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Paleomagnetism of the Liassic member of the Zarzaïtine Formation (stable Saharan craton, Illizi basin, Algeria)

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Abstract

A paleomagnetic study was carried out in the carbonates and marls of the Liassic member of the Zarzaïtine Formation of the Illizi basin (SE Algeria) deposited in a continental environment. Two magnetization components were identified. The first, defined at relatively low blocking temperature, was isolated in five sites, and yields the following paleomagnetic pole (80.8°N, 20.1°E, K = 811 and A_{95} = 2.2°). This magnetization is considered an overprint acquired during Cenozoic times. The second component was defined by both normal and reversed polarity. The normal polarity was identified in fourteen sites using both linear regression and great circles. The reversed one was inferred in four sites from the remagnetization circle and demagnetization path analyses. This component is mainly (it could be in part the primary magnetization) a late diagenesis magnetic overprint. It yields a new Liassic pole (71.8°S, 54.9°E, K = 91 and A_{95} = 3.9°) for Africa.

Key words *Africa – paleomagnetic pole – Liassic – apparent polar wander path – Sahara craton*

1. Introduction

The Illizi basin, in the eastern part of the Algerian Sahara, now represents a reference for the paleomagnetic data of the Saharan craton. Indeed, paleomagnetic analyses were performed in all the favorable formations, whose ages range between Bashkirian and Upper Triassic-Rhaetian and also some older units. In all, five reliable poles were obtained in these Upper Paleozoic (Henry *et al.*, 1992; Derder *et al.*, 1994, 2001a,b) and Lower Mesozoic (Kies *et al.*, 1995) geological formations. Unfortunately, all the samples from the units older than the Bashkirian formation proved to be completely remagnetized (Henry *et al.*, 1991) during Cenozoic times. It was interesting to continue the systematic paleomagnetic investigations in this reference basin, by analyzing more recent new formations. The middle member of the Zarzaïtine Formation, of Liassic age, is the single other Jurassic formation with favorable facies for paleomagnetic analysis.

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2. Geological setting

The Zarzaïtine Formation (figs. 1a and 1b) represents the bottom of the Mesozoic series in the Illizi basin (Saharan platform). It consists of three principal members (fig. 1b, Fabre, 1983), the lower one with sandstone, the middle one with marls and carbonates, and the upper one with argillaceous sandstone. The lower member is of Upper Triassic-Rhaetian age (Achab, 1970; Lehman, 1971; Jalil, 1990). Lower Liassic flora

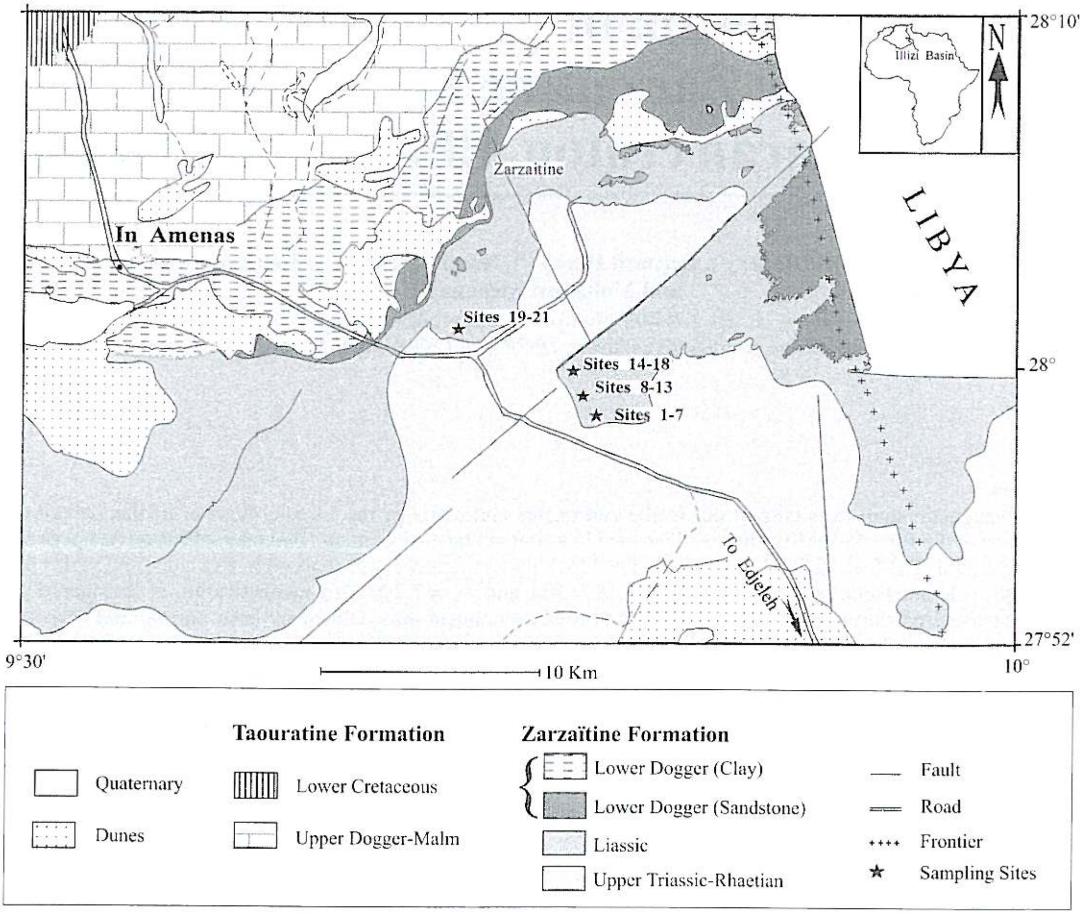
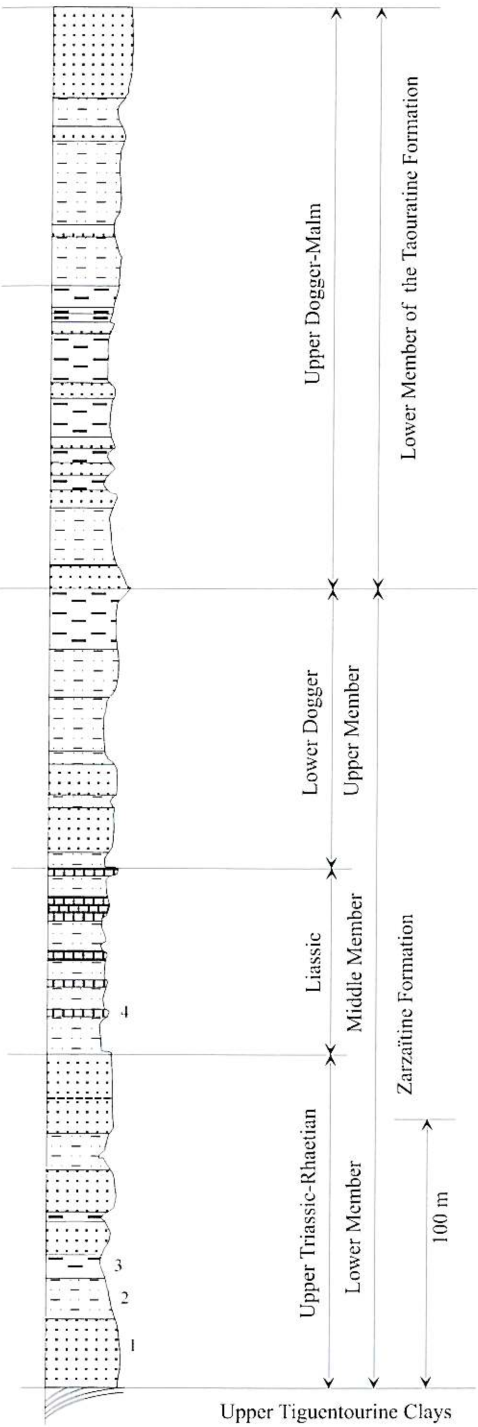


