MINISTRY OF INDUSTRY AND MINES

GEOLOGICAL SURVEY OF IRAN

Explanatory text of the
Esfahan Quadrangle Map
1:250,000

by

M. Zahedi

Geological Survey of Iran, 1976
Geological Quadrangle No. F8

GEOLOGICAL SURVEY OF IRAN

Managing Director: Reza Assefi

For sale at 250 Rials (S3.50) per copy
Geological Survey of Iran, P. O. Pox 1964, Tehran, Iran

Printed by Ministry of Information and Tourism Press, Tehran, Iran

CONTENTS

Abstract

The Esfahan Quadrangle, bounded by longitudes 51° and 52°30' and latitudes 32° and 33° N, has a surface of about 15,000 square kilometers. The region includes rocks of Precambrian to recent age whose sedimentary, structural and geological history and tectonics are described. The oldest rocks (Precambrian), cropping out west of Esfahan, consist of schist, gneiss and metamorphic andesitic volcanics.

Cambrian, Ordovician and Silurian sediments are missing, but Lower Devonian sediments are exposed in the northeast of the Quadrangle. They are composed of reddish to whitish sandstone and quartzite. The Lower Devonian sediments are succeeded conformably by dolomitic limestone, sandy limestone and thin-bedded fossiliferous grey limestone beds of the Middle to Upper Devonian.

Lower Carboniferous beds consisting of fossiliferous marly limestone, sandstone are found in the southeast of the quadrangle. Nowhere in the area have Upper Carboniferous and Lower Permian rocks been found.

Middle-Upper Permian rocks in the quadrangle are exposed northeast, southeast, and west of Esfahan. They consist of a basal sandstone and conglomerate bed succeeded by fossiliferous limestone.

The Triassic sequence comprises a lower part of carbonate rock (limestone and dolomite) and an upper part of mainly terrigenous deposits (shale and sandstone). Sections are exposed southeast, northeast, and northwest of Esfahan.

The Jurassic sediments can be divided into two parts: the northeast (and probably the southeast), consisting of shales and sandstones with intercalations of conglomerate beds (Shemshak Formation); and deposits west and southwest of Esfahan formed of shales and sandstone with intercalations of limestone and volcanics.

Cretaceous rocks are exposed almost everywhere in the area and are more developed south of Esfahan, consisting mainly of limestone, marl and shale ranging from Barremian to Maestrichtian.

The Eocene (mainly Lutetian) rocks form two major units in the Quadrangle area: conglomerate and limestone in the southwest, and lavas and pyroclastics with nummulitic limestone northeast of Esfahan. The Oligo-Miocene (Qom Formation) sediments are represented as white-ish, fossiliferous limestone but are not developed as much as in the north outside the Quadrangle boundaries. The Miocene-Pliocene sediments consist mainly of conglomerate, sandy porous limestone and sandy marls.

The Quaternary deposits represented are travertine, different levels of terraces and alluvium.

The intrusive rocks are Upper Jurassic granodiorite and Early Paleogene dolomite injections to the south of Esfahan. An intrusive rock formed of granodiorite, and belonging to the Neogene, was granodiorite found in the northeast of the area.

EXPLANATORY TEXT OF THE ESFAHAN QUADRANGLE MAP

1: 250,000

INTRODUCTION

Esfahan (pop. 2,000,000) is situated in the middle of the Esfahan Quadrangle on the Esfahan Plain, which lies between two northwest-trending mountain ranges, the Zagros in the southwest, and the Kohrud forming an eastern boundary against the Central Kavir. In the Zagros mountains, with numerous villages and springs, good rainfall and vegetation contrast markedly with the dry and empty plain of Esfahan and the Central Kavir.

The Quadrangle contains a number of high peaks, of which the two highest are Kuh-e-Mareshnan (3,330 m) to the northeast in the Kohrud range, and Kuh-e-Arjeneh to the southwest in the Zagros ranges. The Osin range parallel to the Zagros (NW-SE), and also in the southwestern quadrant of the Quadrangle, has its highest point in Mt. Osin (2,910m), and several peaks reaching 2,500-2,900 m.

The Shah Kuh range, extending diagonally (NW-SE) across the sheet area and dividing it into two parts, has two high peaks: Kuh-e-Boland (2,755m) in the northwest and Kolah-e-Qazi (2,534m) in the southeast. The country immediately to the southwest of the range (the high plain of Riz-e-Lenjan) has an altitude of about 1,800m; that to the northeast (Esfahan plain) is lower, with an altitude of some 1,500m. The Esfahan plain, about 50km wide and several hundred kilometers long, is a northwest-trending depression whose lowest part is a marsh (Mordab-e-Gavkhaneh) located about 100km southeast of Esfahan, beyond the sheet area.

Apart from these two plains, there are several less important, intermontane ones, such as the Najafabad, Mahyar and Sefid Dasht plains, which are used mainly as arable land. The Zayandeh Rud river flows west to east across the northern part of the Riz plain. It cuts the Shah Kuh range in the middle of the map area, then meanders eastwards, to the south of Esfahan, and southeastwards to Gavkhaneh in the neighboring sheet area.

The Quadrangle is crossed by several major roads; a number of other good roads connect the smaller towns and villages with Esfahan. The main roads run to Tehran in the north, Yazd in the east, Shiraz in the south, Borujen and Shahr-e-Kord in the southwest, and Hamadan and Khoramabad in the west.

Acknowledgements

In addition to S. Tatevossian, who assisted with the mapping work, a number of other people have made important contributions to the report in their specialist fields.

Within the Geological Survey of Iran, great assistance was received from paleontologists Dr. M. Mehrnoush, Dr.B. Hamdi, Mr.H. Partoazar, Dr.K. Lessani for the determination of microfossils, Mr.F. Golshani for the study of the brachiopods, and Mr.B. Majidi and Mr. M. Lotfi for the determination of petrographic thin sections, for which my sincere gratitude is proffered. The assistance of Dr.K. Seyed-Emami (Tehran University) in carrying out the determination of ammonites, and assisting in reading and editing the report, was much appreciated, while further paleontological help was received from Dr. D. Brice of Lille University, who is thanked for his determination of the brachiopods. Special thanks are due to Dr. M. Takin, Dr. M. Davoud-zadeh, Dr. M. Amidi and Miss J. Luke for reading and editing the report.

For sympathetic assistance and advice during the multifarious stages of the report and its innumerable problems, appreciation is expressed to Mr. R. Assefi (Director, G.S.I.), Mr. K. Alipour **and** Mr. J. Eftekhar-Nejad.

For the support of chemical, cartographic, photographic and other services, I thank all the staff concerned at the Geological Survey of Iran. Finally, I thank Mr. E. Burman, who has polished and prepared the report for publication.

Previous Geological Investigations

Stahl (1897) mentions the presence of the Cretaceous in the Esfahan area and seems to have been the first geologist to discover Orbitolina in the limestone ranges of the area.

De Bockh, Lees, and Richardson (1929) found Cenomanian ammonite in the southeast of Esfahan.

Kuhn. (1933a) recorded, from the eastern part of Esfahan, rocks containing Cretaceous fossils, which were examined by Gray and Jennings.

Clapp (1940) and Furon (1941) described Cretaceous limestone in the vicinity of Esfahan.

Dehghan (1947) was the first to report Jurassic ammonites from the Esfahan area.

Soder (1954), Stocklin (1954) and Gansser (1955) were the first to map the area of Esfahan and some surrounding localities in detail.

Davoudzadeh and Tatevossian (1966) mapped the Gardaneh-Shir area (Near Ardestan) located in the NE, outside the Quadrangle boundaries.

Seyed-Emami, A.Brants and F. Bozorgnia (1971) described the Cretaceous stratigraphy southeast of Esfahan.

Mehrnoush and Tehrani (1972) studied the microfossils of the Cretaceous section of Shah-kuh in the south of Esfahan.

Finally, M.R. Samadian (1974) made a detailed study of the geology of the Riz area, to the west of Esfahan.

Quadrangle Mapping

The basic mapping materials for the Esfahan Quadrangle consisted of the 1: 250,000, Series K 551, Map NI 39-15 and air photographs of the world wide Aerial Survey Corporation at a scale of 1:60,000.

Preliminary geological studies were made by M. Zahedi and S. Tatevossian in 1968, the main work being carried out later and completed by M. Zahedi. As the area was important both industrially and geologically it was divided into six geological sheets at a scale of 1:100,000, of which three have recently been published

The dolomite and limestone intercalations are strongly metamorphosed. The dolomite is yellow to brownish and conspicuously recrystallized. The limestone is thin-bedded, banded and laminated, bearing intercalations (l-3m thick) of schist and, locally, thin lenticles of chert (5cm thick and lm long). These rocks are overlain unconformably by Permian and Jurassic sediments.

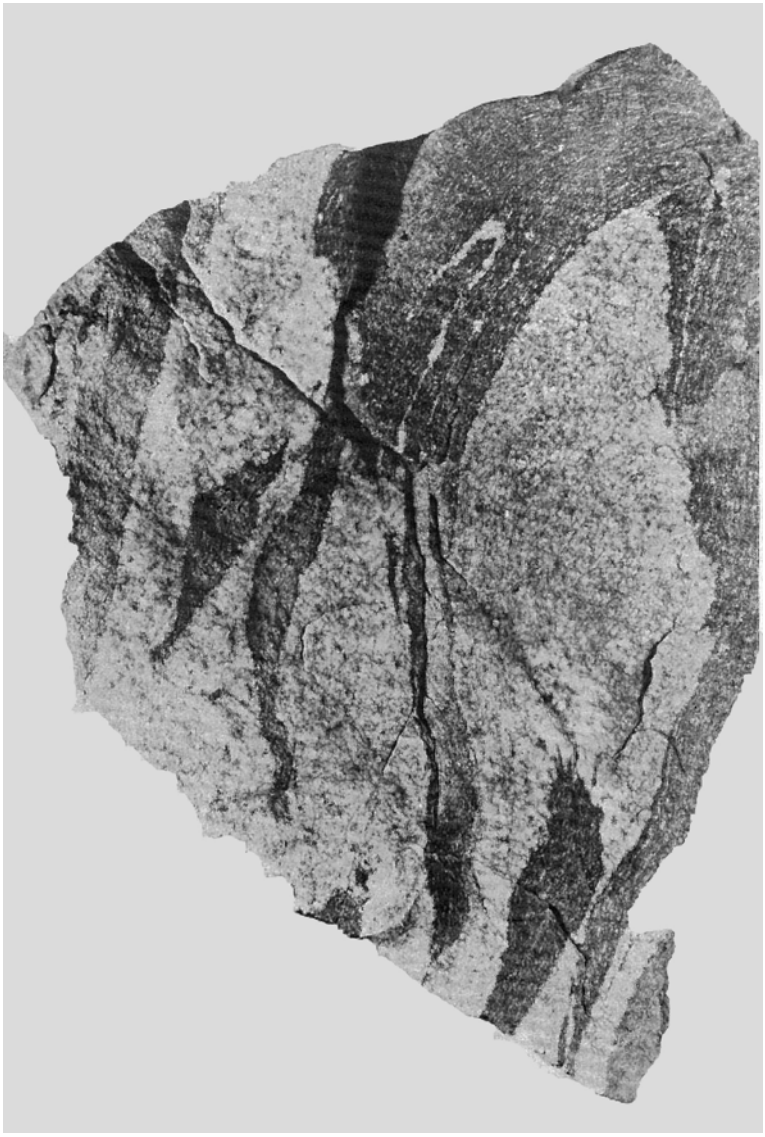


Fig.1. Schistose rock from the Precambrian west of Esfahan.

STRATIGRAPHY

Precambrian

The oldest rocks, cropping out about 60 km west of Esfahan, form a highland consisting of schist, gneiss, and metamorphosed andesitic volcanics, and interbedded metamorphosed dolomite and limestone.

The schist is mainly epidotized, and contains amphibole (tremolite, actinolite) hornblende, and plagioclase. The amphibole shows distinct orientation. More than 55% of the hornblende crystals have distinct cleavages oriented in two directions (at angles of 53"' and 127°). The plagioclase (oligoclase to andesine) is slightly sericitized. Accessory minerals are epidote, quartz, clinozoisite, sphene, apatite, calcite, and a small amount of opaque grains.

The gneiss (Fig. 1) forms lenticular bodies (20 to 50m thick and 1 to 3km long) and is easily distinguished in the field by its light colour. The rock is schistose and has granoblastic texture. The minerals are quartz, feldspar, amphibole, mica, chlorite, epidote, zoiste, apatite, and sphene.

The metamorphosed volcanics contain plagioclase, calcite, chlorite, and opaque grains; the mafic minerals are wholly replaced by carbonate and opaque iron oxides.

Lower Devonian (Padeha Formation)

It should be observed that deposits of Infracambrian to Silurian age are unknown in the Esfahan area. The nearest known beds of this long period are of Infracambrian Soltanieh Dolomite, Lower Cambrian Lalun Sandstone, and the Cambrian-Ordovician dolomite and limestone of the Mila Formation, located in the Soh area about 100km north of Esfahan (Zahedi, 1973).

Lower Devonian sediments are exposed in two localities northeast of Esfahan: Kuh-e-Zard (northeast of Zefreh village), and Kuh-e-Kaftar (east of Chah Riseh village; see Fig. 2 and description below). The deposits are composed of red sandstone and reddish to whitish quartzite, with interbedded sandy siliceous dolomite, thin red shale layers (3 to 5cm thick), and microconglomeratic beds. Their lower contact is faulted but their upper contact is conformable in the fossiliferous Middle to Upper Devonian and Lower Carboniferous beds. Completed sections could not therefore be measured at these localities. However, about 50km to the north (in the Soh area) the same beds are 250m thick. From the lithological composition of the sandstone beds and their stratigraphic position below the Middle-Upper Devonian sequence, these sediments would appear to be equivalent to the Lower Devonian Padeha Formation.

Middle to Upper Devonian - Lower Carboniferous

The Lower Devonian sediments are succeeded conformably by dolomitic limestone, sandy limestone and thin-bedded grey limestone beds. These are well exposed in the western flank of Kuh-e-Kaftar, east of Chah Riseh village (Figs. 1 and 3).

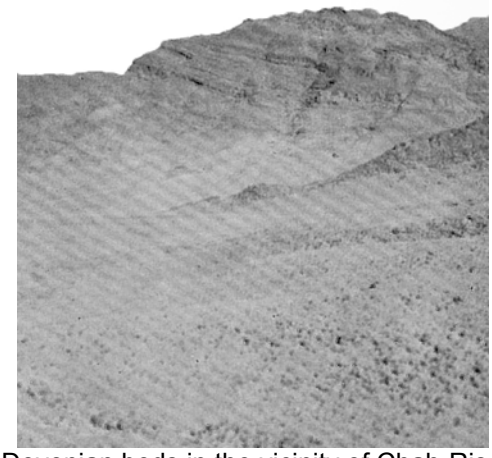


Fig. 2. Fossiliferous Devonian beds in the vicinity of Chah-Riseh village, northeast of Esfahan.

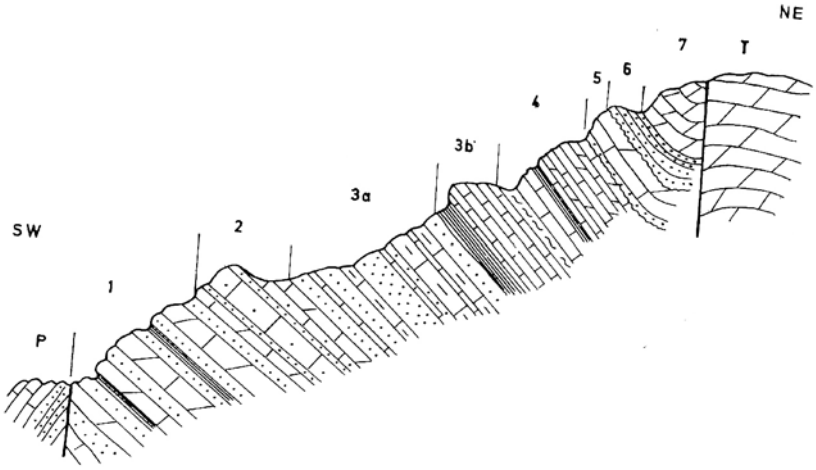


Fig. 3. Sketch of Kuh-e-Kaftar section, Chah-Riseh area, northeast of Esfahan (P = Permian, T = Triassic).

