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Middle Triassic paleomagnetic data from northern Bulgaria: constraints on Tethyan magnetostratigraphy and paleogeography

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Abstract

Magnetostratigraphic and biostratigraphic data are presented from the Anisian (Middle Triassic) Peri-Tethyan Edivetur section of northwestern Bulgaria. A dual-polarity component of magnetization carried by magnetite delineates a magnetic stratigraphy of mainly reversed polarity. Magnetozones are dated by means of foraminifer and conodont biostratigraphy. Data from Edivetur are compared with data from Middle Triassic Tethyan limestone sections with the aim of contributing to the completion of the Middle Triassic magnetic polarity time scale. We also propose that paleomagnetic data from Edivetur can be used as proxy data for the paleogeographic position of the Moesian platform. The Moesian platform was located at 21–24°N along the southern margin of Europe. It was probably marginally separated, but not detached or rotated away from Europe by the North Dobrugea transtensional trough, which is interpreted as a back-arc basin resulting from the northward subduction of the Neo-Tethys (Vardar) or Paleo-Tethys ocean. Paleomagnetic data from this study and other minor tectonic elements are used to generate a paleogeographic sketch map of the Pangea-bounded western Tethys and Peri-Tethys at Middle/early Late Triassic time. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Balkanides; Bulgaria; magnetostratigraphy; Middle Triassic; Moesia; paleogeography

1. Introduction

Middle Triassic magnetostratigraphy and biostratigraphy have been investigated in both Tethyan marine and continental sequences (e.g. Molina-Garza et al., 1991; Gallet et al., 1998; Muttoni et al., 1998). In the Tethys realm, a total of 29 biostratigraphically calibrated reversals were recognized over the late Early Triassic to late Middle Triassic interval of perhaps 10–15 m.y. length (Muttoni et al., 1998). This sequence of reversals, here upgraded with data from Gallet et al. (1998), is, however, still incomplete, especially in the Anisian (Middle Triassic). This paper presents magnetostratigraphic and biostratigraphic results from the Aegean to upper Illyrian (Anisian)

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Edivetur section of northwestern Bulgaria with the aim of contributing to the completion of the Middle Triassic marine magnetic polarity time scale tied to ammonoid, conodont and foraminifer biostratigraphy. This study also represents the first attempt to correlate magnetostratigraphic and biostratigraphic data from the Peri-Tethyan marine environment to data from the literature from the Tethyan marine realm.

The paleomagnetic data from Edivetur can also be used to constrain the paleogeographic position of northwestern Bulgaria, and tentatively of the Moesian platform of northern Bulgaria and southern Romania, in the Middle Triassic. The Moesian platform is considered to be of European affinity (e.g. Robertson and Dixon, 1984; Sengor et al., 1984; Dercourt et al., 1993), and either occupied the region of the modern-day Carpathian loop (Robertson and Dixon, 1984), or was not substantially displaced from its present-day position with respect to stable Europe (Dercourt et al., 1993). However, to date, no useful paleomagnetic data have been produced to help resolve this conundrum.

2. Geology

2.1. Regional geological setting

The study area at Edivetur north of Belogradchik in northwestern Bulgaria pertains to the Fore-Balkan zone (Fig. 1a). The Fore-Balkan is the frontal, less deformed portion of the north-vergent Balkanides thrust-and-fold belt that originated as a consequence of Africa/Europe convergence in the Cenozoic. The Balkanides comprise pre-Alpine basement rocks overlain by Mesozoic to Paleogene sediments. Deformation in the Balkanides occurred in the Late Triassic, Middle Cretaceous, Late Cretaceous, and, most severely, Paleogene. The Fore-Balkan makes transition to the north to the Moesian platform of Northern Bulgaria and southern Romania (Fig. 1a). The Moesian platform comprises Paleozoic to Cenozoic sediments presently buried under the Neogene and Quaternary loess and alluvial cover of the Danube river plain. These sediments, characterized by virtually no tectonic deformation, are known from borehole data to be very similar to coeval sediments from the Balkanides.

The Triassic succession of the Balkanides, as well as the Moesian platform, is of the Peri-Tethyan type and, from bottom to top, consists of (Tronkov, 1973; Tronkov in Tenchov, 1993; Zagorchev and Budurov, 1997):

1. The Petrohan Terrigenous Group, comprising continental red beds with Buntsandstein (Germanic) affinity.
2. The Iskur Carbonate Group, characterized predominantly by shallow-marine limestones and dolomites with subordinate marls and shales.
3. The Moesian Group, which consists of marine shales, siltstones and sandstones, intercalated with thick conglomerate and breccia layers with horst-derived Triassic carbonate pebbles, and occasional limestone beds.

2.2. Geological setting of the Belogradchik area

At the Belogradchik anticlinorium, the Triassic sedimentary succession covers disconformably Permian terrigenous sediments (Fig. 1b). North of Belogradchik, along the Granitovo strip, the Triassic sequence overlies with a depositional contact Paleozoic weathered granitoids. Most probably, these granitoids were emergent during most of the Permian and earliest Triassic times, and were gradually covered by Lower Triassic continental deposits and, subsequently, by sediments related to the Triassic marine transgression. The lower part of the Triassic sequence in the Belogradchik area comprises the Petrohan Terrigenous Group as subdivided into a conglomerate-sandstone formation and the Slivovnik Formation. The conglomerate-sandstone formation consists of reddish, thick-bedded, coarse-grained clastic rocks, bearing mainly quartz grains and pebbles, and characterized by graded and/or cross bedding. Its thickness, laterally variable, is of about 200 m at Belogradchik. The Slivovnik Formation replaces the conglomerate-sandstone formation in the Granitovo strip area (Fig. 1b) and consists of light-reddish, pink or grayish-white coarse arkosic sandstones. The lower contact with the Paleozoic granites is often difficult to observe

