GEOLOGY OF MIANEH DISTRICT OF NORTHWESTERN IRAN

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ABSTRACT. — The area of this report is part of a structural basin situated south of Mianeh in which a thick section of Cenozoic deposits are preserved, whereas in most of the surrounding areas these deposits have been removed by erosion. In the vicinity of this basin, oldest rocks consist of coal-bearing terrestrial beds of Liassic age. Of the Cenozoic rocks the oldest are Eocene-Oligocene Volcanic complex. Over the volcanics and separated from them by an unconformity there are about 3600 meters of sedimentary deposits. The majör elements of this thick section consist of 290 meters of limestone of Upper Oligocene and Lower Miocene age, about 1360 meters of evaporite group of Lovver and Middle Miocene, and 1800 meters of continental Clastic red beds of Upper Miocene age. Over post-Miocene surface of erosion are deposited lacustro-terrestrial beds of Pliocene age.

The majör structure of the area consists of an anticline of about 50 kilometers long with a NW-SE trend in which Miocene evaporite beds are exposed at its crest. There are several faults of small magnitude within Miocene formations.

INTRODUCTION

The primary concern of this study is the Oligo-Miocene formation of Mianeh district. This formation, which consists dominantly of limestone, is the result of an extensive marine transgression of Upper Oligocene and Lower Miocene times which covered greater part of Iran and extended to the eastern part of Turkey. At the present time the remnants of this once extensive marine formation are preserved in isolated structural basins of large and small dimensions (Fig. 1). In the central part of Iran they are preserved in the large Qum-Simnan structural basin, whereas they have been removed by erosion from the surrounding uplifted regions. Towards northwest of Qum they occur in isolated localities as far as the eastern part of Turkey.

The area of this report, which is situated about l0 kilometers south of Mianeh, is one of the majör localities in which-this formation occurs. Qizil Uzan River crosses this area about the middle; Teheran - Tabriz railway and highway passes through the eastern part of it (Fig. 2). With the exception of that highway the only other road suitable for motor vehicle traffic is the one which extends from Nikpay west to the copper mine at Maadan. This is a graded dirt road which is used only during the dry summer months. Where this road crosses Zanjan River and Qizil Uzan River, there are no bridges and when the water is high in these rivers it is impossible to cross them by automobile.

For surveying I used plane table to measure a section from Daghirman Darreh to the vicinity of Goiklar, which is a distance of about 20 kilometers. The other stratigraphic sections were measured by steel tape and connected by plane table Survey to the main line of Survey. The rest of the area was surveyed by means of Brunton compass and the distances measured by telemetec and steel tape.

Large part of this area has aerial photographs and the entire area has quarter inch topographic maps with 250 feet contonr intervals. These topographic maps are in general reliable and they proved very useful in an area like this, which has very rugged topography.

Due to lack of roads and very rugged topography, this area has not been studied previously.

The field trip started on 17th of June, 1953, and ended on 9th of July of the same year.

PHYSIOGRAPHY

This area includes most of the drainage basin of those tributaries of Qizil Uzan River which join that river a short distance to south of Mianeh. To the north of this area lies the Buzgush massif, in some places reaching a height of 3,300 m; on the east is the Qaflankuh uplift; to the south is the mountainous district extending between the valleys of Zanjan River and Zarrineh-Rud River; to the west are highlands which divide the watersheds of Qizil Uzan and Zarrineh-Rud rivers. Between these uplifted regions lies the area of this report covered by Cenozoic rocks. The lowest places are about 1,200 m above sea level and the highest points about 2,300 m. As a result of the steep dip of the beds and their differential erosion together with the numerous tributaries of Qizil Uzan River, the Middle part of the area has a rugged topography. This rough topography is more pronounced close to the Oizil Uzan River and reduced farther away from the Course of this river. In general, where the erosion has not removed the flat-lying Pliocene beds, the district has a rolling topography with low hills (Photo 1). Wherever the mantle of Pliocene beds has been removed, the underlying Miocene and older beds with their higher degree of induration and steep dips are exposed and the topography is rugged. The pre-Pliocene topography of these beds has been a contributing factor also to their present-day features.

Of the former land surface in this area only the remnants of a post-Pliocene alluvial plain are preserved in certain localities east of Qizil Uzan River. Along the Teheran-Tabriz highway, between Sarcham and Jamalabad level, summits of the hills formed by this former alluvial plain form a conspicuous view (Photo 2).

On the east bank of Qizil Uzan River, between the villages of Mushampa and Gara Buta, remnants of two different former river terraces are preserved in several places.

