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*Short Communication*

# Paleomagnetism of Quaternary and Miocene Lavas from North-East and Central Morocco

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## Introduction

One of the main deficiencies in our knowledge of the behaviour of the earth's ancient magnetic field concerns its magnitude and the long-term stability of its non dipole terms. It has usually been assumed that non dipole terms vanish when field directions are averaged over a sufficient long time. But during the last ten years, several authors (Wilson 1970, 1971; Watkins 1972; Creer et al. 1973) have shown that some non dipole terms seem to persist. Therefore it is necessary to accumulate a large body of paleomagnetic data, for several periods and from widely distributed regions.

We now present new results which complete an initial study made by Hamzeh and Westphal (1973) on rocks from north-eastern Morocco.

## Geological Setting

Several volcanic phases are known in Morocco; the most recent being Miocene and Quaternary (Michard 1976).

The Miocene volcanics are restricted to the north-eastern part of the Rif area. All K–Ar date determinations (Bellon 1976) give upper Miocene ages spread between 13 and 5 m.y.

In the Mellila-Nador and Ras Tarf regions, the lavas are mainly calcalkaline (andesites, K-andesites to rhyolites) and are associated with alkaline-trachytic plugs (Hernandez 1975). In addition, a granodiorite batholite of the same age has been recognized in the same area.

The Jebel Guilliz, 100 km south of the area described above, is characterized by alkaline, intermediate and acidic lavas, going from trachyandesites to trachytes.

The last phase, of early to late Quaternary age, is alkaline and basaltic to hawaiitic. It can be found in the above regions