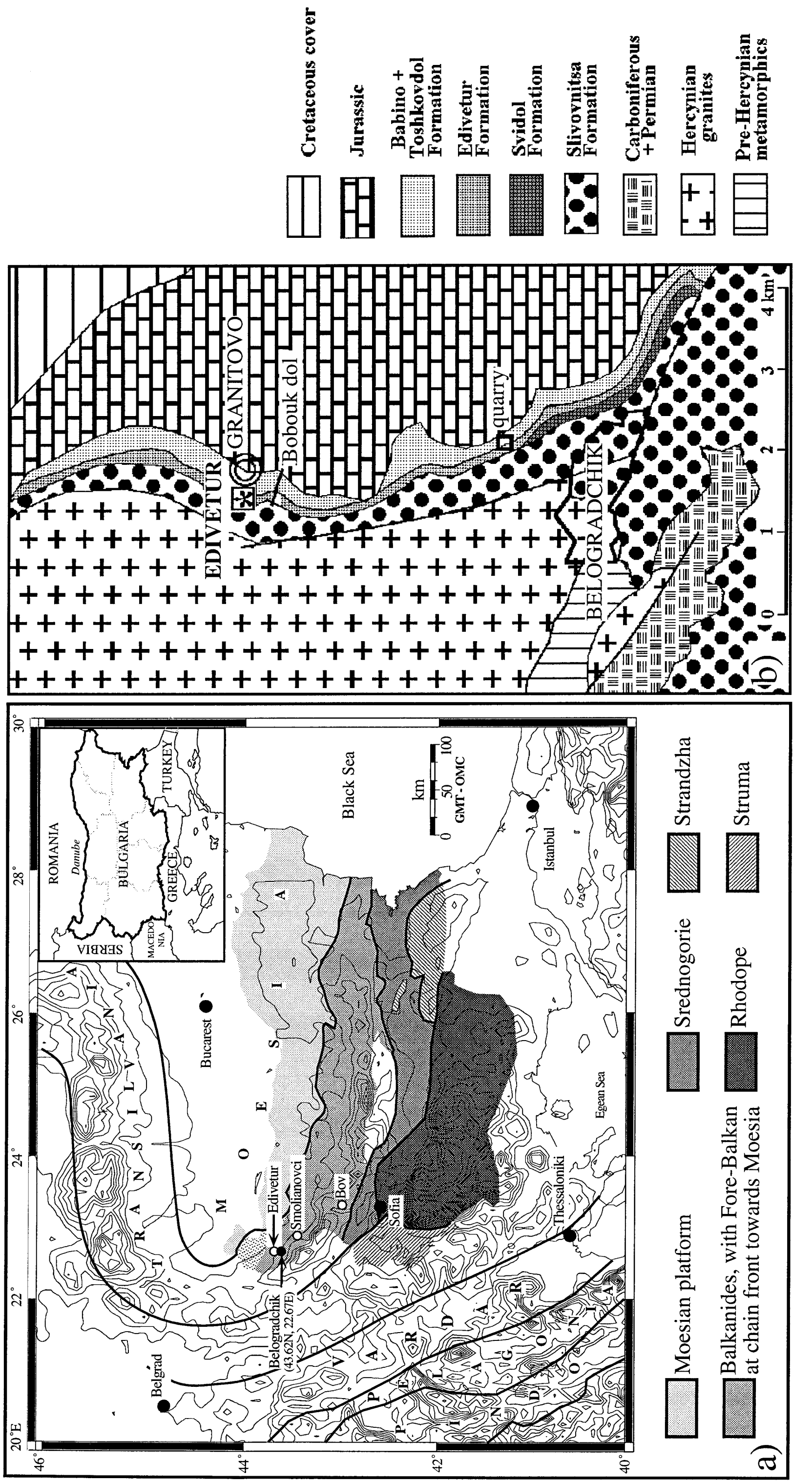


Fig. 1. (a) Simplified geological map of Bulgaria. The study section is located at Edivetur close to the village of Granitovo and about 4 km north of the town of Belogradchik in northwestern Bulgaria; the localities of Smolianovci and Bov of Nozharov et al. (1980) are also reported. (b) Detailed geological map of the study area (after Haydoutov et al., 1995) with the location of the Edivetur sampling section in the Edivetur Formation.

because the Slivovnik basal arkosic sandstones are very similar to the weathered granitoids from which they derived. The marine ingression is represented by the overlying Iskur Carbonate Group. The basal part of the Iskur Carbonate Group, transgressional over the conglomerate-sandstone formation, comprises the Svidol Formation, which consists of alternating reddish, pink, yellowish and gray siltstones, marls and limestones. According to Tronkov (1973) and Tronkov (in Tenchov, 1993), the Svidol Formation is gradually thinning out and is laterally replaced by the Edivetur Formation, which can be followed as a thin strip only along the northern limb of the Belogradchik anticlinorium where it reaches a thickness of 20 m at the type section of Edivetur (Fig. 1b). The Edivetur Formation, which is the object of this study, is characterized by calcareous sandstones and oolithic, biodetrital limestones light brownish or whitish gray in colour, often containing foraminifers at the core of large ooids. The Iskur Carbonate Group ends with the Babino Formation (Tronkov, 1973; Tronkov in Tenchov, 1993). This formation, well exposed along the nearby Bobouk Valley, consists of nodular clayey-silty limestones, sandy limestones and sandy marls, with thin interbeds of pure limestones, containing brachiopods, bivalves and crinoid ossicles. The thickness of this formation in the Granitovo strip is of about 50 m or less.

3. Biostratigraphy

3.1. Petrohan Terrigenous Group

The Petrohan Terrigenous Group is considered Early Triassic in age because it lies immediately below biostratigraphically dated Middle Triassic sediments. Moreover, at the village of Belotintsi (Vidin District), the plant species *Equisetites mougeoti* Brogniart, known from the Early Triassic of Germany, France and Yugoslavia (Harkovska and Tenchov, 1963), was found in the portion of the conglomerate-sandstone formation which, according to Tronkov (in Haydoutov et al., 1995), correlates with the Slivovnik Formation.

3.2. Edivetur Formation of the Iskur Carbonate Group

The Edivetur Formation contains a rich foraminifer fauna with, among others, *Meandrospira deformata* Salaj, *Nodosaria* cf. *scyphica* Efimova, *Nodosaria expolita* Trifonova, *Pilammina densa* Pantic, *Glomospirella vulgaris* Ho, *Meandrospira dinarica* Kochansky-Devide & Pantic, *Arenovidalina chialingchiangensis* Ho, *Earlandia tintinniformis* (Misik), *Pilamminella semiplana* Kochansky-Devide & Pantic, *Ophthalmidium exiguum* Koehn-Zanninetti and *Oberhauserella mesotriasica* Fuchs. The Edivetur Formation is attributed to *M. deformata* and *P. densa* foraminifer zones of Aegean to upper Illyrian (Anisian) age (Fig. 2). Conodonts in the Edivetur Formation are scarce. Fragments of platform conodonts, probably *Paragondolella* cf. *bulgarica* Budurov & Stefanov or *Paragondolella* cf. *regale* (Mosher), were found in sample Gr15 (Fig. 2). These conodonts are attributed to the Pelsonian (Anisian), in general agreement with foraminifer biostratigraphy. The ramiform element *Enantiognathus ziegleri* (Diebel) of Triassic age was found in sample Gr16. In Bulgaria, this element is not known to occur in the earliest part of the Triassic, as well as after the earliest Carnian (earliest Late Triassic). The range of *E. ziegleri* was, however, probably controlled by peculiar environmental conditions in the Peri-Tethyan realm.

