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Paleomagnetic results from the Eastern Alps and their comparison with data from the Southern Alps and the Carpathians

By H. J. MAURITSCH * and W. FRISCH **

With 2 Figures and 1 Table

Zusammenfassung

Aus dem Oberostalpinen Bereich (Nördliche Kalkalpen, Grauwackenzone) werden paläomagnetische Daten vorgestellt. Generell ergibt sich eine rechtsseitige Rotation und nordwärts gerichtete Drift von mehreren hundert Kilometern für die einzelnen untersuchten Gebiete.

Diese Daten werden mit Ergebnissen aus den Südalpen und den Karpaten verglichen und diskutiert. Es ergibt sich, daß die Adriatische Platte in Kreide und Tertiär in mehrere Blöcke zerfallen ist, die während der alpidischen Orogenese verschiedene Rotationen ausgeführt haben. Die Grenzlinien der Blöcke sind auf Grund der vorhandenen Daten noch nicht erfaßbar.

Summary

From the Upper Austroalpine realm (Northern Calcareous Alps, Graywackezone) paleomagnetic data are presented. Generally, the result is a clockwise rotation and a northward drift of several hundred kilometers for the investigated regions.

These data are compared and discussed with results from the Southern Alps, the Apennines and the Carpathians. It leads to the conclusion that during the Cretaceous and Tertiary parts of the Adriatic Plate carried out different rotations during the Alpidic orogeny. The borders of these blocks cannot be defined unless new data are available.

Introduction

In the last decade a number of paleomagnetic data from the Apennine peninsula and the Southern Alps have been published showing an anticlockwise rotation of this region relative to Eurasia. For the Northern Calcareous Alps (NCA) which originally formed a coherent platform with the Southern Alps and the Adriatic region, HARGRAVES and FISCHER (1959) reported paleomagnetic data from Jurassic rocks of the Lofer area showing slight clockwise rotation relative to Eurasia. For a long time these first data from the NCA were disregarded, especially in the light of the overwhelming new data from Italy.

Adresse der Verfasser: * Institut für Geophysik der Montanuniversität Leoben.
** Institut für Geologie der Universität Wien, Universitätsstraße 7, A-1010 Wien.

New results from Jurassic rocks of the Osterhorn mountains in the central part of the Northern Calcareous Alps, however, confirm the data of HARGRAVES and FISCHER (1959). They suggest clockwise rotation of about 45°, and northward drift of several hundred kilometres relative to Eurasia, for the Osterhorn block. Lower Triassic rocks from the Wörgl area show the same trend (SOFFEL, pers. comm.). Lower to Middle Triassic rocks from the southern Dachstein mountains are problematic in their interpretation. Magnesites from the Northern Grauwacken zone, the basement of the NCA, in the Saalfelden area show coincidence with the Cretaceous paleomagnetic direction for Eurasia (MAURITSCH, this volume). This is discussed by MAURITSCH (this volume) in terms of recrystallization with slight Cretaceous metamorphism (SCHRAMM, 1977).

In the following new data from the Northern Calcareous Alps (NCA) are presented and compared with available data from the Southern Alps and Carpathians.