Fig. 1a. Location of the middle member of the Zarzaïtine Formation (modified from CRZA, 1964, 1965) and of the sampling sites (stars).

(Classopolis) was observed in a borehole at the top of this member (Achab, 1970). The Zarzaïtine Formation overlies in angular unconformity the dated Stephano-Autunian Tiguentourine Formation (Attar *et al.*, 1981) and is covered by the Taouratine Formation. The lower part of the Taouratine Formation is dated Middle Dogger (Bajocian - Bathonian) age (Busson, 1961, 1970, 1972). Between these Lower Liassic and Middle Dogger dated levels, the series are constituted by two azoic units: the middle (thickness about 60 m) and upper (thickness about 90 m) members of the Zarzaïtine Formation, which were attributed (CRZA, 1964, 1965) to Liassic and Lower Dogger age respectively (fig. 1b). These attributions were confirmed by correlation with dated series from Northern and Central Sahara (Busson, 1972; Busson and Cornée 1989a,b). The age of the middle member of the Zarzaïtine Formation is therefore Liassic (*i.e.* about 205 Ma to 180 Ma – Odin and Odin, 1990).

The middle member of the Zarzaïtine Formation is constituted mainly of marls, with some limestone beds, often discontinuous and forming calcareous nodules within the marls. It is



within a structurally stable area, and its beds, except for some faults, do not show any significant deformation and are quite horizontal. On the field, it represents outliers dominating the depressions with the older levels (fig. 1a). Westwards and northwards, the Zarzaïtine Formation and the more recent units present on average a very weak dip towards the north, but without suitable outcrops of the middle member of the Zarzaïtine Formation.

Busson and Cornée (1989 a,b) have shown that a rubefaction of the Zarzaïtine Formation occurred during the diagenesis, and that this phenomenon did not affect the whole series at the same time.

3. Sampling and analysis procedure

In all, 62 oriented cores and 61 large oriented (using plaster cap) hand samples were collected at 21 sites located (28°N, 9.7°E) between In Amenas city and Edjeleh area (fig. 1a) along 4 sections. All samples belonging to the same site were collected in different parts of the same limestone bed or in the same level with carbonated nodules (representing here a thickness ranging from 20 to 150 cm), but each site represents a different level in the same section. Sites 19-21 correspond to the lower third of the formation, and the other sites to the two upper thirds. At least 5 hand samples or 8 cores were collected for each site. Oriented cores were drilled in the laboratory from each hand sample.

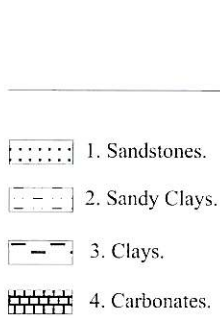


Fig. 1b. Stratigraphic section (CRZA, 1964) of the Lower Mesozoic formations: 1) Sandstone; 2) Sandy clay; 3) Clay; 4) Carbonates.

Remanent magnetization of the specimens was measured using a JR4 spinner magnetometer (Agico, Brno). Demagnetization data analysis was carried out using classical methods: the directions of the magnetization components were analyzed on orthogonal vector plots (Wilson and Everitt, 1963; Zijderveld, 1967); the remaining vectors and vectorial differences of the magnetization were plotted on equal area projections; the remagnetization circles methods (Halls, 1976, 1978; McFadden and McElhinny, 1988) were also used. The mean direction of the different components has been computed using principal component analysis (Kirschvink, 1980), Fisher (1953) statistics and bivariate form of the Fisher statistics (Le Goff, 1990; Le Goff *et al.*, 1992).

Prior to any demagnetization analysis, the specimens were put in a zero field for at least one month, in order to reduce possible viscous components. Several pilot specimens were subjected to stepwise alternating field, and thermal demagnetization to characterize their magnetic behavior. Mostly, alternating field procedure did not allow complete demagnetization, so thermal demagnetization was applied to the remaining specimens.