STRATİGRAPHY

MESOZOİC

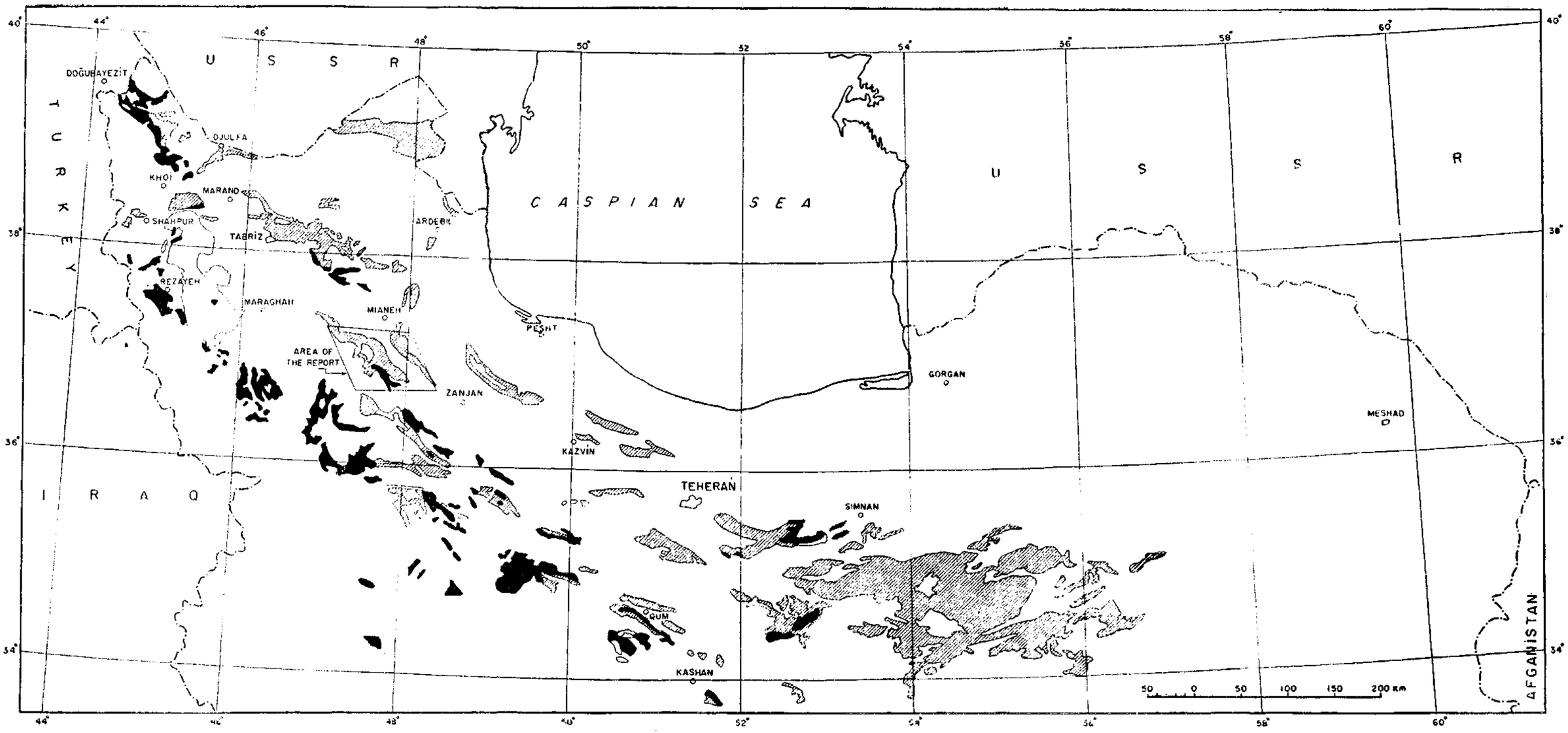
Jurassic

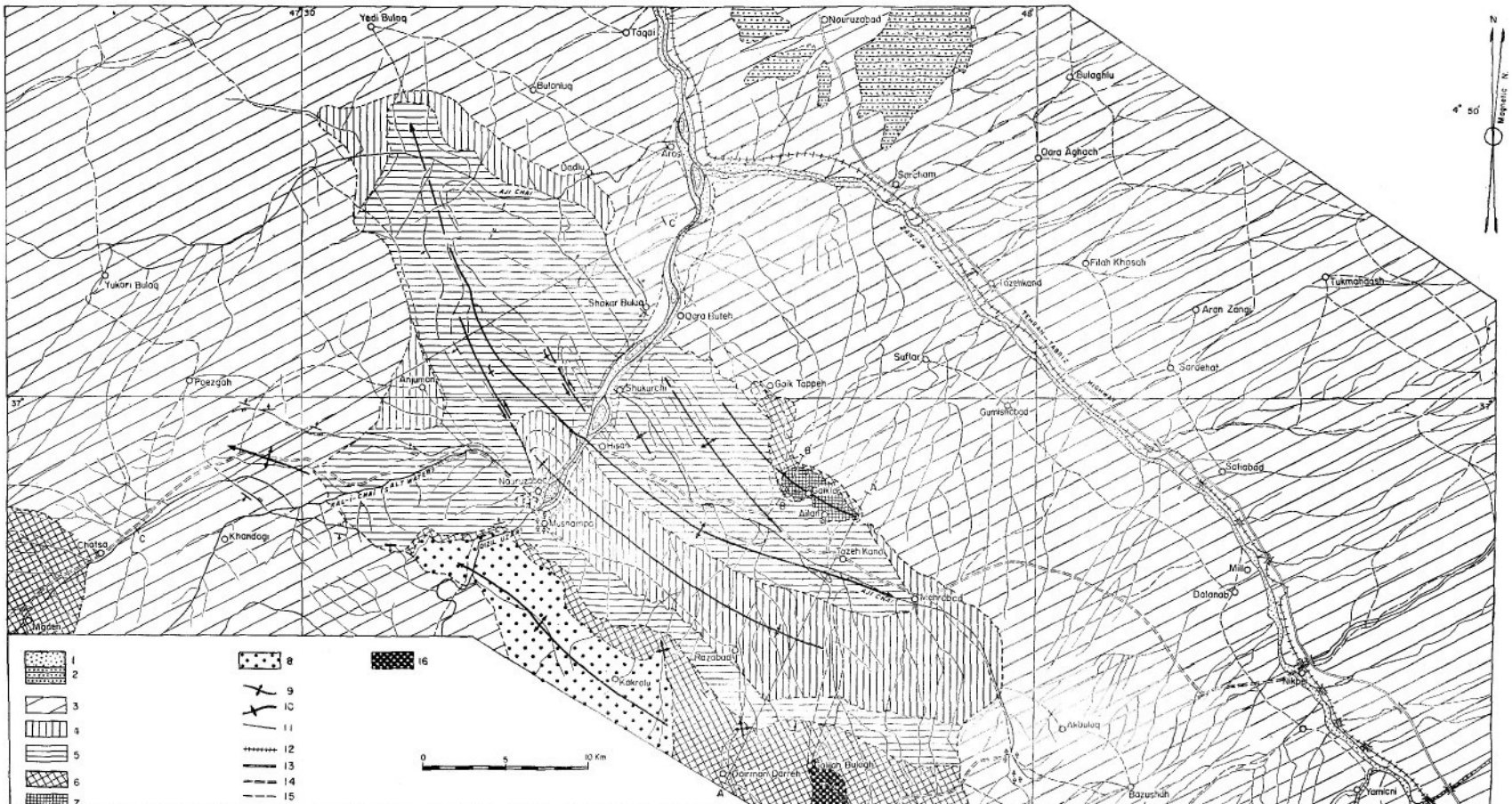
The oldest exposed rocks in this area are coal-bearing beds of Liassic age. They consist of dense, dark-brown sandstone beds of generally one meter each in thickness and some calcareous sandstones.

These sandstones are interbedded with dark-brown shale of generally 8 meters thick each. These beds have a gentle dip of about 20° to the southeast and on the eroded surface of these beds is deposited the Oligo-Miocene limestone.

FIGURE - 1

DISTRIBUTION OF UPPER OLIGOCENE AND MIOCENE FORMATIONS IN CENTRAL AND NORTHWESTERN IRAN





GEOLOGICAL MAP OF MIANEH AREA

1 - Alluvium; 2 - Raised terraces, dissected fans; 3 - Pliocene : Fine clastic mainly fluvial with some calcareous tufa beds; 4 - M.-U. Miocene : Continental group red shale and sandstones with an agglomerate bed; 5 - L.-M. Miocene : Evaporite group gypsum, salt, marl, gypsiferous shale and sandstone, mainly gypsiferous variegated shale; 6 - M.-U. Oligocene-L. Miocene : U. Oligocene-L. Miocene limestone, L.-U. Oligocene marl and conglomerate facies; 7 - Oligocene : Middle Oligocene, mostly extrusive igneous; 8 - Eo-Oligocene : Eocene and Oligocene volcanic complex; 9 - Anticline; 10 - Syncline; 11 - Fault; 12 - Railway; 13 - Highway; 14 - Natural surface road; 15 - Foot-path; 16 - L. Jurassic : Liassic coal-bearing beds.

The locality vvhere I observed these Jurassic rocks is near the village of Galijah Bulagh, 7 kilometers east of Daghirman Darreh. Here in a small valley these rocks are exposed and considerable amount of coal was mined from here about two decades ago.

No coal seam is visible on the surface, but there is every evidence of coal mining activities in this locality. There are four tunnels, the entrances of all of them have caved in, therefore it is not possible to examine the coal beds vvithin the tunnels. Several coal dumps and a battery of coking ovens and a number of buildings which were used in connection with the mining operations clearly indicate presence of coal within these beds. According to the description of a foreman who had been working in that mine, the coal seams in some places reached a thickness of about 2 meters.

Within the area of this report the rocks of Mesozoic age other than Jurassic do not exist.

CENOZOIC

TERTIARY

Eocene and Lower Oligocene

In this area there are no fossiliferous rocks of Eocene age. However, there is a thick series of rocks of Volcanic Origin which, on the basis of stratigraphic position and lithologic character, undoubtedly are part of the same Volcanic complex of Eocene age, which occur so characteristically along the southern flank of Alborz range. Elsewhere in this general region, on the basis of fossiliferous beds included within these Volcanic Series, it is definitly established that most of these rocks are of Eocene age.

These rocks consist of enormous thickness of lava flows interbedded with pyroclastic material of agglomerates and tuffs most of which is deposited under subaqueous conditions. The lava flows are olivine basalt and most of them are vesicular. Without any apparent interval of erosion they grade upwards into the rocks of the same Origin but of Oligocene age.

These rocks are exposed in the southern part of the area of this report, and the outcrops extend for a distance of 20 kilometers in a northwest-southeast direction and have a width of about 5 kilometers (Fig. 2). Here they are exposed at the crest of a steeply folded anticlinal structure, where the stratified pyroclastic beds have a dip of about 50°. Eocene rocks, other than those of igneous Origin, do not occur in this area. However, some of the boulders of the conglomerate overlying the Volcanic series and derived from the rocks of this region consist of fragments of a buff limestone of Eocene age. This is a dense, fossiliferous limestone having typical Middle Eocene (Lutetien) fauna.

The fossil remains of the following fauna are contained in that limestone: Nummulites, Discocyclina, Distichoplax biserialis, Valvulinids, Eorupertia, Rotalia and Bryozoa.

Oligocene

The upper part of these Volcanic series grades into dominantly stratified deposits of pyroclastic Origin interbedded with somft rather thin lava flows. The beds are in

general one meter and half thick, they show, distinct bedding and grâdation of grain size. They all have typically green color, and the grain size ranges from that of coarse sand to fine silt. Their texture is gritty indicating that the grain particles are not rounded by long period of weathering and transportation. The microscopic examination reveals that they consist mostly of chlorite, altered Volcanic glass and quartz particles, with a few fragments of feldspar crystals. The upper part of this section consists of poorly sorted tuff and agglomerate deposits. These stratified deposits of pyroclastic Origin alternate with basaltic lava flows. In Goiklar locality (Figs 3 and 4), about 213 meters below the top of this section a limestone bed carrying Middle Oligocene fossils is interbedded withthese rocks of Volcanic Origin. The limestone bed is 21 meters thick, it is a fine-grained moderately indurated, light-colored rock, in some places marly, composed mostly of Globigerina tests. It is a lithified globigerina ooze, and such abundant presence of Globigerina in this rock is very significant. In addition to Globigerina, some of the other fossils present in this bed are : Miogypsina, Gypsina, Nummulites, Anomalina, Meliolid, Textularia and Bryozoa.

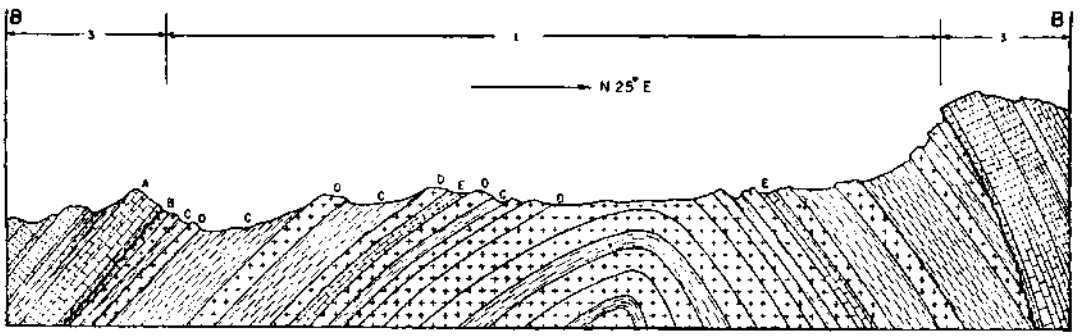


Fig. - 3 Section across a small anticlinal fold 1,5 km west of Goiklar

A - Oligo-Miocene limestone; B - Agglomerate; C - Stratified detrital deposits of pyroclastic origin; D - Basaltic lava flow; E - Globigerina limestone.

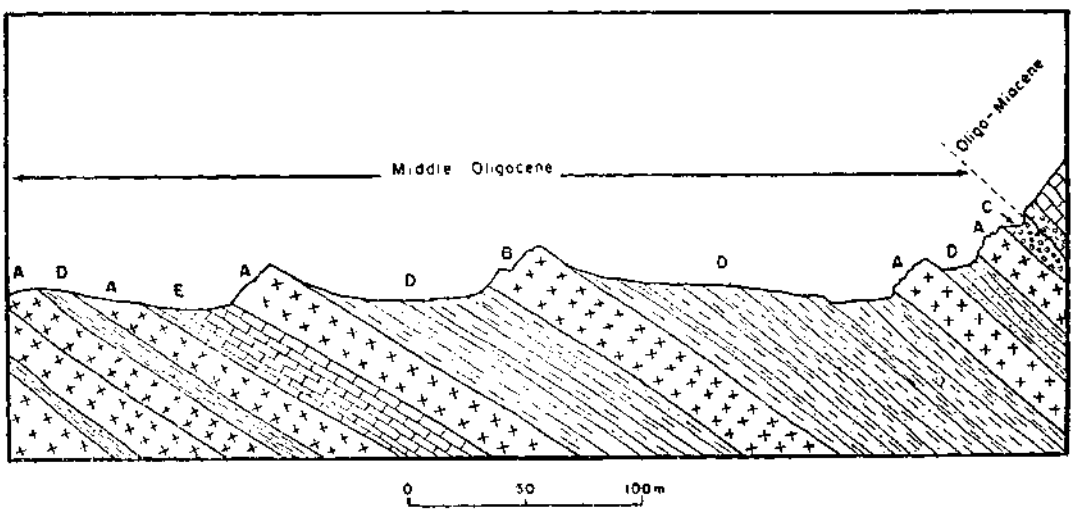


Fig. - 4 Section through Middle Oligocene rocks 2 km SW of Goiklar

A - Basaltic lava; B - Columnar basalt; C - Agglomerate; D - Stratified detrital deposits of pyroclastic origin; E - Globigerina limestone carrying Rupelian fossils.

