Memoirs of the Faculty of Science, Kyoto University, Series of Geol. & Mineral.
Vol. XLIII, No. 1/2, pp. 131–164, Pls 7–9, January 30, 1977

A General Report of the Geological and Paleontological Survey in Maragheh Area, North-West Iran, 1973

By

Tadao Kamei*, Jiro Ikeda**, Hidemi Ishida**,
Shiro Ishida*, Ikuo Onishi***, H. Partoazar',
Sadao Sasajima* and Susumu Nishimura''

(Received Oct. 20, 1976)

Content

Abstract

The present article is a general report on the excavation of the bone beds in Maragheh area, N. W. Iran. The excavation has been done at four sites in Dareh-e Gorg, near Mordagh, in autumn of 1973. Many fossil bones were sampled and those dispositions were recorded. The fossil materials excavated in this time were listed, including many cranial and postcranial bones of *Hipparion*, Antelope, and other Bovidae, Carnivores, *Choerolophodon*, etc.

* Department of Geology and Mineralogy., Fac. Sci., Kyoto University
** Lab. Physical Anthropology, Zoological Dept., Fac. Sci., Kyoto University
*** Inst. Geology, Fac. Liter. and Sci., Shimane University
' Geological Survey of Iran
'' Dept. Earth Science, College Liberal Arts, Kyoto University

The fossil bone was obtained from the sediments of 130 m thick in Mordagh area, consisting mainly of the alternations of tuffaceous sandstone and mudstone. Those are assignable to the lower part of the Maragheh Formation. The six tephra were recognized as the distinct marker beds in those sediments.

Then, the sedimentary environment is presumed. Directions of natural remanent magnetization of 9 sites were measured. Six pyroclastics including one ash flow of basement were dated by fission-track method and the age of the Maragheh fauna was considered as 6.6 to 6.9 my.

Introduction

For the occurrences of fossil bones in the area of Maragheh in North-west Iran many scientists have paid much attention since the middle of last century. In the autumn of 1971, three members of the Kyoto University Scientific Expedition (KUSE) team of Japan, J. IKEDA, S. ISHIDA and N. SHIGEHARA, visited the Geological Survey of Iran (GSI) after their field-work in the Siwalik Hills of India and in Sinap series of Turkey. With the collaboration scheme organized by the GSI, those three members and F. GOLSHANI, a geologist of the GSI, have carried out a brief reconnaissance survey at Dareh-e Gorg, en route from Mordagh to Kerjaveh in Maragheh area, during the middle of November of that year.

Having been based on the result, the team determined to conduct more detailed excavation and geological survey around the vicinity of Maragheh. From September 12th to November 1st, the KUSE team has been honorably given again the opportunity to work jointly with the GSI in Maragheh area. The Japanese team consisted of five members, J. IKEDA, T. KAMEI, S. ISHIDA, H. ISHIDA and I. ONISHI, and the Geological Survey of Iran has dispatched H. PARTOAZAR, to work in collaboration with the Japanese team.

In this report, those members of the joint team state the observation of field-work and excavation at Dareh-e Gorg, and the results of the paleomagnetic study for Maragheh samples by S. SASAJIMA of Kyoto University and the fission-track ages determined by S. NISHIMURA of the same university are included.

Previous Works

The study of the Maragheh bone beds has been undertaken since the middle of last century, but the story of fossil bone of the area went up in legend far more ancient time. R.T. GUNTHER (1899), reviewing the paleontological studies on the bone beds, wrote: "Village people regard the Mastodon bones as the remains of the big men who lived before the flood; but the chief man of the village classified the bones under the heads elephant, deer, swine, unicorn and 'devy', or men with horns like genii."

It was the first scientific paper in which H.W. ABICH (1857) reported tusk of elephant, remains of deers and fossil onager found from Maragheh which had been sent from Russian mission KHANIKOFF to Dorpat University (now, Tortustat University, Estonia). KHANIKOFF, who discovered Maragheh bone beds, had been in Persia in 1840. J.F. BRANDT (1870) and C. GREWINGK (1881) studied the specimens of Dorpat University which had been sent from chemist M.A. GOEBEL, who was also a member of KHANIKOFF expedition.

Based on ABICH's and BRANDT's works, Maragheh mammals had been considered as Pleistocene fauna including living ones by A. GAUDRY, 1878. E. TIETZ (1881) wrote in his "Ueber einige Bildungen der jungeren Epochen in Nord-Persien", regarding Maragheh mammals as "Steppen lehm" fauna. But another view was made by C. GREWINGK in the same year. He found the presence of *Hipparion, Rhinoceros* non *tichorhinus, Mastodon?, Helladotherium* and *Tragoceros* in the fauna, and pointed out the close relation between Maragheh mammals and those of Pickermi in Greece. In addition to this, he commented that the living and Pleistocene forms observed in the fauna by ABICH and BRANDT might be the materials derived from cave deposits nearby.

In 1884, H. POHLIG was invited by a merchant of Tabriz and made a journey to Persia. He excavated the bone beds near Maragheh during the season of June and July. According to him, "The fossil bones have been found in the reddish marls at more than six places, at greater or less distances from the city (up to 30 miles), and at different horizons, which, however, do not differ from each other by any characteristics of the mammalian fauna." (1886). He intended to publish a monograph of Maragheh fossils, but left only the faunal list and short comment. POHLIG listed sixteen species of mammals, and stated, "it seems to me therefore that a Pleistocene fauna does not really occur in the Maragheh valley". POHLIG's collection was mostly deposited in the Museum of Prof. Von FRITSCH at Halle.

In summer of 1885, A. RODLER and E. KITTLE visited Maragheh and excavated bone beds by the help of Kaiserliche naturhistorische Hofmuseum of Wien (RODLER, 1885; KITTLE, 1885). In the report, KITTLE enumerated following fossil localities: Korpan, Korpan-Mescha, Zad-Baschin, Rasat and Ketschara at Murditscha. Those materials excavated were sent to the Hofmuseum, and have been studied by KITTEL (1887), RODLER and WEITHOFER (1890) and G. SCHLESINGER (1917). Owing to their efforts, it became clear that the Maragheh mammals have close relation with those of Pickemi and Samos and have position in "Pontian" fauna.

On the other hand, R. LYDEKKER (1886) formed a notice on fossil materials of Maragheh which were sent from R. DAMON to the British Museum. He, admitting the priority of this study to POHLIG, stated a significant meaning of the Maragheh mammals in relation to the western limits of the Siwalik fauna of India. He assumed that the Maragheh beds are of later age than the Lower Siwalik.

On September of 1899, R.T. GUNTHER visited Maragheh and stayed at the house of Quasha MUSHI who had excavated and dispatched bone materials to POHLIG.

GUNTHER made picking up fossil materials near Kirdjawa (Kerjaveh). The materials were surveyed by C.I. Forsyth MAJOR who was working about the contemporaneous fauna of Samos. MAJOR had already reported the remarks on *Orycteropus* of Maragheh in 1893.

J. de MORGAN, a scientific mission delegated from Ministry of Public Instruction of France, had stayed in Persia during 1889–1891. He passed Maragheh in 1889 and had much interest in bone beds. His reports on the geology and paleontology of Persia were published in 1905, but prior to this, M. Marcellin BOULE of museum d'histore naturell de Paris got in tough with J. de MORGAN and also had much interest in Maragheh bone beds in 1897. On his suggestion, French expedition party went to Persia in 1904, and excavated bone beds at Kirdjawa (Kerjaveh) near Murditchal (Mordagh) three times with twelve workers. They also carried out geological survey at Kingir, Korpan, Chollovend and Mourandjikh. At that time, new fossil localities were found near Kermedjawan, 26 km east of Maragheh. R. de MECQUENEM, a member of this expedition, wrote short notes in 1905 and 1906. He engaged in the paleontological works of Maragheh mammals in the museum d'histoire naturelle and made some reports in 1908 and 1911.

In 1924 and 1925, MECQENEM published a monograph, "Contribution a l'etude des fossiles de Maragha". In this paper, he described 7 families, 26 genera, 32 species of mammals and two genera of birds. Among them, the discovery of *Mesopithecus* from Maragheh was noteworthy. After a long lapse of time, F. TAKAI of Tokyo University of Japan visited Maragheh and picked up some fossil bones at Karjabad in autumn of 1956 (TAKAI, 1958). In 1967, H. TOBIEN, Joh.-Gutenberg University of Mainz, visited Iran and excavated Maragheh bone beds. He reported a fossil list and discussed the occurrence of fossils (TOBIEN, 1968a, b).

Recently, Dutch team of D.P.B. ERDBRINK and others carried out field work in the region in 1973, and they published excellent results on stratigraphy, paleomagnetism and K-Ar dating (ERDBRINK et al. 1976).

General Geography and Geology in Maragheh Area

In the geological map of Iran arranged by NIOC, the basement of this area is assigned to the rocks ranging chronologically from Jurassic to Mio-Pliocene, and the overlying sediments are designated as Plio-Pleistocene (QP1).

The fossil-bearing deposits in Maragheh area is distributed widely ranging more than 300 Km in north-south trend and about 500 Km in east-west trend. Kuh-e Sahand (3,562 m), mass of extinct volcanoe, is surrounded by those deposits within the reach of Tabriz, Maragheh, Miandoab and Mianeh (Fig. 1). In this report, the sediments in which abundant fossil vertebrates are contained were named thereafter as the MARAGHEH FORMATION.

Our excavated sites are located at Dareh-e Gorg, about 2 Km north-northeast of Mordagh, the village of about 15 Km east-southeast of Maragheh (Figs. 2, 3 and 4). This area, is characterised by hilly-land extending about 30 Km from the southern foot (ca, 2,400 m) of Kuh-e Sahand to Mordagh (ca, 1,580 m). In south of Mordagh,

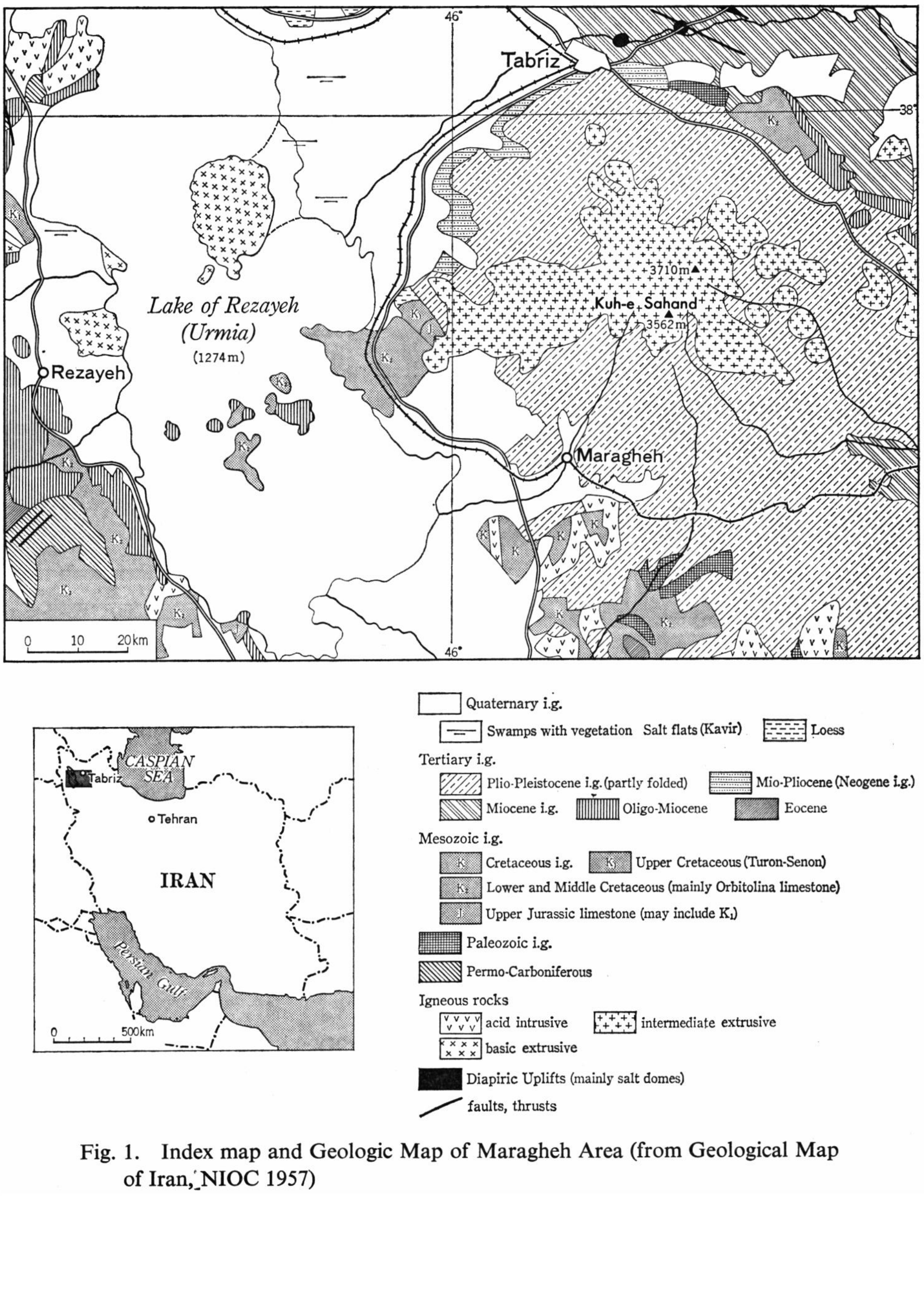


Fig. 1. Index map and Geologic Map of Maragheh Area (from Geological Map of Iran, NIOC 1957)

