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# THE IMPLICATIONS OF SOME PALAEOMAGNETIC DATA FROM IRAN FOR ITS STRUCTURAL HISTORY

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## ABSTRACT

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For palaeomagnetic studies oriented samples were collected from several formations of different ages from various parts of Iran.

Palaeomagnetic data are presented from four formations with volcanic rocks from the Central Alborz. An outline of the geology of Iran is given, and particularly that of the Alborz Mountains. The palaeomagnetic results from rocks of Late Palaeozoic age –Late Devonian to Early Carboniferous and Middle Permian– indicate that Iran, probably with West Afghanistan attached, was located at the edge of Gondwanaland not very far from Arabia's east coast. Palaeomagnetic data of Early Jurassic and Cretaceous age point to a position of Iran that practically coincides with its present location. Iran could have performed its main translation and rotation during the important tectonic phase in Middle and Late Triassic times. The Iranian block is probably bounded in the SW by the Zagros Thrust, and in the N by the Kopet Dagh-Caspian Fault.

## INTRODUCTION

Iran is situated at the crossroads of a number of very important structural units. Major tectonic zones can be observed within the territory itself and in surrounding areas. Some of these zones are still active at present; this is due partly to the recent rotation of the Arabian Shield and partly to sea-floor spreading on the Carlsberg Ridge in the Indian Ocean. Little is known about a possible shift of the Iranian landmass during the geological history; if it shifted, then it may have done so as one subcontinent with or without West Afghanistan attached, or more complicated, broken up into a number of smaller units.

TAKIN (1972) has pointed to the significance of continental drift for the unravelling of the structural history of Iran. His study mainly concerns the structural evolution in post-Triassic times.

Palaeomagnetic data of an area can throw light on its structural history. At different localities in Iran oriented samples were collected from rock formations of various ages from Late Precambrian times onwards. This paper presents the palaeomagnetic results for four rock formations of the Alborz Ranges and points to the tectonic implications.

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## OUTLINE OF THE GEOLOGY OF IRAN

In Iran platform conditions prevailed during most of the Late Precambrian and Phanerozoic. Uniform developments in facies are observed over large areas. Geosynclinal deposits are encountered in a few regions only, viz. in the Zagros Ranges, in the Makran and East Iranian Ranges, and in the Kopet Dagh (Fig. 1).

On present Iranian territory no major tectonic movements have occurred between Late Precambrian and Triassic times (STÖCKLIN, 1968). The 'Assyntian' orogeny terminated with the outpourings of acid volcanic lavas, such as the Rizu lavas in Central Iran (HUCKRIEDE ET AL., 1962). The locally metamorphosed Assyntian rocks are overlain by non-metamorphic continental and shallow-marine deposits ranging in age from Late Precambrian to Late Cambrian.

Slight epeirogenetic movements in Ordovician and Devonian times resulted in incomplete sedimentation in these periods. In East Central Iran, however, a SSW-NNE directed trough formed in Late Precambrian times and received a pile

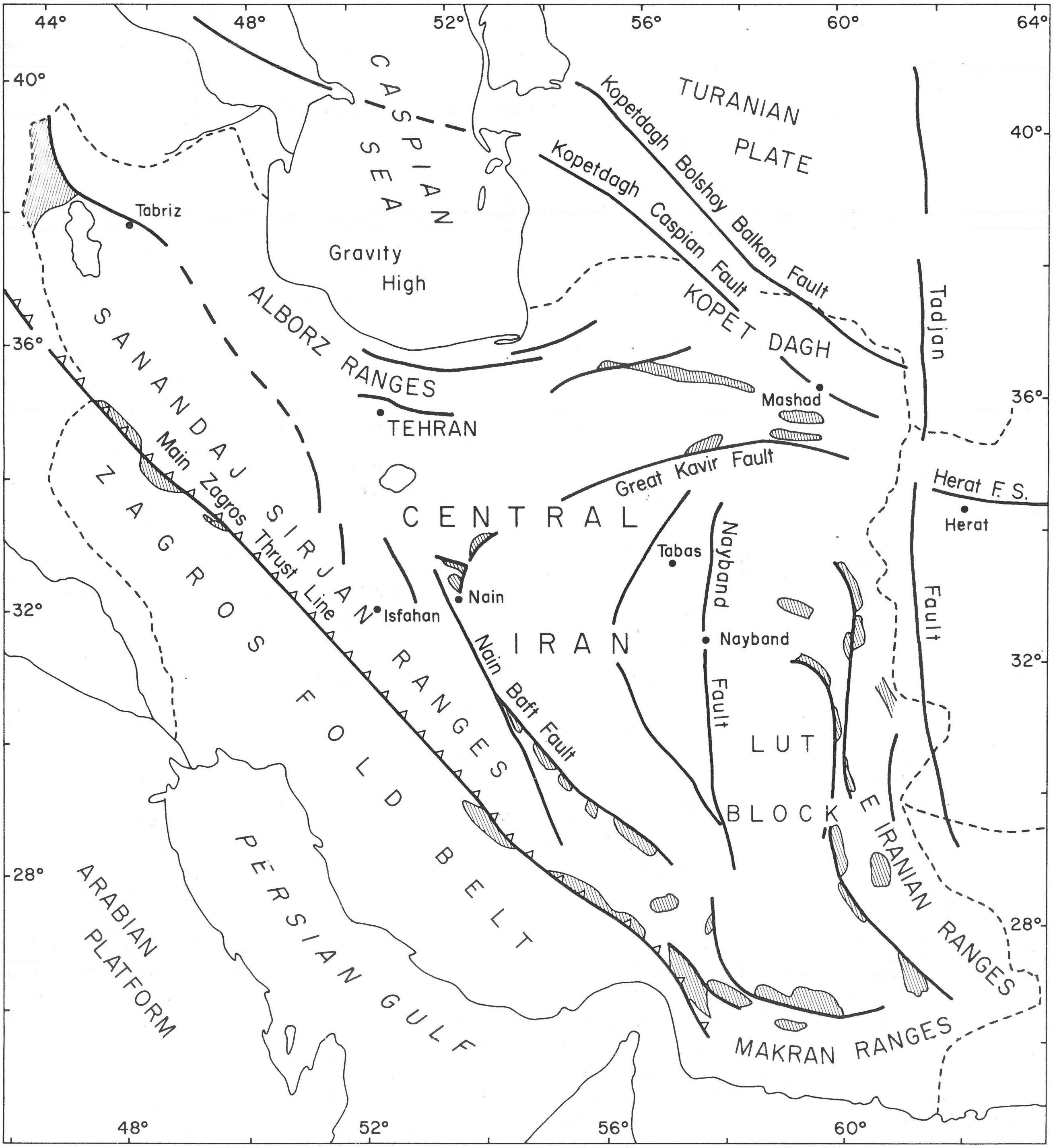


Fig. 1
Map of Iran with the main structural units and the most important dislocation lines. Hatched areas are the zones with 'Coloured Mélange'.

of sediments more than 10 km thick, at least half of which is of Ordovician and Devonian age (RUTTNER ET AL., 1968). Deposits of Carboniferous age are poorly represented. After an emergence in Late Carboniferous times, the sedimentation continued with the deposition of shallow-marine limestones and dolomites of Permian to Middle Triassic age. These sediments have a uniform facies all over the country.