Analytical results

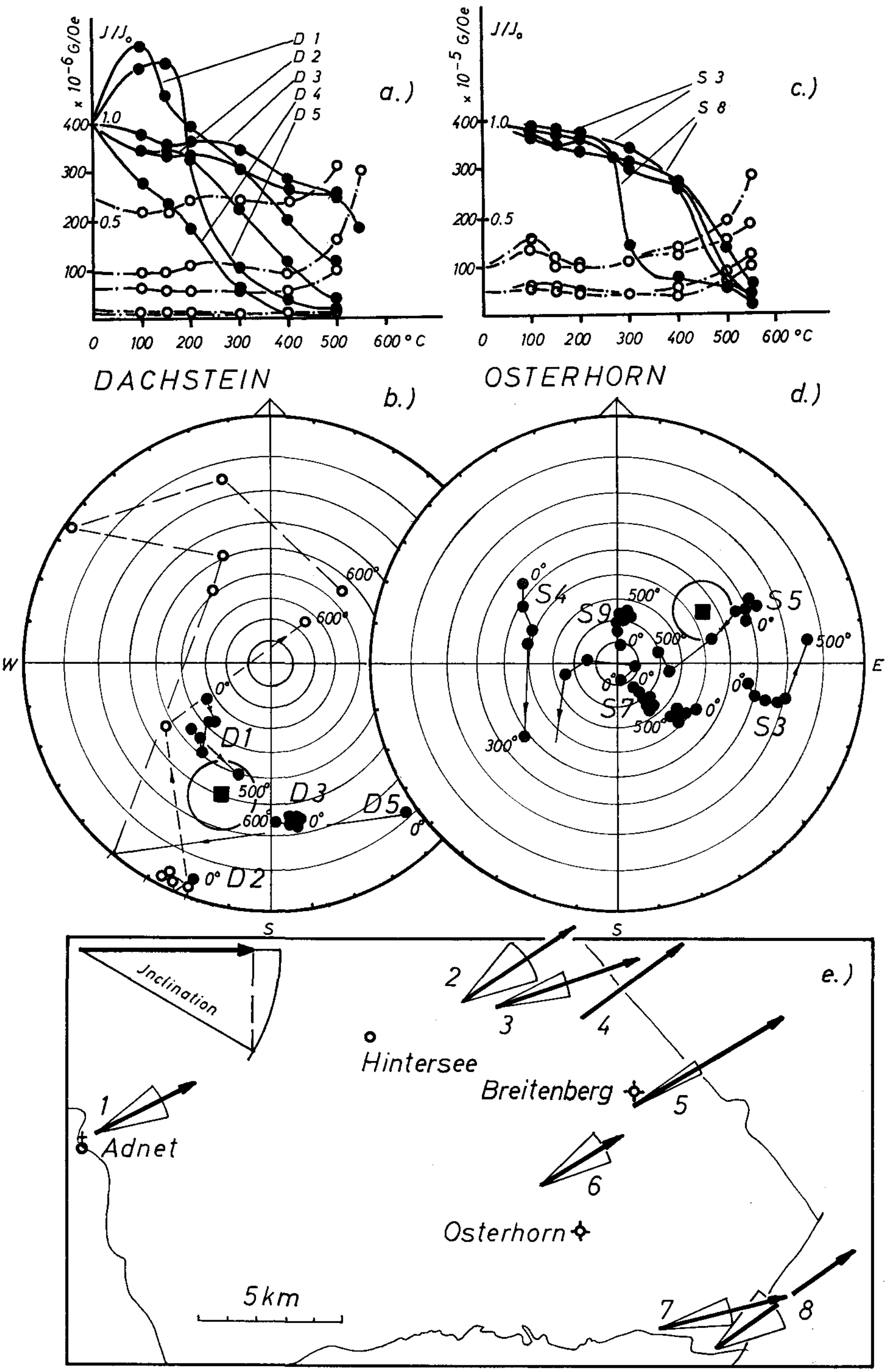
Dachstein-profile

In the Dachstein area a profile near the path from the station of the cable railway to the Südwandhütte was sampled from Scythian to Anisian. In 5 stratigraphic horizons 12 sites with 6–8 cores each, were taken. On one pilotsample per horizon rockmagnetic experiments were carried out and magnetite established as carrier of the natural remanent magnetisation (NRM). As it is shown in Fig. 1a and b some of the material is quite stable and therefore suitable for paleomagnetic use. All samples were cleaned at 300° C. After the tectonic correction a mean value of the paleodirection of magnetisation was found by Dec = 201,8 Inc = 29,7. This direction was taken into consideration in Table 1 just to present all available data, but no satisfying explanation for this direction was found till now. One has to think of the role of tectonics and metamorphism in this area (SCHRAMM 1977).

