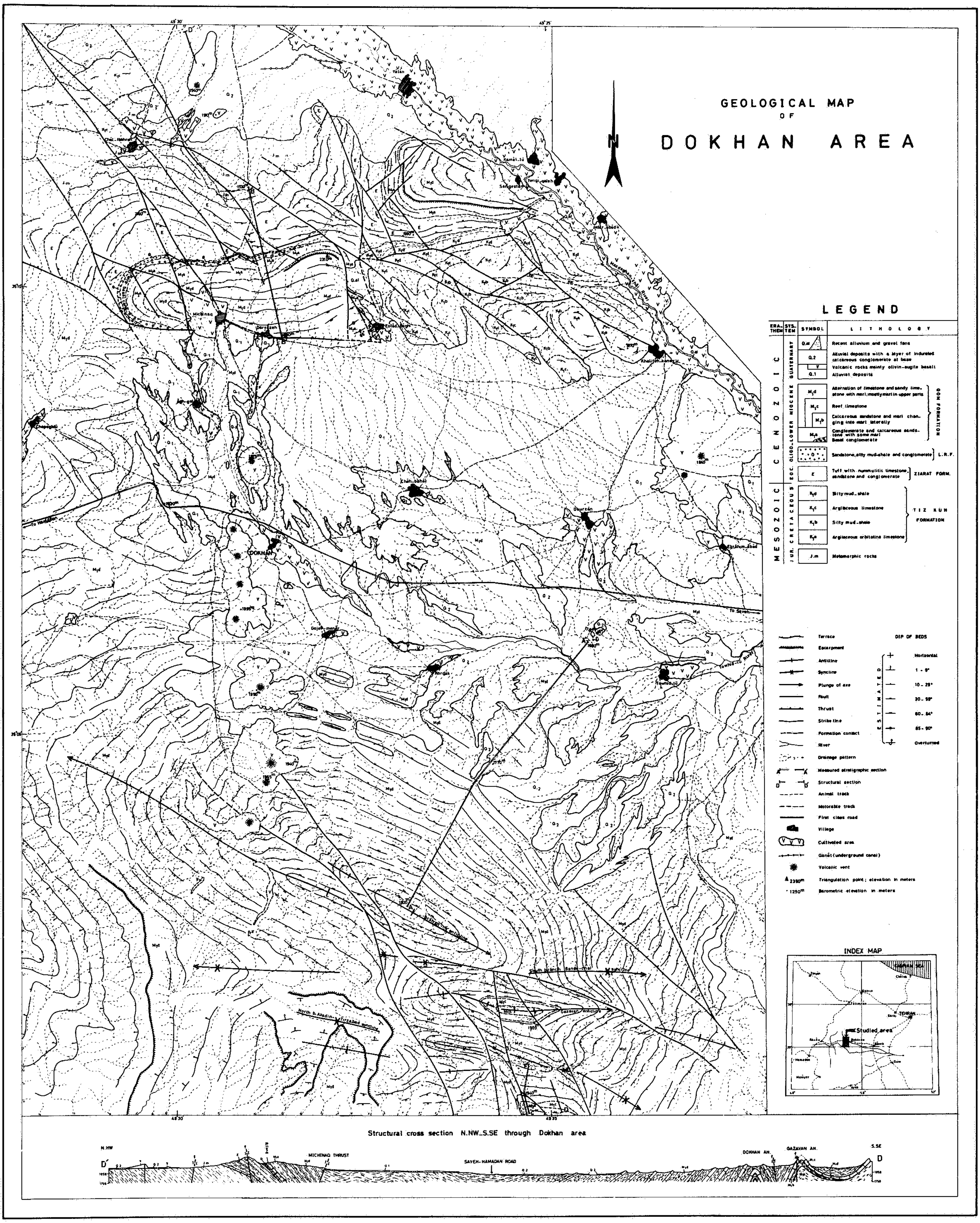


Fig. 2 - Geological map of the study area showing the principal stratigraphic and the structural components.

greatly to the northwest and west, outside of the study area, where the thickness is reported in an order of not less than 200 m (BLOURCHI, 1975). However, determination of the exact thickness of the Jurassic sequence is not possible due to lack of exposure of the Lower Jurassic rocks. Jurassic sediments were metamorphosed regionally during the orogenic period of the Laramide Orogeny. The age of these rocks is determined by a cast of an Amonite found by BLOURCHI (1975) and has given an age of Upper Triassic-Lower Jurassic.

The conversion from Jurassic to the Lower Cretaceous limestones as well as to the volcanic tuffs of the Eocene are represented by an unconformity.