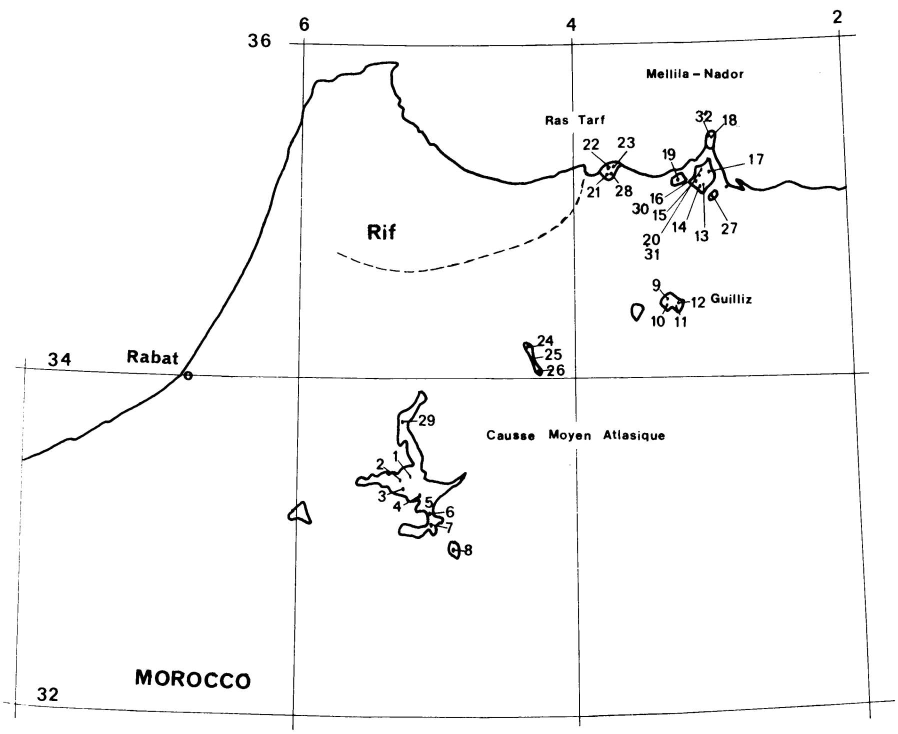


**Fig. 1.**
Location of sampling regions and site numbers

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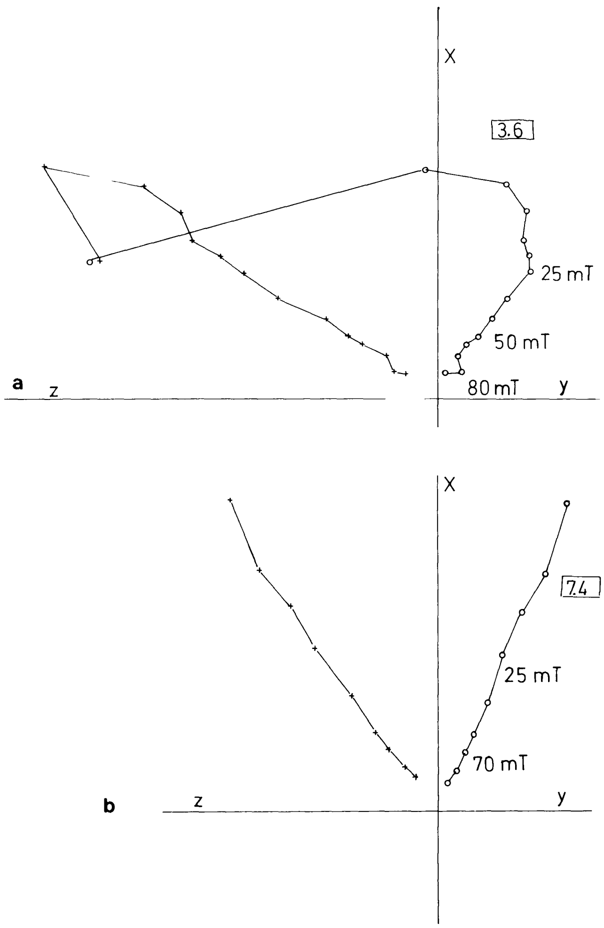


**Fig. 2a, b.** A.F. demagnetization patterns for two Quaternary rocks samples. *Open circles*: vector end-points in the XY plane, *crosses*: vector end-points in the XZ plane

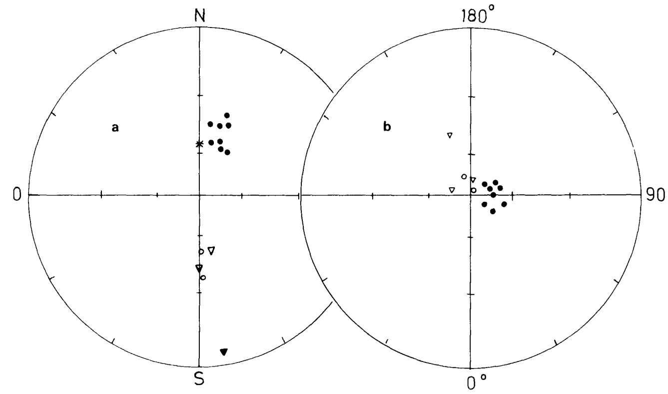


**Fig. 3a, b.** Quaternary sites. **a** Site mean directions. *Black symbols*. positive inclination, *open symbols*. negative inclination, *circles*. present study, *triangles*: Hamzeh and Westphal 1973, *star* represents axial dipole field. **b** Corresponding virtual geomagnetic poles (northern hemisphere). *Black symbols*. normal directions, *open symbols*. reversed directions

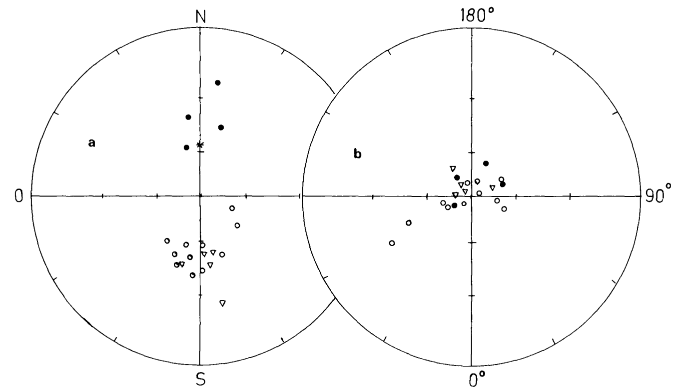


**Fig. 4a, b.** Miocene sites. **a** Mean site directions, **b** corresponding virtual geomagnetic poles; same conventions as for Fig. 3

and also in the 'Causse moyen Atlas', where it seems to be very recent, sometimes lying in recent wadi terraces which, however, have not yet been accurately dated.

## Sampling and Measurements

Five or six hand samples were taken from each outcrop. The orientation was recorded using a magnetic compass and also, if possible, using a sun compass. The samples were then sawn into 50 mm cubes or cored to give standard 25 mm cylinders. The measurements were made with an astatic magnetometer and a Digico spinner.