Osterhorn mountains

In the Osterhorn region two profiles in the Schafbachgraben and Saubachgraben were sampled and the stability of the magnetisation or, with other words, the suitability for paleomagnetic investigations were checked on a number of pilotsamples throughout the profiles (MAURITSCH and FRISCH, 1978). AC-field, thermal demagnetisation, saturation and low temperature experiments were carried out and magnetite established as carrier of the natural remanent magnetisation (NRM). However, the remarkable differences in the behaviour of different samples (Fig. 1c and d) caused further rockmagnetic studies and a second mineralisation was found with a blocking temperature of about 320° C by saturation

Fig. 1: a Shows the thermal demagnetisation behaviour of the pilots of the Dachsteinprofil (full line — normalized intensity, broken line — susceptibility).
b Stability test of the pilots, the square indicates the mean direction with the circle of confidence.
c Demagnetisation behaviour of the Osterhorn-pilots.
d Stability test of the Osterhorn-pilots and the mean direction for the Osterhorn area.
e Distribution of the magnetisation direction over the Osterhorn area.


a.)
J/J₀
× 10⁻⁶ G/Oe
D 1
D 2
D 3
D 4
D 5
1.0
0.5
400
300
200
100
0 100 200 300 400 500 600 °C
c.)
J/J₀
× 10⁻⁵ G/Oe
S 3
S 8
DACHSTEIN
b.)
OSTERHORN
d.)
W
E
S
D1
D2
D3
D5
S3
S4
S5
S7
S9
e.)
Jnclination
Hintersee
Breitenberg
Adnet
Osterhorn
5 km

magnetisation and coercivity spectra, and continued susceptibility measurements up to 400° C. The exact chemical composition of this second mineralisation is yet unknown; it is supposed to be geothite.

With this results in mind, paleomagnetic measurements started and uniform direction of the characteristic remanent magnetisation (ChRM) throughout the profiles (Loc. 2 and 3) was found (MAURITSCH and FRISCH 1978). Within the profiles the Liassic Adneter Limestone occurred as the most stable rock unit, and the continuations were carried out with this member. 8 localities with 32 sites were sampled and all material thermally cleaned at 300° C except locality 6 where AC-field was applied (400 Oe). The mean value for the whole Osterhorn massif showed a very good grouping (Fig. 1e) after the tectonic correction. The calculated virtual pole on one side and the low inclination on the other indicate a major rotation and drift of this unit since the magnetisation was built up. The Osterhorn montains have been rotated clockwise over at least 45°, the rotation angle depending on the used compilation of poles. In this case the poleposition after VAN DER VOO and FRENCH (1974) was used. An additional lateral shift is also necessary as shown in MAURITSCH and FRISCH (1978).

This data were combined with results from the area of Lofer (HARGRAVES and FISCHER 1959), Wörgl (SOFFEL pers. com.) and Entachen (MAURITSCH this volume). So the impression arose that the clockwise rotation is not a local phenomenon but characteristic for a larger tectonic unit.