Between the villages of Ailan and Goiklar, located at the longitude 47° 50'E and the latitude 36° 57' N, the Oligocene rocks of dominantly Volcanic Origin with interbedded marine limestone are exposed in a small local uplift. This outcrop locality has a length of 5 kilometers and a width of two and half kilometers. Two kilometers southwest of Goiklar the upper part of this Series of rocks are exposed in a small valley. Following is a description of that section :

	Unconformity	*Thickness in meters*
Middle Oligocene	Agglomerate and tuff	6
	Basaltic lava	16
	Green stratified beds of pyroclastic origin	14
	Basaltic lava	18
	Green stratified beds of pyroclastic origin	75
	Columnar basalt	25
	Green stratified beds of pyroclastic origin	40
	Basaltic lava	19
	Globigerina limestone	21
	Basaltic lava	50 +

Upper Oligocene

The upper part of the Middle Oligocene rocks of Volcanic Origin is defined by a majör unconformity. In the southern part of this area above this unconformity is deposited a thick bed of conglomerate followed by a group of marl and calcareous sandstones (Fig. 5).

Conglomerate formation- —The thick basal conglomerate consists of boulders ranging in size from half a meter in diameter to small pebbles; however, the great majority of them are belween 2 to l0 centimeters in size. It is typically a polymictic conglomerate; the pebbles and boulders in it are derived mostly from underlying stratified green beds of pyroclastic Origin, from the basalts, a subordinate portion of them come from the brown sandstones of Jurassic beds, a few are derived from a pink rhyolite, and some of the pebbles are derived from a buff fossiliferous limestone of Middle Eocene age. The matrix consists of coarse sand and silt; the cementing material is calcium carbonate and hematite, the latter gives it a brick-red color. The conglomerate is massive and highly indurated. The character of the boulders and pebbles and great thickness of it indicate that during early Upper Oligocene time the land from where these Clastic materials were derived had a high relief and it was undergoing rapid erosion.

The outcrops of this conglomerate extend from the village of Daghirman Darreh for a distance of one and half kilometers to the north of it. East of that village on the opposite side of the valley the conglomerate is exposed at several places. Here only about 60 meters of it is exposed (Photo 4), and the rest of it is covered by the scree. In this locality it has a Strike of N 36°W, and a dip of 24° to southwest. About half a kilometer north of that village, 95 mefers of it is exposed on both sides of the valley (Photo 3, tfhoto 5).

At a distance of one and half kilometers north of that village the conglomerate bed changes its Strike to N 59° W and-farther west it assumes more of an east-west Strike. This conglomerate is also exposed on the trail between Daghirman Darreh and

Mian Darreh, at the bottom of a small valley. Three kilometers to the north of Daghirman Darreh on the east side of the road the same conglomerate is exposed again; here it shows a total thickness of 44 meters. Four kilometers west of village of Rizabad, in the Gara Darreh valley, the crest of a minör anticlinal fold is eroded down to the green stratified beds of Middle Oligocene age. In this locality, above the green beds, this conglomerate is about 95 meters thick. About 5 kilometers northeast of Maadan (copper mine) on both sides of the road this conglomerate is exposed. Here it is 20 meters thick and possesses the same characteristics as those in the Daghirman Darreh locality.

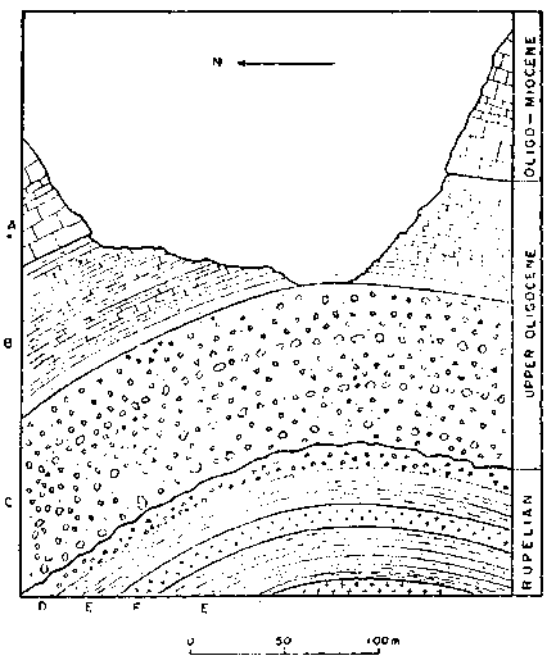


Fig. 5 - Section of Upper Oligocene conglomerate-marl group between unconformity and Oligo-Miocene limestone at Daghirman Darreh locality.

A - Oligo-Miocene limestone, Upper Chattian to Lower Miocene; B - Lower Chattian marls; C - Basal conglomerate above unconformity; D - Agglomerate; E - Stratified deposits of pyroclastic origin; F - Basaltic lava flow.

Marl and sandstone group. — In the vicinity of Daghirman Darreh this basal conglomerate is conformably overlain by a group of beds consisting mostly of marls with some calcareous sandstones (Photo 4). These beds are best exposed in a locality one and half kilometers north of Daghirman Darreh (Fig. 5; Photo 7). Here the sandy matrix of the basal conglomerate grades upward into a sandstone bed of 4 meters thick, and that is followed by about 60 meters of alternating beds of fossiliferous marls and calcareous sandstones. The beds have greenish-gray color and their lithologic character indicates that by this time, the adjecent land mass had been reduced to a very low relief and was gradually lowered close to sea level, where only very fine Clastic Sediments were brought, into the site of sedimentation. At this time both fine clastics and calcareous material were deposited simultaneously. The presence of Globigerina fossils indicates that at this time most of this area was at the threshold of invading deep marine waters and transgression of epieric seas had started.

The following fossils were found in the marl facies of these beds :

Rotalia,
Quinqueloculina,
Penoroplis,
Ammospirata,
Karreriella,
Pseudopolymorphina,
Turrilina,
Adla shumardi,
Pecten (Chlamys),
Amphissa.

The stratigraphic section of these lower Upper Oligocene beds, above the unconformity and below the Oligo-Miocene limestone is as follows:

Photo l - Typical example of the area east of Qizi, Uzan River covered with slightly indurated flat-Iying Pliocene beds.

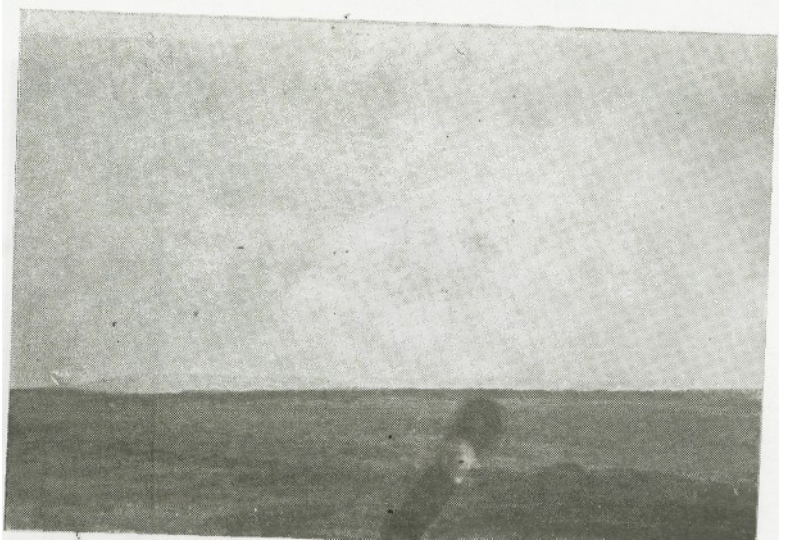


Photo 2 - The hills in foreground with the striking level summits are remnants of a former alluvial plain.

Photo 3 - Columnar basalt forming one of the lava flows exposed about 2 kilometers south-west of Goiklar.

Photo 4 - Basal conglomerate of Lower Chattian age exposed within the immediate vicinity of Daghirman Darreh.

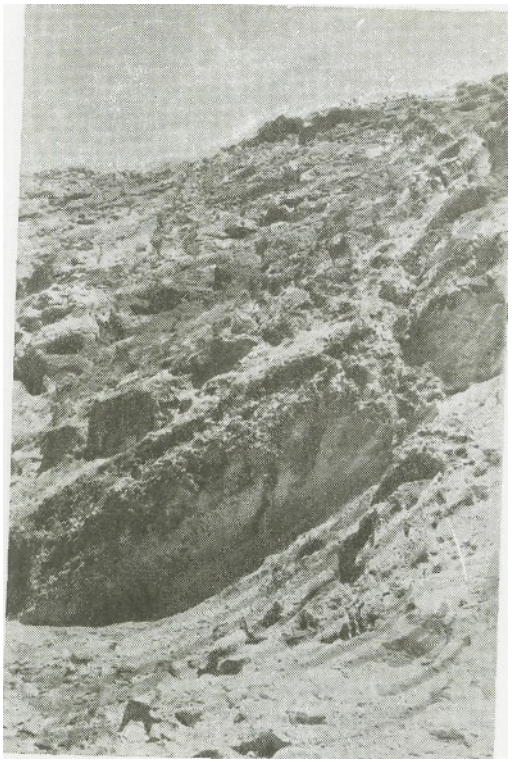


Photo 5 - Great thickness of Daghirman Darreh conglomerate (Lower Chattian) exposed half a kilometer north of Daghirman Darreh.

