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NEW PALEOMAGNETIC RESULTS FROM THE MIDDLE MIOCENE (KARPATIAN AND BADENIAN) IN NORTHERN AUSTRIA

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Abstract: We present new paleomagnetic results from the Middle Miocene in the Molasse Zone and the Vienna Basin system (Northern Vienna Basin, Wiener Neustadt Basin, Hainburg Swell, Mattersburg Bucht). The magnetic measurements were aimed at supporting stratigraphic age determinations where the polarity patterns of the primary magnetizations enabled a magnetostratigraphic zonation. Karpatian sediments in Laa/Thaya (brickyard) yielded a reverse polarity zone in the lower part (3.20 m) and a normal polarity zone in the upper part (6.10 m) of the sequence, which are assigned to Chrons C5Cr and C5Cn.2n. Three other sites in the Molasse Zone yielded single polarity results (two normal and one reverse polarity) for Badenian sediments. Only normal polarity was found in four sites of Badenian age from the Vienna Basin system. The new paleomagnetic results from Middle Miocene basin sediments (Karpatian and Badenian Stages) located North and East of the pre-Neogene Eastern Alpine Basement in Northern Austria show a general trend towards counterclockwise rotation of some 20 degrees with respect to the present North direction (according to 30° rotation with respect to the stable European continent). The observed rotation values and paleo-inclinations are in accordance with previous paleomagnetic results from Karpatian deposits in the Korneuburg Basin and other parts of the Alpine-Carpathian Foredeep.

Key words: Miocene, Austria, Alpine-Carpathian Foredeep, Vienna Basin, magnetic stratigraphy.

Introduction

The Molasse Zone in Austria is part of the Alpine-Carpathian Foredeep, whereas the Vienna Basin, Styrian Basin and Lavant Valley Basin represent the north-western margin of the Pannonian Basin System in Austria (Royden & Horváth 1988). The South Burgenland Swell separates the Styrian Basin from the Pannonian Basin. The separation between the individual basins is incomplete (Flügel 1988; Kröll et al. 1988), thus enabling a partial link between the subbasins (Fig. 1). The Paratethys, separated from the Mediterranean Tethys in the Early Oligocene, deposited its marine sediments in several stages of transgressions and regressions (Rögl 1996; Steininger et al. 1984). These stages also included re-opening and closure of seaways to the Mediterranean. Temporary connections of the Paratethys with the Indopacific Ocean are best documented in the molluscan faunas containing several Indopacific faunal elements. Correlation of biozones between different Paratethys parts (Central- and Eastern Paratethys) and other faunal provinces are complicated by the tectonic events. Global faunal changes could occur delayed in the Paratethys and endemic evolution of the Paratethys inhabitants would continue meanwhile. The stratigraphy of the sedimentary basin filling of the Paratethys encompasses the Oligocene, Miocene and the Pliocene (Rögl 1996).

The magnetic measurements aimed at improving stratigraphic age determinations where the polarity patterns of the primary magnetizations provided a magnetostratigraphic zonation. Earlier studies gave evidence for the suitability of the rocks for paleomagnetic investigations. For instance, Mauritsch (1972, 1975) and Pohl & Soffel (1982) observed primary magnetization vectors, which gave evidence for large rotations of the Tertiary volcanics in the Styrian Basin. During the last years, sediments of Ottnangian to Sarmatian age were collected from several basins of the Eastern Alps and analysed paleomagnetically. Márton et al. (2000) found a tendency of larger rotations in the older intramontane basins sediments indicating essentially Middle Miocene rotation.

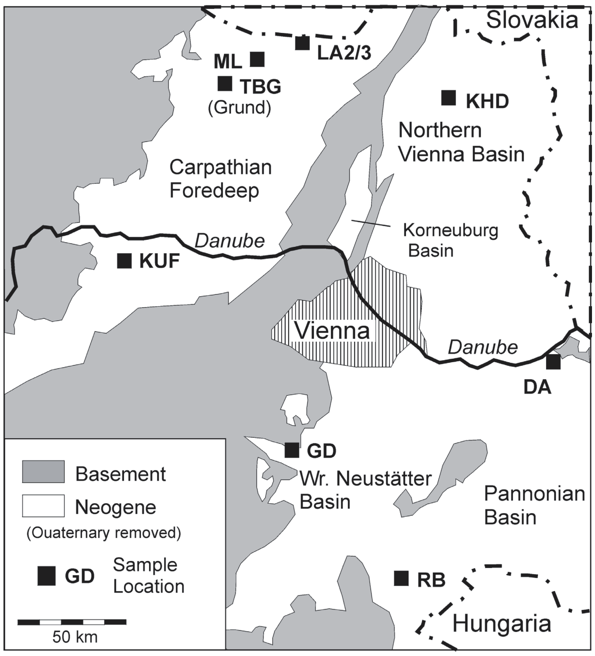

Fig. 1. Geological framework of the study area with sampling locations. **TBG** — Grund, **KUF** — Kuffern, **ML** — Mailberg, **LA** — Laa/Thaya, **KHD** — Kleinhadersdorf, **GD** — Gainfarn, **DA** — Deutsch-Altenburg, **RB** — Rohrbach.