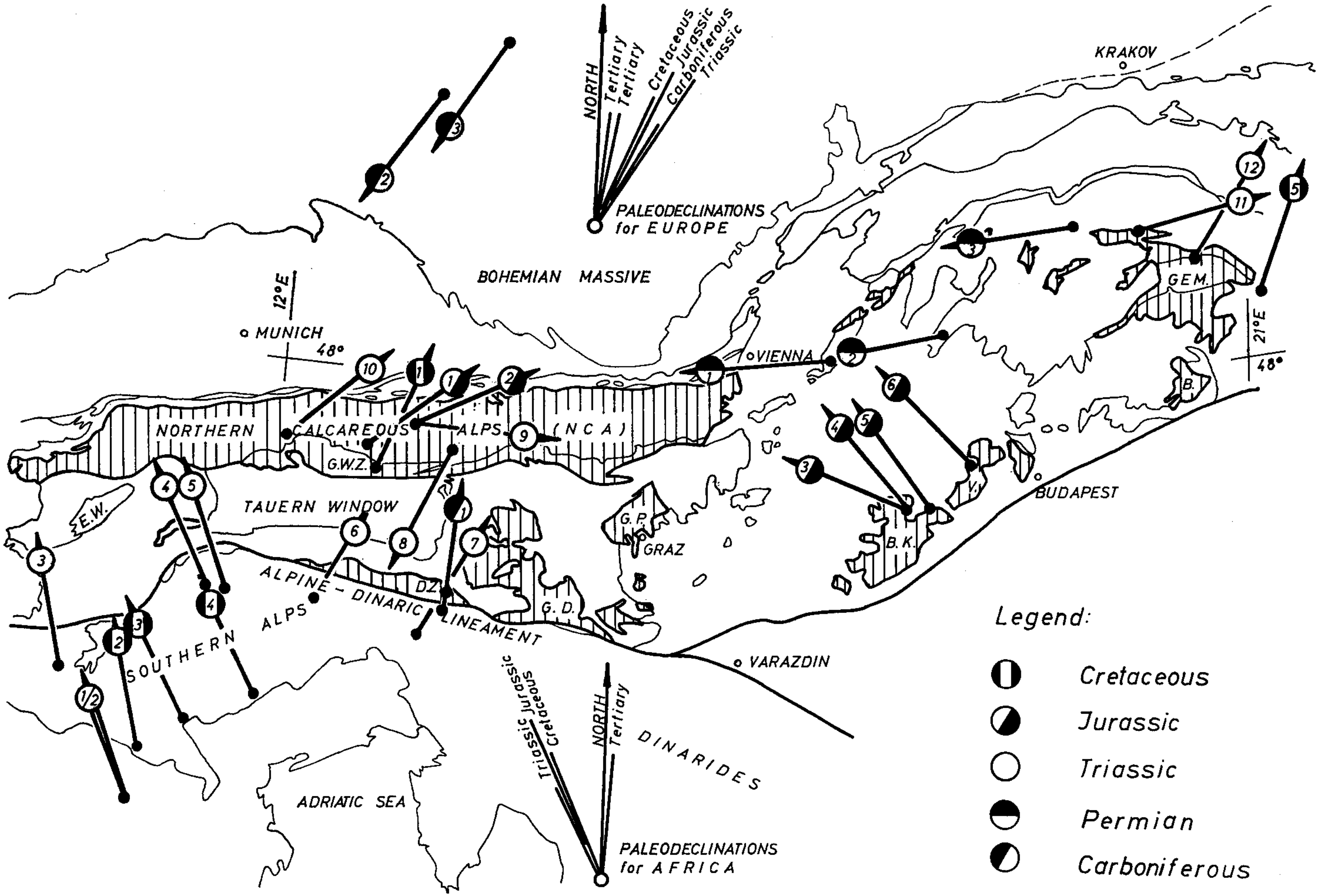
With this data from the NCA a comparison was tried with data from the Southern Alps and the Carpathians. All published data which were used (Table 1) were checked for their reliability in the sense of demagnetizing experiments, tectonic correction and stratigraphic position. A great help were the critical comments to a part of this data by MANZONI (1970) and ZIJDERFELD et. al. (1970, p. 640).

In Fig. 2 this data are plotted on the geological background after TOLLMANN (1969). Watching Fig. 2 one gets the impression that the clockwise and anticlockwise rotation are very distinctly located independent of known major tectonic structures. In the following an interpretation of these rotations in the light of recent plate tectonic models is tried.

Discussion of the results

The available data from the NCA are sufficient to decide that this tectonic unit in its entity did not behave like the great part of the Southern Alps, or the Apennine peninsula which both display anticlockwise rotation relative to Eurasia. CHANNELL and TARLING (1975) and, recently, VAN DEN BERG (1979) showed that the path of the paleomagnetic vectors of the Apennine peninsula is congruous with that of Africa. These results lead CHANNELL and HORVÁTH

Fig. 2: Distribution of Paleozoic and Mesozoic magnetisation directions in the Southern Alps, Eastern Alps and Carpathians. E.W. — Engadin window; G.W.Z. — Grauwackenzone; D.Z. — Drauzug; G.D. — Gurktalerdecke; G.P. — Grazer Paläozoikum; B.K. — Bakoný Mountains; V. — Veres Mountains; B. — Bükk Mountains; GEM. — Gemerides.