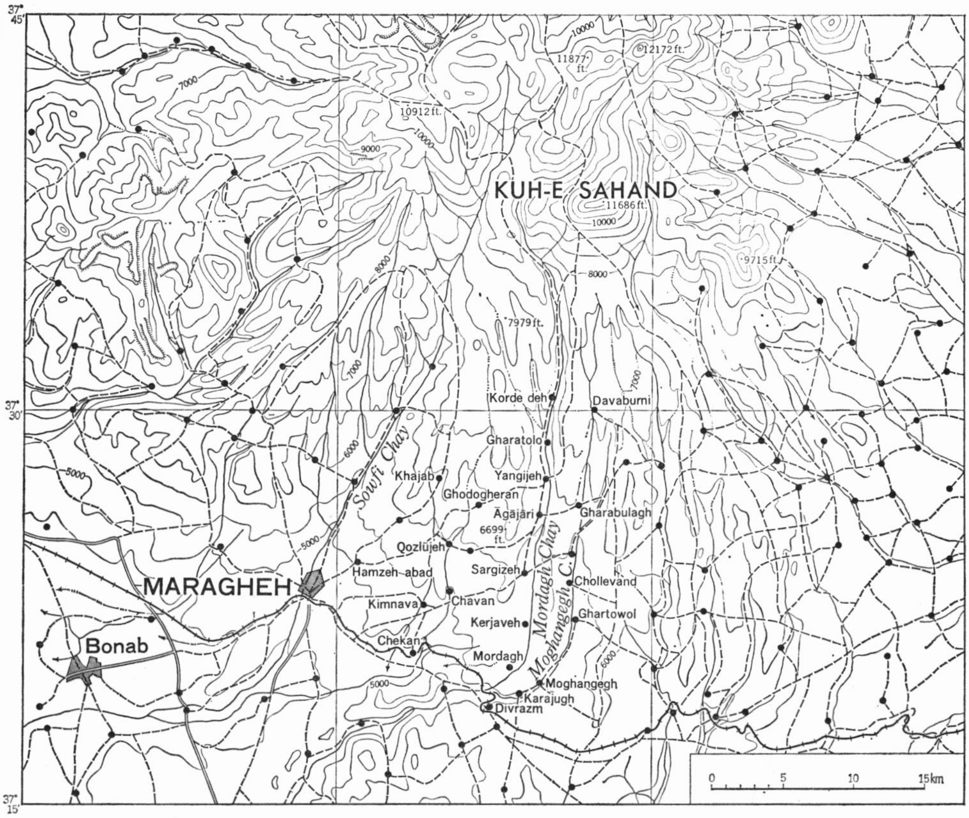


Fig. 2. Topographical Map of Maragheh Area

there is mountainous and hilly area consisting of shales and sandstones belonging to the Mesozoic marine sediments.

Hilly areas near the excavated sites are semi-desert environment with dry valleys occasionally dissected in 20 to 30 m depth. The surface elevation of those dissected hills has altitudes ranging from 1,650 to 1,700 m and the topography has wide and low relief. On the top of the hills, residual andesite gravels are scattered in considerable extent. Nearly horizontal layers, mainly consisting of alternations of tuffaceous sandstone and mudstone, crop out on the surface of slope.

Excavation at Dareh-e Gorg

a. Sites and trenches

The excavation has been carried out at four sites, Site-I, II, III, and IV, in the vicinity of Dareh-e Gorg (Fig. 5). To this excavation the team applied stepped

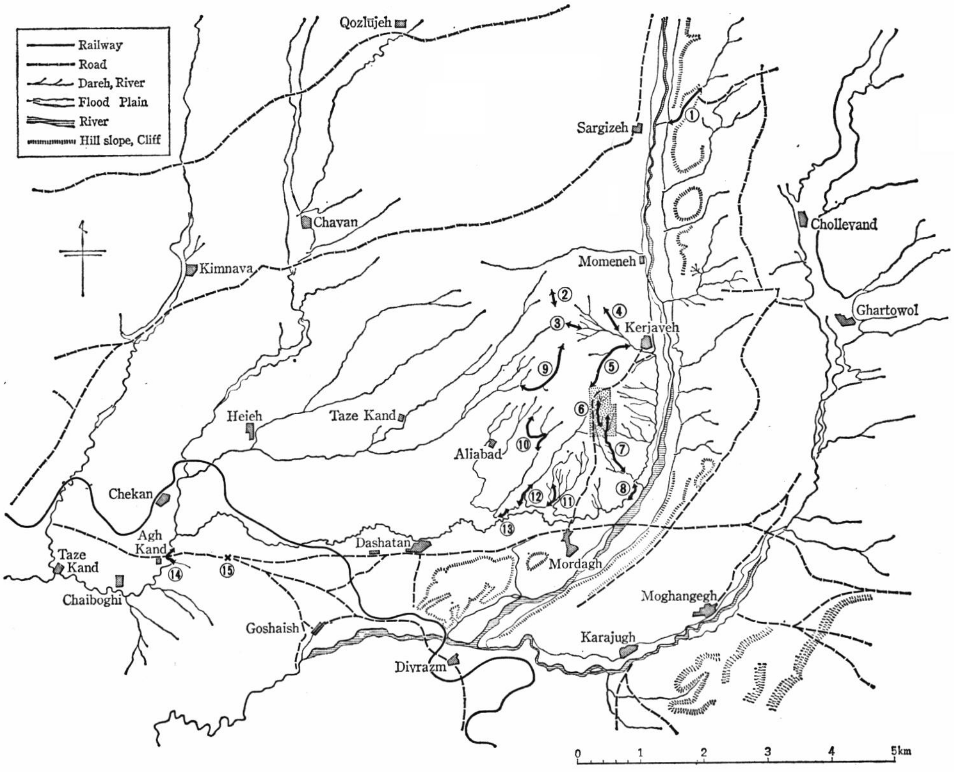


Fig. 3. Map of Surveyed Area and Localities Where Columnar Sections were obtained (1–15 in Fig. 14)

trench method, in order to hold those sites on the steep slope. In the cross-sections of trenches (Figs. 6–8), each horizon excavated is indicated successively by the same marks.

Site I (Fig. 6): A trench with 14 steps was cut in the slope from the top of hill to the valley floor. As the fossil bones were found only in the lowest, the excavation was proceeded to horizontal direction transversely to the slope.

Site II (Fig. 7): A trench with 12 steps was cut in the slope from the top of hill to the valley floor. Fossil bones were unearthed in horizons D and E. For searching small vertebrate fossils, the mudstone were sampled about one ton each from every horizons.

Site III (Fig. 8): During the excavation, an intensive work has been paid to this site. At first, three trenches were dug transversely to the slope. The lowest one, trench-a, was 10 m in length, and other two, trench-b and -c were 12 m in length. In the next stage, the horizon-b′ which was exposed under trench-c, was

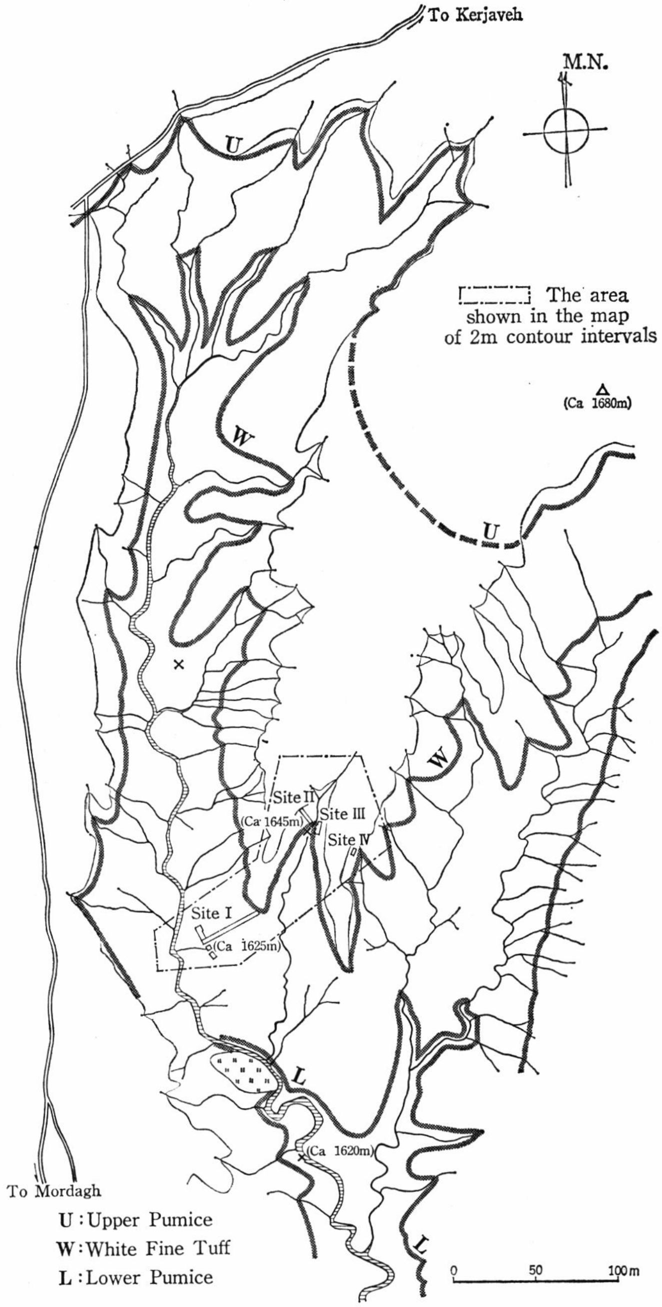


Fig. 4. Geologic Sketch Map of Upper Dareh-e Gorg (drawn by compass and pacing method)

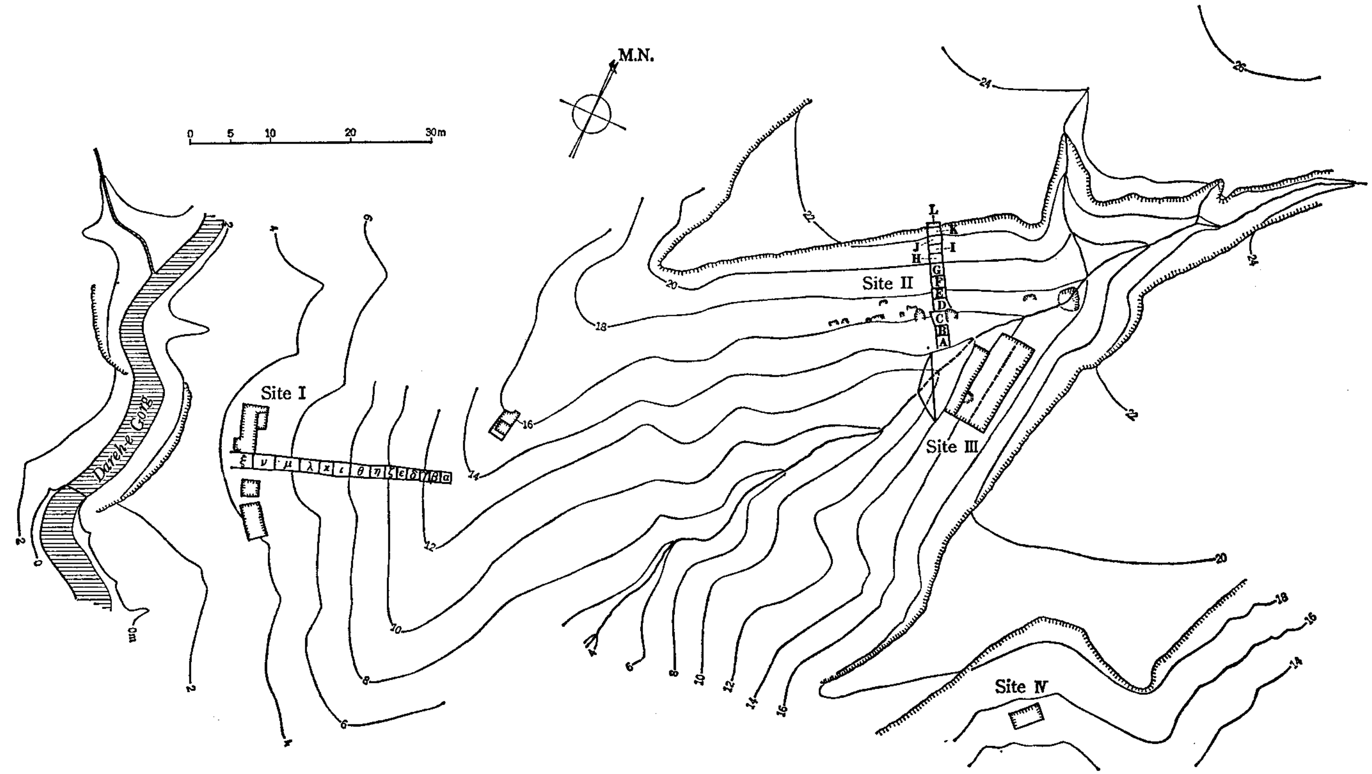


Fig. 5. Topographic Map of excavated Sites (drawn by use of hand-level, tape, and pole-measure)