The presence of a viscous remanent magnetization was checked by two separate measurements as proposed by Thellier and Thellier (1959). Usually the viscous component acquired in a fortnight was less than 5% of the N.R.M.

The samples were then stepwise demagnetized by an alternating field (A.F.) of up to 900 Oe. Some samples, of both Quaternary and Miocene age, possessed a fairly stable single component of magnetization (Fig. 2a), but other samples showed a strong secondary component which could usually be removed by A.F. demagnisation at about 250 Oe (Fig. 2b), revealing a more stable component of magnetization. The within-site scatter was then strongly reduced and a good characteristic magnetization could be defined (Fig. 3).

For a few sites, mainly Quaternary basalts, secondary components were too strong to be removed. The initial magnetization seemed to have been destroyed and replaced by a very strong magnetization which probably originated from lightning strokes. The scatter of directions remained greater than acceptable and these sites were discarded for the calculation of the overall mean (Tables 1 and 2).

## Discussion

A.F. demagnetization showed a final, stable, characteristic component of magnetization for most of the samples. Secondary components were either caused by lightning strokes, or for some samples. by sawing or drilling effects, as shown by Burmester (1977) and Lauer (1978). Tests made by acid leaching showed that this secondary magnetization was located near the surface of the sample. A.F. demagnetization seemed to remove this component. The characteristic remanent magnetization has either normal or reversed polarity near to the present field direction, probably parallel to the original magnetization.

**Table 1.** Mean directions and poles for Quaternary sites

*Mean direction.*

$N=10$ $D_m=14.5°$ $I_m=50.0°$ $k=51.9$ $\alpha_{95}=6.7°$

*With bracketed results.*

$N=13$ $D_m=8.8°$ $I_m=45.9°$ $k=22.3$ $\alpha_{95}=8.9°$

*Mean pole.*

$N=10$ 77.1° N, 95.7° E $k=36.6$ $\alpha_{95}=8.0°$

| Site No./Locality | $N$ | $D_m$ (°) | $I_m$ (°) | $k$ | $\alpha_{95}$ | Poles | | Polarity |
|---|---|---|---|---|---|---|---|---|
| | | | | | | lat (° N) | long (° E) | |
| *Causse moyen atlasique* | | | | | | | | |
| 1/Azrou | 6 | Directions too scattered | | | | | | |
| 2/Azrou | 4 | 16 | 45 | 32 | 17 | 74 | 107 | N |
| 3/Azrou | 5 | 29 | 57 | 162 | 6 | 66 | 68 | N |
| 4/Azrou (J. Hébri) | 5 | Directions too scattered | | | | | | |
| 5/Timahdit | 5 | Directions too scattered | | | | | | |
| 6/Timahdit | 5 | Directions too scattered | | | | | | |
| 7/Oued Guigou | 5 | 19 | 39 | 663 | 3 | 70 | 115 | N |
| 8/Foum Khneg | 4 | 21 | 40 | 230 | 6 | 69 | 109 | N |
| 29/Sebâ-âyoun | 6 | 10 | 45 | 552 | 3 | 78 | 124 | N |
| 24/Sidi Abdallah | 6 | Directions too scattered | | | | | | |
| 25/Sidi Abdallah | 5 | Directions too scattered | | | | | | |
| 26/Sidi Abdallah | 5 | 14 | 56 | 230 | 5 | 78 | 71 | N |
| *Ras Tarf region* | | | | | | | | |
| 21/Ras Tarf | 7 | 21 | 52 | 303 | 4 | 72 | 90 | N |
| 28/Ras Tarf | 3 | 33 | 55 | 156 | 10 | 63 | 76 | N |
| *J. Guilliz* | | | | | | | | |
| 10/J. Guilliz | 3 | (177) | (−39) | (27) | (24) | (77) | (190) | R |
| *7/J. Guilliz | 5 | (168) | (5) | (8) | (30) | (51) | (198) | R |
| *8/J. Guilliz | 4 | (180) | (−45) | (19) | (22) | (81) | (177) | R |
| *Mellila – Nador region* | | | | | | | | |
| *15/Tiraka (Nador) | 5 | 162 | −52 | 97 | 8 | 75 | 262 | R |
| 27/Nador | 5 | 180 | −52 | 276 | 5 | 87 | 178 | R |

$N$ = number of samples used in the statistic
$D_m$, $I_m$ = mean declination and inclination
$k$ = Fisher precision parameter
$\alpha_{95}$ = radius of 95% confidence cone
Lat, long = latitude and longitude of corresponding virtual geomagnetic pole

N = normal polarity
R = reversed polarity
Bracketed results = low confidence mean directions
Starred sites = Hamzeh and Westphal (1973) previous results

## Results

### *Quaternary Lavas*

Most of the sites are on apparently recent flows from the Causse Moyen Atlasique which all have normal magnetization. The between-site scatter is low and the mean direction is somewhat offset to the east. The few other results are normal or reversed and are nearer to the present north-south direction (Guilliz, Ras Tarf, Mellila). The reversed directions are certainly older than the Matuyama-Brunhes transition. The mean pole positon is significantly different from the present geographic pole.