Paleomagnetic results from the Eastern Alps and their comparison

No.	Name	Author/ Year	Age	Treatm.	Area-lat.	Area-long	Palaeo-dec.	Palaeo-incl.	K	α_{95}	N	
1	Entachen	1/1979	Cretaceous	AC/Th.	47,32	13,00	022,0	75,0	431,0	5.9	32 sites	Cretaceous
2	Illasi	2/1974	Senonian	AC/Th.	45,48	11,20	330,5	36,5	69,0	15,0	3 sites	
3	Schio	2/1974	Senonian	AC/Th.	45,73	11,35	343,0	41,4	34,0	7,0	12 sites	
4	Valdobbiadene	2/1974	Cenomanian	AC/Th.	45,85	12,00	330,5	36,5	69,0	15,0	3 sites	
5	Bankov	3/1963	Cretaceous	AC/Th.	48,45	21,10	018,0	70,0	15,0	5,0	65 samples	
1	Lofer	4/1959	Lias		47,37	12,34	047,9	50,6	70,7	6,5	1 site	Jurassic
	Lofer	4/1959	Malmian		47,37	12,34	036,7	47,8	100,0	5,5	1 site	
2	Osterhorn	5/1978	Lias-Malm	Therm.	47,70	13,31	062,5	45,1	29,1	11,3	7 areas	
3	Bakonycsernye	6/1978	L-Jurassic	AC	47,29	18,11	306,7	55,6	41,8	2,7	11 sites	
4	Bakonycsernye	6/1978	M-Jurassic	AC	47,29	18,11	325,9	58,2	45,9	5,5		
5	Tata-kalvaria	6/1978	M-Jurassic	AC	47,64	18,32	326,2	62,4	44,1	7,8		
6	Tardosbanya	6/1978	M-Jurassic	AC	47,67	18,48	316,4	63,0	84,6	6,9		
1	Schio	7/1963	Triassic	AC	45,0	11,0	330,0	41,0	23,0	5,0		Triassic
2	Schio	7/1963	Triassic	AC	45,0	11,0	330,0	49,0				
3	Sclave	8/1969	Ladinian	AC	45,8	10,2	161,5	-21,5				
4	Dolomites	9/1970	Ladinian	AC	46,5	11,7	336,0	43,0				
5	Dolomites	9/1970	Ladin.-Carn.	AC	46,4	11,8	329,0	25,0			12 sites	
6	Dolomites	10/1965	Ladin.-Carn.				026,0	24,0			4 sites	
7	Julian Alps	11/1964	Ladin.-Carn				028,0	43,0			28 sites	
8	Dachstein	1/1979	Anis.-Scyth.	AC/Th.	47,50	13,60	201,8	29,7	10,0	14,9	12 sites	
9	Osterhorn	1/1979	Rhetian	Therm.	47,75	13,32	115,0	55,1			2 sites	
0	Wörgl	12/unpubl.	L.Triassic	Therm.	47,50	12,80	051,4	61,0			1 site	
1	Choč	13/1969	L.Triassic	AC/Th.	49,00	20,00	071,8	19,8	4,4	6,3	141 sampl.	
2	Choč	14/1965	L.Triassic	AC/Th.	48,83	20,50	029,2	16,9		5,33		
1	M.Karpaty	15/1977	U.Permian	AC/Th.	48,47	17,30	264,8	27,2		15,90		Permian
2	Tribec	15/1977	U.Permian	AC/Th.	48,48	18,53	258,3	-20,7		10,34		
3	Nizke Tatry	15/1977	U.Permian	AC/Th.	48,97	19,70	261,2	-28,7		11,80		
1	Nötsch	16/1979	L.Carb.	AC/Th.	46,31	13,37	003,0	09,0		9,0		Carboniferous
2	Plzen	17/1968	U.Carb.		49,8	13,3	214,7	02,1		5,09	65 sites	
3	Kladno	17/1968	U.Carb.		50,2	14,0	211,7	-05,4		2,95	73 sites	

nent as a promontory throughout the Alpidic orogenic period. From new data, (1976) to the conclusion that the Adriatic region was fixed to the African conti-VAN DEN BERG (1979) deduce that the Adriatic block separated in post-Early Eocene time from Africa and carried out a 25–30° anticlockwise rotation relative to Africa. By geologic reasons, FRISCH (1977, 1979, this vol.) suggests a somewhat earlier separation of the Adriatic plate, i.e. in about middle (late Lower) Cretaceous times.

Results from the Vicentinian Alps lead VAN DEN BERG (1979) to the conclusion that the Southern Alps were part of the Adriatic block or promotory up to the Lower Tertiary but did not carry out the 25–30° Tertiary rotation of the Adriatic block relative to Africa.