3.3. Babino Formation of the Iskur Carbonate Group

Budurov (1960, 1962) found the first conodont assemblage in the Babino Formation from the Granitovo strip with specimens of '*Gondolella mombergensis* Tatge' and '*Gondolella navicula* Huckriede'. After taxonomic revision, these condont taxa are referred in this study to *Paragondolella bulgarica* Budurov & Stefanov and *Paragondolella hanbulogi* Sudar & Budurov, respectively. We found additional specimens of *P. bulgarica and P. hanbulogi* at Babino Formation sections located in the Bobouk Valley and in a quarry on the road Belogradchik-Oreshets (Fig. 1b). At these localities, the Babino

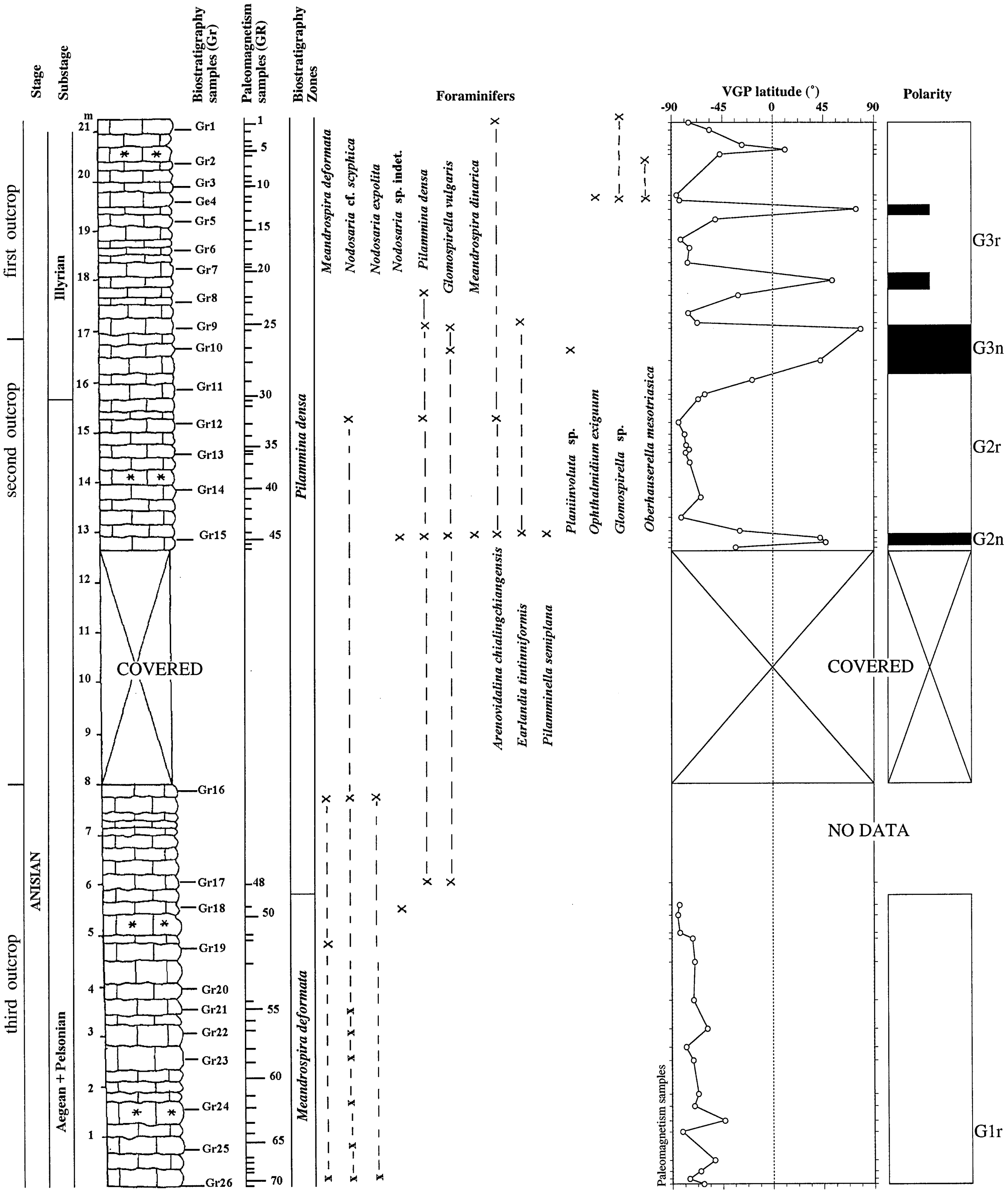


Fig. 2. Magnetostratigraphic and biostratigraphic data from the Edivetur section. The age determination is based on foraminifer biostratigraphy and straddles the Aegean to Illyrian (Anisian) time interval (the Anisian Stage is subdivided, from bottom to top, into Aegean, Bithynian, Pelsonian and Illyrian). To the right of biostratigraphy data is a plot of relative VGP latitudes of the characteristic component as a function of stratigraphic position with polarity interpretation. Magnetic polarity zones are shown by filled and open bars for normal and reversed polarity, respectively; single-sample polarity zones are shown by half bars.

Formation contains conodont index species and other diagnostic taxa that define the *P. bulgarica* Zone and part of the *Pridaella cornuta* Zone of complessively part of the Aegean to Illyrian (Anisian) age.

Until recently, the Babino Formation was referred to as the middle–upper part of the Anisian, and the Edivetur Formation to the lower part of the Middle Anisian (cf. Tronkov, 1973). However, in the locality of Edivetur, a lateral transition of the Babino and Edivetur formations is observed. Our new biostratigraphic results confirm that the two formations are partly coeval.

4. Paleomagnetism

4.1. Paleomagnetic tecniques

A total of 71 cores were collected in the Edivetur Formation at the type locality of Edivetur north of Belogradchik (Fig. 1b) with a water-cooled rock drill and oriented with a magnetic compass. The natural remanent magnetization (NRM) of 70 standard 11.4 cm^3 specimens was measured on a 2G DC-squid cryogenic magnetometer at the paleomagnetics laboratory of ETH Zürich (one core sample, i.e. GR68, did not survive cutting in the laboratory). Basic rock-magnetic experiments were performed in order to determine the magnetic mineralogy content of the Edivetur Formation. After pilot thermal and AF demagnetization studies, all specimens were subjected to progressive thermal demagnetization. A least-square analysis was applied to determine the component directions of NRM (Kirschvink, 1980), chosen by inspection of vector end-point demagnetization diagrams (Zijderveld, 1967). Site mean directions were determined using standard Fisher statistics.

4.2. Rock magnetic properties

The mean NRM intensity is around 6×10^{-5} A/m. The magnetic susceptibility is generally very low but stable during the thermal demagnetization treatment. Acquisition curves of isothermal remanent magnetization (IRM) show the presence of a mixture of high and low coercivity components (Fig. 3a). The high coercivity component(s) does not saturate up to the maximum applied field of 1 T, whereas the low coercivity phase tends to saturate at around 0.2 T. Thermal unblocking characteristics of orthogonal-axes IRM (Lowrie, 1990) show that most of the samples are dominated by the low coercivity phase characterized by maximum unblocking temperatures of about 570°C (Fig. 3b). This main magnetic component, which is interpreted as a magnetite phase, coexists with high coercivity phases with maximum unblocking temperatures around 100 and 650°C, which are interpreted as goethite and hematite, respectively.