Neither the Caledonian nor the Hercynian orogeny has affected the Iranian rock sequences. The tectonic activities began in Late Triassic times. In the opinion of STÖCKLIN (1968) the original Palaeozoic platform in Iran was divided into two parts according to the later NW-SE trending Main

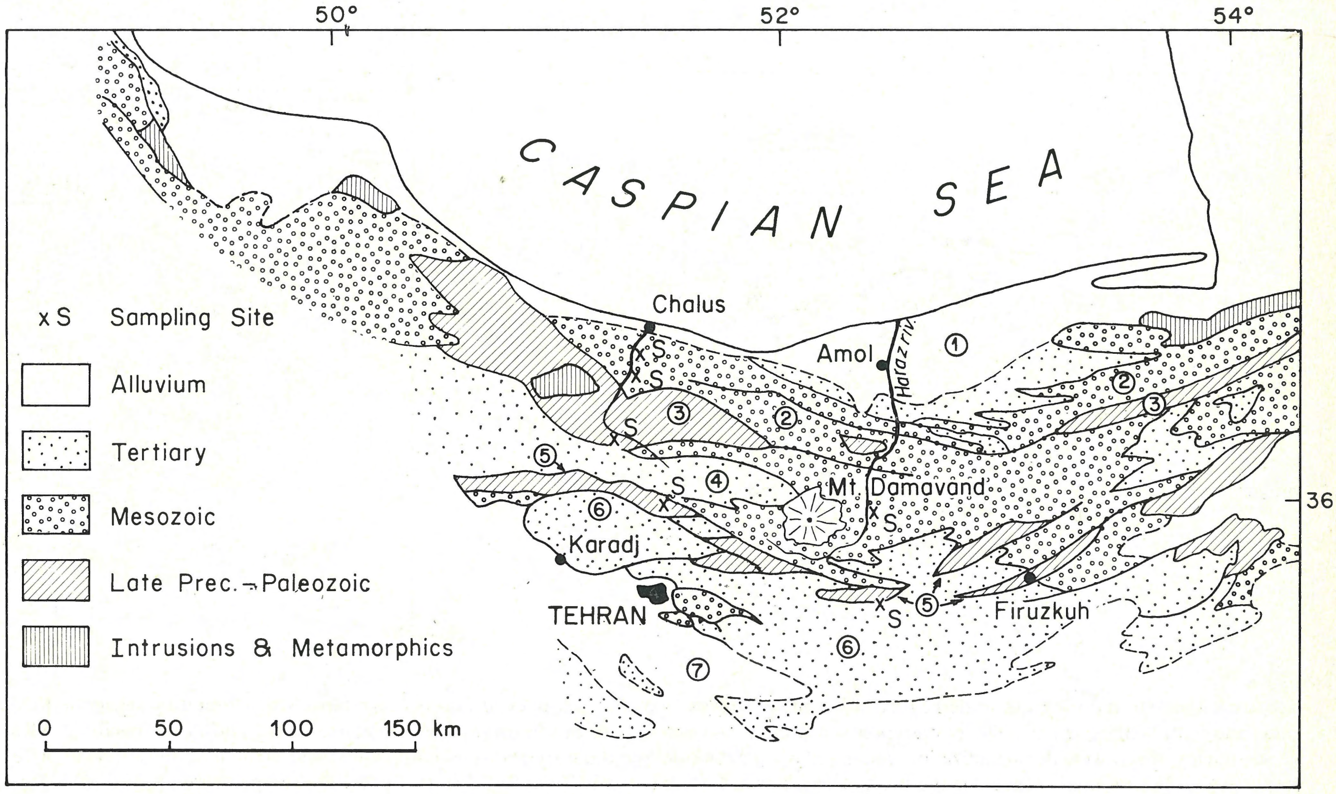


Fig. 2
Schematic geological map of the Central Alborz Mountains with the palaeomagnetic sampling sites. Numbers refer to the main stratigraphic-structural units: Caspian Plain (1); Northern Mesozoic Zone (2); Palaeozoic Central Zone (3); Tertiary Central Zone (4); Southern Palaeozoic-Mesozoic Zone (5); Southern Tertiary Zone (6); Southern Frontal Depression (7). Mainly after Gansser & Huber (1962).

Zagros Thrust Line; SW of this 'Line' the Zagros geosyncline came into existence and received marine sediments continuously until Miocene times; NE of the Zagros Line there was –apart from a few marine incursions– a continental regime that began with the deposition of clastic sediments intercalated with layers of coal of the Shemshak Formation. In the East Central Iranian Ranges the latter sediments usually cover the older sediments with sharp angular unconformities (THIELE, 1966).

Shallow-marine and continental conditions prevailed during Jurassic and Early Cretaceous times with minor volcanism. Locally, there were stronger subsidences in Early Cretaceous times both in NW and in Central Iran resulting in the deposition of up to 3000 m of shales of Barremian-Aptian age. In Late Cretaceous time very strong graben-like subsidences affected many parts of Iran. Deep narrow troughs filled up with ophiolites, radiolarites, and thick sequences of limestones – called 'Coloured Mélange' (GANSSER, 1959) – cut across the country. A 600 km long zone can be observed from Nain in Central Iran to the SE (Fig. 1). The tectonic activity in the Zagros Zone together with the production of ophiolites, resulted in a flysch-type accumulation in the Zagros geosyncline.