4. Rock magnetism analysis

According to the site, the maximum blocking temperature (fig. 2) range from 400 °C to

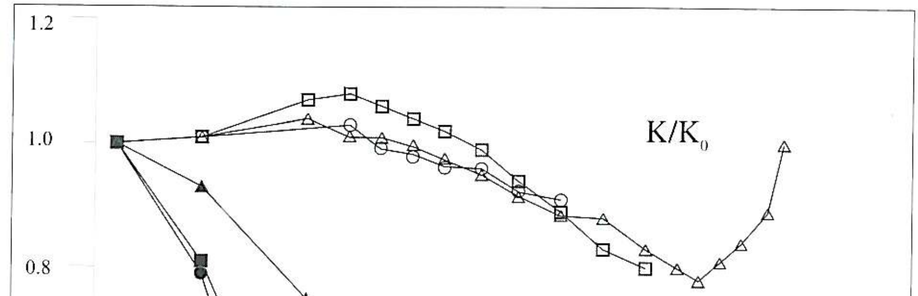
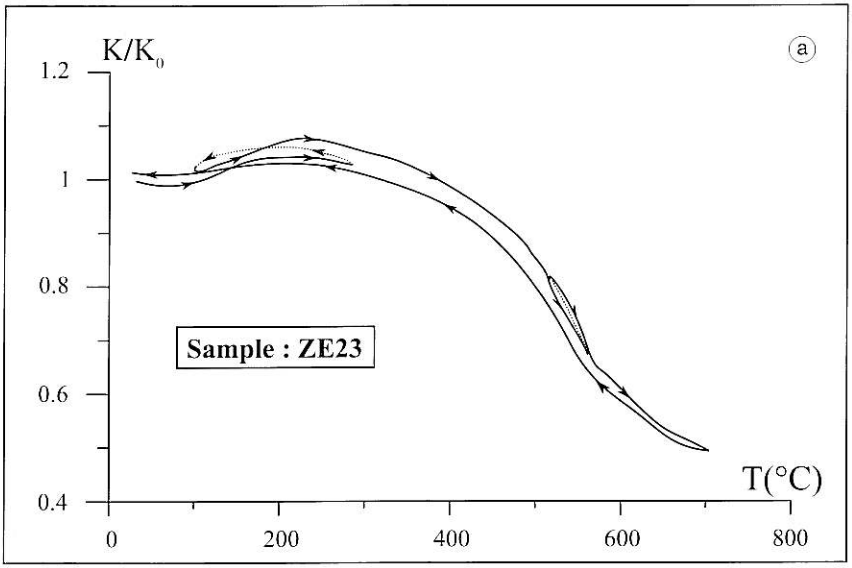


Fig. 2. Normalized magnetic susceptibility and normalized remanent magnetization intensity at room temperature as a function of maximum applied temperature for the samples (ZE65D, ZE122B, and ZE80B).



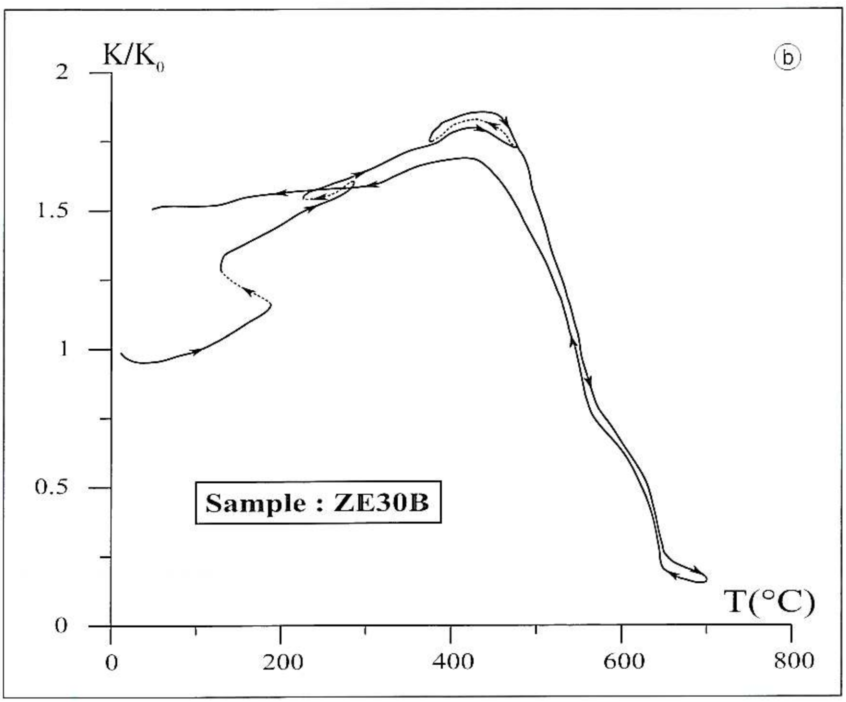


Fig. 3a,b. Typical thermomagnetic (susceptibility in low field as a function of temperature) curve (heating and cooling have been done in the air) for samples (a) ZE23, and (b) ZE30B, pointing out the presence of hematite, and suggesting the existence of magnetite.

650 °C. Hematite is therefore supposed to be the main magnetic carrier at least in some of the sites.

Thermomagnetic curves (fig. 3a,b) were determined for representative samples by heating in air using CS2-KLY2 (Agico, Brno) equipment. The dashed lines represent temporary cooling loops applied to check the occurrence of any mineralogical alterations (showed by the non-fit of the heating and cooling parts of the curve).

They confirm the presence of hematite, but variation of the slope of these curves around 580 °C also suggests the presence of magnetite. The increase in susceptibility at about 150-200 °C corresponds to mineralogical alteration, probably of goethite, and there are no other mineralogical alterations until heating up to at least 580 °C. The observed small decrease of the susceptibility, on the cooling curve compared to that on the heating one, is probably due to oxidation of some of the magnetite at the highest temperature.

The hysteresis loop (fig. 4a) clearly shows the presence of a high coercivity component, even in samples with a maximum blocking temperature in the order of 400 °C. Taking into account the values of maximum blocking temperatures, this component cannot be carried by only goethite and hematite is therefore the main carrier, despite the relatively low blocking temperatures sometimes observed. The wasp-waisted shape of the loop (fig. 4a), however, indicates the presence of another magnetic phase of different coercivity. If this other phase is magnetite, the loops show that this latter should be in a very low amount compared to hematite. To specify the effect of the mineral alteration at about 150-200 °C, another hysteresis loop was determined after heating the same sample at 400 °C. The shape of the loop appears relatively different, with a more pronounced wasp waist (fig. 4b) and a slight increase in the coercive force indicating presence of a high coercivity phase at a more important rate. It is therefore probable that some of the hematite was formed during heating.