4.3. Paleomagnetic directions

Thermal demagnetization of the NRM reveals the presence of an occasional initial component of in-situ steep positive inclination consistent with viscous acquisition along the present-day field direction; this component unblocks between room temperature and 200°C (Fig. 4). A dual-polarity characteristic ('Ch') component of magnetization with dominant southwest and negative directions was obtained in 71% of the specimens in the temperature range between about 200 and 500–560°C. In 7% of the specimens, the 'Ch' component could not be isolated with confidence since successive demagnetization steps moved the remanence vector along a great circle from the present-day towards the 'Ch' direction (the remaining 22% of the specimens yielded unstable paleomagnetic directions during thermal demagnetization treatment).

The 'Ch' component becomes slightly shallower upon correction for bedding tilt (Fig. 5). The average bedding attitude is 59E/20 (azimuth of dip/dip). The overall mean direction in tilt-corrected coordinates, obtained by inverting to common normal polarity the $N=50$ reversed and normal characteristic directions, is Dec. 37.6°E, Inc. 42.2° ($k=7$, $\alpha_{95}=8.4°$) (Table 1).

5. Magnetostratigraphy

A virtual geomagnetic pole (VGP) was calculated for each 'Ch' component stable endpoint

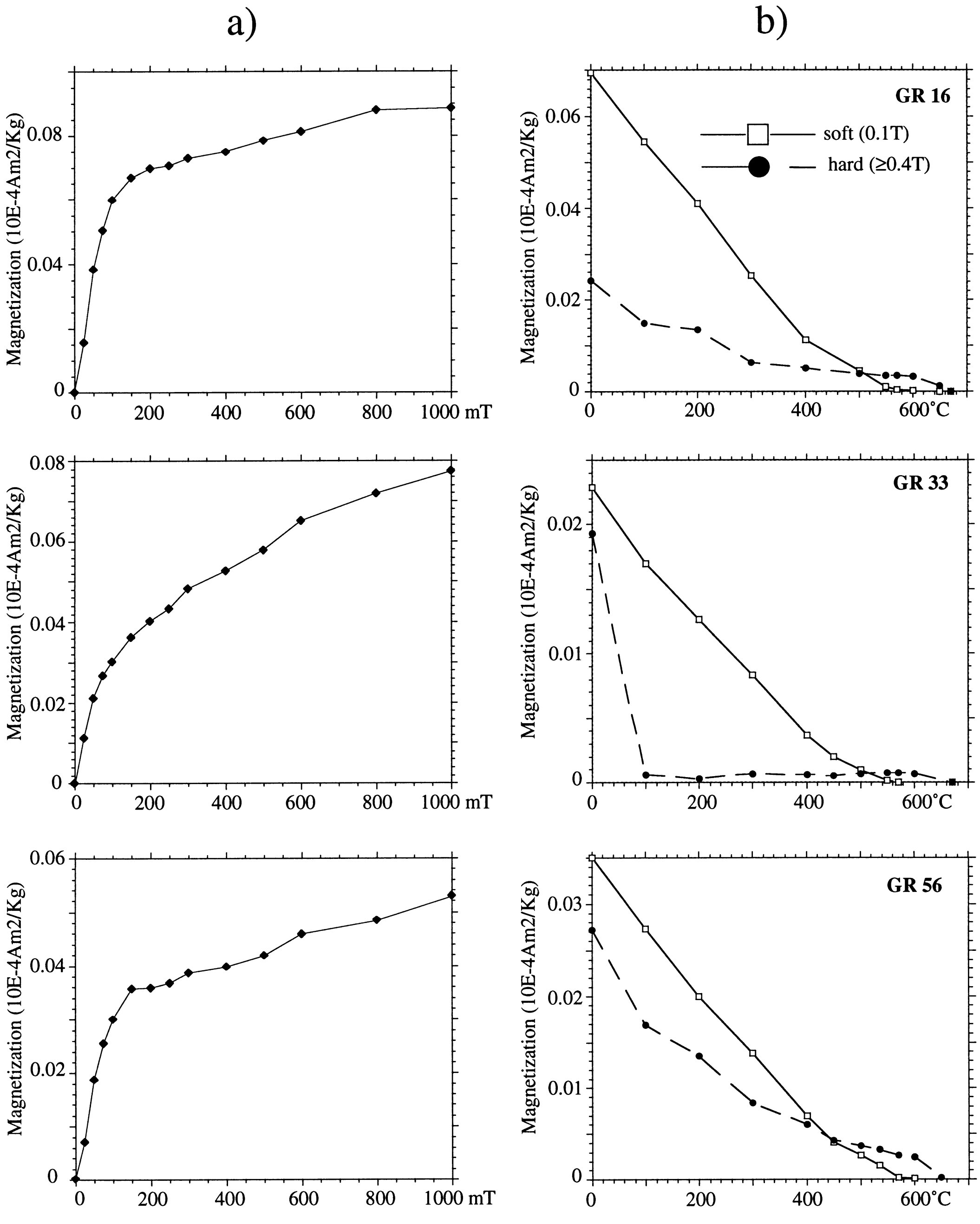


Fig. 3. Rock magnetic properties of selected Edivetur Formation samples were deduced from (a) acquisition curves of isothermal remanent magnetization (IRM) and (b) thermal unblocking characteristics of orthogonal-axes IRMs (Lowrie, 1990). See text for discussion.