The contact between the Jurassic and the Cretaceous rocks is characterized by an emergence which was prevaled in most of Central Iran and represented by an unconformable contact. During the Late Cimmerian tectogenesis the Thethys sea was regressed from northern and Central Iran producing vast lands and several intracontinental depositional basins (IRANPANAH, 1983).

The black Orbitolina limestones, and thinly-laminated shales and gray limestones of the Early Cretaceous Age crop out in a small anticline northwest of Khalifeh-Kandy (Fig. 2). The rocks of the Lower Cretaceous have been subdivided from the bottom to the top into four facies according to their fossil content K_1a, K_1b, k_1c and K_1d). The age of early Cretaceous has been assigned to these rocks not only on the basis of the presence of Orbitolina but also by the lateral correlation of these limestones to the adjacent areas such as Kabutar Ahangh quadrangle where Boydanticeras Amonites are present which are believed to belong to the Upper Barremian to the Upper Aptian. The overlaying shales appear to be of Albian age.

The Orbitolina limestone (Late Barremian and Aptian) can be correlated with the Tiz-Kuh Formation in the Alborz Mountains (north Iran), the Tireghan Formation in Kopet Dagh (northeast Iran) and the Darian Formation (southwest Iran). It is believed that during the Late Barremian and Aptian time, most parts of Iran were covered by a somewhat uniform shallow sea depositing similar facies in various parts of Iran (SEYED EMAMI, 1971).

Rocks of the Eocene age are present in the northern part of the Dokhan region. They are 500 m thick, but their thickness exceeds 650 m in the northern part of Michinaq village (Fig. 3, measured section BB'). The rocks of Middle Eocene age consist of volcanic tuffs with intercalations of Numulitic limestones, sandstones and conglomerates which occur in a variety of colors. The thickness and the facies characteristics of the Eocene sediments change through short distances in the Dokhan region. These rocks overlie the Jurassic shales unconformably with a dip 20°S in Chal-Fakhreh region (Fig. 4A). The thickness of the Eocene sediments is reduced to 50-70 m southwest of Sangestan village. The top of the Eocene rocks is characterized by an emergence and erosional surface which is overlaid by different formations in different localities. The age of the Eocene sediments is determined by means of Numulites which are Early Ypresian to Late Lutetian (BLOURCHI, 1975). The top of the Eocene sediments becomes more tuffaceous and sandy, and the lack of fossils make the age determination difficult for the Upper Eocene boundary. The age of the Eocene rocks in the study area ranges from Early Ypresian to Late Lutetian (BLOURCHI, 1975).

Rocks of the Eocene age are overlaid unconformably (with an angle of 50°S) by a red basal conglomerate of the L.R.F. of Oligocene age (section BB'). The contact is cancelled in many places by erosion and consequent deposition of Quaternary alluvium. Top of the L.R.F. is overlaid by a polygenetic basal conglomerate (M_1a) (Fig. 4B) of the Oligocene-Miocene Marine Formation, which is believed to be equivalent to the Qom Formation, and is referred to as the Qom Formation in this study. The M_1a member of the Qom Formation overlie the Eocene volcanic tuffs directly south of Yatan and the Cretaceous limestones south and southwest of Sangestan. The L.R.F. was deposited in a warm and dry continental environment (with heavy oxidation condition), suggesting a long period of erosion throughout the Upper Eocene which was probably continued during the Oligocene time (IRANPANAH, 1968).

The contact between the L.R.F. and the M_1a conglomerate appears to be gradational, but a disconformable contact can be observed on the top of the L.R.F. in the Hastejhon area south of the Dokhan region.

The marine Oligocene-Miocene deposits cover a greater part of the study area where its thickness exceeds 3600 m in the Dokhan region (Fig. 5). These rock units can be correlated with the Qom Formation in Central Iran and have been subdivided from bottom to top into four members : M_1a, M_1b, M_1c and M_1d (Fig. 5). The sudden change of the facies and the thickness variation of the marine Formation is probably controlled by the paleotopography of the depositional environment. Horsts and grabens were probably the major structures controlling the thickness of the Qom Formation in the study area.