In many parts of Iran both subaerial and submarine volcanism occurred in Eocene times. The Early Oligocene orogeny was accompanied by widespread granitic and dioritic intrusions. Volcanic activity of continental character has continued up to the present day. The folding of the Zagros belt is of Plio-Pleistocene age; the asymmetrical folds lean to the SW. The NE boundary of the Zagros Fold Belt is formed by the steeply NE dipping Zagros Thrust. The folding in the Kopet Dagh is also very young. The Makran and East Iranian Ranges are more closely related to the Baluchistan-Indus Ranges of Pakistan than to the rest of Iran (STÖCKLIN, 1974).

## THE ALBORZ MOUNTAINS

There is a strong resemblance between the sedimentary sequence of the Alborz area and that of the rest of Iran. In the Alborz area shallow-marine and continental conditions prevailed from Late Precambrian times to the beginning of the Tertiary. During the Mesozoic the tectonic activity in the Alborz area was much less than elsewhere in Iran. There were neither major disturbances during the Late Triassic tectonic phase nor during such phases of Early and Late Cretaceous age. Some local volcanic activity coincides with the major tectonic phases outside the present mountain

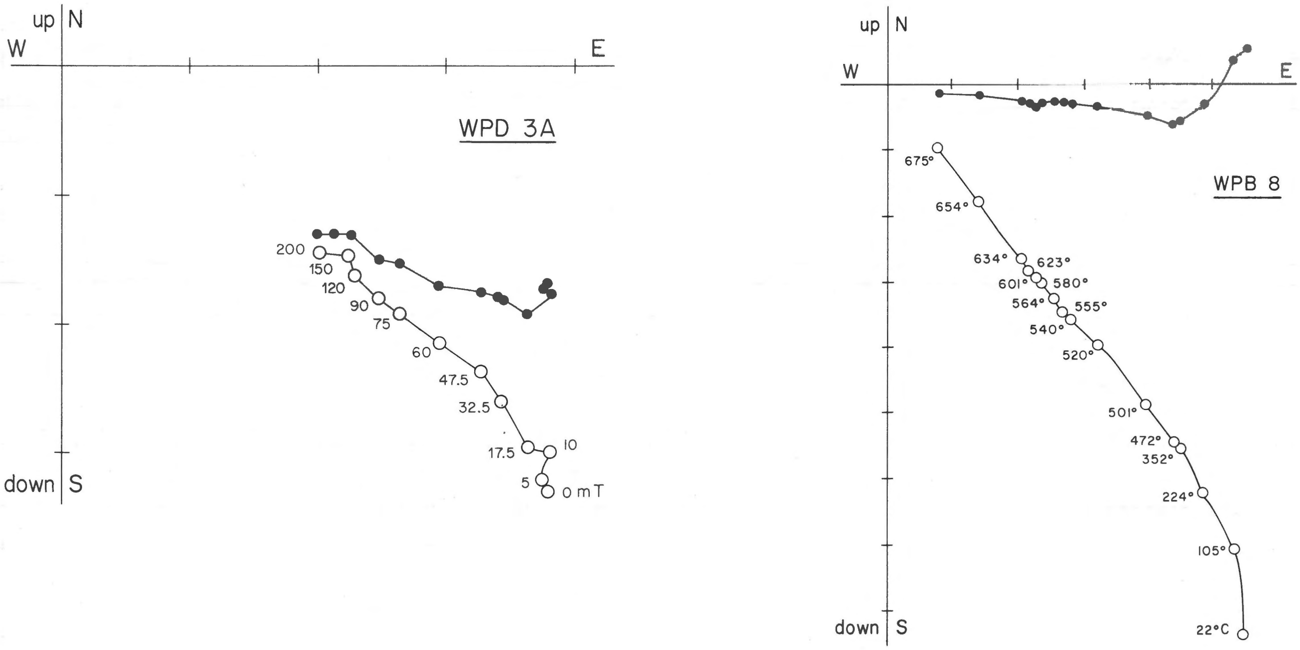


Fig. 3
Diagrams showing the progressive demagnetization of specimens from the volcanics of Permian age both with alternating magnetic fields (left) and with heating (right). The plotted points represent successive positions in orthogonal projection of the end of the resultant NRM vector during progressive demagnetization. Solid and open circles denote the projections on a horizontal and on an east-west vertical plane, respectively. The numbers represent the peak strength in mT (1 mT = 10 Oerstedt) of af (left) and the temperature applied in degrees centigrade (right). On both diagrams each unit on either axis represents 0.1 A/m.

chain. In the Alborz area geosynclinal deposits are practically missing; there are no ophiolites or radiolarites.

After the uplift of a median zone, a thick pile of volcanics was deposited to the S of it in the present Southern Alborz (GANSSER & HUBER, 1962; DEDUAL, 1967). The 4000 m thick volcanic sequence with green tuffs, agglomerates, and lava flows of the Karadj Formation has an Eocene and Early Oligocene age.

The tectonic movements of Oligocene age seem to be subordinate to those which occurred in Plio-Pleistocene times. During the Late Pliocene compressional phase the sequence was strongly folded, faulted and thrust.

The intensity of the folding increases from N to S. Although folding is important, the Alborz area is a block-faulted mountain chain. Thrusting is seen both in the S and in the N with steep southerly and steep northerly directed thrusts, respectively. The N-S sections through the central part of the chain show a crustal shortening, combined with an upheaval in the centre.

GANSSER & HUBER (1962) divided the Central Alborz Mountains into 7 stratigraphic-structural elements (Fig. 2).

## PALAEOMAGNETIC RESEARCH

### *General aspects*

The central part of the Alborz Mountains was chosen for palaeomagnetic research, because the geology of that part is well documented (ALLENBACH, 1966; ASSERETO, 1966; CARTIER, 1971; GLAUS, 1965; SIEBER, 1970; STEIGER, 1966). Oriented samples were collected from several formations. For the sampling a portable diamond drill was used provided with a coring tube of 25 mm inner diameter; in areas off the beaten track oriented hand samples were collected.

From a particular rock formation, e.g. a lava sequence, material was collected at several sites. Normally, in a lava sequence a site represents a single lava flow. At one site a number of oriented hand samples and cores was collected.

The investigations on the collected material are still in progress, but in a few collections the research is finished. Part of the palaeomagnetic data presented in this paper are preliminary.

For the analyses in the laboratory specimens of about 25 mm in diameter, and 22 mm in length were used. Use was made of standard equipment available. The specimens were measured with sensitive magnetometers to discover both the intensity and the direction of the natural remanent magnetization (NRM).