Photo 6 - Basal conglomerate conformably overlain by marls and calcareous sandstones (both of Lower Chattian a*ge)*. On the top is shown the Oligo-Miocene limestone formation which follows the sandstone-marl series.

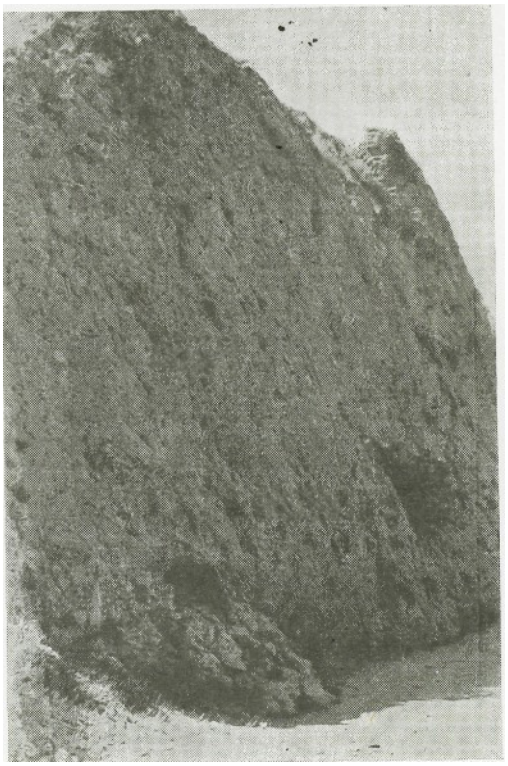


Photo 7 - Marls and sandstones of Lower Chattian age exposed one and half kilometers north of Daghirman Darreh. On the top is shown the Oligo-Miocene limestone formation conformably overlying these beds.

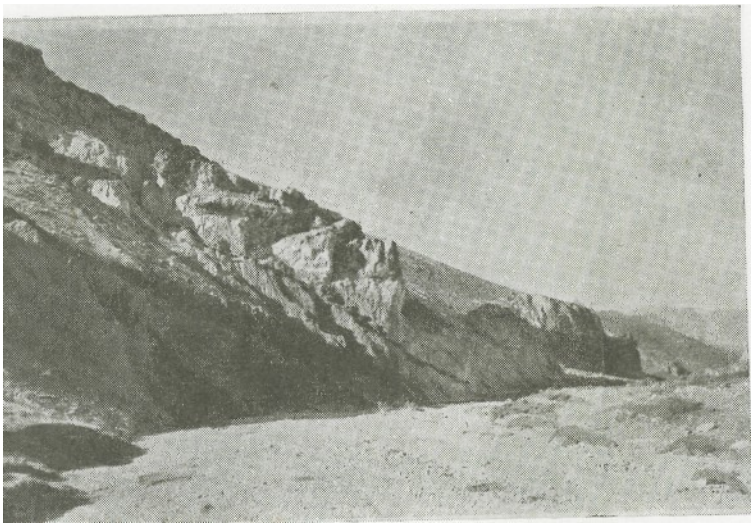


Photo 8 - The Oligo-Miocene limestone overlying directly the volcanics of Middle Oligocene age in a locality 2.5 kilometers soutlmest of Goiklar.

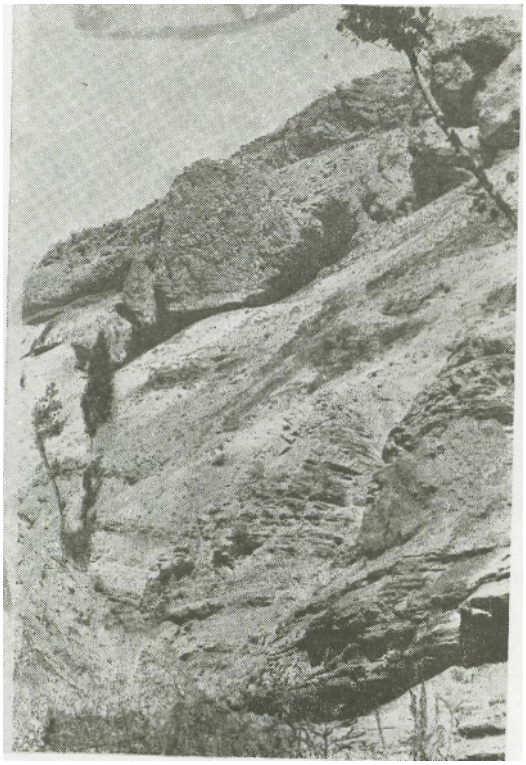


Photo 9 - Massive reef facies of the Oligo-Miocene limestone formation exposed about 3 kilometers north of Daghirman Darreh.

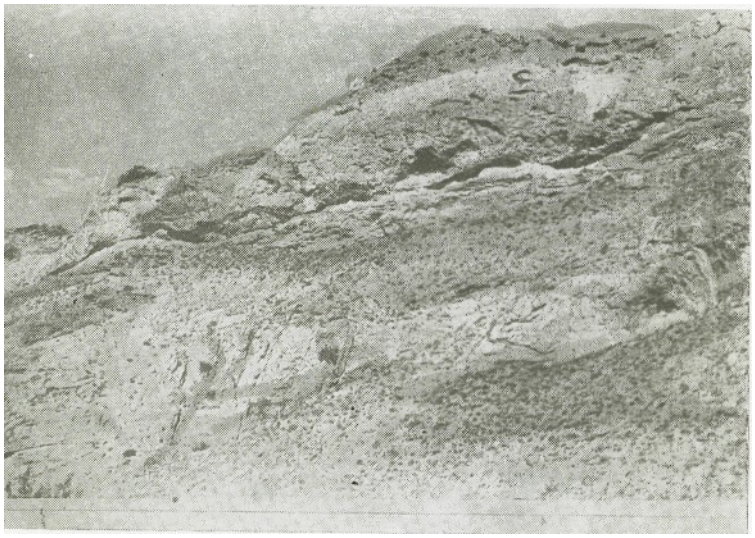


Photo l0 - Thin-bedded limestone below and massive reef limestone on the top; both are members of the Oligo-Miocene limestone formation. The locality is about 2.5 kilometers north of Daghirman Darreh.

Photo 11 - Bedded limestone grading laterally (toward left of the photo) into a bioherm devoid of bedding. The locality is about 2.5 kilometers north of Daghirman Darreh.

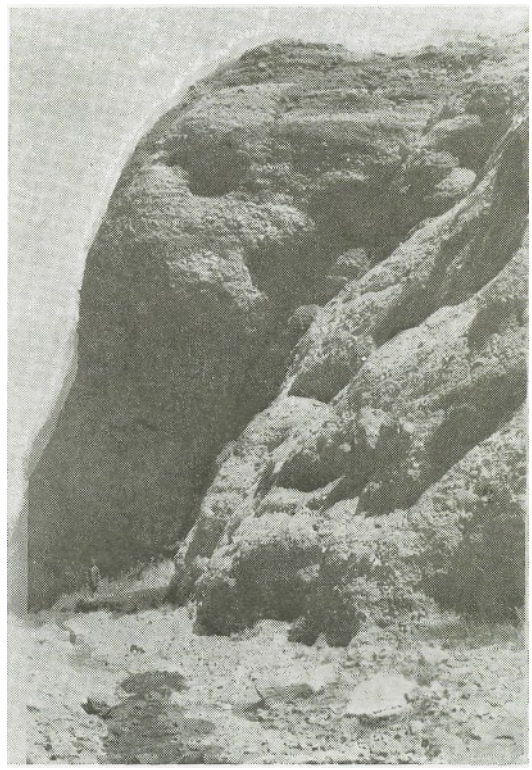


Photo 12 - Half a kilometer south of Goik Tappeh showing marl and chalky limestone below and massive reef limestone above.

Phota 13 - Upper part of the Oligo-Miocene limestone formation (on the left) grading into the marls and gypsiferous shales of the evaporite group (on the right). The locality is about 3.5 kilometers north of Daghirman Darreh.

Photo 14 - Marls, gypsiferous shales, and thin gypsum beds of lower part of the evaporite group exposed about 3.5 kilometers north of Daghirman Darreh.

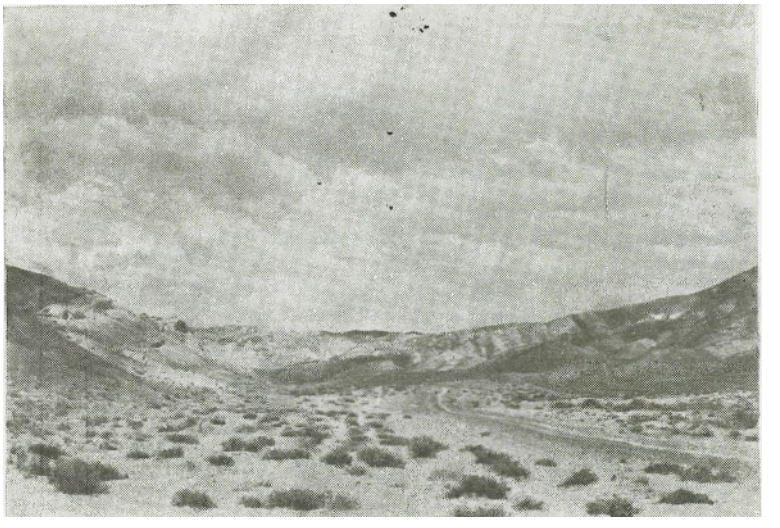


Photo 15 - On the extreme Ieft of the photograph are shown red beds of the continental group overlying beds of the evaporite group. The locality is about 12 kilometers north of Daghirman Darreh.