The magnetic susceptibility at room temperature was measured after each step. The results (fig. 2) confirm the relative stability of these samples, since no large changes in susceptibility are observed. The demagnetization curves (fig. 2) also failed to reveal any suspect slope changes due to the mineralogical alterations. The carriers of the remanent magnetization are therefore not affected by these alterations. Thermal treatment is thus suitable for the analysis of the Natural Remanent Magnetization (NRM) of these samples.

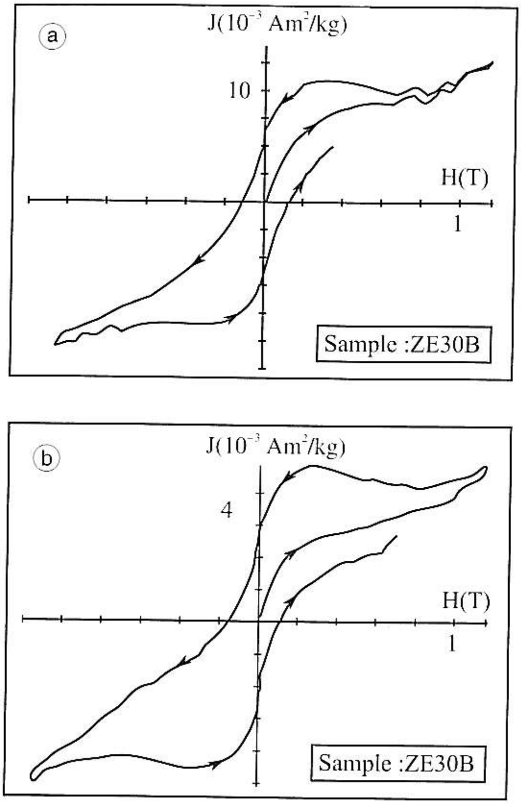


Fig. 4a,b. Hysteresis loop (a) of sample ZE30B showing high coercive force and (b) of the same sample heated to 400 °C.

5. Paleomagnetic results

The NRM vector directions are grouped slightly west of the Present Day Field (PDF) direction; we note, however that some vectors

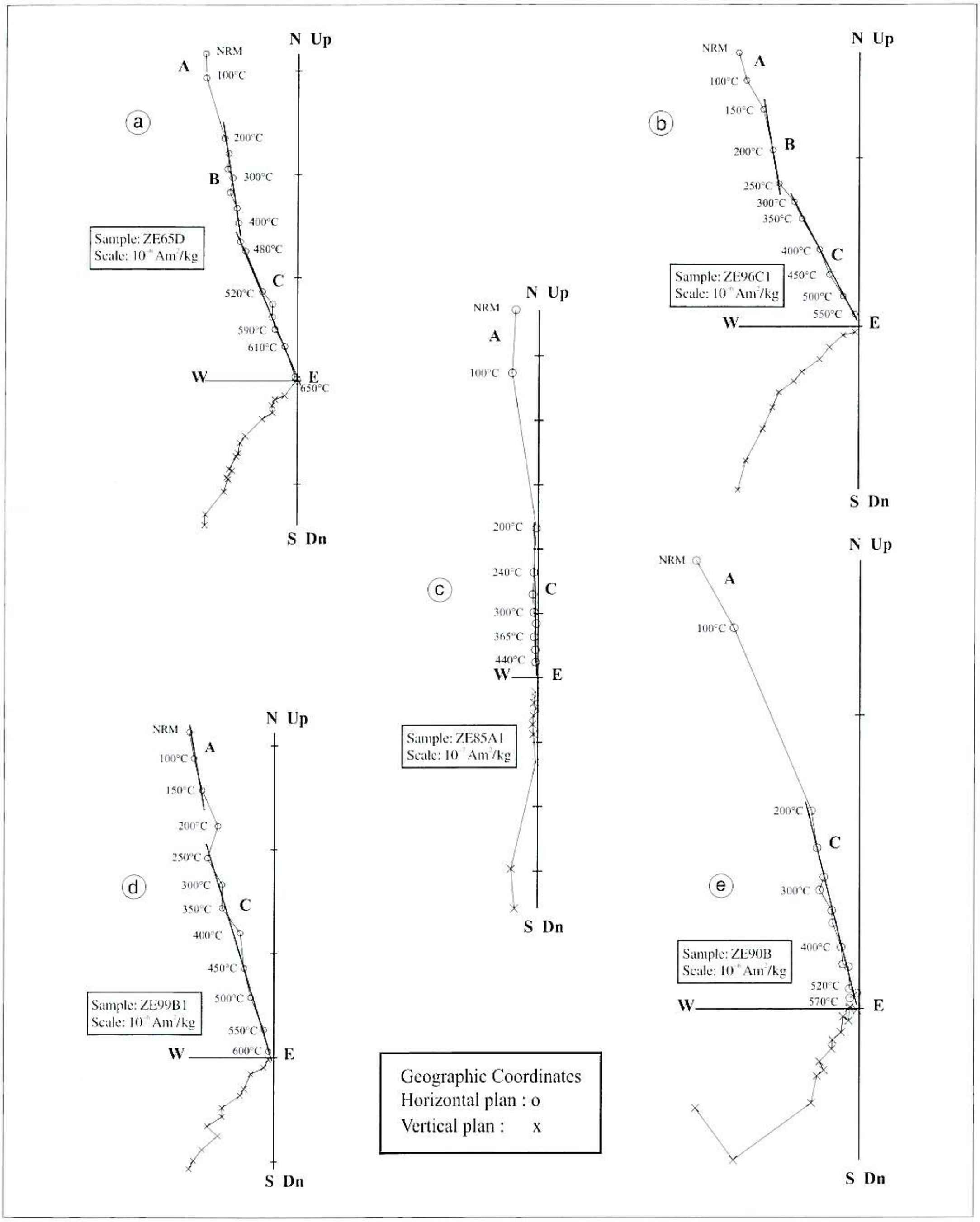


Fig. 5a-e. Orthogonal vector plots (open circles: horizontal plane; cross: vertical plane) of samples displaying the A, B and C components (a, b) or only the A and C components (c, d, e).

lie on NW directions. This arrangement could suggest the existence of more than one component in the NRM.