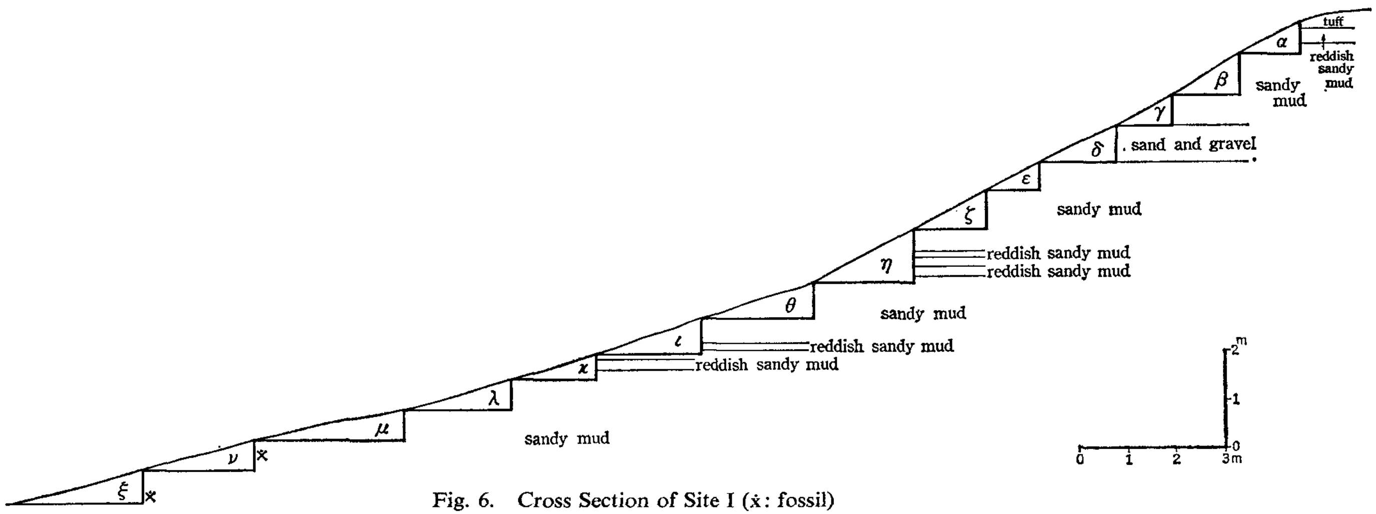


Fig. 6. Cross Section of Site I (ẋ: fossil)

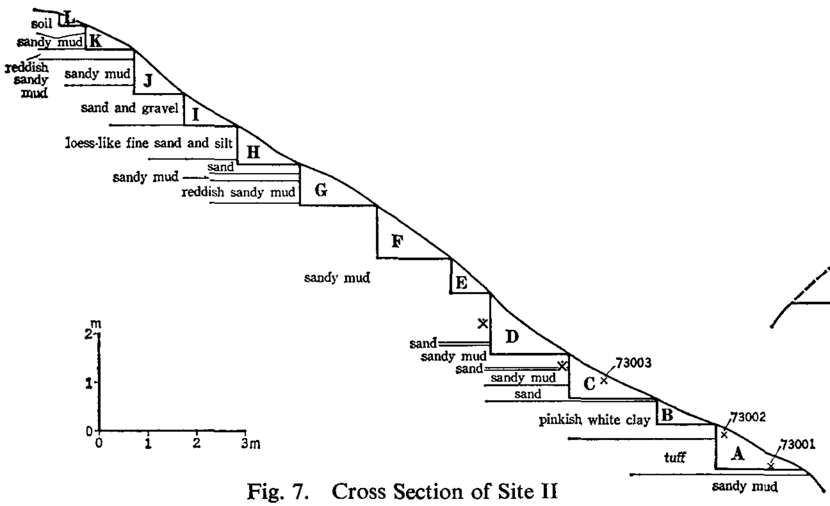


Fig. 7. Cross Section of Site II

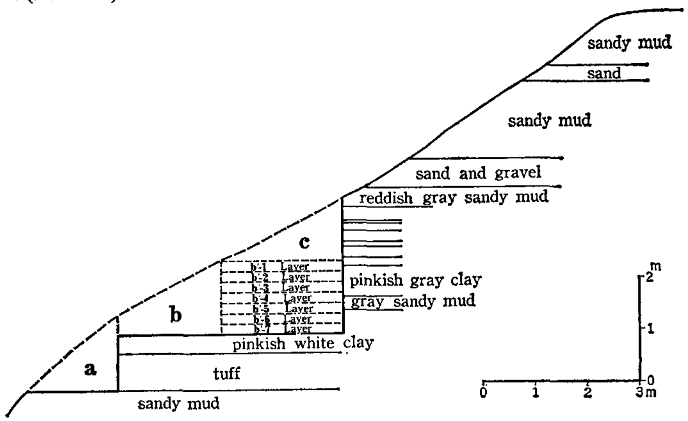


Fig. 8. Cross Section of Site III

subdivided into seven layers successively each 20 cm in depth. Stratigraphically upper six layers correspond to Horizon-b, but the lowest layer, Layer 7, is equivalent to Horizon-a. For the convenience of excavation, each trench was divided into five or six sections, each of which was 2 m in length. Fossil bones were concentrated in Horizons-b, -c and -b′. The mudstone were sampled at about one ton from Horizon-b for studying small vertebrate fossils.

Site IV: Many fossil bones were yielded from the trench.

b. Condition of fossil preservation

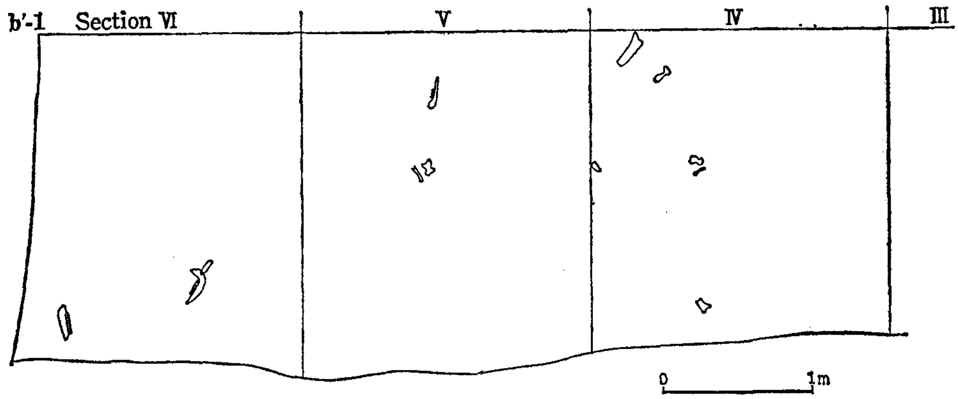
It seems that the preservation of fossil bones is rather well. The matrix was moderately hard, and, therefore, various sharply pointed chisels were effective to pick up bone materials from the matrix. As the fossil bones were so fragile and were also much distorted, it was necessary to pick up them carefully together with surrounding matrix. Sometimes, however, it happened to be broken down to pieces.

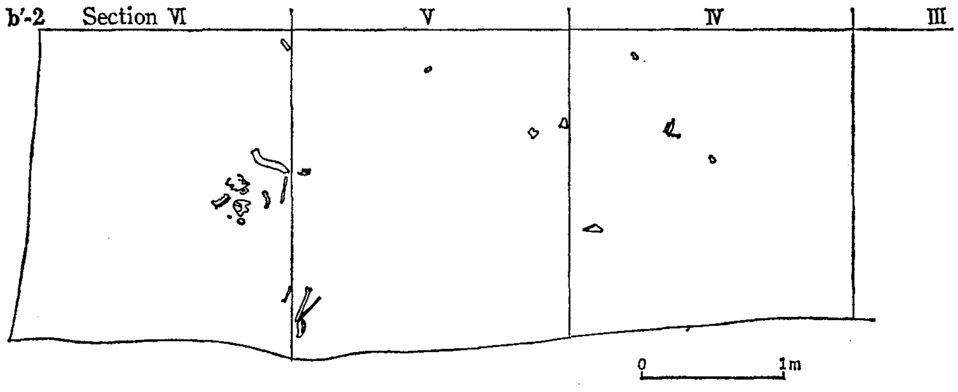
c. Disposition of fossil bones

Throughout the territory of Dareh-e Gorg, fossil bones were discovered in some clustered assemblages. In each cluster of bones, the disposition of fossils seems to have a definite orientation in exposition, as recognized clearly in Layers 4, 5 and 6 of Horizon-b′ (Fig. 9). In addition to this, the assemblage of fossil bones seems to form concentrated piles in some sections and layers, noticeably in Layers 4, 5 and 6 of Sections IV, V and VI (Figs. 9 and 10). From the above-mentioned facts, it may be possible to deduce that the fossil bones were transported by a sort of a stream. However, there is another evidence that some fossil bones were found to be standing obliquely to the surface plane of the bed. Moreover, it was true that some bones, e.g. leg bones of *Hipparion*, were uncovered in the statas of articulation *in situ*. Accordingly, it is possible to assume that those fossil bones had been transported by a stream, but not been drifted for a long distance.

d. Fossil specimens

The fossil materials excavated in this time were listed below. They include many cranial and postcranial bones of *Hipparion*, Antelope and other Bovidae, Carnivores, *Choerolophodon*, etc. As the team adopted stepped trench method for the excavation, the analysis of fossil assemblages may be possible not only qualitatively but also quantitatively.





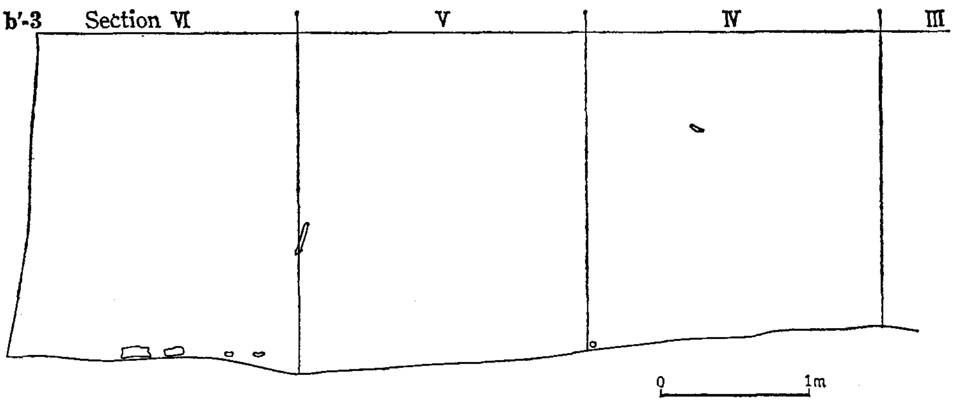
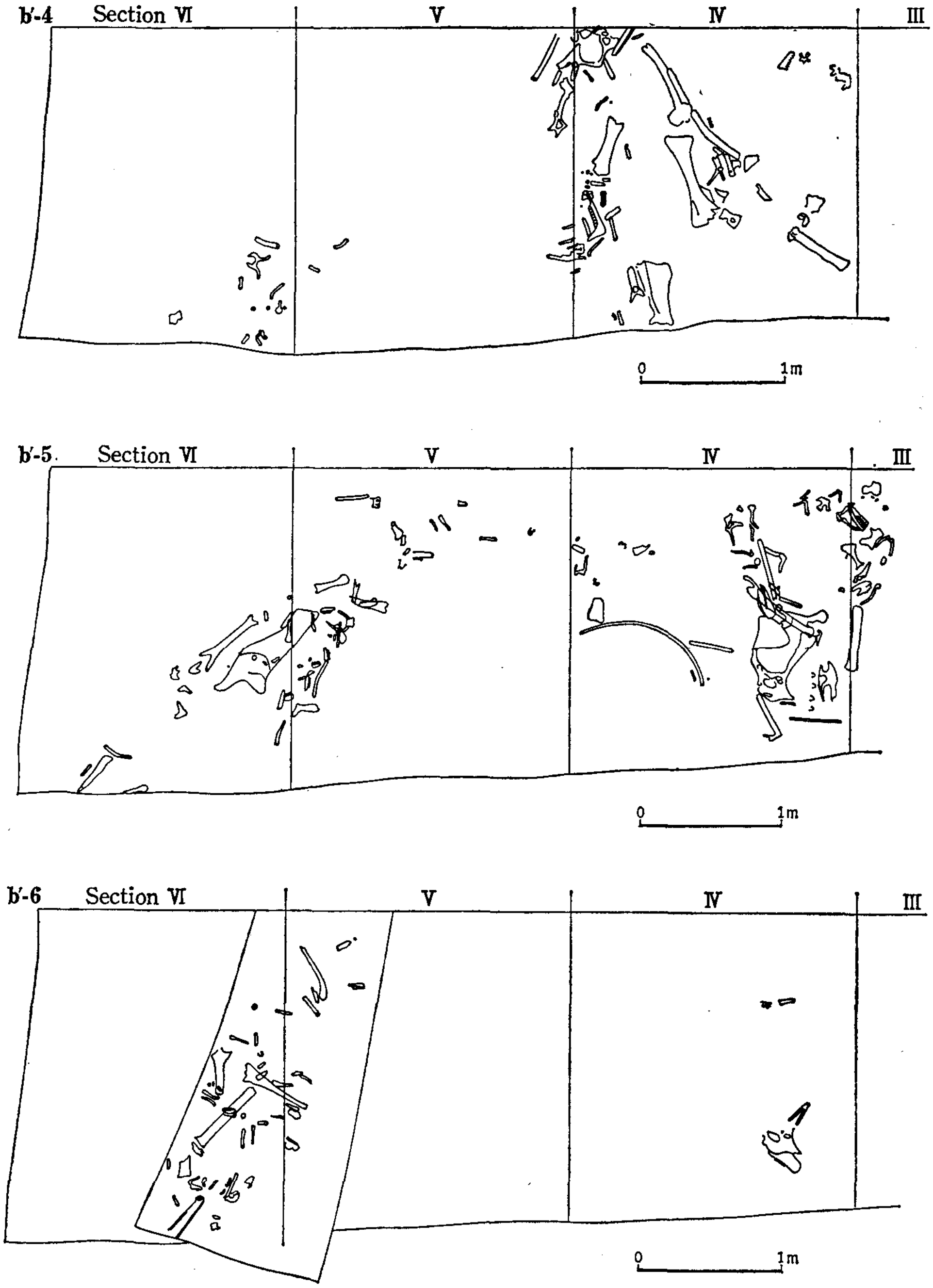