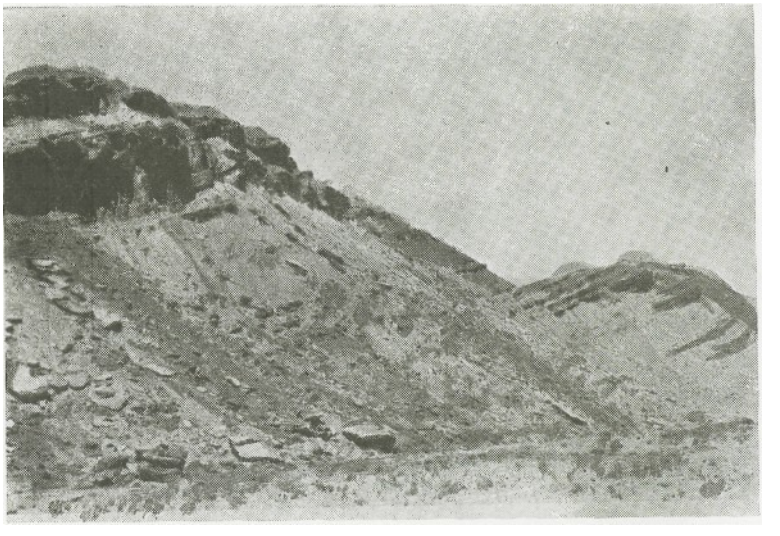


Photo 16 - Red shale and sandstone beds of the continental group exposed about 12 kilometers north of Daghirman Darreh.

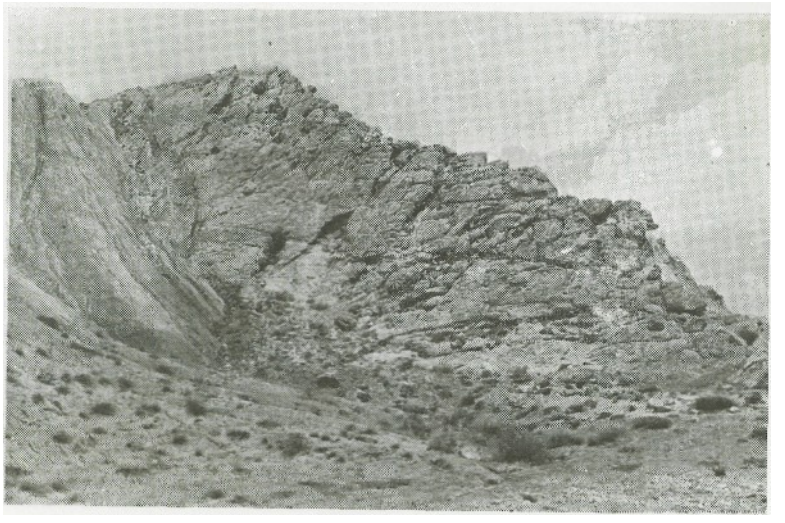


Photo 17 - Coarse-grained cavernous sandstone in the continental group exposed about l0 kilometers north of Daghirman Darreh.

Photo 18 - Mud cracks in the continental group exposed about one and half kilometers northwest of Mushampa.

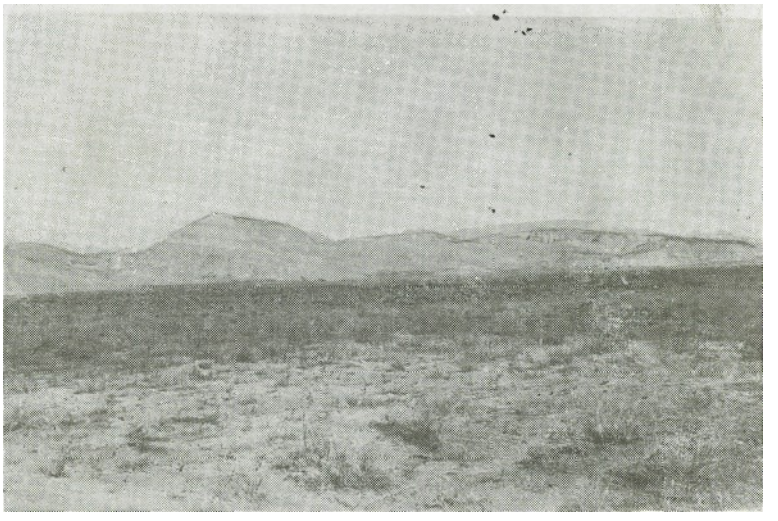


Photo 19 - Low-dipping Pliocene beds of a small anticlinal structure located about 18 kilometers northwest of Mushampa.

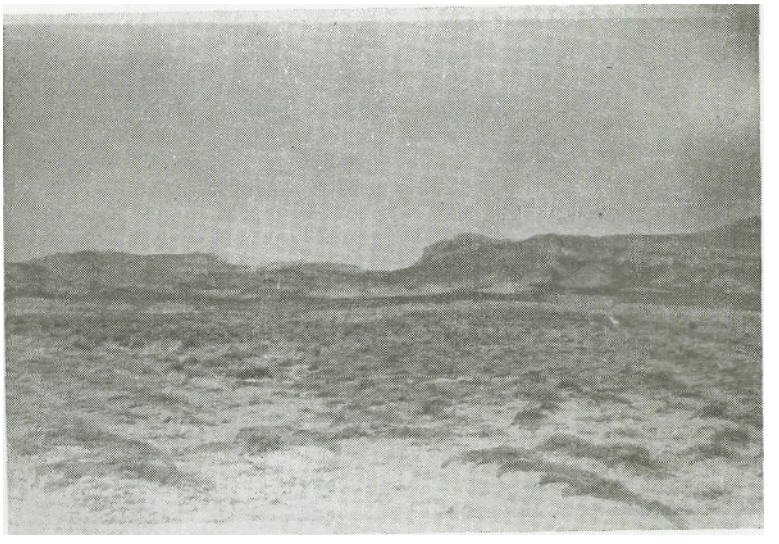


Photo 20 - Pliocene beds on the northern flank of the above-mentioned small anticline. The dark band shown wifhin the group on the right is the greenish-gray marl bed.

Stages	*Description of the beds*	*Thickness in meters*
U. Chattian to Burdigalian	*Oligo - Miocene Limestone*	
Middle Upper Oligocene	Greenish-gray marl	1
	Fine - grained calcareous sandstone	2
	Greenish-gray fossiliferous marl	14
	Fine-grained calcareous sandstone	3
	Greenish-gray fossiliferous marl	15
	Fine grained calcareous sandstone	2
	Greenish-gray fossiliferous marl, Pecten (Chlamys) bed	12
	Fine-grained calcareous sandstone	3
	Greenish-gray fossiliferous marl	5
	Coarse-grained sandstone	4
	Basal conglomerate	95
	Unconformity	
Middle Oligocene	Green stratified beds of volcanic origin	

Three kilometers north of Daghirman Darreh these Upper Oligocene conglomerate and marl deposits are reduced to 44 meters of conglomerate, 2 meters of sandstone and 80 centimeters of marl. About 5 kilometers northeast of Maaden (copper mine) 15 meters of greenish-gray marls are exposed overlying the basal conglomerate conformably. These beds are completely missing in the northern part of this area and the Oligo-Miocene limestone is deposited directly on the volcanics of Middle Oligocene age (Photo 10). The convergence of these beds manifested by pinching out of lower Upper Oligocene conglomerate and marl deposits indicates that the transgression was from south to north. The geologic record shows that the southern part of this area was submerged under the adyancing sea and typically marine sedimentation was in progress while the northern part of the area was above sea level. It was not until the Upper Ghattian time before the northern part of this area was submerged under marine waters.

Oligo-Miocene limestone formation

In the southern part of this area the marl deposits are conformably overlain by a thick limestone formation which in time range extends from Upper Oligocene to Lovver Miocene (Fig. 6; Photo 6). However, in the northern part near Goiklar it is deposited directly on the volcanics (Fig. 7; Photo 8). This limestone formation is of vast regional extent and overlaps transgressively eroded surface of the older beds in this region, it consists of massive reef limestone, marl, thin-bedded arenaceous limestone, and some calcareous, sandstone (Photo 9, l0, 11, 12). Throughout this area the lovver beds of the limestone formation have light-cream color, whereas the upper beds are reddish. The massive beds of this formation in some places are biostrome consisting of algal colonies, corals, pelecypods, echinoid remains, and foraminifers. The thin-bedded members contain abundant foraminifera and - Bryozoa. The marls and calcareous sandstones have light-cream to grayish color and are interstratified with the limestone beds. From this limestone formarion the following macrofossils were identified: Heliastraea (=Orbicella) defrancei Milne Edwards & E. Haime, Astraroara cf. Reuss, Flabellum sp., Clypeaster rogersi Morton, Diploastrea sp., Conodypeus sp., Psammechinus sp., Spondylus sp., Lithophaga cordata -Bolten, Anadara osmondi Dall, Ostrea digitat Eichwald, Pecten beudanti Basterod, Venus, (Chione) securis Shumard, Dosinia sp., Conus sp., Natica sp., Cyprea sp.