The conglomerate of M_1a overlie the L.R.F. disconformably. However, the contact appears to be indistinct and gradational. The conglomerate is absent in the Dokhan anticline and only the upper part of the conglomerate crops out in section CC' (Fig. 2). In the north of the Foolad-Baghi the contact between the conglomerate (M_1a) and the Lower Cretaceous rocks is covered by debris of the Quaternary sediments. In the south of Yatan, the conglomerate of M_1a rests directly over sandstones, marls and tuffaceous marls of Eocene with an angular unconformity dipping 5°-10°E. In the south and southwest of Sangestan the conglomerate (M_1a) overlie the Lower Cretaceous shales (K_1d) unconformably and rests on tuffs and calcareous sandstone. The conglomerate changes abruptly and vertically into limestones and marls of M_1d and into a reef limestone in the

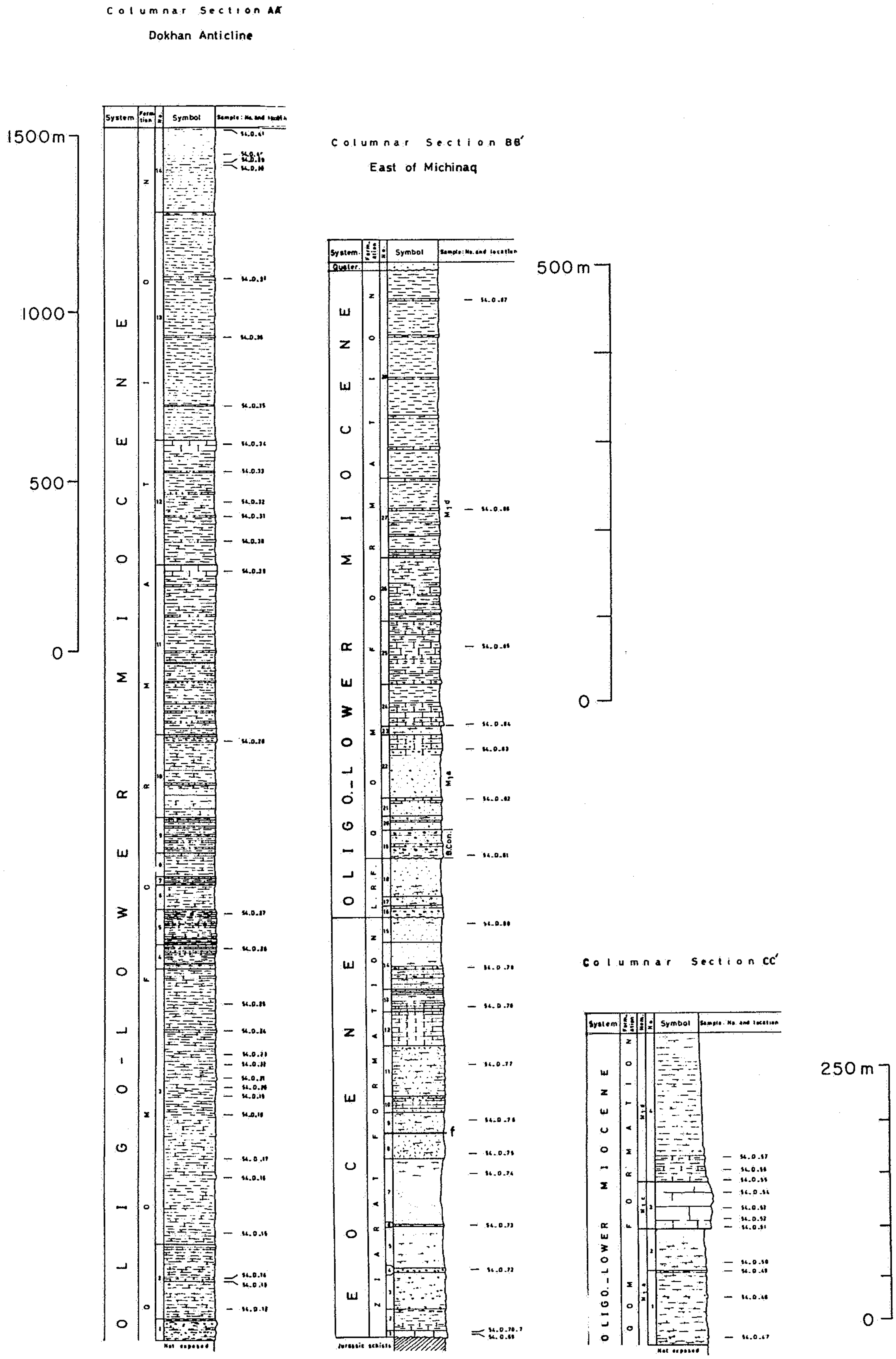


Fig. 3 - Stratigraphic correlation scheme between the Dokhan anticline (AA'), east of Michinaq (BB') and the most southern part of the Dokhan region. The numbers on the right of each section refer to the sections described in the field.