Fig. 9. Sketch of Horizontal Plane, Showing Fossil Disposition in Layers b' 1-6 of



Sections IV-VI at Site III

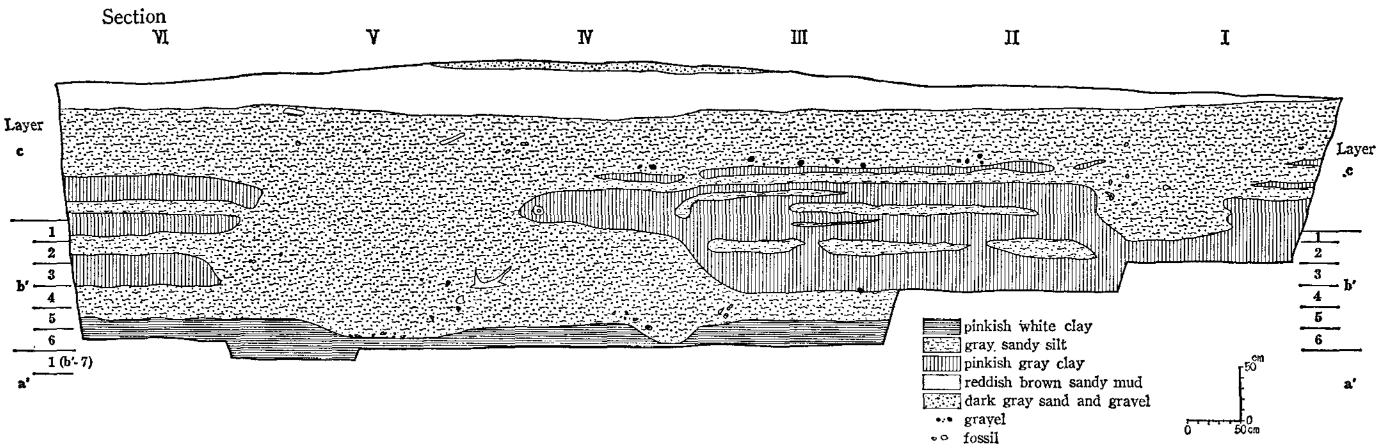


Fig. 10. Sketch of Vertical Plane of the East Wall at Site III

List of the collected fossils

MAMMALIA

Proboscidea:

Choerolophodon penteleci GAUDRY

Broken but rather well preserved cranial bone with ^{2}I, ^{1}M^1, ^{2}M^2 and unerupted ^{3}M^3 *in situ*; vertebral bone, probably lumbar vertebra; broken left scapula, rib bone; broken right humerus; broken left femur without epiphyses; left tibia, phalanges. Those materials are belongings of more than two individuals.

Perisodactyla:

Aceratherium persiae POHLIG

Only one broken left humerus is preserved.

Chilotherium morgani MECQU.

Mandibles, one isolated tooth and one phalanges.

Hipparion gracile KAUP

Cranial bones are preserved; broken and fragile maxila; mandibles; isolated teeth; the vertebral bones are composed of one axis, one cervical vertebra and one thoracic vertebra.

Scapulae, pelvis but broken are present. One left humerus and one right ulna. Metacarpus, one calcaneous, one astragulus, metatarsus, phalanges and one hoof remains are identified.

Artiodactyla:

Suid gen. et sp. indet.

One femur, one fibula may belong to Suid.

Helladotherium gaudryi MECQU.

One right maxila with M^2, M^3 and one broken mandible.

Achtiara coelophrys RODLER et WEITHOFER

Only one isolated tooth is preserved.

Giraffid gen. et sp. indet.

One mandible, one isolated tooth and one calcaneous.

Microstonyx sp.

One mandible.

Gazella spp.

Mandibles and isolated teeth, one pelvis, metatarsals.

Tragocerus spp.

Fragmental cranial bones, mandibles, isolated teeth, fragmental horns, vertebrae, scapula, rib bones, pelvis, humerus, tibia, astragalus, calcaneous, metatarsals.

Hippotragus sp.
Fragmental cranial bone, mandible, radius, ulna, metacarpus, tibia.
Oioceros boulei MECQU.
Fragmental cranial bone, femur.
Oioceros sp.
Tibia.

Carnivora:
Hyaenarctos maraghanus MECQU.
Mandible.
? *Machairodus* sp.
Mandible.

AVES
Struthio sp.
Pelvis.

REPTILIA
Ophidia gen. et sp. indet.
Vertebral column.
Clemys sp.
One shield.

As already mentioned, for the purpose of searching small vertebrate fossils, the materials were sampled at Sites II and III. As the result of careful washing and sieving by use of 1 mm mesh sieve, contrary to our expectation, no traces of small vertebrate fossils whatever were recognizable.

Stratigraphy

As the main subject of this research has devoted to the excavation, the geological survey was carried out only for a week from October 15th to 21st. Due to a very short field work, the geological survey was compelled only to confine to take some geological columns in the neighbourhood of Dareh-e Gorg (Figs. 3, 11 and 12).

The sediments 130 m thick in Mordagh area, mainly consisting of alternations of tuffaceous sandstone and mudstone, are assignable to the lower part of the Maragheh Formation. In this area, it is possible to recognize the following six distinct marker beds from the view point of tephro-chronological observation.

The Maragheh Formation lies unconformably on the basement rocks near Chekan. At locality 15 (Fig. 3), biotite-bearing ash flow with a bedding plane of N16°E, 23°W overlies Jurassic ammonite-bearing marine shales with bedding plane of N26°E, 31°S. In other places, gray siltstones of the Maragheh Formation abut