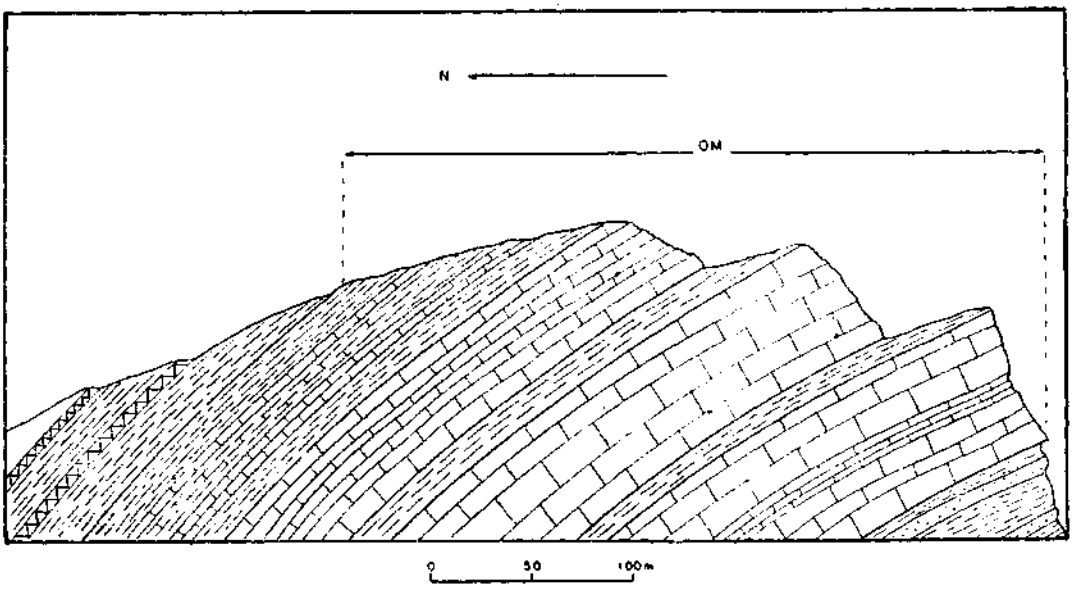


Fig. 6 - Section of Oligo-Miocene limestone at Daghirman Darreh locality.

The following microfossils were found in this formation : *Miogypsina* sp., *Operculina* sp. *Lepidocyclina* sp., *Rotalia sp., Amphistegina* sp., *Globigerina sp., Nummulites* sp., *Neoalveolina melo* ssp. and Miliolidae.

This fossil assemblage indicates that the limestone is a transitional formation, chronologically extending from Upper Oligocene to Lovver Miocene.

In the southern part of the area this limestone formation is exposed overlying the Upper Oligocene marls. Following is a description of that section.

Stages	*Description of the beds*	*Thickness in meters*
Upper Chattian to Burdigalian	Thin-bedded chalky limestone interstratified with rather thick and light-colored marl	50
	Dense fossiliferous pink limestone	40
	Thin limestone beds interstratified with light-colored marls	25
	Massive porous reef limestone, in some places biostrome	70
	Thin-bedded arenaceous limestones and thin beds of calcareous sandstones alternating with gray marls	30
	Light-cream-colored massive reef limestone consisting of algal colonies, corals, pelecypod remains and foraminifera.	75
		290

Three kilometers north of Daghirman Darreh there is a reduction in the amount of Clastic elements in this formation; and that is manifested in the following section: Measured from base to top, there are 70 meters of cream-colored massive reef limestone; l0 meters of thin-bedded arenaceous limestone alternating with gray marls, 60 meters of massive porous reef limestone, 15 meters of thin-bedded limestone interbedded

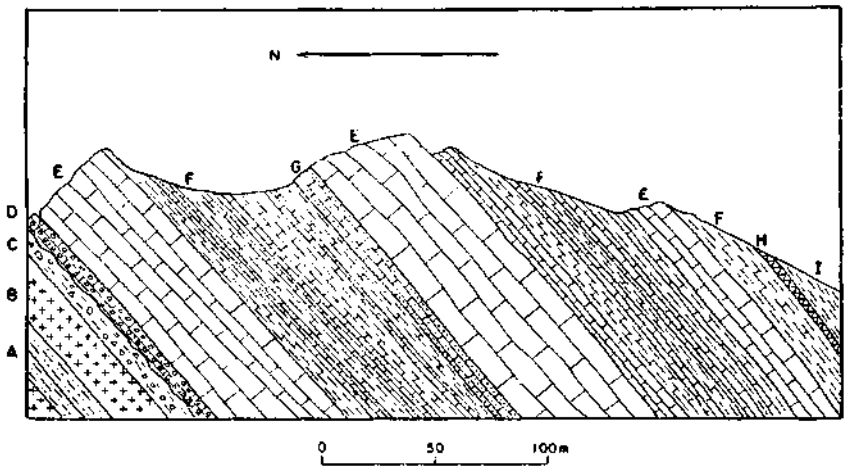


Fig. 7 - Section of Oligo-Miocene limestone 2 km SW of Goiklar.

with marl, 45 meters of dense fossiliferous limestone, and 50 meters thin-bedded chalky limestone interstratified with light-colored marls (Fig. 8).

About two and half kilometers southwest of the village of Goiklar, the Oligo-Miocene limestone is exposed overlying the Upper Oligocene volcanics directly, without the thick basal conglomerate and marl group above the unconformity (Fig. 7; Photo 8). This section is exposed on the southern flank of a small anticlinal fold at the crest of which Upper Oligocene volcanics are exposed. A comparison of Daghirman Darreh section with that of Goiklar shows that there is a definite convergence of conglomerate and limestone from south to north. Here, above the Rupelian-Chattian unconformity, the basal member of the Oligo-Miocepe limestone formation consists of a bed of three meters thick of conglomerate. In this basal conglomerate the boulders and pebbles are derived from the underlying volcanics and the matrix is limestone. The boulders and pebbles are angular to subangular, and they are rather sparsely scattered in the limestone matrix. These two aspects of the conglomerate indicate that the rock fragments have been incorporated in this bed right in place, without being transported and concentrated by the currents. They indicate that a land with low relief was gradually being submerged and the sea was transgressing over the land without any major change on the surface material.

A tabular description of the limestone section in this locality is given on the following page (see also Fig. 8).

Half a kilometer southwest of the village of Goik Tappeh in a small valley about 230 meters of Oligo-Miocene limestone is exposed overlying pink palagonitic tuffs. The limestone here has the same characteristics as that in Goik Tappeh section. About 5 kilometers northeast of Maadan (copper mine) 250 meters of this limestone is exposed on both sides of the road.

Middle and Upper Miocene

In this area above the Oligo-Miocene limestone formation and below the Pliocene beds there is a great thickness of predominantly Clastic deposits, which on the basis of lithologic character. form two distinct divisions. The lovver division is characterized by

Goiklar Section (Oligo - Miocene Limestone)

Epoch	*Stage*	*Description of the beds*	*Thickness in meters*
Upper Oligocene - Lower Miocene	Upper Chattian to Burdigalian	Massive dense pink fossiliferous limestone	18
		Chalky white limestone with some thin beds of greenish-gray marl	40
		Dense pink limestone	11
		Dense, thin-bedded limestone	9
		Massive porous reef limestone	48
		Interformational conglomerate in which scattered small pebbles are derived from volcanic material	4
		Thin beds of chalky limestone alternative with light-cream-colored marl	56
		Massive light-colored limestone consisting of algal colonies, corals, and pelecypod remains	45
		Basal conglomerate	3
		Unconformity	
Middle Oligocene		Agglomerate and tuff	224

the presence of evaporites and seems to be mostly deposits of shallow restricted seas and lagoonal environment. The upper division consists of cpntinental-type deposits. Structurally the lower division is distinguished from the upper division by contortion of beds and complex folding which it exhibits.

The Lower division (evaporite group). — The beds of this division overlie concordontly the Oligo-Miocene limestone without any sign of break in sedimentation, (Photo 13) and they show certain degree of variation of facies from one place to the other.

In the locality southvvest of Goiklar, the Oligo-Miocene limestone is overlain by 20 meters of buff marl, and that is followed by a gypsum bed of 6 meters thick. The gypsum is overlain by about l0 meters of gray shale and then follows a 40 meters section of red sandstone and red shale.

Over this section of red beds lies about 1320 meters of light-cream-colored marl, thin-bedded limestone, calcareous sandstone, beds of gypsum and salt, and thick beds of gypsiferous gray shale (Fig. 9).

In the southern part of this area near Daghirman Darreh the Oligo-Miocene limestone formation is overlain by 14 meters of marl, followed by a gypsum bed of 4 meters thick and 6 meters of gypsiferous shale. That is overlain by 90 meters of alternating red and marron shale and sandstone (Photo 14). This variegated section is overlain by about 1250 meters of marl, thin-bedded limestone, sandstone, salt, gypsum and thick beds of gray gypsiferous shale (Fig. 9). Goiklar and Daghirman Darreh sections are respectively the exposures on the northern and southern flanks of the majör anticline (Nauruzabad anticline). The beds characterized by evaporites are exposed also along the crest of the Nauruzabad anticline, extending from the village of Mehrabad in a northwesterly direction for a distance of about 40 kilometers (Fig. l0).

The Upper division (continental group). — This division consists of a group of alternating beds of red shale, siltstone, and sandstone (Photo 16). They overlie the

COLUMNAR SECTION OF DAGHIRMAN DARREH - GOIKLAR AREA

Daghirman Darreh section

Lithologic character

Alternating red beds of shale and sandstone with numerous mud cracks and ripple marks. Most of the sandstones with medium to coarse texture. A bed of 20 meters of agglomerate located above the base of the group.

Agglomerate.

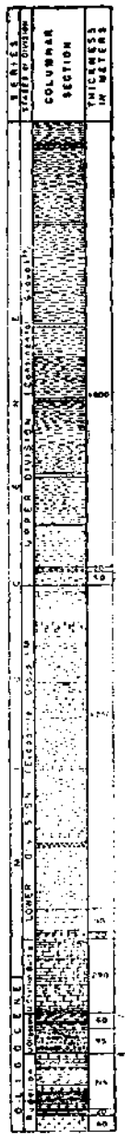
Characteristically light-colored marl, gypsiferous shale, thin-bedded, flaggy limestone, salt, gypsum and thin-bedded calcareous sandstone. A zone of about 40 meters thick variegated shale and sandstone beds of crimson, purple and red color located about 36 meters above the base of the group.

The variegated beds of shale and sandstone.