Normally, the initial NRM is composite: the primary magnetization is masked by secondary components of magnetization. Progressive demagnetization techniques can be applied in order to try to isolate the characteristic remanence (ROY & LAPOINTE, 1978).

Progressive partial demagnetization techniques were used both with alternating magnetic fields (af) and with heating.

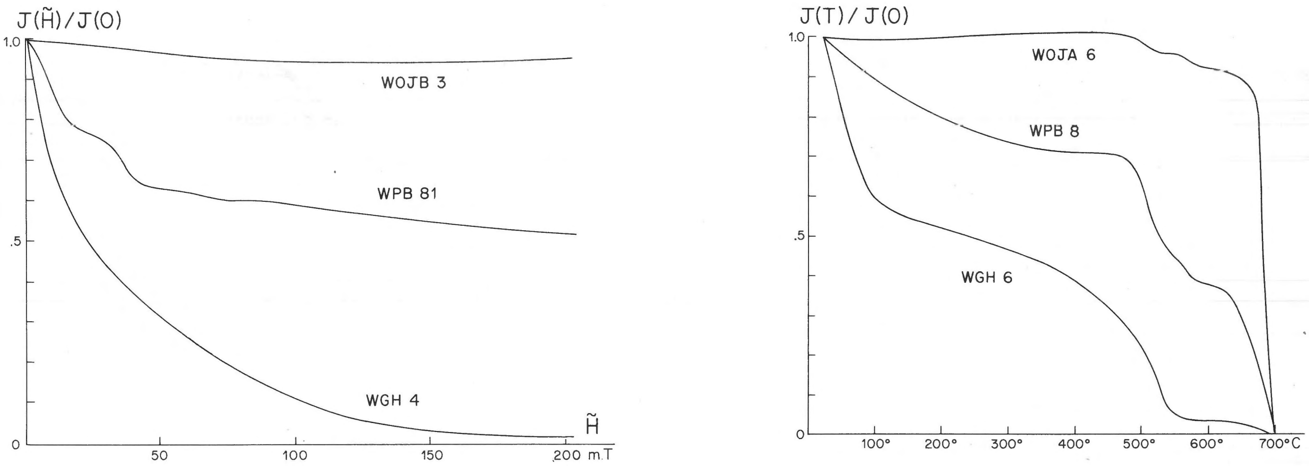


Fig. 4
Comparison of normalized alternating magnetic field (left) and thermal (right) decay curves of the natural remanent magnetization of specimens from the volcanics of Late Devonian - Early Carboniferous age (WGH 4; WGH 6); of Middle Permian age (WPB 81; WPB 8); and of Late Triassic - Early Jurassic age (WOJB 3; WOJA 6).

From each site one pilot specimen was treated with af in at least 10, but usually up to 15 successive steps, normally with a peak value of 200 mT, and occasionally up to a peak value of 300 mT. Also, a pilot specimen was progressively heated in about 15 successive steps up to a maximum of 700 °C. The remaining specimens from each site were treated with af in 4 to 10 successive steps, depending on their magnetic properties.

The progressive demagnetization procedures are best visualized by a graphical method (ZIJDERVELD, 1975) in orthogonal projection (Figs. 3, 5, 6). This method is often effective, because the individual components of magnetization normally have constant directions with only partly overlapping spectra of their (combined) remanent coercive forces. Usually, for each site the mean value of the characteristic remanence direction is calculated from the characteristic directions of magnetization of the individual specimens. From the site mean directions of a particular rock sequence an overall mean is computed.

The palaeomagnetic results obtained from four rock formations of the Central Alborz Mountains are described in succession.

### *The Geirud basalts*

In the Djadjerud valley, about 40 km NE of Tehran, samples were collected from subaerial basaltic lava flows of the Geirud Formation, located in the Southern Palaeozoic-Mesozoic Structural Zone (Fig. 2). This formation contains shallow-marine detrital and calcareous sediments (ASSERETO, 1966). The basalts are intercalated in the lowermost member of the formation, the fossils of which point to a Late Famennian to Early Tournaisian age (GAETANI, 1965).

For this study 80 cores were drilled at 11 sites. In the ultimate analysis the data from 5 sites only could be used (WENSINK ET AL., 1978). Characteristic remanent magnetization directions were obtained after applying the standard demagnetization procedures.

Polished sections reveal that the main Fe-Ti-oxydes are (titano-) magnetite, ilmenite, hematite, and leucoxene. Magnetite is the most common primary magnetic mineral. Martitisation is a common phenomenon: i.e. the oxydation of magnetite into hematite, which usually starts with the occurrence of lamellae of hematite along the octahedral planes of the magnetite crystals. This process often occurs during cooling of the lavas, shortly after deposition.

The magnetic properties of the basalt specimens are a good reflection of ore mineral content. In specimens with only magnetite, the remanence is completely lost after heating at 580 °C, and after af treatment in fields of 200 mT peak value. Specimens with magnetite and a substantial part of hematite had to be heated to nearly 700 °C before the remanence disappeared; these specimens resist af of more than 200 mT.

The decay rates of the remanence during progressive demagnetization commonly provide useful information. In figure 4 the curve of Geirud specimen WGH 4 shows a rapid decay during af treatment, which is characteristic for magnetite. The decay curve of specimen WGH 6 reveals that the initial NRM has three components; magnetite is probably the main magnetic constituent, but some hematite is present as well.

### *Middle Permian volcanics*

In the Palaeozoic Central Zone samples were collected from basaltic lavas (Fig. 2). Epicontinental deposits of Middle Permian age are found below these volcanics. The volcanic sequence is up to 200 m thick, and consists of lavas, tuffs, and agglomerates. On top of the volcanics there are fossiliferous limestones with a Middle to Upper Permian age