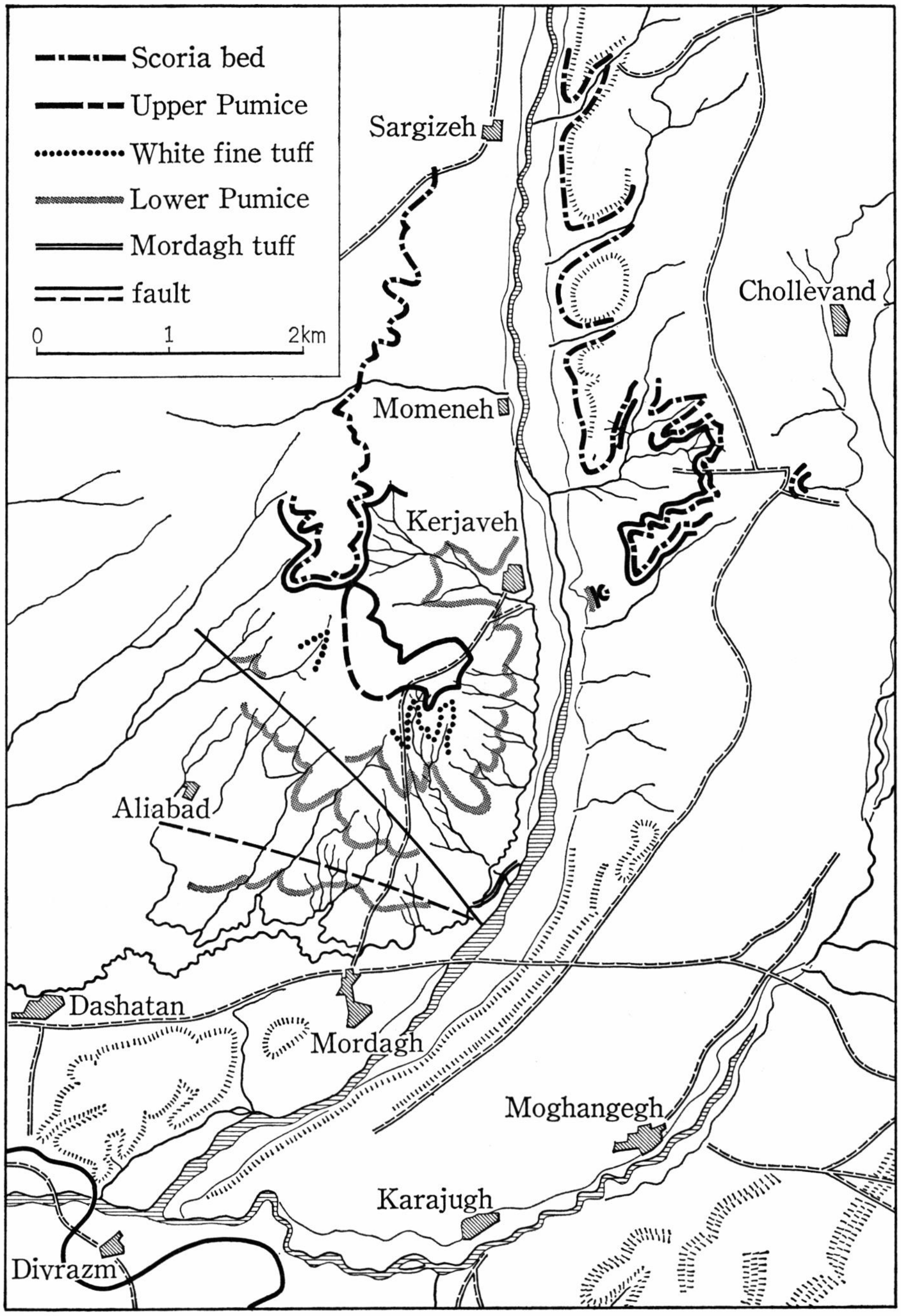


Fig. 11. Geologic Sketch Map in the Neighbourhood of Mordagh

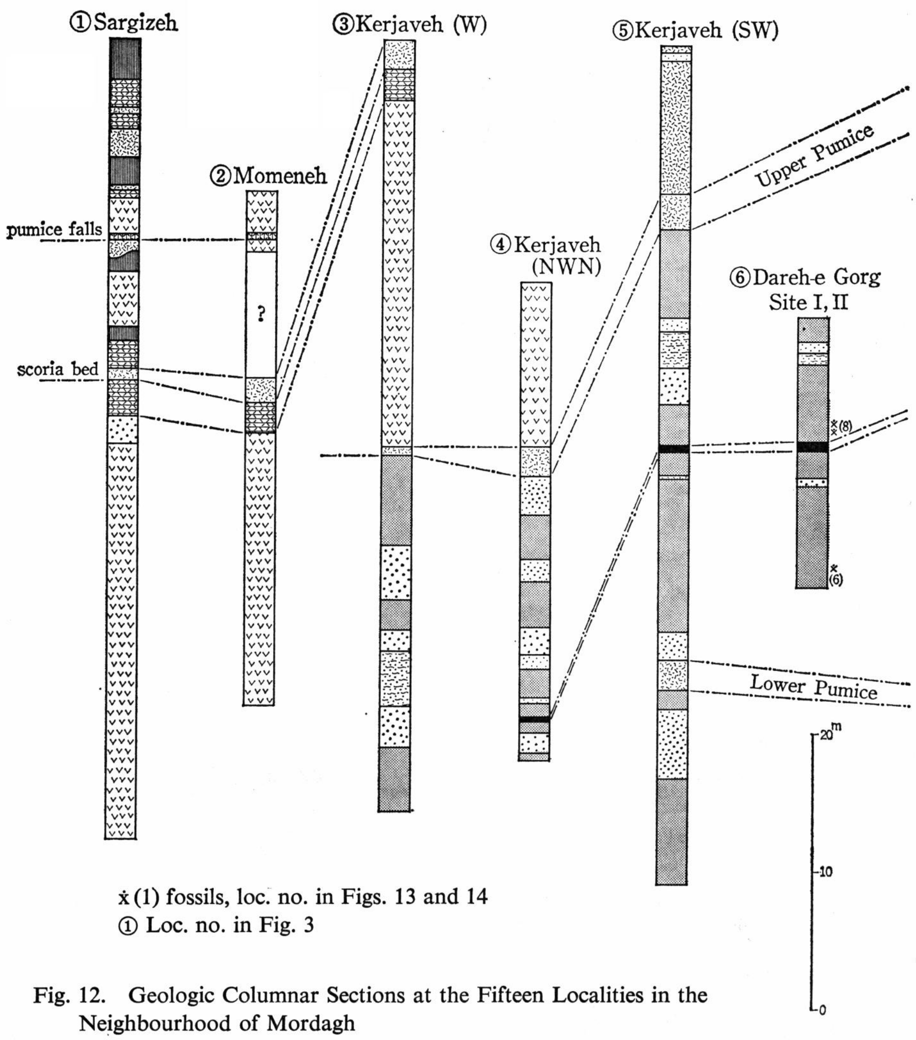
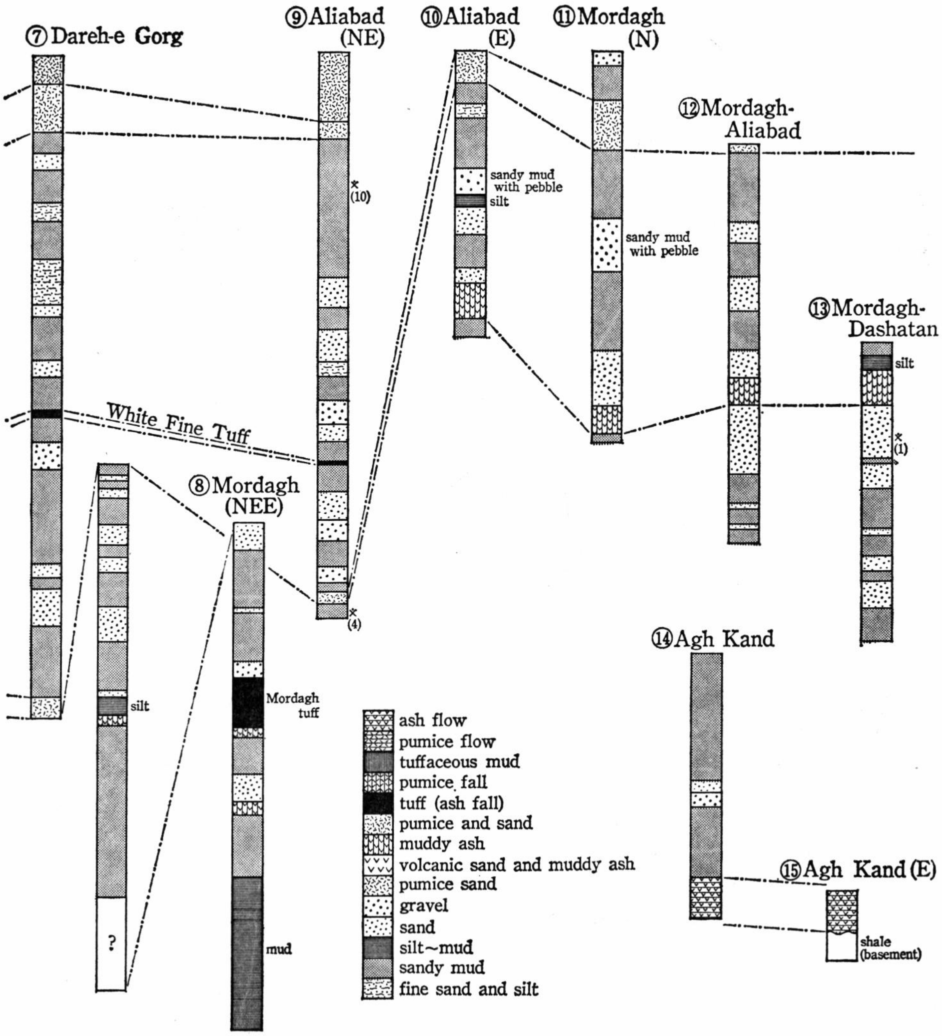


Fig. 12. Geologic Columnar Sections at the Fifteen Localities in the Neighbourhood of Mordagh

on alternations of sandstone and mudstone of Mesozoic age. Owing to high relief of the basement topography, in southern area some fenster hills of the basement rocks are surrounded by the Maragheh Formation. At 250 m west of Divrazm, hard dacitic fine ash flow lies on the scoria fall deposit. The ash flow is about 4 m thick, nearly horizontal, and is cut by fault which runs in N80 °W, 44 °S. In the north of fault, there are cobble conglomerates and red sandy mudstones with a dip of 46 °NE and a strike of N55 °W, it seems that cobble conglomerates belong to a member of the basement rocks and red sandy mudstones may represent a local facies of the



Maragheh Formation.

The marker beds were named ascendingly as Mordagh tuff, Lower pumice, White fine tuff, Upper pumice, "Scoria" bed and Pumice falls (3 layers).

Mordagh tuff crops out at the cliff along the waterway for irrigation at 1.2 Km NEE of Mordagh as shown in Column 8 of Fig. 12. It is 4.1 m thick in total. The detail lithology and sampled horizons are as follows:

0.4 m reddish-purple pumiceous tuff
0.3 reddish-purple granules

0.5 reddish-purple granule breccia bearing muddy ash 73015–2
0.5 yellow volcanic medium sands
0.2 fall pumices
1.0 bedded greenish tuff with intercalation of coarse sand layer
0.5 greenish tuff with abundant pumices of 5 mm dia. pumices at the top are 1 cm dia.
0.3 volcanic gravels of granule size
0.4 green tuff 73010, 73015–1

Lower pumice bed crops out at the slope from Dareh-e Gorg to Kerjaveh. At the southwest of Kerjaveh, it is 2.3 m thick.

1.5 m red-brown muds with rounded pumices, 10 cm in max. dia.; two kinds of pumice: light purple, ill-bubbled pumices with 0.5 mm long hornblende and white, fibrously bubbled pumices with 1 mm long hornblende and 0.5 mm biotite
0.3 volcanic sands and small pumices
0.3 pumices, 3 cm in max. dia., matrix a little ash
0.1 pumice sands and ash, thin alternated
0.05 light pink ash
0.07 coarse ash with pumices

White fine tuff consisting of fine glass lies immediately below the fossil bed at Site II, and III and IV in Dareh-e Gorg, and 67 cm thick at Site II. This tuff shows reddish-gray color (10R 5/1 in Munsell's soil color names) at the time of excavation, but becomes white in color in dry and weatherd condition.

Upper pumice bed is 2.5 m thick at the top of eastern Dareh-e Gorg, Loc. 7. A variety of pumices are contained as follow:

a) light-reddish purple, somewhat ill-bubbled, 3 mm feldspar is conspicuous, with biotite and hornblende
b) pinkish, ill-bubbled, 1–2 mm quartz and feldspar, with biotite and hornblende
c) light-purple, ill-bubbled, 0.5 mm hornblende, a less amount of phenocryst
d) white, ill-bubbled, partly fibrous, 0.2 mm hornblende, a little amount of phenocryst

2.0 m alternations of volcanic sand and pumiceous sand
0.6 rounded pumice gravels of pebble and cobble size
0.2 volcanic sands
0.1 pumice bed
0.2 volcanic sands
0.6 rounded pumice gravels of pebble and cobble size
0.6 alternations of pumiceous sand and sand

0.5	volcanic sands with lens of pumice pebble
0.6	pebble and cobble pumice gravels
0.1	ash
0.5	red sandy muds

Scoria bed lying on pumice flow deposits is 0.5–2 m thick and hard, and projecting like eaves.

Loc. 1, east of Sargizeh

0.5 m	hard subangular andesite granules, 0.5–1 cm dia.
0.4	red-brown pumiceous muds
0.2	dark-gray volcanic sand
2.2	red-brown pumice flow

Loc. 2, western southwest of Momeneh

0.8 m	hard laminated sands
1.0	laminated coarse sands and granule breccias with pumices pebble and round-subangular gravels
0.3	reddish-brown sandy muds with pumices
2.0	subround andesite pebble-bearing pumice flow

Loc, 3. west of Kerjaveh

1.2 m	angular—subangular granules with 20 cm dia. andesite gravels
0.4	3–4 cm dia. pumice
0.25	volcanic sands with breccias
2 m	pumice flow

Pumice fall bed consists of 2 or 3 falls of small pumices, showing graded bedding. The top of this bed is reverse by graded and shows convolute structure.

Loc. 2, western southwest of Momeneh

0.02 m	coarse (2–3 mm dia.) fall pumices, reverse by graded
0.02	graded fine (medium sandy) fall pumices
0.05	graded coarse (3–5 mm dia.) fall pumices
0.15	graded fall pumices

Loc. 1, east of Sargizeh

0.15 m	fine laminated (medium sandy) pumices
0.03	fine ash
0.07	yellow fall pumices
0.03	fine ash
0.06	fall pumices
0.02	fine ash
0.1	fall pumices

Owing to the fault run at the southside of Mordagh, the Mordagh tuff is not exposed there. Therefore, in the area extending from Mordagh to the south it was impossible to obtain precise data in this survey.

The uppermost part of the sediments in the areas of Mordagh and Kerjaveh

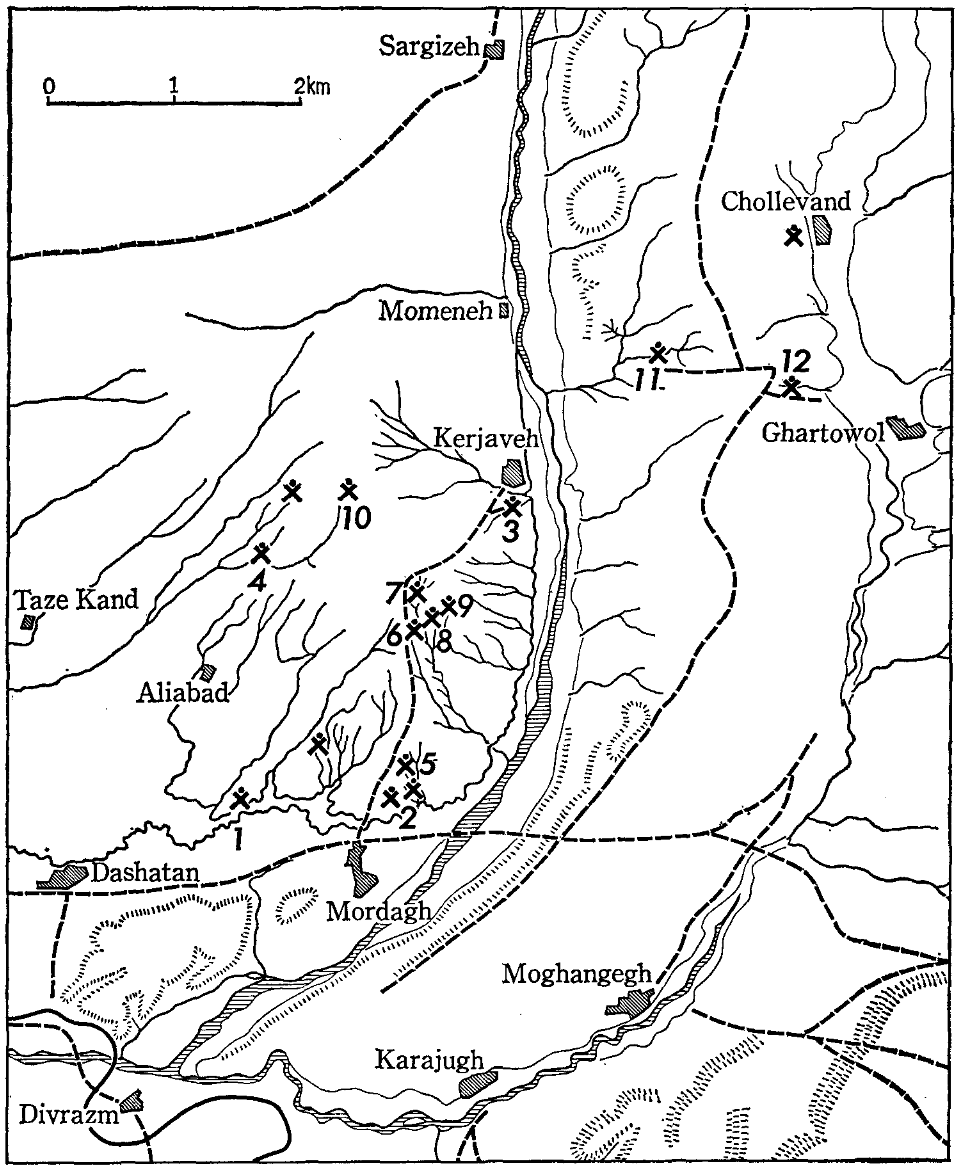
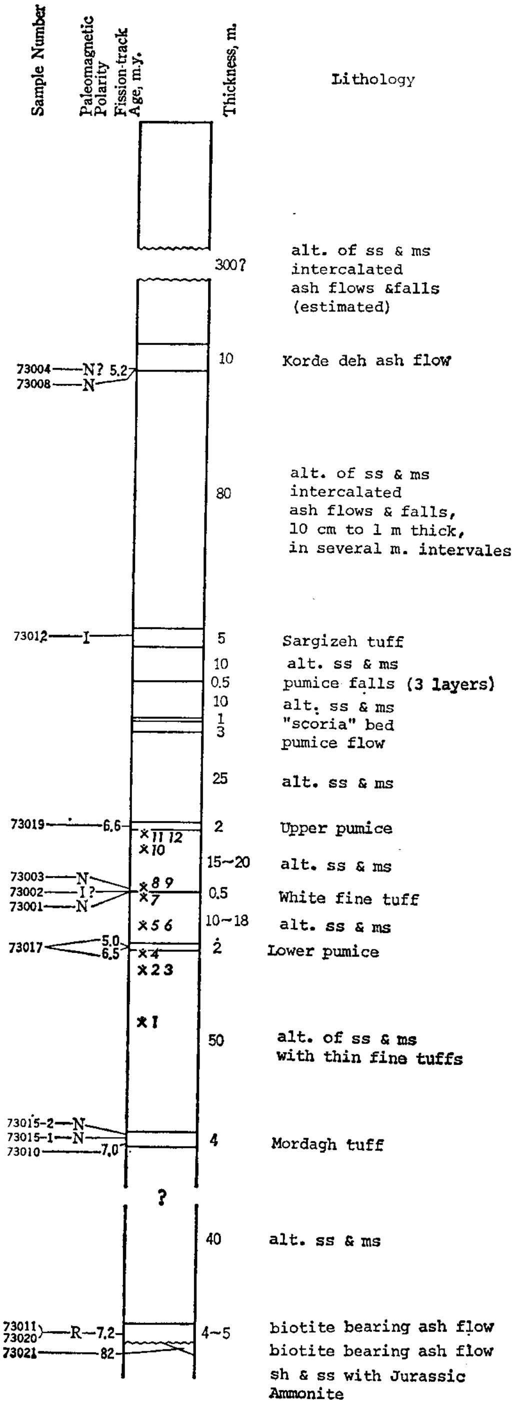