During the demagnetization process, the magnetization direction of the samples shows, after possible elimination of a small viscous component A, two types of evolution: either a relatively stable magnetic direction, allowing determination of one or two distinct components, or an evolution of the direction along great circles which indicates a superimposition of unblocking temperature spectra of at least two components:

– In the first case, the application of the principal component analysis (Kirschvink, 1980) to linear segments on Zijderveld plots revealed the presence of one or two components (B and C). Component B was found in five sites, and isolated for relatively low blocking temperature, generally up to 300, but sometime up to 400 °C (fig. 5a). Its direction has a normal polarity and is defined by N = 26, D = 358.2°, I = 34.5°, k = 506 and α_{95} = 2.8° (fig. 6a and table I). The corresponding paleomagnetic pole (80.7°N, 24.5°E) lies in the vicinity of the Eocene African poles (Besse and Courtillot, 2002). The component C is the ChRM; it has been isolated either as juxtaposed with the component B (fig. 5a,b) with maximum blocking temperature up to 650 °C (it is therefore carried by hematite), or (mostly) as a unique component (juxtaposed with the viscous component A) determined at blocking temperature between 440 and 600 °C. In many cases, it is the single evident component (fig. 5c,d,e). Here also, the main carrier is hematite (fig. 4a). Its direction also has a normal polarity and is very coherent from one site to another (table II – fig. 6b). The mean value of this direction obtained by giving unit weight to each specimen (N = 82, D = 346.4°, I = 27.5°, k = 102, α_{95} = 1.5° – fig. 6b; table II) is very close to that obtained by giving unit weight to each site (N = 14, D = 346.1°, I = 27.2°, k = 246, α_{95} = 2.4°).

– In samples showing only superimposed components (obtained from 4 sites where other samples yield the ChRM), the magnetization vector drew on the projection sphere great circles during thermal analysis (fig. 7a,b). The best intersection point of these circles (Halls, 1976; 1978) has a well defined direction (fig. 8) in the four sites (table III). This obtained direction is coherent from one site to another. The corresponding component of magnetization has a mean direction (D = 348.8°, I = 28.0°) remarkably similar to that determined by ChRM C analysis (table II). In order to have statistical result integrating both the ChRM and great

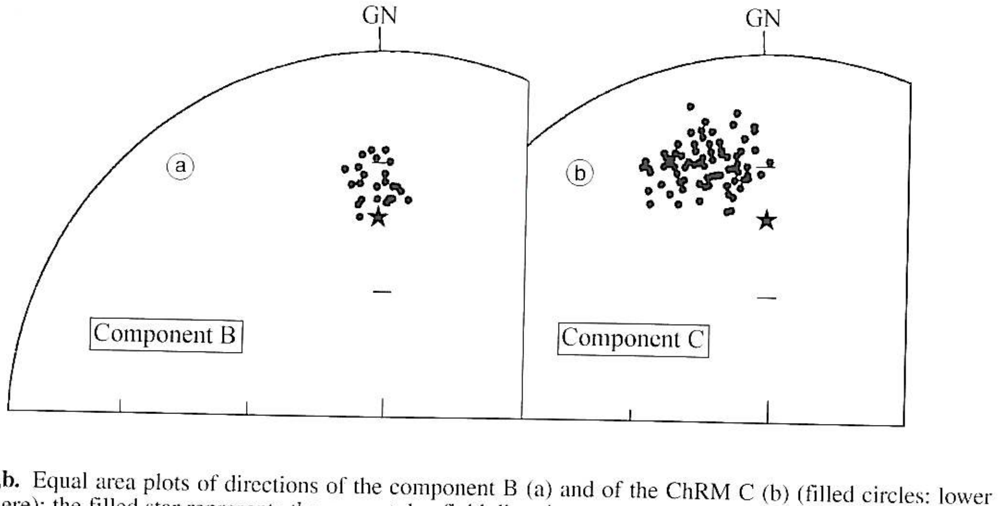


Fig. 6a,b. Equal area plots of directions of the component B (a) and of the ChRM C (b) (filled circles: lower hemisphere); the filled star represents the present day field direction.

Table I. Component B: mean direction (*D* and *I* in degrees) in each site (*N* = number of samples), corresponding paleomagnetic pole and Fisher's parameters (k, α_{95}, K, A_{95}; α_{95} and A_{95} in degrees).

Site	*N*	*D*(°)	*I*(°)	*k*	α_{95}	Lat. (°S)	Long (°E)	*K*	A_{95}
1	3	358.2	37.1	261	5.0				
2	2	353.8	37.0						
3	3	355.3	31.1	207	5.6				
5	2	357.4	41.1						
6	6	0.2	34.2	231	3.7				
7	4	0.0	38.3	1348	1.9				
12	3	357.6	31.7	301	4.6				
16	1	354.0	39.2						
17	1	6.4	39.1						
20	1	355.4	28.2						
Mean	26	357.9	35.4	197	1.9				
Mean	5 sites	358.2	34.5	506	2.8	80.7	24.5		
Mean	5 sites					80.8	20.1	811	2.2

Table II. ChRM C: same caption as for table I.