Fig. 4A - Photograph showing the angular unconformity between the Eocene : Ziarat Formation (E) and the Jurassic shale (Jur.) in about 100 m south of Chal-Fakhreh village. The Eocene sediments dip 20°S on the top of the Jurassic shales.

Fig. 4B - Photograph of basal conglomerate of M_1a as observed along the section BB' in the south of Sanghestan village.

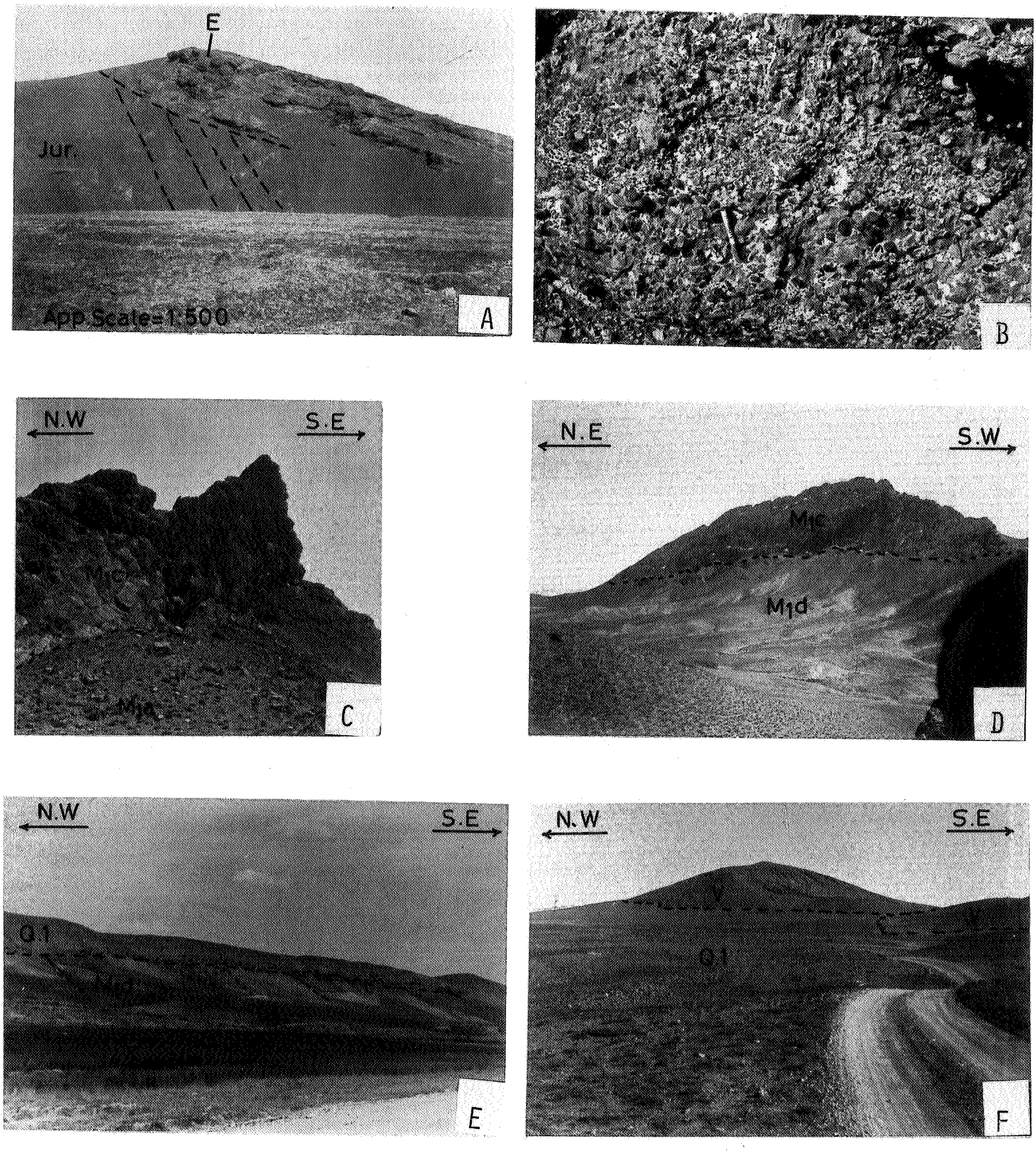
Fig. 4C - Looking northeast, sharp disconformable contact between M_1a and M_1c.

Fig. 4D - Looking east to the sharp contact between M_1c and M_1d. The massive reef limestones of M_1c are oc-occupying the higher topography and marls of M1d are occupying the core of the syncline at the south of the Xen-Oven anticline.