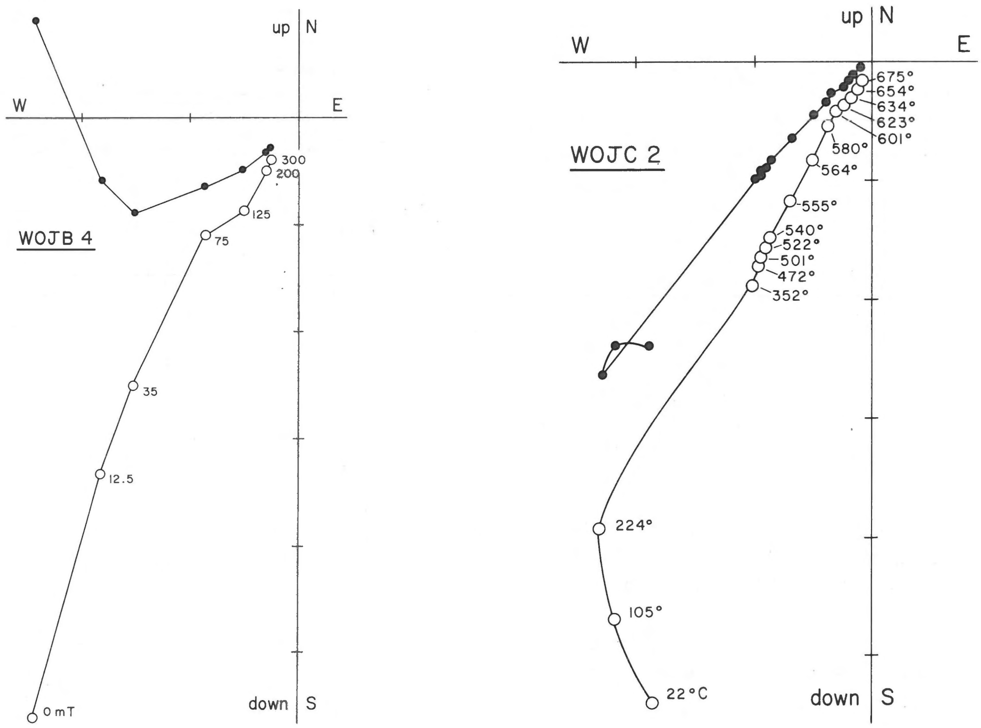


Fig. 5
Diagrams showing the progressive demagnetization of specimens of the volcanics of Late Triassic - Early Jurassic age both with af (left) and with heating (right). On both diagrams each unit on either axis represents 0.2 A/m. For further explanation see caption of figure 3.

(GLAUS, 1965).

From 6 individual sites a total of 30 hand samples and 12 cores were collected. In the ultimate analysis 71 specimens are included from 5 sites. Ore mineralogical studies will be carried out later.

With the standard progressive demagnetization techniques it was possible to isolate the characteristic remanence directions. There is good agreement between the ultimate results obtained from two pilot specimens from a particular site, the one treated with progressive heating, the other with progressive af. Progressive heating revealed that most of the specimens contain hematite, because temperatures of at least 675 °C were needed to remove the remanence intensity (Fig. 3: WPB 8). The characteristic remanence direction could be isolated with af treatment of a field between 25 and 40 mT (Fig. 3: WPD 3A).

The decay curves of figure 4 are illustrative: the diagram of specimen WPB 8 shows that the magnetic constituents will probably be both magnetite and hematite. The specimen WPB 81 strongly resists progressive af demagnetization, which is normally associated with hematite.

*Late Triassic – Early Jurassic volcanics*

In the Damavand-Firuzkuh region basic lavas occur in a narrow area stretching E-W in the Southern Palaeozoic-Mesozoic Zone (Fig. 2). Here, a continuous section of Late Precambrian to Early Tertiary sediments is exposed in subvertical to overturned positions. The base of the lavas contains fossiliferous sediments of Early to Middle Triassic age. The top of this formation is an erosion plane covered with a bed of bean ore. Subaerial olivine-bearing basalts subsequently poured out; the volcanics seldom reach a thickness of more than 100 m. Continental deposits of late Lower Jurassic to early Middle Jurassic age overlie the volcanics (ALLENBACH, 1966; STEIGER, 1966).

From the basalt lavas 42 hand samples and 7 cores were collected at 8 sites. The palaeomagnetic analysis is in progress. Preliminary results obtained from 21 specimens are reported.

Progressive af treatment is not always successful in diminishing the remanence intensity (Fig. 4: WOJB 3). In specimen WOJA 6 (Fig. 4) a final rapid decrease of the remanence intensity occurs only after heating at 670 °C. Hematite is probably the main magnetic constituent in these specimens. Demagnetization diagrams (Fig. 5) show that characteristic remanence directions can be obtained. The magnetic minerals of the specimens of figure 5, however, have much lower coercive forces, because the remanence intensities decrease rapidly during progressive demagnetization.

*Cretaceous volcanics*

In the Central Alborz Mountains the deposits of Late Jurassic and Cretaceous age show facies changes over short distances. Volcanics occur both E of Mount Damavand in the southern Palaeozoic-Mesozoic Zone, and about 80 km to the NW in the Chalus valley situated in the Northern Mesozoic Zone (Fig. 2).

E of the Quaternary volcano Mount Damavand, limestones of Middle and Late Jurassic age are found below basic volcanics. During a period of regression subaerial basalt lavas have poured out. Part of the lavas alternate with layers of gypsum of the 200 m thick Gypsum-Melaphyr Formation. *Orbitolina* limestones of Aptian age overlie the volcanics.

In the Chalus area shallow-marine sediments of Late Jurassic to Barremian age occur beneath the volcanics of the Chalus Formation. This 1200 m thick formation can be subdivided into 5 members. Members 1, 3 and 5 consist of volcanics with lavas, tuffs, and agglomerates. The fossiliferous member 2 is about 100 m thick and has a Late Barremian to Aptian age. There was a break during the deposition of the 40 m thick member 4. Early Aptian and Turonian to early Senonian ages are ascribed to the lower and upper part of this member respectively (CARTIER, 1971).

Samples were collected from the Gypsum-Melaphyr Formation and from members 1 and 5 of the Chalus Formation. A total of 103 hand samples and 30 cores were collected from 23 sites. The ultimate palaeomagnetic analysis includes 142 specimens from 20 sites (WENSINK & VAREKAMP, 1979).

The volcanics provide reliable palaeomagnetic data. The progressive demagnetization by heating of pilot specimens from 18 sites shows that normally the remanence intensity has been removed after heating at 580 °C. Examples of specimens of member 5 show a moderate to quite rapid rate of decay (Fig. 7). The characteristic remanence direction has been set free after heating at 400 °C (Fig. 6). Progressive partial demagnetization with af of pilot specimens shows that the characteristic remanence direction is isolated after application of fields between 25 to 40 mT (Fig. 6). From two specimens drilled from the same hand sample, one progressively treated with af and the other with heating, consistent palaeomagnetic results have been obtained (Fig. 6: WKW 4A, WKW 4). Because of the rapid rate of decay of the intensity of magnetization during progressive af treatment, and because of the complete removal of remanence intensity after heating at 580 °C, magnetite is probably the main carrier of remanence in the Cretaceous volcanics. The initial increase in remanence intensity during progressive demagnetization, as is illustrated with the specimens WKO 4A and WKW 4A (Fig. 7), can be explained by the decay of a secondary magnetization component that has a direction approximately opposite to that of the characteristic remanence (see also diagrams WKW 4A and WKW 4 in figure 6).