The sediments in the Kuh-e-Kaftar section, about 400m thick, are divided into the following lithologic units:

Thickness (m)

7. Dolomite, siliceous, yellowish and greyish (the summit of Kuh-e-Kaftar) 500-600
6. Sandstone, quartzite, whitish and reddish, with local intercalations of yellowish dolomite. This unit is the basal part of the above dolomite (Middle Triassic). 10-12
5. Limestone, sandy, yellowish grey to reddish, a thin layer of sandy reddish shale and a band of sandstone near the base, the limestone contains fusulina (Permian). 25-35

The supposed top of the Middle-Upper Devonian - Carboniferous section:

4. Limestone, cliff-making, partly sandy, dolomite, yellowish, partly thin-bedded, dark-grey. A few intercalations of sandy marl occur, but yielded only a few small brachiopods and fragments of gastropods. 65-70
3. Sandstone, sandy shale and limestone containing many fossils. 140-160
(b) 100 to 110m of sandstone with intercalated fossiliferous marly limestone and platy yellowish-weathering slightly sandstone fossiliferous limestone.
(a) 40 to 50m of limestone dark, marly, fossiliferous, thin-bedded, with thin (2 to 3cm) layers of dark-grey shale; within the sequence a sandy shale bed, about 1m thick, is succeeded by a band of dark grey shale 6 to 8 m thick.

The following fossils are found throughout unit No.3: *Schizophoria* sp. *Leptaena* sp., *Aulacella* cf. interlineata(Sovf.),*Gastrodetoechia dichtomians assimulata* (Abramian), *Centrorhynchus* cf. *turanica* (Rom), *Megalopterorhynchs* sp., *Evanescirostrum* sp., *Mesoplica* sp., *Cyrtospirifer* cf. *wangi* (Tien), *Eobrachythyris* sp., *Cyrtospirifer* aff-*quadratus* Nal., *Eobrachythyris* aff. *proovalis* (Brice), *globosa*, *Cyrtiopsis graciosa chakhaensis* (Brice). *Composita* cf. *globosa*, *Cleiothyridina* cf. coloradensis (Girty), *Composita* cf. *globosa*. They indicate the upper part of the Upper Devonian (Famennian). The uppermost beds of the unit contain *Eobrachythyris* cf. *strunianus* (Goss.) and fragments of the trilobite Phacops occipitrinus (indicative of uppermost Famennian), as well as several productacea that appear to have affinities with Lower Carboniferous forms. It should be remarked that Djafarian and Brice (1973) have recorded Lower Carboniferous fossils from the same area.

2. Dolomitic limestone with intercalated sandy limestone and thin sandstone layers. 50-60
This unit is rarely fossiliferous, but the same beds in the Kuh-e-Zard section, located about 15km. west of Kuh-e-Kaftar are quite rich in fossils, mainly brachiopods but also lamellibranchs, coralsand ttfilobite fragments. The fossiles determined (det. Mile Denise Brice, Laboratoire de Paleontologie Stratigraphique, Lille Cedex) are as follows:
Hexagonaria sp., *strophomenid* represented by *Mesodouvillina birmanica* (Reed),

Spinatrypina sp., *Athyris*, sp., and *Sulcathyris* sp. indicating Middle Devonian; Cyrtospirifer sp., *Ripidiorhynchus* sp., *Cypholerorphynchus* aff. *arpaensis* (Abramian), *Pampoecilorhynchus* sp., *Vchtospirifer* sp., *Cyrtospirifer* cf. *bisinus* le Hon, Cyrtospirifer eg syringothyiformis and fragments of Cyphoterorphynchus cf. koraghensis (Reed), indicating the lower part of Upper Devonian (Frasnian):

1. Reddish and whitish sandstone and quartzite interstratified with dolomite, dolomitic limestone and thin layers of red shale, 100

Another fossiliferous section lies about 6km northeast of Zefreh village (NE of Esfahan). Fossils collected from it are as follows (det. F. Golshani, G.S.Ir).

Schellwienella sp., Schurchertella ex gr. radialis. Chonetes sp., Productella ex gr. baitalensis, Cyphoterorhychns koraghensis, Camarotoechia cf. nalivkini, Pamoedlor-hynchus aff. arianus, Camarotoe Chia sp., Ptychomaletoechia sp., Kransia sp., Ripidio-rhynchus sp., Gastrodetoechia sp,, Megalopterorhyachus sp., Ripidiorhynchus cf. elburzensis, Gastrodetoechia ex gr. diochotomians, Evanescirostrum sp., Ptychomaleto-chia turanica, Ptychomaletochia charakensis, Ripidiorhynchus exgr. Kotalensis, Meso-plica sp.,Cyrtospirifer sp., Uchtospirifer sp., Platyspirifer sp., Acrospirifer sp., Cjrtos1-pirifer ex gr, vernenili, Dichospirifer; Cyrtospirifer ex gr. Eobrachithyris sp., Spinatrypa sp., Tylothyris sp., Athyris aff. chitralensis, Cleotithyridina sp., Composita sp., indicating Late Devonian age.

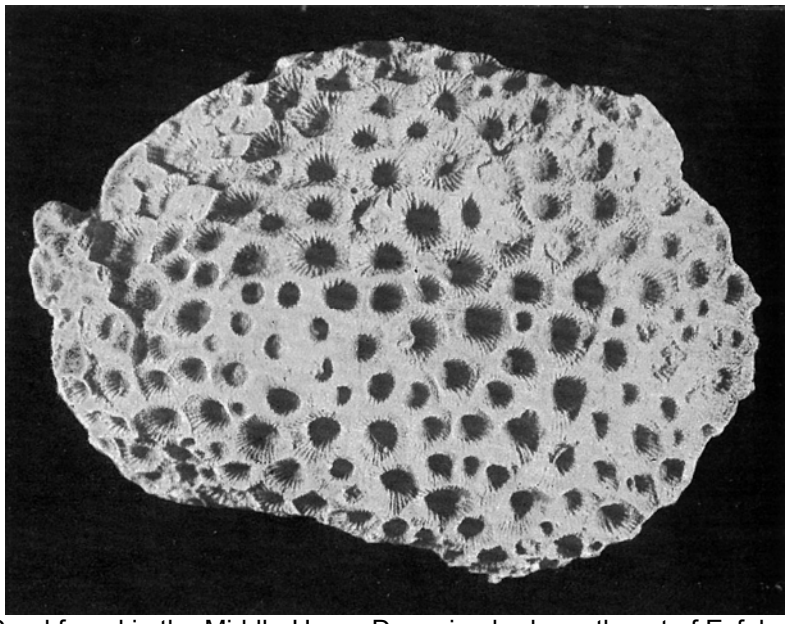
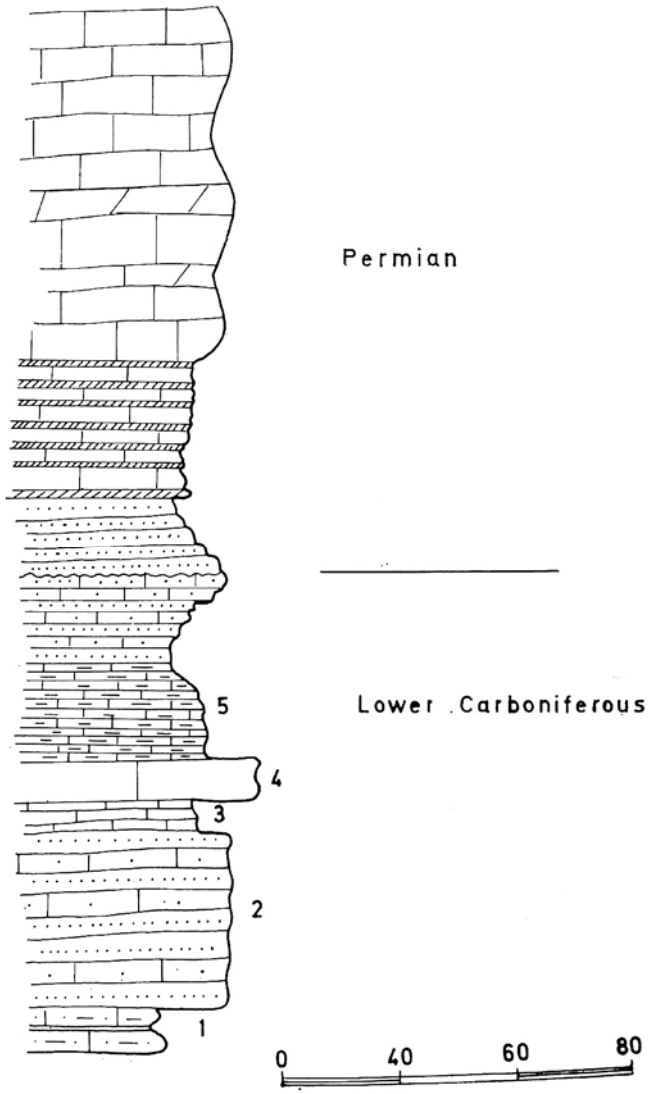


Fig. 4. Coral found in the Middle-Upper Devonian beds northeast of Esfahan (life size).



Pig. 5. Lower Carboniferous beds northeast of Shahreza, southeast of Esfahan.

About 100km south of the above-mentioned localities (southeast of Esfahan and 20km northeast of Shahreza) sandy carbonaceous beds in the core of a small Permian anticline contain microfossils of Lower Carboniferous age. The beds are about 165m thick and are disconformably overlain by some 25m of reddish sandstone and quartzite, succeeded by thick sediments with Permian fusulinids. The following is a description of the Carboniferous section (beds 1 to 6; see Fig. 5):

Thickness (m)

9. Limestone, dark-grey to light-grey well bedded with Fusulina, Middle-Upper Permian 500-700

8. Limestone, bedded (layers 20 to 40cm thick), grey, containing cherty layers 10 to 20 cm thick. 50

7. Sandstone and quartzite, reddish and whitish, disconformable on the Lower Carboniferous sediments. 25

6. Sandstone alternating whitish to reddish brown, and limestone sandy, dark-grey fetid. The following Lower Carboniferous microfossils are distinguished in this horizon. *Archeodiscus* sp., *Aoujgalina* sp., *Earlandia* sp., *Endolhyra* sp., *Townayella* sp,, and an abundance of crinoid fragments and bryozoans. 30

5. Limestone, slight marl thin-platy, fetid, containing badly preserved brachiopods and microfossils similar to those in bed No 1. 35

4. Limestone, massive thick-bedded grey. 15

3. Limestone, sandy thin-bedded with fragments of gastropods. 10

2. Sandstone, well bedded reddish to brownish with intercalations of sandy limestone containing fragments of reworked brachiopods. 60

1. Limestone, sandy marly dark-grey with intercalations of thin beds (2 to 3cm) of sandy marl. The limestone contains, besides *tentaculites* sp., the following Lower Carboniferous

microfossils: *Endothyra* sp., *Archeodiscus* sp., *Earlandis* sp., *Diplosphaerina* sp., *Tournayella discoidea*, *Tetrataxissp.*, *Septabranisina* sp. 15

Upper Carboniferous and Lower Permian rocks have not been found in the mapped area. In the Soh area, about 80km north of Esfahan, Middle-Upper Permian sediments directly overlie the Upper Devonian rocks with a disconformable contact. There was probably an erosion phase in the Carboniferous, and the area was emergent for most of the Carboniferous and Lower Permian periods. The geological history of the Lower to Middle Paleozoic in the western part of the Esfahan area is less clear because Middle to Upper Permian sediments, with basal conglomerate, rest on the highly metamorphosed Precambrian basement. In conclusion, it seems that the Middle to Upper Devonian and Lower Carboniferous sea invaded parts of the Esfahan area and that the whole area was emergent during the Upper Carboniferous and the Lower Permian.

Middle to Upper Permian

Within the Quadrangle, Permian rocks are exposed northeast, southeast and west of Esfahan (Figs. 1, 6, and 7):

A) In the northeast (about 50km NE of Esfahan), as mentioned above, the Permian deposits consist of a basal sandstone bed (1 to 2m thick; disconformably overlying the Lower Carboniferous) succeeded by 20 to 25 m of sandy yellowish-grey to reddish limestone, with thin intercalations of reddish sandy shale containing the following microfossils: the brachiopods, Leptodus sp. cf. nobilis (Waagen), Spiriferellina sp.cf. cristata (Schl), Juresania juresanensis (Tscheryschew), Derbya cf. regularis Waagen, Athyris sp., Marginifera sp., Linoproductus. sp., cf. com (d'Orb.); the Bryozoa Fenestelles; Schizophoria sp.; the Gastropods Bellerephontides and other gastropod fragments. The fossil assemblage is indicative of Middle to Upper Permian.

The lithology of the Permian sediments varies considerably within short distances, their thickness increasing southeastwards from the Kuh-e-Kaftar section. About 4km to the southeast of that section (Fig. 6) the basal sandstone reaches 100m; it is here intercalated with coarse-grained sandstone and microconglomeratic layers; cross-bedding and ripple marks are common. The overlying limestone, containing abundant fusulines, is 200 to 300m thick with intercalations of dolomite; the upper part also contains several layers of reddish quartzitic sandstone. The limestone has yielded the following Middle to Upper Permian microfossils: Nodosaria sp., Pseudovermiporel-la sp., Pachyphloia sp., Climacammina sp., Cribrogenerina sp., Tuberitina sp., Globi-valvulina sp., Deckerella sp., Staffella sp., Agathammina sp., Mizzia sp., (det.K.Lessani and S. Kalani, G.S.Ir.).

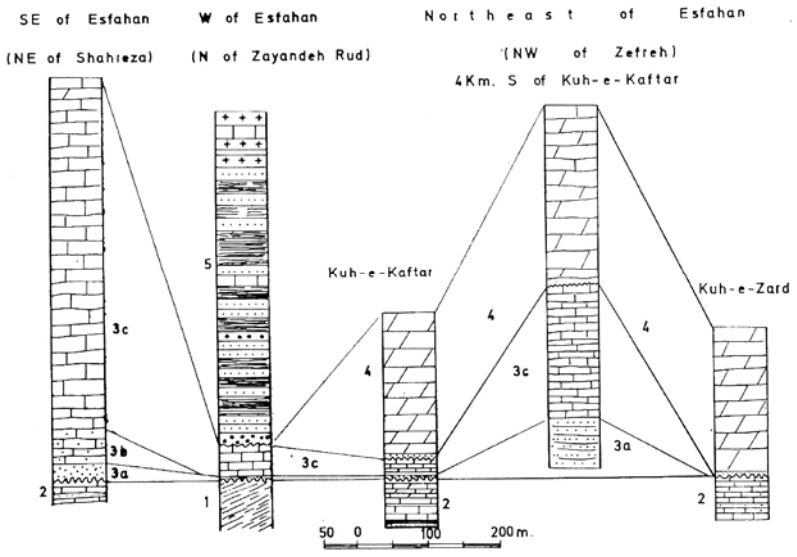


Fig. 6. Correlation of Permian sections in the Esfahan Quadrangle. 1. Precambrian; 2. Middle- Upper, Devonian - Lower Carboniferous; 3a/b/c. Permian; 4. Triassic; 5. Jurassic.