Fig. 4E - Looking northeast to the angular unconformity between M_1d and the Lower Quaternary sediments.

Fig. 4F - Looking northeast to the nonconfortable contact between the lower Quaternary sediments (Q_1) and the two basaltic volcanic cones (V) on the top of the Q_1 in the north of Ebrahimabad.

Figure 4.


E
Jur.
App.Scale=1:500
A
B
N.W
S.E
M1c
M1a
C
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D
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Q1
M1d
E
N.W
S.E
V
Q1
V
F

north and south respectively (Fig. 3, section CC').

The M_1b-Member is composed mainly of marls and exposed only in the southern part of the study area. These rocks interfinger with the reef limestones of the M_1c laterally and are not present in section CC'. However, marls of M_1b are present beneath M_1c along a sharp contact 1 km north of section CC', where 45 m of marls were measured (Fig. 3).

The M_1c-member consists of a cliff-forming reef limestone exposed only in the southern part of the study area (Fig. 4C), where 55 m of this rock unit was measured along the section CC'. Its thickness reaches to 100 m at Amdjak-Dagh in the southeast outside of the study area (HUBER, 1953).

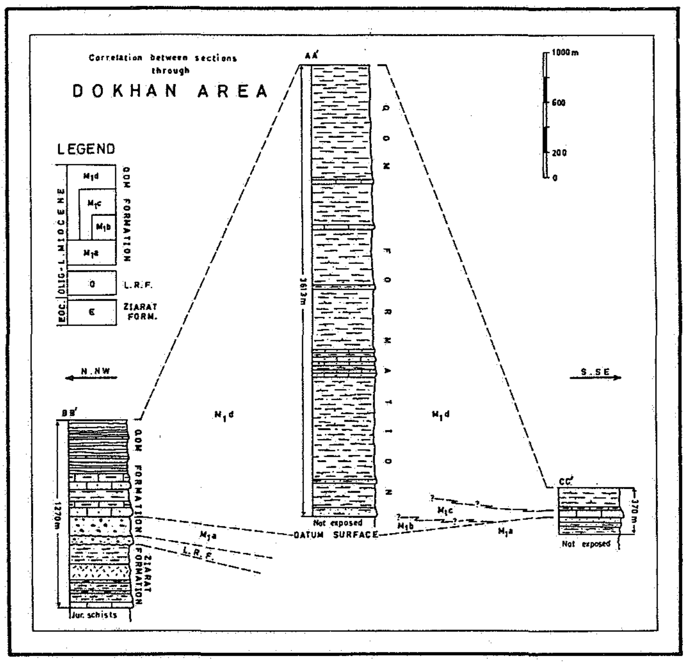

Fig. 5 - Stratigraphic correlation of Qom Formation throughout the Dokhan region. Note the abrupt reduction in thickness from the Dokhan anticline in the North (AA') to the section in the most southern part of the area (CC').

The M_1d-member is composed mainly of alternation of limestones, calcareous sandstones and marls. At the top of the section green and gray marls occur abundantly (Fig. 4D). The calcareous sandstones are missing or are found infrequently. Gypsum layers are absent in the M_1d-member in the Dokhan region in contrast to its presence in the neighboring basins.

The top of the Qom Formation in the Dokhan region is characterized by an erosional surface. The Formation is covered by a series of horizontal terrigenous sediments, and some basalt flows of post-Pleistocene age overlying with an angular unconformity (Fig. 4E).

The poorly sorted, moderately-to-well indurated, more or less horizontal beds of terrigenous sediments of the Quaternary age cover the Qom Formation unconformably in the Dokhan region. The dip of the Quaternary sediments varies from 1° to 3° and their thickness varies from one meter to several meters. The Quaternary sediments have been subdivided from the oldest to the youngest into the following mappable stratigraphic units : Q_1, Q_2 and Qal.

Unlike the Hezardarreh Formation (in the Alboroz Mountains) and the Bakhtiari Formation (in the Zagros Mountains) both of Pliocene age, there is no sign of Pliocene-Pleistocene tectogenic movements in the Dokhan region. It is believed that Q_1 is certainly deposited after the post Neogene tectonic pulse.

Intrusive igneous rocks have not been found in the Dokhan region except a dike which was examined south of the Gazavan anticline. In this locality, a small extrusion (1x10 m) of basaltic lava is present which is probably extruded along the fault where a dike (150-200 m long and 0.70 to 1.00 m (wide) has been observed. The dike appears to be part of the same basaltic magma which has been injected along the fault plane.