Fig. 13. Fossil Localities Observed in this Survey



Explanation of Fossil Localities

1. Northwest of Mordagh, 20 m lower than Lower pumice
2. North of Mordagh, 5 m lower than Lower pumice
3. South of Kerjaveh, 5 m lower than Lower pumice
4. Northeast of Aliabad, below Lower pumice
5. North of Mordagh, 5 m upper than Lower pumice
6. Dareh-e Gorg (Site I), 5 m upper than Lower pumice
7. North part of Dareh-e Gorg, 1.5 m lower than White fine tuff
8. Dareh-e Gorg (Site II, III, IV), 0–2 m upper than White fine tuff
9. Northeast part of Dareh-e Gorg 0–2 m upper than White fine
10. Northeast of Aliabad, 5 m lower than Upper pumice
11. Northeast of Kerjaveh, below Upper pumice
12. Northwest of Ghartowol, below Upper pumice

N: Normal Polarity
R: Reversed Polarity
I: Intermediate Polarity
(Paleomagnetic polarity of 73010 is N.)

Fig. 14. Compiled Geologic Column with List and Stratigraphical Horizons of Fossil Localities, Palaeomagnetic Polarity and Fission-track Age of Pyroclastics

submerges towards north in the area between Sargizeh and Agajari. To the north from Agajari, the upper part of the Maragheh Formation is accessible to observe. As to the upper part of this formation, the geological relation was ascertained in the region from Sargizeh to Korde-deh, the northernmost village of this area. The upper part of the Maragheh Formation in this area consists mainly of alternations of tuffaceous sandstone and mudstone with intercalations of tuff and ash flow which are superimposed in every 5 to 10 m intervals. The most of tuff and ash flow beds have a thickness of less than 1 m. At Korde-deh, a remarkable non-welding ash flow bed, called as the Korde-deh ash flow, is observed at about 40 m higher above the river bed. The sediments, ranging from the Pumice falls of lower distinc tmarker bed below to this upper ash flow, is estimated to be about 90 m thick. Furthermore, the thickness of the upper part above the Korde-deh ash flow is estimated as approximately 300 m as thick. Accordingly, the total amount of thickness of the Maragheh Formation is assumed to be within a range from 500 to 600 m (Fig. 14).

In the lower part of Maragheh Formation, eight horizons of fossil bones can be discriminated based upon some characteristic interventions of pyroclastics.

Throughout the areas researched, the Maragheh Formation is horizontal in general except for some local disturbance. Such local distortion of the geological structure is probably due to tectonic warping depending upon the basement structure. Furthermore, it is recongnized that the area is thrown down by south side down fault, and those are situated in the fault zone in NW-SE direction which runs through the northern part of Mordagh.

The Maragheh Formation is composed mainly of alternation of tuffaceous sandstone and mudstone with intercalations of volcanic ejecta such as ash flow, ash fall, pumice flow and so on. Though those sediments have some intercalations of gravels, no conspicuous conglomerate exists so far as we observed. From the observation given to those sediments, it may be possible to assume that the sedimentary environment had been predominated by fluviatile condition. On the other hand, however, the many insertion of red clay within the deposits suggests that the land had occasionally emerged from subaquatic conditions. Moreover, well preserved continuity of graded or reversely graded pumice fall and tuff may suggest the presence of widespread lacustrine environment throughout this area. From the consideration stated above, it is probable to deduce that there was the repetition of fluviatile, steppe and lacustrine environments. During that time, the northern volcanoes of Mt. Sahand had provided intermitently ash and pumice flows, ranging from acid to intermediate type.

Palaeomagnetism of Pyroclastic Sediments

Recent geomagnetic data (1965) obtained at near Maragheh area, about 37°

20′N in lattitude and 46°20′E in longitude, are about 4°E in declination, about 55.5° in inclination and about 0.39 gauss in vertical component.

Directions of natural remanent magnetization (NRM) of some pyroclastics were measured by means of an astatic magnetometer. Sample, No. 73011 was taken from the coarse biotite tuff, the lowermost Maragheh Formation lying unconformably on the Jurassic shales at locality 15, south of Chekan. The NRM polarity of this sample is reversed, though only one specimen is available (Fig. 15).

NRMs of nine specimens from sample No. 73010, the basal part of Mordagh tuff at locality 8 are measured before and after magnetic cleaning with a peak field

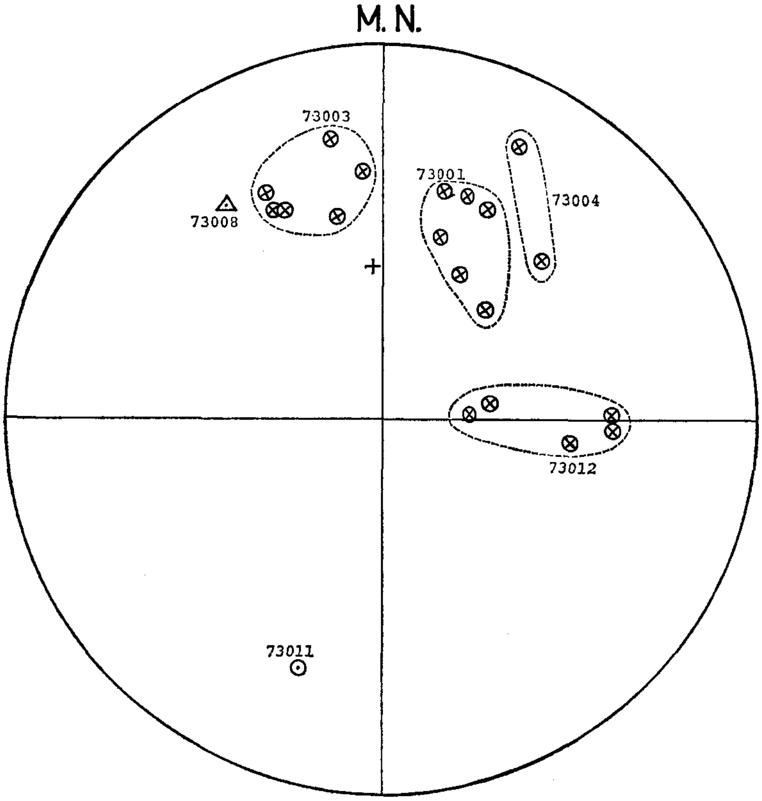


Fig. 15. Directions of NRMs, Schmidt's equal area projection

73001, 003 (N): White fine tuff after magnetic cleaning in a peak field of 200 Oe

73004, 008 (N): Korde-deh ash flow

73011 (R): basal biotite bearing ash flow ⎤ not magnetically cleaned

73012 (I): Sagizeh tuff ⎦

73011 is shown in upper hemisphere

+: Direction of the present axial dipole field in this area of 80 Oe. As shown in Fig. 16, NRMs do not exhibit well grouping after a.f. demagnetization of 80 Oe. However, the polarity of this sample is certainly supposed to be normal. No. 73015-1 was collected from the same part with No. 73010. No. 73015-2 was from the upper part of Mordagh tuff at the same locality. Their NRM directions are pointing within the variation range of No. 73010.

Sample No. 73001 taken from White fine tuff, II-A bed, was measured by 6 specimens, and after magnetic cleaning of 80 Oe it showed normal polarity having the mean values, declination of N24°E and inclination of 45°. The top of this tuff, No. 73002 showing disturbed deposition indicates extraordinary directions (Fig. 16). No. 73003 from II-C bed, of which lower part of mudstone bearing fossil bones, shows declination of N18°W and inclination of 36° after a.f. demagneti-

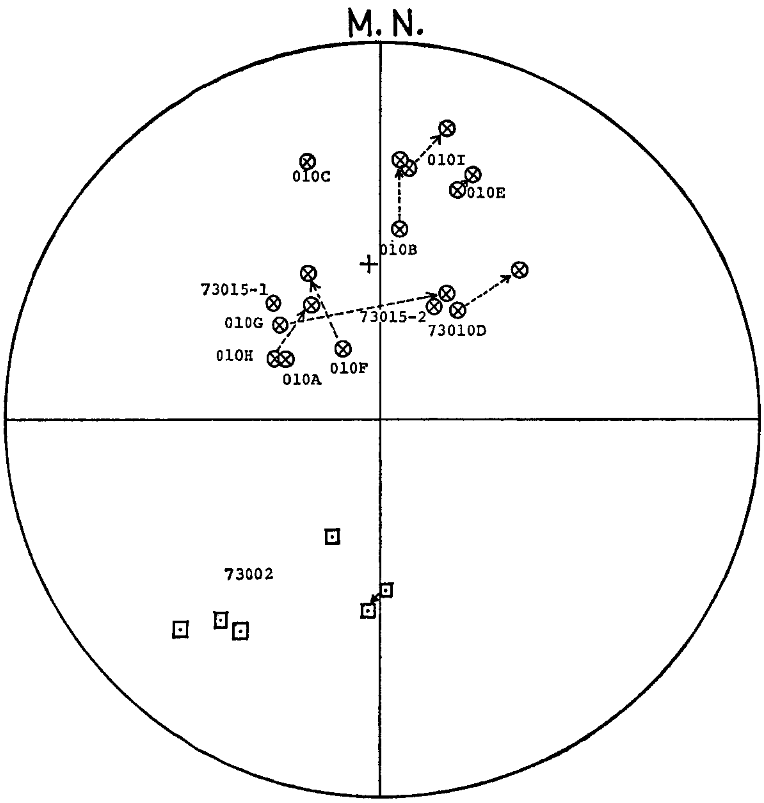


Fig. 16. Directions of NRMs

73002 (I?): White fine tuff; only one specimen after magnetic cleaning in a peak field of 100 Oe (lower hemisphere)

73010 (N): Mordagh tuff after magnetic cleaning in a peak field of 80 Oe

73015 (N): Mordagh tuff

zation of 80 Oe (Fig. 15).

No. 73012, the basal part of Sergizeh ash flow, 8 m higher than Pumice fall, shows intermediate polarity, 90°E in declination and 55° in inclination. Three specimens from the lowest part of Korde-deh ash flow, No. 73004 and 008 all show normal polarity, although their declination are quite different (Fig. 15).

Thus, the NRMs of the pyroclastics intercalated in Maragheh Formation show almost normal polarity excepting the basal one. This is not consistent with the postulation for the stratigraphic position of the Maragheh fauna, as BERGGREN and Van COUVERING (1974) considered in palaeomagnetic stratigraphy as comparative longer reversed polarity event c of Epoch 7.

Fission-track Age of Pyroclastics and Chronology of Maragheh Formation

Seven fission-track ages of zircons in pyroclastics were obtained.

Zircon, because of its high uranium impurity content, its fragmental occurrence in common clastic rocks and of its high temperature stability, is suitable for the application of fission-track dating. Zircon crystals were separated from samples using the standard separating procedure with heavy solutions and isodynamic separator. For obtaining the best etching of fission-tracks in zircon it requires 2 hours in 1:1 concH_2SO_4 and 55% HF at 180°C using tefron capusule in stainless steel container which is similar to what was designed by NISHIMURA (1975).

For the reactor run, a small amount of zircon was packed in a plastic container and irradiated in a reactor of Kyoto University of which neutron flux was also calibrated by the fission-track method (HASHIMOTO et al., 1969).