*Compilation of the palaeomagnetic data*

The mean values of the characteristic directions of magnetization together with the statistical parameters of the successive rock formations are computed from the mean values of their individual sites (Fig. 8). The results are presented in table I which also lists the palaeomagnetic pole positions.

Table I
Palaeomagnetic results from rocks of the Central Alborz Mountains, Iran.

| | rock unit with coordinates | number of sites | number of specimens | mean characteristic direction of magnetization (degrees) | | $\alpha_{95}$ (degrees) | pole position | |
|---|---|---|---|---|---|---|---|---|
| | | | | D | | I | latitude | longitude |
| IV | Late Devonian –<br>Early Carboniferous<br>volcanics<br>(36°N, 51.5°E) | 5 | 31 | 210.8 | + 66.9 | 3.9 | 0.2° S | 32.1°E |
| III | Middle Permian<br>volcanics<br>(36.5°N, 51.5°E) | 5 | 71 | 132.7 | + 27.6 | 19.4 | 22.5°S | 101.8°E |
| II | Late Triassic –<br>Early Jurassic<br>volcanics<br>(35.7°N, 52.3°E) | 5 | 21 | 43.7 | + 36.1 | 5.7 | 48.7°S | 27.4°W |
| I | Cretaceous volcanics<br>(36.3°N, 51.8°E) | 20 | 142 | 33.6 | + 47.5 | 7.2 | 60.8°S | 32.7°W |

D and I are the declination and inclination; $\alpha_{95}$ is the semi-angle of the cone of 95% confidence.

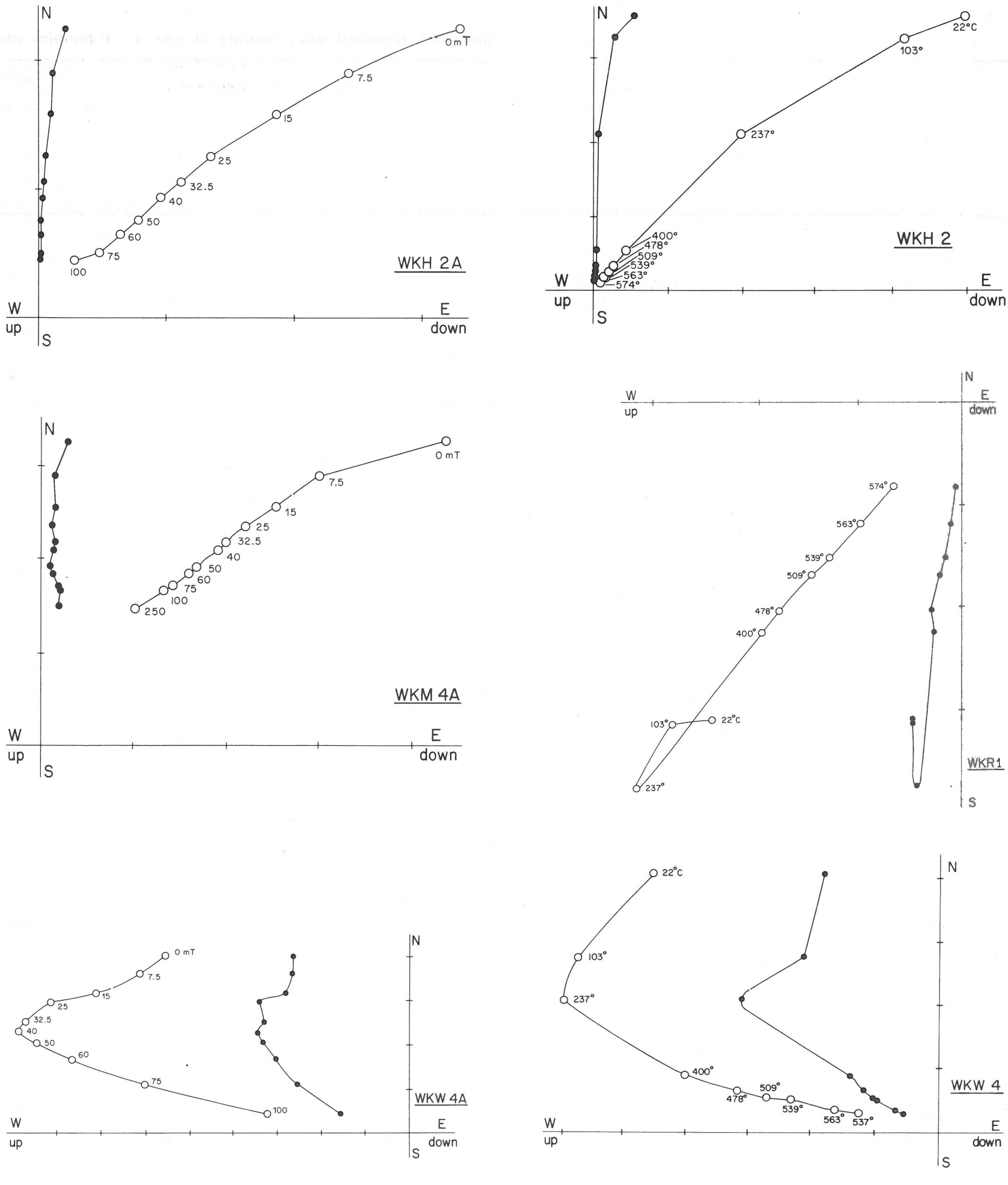


Fig. 6
Diagrams showing the progressive demagnetization of specimens from the volcanics of Cretaceous age both with af (left diagrams) and with heating (right diagrams). The upper, middle, and lower set of diagrams represent specimens of member 5 of the Chalus Fm., of member 1 of the Chalus Fm., and of the Gypsum-Melaphyr Formation, respectively. Solid and open circles denote the projections on a horizontal and on a north-south vertical plane, respectively. Each unit on either axis represents on the diagrams WKH 2A, WKH 2, WKR 1: 0.5 A/m; on WKW 4A, WKW 4: 0.1 A/m; on WKM 4A: 0.005 A/m. For further explanation see caption of figure 3.