Site	*N*	*D* (°)	*I* (°)	*k*	α_{95}	Lat. (°S)	Long. (°E)	*K*	A_{95}
1	4	349.4	29.1	150	5.7				
2	3	348.2	23.9	31	14.4				
3	5	348.4	31.9	141	5.3				
4	8	348.6	25.9	97	5.0				
5	7	348.2	31.6	215	3.6				
6	9	351.5	28.0	132	4.1				
7	6	351.3	32.5	401	2.9				
8	3	341.2	26.1	91	8.4				
10	1	347.3	21.0						
11	2	342.8	31.0						
12	6	343.9	26.6	104	5.6				
13	7	348.2	25.2	91	5.5				
14	7	341.4	27.2	189	3.8				
16	4	339.1	22.3	234	4.6				
17	5	349.4	24.9	125	5.6				
19	1	332.8	28.9						
20	4	339.0	24.3	847	2.4				
Mean	82	346.4	27.5	102	1.5				
Mean	14 sites	346.1	27.2	246	2.4	71.3	56.1		
Mean	14 sites					71.8	54.9	91.3	3.9

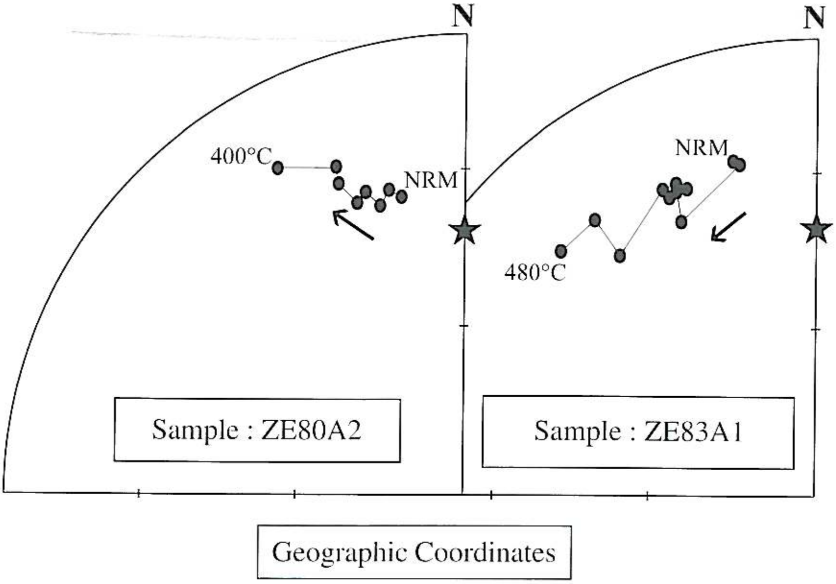


Fig. 7. Equal area plots of magnetization direction during thermal treatment from samples (ZE80A2 and ZE83A1) showing an evolution along great circles (filled circles: lower hemisphere); the arrow shows the magnetization direction evolution; the filled star represents the present day field direction.

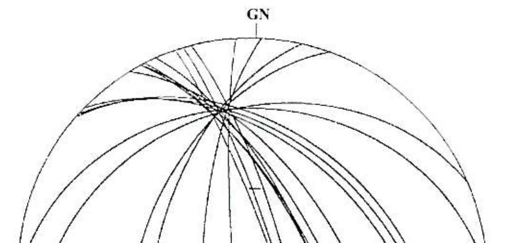


Fig. 8. Best intersection of the remagnetization circles (equal area plot, lower hemisphere).

circles data, the McFadden and McElhinny (1988) method was applied (table III), and the obtained mean direction ($D = 349.1°$, $I = 28.2°$, $\alpha_{95} = 1.6°$) is very close to those determined using only ChRM or only great circles data.

6. Discussion

6.1. *Sites 1, 3, 6 and 12*

6.1.1. Existence of a component D of reversed polarity

Evolution of the magnetization vectors along great circles was obtained for some samples in sites 1, 3, 6, and 12. It is due to the superimposition of two components with partial overlap of their blocking temperature spectra. The first is component C (fig. 8), as the best intersection direction of the great circles is exactly that of the ChRM C. This also indicates that the

Table III. Mean direction (*D* and *I* in degrees) obtained in each site (*N*= number of ChRMs; *N'* = number of great circles) using remagnetization circles analysis (Halls, 1978; McFadden and McElhinny, 1988).

Remagnetization circles analysis			Halls (1978) method		McFadden and McElhinny (1988) method		
Site	*N*	*N'*	*D* (°)	*I* (°)	*D* (°)	*I* (°)	α_{95}
1	3	4	344.4	26.4	349.8	29.3	3.5
3	4	5	339.7	16.5	348.1	29.2	4.4
6	4	9	342.4	21.8	351.1	27.7	2.8
12	5	6	351.2	28.9	347.5	27.6	3.1
Mean direction	16	24	348.8	28.0	349.1	28.2	1.6

ChRM C is a single component and does not result from the vectorial sum of distinct components, with perfectly overlapping unblocking temperature spectra (Merabet *et al.*, 1999). Because the evolution of the magnetization direction during thermal demagnetization always starts from a direction close to this ChRM C towards a direction farther away (fig. 7a,b), the other component has mainly high blocking temperatures and is also carried by hematite. It could never be A or B components, because these components are mostly not included in the circles and have low blocking temperatures. The other component is therefore an unknown component D, which can be inferred only from remagnetization circle and demagnetization paths analyses.

The great circles orientation is not very well defined, because evolution of the direction during thermal demagnetization corresponds only to a small arc on these circles (variation in direction less than 30° – fig. 7a,b), but this cannot explain the scattering in orientation of the circles (fig. 8). Such a scattering of great circles around the component C indicates component D practically randomly scattered, or component D strictly antiparallel to C. Assumption of randomly scattered component D appears hardly tenable. Indeed, parasitic isothermal remagnetizations related to lightning are probably exceptional in such sites located on hillsides and with very low susceptibility (such remagnetizations were never observed in similar locations on hillsides in the Stephano-Autunian Formation west and south of the studied area, though higher susceptibility – Derder *et al.*, 1994). Moreover, lightning affects limited areas, whereas, we obtained great circles in different sites. Because of the lack of thermal events in this region, a remagnetization should therefore be of chemical origin. Assuming numerous periods of remagnetization, the variations of the earth magnetic field direction since the Liassic are insufficient to explain the scattering of component D necessary to have so different orientation of great circles. The single possible explanation of scattering could have been that component D itself results from the superimposition of other components (Henry *et al.*, 1999; Merabet *et al.*, 1999; Derder *et al.*, 2001c). However, these components cannot be A or B magnetizations (low blocking temperature). If one of these other components is C, the other one is on the same great circle (*i.e.* randomly scattered or antipodal to C…). Moreover, no scattered directions have been observed in the different formations, from the Silurian to the Lower Cretaceous, where paleomagnetic studies or tests have been carried out in the Illizi basin (Henry *et al.*, 1991, 1992; Derder *et al.*, 1994, 2001a,b). Component D is then very probably antipodal to component C. Such antipodal directions have already been isolated in the lower member of the Zarzaïtine Formation (Kies *et al.*, 1995) using principal component analysis (Kirschvink, 1980). The Earth magnetic field was therefore reversed during the acquisition of at least part of the high blocking temperature magnetization in samples allowing the determination of the great circle. The antipodal disposition of these components C and D shows that they were acquired during very neighboring periods. It could be during either two distinct times (in this case, at least one of these components is a remagnetization) or during a period corresponding to 2 polarity intervals (in these cases C and D are the same magnetization).