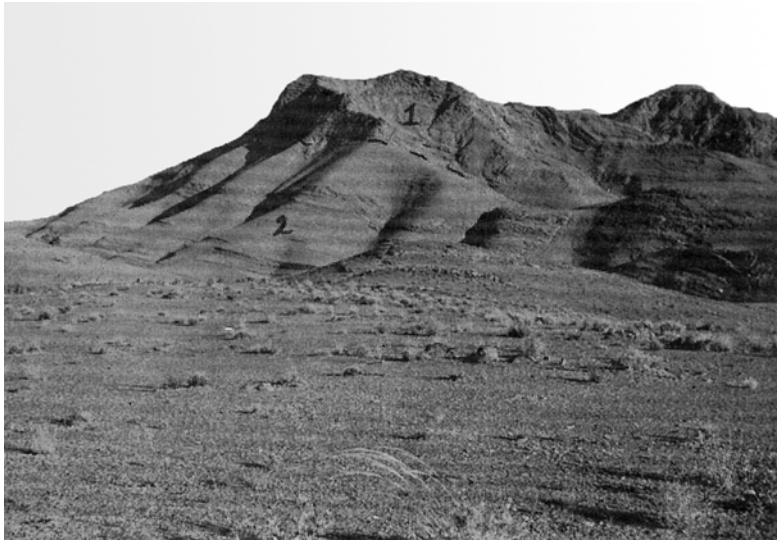


Fig. 7. Permian fusulinid limestone (1) with basal reddish quartzitic sandstone (2) northeast of Esfahan.

The Permian sediments wedge out eastwards, and in the Kuh-e-Zard section (15km east of Kuh-e-Kaftar) yellowish Triassic dolomite disconformably overlies the Middle to Upper Devonian beds.

B) In the southeast (about 80km SE of Esfahan) a basal red sandstone disconformably overlies Lower Carboniferous deposits; it is 20 to 40m thick and has intercalations of microconglomerate and whitish quartzite. The sandstone beds are followed conformably by 40 to 60m of bedded grey limestone interstratified by thin layers of chert; overlying them are 500 to 700m of dark-grey to light-grey fusulinid limestone containing intercalations of dolomite, sandy marl and platy sandy limestone. The upper part of the limestone contains *Verbeekina* sp., *Climacamina* sp., *Globivalvulina* sp., *Geinitzina* sp., *Paleofusulina* sp., *Afghanella* sp., *Agathamina* sp., *Eotubevirina* sp., *Staffe*lla sp., *Mizzia* sp., and a few gastropods (det. M. Mehrnoush, G.S.Ir.). These fossils indicate a Middle to Upper Permian age.

Permian beds form the northwest-trending ranges northeast of Shahreza. About 15km to the northeast of this town, the sediments comprise steeply dipping (60-85°) dark-grey dolomite and grey dolomitic limestone and contain the fusulinids: *Ammodiscus* sp., *Hemigordius* sp., *Stafella* sp., *Glomospira* sp., *Tuberitina* sp., *Pseudovermiporella* sp., *Pachyphloia* sp., and *Climacammina* sp., together with Bryozoa, and Algae. The fossil assemblage indicates Middle to Upper Permian age. The contact with the underlying beds is exposed to the east in the core of an anticline, where Permian fusulinid limestone, with 20 to 40 m of reddish quartzitic sandstone at the base, disconformably overlies early Carboniferous beds. The upper contact is transitional, and the grey Permian limestone gradually gives way to reddish argillaceous ammonite-bearing limestone of Early Triassic age.

C) In the west (about 60km west of Esfahan), Middle to Upper Permian fusulinid limestone with a greenish basal conglomerate, 10 to 30cm thick, is unconformable on Precambrian rocks. The exposed thickness of Permian rocks varies from 20 to 100m; as the limestone is overlain unconformably by Jurassic rocks, the total original thickness is not known. The area appears to have been emergent through all or most of the period from Infracambrian to Lower Permian, and seems to have undergone little orogenic deformation during this time, a feature also true of other parts of Iran. The unconformity at the base of the Permian rocks is attributed to the Assyntic (Baikalian) orogeny in late Precambrian times. Epeirogenic movements took place, however, and during the whole of this period, the area was probably a barrier between the northern and southern seas. About 10km south of the above-mentioned exposure, beds with a gentle dip towards the southwest crop out in a long, narrow, northwest-trending range. They consist of bedded yellowish to whitish limestone (in part dolomitic) bearing *Fusulina* sp., *Orionastrea* sp,, and corals. The contacts with Jurassic sediments on both sides of the range are faulted, so that the structure is a horst. There are other

exposures of Permian rocks in three isolated hills about 50km to the southeast. They consist of grey limestone containing Mizzia sp., *Pseucovermiporella* sp., and *Padangia* sp. (det. H. Partoazar, G.S. Ir.) and ostracods, indicating late Permian age.

Triassic

The Triassic sequence comprises a lower part of carbonate rocks (limestone and dolomite) and a upper part of mainly terrigenous deposits (shale and sandstone). Sections are exposed southeast, northeast, and northwest of Esfahan (Fig. 8).

A) Southeast of Esfahan. East northeast of Shahreza (about 45km east of Shah-reza Ali Akbar village), Upper Permian dolomitic fusulinid limestone is conformably overlain by 3O-5Om of slightly reddish marly limestone, which yielded abundant ammonites (Fig. 9) of the genera *Paratirolites* (see Zahedi, 1973; Davoudzadeh and Seyed-Emami, 1972), representing the *paratirolites* zone of the uppermost Permian (Dzhulfian). At this locality the section is cut off at a fault contact with volcanic rocks, but several kilometers to the east the sequence, from top to bottom, is as follows:

Thickness (m)

5. Dolomite, massive yellowish, containing intercalations of siliceous dolomite and chert patches. 100-500

4. Dolomite and dolomitic limestone, thick-bedded, yellowish-grey, the upper part slightly marly. 50

3. Limestone, platy vermicular, with intercalations of marl containing worm tracks, gastropods, and lamellibranchs (claraia); this horizon is not, or is only slightly, oolitic, 70

2. Limestone, bedded, oolitic and pisolitic, (containing lamellibranchs) with intercalations of dolomitic limestone and dolomite (1 to 2m thick), platy oolitic grey sandy limestone (1 to1,2m) and thin layers (20cm) of limestone rich in gastropods 50

1. Shale, calcareous greenish with intercalated thin limestone beds containing lamelli branchs and pectens. 10-15

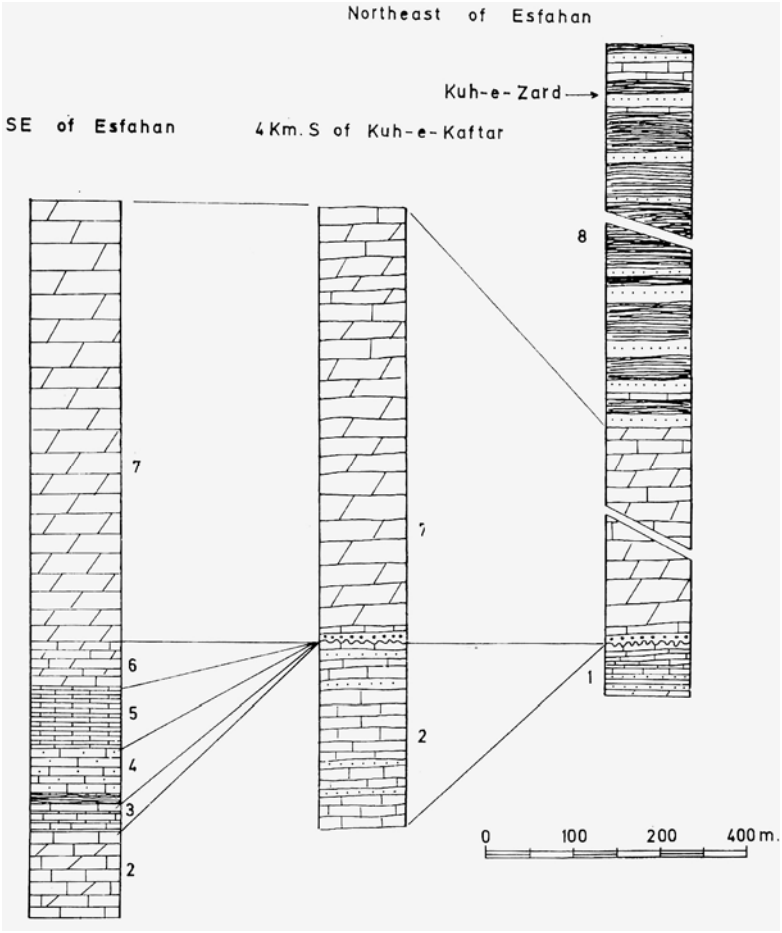


Fig. 8. Correlation of Triassic sections in the Esfahan Quadrangle. 1. Middle-Upper Devonian -Lower Carboniferous; 2. Permian; 3. Scythian; 4. 5. 6. 7. Lower-Middle Triassic-8. Upper Triassic.

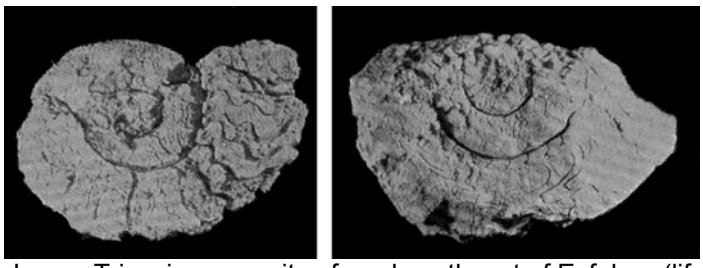


Fig. 9. Lower Triassic ammonites found southeast of Esfahan (life-size)

Ten kilometres northeast of Shahreza, units 1 and 2 and part of 3 are missing and the lower part of the sequence contains volcanic rocks.

B) Northeast of Esfahan west of Zefreh, the uppermost Permian ammonite-bearing beds and the overlying shale and platy vermicular limestones are absent. Massive yellowish Middle Triassic dolomite (Shotori Formation with basal red sandstone, conglomerate and locally volcanic rocks) overlies either Permian (in Kuh-e-Kaftar) or the Devonian-Lower Carboniferous beds (in Kuh-e-Zard). The volcanic rocks exposed locally at the base of the dolomite are mainly altered quartz dolerite, with doleritic texture but the groundmass altered to carbonates. Another sample collected from the volcanic rocks is an altered basalt with porphyritic texture and mostly plagioclases (andesine-labradorite) as phenocrysts. The massive dolomite is 500 to 600m thick, yellowish to grayish, and for the most part siliceous. Locally it contains intercalations of reddish, porous dolomite. It was deposited in shallow water and contains numerous reddish dolomite fragments.

Northeast of Zefreh the dolomite is overlain, conformably, by a sequence of shale and sandstone (Nayband Formation), containing small lenticular intercalations of Heterastridium limestone. The sequence is about 1,300m thick

and is overlain by the Lower Jurassic (Lias) ammonite-bearing Shemshak Formation.

C) Northwest of Esfahan. Lower and Middle Triassic rocks are not exposed. The Upper Triassic deposits are composed of black shale with intercalations of quartzitic sandstone and a few lenticular interbeddings of limestone, the latter with *Heterastridium* sp., corals, *Myophoria* sp., and *Indopecten* sp. A lens of *Hetrastridium* limestone (50m thick and 5 to 6km long) crops out in the shale sandstone sequence east of the village of Chaleh Siah. Here, in spite of local slight metamorphism of the shale and the limestone, specimens of *Heterastridium* sp., are abundant and well preserved (Fig. 10). About 20km southeast of the same village a thin (1 to 2m) limestone bed in the shale sequence contains Upper Triassic ammonites of the genera *Cladiscites*, *Arcestes*, and *Placites* (det. M. Collignon).Similar ammonites collected from the same bed indicate a Norian age (Seyed-Emami et al. 1971, Seyed-Emami, 1975).

Fig. 10. Heterastridium sp., pectens and corals in Upper Triassic beds northwest of Esfahan.

In age, lithology, and faunal assemblages, this shale sandstone series correlates with the Upper Triassic Nayband Formation of east-central Iran, and is so named in this report.

Jurassic

Jurassic deposits in the Esfahan area differ in the northeast and southwest parts of the Quadrangle (columnar sections are given in Fig 11).

A) *Northeast and southeast of Esfahan*. On the northern flank of Kuh-e-Zard (northeast of Zefreh village), the Upper Triassic Nayband Formation is succeeded conformably by a shale/sandstone sequence containing in its middle part two thick limestone beds. These yielded the ammonites *Hildocems sublercisoni Fucini* and *Dactylioceras* sp., (det. R. Mouterde, Facultes Catholiques de Lyon), together with bryozoans, belemnites, and Algae. The ammonites indicate Lower Toarcian.

The upper part of this sequence is formed mainly of sandstone and conglomerates containing elongated, rounded siliceous pebbles (1 by 3cm). They are overthrust by Cretaceous rocks and the uppermost part of the original sequence is not present in the mapped area. The visible thickness of these Liassic beds is about 900m, corresponding with the Shemshak Formation. Similar sediments (1050 m thick) exposed about 60km to the northwest contain coal seams in the upper part.

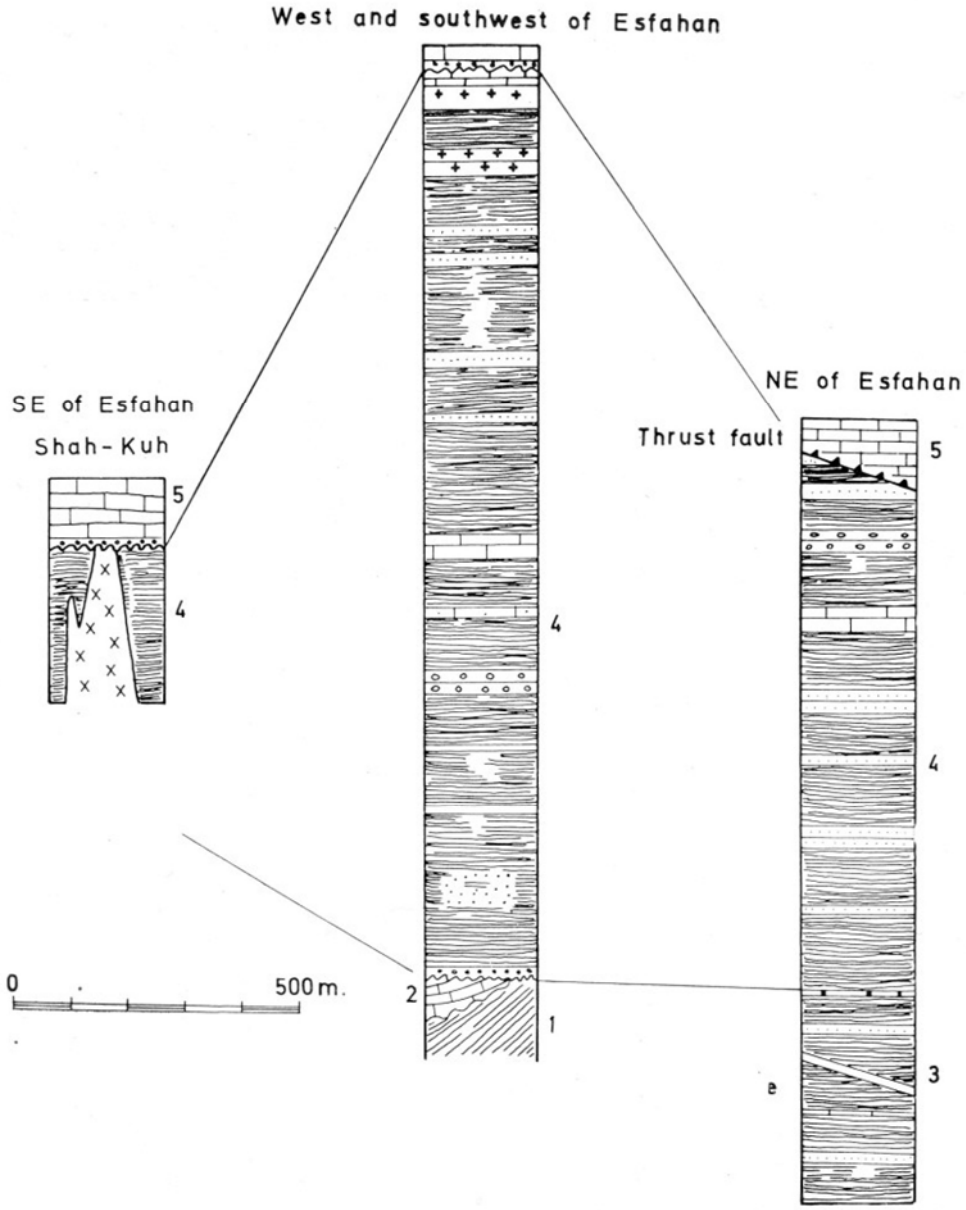


Fig. 11. Correlation of Jurassic sections in the Esfahan Quadrangle. 1. Precambrian schist; 2. Permian limestone; 3. sections Upper Triassic shale/sandstone; 4. Jurassic sandstone, schist; shale, limestone, limestone; andesite and granodioritc; 5. shale/sandstone; Cretaceous limestone.