Fission-track age, T yr, can be represented by the following equation (FLEISCHER and PRICE, 1964);

$$T = \frac{1}{\lambda} \ln \left[1 + \frac{\lambda}{\lambda_f} \frac{\rho_s}{\rho_i} \frac{\phi\sigma}{\eta} \right]$$

where ρ_s is the fossil fission-track density (cm^{-2}), ρ_i the induced track density by bombardment with the thermal neutrons (cm^{-2}), the total decay constant for uranium (yr^{-1}), λ_f the fission decay constant for ^{238}U (we used 6.85×10^{-17} yr^{-1}, Nishimura, 1975), σ the thermal neutron cross section for fission ^{235}U (cm^2), ϕ the thermal neutron dose (cm^{-2}), and η the isotope ratio $^{235}U/^{238}U$ respectively. If T were smaller than 10^9 yr, the equation can be written

$$T = 6.12 \times 10^{-8} \phi \frac{\rho_s}{\rho_i} .$$

Ages of zircons obtained from pyroclastics are given in Table 1. The precision of the dates was usually under 10%, being calculated from the sum of errors determined on the number of spontaneous and induced tracks counted in the volcanic crystals and the number of tracks counted in the standard.

Errors in the uranium determination of the standard, in the decay constant and in ununiform distribution of uranium in crystals were not included. It is estimated

Table 1. Fission-track ages of zircons of pyroclastics in Maragheh Formation

Sample No.	Spontaneous fission-track density ρ_s (cm^{-2})	Induced fission-track density ρ_i (cm^{-2})	Thermal neutron dose ϕ (cm^{-2})	Fission-track age T (my)
73021	6.3×10^6	5.2×10^6	1.10×10^{15}	82
73020	9.3×10^5	8.3×10^6	1.05×10^{15}	7.2
73017	7.2×10^5	9.2×10^6	1.05×10^{15}	5.0
73017	9.1×10^5	4.6×10^6	0.54×10^{15}	6.5
73019	1.1×10^6	5.5×10^6	0.54×10^{15}	6.6
73004	6.6×10^5	4.2×10^6	0.54×10^{15}	5.2
73010	1.1×10^6	5.2×10^6	0.54×10^{15}	7.0

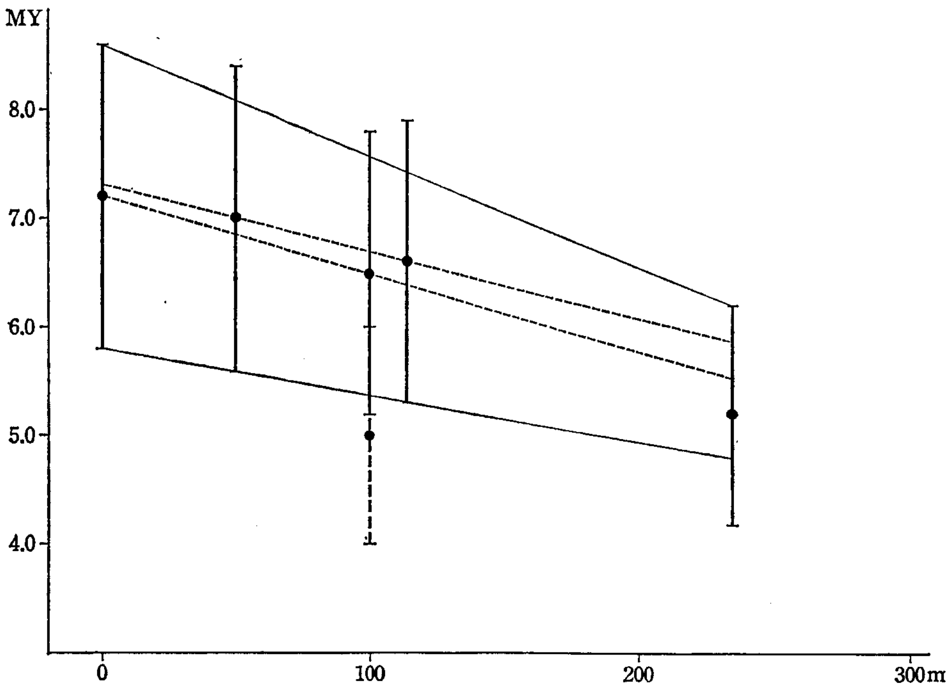


Fig. 17. Fission-track ages and thickness of beds between specimens and base of Maragheh Formation

at about 5–10%.

On the other hand, when we get the fission-track age of each crystal in one sample, the standard deviation is about 15%.

Then, accuracy of these dates is under 20%. In Fig. 17, the range of $\pm 20\%$ to each value is shown.

Age Estimation of Maragheh Fauna

A full succession of the Maragheh Formation is composed mostly of the product of fluviatile deposition. Therefore, it seems that there are some difficulties in the discussion of age estimation when we wish to combine fission-track age determination and paleomagnetic polarities of those deposits. In fact, the relation between the fission-track ages and the stratigraphic horizons are examined basing on the results of the measurement for the basal part of this Formation (Fig. 14).

At the road cut, west of Divrazum, biotite-bearing dacite ash flow of the basement is exposed. The result of fission-track age of that rock (Sample No. 73021) is 82.0 my and suggests the surface erosion of continental environment in the Late Cretaceous. The basal biotite tuff of Maragheh Formation (No. 73011) indicates reversed polarity, and the same rock (No. 73020) is 7.2 my in fission-track age. Successively, tephra layers intercalated in the Maragheh Formation have following fission-track ages; the basal part of the Mordagh tuff (No. 73010) is 7.0 my; pumice gravel from the Lower pumice bed (No. 73017) reveals 5.0 and 6.5 my; pumice gravel from the Upper pumice bed (No. 73019) is 6.6 my; the lowest part of Korde-deh ash flow is 5.2 my. Because of an internal inconsistency we may discard a value of 5.0 my for the Lower pumice.

Referring to the Late Neogene paleomagneto-stratigraphy reported by BERGGREN and Van COUVERING (1974), the present paleomagnetic data and fission-track ages of the Maragheh Formation are very effective in making strict correlation of Neogene stratigraphy. The basal ash flow (7.2 my, reversed polarity) is correlatable with Epoch 7-b of BERGGREN and Van COUVERING. The Mordagh tuff (7.0 my, normal polarity) may be correlated to the normal interval between a and b of Epoch 7. The fission-track age and the polarity of the Korde-deh ash flow, 5.2 my, normal polarity, is inconsistent to the estimation of BERGGREN and Van COUVERING in paleomagneto-stratigraphy. On the other hand, the horizon of Maragheh fauna in our excavation is represented by the White tuff and it is measured as older than 6.6 my or younger than 6.5 my, normal polarity. Therefore, it may be reasonable to take such assumption into consideration for the age estimation of the Maragheh fauna basing upon the fission-track age, the geomagnetic polarity and the thickness values of the sediments between the marker beds. On the consistency concerning the thickness and fission-track age, it seems to be reasonable to adopt the values of 7.2, 7.0 and 6.6 my for the basal ash flow, the Mordagh tuff and the Upper pumice. In this way, it may be possible to designate the stratigraphical position of the Lower pumice to 6.8 my of the upper part of Epoch 7, and the Korde-deh ash flow to 5.8 my of the lower part of Epoch 5. As the result, those considerations will lead a conclusion that the White tuff of the normal polarity is corrrelatable to the top of Epoch 7, and then, about 6.7 my. Accordingly, it seems to be reasonable to estimate that the ages of the 12 localities of Maragheh fauna range from 6.6 to 6.9 my.

BERGGREN and Van COUVERING (1974) considered that the Maragheh fauna was contemporaneous with Hipparion fauna of Morocco, Melka el Ouidane (Camp-Berteaux). As the K-A age of Melka el Ouidane is reported as 7.4 my (CHOUBERT

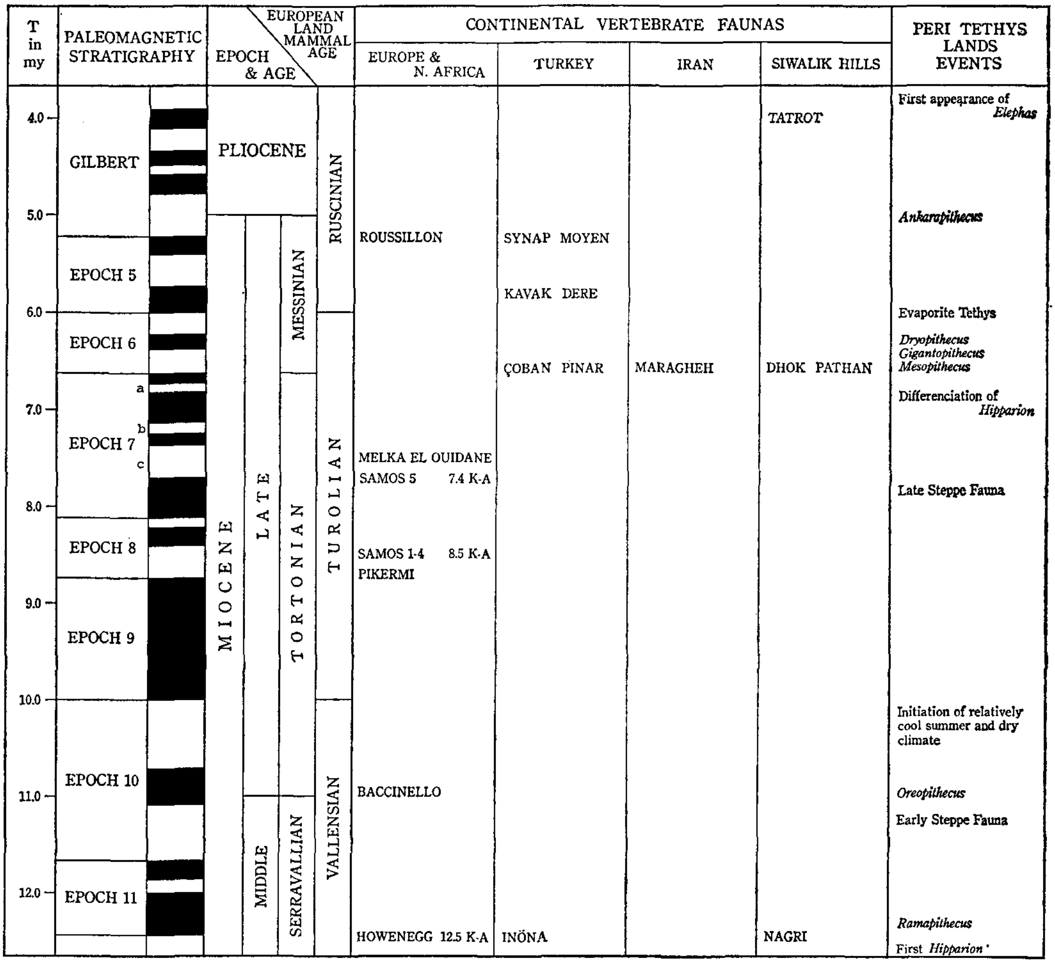


Fig. 18. Correlation chart of the Maragheh fauna and its equivalents

et al, 1968), BERGGREN and Van COUVERING assigned the stratigraphical position of Maragheh fauna to the c of Epoch 7.

Recently, ERDBRINK et al. (1976) published a report, "The bone bearing beds near Maragheh in N.W. Iran". In the article, they stated precisely geology, stratigraphy, K-A dating and paleomagnetic survey in the Maragheh area. Their investigation is very profitable for us to make the present report. However, it should be mentioned that the results of our survey leads to another conclusion as to the time range of the bone bearing beds and the age of the Maragheh fauna.

According to ERDBRINK and others, the range of the bone bearing beds near Maragheh has a duration of about 10 million years. In opposition to this, the result of our investigation suggests that the Maragheh fauna covers a longevity of about 2 million years. Moreover, being taken into consideration faunal assemblage, it seems adequate to correlate the Maragheh fauna with Late steppe fauna (7.4 my), rather than with Early steppe fauna (12.5 my).

Here is given our tentative correlation of the Maragheh fauna with other faunas in the neighbourhood and with BERGGREN and Van COUVERING's paleomagnetostratigraphy (Fig. 18). Anyhow, it is not to say that the synthetic study on the Maragheh fauna has important role in the study of Cenozoic vertebrate evolution in Asia, Europe and Africa. Therefore, it is necessary to continue the study of the Maragheh Formation, more precisely and syntheticaly from the view points of geology, stratigraphy, paleontology, paleomagnetism, geochronology and so on.

Summary

The geological and paleontological survey in Maragheh area was carried out by the joint team of Kyoto University and Geological Survey of Iran, 1973. They excavated at four sites in the vicinity of Dareh-e Gorg, about 2 km north-northeast of Mordagh and about 15 km east-southeast of Maragheh. The excavation was performed by the stepped trench method. And the fossils were sampled qualitatively as well as quantitatively.

There are many pockets of fossil bone assemblage. It may be possible to assume that those fossil bones had been transported by a stream, but never been drifted for a long distance. The collected fossils contain many mammals, birds and reptiles as listed.

The fossil-bearing sediments were named as the Maragheh Formation. It is composed mainly of alternation of sandstone and mudstone with intercalations of volcanic ejecta such as ash flow, ash fall, pumice flow and so on. The deduction from the lithology reveals the repetition of fluviatile, steppe and lacustrine environments. The Maragheh Formation is estimated to be within a range from 500 to 600 m in thickness. The sediments of 130 m thick distributed in Mordagh area are

assignable to the lower part of this Formation.

NRMs of pyroclastic sediments shows almost normal polarity excepting the basal one. Seven fission-track ages of zircons in 6 pyroclastic layers were given. The fission-track ages and paleomagnetic data were compared with the paleomagnetic stratigraphy by BERGGREN and Van COUVERING (1974). It is estimated that the ages of the Maragheh fauna range from 6.6 to 6.9 my.