During the Quaternary time, thirteen small volcanic cones (120-150 m high) were formed in the Dokhan region (Fig. 4-F). The samples collected from these eruptive centers are composed mainly of olivine and a single pyroxene-augite, plagioclase An50 and volcanic glass. Accessory minerals of the phlogopite-biotite series are present in some samples which are believed to be Kaersutite or phlogopite. The samples from north of Ebrahimabad contain an analcime (isometric zeolite) of secondary origin. The general petrological composition of these volcanic rocks is phlogopite-bearing augite-olivine basalt.

Proximity of the mineralogical composition of these widely scattered eruptive centers suggests that they have probably shared a single deep-seated parental magma chamber which was erupted contemporaneously.

TECTONIC HISTORY.

The Dokhan region is part of the Central Iranian structural zone. Central Iran is a triangular-shaped structural zone which is bordered by the Lut depression in the east, the Alborz Montains in the North, and the Sanandaj-Sirjan metamorphic belt in the west and southwest. The Central Iranian structures are part of the Alpine-Himalayan Orogen and closely resemble the Alborz Mountains in both structure and stratigraphy (IRANPANAH et al., 1979a). The Mesozoic tectonic movements (Late Triassic, Late Jurassic, Early Cretaceous and Late Cretaceous) have produced angular unconformities along the boundaries of the foregoing geologic time in the study area, while only disconformable contacts are found in the above geologic boundaries in the Alborz Mountains (STOCKLIN, 1974a).

The Dokhan region, like the other parts of Central Iran, had a rather stable platform condition throughout the Paleozoic time. But during the Late Triassic, primary movements of the Alpine Orogeny occurred, following deposition of parallic sediments over the platform deposits (of Paleozoic age). During Early Alpine tectogenesis, Central Iran was divided into several basins (STOCKLIN, 1974b) which were characterized by block faulting in the study area (IRANPANAH, 1977). During Late Liassic, Early Cretaceous and Early Eocene, the platform condition similar to that of the Paleozoic was prevailed in the Dokhan region and the adjacent areas (IRANPANAH et al., 1980). The platform was covered by an epicontinental sea for the most part of the Toarcian time (STOCKLIN, 1968).

ALPINE OROGENY.

The Alpine Orogeny has been studied in the Dokhan region in two distinct stages (Fig. 6) :

1. EARLY ALPINE OROGENY.

In the early and the primary stage of the Alpine Orogeny, three major phases op uplift are recognized in the Dokhan area.

a. Late Cimmerian movements occurred between Jurassic and Cretaceous. The Late Cimmerian uplift has produced a large gap between the Late Jurassic and the Early Cretaceous sediments in the Dokhan region (Fig. 6). As a result of the Late Cimmerian tectogenesis, the Orbitolina limestone of Barremian and Aptian age overlies the Jurassic shales in the study area. Rocks of Lower Cretaceous (Neocomian) have been reported only from a few localities from Central Iran such as Kerman (HUCKRIEDE et al., 1962), the Tabas region, and from the Sabzevar area.

b. The Austrian (Oregonian) Orogeny is characterized by the absence of the basal sediments of the Upper Cretaceous in the Dokhan region (Fig. 6).

c. The Laramide Orogeny is believed to be the main factor causing low grade metamorphism in the Dokhan area. During the Laramide tectogenesis (Late Cretaceous and Early Tertiary prior to Lutetian time) part of Iran was uplifted and the Eocene volcanics were laid over the older sediments unconformably during the proceeding submergence (Fig. 6).