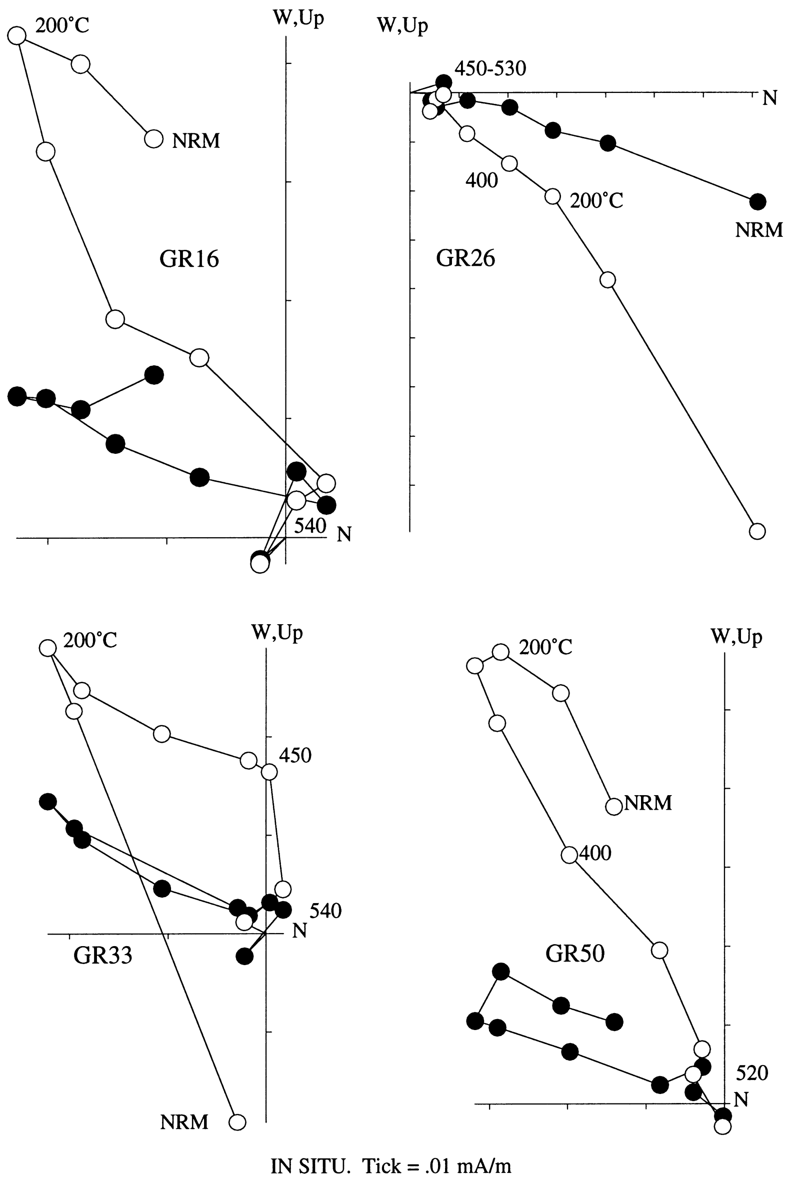


Fig. 4. Zijderveld thermal demagnetization diagrams of NRM of selected Edivetur Formation samples bearing characteristic magnetizations of reversed (GR16, GR33, GR50) and normal (GR26) polarity. Closed symbols are projections onto the horizontal plane, and open symbols are projections onto the vertical plane in in-situ coordinates. Demagnetization temperatures are in °C.

direction after correction for bedding tilt. The latitude of the specimen VGP with respect to the overall mean north paleomagnetic pole was used to delineate the magnetic polarity stratigraphy (Lowrie and Alvarez, 1977; Kent et al., 1995). VGP relative latitudes approaching +90°N and −90°N are interpreted as recording normal and reversed polarity, respectively. For polarity magnetozone identification, we adopt the nomenclature used by Kent et al. (1995). The VGP latitudes at Edivetur define a lower reversed (G1r)–normal (G2n)–reversed (G2r)–normal (G3n)–reversed

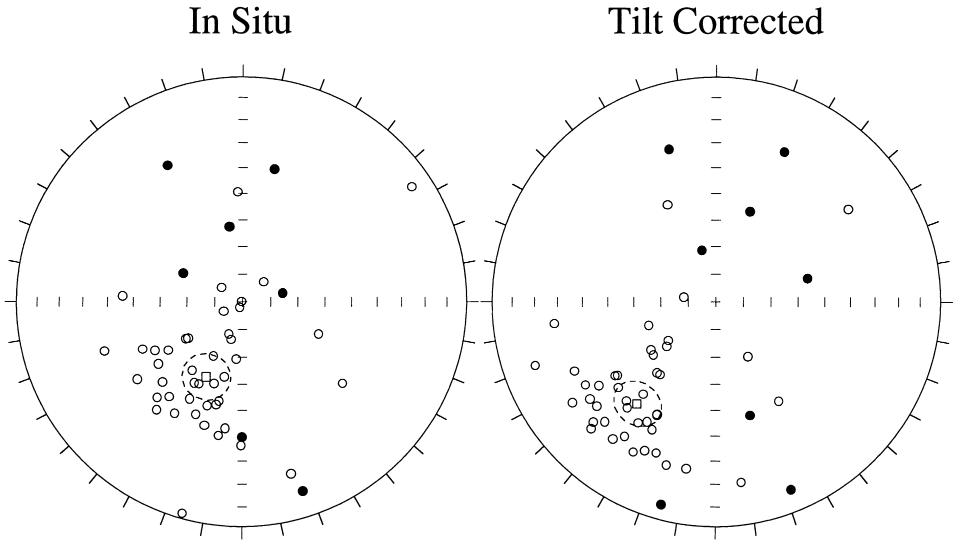


Fig. 5. Equal-area projections before (in situ) and after bedding tilt correction of the characteristic component directions from the Edivetur Formation.

(G3r) polarity sequence (Fig. 2). Two normal polarity intervals, each defined by only one sample and therefore reported as half bars in the magnetic polarity column, are embedded within reversed magnetozone G3r (Fig. 2). The Pelsonian/Illyrian boundary as based on foraminifer biostratigraphy falls between about meters 15.5 and 17 at the top of reversed polarity magnetozone G2r.