6.1.2. Component D also of normal polarity?

In these four sites, according to the samples, we obtained only great circles or only ChRM. There is no evidence of superimposition of components for samples with only ChRM (no curvature on Zijderveld plots). All these samples, with only great circles or only ChRM, have exactly the same magnetic characteristics. The single difference is that they were always sampled in slightly different stratigraphical levels, and therefore correspond to different ages of deposition. Existence of samples with only ChRM could be explained by a complete overprint C of a reversed component D, but no magnetic, mineralogical or sedimentological argument explains why this complete overprinting should be limited to some levels. A second assumption is that the samples with apparently only the ChRM C actually also have the component D, but that these components C and D cannot be separated because the component D should be of normal polarity (and therefore with a direction not significantly different from component C). Taking into account the fact that this component D is of reversed polarity on samples showing an evolution along great circles, this means that the polarity of magnetization D should be different according to the stratigraphical level and should argue for a very early acquisition of this magnetization. Several polarity inversions of the Earth magnetic field occurred during Liassic times, and obtaining different polarities should be an expected result in formations of this age. That represents an argument in favor of this second assumption.

6.2. *Other sites*

In the other sites, only ChRMs were obtained. That means a single component C, or two components C and D only of normal polarity with similar directions. It is important to note that the obtained direction is exactly the same as in samples with antipodal C and D magnetizations.

6.3. *Comparison with the lower member of the Zarzaïtine Formation*

In the lower member of the Zarzaïtine Formation, juxtaposed and superimposed components have been obtained (Kies *et al.*, 1995): the viscous overprint (normal polarity), the Cenozoic overprint (normal polarity) and a magnetization of normal and reversed polarities with positive reversal test. Some samples of carbonated sandstones pointed out during demagnetization of the two polarities, with a positive reversal test. This showed that the magnetization was acquired progressively during two polarity intervals. Except for recent weathering and fluid migration probably at the origin of the Cenozoic remagnetization (Henry *et al.*, 1991), the single chemical event known in these rocks is the rubefaction of the series which occurred during the diagenesis (Busson and Cornée, 1989a,b). The magnetization was mainly therefore acquired during this rubefaction (thus during the diagenesis of long duration) and may be for a part during deposition of the Formation.

Comparing the results from the lower and middle members of the Zarzaïtine Formation, few differences appear:

– The Cenozoic overprint mostly has lower maximum blocking temperatures for the middle member than for the lower member (this overprint is even the ChRM for some of the lower member samples).

– In samples with both polarities, the reversed component for the lower member is associated with the lowest blocking temperatures, whereas it corresponds to the highest ones for the middle member.

They represent minor characteristics when compared to the common features between lower and middle members of the Zarzaïtine Formation. In both cases:

– Some of the samples shows antipodal magnetizations with normal and reversed polarity.