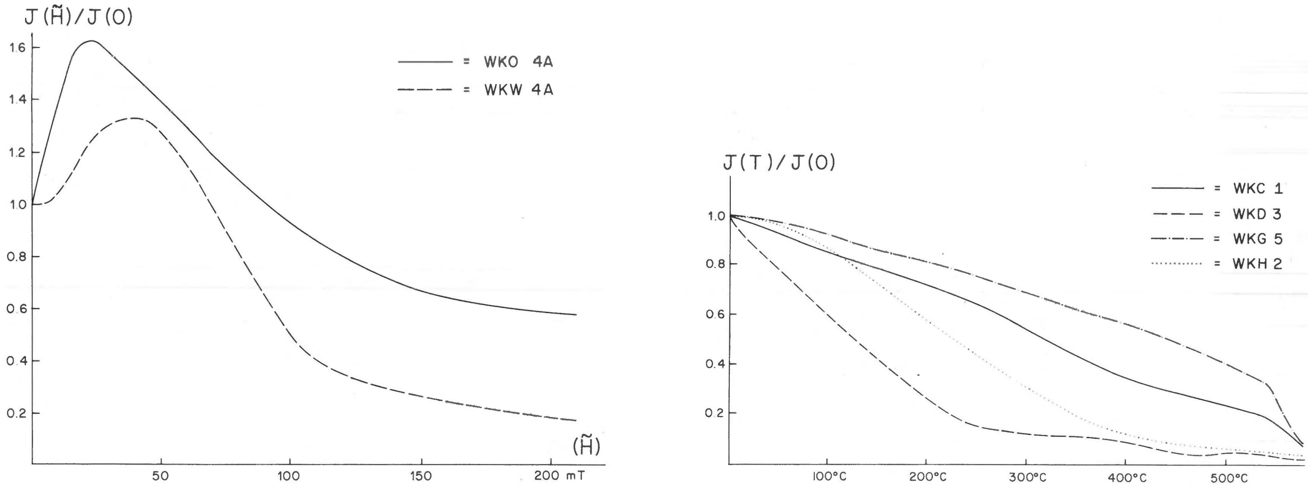


Fig. 7
Normalized alternating magnetic field (left) and thermal (right) decay curves of specimens from the volcanics of Cretaceous age.

## IMPLICATIONS FOR THE STRUCTURAL HISTORY OF IRAN

From the palaeomagnetic result derived from the Geirud basalts of Late Devonian to Early Carboniferous age it was concluded that in Palaeozoic times Iran formed part of Gondwanaland. The Geirud palaeomagnetic pole is situated in Africa near Lake Victoria (Table I). A shift of this pole towards the Early Carboniferous position on the Gondwana polar wander curve implies a migration of the Iranian landmass to a position just off the Arabian coast (WENSINK ET AL., 1978). The Geirud site location has an Early Carboniferous palaeolatitudinal position of 50° S which can be derived from the inclination of the characteristic NRM of the basalts. The African 50° southern parallel in Early Carboniferous times crossed the SE Arabian coast at about the present 15° N. Lat.

Palaeomagnetic research on iron ores, volcanics and red beds of infra-Cambrian age from Central Iran yielded a palaeomagnetic pole at 36° S, 26.5° E (BECKER ET AL., 1973). This position corresponds to the positions derived from red beds of the Salt Range in Pakistan of Early to Middle Cambrian age: Salt Pseudomorph Beds with 26.5° S, 33.5° E (WENSINK, 1972), and Purple Sandstones with 28° S, 32° E (MCELHINNY, 1970). BECKER ET AL. (1973) concluded that Central Iran was once part of Gondwanaland.

The position of the palaeomagnetic pole determined from volcanics of Middle Permian age of the Alborz area (this paper) does not coincide with the nearest pole derived from Eurasian rocks of Permian age situated at 43° N, 165° E (IRVING, 1977). During most of the Carboniferous and Permian the geomagnetic field had a reversed polarity. Therefore, the position of the nearest pole derived from the characteristic remanence direction of Iranian Middle Permian volcanics with D = 133° and I = + 28° is opposite to the Permian pole position situated in the Pacific NE of Japan, as derived from Eurasian rocks. One should compare the Iranian Middle Permian palaeomagnetic S pole at 22.5° S, 102° E with the positions of the palaeomagnetic S poles obtained from rocks of the same age from the India-Pakistan subcontinent: Early Permian Speckled Sandstones of the Salt Range in Pakistan with 13° N, 137.5° E (WENSINK, 1975); Middle Permian Wardha Valley red beds in India with 4° N, 129° E (KLOOTWIJK, 1976).

Palaeomagnetic research carried out on sediments of Permian age of Afghanistan from a locality just SW of the conjunction of the dextral Herat Fault and the sinistral Chaman-Moqur Fault reveals a palaeomagnetic pole at 8° S, 138° E (KRUMSIEK, 1976). Krumsiek concluded that a combined Afghan-Iranian plate has moved northwards rotating anticlockwise from a position at the edge of Gondwanaland.

A reconstruction of Gondwanaland (Fig. 9) is presented according to the best fit (SMITH & HALLAM, 1970), and based on the most reliable palaeomagnetic data (BRIDEN ET AL., 1974; KLOOTWIJK, 1976; IRVING, 1977). In this reconstruction Madagascar is placed off East Africa near Kenya and Tanzania in agreement with EMBLETON & VALENCIO (1977). The Indian subcontinent is positioned in accordance with its palaeomagnetic data of Middle Permian age. A better fit is obtained if India's east coast is placed alongside Antarctica. Such a reconstruction, however, has to contend with a shortage of space; to solve this problem Sri Lanka is then placed towards the S of the present south cape of India (JOHNSON ET AL., 1976). In the reconstruction of figure 9 Iran is positioned according to its Middle Permian palaeomagnetic data estimated in this paper.