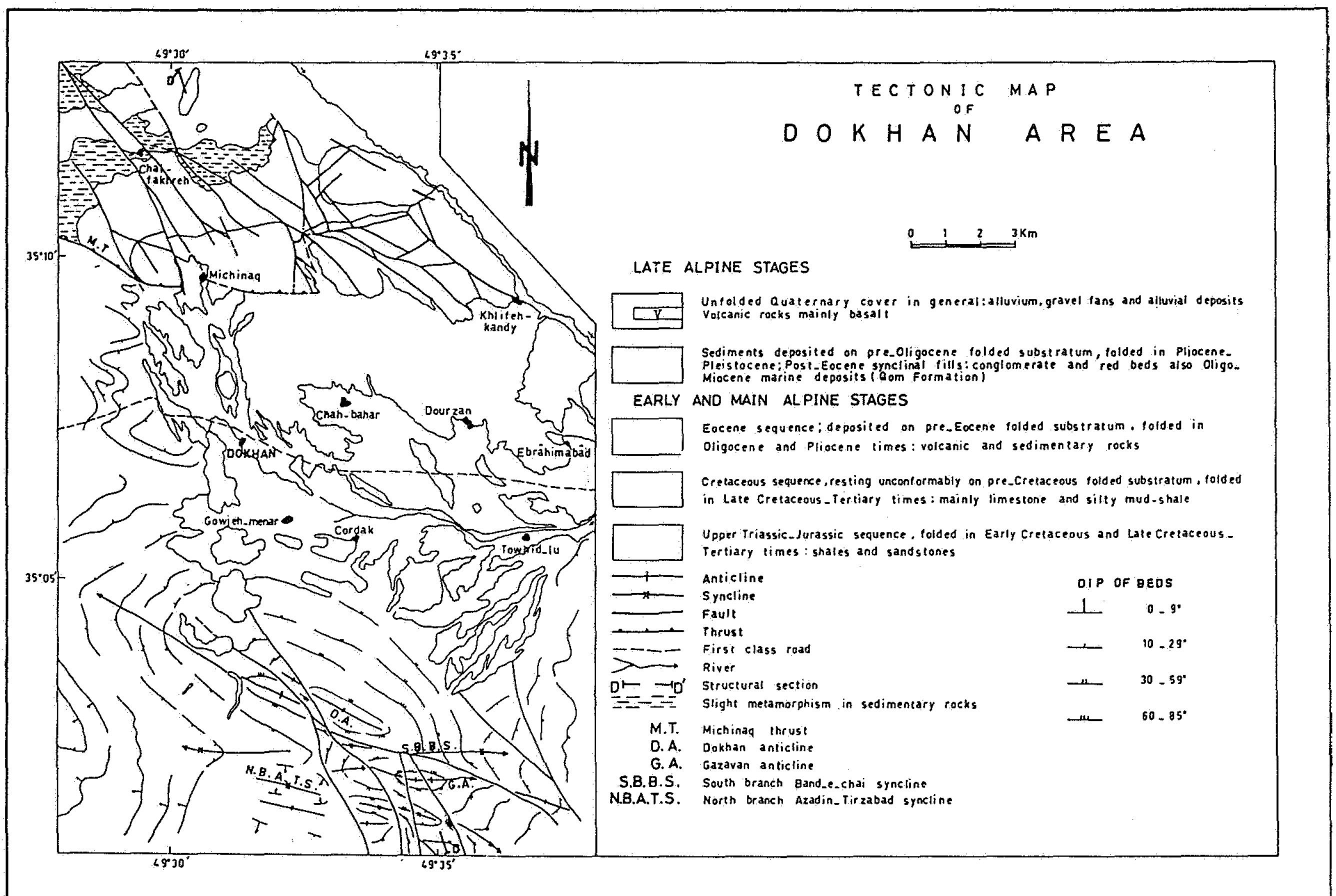

Fig. 6 - Tectonic map of the Dokhan region.

Middle Alpine Orogeny is characterized by the presence of the Pyreneean and the Savian tectogenesis in the Dokhan region. During the Pyreneean tectogenesis the Eocene sediments were slightly folded and the sediments of the Middle Oligocene age were deposited unconformably over the Eocene sediments. The Savian tectogenesis (between Oligocene and Miocene) is not clearly observed in the Dokhan region. It is believed that this stage may have been an epirogenic movement and no apparent dip difference is observed between the sediments on top of the L.R.F. and the base of the sediments of the Qom Formation (Upper Oligocene-Lower Miocene). A slight erosional surface can be identified between the L.R.F. and the Qom Formation (Fig. 6).

2. LATE ALPINE OROGENY.

During the Pliocene-Pleistocene (Wallachian tectogenesis) the sediments of the Oligocene and Miocene were uplifted. The Quaternary sediments overlie the folded and faulted rocks of Oligocene-Miocene with angular unconformity. This suggests that the Quaternary sediments in the Dokhan area are younger than the Hezardarreh (in the Alborz Mountains) and the Bakhtiari (in southwest Iran); and since their deposition there has been no distinct active tectogenic movements in the study area.

The following unconformities are recognized during mapping and field studies (Fig. 6) :

a. Post Jurassic and pre-Cretaceous.

b. Post Cretaceous and pre-Eocene.

c. Post Eocene and pre-Middle Oligocene.

d. Slight disconformable contact between the L.R.F. (Middle Oligocene) and Qom Formation (Upper Oligocene).

e. Post Lower Cretaceous and Pre-Quaternary.

f. Post Pleistocene nonconformable contact of the continental alkali basalt flows with subhorizontal sediments of Quaternary and Recent.