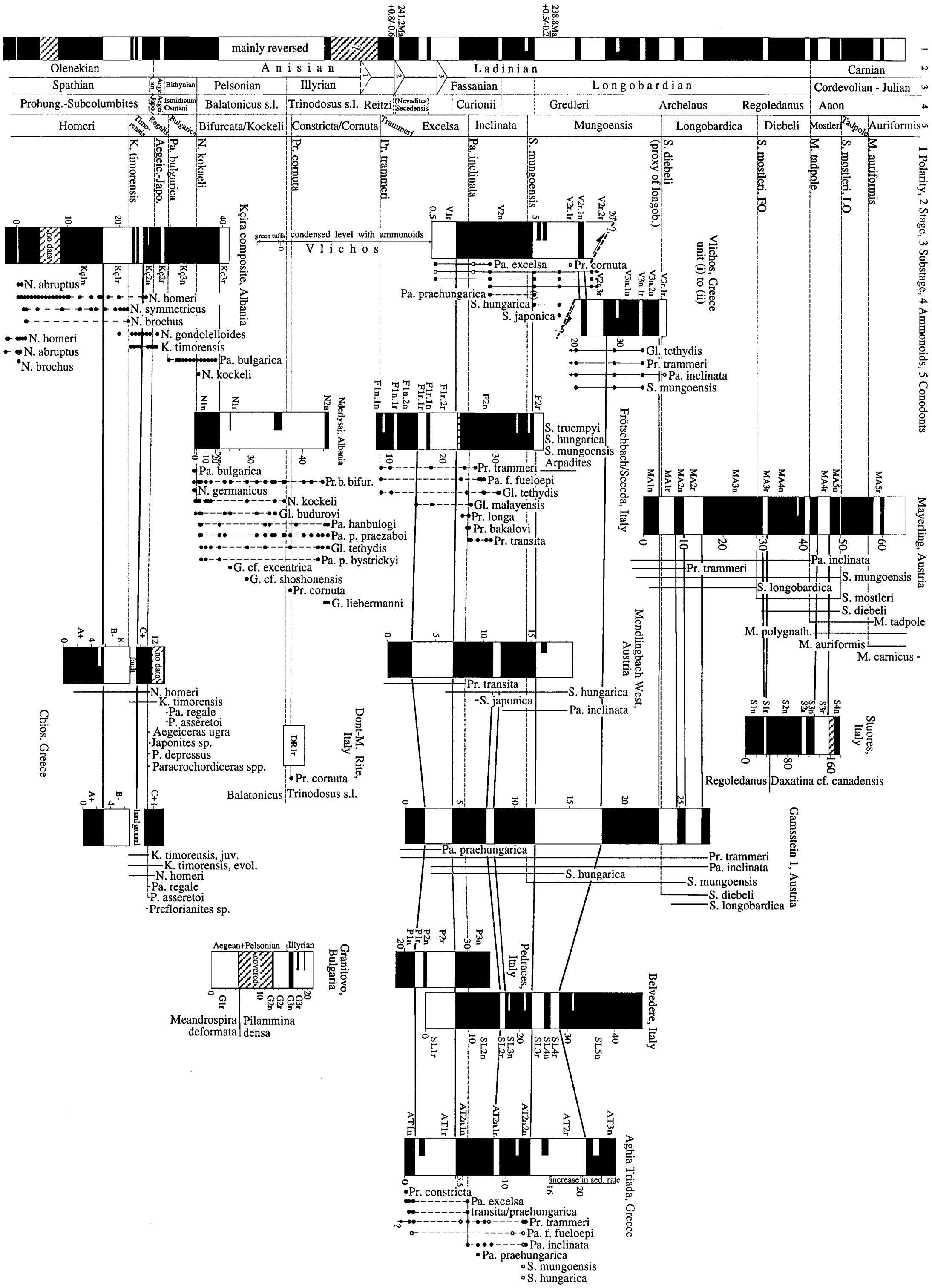
5.1. Correlations with sections from the literature

We compare our results from Edivetur with data from the literature from Kçira, Chios, Nderlysaj, Dont-Monte Rite, Vlichos, Frötschbach/Seceda and Aghia Triada (Muttoni et al., 1998 and references therein), Pedraces and Belvedere (Brack and Muttoni, in press), Mendlingbach, Gamsstein and Mayerling (Gallet et al., 1998), and Stuores (Broglio Loriga et al., 1999) (Fig. 6). Data from Edivetur complete partially this Middle Triassic composite record across the Pelsonian/Illyrian (Anisian) boundary. We propose that the predominantly reversed magnetic polarity stratigraphy of the Edivetur Formation partly correlates with the reversed portion of the Nderlysaj section from the Albanian Alps as well as with the Dont-Monte Rite section from the Dolomites. Precise correlation amongst these sections is, however, at present hardly possible because of the fragmentation and incompleteness of the magneto-biostratigraphic data in the Illyrian-basal Ladinian time interval.

Table 1
Paleomagnetic directions from the Edivetur Formation

		In-situ				Tilt-corrected			
	N_1/N_2	Dec.	Inc.	k	α_{95}	Dec.	Inc.	k	α_{95}
	71/50	25.5°E	59.7°	7	8.5°	37.6°E	42.2°	7	8.4°
Paleopole						Long. = 132.4°E	Lat. = 53.8°N	dp/dp = 6.3/10.3°	

N_1 is the number of standard 11.4cc specimens cut from core samples; N_2 is the number of the paleomagnetic directions used to calculate the mean. Dec., Inc.: declination and inclination; k: Fisher precision parameter; α_{95}: Fisher radius of cone of 95% confidence about the mean direction; Long., Lat.: longitude and latiude of paleomagnetic ploe; dp/dp confidence oval abot the paleomagnetic pole.


241.2Ma +0.8/-0.6
238.8Ma +0.5/-0.2
mainly reversed
Olenekian
Anisian
Ladinian
Carnian
Spathian
Pelsonian
Illyrian
Fassanian
Longobardian
Cordevolian - Julian
Prohung.-Subcolumbites
Bithynian
Ismidicum Osmani
Balatonicus s.l.
Trinodosus s.l.
Reitzi
(Nevadites) Secedensis
Curionii
Gredleri
Archelaus
Regoledanus
Aaon
Homeri
Bifurcata/Kockeli
Constricta/Cornuta
Excelsa
Inclinata
Mungoensis
Longobardica
Diebeli
Mostleri
Auriformis
1 Polarity, 2 Stage, 3 Substage, 4 Ammonoids, 5 Conodonts
K. timorensis
Aegeic.-Japo.
Pa. bulgarica
N. kockeli
Pr. cornuta
Pr. trammeri
Pa. inclinata
S. mungoensis
S. diebeli (proxy of longob.)
S. mostleri, FO
M. tadpole
S. mostleri, LO
M. auriformis
Kçira composite, Albania
condensed level with ammonoids
green tuffs
Vlichos
Vlichos, Greece unit (i) to (ii)
N. abruptus
N. homeri
N. symmetricus
N. brochus
N. gondolelloides
K. timorensis
Pa. bulgarica
N. kockeli
Pa. excelsa
Pr. cornuta
Pa. praehungarica
S. hungarica
S. japonica
Gl. tethydis
Pr. trammeri
Pa. inclinata
S. mungoensis
Nderlysaj, Albania
Frötschbach/Seceda, Italy
S. truempyi
S. hungarica
S. mungoensis
Arpadites
Pa. bulgarica
Pr. b. bifur.
N. germanicus
Pa. f. fueloepi
Gl. tethydis
N. kockeli
Gl. budurovi
Gl. malayensis
Pr. longa
Pr. bakalovi
Pr. transita
Pa. hanbulogi
Pa. p. praezaboi
Gl. tethydis
Pa. p. bystrickyi
G. cf. excentrica
G. cf. shoshonensis
Pr. cornuta
G. liebermanni
Mayerling, Austria
Pa. inclinata
Pr. trammeri
S. mungoensis
S. longobardica
S. mostleri
S. diebeli
M. tadpole
M. polygnath.
M. auriformis
M. carnicus -
Mendlingbach West, Austria
Pr. transita
S. hungarica
-S. japonica
Pa. inclinata
Chios, Greece
no data
fault
N. homeri
K. timorensis
-Pa. regale
-P. asseretoi
Aegeiceras ugra
Japonites sp.
P. depressus
Paracrochordiceras spp.
Dont-M. Rite, Italy
Pr. cornuta
Balatonicus
Trinodosus s.l.
Stuores, Italy
Regoledanus
Daxatina cf. canadensis
Gamsstein 1, Austria
hard ground
Pa. praehungarica
Pr. trammeri
Pa. inclinata
S. hungarica
S. mungoensis
S. diebeli
S. longobardica
K. timorensis, juv.
K. timorensis, evol.
N. homeri
Pa. regale
P. asseretoi
Preflorianites sp.
Granitovo, Bulgaria
Aegean+Pelsonian
Illyrian
covered
Meandrospira deformata
Pilammina densa
Pedraces, Italy
Belvedere, Italy
Aghia Triada, Greece
increase in sed. rate
Pr. constricta
Pa. excelsa
transita/praehungarica
Pr. trammeri
Pa. f. fueloepi
Pa. inclinata
Pa. praehungarica
S. mungoensis
S. hungarica

Finally, it is still difficult to incorporate or correlate the magnetic polarity stratigraphy from mainly continental redbed sections from Eastern Spain and Western US (Molina-Garza et al., 1991) because of the limited and endemic biostratigraphic control and the generally lower sampling resolution in the available continental sequences for the Middle Triassic.