Fig. 12 a. Unconformity between the basal conglomerate (B) of the Jurassic rocks and the fusulinid limestone (A) west of Esfahan.

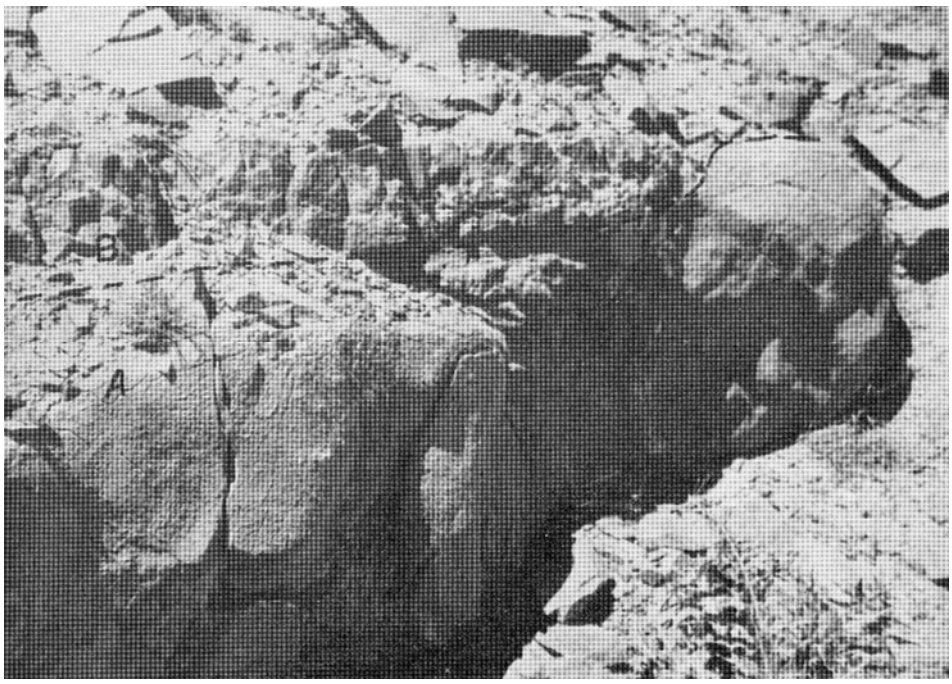


Fig. 12 b. Close-up of Fig. 12 a.

Near Esfahan to the south and east on both sides of the Zayandeh Rud, other outcrops of Shemshak Formation sandstone and shale occur. These contain small limestone lenses with corals, bryozoans, lamellibranchs, belemnites and Algae. On the northern flank of Shah-Kuh is a small outcrop of dark-grey shales with sandstone and siltstone intercalations; rarely, shell fragments and plant remains are present. At the southern extremity of the Shah-Kuh range the Jurassic sandstone/shale sequence contains granodioritic intrusions. They are older than Barremian since the Barremian-Aptian basal conglomerate, which is formed largely from them, overlies not only the intrusives but also the Jurassic shales into which they are intruded.

B) West and southwest of Esfahan. The Jurassic deposits here consist of a basal conglomerate and overlying dark-grey to black shale with intercalations of sandstone, quartzite, limestone and volcanics. Their total thickness is 1000-2,000m.

The basal conglomerate unconformably overlies either Permian fusulinid

limestone or Precambrian metamorphics (Figs. 12 and 13). Its thickness varies from 20 to 100m. The pebbles are grey-and-white Permian fusulinid limestone, dolomite, quartzite, and Precambrian schist. Many of the limestone pebbles are angular or subrounded and have evidently not been carried far. Locally the conglomerate is replaced by conglomeratic limestone and sandstone, which is succeeded by reddish or light-greenish grey shale and sandstone.

Fie. 13. The basal Jurassic conglomerate west of Esfahan.

The thick black shales, overlying the basal conglomerate, contain numerous interbeddings of intraformational conglomerate and sandstone and less commonly of limestone and volcanic rocks. The shales contain perisphinctoid ammonites of Late Jurassic age (Fig. 14). The intraformational conglomerate and sandstone bodies consist mainly of quartz pebbles or locally of altered volcanic fragments cemented in a black argillaceous matrix. The sandstone is cross-bedded and ripple-marked. The limestone intercalations contain *Trigonia*, *Pholadomya*, *Pleuromya* and numerous other lamellibranch fragments; some of the limestone is reddish and siliceous and contains Radiolaria. Farther south, the Jurassic shales are well exposed north and south of the Za-yandeh Rud. Here, also, the basal conglomerate unconformably overlies Permian fusulinid limestone, but is down faulted (on a northwest-trending fault) and not extensively exposed. Ammonites obtained from different levels of the shale (Pleydellia subcompta Branco, Leioceras constosum, *Holcophylloceras* sp., *Nebrodites* sp., *Idoceras* sp., (after Samadian, det. by K. Seyed-Emami) indicate an age ranging from Toarcian to Kimmeridgian.

(a)

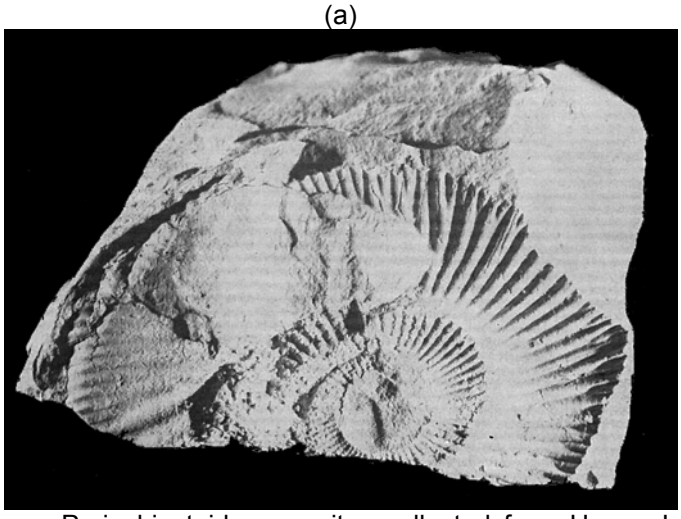
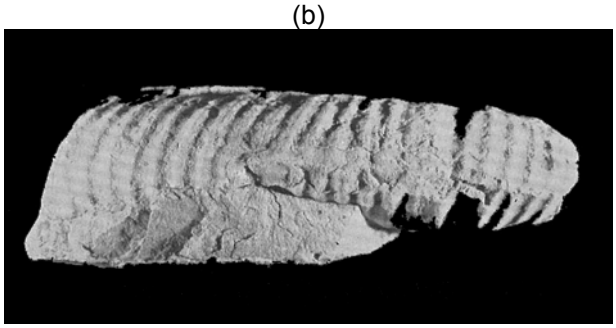
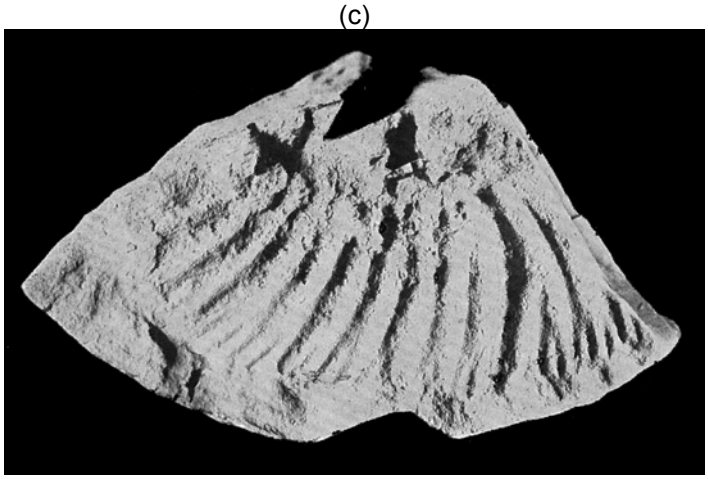


Fig. 14. a, b, c, Perisphinctoid ammonites collected from Upper Jurassic shale west of Esfahan (life-size).

(b)



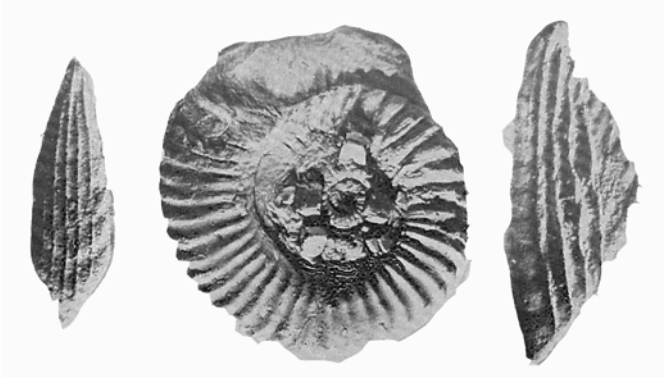
(c)



A few belemnites, some species of *Trigonia*, *Pholadomya*, *Pleuromya*, and plant fragments have also been found (Fig. 15). The shales contain some intercalations of sandstone, conglomerate, limestone, and andesitic volcanics. Beds of sandstone and conglomerate ("conglomerates dragees") are particularly common and extensive north of the Zayandeh Rud. The limestone intercalations are lenticular, locally oolitic, and contain corals (Fig 16), bryozoans, Algae (Codiacea), crinoids, and echinid spines, as well as *Clypeina* sp., *Nautiloculina* sp., and textularids.

The andesitic volcanics, which occur predominantly in the upper part of the shale, are exposed mainly south of the Zayandeh Rud (Fig. 17). A sample of andesitic lava shows distinct amygdaloidal vesicular texture; the vesicles are filled with calcium carbonate. The groundmass is strongly altered to opaque minerals, probably a mixture of carbonate and clay minerals. The other minerals are altered plagioclase, pyroxene, quartz, chlorite, and zeolite. A few andesite dykes are found in lower parts of the shale. They are doleritic to granular in texture and extensively altered to carbonate, chlorite and opaque minerals.

On the northern slopes of Kuh-e-Shahlora, near Gardaneh-ye-Rokh, 10m of radiolarite and algal limestone are exposed in the upper part of the shale/volcanics sequence. They contain Calpionella alpina, radiolarian, *Agathammina* sp., *textulariids*, *Glomos*-pira sp., *Gayeuxia* sp., *Thaumatoporella* sp., *Parrovecicalifera* sp., and *Cyclammina* sp., (det. H. Partoazar, G.S. Ir.)s and many echinoid spines, microgastropods and algal debris. The stratigraphic position, and the microfossils of the limestone, indicate a Late Jurassic age for the upper part of the sequence as a whole. The Jurassic beds are unconformably overlain by Early Cretaceous (Barremian-Aptian) deposits.



Fig, 15. a *Nebrodites* sp. and *Idoceras* sp. from Upper Jurassic (Upper Oxfordian - Lower Kimmeridgian) shale southwest of Esfahan (life-size).

Fig, 15-b- Argillaceous limestone with belemnites, from Upper Jurassic beds southwest of Esfahan.

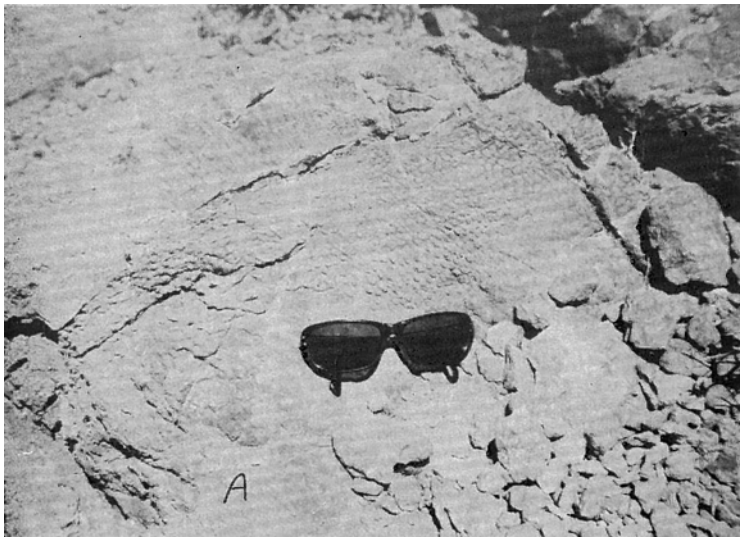


Fig. 16. Lenticular coral-bearing limestone in the Jurassic beds west of Esfahan.

Fig. 17. An old bridge (Pol-e-Zamankhan) over the Zayandeh Rud, built on the andesitic volcanics of the Jurassic deposits west of Esfahan.

Cretaceous

The northern flank of the Shah-Kuh range south of Esfahan provides one of the most complete Cretaceous sections in the Esfahan region. The maximum thickness exceeds 1000m. The rocks are limestone, marl, and shale ranging from Barremian to Maestrichtian, and can be subdivided as follows:

A) A basal horizon, 5 to 20m thick, of red sandstone and conglomerate (Fig 19). The pebbles are mostly subrounded quartz and quartzite, cemented in a red marly argillaceous matrix. This unit contains thin layers of sandy dolomite and generally ends with a layer (2 to 5m thick) of yellowish sandy dolomite. It does not contain fossils in the Shah Kuh section, but species of *Trigonia* have been found to the west on the western flank of Kuh-e-Jowzan (about 40km southwest of Esfahan). The unit thickness increases to the southwest. About 12km southwest of Mahyar it is more than 100m thick, the dolomitic intercalations are thicker and more numerous, and sandy limestone and calcareous shale are also present.