Acknowledgement

Thanks are due to the Ministry of Education of Japan and Geological Survey of Iran, for providing a grant in aid of this research. Grateful acknowledgement is made to Dr. N. KHADEM, the former Managing Director of the Geological Survey of Iran, and staff members of the G.S.I. especially to Mr. H. TARAZ, Dr. M. MEHRNUSH, Mr. M.H. NABAVI, Mr. F. GOLSHANI, for their helpful advices and help to the expedition. The authors are much indebted to Mr. R. ASSEF, the PRESENT Managing Director of the Geological Survey of Iran for his kind permission to publish the report. Thanks are also due to Mr. N. SHIGEHARA of Dokkyo Medical College for his cooperation, and also to late Mr. S. OMACHI, Mr. A. YOSHIKAWA, Mr. F. OKITSU of Iranian Petroleum Company at Teheran for their friendly guidance and hospitality.

References

BERGGREN, W.A. and J.A. Van COUVERING 1974: The late Neogene—Biostratigraphy, geochronology and paleoclimatology of the last 15 million years in marine and continental sequences. *Palaeogeography, Palaeoclimatology, Palaeoecology* **16**, 1/2, 1–216.

CHOUBERT, G., R. CHARLOT, A. FAURE-MURET, L. HOTTINGER, J. MARCAIS, D. TISSERANT and P. VIDAL 1968: Note préliminaire sur le volcanism e messinien—"pontien" au Maroc. *C.R. Acad. Sci. Paris, Sér. D*, **266**, 197–199.

ERDBRINK, D.P.B, H.N.A. PRIEM, E.H. HEBEDA, C.C.P. DANKERS and S.A.P.L. CLOETINGH 1976: The bone bearing beds near Maragheh in N. W. IRAN I. *Koninkl. Nederl. Akad. van Wetenschappen-Amsterdam Ser. B*, **79** (2), 85–101.

———, ———, ———, ——— and ——— 1976: The bone bearing beds near Maragheh in N. W. IRAN II. *ibid* 102–113.

FLEISCHER, R.L. and P.B. PRICE 1964: Techniques for geological dating of minerals by chemical etching of fission fragment tracks. *Geochim. Cosmochim. Acta*, **28**, 1705–1714.

GREWINCK, C. 1881: Ueber fossile Säugethiere von Maragha in Persien. *Jahrg. Verhandl. k. k. Geologisch Reichsanstalt*, Nr. 15, 296.

GUNTHER, R.T. 1899: The Pliocene Mammalia of the Bone-beds of Maragha. *The Jour. of Linnean Soc. Zool.* **27** (177), 376–378.

HASHIMOTO, T., S. IWATA, S. NISHIMURA, T. NAKANISHI, and M. SAKANOUE 1969: Measurements of reactor neutron flux by fission-track method. *Paper 9th Ja. Conf. Radioisotopes*, 231–234.

KITTLE, E. 1885: Die fossile Säugethier-Fauna von Maragha in Persien. *Jahrg. Verhandl. k. k. Geologisch Reichsanstalt*, Nr. 16/17, 397–399.

——— 1887: Beiträge zur Kenntniss der fossilen Säugethiere von Maragha in Persien. I.

Carnivoren. *Annal. k. k. Naturhistorischen Hofmuseums,* **2** (4), 317–338, taf. 14–18.

LYDEKKER, R. 1886: On the Fossil Mammalia of Maragha, in North-western Persia. *Quart. Jour. Geol. Soc. London,* **42,** 173–176.

MECQUENEM, R. de 1924–1925: Contribution a l'etude des Fossiles de Maragha. *Annales de Paléontologie,* **13** (1924), 135–160, pl. 19–22; **14** (1925), 1–62, pl. 1–5.

NISHIMURA, S. 1975: On the problem of the application of fission-track dating for tephrochronology. (in Japanese) *Tsukumo Earth Science,* No. 10, 1–8, College Liber. Arts, Kyoto Univ.

OZANSOY, F. 1965: Étude des Gisements Continentaux et des Mammiféres du Cénozoique de Turquie. *Mém. de la Soc. Géol. de France, N.S.* **44** (1), Mém. 102, 1–92, pl 1–10.

POHLIG, H. 1884: Geologische Untersuchungen in Persien. *Jahrg. Verhandl. k. k. Geologisch Reichsanst.,* Nr. 14, 280–284.

——— 1886: On the Pliocene of Maragha, Persia, and its Resemblance to that of Pikermi in Greece; on Fossil Elephant Remains of Caucassia and Persia; and on the Results of a Monograph of the Fossil Elephants of Germany and Italy. *Quart. Jour. Geol. Soc. London,* **42,** 177–183.

RODLER, A. 1885: Das Knochenlager und die Fauna von Maragha. *Jahrg. Verhandle. k. k. Geologisch Reichsanst.,* Nr. 14, 333–337.

——— 1889: Ueber Urmistherium Polaki, einer neuen sivatheriiden aus dem Knochenfelde von Maragha. *Denksch. d. Math.-Natur. Classe der K. Akad. der Wiss.,* **56.**

RODLER, A. und K.A. WEITHOFER 1890: Die Wiederkauer von Maragha. *Denksch. d. Math.-Natur. Classe der K. Akad. der Wiss.,* **52.**

TAKAI, F. 1958: Vertebrate fossiles from Maragha. (in Japanese) *Oriental Culture,* No. 26, 7–11. Inst. Orient. Cult., Univ. Tokyo.

TOBIEN, H. 1967: Subdivision of Pontian Mammalian Faunas. Commitee Mediterranean Neogene stratigraphy. Proc. IV Session, Bologna 1967 *Giornale di Geologia* **(2) 35,** 1, 1–5.

——— 1968: Palaontologische Ausgrabungen nach jungtertiaren Wirbeltieren auf der Insel Chios (Griechenland) und bei Maragheh (NW-Iran). *Jahrb. d. Ver. "Freunde der Universität Mainz",* 51–58.

Explanation of Plate 7

Fig. 1. Excavation Sites of Upper Dareh-e Gorg, Site I to III from left to right (south view)
Fig. 2. Site I and III (southwest view)
Fig. 3. Scoria bed and Upper Pumice bed between Kerjaveh and Chollevand (south view)
Fig. 4. Fossil disposition in Layer b'-4 at site III (north view)
Fig. 5. Occurrence of the mandible of *Hipparion gracile* (Site I)

Explanation of Plate 8

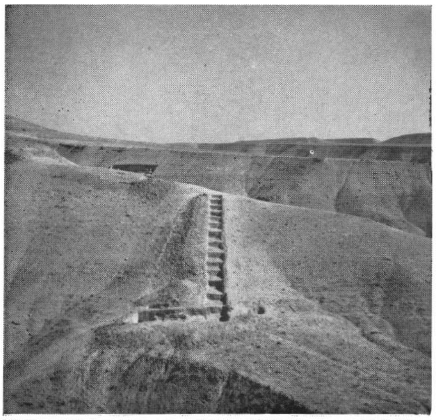
Fig. 1. *Choerolophodon penteleci* GAUDRY, left side view of the skull. (1/4)
Fig. 2. ibid, palatinal view of $^{1}M^{1}.^{2}M^{2}$ in situ. (1/2)

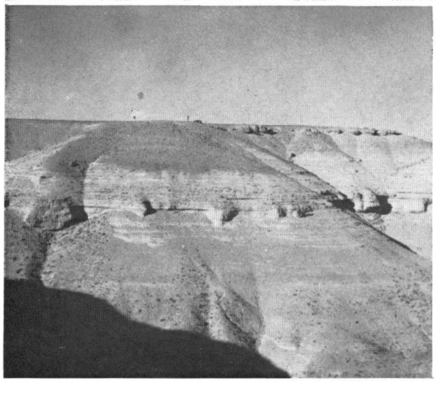
Explanation of Plate 9

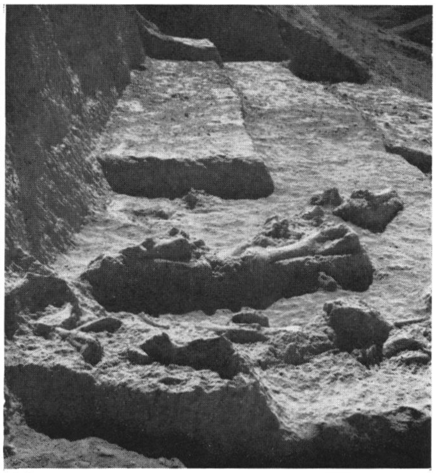
Fig. 1. *Hipparion gracile* KAUP, palatinal view with $^{4}P.^{1}M.^{2}M.^{3}M$, $M^{1}.M^{2}.M^{3}$.
Fig. 2. ibid, astragalus (upper) and metacarpus (lower).

unit of scale is 1 cm each.


1

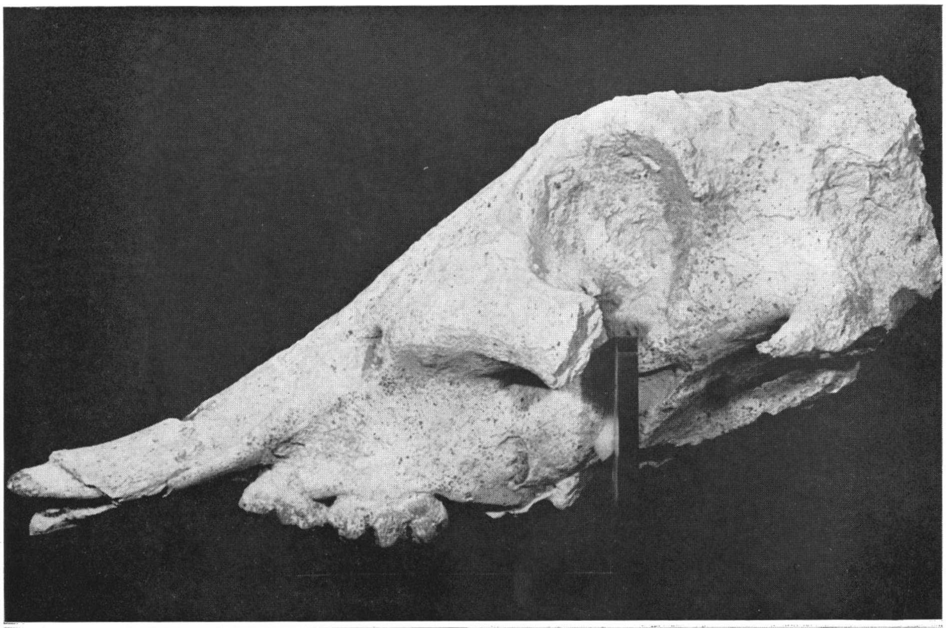

2


3


4

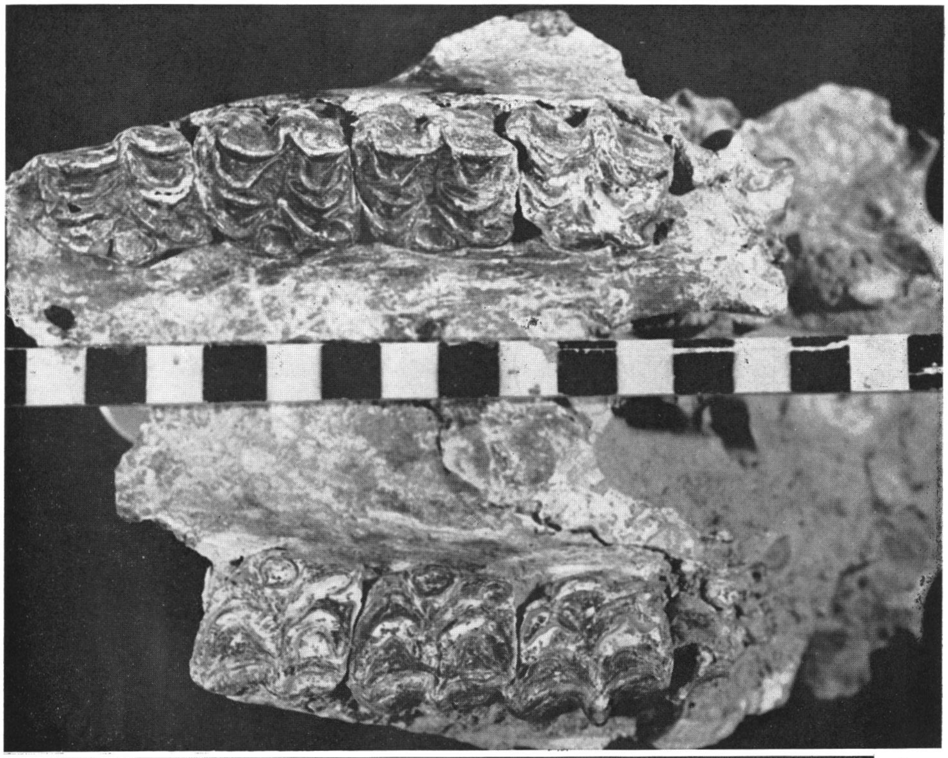

5

Mem. Fac. Sci., Kyoto Univ., Ser. Geol. & Min., Vol. XLIII, No. 1/2 Pl. 8



1

2



1

2