Thin-bedded chalky limestone interbedded with rather thick marl, dense fossiliferous pink limestone, thin-bedded limestone, massive porous reef limestone, thin-bedded arenaceous limestone, massive reef limestone consisting of coral and algal colonies.

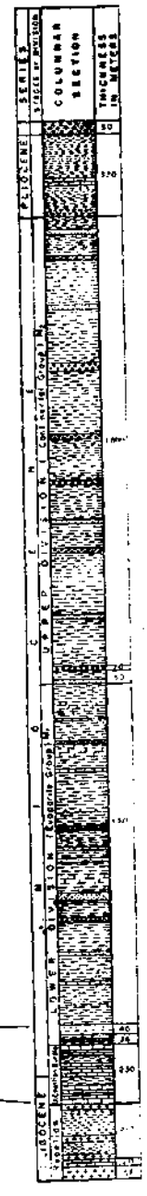
Greenish-gray marl interbedded with fine-grained calcareous sandstone. Thick basal conglomerate.

Agglomerate tuff, basaltic lava flows, green stratified beds of pyroclastic origin. 21 meters of Globigerina limestone interbedded with basaltic lava flows.



2000 meters above sea level (approx.)

Goiklar section



Lithologic character

Outwash gravel of former alluvial plane, terrace, gravel and alluvium.

Thin-bedded soft shale and siltstone of buff color, gray thin-bedded sandstone, greenish-gray marl, and basal conglomerate. Calcareous tufa and travertine bed of 30 meters thick about the middle of the section.

Alternating rea beds of shale and sandstone with numerous mud cracks and ripple marks. Most of the sandstones with medium to coarse texture. A bed of 20 meters of agglomerate located above the base of the group.

Agglomerate.

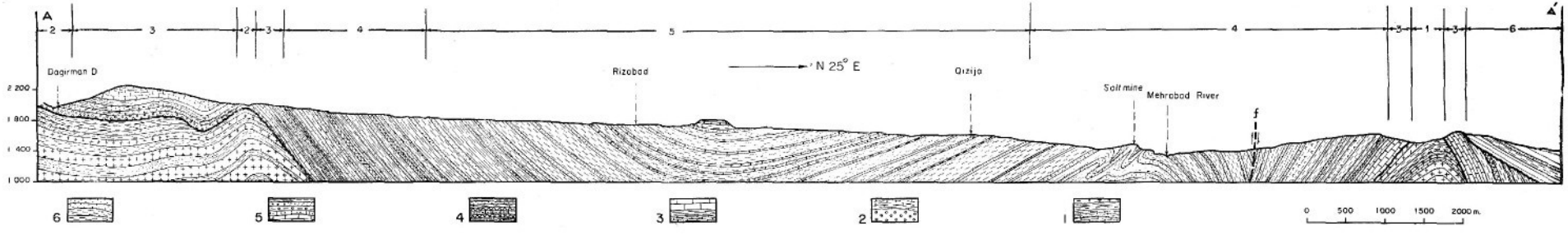
Characteristically light-colored marl, gypsiferous shale, thin-bedded flaggy limestone, salt, gypsum and thin-bedded calcareous sandstone. A zone of about 40 meters thick variegated shale and sandstone beds of crimson, purple and red color located about 36 meters above the base of the group.

Red beds of shale and sandstone.

Massive dense pink fossiliferous limestone, chalky white limestone greenish-gray marl, massive porous limestone, buff colored marl, massive light-colored reef limestone of coral and algal colonies. Three meters of basal conglomerate.

Agglomerate tuff, basaltic lava flows, green stratified beds of pyroclastic origin, columnar basalt, 21 meters of Globigerina limestone interbedded with basaltic lava flows.

Globigerina limestone.



SECTION ACROSS NAURUZABAD ANTICLINE EAST OF QIZIL UZAN RIVER DAGHIRMAN DARREH — GOIKLAR SECTION

1 - Pliocene : *Slightly indurated fine clastics, mainly fluvio-lacustrine;* *2* - M.-U. Miocene : *Continental group, red shale and sandstone with an agglomerate bed;* *3* - L.-M. Miocene : *Evaporite group, gypsum, salt, marl, gypsiferous shale and thin-bedded sandstone;* *4* - U. Oligocene-L. Miocene : *Oligo-Miocene limestone formation;* *5* - L. Chattian : *Basal conglomerate and marl beds;* *6* - Rupelian : *Stratified green beds of pyroclastic origin interbedded with basaltic lava flows.*

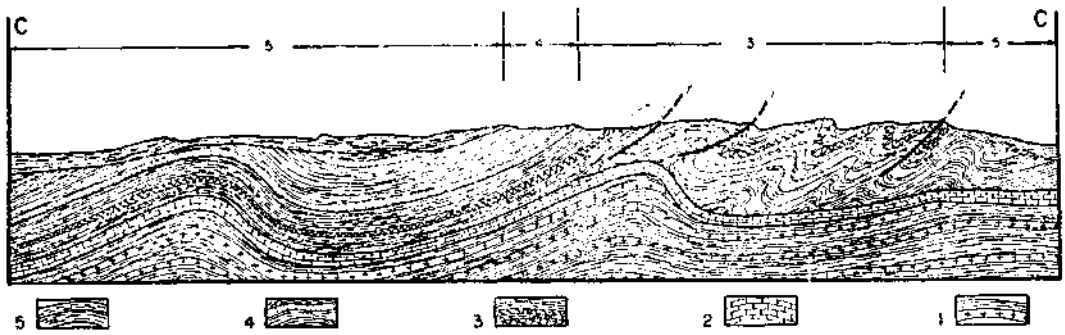


Fig. 10 - Section C-C′ across Nauruzabad Anticline

1 - Pliocene : *Fine clastics, mainly fluvio-lacustrine with some calcareous tufa deposits;* *2* - M. & U. Miocene : *Continental group red shale and sandstone with an agglomerate bed;* *3* - L. & M. Miocene : *Evaporite group gypsum, salt, marl, gypseferous shale and sandstone;* *4* - U. Oligocene & L. Miocene : *Oligo-Miocene limestone formation;* *5* - Oligocene : *Stratified green beds of pyroclastic origin interbedded with basaltic lava flows.*

evaporite group conformably and there is no evidence of break in sedimentation between the two groups (Photo 15). There is marked contrast between the two groups in that the upper division, in contradistinction to the lower division, has no evaporite beds, the Clastic particles constituting rocks of this group are in general coarser-grained, and the entire group is characterized by red color (Photo 17); whereas the lower division in addition to salt and gypsum beds, consists predominantly of light-colored deposits of generally finer grain size, like marls and gypsiferous shale. These two groups are structurally also distinguishable from each other. The lower division, wherever it is unconvered by erosion of overlying beds, shows a great deal of contortion and intricate folding; whereas the upper, division does not exhibit any complex folding.

The coarseness of Clastic particles and numerous current ripple marks indicate that part of the Sediments of the upper division were deposited in the waters which had very shallow depth. Many of these beds have mud cracks (Photo 18), which indicate that these deposits were desiccated due to their exposure to subaerial agents. The red color of these deposits indicates that these Sediments in their provenance as well as partly in their site of deposition were exposed to subaerial agents of semi-arid climate.

About 50 meters above the base of this division is a layer of tuff and pyroclastic breccia of 20 meters thick. In this pyroclastic bed the matrix is pink palagonitic tuff and the lapilli consist of cognate intermediate igneous material, which have an average size of about 3 centimeters and non-cognate lappili, which are small fragments of a green shale. Due to the fact that the particles of these Volcanic ejecta are not sorted at all, it becomes evident that they were deposited under subaerial conditions. This pyroclastic deposit is exposed west of the village of Mushampa, directly on the right bank of Qizil Uzan River.

The red beds ,are exposed in the vicinity of Mehrabad around the southeast plunging end of Nauruzabad anticline, and from there they extend northwestward along the southern flank of that structure up to the village of Nauruzabad. They are exposed on the northwest plunging end of the ariticline along Aji Ghai, also along Kali Ghai in the vicinity of Anjuman.

The maximum thickness of these red beds in this area is 1800 meters; however, there are obvious indications that the original thickness was more than this figüre, because everywhere the upper part of these beds is removed by erosion. This thickness is measured in the vicinity of Rizabad from that portion of these beds which are preserved in a synclinal trough.

The red beds as well as the older beds are folded and subjected to extensive erosion before the deposition of overlying Pliocene beds.

Pliocene

Over the Miocene beds, which are highly folded and extensively eroded, lies a Series of beds which lithologically and structurally form a group very distinct from the underlying Upper Miocene red beds and are separated from them by a major unconformity. These beds overlap transgressively the outcrops of volcanics, the Oligo-Miocene limestone, and the Miocene beds.

In contrast to the highly folded Miocene beds below the unconformity, these beds in most places have a dip of about 4° , in some places they do not seem to be disturbed at all and they are almost horizontal (Photo 1). Only on the periphery of uplifted anticlinal structures these younger beds have their maximum dip of about 25 degrees away from these structures (Photo 19, 20).

These beds consist mostly of soft shale and siltstone, with some gray marl; most of them have typically buff color. There is a bed of about 30 meters thick of calcareous tufa in the middle of the section. It is very probable that the materials of these beds are derived from the Miocene beds of this region. They are not marine deposits and seem to be deposited in vast alluvial plains and lacustrian environments. In this Series there are many alternating cyclic beds, which are as thin as 3 centimeters in thickness, indicating typical lacustrian deposits.

These beds have been removed from the uplifted places of this area, like southern part of the majör anticlinal structure. East of Qizil Uzan River, on the northern flank of the anticlinal structure (Nauruzabad anticline), in some places the pre-Pliocene erosion has affected all of the deposits down to the Volcanic Series. On this surface of erosion these Pliocene beds are deposited. North of the village of Shakar Bulagh on the eroded surface of Miocene strata having a dip of 78° is deposited the Pliocene beds which have a dip of only 19° to the northeast. One kilometer northeast of Mushampa the Pliocene beds are lying horizontally on the eroded surface of Miocene beds, which have a dip of 85° to the north.