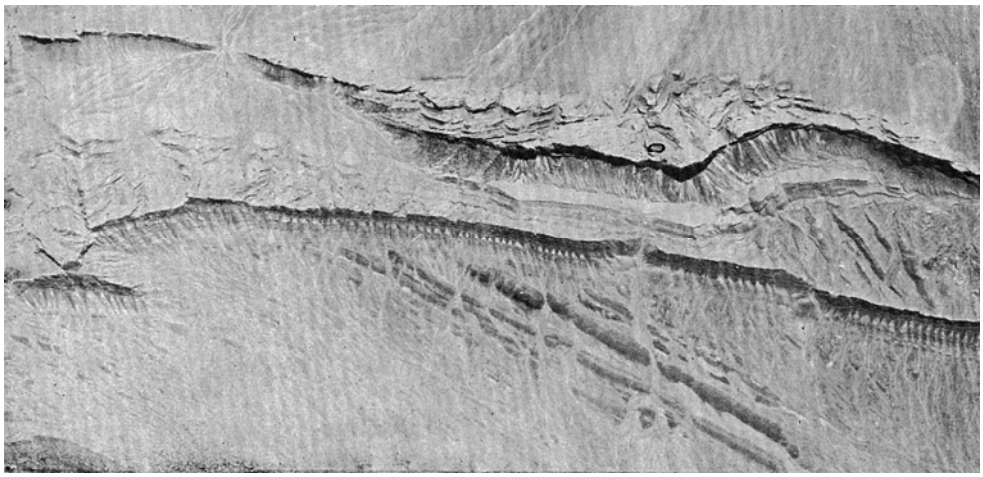


Fig. 18. Cretaceous limestone, marl, and marly limestone, with basal sandstone unconformably overlying the Upper Triassic shale/sandstone of the Nayband Formation (northeast of Esfahan) at Long. 51°55'E and a few kilometers north of the Quadrangle boundary.

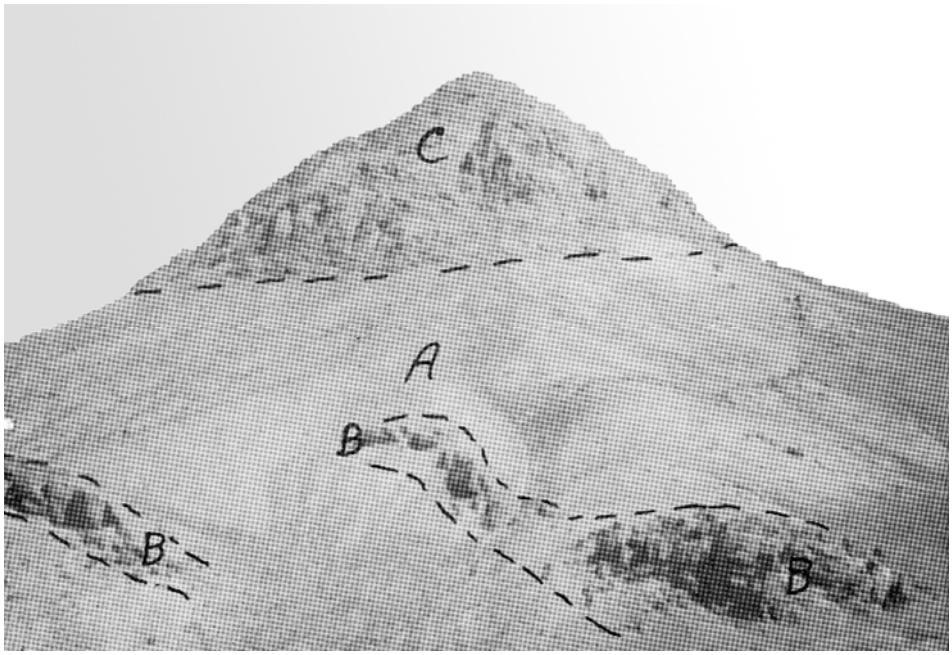


Fig. 19. A: Shale/sandstone of the Upper Trias.
B: Lenticular limestone containing Heterastridium sp.
c: Orbitolina limestone with a basal conglomerate.

The basal unit is unconformable on Liassic shale/sandstone (Shemshak Formation), or on Upper Jurassic granodiorite intrusives in the southeastern end of the Shah Kuh range. Further south (southeast of Esfahan, near Shahreza) basal sandstone transgresses Middle Triassic dolomites. In the southwest of the mapped area, around Riz-e-Lanjan, the unit is about 50m thick and contains red shale intercalations. On the northern slopes of Kuh-e-Shahlora (near Gardaneh-ye-Rokh), where the sediments overlie Late Jurassic shale-and-volcanics, the thickness is only 5m. Further south this member is not exposed and probably thins out, locally, below the limestone beds. In the northwestern corner of the quadrangle (north and northwest of Najafabad) it is 10m thick and overlies, unconformably, the shales and sandstones of the Upper Triassic Nayband Formation (its unconformable relation with these rocks is evident about 15km northwest of Esfahan; Fig 20). In the northeastern corner of the quadrangle (northwest of Zefreh), the basal sandstone unconformably overlies Middle Triassic dolomite, and beyond, outside the quadrangle, it overlies the Upper Triassic shale/ sandstone of the Nayband Formation (Fig. 18) and the Jurassic shales of the Shemshak Formation. The basal unit is succeeded transitionally by the next horizon.

B) 100 to 400m of massive grey limestone (Barremian-Early Aptian) locally dolomitized (Fig 21) and containing intercalations of marls and thin-bedded marly limestone, including oolitic layers. The dolomite is extremely sandy at lower levels, but upwards the sand content decreases and the beds become more and more calcareous. The massive limestone has yielded palorbitolina lenticularis (Blumenbach), Dictyoconus arabicus Henson (dets. M. Mehrnoush G.S. Ir.), the ammonites *Tonokamites* sp.s *Deshayesites* cf. *deshayesi* (d'Orbigny), *Prodeshayesites tenuicostatus* (Koenen), P. bodei (Koenen), *Cheloniceras* sp., (Seyed-Emami et al. 1971), and indeterminable brachiopods, pelecypod fragments, echinids, oysters, corals, large Nerinea and small rudists. These fossils indicate an Early Aptian age.

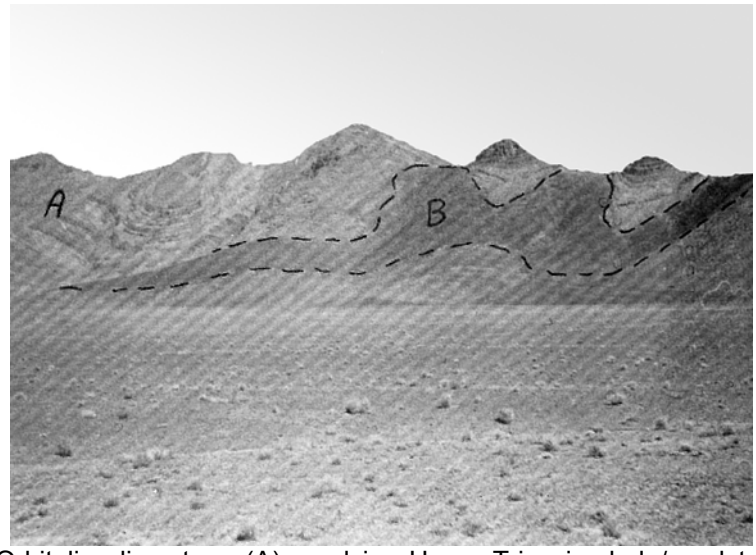


Fig. 20. Orbitolina limestone (A) overlying Upper Triassic shale/sandstone of the Nayband Formation (B), northeast of Esfahan.

Fig. 21. Irregularly dolomitized Cretaceous limestone northwest of Esfahan. (A: limestone. B: dolomite.)

North of Zefreh (about 60km NE of Esfahan) "the lower dolomitic part consists of about 100m of thin-bedded, platy, sandy, and dolomitic limestone with ripple marks and worm tracks and contains the same pelecypods and echinids as in the Esfahan area. A few ammonite fragments were also obtained, among them a fragment of *Matheonites soulieri* Math., which is indicative of Upper Barremian" (Seyed-Emami et al, 1971). The deposits are conformably succeeded by 100 to 300m of grey Orhitolina limestone with interbedded marl.

Northwest of Esfahan the limestone, 300 to 400m thick, is light-grey, thickly bedded and contains Orbitolina *lenticularis*, *Dictyoconus* cf. *arabicus*, *Texaster* sp., oysters, and brachiopods. To the south the lower part of the Orbitolina limestone in KLuh-e-Panji (15m south of Najafabad) and Kuh-e-Jowzan (8km north of Riz-e-Lenjam) contains the Barremian-Aptian ammonites *Matheronites soulieri* and the upper part contains *Deshayesites* sp, of Upper Barremian - Aptian age (after M.R. Samadian). In the northwestern part of the Najafabad sheet (1:100,000) the lower part of the limestone unit is dolomitic; in the extreme northwest the limestone becomes marly and contains thin marl layers.

Southwest of Esfahan 400-500m of dark to light-grey thick-bedded crystallized Orbitolina limestone with intercalations of sandy limestone and oolitic limestone occur (Fig 22), The upper part contains Orbitolina kurdica, O. cf, *conica*, *Iraqia* sp., *Cuneolina* sp., and *Nezzazata* sp. To the southwest, the lower part of the limestone becomes thin-bedded, marly, and sandy and interfingers with the underlying unit, which is composed of 500 to 600m of thin-bedded slaty and marly limestone. Around the village of Send Dasht this latter unit contains intercalations

of argillaceous siltstone and shale. About 10km north of the village, the limestone is sandy, the siltstone intercalations are calcareous and volcanics are interbedded; these are conformably overlain by thick-bedded Orbitolina limestones. Southwards from Send Dasht the unit becomes argillaceous and shaly and contains intercalations of oolitic limestone. Towards the western sheet boundary it gives way to a sequence of thin siltstone, shales, and platy-sandy limestone beds, particularly well-developed around Shahr-e Kord outside the mapped area; this sequence is partly Upper Cretaceous in age.

C) 100 to 300m of well-bedded marly limestone (Late Aptian-Early Albian) comprising three members:

(i) A lower marl member consisting of 30-70m of yellowish to white marl with interbedded limestone layers containing abundant Orbitolina: *Dictyoconus Pachmarginalis* n-sp Schroeder, *Palorbitolina lenticularis* Blumenbach, *Orbitolina* (Mes.) lotzi Schroeder, *Orbitolina* (Mes.) *texana texana* (Roemer), *Orbitolina* (Afe.) texana Parva Douglass indicative of Gargasian (Late Aptian), (det.M. Mehrnoush).

(ii) A middle limestone member consisting of 50 to 200m of light grey marly limestone with thin intercalations of marl. The microfossils are the same as in (i). In addition, early Albian ammonites (*Leymeriella tardefurcata*, L. regularis (Seyed-Emami et al., 1971), are found locally near the top of the member. The age range is thus Late Aptian to Early Albian.

(iii) An upper limestone member consisting of 20 to 30 of siliceous, sandy, thin-bedded limestone containing thin chert layers (2-3cm). Locally the sediments are argillaceous with brownish to pinkish weathering colors. The member contains early Albian ammonids of the Leymeriella group (X. tardefurcata, L. regularis) (det. K. Seyed-Emami).

These three members mutually interfinger and form a single unit composed of limestone with intercalations of marls and shale (Fig 23).

D) 100 to 150m of dark-greenish to olive-grey glauconitic shale containing several intercalations of gastropod limestone. The shale contains *Beudanticeras beudanti*, *Beudanticeras* cf. *iniaum* (d'Orb.), *Puzosia* sp., *Douvilleceras* sp., and Hoplites dentatus indicating Albian age (dets: Breistroffer andK. Seyed-Emami).

Fig. 22. Northern slopes of Rokh Pass (Gardaneh-ye-Rokh) 65 km southwest of Esfahan. 1. Jurassic volcanics; 2. Fossiliferous Jurassic limestone; 3. Basal Cretaceous conglomerate; 4. Cretaceous Orbitolina limestone.

Fig. 23. West of Esfahan.
A: White marls with intercalations of Orbitolina limestone; giving way laterally and vertically to Orbitolina limestone.
B: Orbitolina limestone with interbedded marl.

Northwest of Esfahan (northeast of Tiran) about 200m of light grey marly shales and interbedded marly Orbitolina limestone is exposed. The thickness of the sequence increases westwards, reaching its maximum (about 450m) near the village of Varposlit. Here the shale is rarely marly, and limestone intervals are less common, though they still contain well-preserved Orbitolinas. This unit interfingers with the underlying and overlying limestone beds and should be considered as shale fades, of equivalent age. About 15km south of Najabad, the thick-bedded Barremian-Aptian Orbitolina limestone is succeeded by marly limestone containing abundant shale intercalations. The shales contain ammonites of the genus Deshayesistes (Aptian) and numerous mollusc shells. In the northwestern corner of the mapped area the Orbitolina beds of Barremian-Aptian age are conformably overlain by Aptian-Albian light-grey thin-bedded platy and marly limestone containing ammonites.

In the northeast corner of the quadrangle (northwest of Zefreh) the Upper Barremian beds are conformably followed by 100 to 300m of grey thick-bedded ammonite (Cheloniceraj)-bearing Orbitolina limestone of Aptian age. This is succeeded by marly, ammonite-bearing Albian limestone (Fig 24). About 10km northwest of Zefreh a section exposes some Cretaceous sediments thrusting over the Jurassic Shemshak Formation (see Fig 25). The Cretaceous beds begin with dark-grey limestone containing abundant *Pseudothoucasia* sp., (det.K.Seyed-Emami) of lower Middle Aptian age. In the same area the limestone is succeeded by 30 to 150m of grayish green shale containing the ammonites Leymeriella tardefurcata (Leymerie), L. *regularis* (Brugiere), Beudan-ticeras newtoni Casey, and Cleoniceras cf. morgani Spath, of Early Albian age. (dets, K. Seyed-Emami); also present are Rhynchonellids and terebratulid brachiopods, and small turritellid gastropods, *Trigonia* sp., *Nucula* sp., and *Nautilus* sp. (dets. K. Seyed-Emami).

The shale is conformably overlain by Upper Cretaceous marly and slaty limestone containing abundant Inoceramus. The Cretaceous beds are closely folded.

E) Two to three metres of glauconitic ammonite limestone (Late Albian-Cenomanian), which north of Kolah-Qazi mountain (in the southeast sector of the quadrangle) is succeeded by glauconitic shales with abundant ammonites, brachiopods and echinids. The ammonites found (det.K.Seyed-Emami) are *Cymatoceras* sp., *Stomohamites* sp., *Antisoceras perarmatum*, Ostlingoceras *Puzosianum*, *Turrilites* costatus, Lamark, *Hypoturrilites* sp. *Tuberculatus* (Bosc), *Hypoturritites* sp.cf. *gravesianus* (d'Orb.), Para-*turrilites* sp. aff. *lewesiensis* (Spath), *Mariella* bergeri (Brongniart), *Scaphites* sp. cf *equalis* J.*Sow*., *Scaphites* simplex Juke & Brown, S. *obliquus*, *Puzosia* sp., cf. *sharpei Spath*, *Hyphoplites* sp. cf. curvatus (Mant), *Schloenbachia* cf. *varians* (J. Sow), Man-*telliceras* sp. ex. gr. Hyatti *Spath*, *Mantelliceras* sp.ex.gr. *mantelli* (J. Sow), *Calycoceras* sp.ex.gr. *subgentoni* Spath, *Calyoceras naviculare Acanthoceras rhotomagense*. Some of the same ammonite species also occur in the upper part of the Beudanticeras shale about 40km northeast of Shahreza indicating that the ammonite limestone interfingers locally with the uppermost part of the shale. A marked condensation of ammonite forms from Upper Albian to Cenomanian is recorded in the ammonite limestone (Seyed-Emami et al., 1970). The fragmental state of the fossils in the upper part of the Albian Beudanticeras shale may indicate that this part has been reworked.

Fig. 24. Lower Albian ammonites (Leymeriella tardefurcata (Leymerie)) from the marly limestone in the region northeast of Esfahan.