The palaeomagnetic data obtained from Late Palaeozoic rocks of Iran indicate that at that time the Iranian landmass was located in the vicinity of both the NE part of the Arabian continent and the India-Pakistan subcontinent. This is not in conflict with the facies developments of the sediments. During late Precambrian and early Palaeozoic times platform conditions prevailed in these areas showing uniform deve-

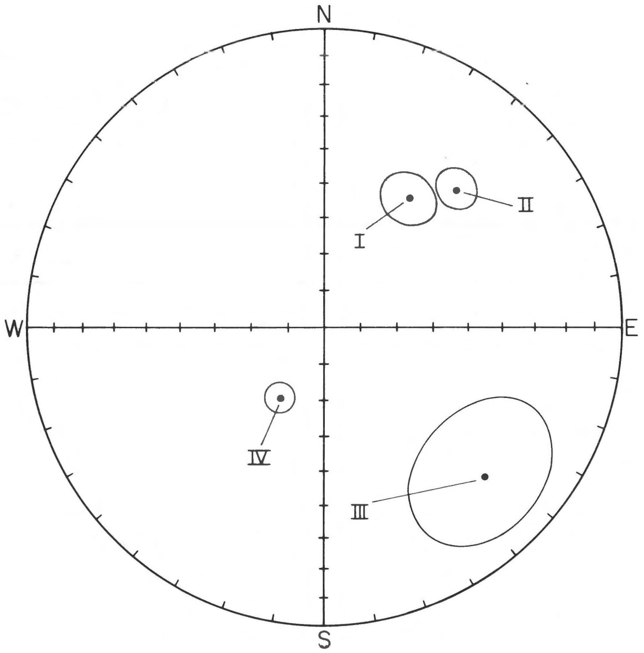


Fig. 8
Equal area projection of the mean characteristic directions of magnetization of some volcanic rock formations from the Central Alborz area with the ovals of 95% confidence. The Roman numerals IV, III, II, I, denote the directions of rocks of Late Devonian - Early Carboniferous age, Middle Permian age, Late Triassic - Early Jurassic age, and Cretaceous age, respectively.

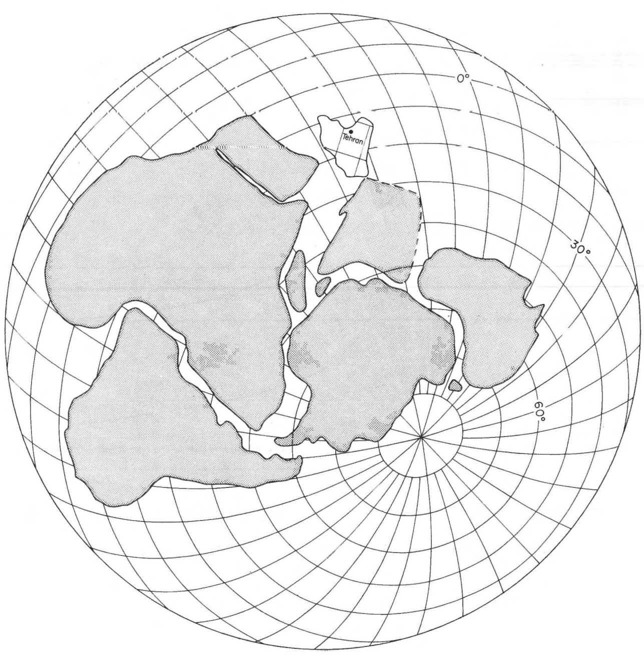


Fig. 9
A reconstruction of Gondwanaland in Middle Permian times. The position of India is based on the palaeomagnetic data of Wensink (1975) and Klootwijk (1976). The position of Iran is based on palaeomagnetic data from the Alborz Mountains, presented in this paper.

lopments. Except in Iran, the Late Palaeozoic deposits normally are incomplete. It seems reasonable to assume that the main Iranian landmass along with the Afghan block, bounded by the Herat and the Chaman-Moqur Fault System, moved as one single subcontinent. The N-S running dextral Tadjan Fault (Fig. 1), along which a possible displacement of 100 km has occurred, is very probably a post-Palaeozoic structural element (BRATASH, 1975).

From a position east or northeast of Arabia, the main drift of the Iranian block towards the N most probably occurred between post-Middle Permian and pre-Early Jurassic times. The preliminary palaeomagnetic pole of Late Triassic-Early Jurassic age obtained from volcanics of the Alborz Mountains (this paper) has a position[2] that corresponds to most of the pole positions derived from Eurasian rocks of the same age (KHRAMOV, 1977). The palaeomagnetic pole obtained from lavas of the Alborz area of Cretaceous age (this paper) has a position[2)] that surprisingly coincides with pole positions derived from rocks from S Siberia of the same age. Therefore, from the palaeomagnetic data one can conclude that the main movement of Iran occurred before Cretaceous, and possibly even before Jurassic times.

[2] In table I the position of the S pole is given.

## STRUCTURAL EVENTS DURING TRIASSIC TIMES

Tectonic events of greater consequence than any of the Palaeozoic epeirogenetic movements took place in Middle to Late Triassic times (STÖCKLIN, 1968, 1974). Iran may have shifted mainly during this tectonic phase. We have seen that Iran, connected to West Afghanistan, possibly drifted as one subcontinent: the 'Iranisch-Afghanische Platte' (KRUMSIEK, 1976). The Main Zagros Thrust Line can be considered as the SW boundary of this subcontinent. The Zagros Line was a facies divider from late Precambrian to Triassic times. After the Triassic tectonism the stratigraphic and structural development remained entirely different on either side of the line: in the SW the Zagros trough formed which was filled up with marine sediments till late Tertiary times; in the NW there was a variegated development with deposits rapidly changing in facies and thickness.

The northern boundary of the subcontinent is formed by the Kopet Dagh-Caspian Fault that runs from Mashad to the NW (Fig. 1). This line crosses the Caspian Sea to the NW near to Baku and continues on between the Greater and Lesser Caucasus. BRATASH (1975) has shown that the trough running SSW-NNE in East Central Iran, which is filled with sediments of Palaeozoic age and which can be followed from Kerman onwards, is cut off abruptly near Mashad by the Kopet Dagh-Caspian Fault; this fault dips steeply to the N.

The trough is about 800 km long and 200 km wide, and has a depth of 14 km near Mashad just S of the fault. The time of thrusting can be fairly reliably determined as Triassic, because the formations of pre-Triassic age have quite different facies developments on either side of the Kopet Dagh-Caspian Fault. The detrital sediments of the Shemshak Formation of Early Jurassic age unconformably overlie the pre-Jurassic rocks both to the N and to the S of the fault.

Troughs in Afghanistan, running approximately parallel to the Kerman-Mashad trough in E Iran, have been cut off by the Herat Fault System (Fig. 1). This fault is probably the eastward continuation of the Kopet Dagh-Caspian Fault.

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