Half a kilometer south of Shakar Bulagh the Miocene-Pliocene contact at the base of the Pliocene beds is exposed. Here a basal conglomerate bed of 2.5 meters thick consists of pebbles and boulders up to 20 centimeters in size. These coarse Clastic materials are mostly rounded fragments of underlying red and gray Miocene sandstones. The matrix of the conglomerate consists of fine-grained gray sandstone. The sequence of beds above the conglomerate is as follows: 2 meters of siltstone, 20 meters of greenish-gray soft sandstone, 3 meters of siltstone, and about 200 meters of alternating beds of buff shale and siltstone. In this locality, below the unconformity, the Miocene beds have a dip of 78° and on the eroded surface of these steeply dipping strata lie the Pliocene beds with a dip of 25° to the northeast. Four kilometers northeast of

Shakar Bulagh these beds have a dip of only 14° . Five kilometers north of Jamalabad, on both sides of highway, a layer of calcareous tufa of 30 meters thick is exposed which is interbedded with the Pliocene beds about the middle of the section. This is a deposit of thermal springs typical of the regions with Volcanic activity. The maximum exposed thickness of these Pliocene beds in this area is about 400 meters; it is probable that the total thickness is more than that figüre.

The geological record in this area indicates that after the deposition of Upper Miocene beds it took a considerable amount of time until these beds above the unconformity were deposited. When it is taken into consideration, the time required for the Miocene beds to be folded, uplifted, an exposed to the processes of erosion for a long time such that in some places these beds were completely removed together vvith part of the underlying volcanics. Also the time required for the necessary crustal re-adjustment which had to take place so that this region changed from an upland prone to erosion and degradation to a depression suitable for aggradation and accumulation of Sediments. It becomes evident that the time span between the folded and eroded Upper Miocene red beds below unconformity and the less disturbed beds above it must have been rather long.

The photogeological observation on this region shows that these beds vvith typically low dip extend to the west for a considerable distance. South of Maragha, within the deposits of similar description, Stahl reports that (A.F. v. Stahl, Handbuch der Regionalen Geologie, Vol. 6, 1911), the following Mammalia fossils of Pliocene age were discovered: Hipparion, Rhinoceros, Mastodon, Tragoceros, *Cervus* sp., and a few others.

QUATERNARY

The Quaternary deposits in this area are remnants of outwash gravels of former alluvial plain. These deposits are well preserved east of Qizil Uzan River, especially in the area between Sarcham and Jamalabad. They cap the hills carved out of the Pliocene beds and their profile of level surface of the former alluvial plain is a very striking view (Photo 2). The gravels of these former alluvial plains consist mostly of pebbles derived from the igneous rocks of early Tertiary, and partly from the sedimentary rocks of Neogene age of this region. The matrix consists of clay and the cementing material is calcium carbonate.

The other Quaternary deposits are some terrace gravel deposits of Qizil Uzan River on the east bank of it and the alluvium deposited in the stream beds and the flood channels.

STRUCTURE

The area of this report is part of a structural basin produced by the relative uplift of surrounding regions. Within this structural depression the Tertiary Sediments up to and including Pliocene beds are preserved. The surrounding regions, with the exception of western part, have been uplifted to such an extent that Mesozoic and early Tertiary rocks stand higher than Pliocene beds of this structural depression. The western limit of it is a zone of general uplift extending along Zarineh Rud valley, but this uplift is not of such a magnitude as to cause removal of Neogene deposits.

The dominant structural trend in this area is northwest-southeast, and the folds are asymmetric with their axial plane tilted to the northeast. Within the area of this report there is a major anticlinal structure (Nauruzabad anticline), which extends from Mehrabad for a distance of about 50 kilometers in a general direction of N 45° W. At the crest of this structure the evaporite group of Lower Miocene is exposed, and because of their plastic nature they show several minör folds on this majör structure. I believe these minör folds are confined. to the evaporite group only and have no effect on the underlying limestone formation. The Oligo-Miocene limestone formation, on account of its physical characteristics will be folded into broad flexures. The south-eastern half of this anticlinal structure, which is located east of Qizil Uzan River, is steeply folded; whereas the other half to the west of that river has relatively broad fold.

There is another anticlinal structure which is located in the southern part of the area (Fig. 1). It extends from the vicinity of Daghirman Darreh in a northwesterly direction for a distance of about 35 kilometers. Its axis has a general trend of N 70° W and it is plunging in the northwestern direction. In the eastern half of it, erosion has removed all of the Miocene deposits together with Oligo-Miocene limestone, and Eocene-Oligocene volcanics are exposed at the crest of the anticline. On the western part of it, the Neogene beds are plunging under the Pliocene beds and this structure is reflected in the overlying Pliocene beds giving them anticlinal fold in a locality 16 kilometers to the northwest of the village of Mushampa (Photo 19).

There is another set of folds which are of minor magnitude and post-date the majör folding; they have a general trend of N 7° E. One of these secondary folds is located 3 kilometers north of Daghirman Darreh, directly on the east side of the road. The other one is in Gara Darreh valley about 5 kilometers west of Rizabad.

In the area of this report the dominant orogenic movements during Cenozoic era belong to two separate episodes; one is pre-Pliocene and the other post-Pliocene. The most important pre-Pliocene event occurred at the end of Miocene, and in that event folding due to lateral compressional forces has been primary factor and vertical uplift a secondary one. Whereas in post-Pliocene orogenic movements vertical uplift has been all-important factor and folding has been very minör element and consequential to vertical uplift. Miocene beds show great deal of folding and most of the folds are asymmetric. Pliocene beds are in many places almost horizontal and they are disturbed wherever an underlying Miocene structure has experienced a post-Pliocene vertical uplift. Tilting of Pliocene beds on the periphery of Nauruzabad anticline has been produced due to post-Pliocene uplift of the Miocene anticline below these beds. The same is true about the anticline 16 kilometers to the northwest of Mushampa. Here the anti-clinal structure manifested in Pliocene beds has come into existence due to uplift of underlying Miocene structure.

Within this area, the faults are of small to intermediate magnitude, all are of compressional type and confined to the evaporite group of Miocene beds. They have the same trend as the axis of majör folding and have been produced as a result of shearing of the beds of evaporite group in the process of folding (Fig. 2). One of these extends from Nauruzabad for a distance of about 30 kilometers to the northwest. As a result of this faulting the northeastern block has been displaced towards the northwest. Five kilometers east of this one, another fault, but smaller in size, constitutes the northeastern

boundary of the same block. There is a third fault about one kilometer west of Shakar Bulagh, which has a northwest-southeast trend.

In this area there are two unconformities of majör magnitude. One of these is above the Volcanic series and below the Upper Oligocene and Oligo-Miocene beds. This interval of erosion lasted from the late Rupelian until the middle of Chattian time. The other unconformity separates the folded and eroded Upper Miocene red beds from the overlying less disturbed Pliocene beds.

THE GEOLOGIC HİSTORY

From the observations made on the geology of this area, the following Course of events are indicated. It seems that during Eocene and at least up to the end of Middle Oligocene times there was extensive Volcanic activity, vvhich resulted in the extrusion of large quantities of lava flow and ejection of considerable amount of pyroclastic material. There are positive indications that some of the lava flows are of submarine Origin, as they are associated with typically fossiliferous marine Sediments. Great majority of pyroclastic material shows stratification and sorting of grain particles, which indicate that they were deposited under aqueous conditions. The fact that many of the beds consist of pyroclastic Origin showing perfect sorting makes it probable that the materials of some of the beds were transported by water and then deposited in the site of sedimentation. In that case it must be assumed that most of the Volcanic eruption was peripheral to the basin of sedimentation and only a small portion of Volcanic activity took place within the basin.

During the Middle Oligocene time there was a short period of marine transgression and at this time about 21 meters of typically marine Sediments of Globigerina limestone were deposited. After that there was certain degree of regression resulting in disappearance of pelagic deposits and recurrehce of conditions suitable for deposition of Clastic material. This regression continued until about the end of Rupelian, at which time this area was completely emerged. From the end of Rupelian until early Chattian time this arca was subjected to erosion producing the unconformity below basal conglomerate of Daghirman Darreh. From Upper Chattian time on marine transgression continued until at least Burdigalian time. During this period of transgression the basal conglomerate of Daghirman Darreh, the greenish-gray fossiliferous marls of that locality and the Oligo - Miocene limestone formation were deposited. After deposition of Oligo-Miocene limestone again regression started and marine vvaters retreated as a result of vvhich and gypsiferous shales, gypsum and salt deposits overlying Oligo-Miocene limestone were deposited in restricted shallow seas and lagoons. This period of regression ended in deposition of about 90 meters of red beds. After that, again a weak transgression started during which the main part of evaporite group of Lovver Division was deposited. This event of transgression gave way to the final episode of regresion, as a result of which deposition of evaporite group was ended and Upper Miocene red beds were deposited. During Upper Miocene time great thickness of Clastic material was deposited under continental conditions.

The recurrent processes of transgression and regression, which had started at least since Middle Oligocene, came to an end at the close of Miocene time. At the end of Miocene, the area experienced a period of folding and uplift. This period

of uplift must have been rather long, because during this time in some places erosion has removed all of the Miocene beds, the Oligo-Miocene limestone, and part of the volcanics. After this period of uplift and erosion the region subsided again and on the folded and eroded surface of Eocene, Oligocene, and Miocene beds were deposited the Pliocene beds under lacustro-continental conditions.

Since the deposition of Pliocene beds the orogenic activities in this area have been one of gradual general uplift. This concept is based on the fact that in some places Pliocene beds are almost horizontal and in the other places their disturbance does not exceed moderate tilting.

The noteworthy post-Pliocene geological record in this area is the remnants of gravel deposits of former alluvial plains.

Manuscript received March, 1965