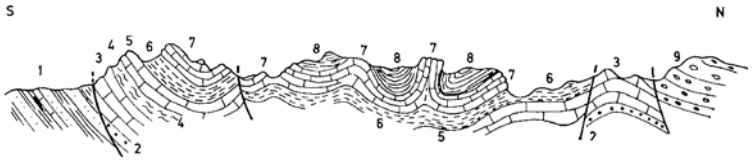


Fig. 25. Sketch section of the Cretaceous rocks northwest of Zefreh (northeast of Esfahan).
1. Jurassic sandstone/shale; 2. Basal red sandstone and conglomerate; 3. Barremian -Aptian Orbitolina limestone; 4. Aptian marl and interbedded Orbitolina limestone; 5. Upper Aptian - Lower Albian black rudist-bearing limestone; 6. Albian ammonite-bearing shale; 7. Upper Cretaceous Inoceramus limestone; 8. Upper Cretaceous marly and slaty Inoceramus limestone; 9. Tertiary conglomerate.

F) 80 to 100m of medium-to thick-bedded light-grey marly pelagic limestone overlies the glauconitic ammonite limestone with slight disconformity. These beds contain abundant' Inoceramus (I. latnarki, parkinson), Micraster sp., *Echinocorys* sp. *Oligostigina* sp., *Globotruncana helvetica*, G. *lapparenti Brotzen*, and G. *Imbricate Mornod*, indicative of Turonian-Coniacian age. The limestone becomes increasingly marly upwards and is succeeded by the following member.

G) 120 to 150m of light-bluish to grey calcareous marls with limestone intercalations consisting largely of shell fragments. The marl and limestone contain abundant echinids *(Micraster coravium* Posl., *Isomicraster* gibbus (Lamark), *Echinocorys* sp., Seyed-Emami et al.,1971), brachiopods, and Globotruncana concavata indicative of early Campanian. The unit probably has a Santonian-Campanian age range.

H) 30 to 40m of brownish, massive, organo-detritic and sandy limestone forming the top of the Cretaceous sequence in the mapped area. The limestone contains abundant rudist fragments, and as it conformably overlies the Campanian marls of unit G it can be considered Campanian and/or Maestrichtian in age.
The last three units (with the same fossils) are also exposed about 40km northeast of Shahreza; their thicknesses here are 110m, 130m, and 40m respectively.
Correlation of Cretaceous sections in the Esfahan Quadrangle is illustrated in Fig. 26.

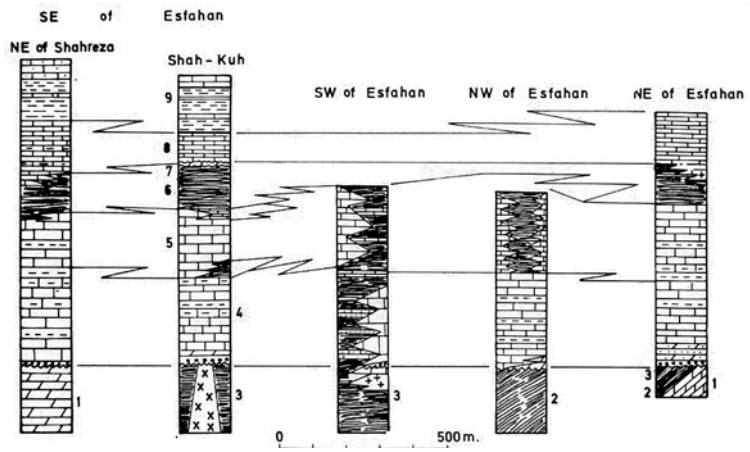


Fig. 26- Correlation of Cretaceous sections in the Esfahan Quadrangle. 1. Middle Triassic dolomite; 2. Upper Triassic shale/sandstone; 3. Jurassic shale, sandstone, limestone, andesite and granodiorite; 4. Barremian-Aptian limestone, marl and basal conglomerate; 5. Upper Aptian - Lower Albian limestone, shale, marl and thin-bedded cherty limestone; 6. Albian shale; 7. Albian-Cenomanian ammonite-bearing limestone; 8. Turontan-Coniacian limestone; 9. Caropanian-Maestrichtian marl and sandy limestone.

Eocene

Eocene (mainly Lutetian) rocks form two major units, of different lithology and distribution, namely conglomerate and limestone to the southwest, and lavas and pyroclastics to the northeast of Esfahan.

A) Conglomerate and limestone (100 to 300m thick) exposed in the

southwestern part of the quadrangle. On the southern flank of Kuh-e-Panjeh and Kuh-e-Shahlora (near Gardaneh-ye-Rokh) the Lower Cretaceous rocks are unconformably overlain by 50 to 300m of conglomerate, intercalations of sandy conglomeratic limestone, marl and marly limestone, constituting the basal part of the Eocene sequence. In the northern slope of Gardaneh-ye-Rokh the conglomerate is formed of head-size limestone boulders cemented in a reddish sandy matrix and overlies Jurassic rocks. Just south of the same pass, however, the conglomerate (here formed of large angular to subangular cobbles of Orbitolina limestone) unconformably overlies Lower Cretaceous limestone; further south the components in the upper part of the conglomerate are smaller and rounded.

Marls, whitish limestone and conglomeratic limestone with nummulites are intercalated in the upper part of the conglomerate. 30 to 50m of white nummulitic limestone and conglomeratic limestone with abundant nummulites conformably overlie the above-mentioned unit. These beds yielded Nummulites sp., Alveolina sp., Assilina sp., Cuvillierina sp., Rotalia trochidiformis Lamarck, textulariids, and Algae (det. F. Lessani).

About 12km northeast of Sefid Dasht (along the road to Esfahan) nummulites are abundant in the white (nummulitic) limestone, and there are numerous intercalations of conglomeratic limestone. The nummulitic limestone contains *Cuvillerina* sp., *Discocyclina* sp., Algae and shell fragments. Locally it overlies directly (i.e., without the conglomerate) Lower Cretaceous Orbitolina beds.

About 10km northeast of the village of Fara Dombeh, near the southern margin of the quadrangle and south of Sefid Dasht the Eocene nummulitic limestone and conglomerate are seen unconformably overlying Lower Cretaceous limestone and succeeded by Neogene (Mio-Pliocene) conglomerate (Bakhtiary Formation).

About 15km north of Shahreza, Aptian limestone is overlain, with slight unconformity, by some 50m of conglomerate containing subangular to rounded pebbles of Orbitolina limestone, red and grey sandstone, and slaty limestone, cemented in a sandy carbonate matrix. To the northwest, the conglomerate thickens and is interbedded with sandy nummulitic limestone containing Nummulites millecaput Boubee and N. fabiani (Prever) (a few samples exceeding 3cm in diameter), miliolids, Algae, and shell fragments indicating a late Lutetian age.

Northwest of Esfahan, about 8km north of Najafabad, some 20m of nummulitic limestone, with intercalations of conglomerate and a thin (1-2m) bed of conglomerate and conglomeratic limestone at the base, transgresses, with distinct unconformity, the Barremian-Aptian Orbitolina limestone. The Nummulites (Nummulites helveticus (Kaufmann), N. munieri Ficheur) indicate late Lutetian age. The nummulitic unit ends with 5 to 10m of marls and is succeeded by 30 to 40m of conglomerate with abundant Orbitolina limestone pebbles. Southwestwards from this locality the conglomerate thickens to more than 300m and unconformably overlies Orbitolina beds. The main components of the conglomerate are head-sized angular to subangular boulders of Orbitolina limestone cemented in a fine-grained reddish, argillaceous matrix. Some reddish sandstone and red sandy marl are interbedded in the middle of the conglomerate unit. The upper part contains interbedded conglomeratic limestone and thin layers of nummulitic limestone. The conglomerate unit forms part of the piedmont of the northern flank of the Cretaceous mountain range and continues far to the northwest of the mapped area.

B) About 1,800 to 2,000m of Eocene (Lutetian) lavas and pyroclastics with intercalations of nummulitic limestone crop out about 70km northeast of Esfahan, They can be divided into five main units (from bottom to top):

(i) Tuffs and andesitic volcanics, 300-310m thick (near, and northeast of Zefreh), comprising from bottom to top:

1- 100m of volcanic tuffs and andesitic lava
2- 140- 150m reddish tuff and andesitic volcanics
3- 50m greenish marly shale
4- 10m andesitic volcanics

These beds can be considered as the basal part of the Eocene sequence since they, and a stratigraphically equivalent conglomerate bed exposed west of Zefreh where Middle Triassic dolomite transgressively overlies, are conformably

succeeded by the nummulitic limestone of unit (ii).

(ii) 10 to 40m of nummulitic limestone containing *Nummulites* sp., N. aturicus, joly et *Leymerie*, N. globulus *Leymerie*, *Alveolina* sp., A. *pasticilata* (Schwager), Dis*cocylina* sp., *miliolids* (Biloculina sp., *Quinqueloculina* sp., *Triloculina* sp., *Lituonella* sp., *Valvulina* sp., Rotalia sp.) and textulariids.

(iii) 700 to 720m of acid to intermediate tuff breccia and andesitic volcanics composed, from top to bottom, of:

Lava, intermediate to basic	50 meters
Volcanics, acid	300 »
Tuff, reddish	20 »
Tuff, greenish acid Japilli	100-120 »
Lava, greenish acid	10 »
Tuff, reddish	2 »
Lava, reddish andesitic with interbedded reddish ash	20 »
Tuff, greenish to reddish	1 »
Lava, andesitic	2 »
Tuff, greenish hard, cliff-forming	15 »
Lava, andesitic	30 »
Sandstone reddish thin-bedded (2 to 10cm), fine grained, containing volcanic fragments	20 »
Lava, andesitic	80 »
Tuff, whitish, acid	50 »

(iv) 500 to 600m of andesite lava containing one dacite and one latite bed as intercalations. The upper part of the andesite lava is porphyritic, consisting of phenocrysts of twinned plagioclase (oligoclase-andesine) and relict mafic minerals (now wholly replaced by chlorite, carbonate and epidote), in a groundmass (60-65:%;) formed mainly of patches or slender prisms of plagioclase mixed with secondary chlorite. Other minerals are opaque grains, apatite, epidote and calcite.

The lower part of the lava consists of hyaloandesite (ferruginous andesite) with slightly porphyritic, vesicular texture. The rock contains plagioclase phenocrysts set in a groundmass of plagioclase microlites and iron oxides. The plagioclase phenocrysts are albitized, subhedral crystals up to 0.3mm long; no twinning or zoning was seen. Quartz fills vesicles in the rock. Carbonate, glass and opaque grains are abundant in the groundmass.

The dacite intercalation has a felsophyric texture. Phenocrysts are: plagioclase (oligoclase-andesine) forming euhedral crystal slightly saussuritized, albite-carlsbad twinning, quartz, corroded in places and amphibole (hornblende), almost entirely chloritized, and epidotized. The groundmass is holcrystalline, consisting largely of anhedral grains of quartz, and K-feldspar. The other minerals present are opaque grains apatite, sphene, chlorite, zoisite, epidote, clinozoisite and tremolite-actinolite.

The latite intercalation contains potash feldspar and plagioclase, the former concealed in a fine-grained crystalline or glassy groundmass. Other minerals are augite, hornblende, apatite and opaque oxides.

(v) 300 to 400m of basaltic andesite and andesitic basalt with porphyritic, trachytic, and seriate textures. The andesite contains small phenocrystals of twinned plagioclase (oligoclase-andesine) and pyroxene (augite), which is mainly uralitized and chloritized. The groundmass is formed of slender prismatic plagioclase crystals, albitized and twinned on the albite law and constitutes the main part of the rock volume. The andesitic basalt has textures ranging from slightly porphyritic to fluidal, to diabasic in some samples. The rock is composed of small plagioclase phenocrysts (andesine-labradorite) and replaced mafic minerals set in groundmass of prismatic plagioclase laths. The mafic minerals seem to have been pyroxene replaced by uralite and chlorite. Calcite and opaque grains are also present.

The volcanic rocks forming the rounded blackish hills in the northeast corner of the quadrangle are composed of coarse-grained basalt, more or less similar to the rock described above, but mafic minerals are wholly replaced by carbonate, iron oxides and chlorite. These rocks also contain abundant slender prismatic plagioclase laths, but pyroxene is absent.

As explained above, the Eocene deposits (conglomerate, limestone and volcanics) correspond to the Lutetian stage; both Early Eocene and Late Eocene rocks are absent in the Esfahan area.

Oligo-Miocene (Qom Formation)

The Qom Formation, developing a considerable thickness of 500 to 1000m in the Qom area (about 200m N of Esfahan), represents only 50 to 100m of whitish fossiliferous limestone in the Esfahan Quadrangle. It unconformably overlies the various older rocks and has locally a conglomerate member at its base.

The thickness of the basal conglomerate varies from 0 to 50m. About 2km SE of Zefreh village (NE of Esfahan area) some 30m of conglomerate, containing mainly pebbles of Orbitolina limestone, overlies the nummulitic limestone (Lutetian). Eastwards (about 15km) the thickness of the conglomerate increases to about 50m and contains intercalations of reddish conglomeratic sandstone or reddish sandy marls. The conglomerate member overlies, here, Cretaceous (Albian shales), Middle Triassic (dolomite) and even Permian rocks. The conglomerate is conformably succeeded by about 60m of whitish limestone with the following foraminifers: *Lepidocyclina* sp., *Miogypsine* sp., *Globigerian* sp., *Heterostegina* sp., *Spaherogypsina* sp., *Textularia* sp., *Amphistegina* sp., *Miliolids*, Algae, corals, and bryozoans, giving an *Aquitanian* age. West of Zefreh the limestone is succeeded by gypsiferous marl, containing coral in which is an intercalation of limestone containing Kuphus arenarius (Linne). As the upper part of the marl is covered by Quaternary deposits, only 40m of the sediments are exposed and the total thickness is not known. This horizon is lithologically comparable to the upper part of the Qom Formation in other districts of Iran, which belongs to early and middle Miocene.

About 35km to the north of Esfahan the Oligo-Miocene Qom Formation unconformably overlies the Lower Cretaceous Orbitolina. The basal conglomerate is here reduced to nearly lm. About 90km to the southeast of Esfahan the basal conglomerate is entirely absent and the Orbitolina limestone is directly, and unconformably, overlain by the fossiliferous Oligo-Miocene sediments.

Miocene - Pliocene

About 5km west of Varposht village (60km west of Esfahan) 20 to 30 m of white porous crystallized sandy limestone are underlain by conglomerate and sandy white marls with intercalated conglomeratic limestone. These beds rest unconformably on Lower Cretaceous (Aptian) calcareous shales. No intact fossils have been found in the limestone but a Mio-Pliocene (locally Oligo-Miocene) age is assumed on the basis of the resemblance of its formal assemblage lithology to those of similar, flat-lying deposits of known Mio-Pliocene age in other parts of Iran.

About 15km west of Fara Dombeh (in the southwest corner of the mapped area) a mainly conglomerate fades is exposed. Its thickness exceeds 300 m and it contains intercalations of greenish to reddish sandstone and sandy marl. The pebbles of the conglomerate are mainly of grey Lower Cretaceous limestone, white Paleocene limestone, and greenish to reddish sandstone. The conglomerate beds are folded (dip 5° to 25°), forming a shallow syncline with axis striking northwest. These conglomeratic beds may be equivalent to parts of the Mio-Pliocene (Bakhtiary Conglomerate) in the Zagros Mountains.

Another conglomerate (probably Pliocene), 100 to 300m thick, crops out extensively northeast of the village of Fara Dombeh. It is not folded, and it unconformably overlies various Lower Cretaceous and Eocene beds. The lower part of the conglomerate contains intercalations of sandy marl and sandstone but no fossils have been found in them. The pebbles are variable in size (lem to 7m) and are formed of grey Orbitolina limestone, algal limestone, nummulitic limestone, red and greenish sandstone and volcanic fragments.