The paleomagnetic data from the Northern Calcareous Alps show, besides northward drift of several hundred kilometres, clockwise rotation relative to Eurasia which is now confirmed by several results (Table 1). The rotation angle varies in the different sampling areas between 20° and 50°. This is considered to be due to inaccuracies with the smoothing of local tectonics, and to differential movements between single blocks within the NCA during the thrusting processes. More data are still recommended to receive a valid and testified picture.

This particularly applies to the tectonically contorted southern margin of the NCA where SOFFEL (pers. comm.) reports deviating results from Permoscythian rocks.

The paleolatitude of the NCA resulting from the magnetic inclination values of Jurassic rocks, concede a paleoposition of this region as the northernmost part of the Adriatic region when forming a promontory to the African continent (CHANNELL and HORVÁTH, 1976; MAURITSCH and FRISCH, 1978). The clockwise rotation of the NCA is suggested by FRISCH (loc. cit.) to be induced by oblique continental collision of the northern margin of the Adriatic plate (meanwhile separated from Africa) with continental masses to the north in the Middle to Upper Cretaceous.

Clockwise rotation relative to Eurasia is not restricted to the Northern Calcareous Alps but is also reported from the eastern continuation of this unit in the Carpathians. KOTASEK and KRS (1965) report slight clockwise rotation (about 0–20°) in the Gemerids which correspond to the southern part of the NCA (TOLLMANN, 1965), and more prominent clockwise rotation (about 65°) in the Choč nappe (MUSKA and VOZAR 1978) which corresponds to the northern part of the NCA. The data derive from Permoscythian rocks.

The available data from the Adriatic region, the Southern Alps, the Upper Austroalpine of the Eastern Alps and its continuation into the Carpathians establish that these formerly coherent regions forming the Adriatic promontory, resp. the Adriatic plate, disintegrated into several blocks which behaved differently

Tab. 1: Table of the used Palaeomagnetic Data from the Eastern-Southern Alps and the Carpathians.
Authors: 1 — Mauritsch, 2 — Channell-Tarling, 3 — Hanus-Krs, 4 — Hargraves-Fischer, 5 — Mauritsch-Frisch, 6 — Marton-Marton, 7 — De Boer, 8 — Zijderfeld-De Yong, 9 — Manzoni, 10 — Chatterjee, 11 — Guicherit, 12 — Soffel, 13 — Krs, 14 — Kotasek-Krs, 15 — Muska-Vozar, 16 — Heinz-Mauritsch, 17 — Birkenmajer et al.

during the Alpidic orogeny in the Cretaceous and the Tertiary. At least we can discern three blocks:
(a) the Adriatic block s. str. (comprising the Apennine peninsula) which carried out the largest anticlockwise rotation relative to Eurasia;
(b) the South Alpine block which rotated around an angle of 25–30° less than the Adriatic block s. str. (VAN DEN BERG, 1979); and
(c) the Austroalpine-Carpathian block with very slight or even no rotation within the cone of confidence, but partly clear clockwise rotation relative to Eurasia.

Data from this last region are still too scarce to reconstruct the motions during Alpidic orogeny.

VAN DEN BERG and WONDERS (1976) showed that the differential rotation between the Apennine peninsula (Adriatic block s. str.) and the Southern Alps is compensated beneath the Po plain. The Periadriatic lineament, however, although responsible for major right-lateral slip motion during the Alpidic orogeny (e. g., TOLLMANN, 1978), cannot account for the differential rotation between the Southern and the Eastern Alps. This is shown by data from Lower Carboniferous strata on both sides close to the lineament: they display congruous paleomagnetic vectors (HEINZ and MAURITSCH, 1979, 1980). Here it is of interest that paleomagnetic results from Triassic rocks in the northeastern part of the Southern Alps show good agreement with the Triassic direction for Eurasia (GUICHERIT, 1964; CHATTERJEE, 1965). On the other hand, data from the Bakony exhibit major anticlockwise rotation (MARTON and MARTON, 1978).

The timing of disintegration of the northern part of the Adriatic plate, and the line separating the regions of differential movements between Southern Alps and Eastern Alps and Carpathians, are still insufficiently established. While the data from the Apennine peninsula are relatively dense, they are less so from the Southern Alps, and in particular scarce from the Northern Calcareous Alps. This contribution shall be a step in the direction of better understanding of the paleomotions of the northern margin of the Adriatic plate.

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