### *Miocene Lavas*

Both polarities occur. The mean direction is centred in the present north-south direction but the mean inclination is slightly lower than that of the geocentric axial dipole field.

Special mention must be made of the two sites from Cap des Trois Fourches which gave significantly different directions from other sites. The difference may be explained in two ways; either they may represent a true dirction of the field, or the flows have been tilted by about 30° towards the north-east. This tilt cannot be measured but is geologically realistic.

The mean pole position does not exactly coincide with the present geographic pole. The difference is statistically significant for the Quaternary sites but not for the Miocene sites.

**Table 2.** Mean directions and poles for Miocene sites

*Mean directions:*

$N=18$ $D_m=182.0°$ $I_m=-49.1°$ $k=35.7$ $\alpha_{95}=5.9°$

*Including sites from Cap des Trois Fourches:*

$N=20$ $D_m=177.9°$ $I_m=-51.7°$ $k=22.1$ $\alpha_{95}=7.1°$

*Mean pole:*

$N=18$ 85.8° N, 161.5° E $k=29.6$ $\alpha_{95}=6.4°$

| Site No./Locality | $N$ | $D_m$ (°) | $I_m$ (°) | $k$ | $\alpha_{95}$ | Poles lat (° N) | Poles long (° E) | Polarity |
|---|---|---|---|---|---|---|---|---|
| *J. Guilliz Region* | | | | | | | | |
| 9/J. Guilliz | 5 | 182 | −42 | 107 | 8 | 80 | 169 | R |
| 11/J. Guilliz | 5 | 186 | −53 | 895 | 3 | 85 | 97 | R |
| 12/J. Guilliz | 5 | 160 | −55 | 506 | 3 | 73 | 278 | R |
| *1-2-5/J. Guilliz | 13 | 167 | −27 | 3075 | 2 | 67 | 210 | R |
| *3/J. Guilliz | 4 | 167 | −56 | 410 | 5 | 80 | 280 | R |
| *4/J. Guilliz | 4 | 195 | −47 | 259 | 6 | 76 | 108 | R |
| *Guilliz | 5 | 174 | −54 | 627 | 3 | 85 | 264 | R |
| *Ras Tarf region* | | | | | | | | |
| 22/Ras Tarf | 4 | 10 | 24 | 784 | 3 | 65 | 152 | N |
| 23/Ras Tarf | 5 | Results too scattered | | | | | | |
| *Mellila Nador region* | | | | | | | | |
| 13/Massif du Gourougou | 5 | 194 | −59 | 194 | 5 | 78 | 292 | R |
| 14/Segangane | 5 | 196 | −46 | 50 | 11 | 74 | 112 | R |
| 15/Oulad Minoun (Gourougou) | 5 | 177 | −59 | 490 | 3 | 85 | 331 | R |
| 16/Souk Télat | 5 | 347 | 58 | 171 | 6 | 79 | 289 | N |
| 17/Atalayoum | 6 | 179 | −45 | 89 | 7 | 81 | 185 | R |
| 19/Amjar | 4 | 19 | 47 | 114 | 9 | 72 | 106 | N |
| 20/Tidienit | 8 | 201 | −52 | 67 | 7 | 73 | 88 | R |
| 30/Télat | 4 | 350 | 39 | 59 | 12 | 74 | 211 | N |
| 31/Tidienit | 4 | 213 | −58 | 1170 | 3 | 64 | 68 | R |
| *Isaroualène (Nador) | 5 | 174 | −48 | 48 | 11 | 82 | 215 | R |
| 32/Cap des 3 Fourches | 4 | 123 | −60 | 687 | 4 | 45 | 293 | R |
| 18/Cap des 3 Fourches | 5 | 107 | −64 | 97 | 8 | 36 | 302 | R |

Same conventions as for Table 1.

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