There are some flat-lying outcrops of marl with sandy beds and gypsum layers about 45km to the northeast of Esfahan. Their total thickness is not known as they form only isolated small flat-topped hills in the Quaternary deposits. The hills are in a northwest-trending belt about 40km long and 0.5 to 3.5km wide. The sediments do not contain fossils. They may belong either to the uppermost part of the Oligo-Miocene (Qom Formation) or to the Pliocene or Recent (possibly the early deposits in the Gavkhaneh depression).

Quaternary and Recent

The Quaternary deposits can be conveniently grouped under the following

headings:

A) Travertine. This is only exposed in the northeast of the Quadrangle. About 10km north of Vartun village, around a hot spring (Ab-e-Garm-e-Sagzi village), 10 to 25m of travertine overlie the Oligo-Miocene (Qom Formation) limestone.

B) Old terrace deposits. In the western and southwestern parts of the Quadrangle, terraces are found at relatively high altitudes (about 2000m). The terraces are 100 to 150m high and are formed of conglomerate containing large blocks of limestone and pebbles of older rocks (Fig. 27) and overlying various Mesozoic and tertiary rocks. The terraces in northeastern districts are more regularly bedded and consist mainly of smaller pebbles, only rarely including large blocks. Pebbles of volcanics are locally abundant.

C) Subrecent terraces. These ("dashf'-forming) deposits are the most extensive of the Quaternary rocks. They consist of conglomerate layers and intercalated sandy marls totaling 80 to 100m thickness. They consist for the most part of relatively small, mainly rounded, pebbles of limestone and sandstone. They overlie Tertiary and Mesozoic rocks and, locally, other older terrace deposits. They are not tilted, but follow the hill slopes and occupy intermontane areas. Old deposits of the Zayandeh Rud formed of marl, conglomerate and shaly argillaceous material containing quartz and sand grains are exposed along the present course of the Zayandeh Rud in the mapped area.

D) Undifferentiated Terraces and Old Alluvium. Northeast of Esfahan, located between the above subrecent terraces and present-day terraces and alluvium, there are some isolated terraces cut off by flood water erosion. They are surrounded by old alluvium.

E) Recent terraces and other alluvium. The recent terraces are formed mainly of fine-grained conglomerate and argillaceous sediments. Other recent deposits are alluvial plains and river deposits. They are usually covered by agricultural soils and are under cultivation.

Fig. 27. Quaternary terrace (B) covering Jurassic deposits (A) west of Esfahan, near the Zayandeh Rud.

Igneous Rocks

In addition to the Jurassic volcanics in western districts, and the Tertiary volcanics in the northeast (described earlier) other igneous rocks are present as described below:

A) Upper Jurassic granodiorite intrusives are found in the southeastern continuation of the Shahkuh-Kolah Qazi range. They are older than Barremian, because the Barremian-Aptian basal conglomerate, which -is formed largely from them, overlies not only the intrusives themselves, but also the Jurassic shales into which the granodiorite is intruded.

B) In Early Paleogene time, or perhaps contemporaneously with Eocene volcanic activity in the northeast of the quadrangle area, the Lower Cretaceous rocks in more southerly localities were intruded by dolerite (10km north of Mahyar and east of Qamishlu). The rock is an altered quartz dolerite with doleritic texture

and a highly carbonatic groundmass. The minerals are plagioclase (andesin, forming lath-shaped crystals) and intersertal quartz, iron oxides, and ferromagnesian minerals, which are mainly altered to carbonate, chlorite, and opaques. Similar dolerite is intruded into the Middle Triassic dolomites about 6km northwest of Zefreh.

C) In Neogene time (probably Late Neogene) the Eocene volcanic rocks of the northeast were intruded by an acidic intrusive rock composed mainly of granodiorite. The essential minerals of this rock are as follows:
Plagioclase (albite-Oligoclase), forming 45% of the rock volume in euhedral to subhedral crystals, variable in size, reaching 0.3mm in diameter with albite-carlsbad twinning, is slightly sericitized and epidotized; anhedral K-feldspar grains, often mixed with plagioclase or quartz and pseudopropylitized in places; anhedral grains of quartz; amphibole (hornblende), wholly replaced by tremolite-actinolite and chlorite, fibrous in places and showing faint pleochroism. Other minerals are opaque grains and sphene.

Near the contact with volcanic rocks, the granodiorite becomes microcrystalline and locally gives way to amphibole diorite grading to microdiorite. This rock has hypidiomorphic texture and contains plagioclase, hornblende, opaque minerals and sphene. The plagioclase (oligoclase-andesine forming the bulk of the rock) is in sub-hederal to anhedral crystals, up to 2mm in length, and showing albite-carlsbad twinning. The crystals are slightly sericitized and show slight zoning around their borders. Most of the hornblende crystals are altered to tremolite-actinolite, but some of the original crystals are preserved and show multiple twinning. A small amount of quartz is visible in some specimens. The main secondary minerals are tremolite-actinolite, chlorite, zoisite, and sericite.

GEOLOGICAL HISTORY AND TECTONICS

The southwestern sector of the Quadrangle embraces parts of the Zagros mountains and the northeastern sector includes parts of the Central Iranian range (Kohrud range). These two sectors have had diverse geological histories.

The oldest rocks (i.e., the Precambrian basement complex) are exposed west of Esfahan. They were consolidated by Baikalian diastrophism and metamorphism. The Baikalian basement emerged as a horst (Zayandeh Rud Horst) as a result of epeirogenic (epi-Baikalian) movements. The horst was probably emergent from Infracambrian to Lower Permian time. The trend of the horst and its exact limits are not known, but considering present knowledge of the geology of the wider area around the Esfahan Quadrangle, it can be deduced that the eastern boundary of the horst was approximately north-south.

In the eastern part of the quadrangle, the oldest rocks are the lower Upper Devonian and Lower Carboniferous sandy and carbonatic (sandstone, dolomite and limestone) formations, indicating that a shallow sea existed in Lower Devonian time. Transgressive, marine conditions existed in Middle and Upper Devonian and continued into the Lower Carboniferous; this sea was connected with the transgressive sea to the northeast, and the terrigenous deposits of the earlier sedimentation were succeeded by mainly carbonatic sediments. But the facies and fauna indicate that the epicontinental sea was never very deep. Striking resemblances between the Middle-Upper Devonian fauna of Iran, U.S.S.R. and Europe indicate that the sea was contiguous with seas in those areas (N. K. Ovechkin, 1958).

The lack of evidence of Late Carboniferous and Early Permian rocks suggests an absence of sedimentation during this period which could be due to a wider, regional, emergence embracing not only the Esfahan area, but the main parts of what is now Iran. It should be noted, however, that this important gap displays no unconformity; Middle-Late Permian deposits with a basal red sandstone disconformably overlie Early Carboniferous beds.

Although this sandstone gives evidence of pre-Permian emergence, its conformable contact with the underlying rocks does not suggest a major pre-Middle Permian orogenic activity but rather the alternated effect of the Hercynian Orogeny experienced in other parts of the world. The unconformable contact between the Permian sediments and the Precambrian basement rocks in the west of the area, however, is perhaps due to Precambrian orogenic activity.

In the Middle Permian, the quadrangle area was largely submerged by vast marine transgression, though some small areas (e.g., the Zard Kuh district in the northeast) remained emergent and were later disconformably overlain by Middle Triassic sediments.

The epicontinental Permian sea, though relatively shallow, was an open sea with normal salinity, as indicated by its fauna and the nature of its sediments. The marine transgression of Permian times persisted into the Lower Triassic, at least in the southeastern part of the sheet area. But the main part of the area was affected by precursory movements of the early Kimmerian orogeny and the Permian sea regressed before the deposition of the Middle Triassic sediments. Some parts (including the Zayandeh Rud Horst) remained emergent throughout Triassic and Lower Jurassic time. With the exception of the emergent horst, all the Esfahan area was transgressed, from the southeast, in the Middle Triassic (see Fig 4., and the colored section on the map sheet). The Middle Triassic dolomite, which is remarkably uniform over most of Iran, was deposited in a shallow-marine environment. In the north and especially the northeast, marine conditions persisted into Upper Triassic and Lower Jurassic. The very rapid lithologic changes from Middle Triassic dolomites and limestone to the thick, sandy argillaceous deposits of the Upper Triassic (Nayband Formation) and Lias (Shemshak Formation) can be attributed to a change in paleogeographic conditions due to the early Kimmerian orogenic phase.

In the southwest, the area was invaded gradually by the Liassic sea, and not only the Permian carbonate deposits but also the Precambrian metamorphic rocks were overlapped by the mainly clastic sediments and volcanics of the Jurassic period. The complete change in lithology and the nature of the unconformable contact of the Liassic sediments bear witness to the creation of new reliefs, an erosional phase, and the occurrence of orogenic (early Kimmerian) movements before the Liassic sediments were deposited.

No evidence of the Neocomian Stage could be found in the whole of the quadrangle area, and the Upper Jurassic and the beginning of the Cretaceous correspond to the late Kimmerian orogenic phase,during which the mapped area was subjected to folding and associated emergence and erosion. In the Late Jurassic, and before the Barremian-Aptian sedimentation, late Kimmerian movements caused gradual emergence in the north and southeastern part of the area, but the southwestern part continued to subside and emerged later, by the end of the Jurassic.

The Barremian and Aptian limestone, calcareous shales and marls, unconformably overlying different folded beds of Jurassic, Upper and Middle Triassic age, indicate a return to marine conditions. The Lower Cretaceous sea, though very extensive, regressed from the main parts of the mapped area in the Albian, before the deposition of the Upper Cretaceous rocks. The sea regressed eastward but apparently persisted into the Upper Cretaceous, so that about half of the eastern part of the mapped area remained covered by the sea. Mainly pelagic sediments were deposited during the Upper Cretaceous. Regression was completed by the end of the Cretaceous.

The area underwent a second, but relatively moderate, orogenic phase (attenuated Laramian phase) during the end of the Cretaceous and the beginning of the Eocene, characterized by folding, emergence and erosion. Paleocene and early Lower Eocene rocks are not known in the area. The Laramian movements were succeeded by shallow-marine transgression in Lutetian time over most of the area; the Lutetian deposits unconformably

overlie not only various beds of Cretaceous age, but also locally Jurassic and even Middle Triassic rocks. The presence of volcanic activities in the north-eastern part of the area indicates instable conditions during this time.

The Lutetian sea retreated in Upper Eocene times. The area was again subjected to folding, uplift and erosion during the Alpine orogenic movements in Oligocene times. The Oligo-Miocene sea, which subsequently invaded the region, was confined to the eastern part of the quadrangle area, where thin foraminiferal limestone was deposited.

In Mio-Pliocene times the sea regressed eastwards and the area was locally occupied by intramontane lakes. Some sandy limestone deposits were laid down unconformably on different older beds in the western part of the quadrangle, and thick deposits of coarse conglomerates accumulated in the southwestern intermontane depressions. In the northeast some gypsiferous marls were deposited in a lagoonal environment which may have represented the last remnants of the Miocene sea.

Finally, the formation of recent faults, associated dolomitization and mineralization, thrusting, reactivation of old faults, magmatic activity, and appearance of hot springs are indications of later Alpine orogenic movements.

The horst-graben structural form in the northeastern part of the area, thrust faults, moderate folding of the Paleozoic-Mesozoic rocks and gentle folding of the overlapping Tertiary sequence, with predominant northwest-southeast trends parallel to the main Zagros thrust fault, have controlled the present structural pattern in the area.

METALLIC MINERALS

Lead and zinc occurrences are mainly in the Cretaceous sediments, usually where the deposit is dolomitized and along faults or fissures intersecting a major fault. In the lead-zinc mines northwest of Najafabad, the mineralization seems to have a sedimentary origin. Subsequently a deposit along the major Shak Kuh fault supports an important lead-zinc mine and can be followed for several kilometers in the northwesterly continuation of Shak Kuh. Another lead-zinc deposit occurs northwest of Gardaneh-ye-Rokh (west of Rokhabad). Rarely, the underlying shale unit is mineralized, e.g., north of Kachuieh.

Copper (malachite-galena) indications are rare in the mapped area. There is a mine eight kilometres of Najafabad and indications of copper in the west in the Precambrian schist and dolomite. Around the village of Hardang in the southwestern part of the area, the Jurassic volcanics contain small amounts of malachite and galena.

REFERENCES

AGHANABATI,S.A., 1975. Etude geologique de la region de Kalmard (W. Tabas, Iran Central): Stratigraphie et tectonique. These, Universite Scientifique et Medicate de Grenoble.

ALAVI.M., and J.FLANDRIN, 1970. La limite paleogeographique des domaines de l'Elbourz et de l'Iran central dans la region de Djam (Departement de Semnan, Iran). C.R. Acad. Sc. Paris, ser. D,v. 270, p. 1424-1426.

AMIDI, S.M.,1969. A short Geological report on Nain-Anarak Area. Tehran, Geol. Survey Iran,(Text in Farsi).

BITTNER, A., 1899. Triassic Brachiopoda and Lamellibranchiata: Himalayan fossils. Paleont. India Calcutta, ser. XV, v. Ill, 276p.

BOLOURCHI, M.H., 1975, Etude geologique de la region d'Avaj (NW de l'Iran). Universite Scientifique et Medicale de Grenoble.

CLAPP, F.G., 1940. Geology of Eastern Iran. Geol. Soc. Amer. Bull, v.51, no. l,p. 1-102.

DAVOUDZADEH, M., and S. TATEVOSSIAN, 1966. Geology of the Gardaneh-Shir sedimentary area. Geol. Survey Iran (unpublished note).

DEHGHAN, M., 1947. Sur l'age mesozoique de la zone de Hamadan (Iran septentrional). C.R. Acad. Sc. Paris, v. 224, no. 21, p. 1516-1518.

GANSSER, A., 1955. New aspects of the geology in Central Iran. Proc. 4th World Petrol. Congr., Rome, Sect. I/A/S, paper 2, p. 280-300.

HADJI AN, J., 1970. Geologie de la region de Tafresh (NW de ITran Central), Unpubl. Thesis, Fac, Sci. Univ, Lyon, 295p.

HAGHIPOUR, A., 1972. Etude geologique de la region de Biabanak-Bafq (Iran Centra!). Petrologie et Tectonique du Socle Precambrian et de sa couverture. Universite Scientifique et Medicale de Grenoble.

KUHN, O., 1933 a. Das Becken von Isfahan-Saidabad und sein altmiocane Korallenfauna. Palaeon-tographica, Abt. A,v. 79. p. 173-1283 pis.

MEHRNOUSH, M., 1970. Cretaceous in Esfahan Area, Ministry of Economy, Geol. Survey Iran, Note No. 67.

OVECHKIN, N.K., 1958. Structure geologique de l'U.R.S.S. (Reducteur responsable: MARKOVSKY A.P.), Institut de Recherches des Sciences geologique, Ministers de la Geologie et de la Protection du sous-sol, Tome I, Stratigraphie. Traduction en francais: Pietresson de Saint-Auben et J.Roger. Fascicule 3, Paleozoique, p. 185-503; 4, Mesozoique, p. 504-651 ;5, Ceno-zoique, p. 652-735, Paris 1959.

REYRE and MOHAFEZ, 1969. A first contribution of the NIOC-ERAP agreements to the knowledge of Iranian Geology. (Submitted by the Governments of France and Iran),

SAMADIAN, M.R., 1973. Geology, Sedimentology and Engineering Geology of the Riz area. Unpublished M.Sc. thesis, Science Faculty, Tehran Univ. (in Farsi).

SAMIMI NAMIN, M., 1965. New discoveries of phosphate in Iran. Cento Seminar on field techniques for mineral investigation, Iran, Centra! Organization, p. 145-156.