The general structural trends in the Dokhan region is northwest-southeast. Gentle folding occurs in the central part and the dip of the marls (Lower Miocene) does not exceed 45°. On the anticline south of Dokhan (Fig. 6) the rocks are tightly folded; and the dip measured in the core of the anticline is more than 75°. The major faulting in the Dokhan area occurs approximately parallel to the Zagros Main Thrust trending northwest-southeast. However, the importance of the transverse faults mapped in this area must not be neglected.

Along the Michinaq thrust, the Mesozoic rocks are thrusted over the Tertiary rocks, suggesting a NNE principal horizontal stress. The anticlines and synclines south of the Dokhan region with accompanying longitudinal faults also suggest a general compression NNE, which is compatible with the general compression suggested for the major part of the Iranian Plateau (NOWROOSI, 1972; IRANPANAH et al., 1979 and 1980).

TECTONIC SETTING OF THE ALKALI-BASALT VOLCANICS.

Obvious and broad interdependence between the continental alkaline volcanism and tectonism have been recognized from several localities around the world. The East African rift-valley system is the site of a close association of volcanism and faulting from Miocene to the present day (KING, 1966, 1970; WILCOCKSON, 1964). The Miocene and Pliocene alkaline volcanism in Rhine-Graben rift system is the site of normal faulting (CARMICHAEL et al., 1974). Several Miocene volcanic fields of alkaline composition are reported from eastern Australia (McDOUGALL and WILKINSON, 1967). Alkaline magmas have been reported from three major eruptive centers in New Zealand, which are believed to be structurally controlled (CARMICHAEL et al., 1974). Alkaline olvine-basalts have also been found in Basin and Range province, Western United States. These alkaline volcanics are of Miocene age and they have been postulated as the site of the major deep-seated normal faults in this region (LEEMAN and ROGERS, 1970).

Young continental volcanics of sub-Recent ages have been reported from various parts of Iran such as Azarbayejan, Eurmeyeh-Dokhtar (RIOU, 1979; DIDON and GERMAIN, 1976), Kuh-e Bazman and Kuh-e Taftan (WALKER et al., 1976), the Lut depression and the central Alborz Mountains (STOCKLIN et al., 1972; ALLENBACH, 1966). The very young (post-Pleistocene) basaltic volcanic cones west and east of Dokhan village follow a distinct linear trend, striking approximately north-south and N30E respectively (Fig. 6).

The basement in the study area is thickly mantled with Mesozoic and Tertiary geosynclinal sediments. It is fractured with a series of north-south trending normal faults of Precambrian age in a horst and graben structural system (STOCKLIN, 1968). The tectonic environment of the broadly associated volcanism in the Dokhan region is postulated to be the site of the major north-south trending normal faults of Precambrian age. Recent rejuvenation of these deep-seated faults has been associated with volcanism in Dokhan region. A shear-type dislocation striking N30E is believed to be responsible for the extrusion of the basaltic magma in the eastern Dokhan region.

Evidence of an independent character reinforce the idea of the presence of a set of north-south trending normal faults in a horst and graben structural system in Dokhan region. This evidence is contributed by the data relating to the abrupt variation in the thickness of the Oligocene-Miocene marine sediments (e.g. from 700 m in the south to more than 3800 m in the north, in a distance of less than 10 km).

CONCLUSIONS.

Geological and structural mapping in Dokhan region (northwestern part of Central Iran) had revealed the presence of ten northerly-trending and three northeasterly-trending basaltic volcanic cones of post-Pleistocene age. The volcanic rocks have a consistent and similar mineralogical characteristics consisting mainly of phlogopite-bearing augite-olivine basalt. Based on the close correspondence of the mineralogical characteristic of these rocks with the typical continental alkali basalts, it has been postulated that these basalts were drawn from a deep-seated (40-100 km) magma chamber.

The proximity of time of extrusion (post-Pleistocene), and the similarity in mineralogical characteristics, strongly suggest that these volcanic rocks are monogenetic and were originated from a single parental magma contemporaneously.

The tectonic environment of these volcanic cones is believed to be the site of north-south trending normal faults and the shear-type dislocations striking N30E. Testimony from an independent source strengthens the idea of the presence of a set of north-south trending normal faults. The testimony is provided by the abrupt lateral variation in both facies and thickness in Oligocene-Miocene marine sediments (from 700 m in the south to more than 3800 m in the north in a distance of less than 10 km).

The thickly mantled basement in Dokhan region has been fractured with a series of north-south trending normal faults in a horst and graben structural system. The rejuvenation of these faults are associated with continental alkali basalt volcanism during the Quaternary time in the Dokhan region. However, the importance of the association of volcanism with shear-type dislocations (striking N30E) must not be overlooked in this area.

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