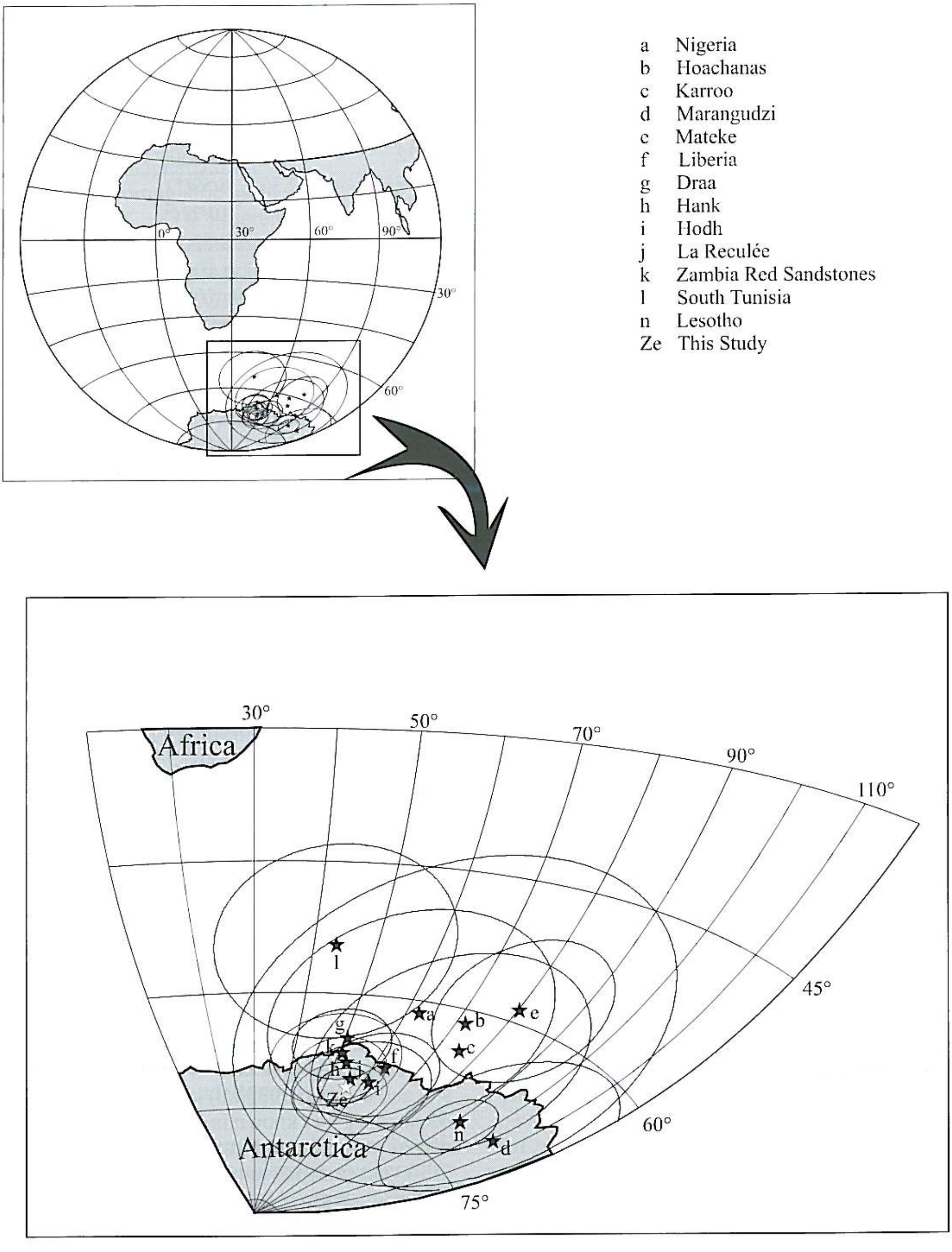


Fig. 9. African Liassic-Dogger paleomagnetic poles (see table IV).

Table IV. List of selected African poles for Triassic to Dogger. (*) Refers to the GJRAS pole list (McElhinny, 1968, 1969, 1972; McElhinny and Cowley, 1977, 1980). (+) Absolute age according to Odin and Odin (1990) time scale.

	Age (Ma)	Rock unit	Lat. (°S)	Long. (°E)	A_{95}	Reference
a	140-178	Nigeria	62	62	13.0	16/120(*)
b	161-173	Hoachanas	62	72	20.0	14/250(*)
c	154-190	Karroo	65	75	12.3	8/59(*)
d	173-181	Marangudzi	71	107	9.7	10/77(*)
e	173-181	Mateke	59	80	8.3	8/63(*)
f	173-192	Liberia	69	62	5.3	14/248(*)
g	180-186	Draa	66	50	4.4	13/36(*)
h	182-192	Hank	69	52	4.0	Sichler *et al.* (1980)
i	182-192	Hodh	71	60	6.0	Sichler *et al.* (1980)
Ze	**180-205**	**Zarzaïtine**	**72**	**55**	**4.0**	**This study**
j	205-230(+)	La Reculée	71	55	2.3	Kies *et al.* (1995)
k	205-230(+)	Zambia red sandstone	68	50	5.8	8/67(*)
l	210-230(+)	South Tunisia	55	43	11.5	Ghorabi and Henry (1991)
n	175-185	Lesotho	71.6	93.5	3.2	Kosterov *et al.* (1996)

– In the other samples (except some lower member samples where the ChRM is the Cenozoic overprint), a single component C was determined, with direction similar to Component C obtained from samples displaying two polarities.

The middle member was also affected by rubefaction. The process of magnetization acquisition could be therefore the same as in the lower member, *i.e.* related to this rubefaction during a diagenesis of long duration.

6.4. *Age of magnetization acquisition*

The paleomagnetic directions for lower and middle members of the Zarzaïtine Formation are very close, and their corresponding poles are near to the previous African Middle Mesozoic poles and different from those of the Cenozoic remagnetizations. The magnetization acquisition occurred therefore during the Mesozoic. In the lower and middle members of the Zarzaïtine Formation, the components of the magnetization often have different characteristics (polarity, relationship polarity-blocking temperature spectrum,...) according to the levels. They were thus not acquired during the same period, and cannot be a uniform remagnetization of all the series. Moreover, the remagnetizations determined in the other formations studied in the Illizi basin are only of Permian, Cenozoic and present ages (Henry *et al.*, 1992, Derder *et al.*, 1994, Derder *et al.*, 2001a,b). In the middle member, Cenozoic and present overprints are now known and the attribution of the C and D components to another post-Liassic remagnetization should have been a particular case in this basin.

To explain the superposition of components of the same direction and of different polarity, we have to look for a long duration (sometimes during two periods of opposite polarity) chemical phenomenon which occurred at different periods according to the stratigraphical level. The diagenetic rubefaction of the series (Busson and Cornée, 1989a,b) is the single chemical Mesozoic event known in these rocks. The main carrier of the magnetization was formed during this event (may be some hematite already existed during deposition?). The remanent magnetization was therefore acquired progressively during the diagenesis (may be for a part during deposition?). Components C and D have likely the same origin, but because of the long duration of the diagenesis, they can represent opposite polarities. The magnetization was therefore at least in part a chemical remagnetization which appeared very early in the rock evolution, and which should be not significantly different from the primary magnetization.

The paleomagnetic pole (71.8°S, 54.9°E, $K = 91$ and $A_{95} = 3.9°$) therefore corresponds to the Liassic age. It is close to some previous African paleomagnetic pole for Triassic-Dogger times (fig. 9 – table IV). Reliable paleomagnetic poles determined in the Illizi basin cover now the period from Middle Carboniferous to Liassic.

7. Conclusions

Two non-viscous magnetization components were identified in the carbonates and marls of the Liassic member of the Zarzaïtine Formation deposited in a continental environment. The first is interpreted as a magnetic overprint acquired during Lower Cenozoic times. The second was determined by both normal and reversed polarities. The normal polarity was obtained in fourteen sites using both ChRM and great circles data. The reversed one was inferred in four sites from remagnetization circle and demagnetization path analyses. This component is interpreted as mainly (it could also include the primary magnetization) a late diagenesis magnetic overprint. It yields a new paleomagnetic Liassic pole (71.8°S, 54.9°E, $K = 91$ and $A_{95} = 3.9$) for Africa.

The new pole obtained in this study confirms the previous hypothesis (Kies *et al.*, 1995), which stipulates that Africa underwent a latitudinal movement towards the north with major anticlockwise rotation from Autunian to Liassic times.

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