STOCKLIN, J., 1954. Geology of the area between Kashan, Ardestan and Isfahan. Nat. Iran. Oil, Co., Geol. Rep. No. 108, 24p. (unpublished)

TARAZ, H.,= 1969. Permo-Triassic sections in Central Iran, Ass. Petrol. Geologists Bull., Tulsa, Vol. 53, no 3, p. 688-693.

TEHRANI, K., 1973. An Orbitolinid fauna from the Lower Cretaceous of Esfahan (Central Iran). N. Jb. Geol. Palaont, Mh.,

THIELE, O., M. ALAVI, R. ASSEFI, A. HUSHMAND-ZADEH, K. SEYED-EMAMI, and M. ZAHEDI, 1968. Explanatory text of the Golpaygan Quadrangle Map, 1:250,000. Geol. Survey Iran, Geol. Quad. Rep. E-7, 24p.

ZAHEDI, M. 1973. Etude geologique de la region de Soh (W de ITran Central. Geol. Survey Iran Rep. No. 27, 197 p.

درائوسن پسین دریای لوتسین از منطقه کناررفت وجنبشهای بعدی کوهزائی آلپی در اولیگوسن همراه باچین خوردگی و بالاآمدگی بوقوع پیوست . سپس دریای اولیگوسن میوسن قسمتهای خاوری منطقه رافراگرفت ولایه های کم ضخامتی از آهکهای فسیل دار در آن نهشته گردید .

درمیوسن دریاشروع به پس روی نمود ودر دورپلیوسن همچنان پس میرفت وتنها بطور محلی درچند نقطه اززاحیه ، دریاچه هایی دربین کوهها بوجود آمد ونهشته های آن(لایه های نازکی ازآهک ماسه یی) درباختر ناحیه یا دگرشیبی برروی سنگهای قدیمیترقرارگرفت ولی درجنوب باختری ناحیه رسوبهای دانه درشت وکنگلومرایی برروبهم انباشته گردید وبالاخره درشمال خاوری ناحیه، مارنهای گچ دار آخرین اثر دریای میوسن پلیوسن؟ هستند که بطورافقی وباضخامت کمی رخنمون دارند .

دردوره‌ی کواترنر ، نهشته های آواری دانه درشت دربیشتر جاهای ناحیه‌ی مورد بررسی تشکیل شده وهم چنان درحال تشکیل اند وگانه های آبرفتی مختلفی که درچند سطح توپوگرافی دیده میشوند بازمانده‌ی آبرفتهای قدیمی ترکواترنر میباشند .

رسوبگذاری است که میتوان آنرا بیک خشکیزائی عمومی درسطح پهناوری از ایران زمین مربوط نمود.

پیشروی وسیع دریا درپرمین میانی تمام‌سطح منطقه‌رافراگرفته بوده است‌گرچه این دریاخیلی عمیق نبوده ولی‌گسترش زیادی داشته وویژگیهای یک دریای بازرباشوری معمولی دارا بوده‌است. این محیط دریایی دراغلب جاهای منطقه تاپایان دوره‌ی‌پرمین دوام داشته‌ولی باشروع اولین جنبشهای کوهزائی کیمری پیشین ،دریای پرمین بتدریج پس‌روی کرده وبجز قسمتهایی از جنوب خاوری ناحیه که محیط دریایی تاتریاس میانی ادامه داشته ، بقیه‌ی جاهارا خشکی وسیعی فرا گرفته ومحیطی برای تشکیل دولومیتهای تریاس میانی که یکنواختی‌وگسترش شگفت‌انگیزی در بیشتر جاهای ایران زمین دارد فراهم‌گردیده است . این‌محیط دریایی که عمق زیادی درتریاس میانی نداشته بتدریج در اواخرتریاس (بویژه درشمال‌وشمال خاوری ناحیه) عمیق‌تر گردیده و تاژوراسیک‌پیشین ادامه یافته است. تغییرهای زیادی که درجنس رسوبهای تریاس میانی (دولومیت وآهک) وتریاس بالایی (لیاس ـ شیل‌وماسه‌سنگ) مشاهده میکنم نتیجه‌ی تغییر جغرافیای دیرین ناحیه است که مربوط به جنبشهای پیشین کوهزایی کیمرین پیشین میباشد .

خشکی ایجاد شده درقسمتهای باختری بتدریج بوسیله‌ی دریای لیاس (توآرسین) تسخیرشده ورسوبهای آواری وسنگهای آذرین بیرونی نه تنها برروی‌سنگهای پرمین تشکیل شدند بلکه بطور دگرشیب برروی سنگهای قدیمی‌ترودگرگون شده‌ی پرکامبرین نیز قرارگرفتند . دراینجا نیز تغییر جنس سنگها ووجود دگرشیبی بین‌لایه‌های متعلق به ژوراسیک وسنگهای قدیمترگواهی است برایجاد رخنمونها واثر فاز فرسایشی برروی آنها که در نتیجه‌ی جنبشهای کوهزایی کیمری پیشین اتفاق افتاده است (پیش‌ازتوآرسین).

نظربااینکه هیچگونه دلیلی بروجود سنگهای نئوکومین دردست نیست وسنگهای کرتاسه بادگرشیبی برروی نهشته‌های قدیمتر قرارگرفته‌اند ، چنین نتیجه میشود که در حد فاصل‌بین‌ژوراسیک وکرتاسه ، درمنطقه‌ی مورد بررسی فازکوهزایی کیمری پسین نیزوجود داشته‌است . دراین فاصله است که رسوبهای منطقه بطور شدیدی چین خورده ، ازآب خارج شده ومورد هجوم عاملهای فرسایش قرارگرفته است .

دگرشیبی بین سنگهای‌رسوبی (آهک ـشیل ومارن) بارمین ـ آپسین‌وسنگهای مختلف‌ژوراسیک وتریاس نمایانگر پیشروی دریای کرتاسه دراین منطقه میباشد .

دریای کرتاسه‌ی پیشین‌گرچه وسعت زیادی داشت ولی قبل‌از تشکیل نهشته‌های کرتاسه‌ی بالا ،پس‌روی کرد وازقسمتهای زیادی از منطقه عقب رفت . این پس روی بطرف خاور بود وبجز قسمتی ازنیمه‌ی خاوری ناحیه که محیط دریایی درآنجا تاکرتاسه‌ی پسین دوام داشت ، بقیه‌ی جاهارا خشکی فراگرفت وبالاخره درپایان کرتاسه ،پس روی دریا کامل شد .

بین کرتاسه وائوسن جنبشهای کوهزایی برای باردیگر ازسرگرفته شد ورفته‌رفته شدت یافت (فازکوهزایی‌لارامی) بطوریکه رسوبهای تشکیل شده چین خوردگی حاصل نموده ودرپی آن عاملهای فرسایش شروع بفعالیت نمودند .

بعداز جنبشهای لارامی ، دریای کم ژرفای لوتسین شروع به پیشروی نمود وقسمت‌زیادی از منطقه رافراگرفت دراین مدت نسبتاً آرام ، نهشته‌های لوتسین بطوردگرشیب نه فقط برروی سنگهای مختلف کرتاسه قرارگرفت بلکه دربرخی ازجاها روی سنگهای ژوراسیک وحتی تریاس وسط را نیز پوشانید . وجود سنگهای آتشفشانی درشمال خاوری منطقه ، نشاندهنده‌ی‌ناآرامی‌نسبی آن زمان‌است.

آهکی ودولومیتی تشکیل شده وحال‌آنکه درقسمت بالا شیل وماسه سنگ بوجود آمده است . رخنمونهای مربوط به تریاس درجنوب خاوری ، شمال خاوری وهم چنین درشمال باختری منطقه گسترش دارد.

سنگهای ژوراسیک رانیز میتوان بدوبخش تقسیم نمود . درخاور چهارگوش شیل وماسه سنگ‌گسترش دارد که آنها به سازند شمشک نسبت داده‌ایم ودرلابلای آن لایه‌های کنگلومرایی وجوددارد . درباختر وجنوب باختری منطقه درلابلای‌سنگهای شیلی‌وماسه سنگی ژوراسیک ،لایه‌های آهکی وآتشفشانی فراوان است .

رخنمون سنگهای کرتاسه تقریباً درسراسر ناحیه یافت میشود ولی درقسمتهای جنوبی‌گسترش بیشتری دارند . این سنگهای رسوبی درقاعده بایک کنگلومرا وماسه سنگ قرمز رنگ‌شروع میشود که بوسیله آهک ، مارن وشیل دنبال شده است . سن رسوبها ازبارمین تاماستریشیتین میباشد .

سنگهای ائوسن (بیشتر مربوط به لوتسین)از دوواحد اصلی تشکیل شده است : در جنوب‌باختری کنگلومرواوآهک وجوددارد سنگهای آتشفشانی (گدازه‌هاوسنگهای آذرآواری) که در لابلای آن لایه‌های آهک نومولیت‌داروجود دارد درشمال خاوری ناحیه گسترش دارند . رسوبهای اولیگوسن ومیوسن (سازندقم) ازآهکهای فسیل‌دار سفیدرنگ ساخته شده است که‌درناحیه‌ی اصفهان‌گسترش زیادی ندارد ولی درقسمتهای شمالی (چهارگوش کاشان) دامنه‌ی‌گسترش‌آن بسیار زیاداست . سنگهای میوسن ویلیوسن دربیشتر جاهای ناحیه‌ازکنگلومرا ، مارن وآهکهای ماسه‌یی متخلخل‌تشکیل یافته ولی درشمال خاوری ناحیه اصفهان جنس این سنگها ازمارن وماسه سنگ است ودرلابلای آنها لایه‌های‌گچی تشکیل شده است . این سنگها بصورت لایه‌های افقی‌گسترده‌اند واکثراً بوسیله‌ی لایه‌ی نازکی از نهشته‌های جدید پوشیده شده‌اند .

علاوه برسنگهایی که یادشد درمنطقه‌ی مورد مطالعه ، توده‌هائی ازسنگهای نفوذی از جنس گرانودیوریت وجوددارد که‌دردوزمان مختلف بوجود آمده‌اند . یکی‌در دورژوراسیک‌پسین که‌درجنوب ناحیه دیده میشود ودیگری درنئوژن که درشمال خاوری ناحیه رخنمون دارند . در برخی ازجاهای جنوب ناحیه‌ی اصفهان ، رخنمونهای کوچکی ازسنگهای دولریتی نیز دیده میشود که سن آنها بطور قانع کننده‌یی مشخص نشده است .

چنانکه دربالا اشاره‌گردید منطقه شامل دورشته کوه‌مهم (زاگرس درجنوب باختری وکهرووددر شمال‌خاوری) است وبااینکه روند هردورشته یکسان است ، از نظرزمین‌شناسی‌ساختمانی ویژگیهای مختلفی دارند .

درباختر اصفهان سنگهای قدیمی پرکامبرین بعلت جنبشهای بایکالی دگرگون و سخت‌گردیده وبصورت پی‌سنگ ناحیه میباشند که بعداً بوسیله جنبشهای اپیروژنی بالا آمده و تشکیل یک بالاآمدگی‌درحوضه‌ی کنونی زاینده‌رود (درباختر ناحیه) داده است . این‌بالاآمدگی (هورست) ازاواخر پرکامبرین تاپرمین پیشین وجود داشته .

درشرق چهارگوش سنگهای ماسه‌یی ، دولومیتی وآهکی دونین زیرین‌تاکربینفرزیرین‌نشان میدهد که دریای نسبتاً کم عمقی دردونین‌پیشین وجودداشته که بتدریج دردونین‌پسین‌وکربینفر پیشین عمیق‌گردیده است . فسیلهائیکه درنهشته‌های این‌دریا یافت‌گردیده ارتباط مستقیم‌آنرا بادریای شمال درالبرز وروسیه نشان میدهد .

نبودچینه شناسی مربوط به سنگهای کربینفر بالا وپرمین پائین درسراسر چهارگوش روشنگرعدم

خلاصه

نقشه‌ی زمین شناسی چهارگوش اصفهان که محدود بین دوطول جغرافیائی ۵۱درجه‌و۳۰دقیقه و۵۲ درجه ودوعرض ۳۲و۳۳درجه میباشد سطحی برابر ۱۵۰۰۰ کیلومترمربع را میپوشاند .

دراین چهارگوش کوههایی قرارگرفته‌اند که بلندترین قله های آنها یکی کوه مارشان (۳۳۳۰متر) مربوط برشته کوه کهرود واقع در شمال خاوری ناحیه و دیگری کوه ارجند (۳۱۸۹متر) مربوط برشته کوههای زاگرس که قسمتهای جنوب باختری منطقه راشامل‌میگردد . دیگراز کوههای مهم‌منطقه‌شاه کوه میباشد که بلندترین قلهٔ آن بیش‌از ۲۵۰۰مترارتفاع دارد وناحیه‌روندآن شمال باختری ـجنوب خاوری است که باروند کوههای زاگرس‌درجنوب باختری ناحیه و کهرود درشمال خاوری ناحیه‌موازی بوده ومنطقه را بدو قسمت مینماید .

سنگهای موجود در ناحیه اصفهان مربوط به پرکامبرین تاعهد جدید است که از نظر چینه شناسی وزمین شناسی ساختمانی مورد مطالعه قرارگرفته است .

رخنمونهای قدیمترین سنگهای پرکامبرین که در باختر اصفهان قرار دارد شامل شیست ،کینس وسنگهای آندزیتی دگرگون شده میباشد .

سنگهای مربوط به کامبرین ، اردویسین وسیلورین دراین منطقه دیده نمیشوند وبنظرمیرسد که درفاصله‌ی زمانی بسیار طولانی نه رسوبگذاری انجام شده ونه فعالیت ماگمایی‌وجود داشته است . دردورهٔ دونین بدنبال پیشروی‌دریا رسوبهایی بوجود آمده‌اند که‌آنها را در شمال خاوری ناحیه میتوان دید جنس این رسوبها عبارتست از ماسه سنگ کوآرتزی و ماسه سنگ برنگهای قرمز وسفید میباشد که آنها را به دونین‌پایین نسبت داده‌اند . روی این سنگهای رسوبی ، بطورهم شیب‌آهکهای دولومیتی وآهکهای ماسه‌یی وبالاخره آهکهای خاکستری رنگ فسیل‌دارکه دارای لایه‌بندی نازکی‌میباشند تشکیل شده است . فسیلهای یافت شده دراین آهکها متعلق به دوئین میانی وبالائی است .

سنگهای کربونیفر پائین آهکی وماسه سنگی بوده ودرجنوب خاوری منطقه گسترش دارندولی درهیچ نقطه‌یی از منطقه مورد مطالعه سنگهای کربونیفر بالا وپرمین پائین دیده نشده است.

سنگهای پرمین میانی و بالا درشمال خاوری ، جنوب خاوری و هم چنین در باختر اصفهان رخنمون دارد . درقاعده‌ی این سنگها یک واحد ماسه سنگی وکنگلومرایی وجود دارد که بوسیلهٔ آهکهای فسیل‌دار دنبال شده وسن آنهاپرمین میانی وپسین میباشد .

سنگهای مربوط به تریاس ازدوقسمت متمایز تشکیل یافته است . قسمت زیرین ازسنگهای

سازمان زمین‌شناسی کشور

رئیس سازمان : رضا آصفی

بهای هر جلد ۲۵۰ ریال

سازمان زمین‌شناسی کشور - صندوق پستی ۱۹۶۴ - تهران - ایران

چاپخانه وزارت اطلاعات و جهانگردی

وزارت صنایع ومعادن

سازمان زمین شناسی کشور

شرح نقشه زمین شناسی اصفهان بمقیاس $\frac{۱}{۲۵۰۰۰۰}$

بوسیله :

مصطفی زاهدی

سازمان زمین‌شناسی کشور - نقشه‌زمین شناسی

شماره F ۸ ــ سال ۲۵۳۵