6. Tectonic interpretation

The paleomagnetic data from Edivetur yield a tilt-corrected paleomagnetic pole that lies at Long. 132°E, Lat. 54°N (Table 1) very close to the Triassic portion of the Laurussia apparent polar wander path of Van der Voo (1993) (Fig. 7). A paleolatitude of about 24°N and a declination of 38°E at Edivetur compare well with the value of paleolatitude and declination of 21°N/40°E expected at Edivetur from the upper Middle Triassic Laurussia paleopole. The agreement is further enhanced if only the $N=42$ full polarity directions at Edivetur are taken into account (i.e. excluding $N=8$ directions with VGP latitudes comprised between -45 and 45°), which yield a value of paleolatitude of 21.5°N and declination of 38°E. These data suggest that no significant tectonic displacement with respect to stable Europe took place at Edivetur since the Middle Triassic, i.e. during deformation of the Balkanides in the Mesozoic and Cenozoic. No useful paleomagnetic data are presently available from the Moesian platform located north of the Balkanides thrust-and-fold belt (Fig. 1a). We propose that data from Edivetur, located at the very front of the Fore-Balkan, north of the major north-vergent Eocene thrusts, can be used as proxy data for the paleogeographic position of the adjacent Moesian platform,

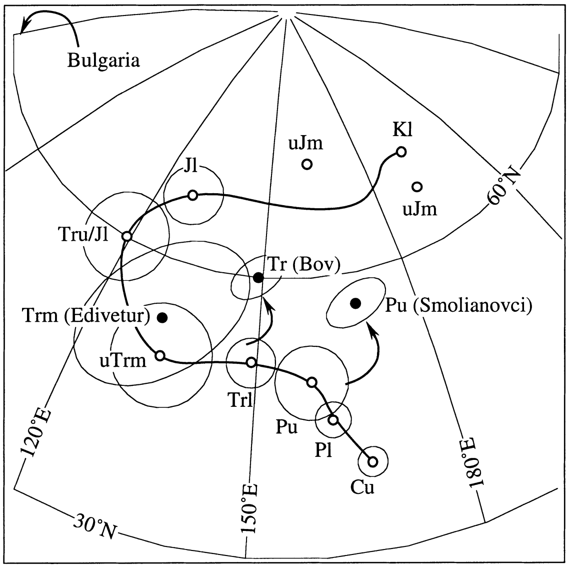


Fig. 7. Paleomagnetic pole from the Middle Triassic Edivetur Formation of this study and Late Permian and Triassic sediments from Smolianovci and Bov, respectively (Nozharov et al., 1980) (black dots), are compared with the apparent polar wander path of Laurussia of Van der Voo (1993, table 5.7) (white dots). 'Cu' is Upper Carboniferous, 'Pl' il Lower Permian, 'Pu' is Upper Permian, 'Trl' il Lower Triassic, 'uTrm' is upper Middle Triassic, 'Tru/Jl' is Upper Triassic/Lower Jurassic', 'Jl' is Lower Jurassic, 'uJm' is upper Middle Jurassic (two options, see Van der Voo, 1993, table 5.7), and 'Kl' is Lower Cretaceous.

whose European affinity therefore finds paleomagnetic confirmation.

Paleomagnetic data from Late Permian and Triassic sediments from Smolianovci and Bov, respectively (Nozharov et al., 1980) (Fig. 1a) seem to indicate, instead, that a small, approximately 10–15° counter-clockwise rotation with respect to Europe/Moesia occurred south of the study area (Fig. 7). These and other localities from the Balkanides (Bergerat et al., 1998 and references

Fig. 6. Comparison of magneto-biostratigraphic data from the Edivetur section with data from the Tethys for the late Early to Middle Triassic time interval. Note the revised interpretation of the Vlichos section magnetostratigraphy with respect to Muttoni et al. (1998). Conodont names are taken from the original publications. According to two of us (K.B. and L.P.), however, conodont generic names should be changed as follows: *Gondolella regalis*, *G. excelsa*, *G. inclinata*, *G. praehungarica*, *G. fueloppi*, *G. bulgarica*, *G. hanbulogi*, *G. praezaboi*, *G. bystrickyi*, to *Paragondolella regale*, *Pa. excelsa*, *Pa. inclinata*, and so on; *Gondolella trammeri*, *G. cornuta*, *G. bakalovi*, *G. longa*, *G. transita*, *G. b. bifurcata* to *Pridaella trammeri*, *Pr. cornuta*, and so on; *Budurovignathus* to *Sephardiella*; *Chiosella* to *Kashmirella*. For further information on this nomenclatural issue, see Budurov (1998) and Budurov and Petrunova (1998).

therein) are located south of the major Eocene thrusts, and may have been affected by tectonic rotation during thrusting.

7. Paleogeographic interpretation

Paleomagnetic data of this study and the literature from other tectonic elements of uncertain position are used to reconstruct the paleogeography of the western Tethys at Middle/early Late Triassic Pangea times. We adopt a Pangea A-2 configuration very similar to that of Muttoni et al. (1996a), characterized by internal mobility induced by incipient transformation into A-1 type configurations. The Pangea reconstruction proposed here (Fig. 8) does not change substantially if the 230 Ma paleopole of Laurussia of Torcq et al. (1997) is used instead.

The paleomagnetic data of this study indicate a paleolatitude of 21–24°N for the Moesian platform consistent with a position along the southern margin of Europe, from which it may have been partially separated, but not completely detached or sensibly rotated away, by the North Dobrugea transtensional trough (Do) (Fig. 8). The North Dobrugea trough was floored by a thinned transitional or even true oceanic crust during the Middle Triassic (as testified by MORB-type pillow basalts of the Niculitel Formation, Savu, 1986). The North Dobrugea trough is interpreted as a back-arc basin resulting from the northward subduction of the Neo-Tethys (Vardar) or Paleo-Tethys ocean underneath the Moesian platform. Back-arc exten-

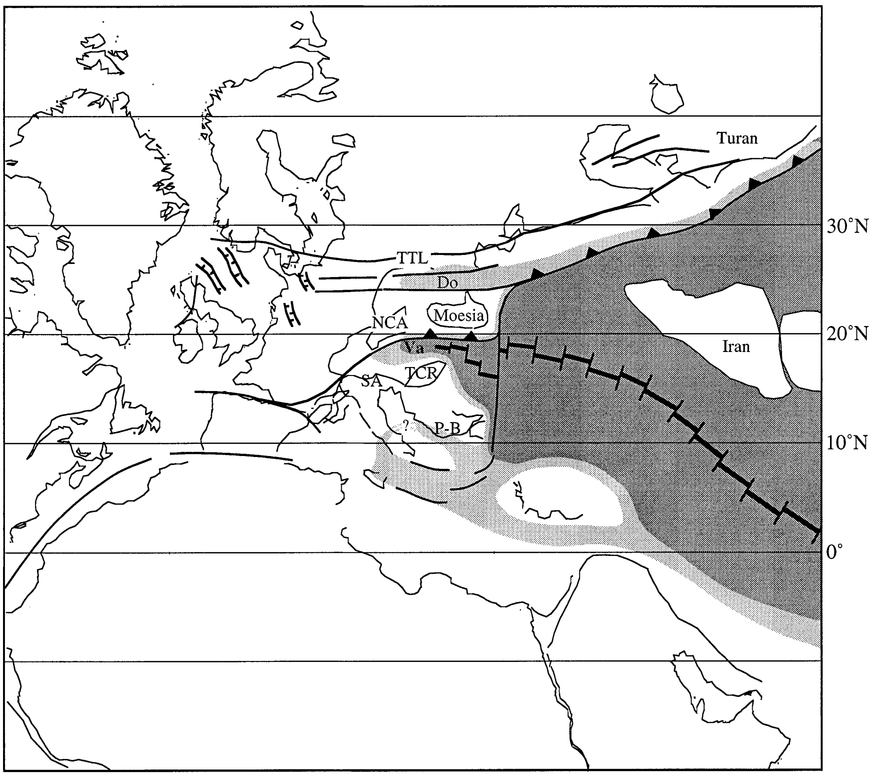


Fig. 8. Paleogeographic reconstruction of the western Tethys in the Middle/early Late Triassic. 'TTL' is the Tornquist–Teisseyre Lineament, 'Do' is Northern Dobrugea, 'Moesia' is the Moesian platform, 'NCA' are the Northern Calcareous Alps, 'Va' is the Vardar ocean, 'TCR' is the Transdanubian Central Range, 'SA' are the southern Alps, 'P-B' is the Pindos–Krasta–Budva deep-sea trough, and 'Iran' is the Iran–Afghanistan–Mega Lahsa block(s). The dark gray pattern represents truly oceanic setting, and the light gray pattern represents extended continental or transitional setting. See text for discussion.

sion was accompanied by transtension along the Tornquist–Teisseyre (TTL) or associated lineaments that mark the modern-day boundary with the East European Platform.

The Northern Calcareous Alps (NCA) of Austria were recently investigated paleomagnetically at three main Upper Anisian to Lower Carnian sections: Mayerling, Mendlingbach and Gamsstein (Gallet et al., 1998; see also Fig. 6). The average inclination indicates that the Northern Calcareous Alps were located at about 19.5°N, in substantial agreement with the paleolatitude expected from the Laurussia pole (i.e. 21°N) (Van der Voo, 1993, table 5.7), and not far from Moesia. The average declination at Mayerling and Gamsstein of 95°E indicates a 58° clockwise rotation relative to the Laurussia pole (or 107° relative to West Gondwana), in agreement with the consistent pattern of clockwise paleomagnetic rotations observed in the Adnet Limestone of Liassic age (Channell et al., 1992). Data from the Northern Calcareous Alps do not conform to the African polar wander loop typically observed in Adria data. The Northern Calcareous Alps are therefore interpreted as a unit of non-Africa affinity (European?), facing to the east the western Tethys, and which underwent clockwise rotation in post-Liassic times (Channell et al., 1992; Channell, 1996).

The Transdanubian Central Range (TCR) of northern Hungary, located between the western Carpathians to the north and the Zagreb–Kulcs lineament to the south in modern-day coordinates, is considered to have moved in conjunction with West Gondwana since at least Late Cretaceous times, to undergo successively an approximately 30° counter-clockwise rotation of thrust sheets probably during Pannonian deformation in the Cenozoic (Channell, 1996). Therefore, in Pangea times, the Transdanubian Central Range was the northeastern 'bulge' of the African promontory of Adria (Van der Voo, 1993) and is predicted to have a paleolatitude similar to that of the Southern Alps (SA), i.e. about 15.5°N (Muttoni et al., 1996a upgraded with data from Broglio Loriga et al., 1999 and Brack and Muttoni, in press).

In between the Southern Alps/Transdanubian Central Range and the Northern Calcareous Alps/Moesia, enough room is left for the Vardar (Va) transtensional deep-water to oceanic basin (e.g. Pamic et al., 1998). Recently published Middle Triassic paleomagnetic data from Albania and Greece (Muttoni et al., 1996b; Muttoni et al., 1997, 1998) can be used as proxy data for the paleolatitude of the Pindos–Krasta–Budva deep-water basin (P–B), which attains a position of about 13–15°N (Fig. 8).

Finally, more to the east, in a truly oceanic setting, the Iran–Afghanistan–Mega Lahsa block(s) navigates to the north to eventually collide with the southern margin of Europe in the Middle/Late Triassic (Wensink, 1982 and references therein; Ricou, 1996; Besse et al., 1998).

8. Conclusions

We found a dual-polarity component of magnetization of presumed Anisian (Middle Triassic) age in the biostratigraphically dated Peri-Tethyan Edivetur Formation from northwestern Bulgaria. This component delineates a magnetic polarity stratigraphy that was tentatively correlated with magneto-biostratigraphic data from Tethyan sections from the literature. Despite these new results, a gap of data of Illyrian (Anisian) age is still present in the Middle Triassic marine magnetic polarity time scale.

The study area of Edivetur is located adjacent to the Moesian platform in the Fore-Balkan domain, which is the less deformed frontal portion of the Balkanides thrust-and-fold belt. Paleomagnetic data from Edivetur have European affinity, and, in virtue of the regional structural setting of the Fore-Balkan domain, they are used as proxy data for the paleogeographic position of the Moesian platform in the Middle Triassic. The Moesian platform was located at 21–24°N along the southern margin of Europe in a position similar to that proposed by Dercourt et al. (1993). The Moesian platform was probably only marginally separated, but not rotated away, from the European margin by the North Dobrugea transtensional trough interpreted as a back-arc basin resulting from the northward subduction of the Neo-Tethys (Vardar) or Paleo-Tethys ocean.

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