Scholger (1998) studied Miocene (Karpatian) sections in the Korneuburg Basin. In the Teiritzberg waste disposal site, a section of 4 meters thickness across a fossil rich layer was excavated for paleomagnetic sampling. In the Obergänserndorf sandpit, two parallel profiles of 6 meters thickness across fossil rich layers and an overlapping section towards the hanging wall were sampled. The overall mean magnetization for the Teiritzberg and Obergänserndorf sites showed normal polarity with evidence for a counterclockwise rotation of the Korneuburg Basin of approximately 20 degrees with respect to the present magnetic North direction and a paleolatitude of 34 degrees at the time of deposition (Scholger 1998).

Similar results were obtained in the Early Miocene Lignite mining district of Voitsberg (Styrian Basin), with evidence for a 20° counterclockwise rotation of the basin with respect to present North direction (Mauritsch & Scholger 1998). A detailed magnetostratigraphic section of the coal bearing sequence was studied with the task of an age determination for the sediments (Steininger et al. 1998). The rich mammal fauna from the upper part of the hanging wall sequence, indicative of Neogene mammal Zone MN4, allowed a biostratigraphic correlation of the normally magnetized part of the section with Chron C5Dn and the lower, reversely magnetized part of the section with Chron C5Dr of the geomagnetic polarity time scale (GPTS). Thermal treatment with temperatures of 700 °C lead to a corresponding paleomagnetic result for tuffites, which overlie the coal bearing sequence.

Methods

Sampling in the Molasse Zone included the section in the locality Grund (TBG), which was excavated and studied in detail (Ćorić et al. 2004). Complementary results of Karpatian–Badenian age could be obtained from the former sandpit Silberberg located 700 m south of Kuffern (KUF), the quarry on the south-eastern slope of the Buchberg at Mailberg (ML) and the brickyard in the eastern part of Laa/Thaya (LA) in the Eastern Molasse Zone (Fig. 1, Table 1). The data for the Vienna Basin comprise published results from sites in the Korneuburg Basin (Teiritzberg and Obergänserndorf), a new site in a gravel pit located 500 m south of Kleinhadersdorf (KHD) in the Northern Vienna Sub-Basin, as well as one new site from an excavation south-west of Gainfarn (GD) in the Wiener Neustadt Sub-Basin. The easternmost part of the study area was covered by sampling sites from the Hainburg Swell in the Pfaffenberg quarry near Deutsch-Altenburg (DA), and from the brickyard at Rohrbach (RB) located in the Mattersburg Bucht (Fig. 1, Table 1). Importantly, all investigated sites have been studied by means of other, independent stratigraphic methods at the same time (Ćorić et al. 2004).

Standard paleomagnetic sample cubes and cylinders for unconsolidated rocks were used. Alternatively, oriented cores of 2.5 cm diameter were collected using a portable coring apparatus with a non-magnetic hollow drill bit, where drilling was possible. Specimens were subjected to detailed stepwise demagnetization procedure (alternating field and/or thermal treatment). During thermal demagnetization, the bulk susceptibility of the specimens was routinely measured to observe possible mineral transformations. Paleomagnetic data analyses included principal component analysis based on visual inspection of orthogonal projections. Stepwise saturation, measurements of the coercivity, demagnetization of the saturation magnetization and Curie-point determinations helped to identify the magnetic minerals in the sediments. Additional measurements of the anisotropy of the magnetic susceptibility were intended to describe the sediment texture in terms of paleocurrent directions and foliation planes. All measurements were carried out in the Paleomagnetic Laboratory Gams of the University of Leoben. Natural remanent magnetization (NRM) was measured on a three-axis cryogenic dc-squid magnetometer with in-line degausser (2G Enterprises). Geofyzika KLY-2 instruments were used for measuring low-field magnetic susceptibility and its anisotropy.

Results

Laboratory measurements

In the localities Grund and Kuffern, anisotropy of low-field magnetic susceptibility gave reliable evidence for a primary sedimentary origin of the magnetic fabric. Most of the specimens did not show a statistically significant anisotropy at all, and the remaining samples yielded susceptibility ellipsoids which indicated depositional fabrics: the maximum susceptibility axes (k1) were aligned in the horizontal plane, while the minimum susceptibility axes (k3) formed clusters around the

Table 1: Basic geographical and geological data of the paleomagnetic sampling localities in Northern Austria. **TBG** — Grund, **KUF** — Kuffern, **ML** — Mailberg, **LA** — Laa/Thaya, **KHD** — Kleinhadersdorf, **GD** — Gainfarn, **DA** — Deutsch-Altenburg, **RB** — Rohrbach.

ID	Site	WGS84E	WGS84N	Tectonic unit	Strat	Lithology	Facies	Azimuth	Dip
TBG	Grund	16.059	48.639	Eastern Molasse Zone	B	clay, silt	marine	0	0
KUF	Kuffern	15.653	48.317	Eastern Molasse Zone	B	clay, sand	shallow sea	149	10
ML	Mailberg	16.157	48.671	Eastern Molasse Zone	B	lime marl	shallow sea, reef	150	6
LA2	Laa/Thaya	16.411	48.717	Eastern Molasse Zone	K	clay, silt	deep sea	0	0
LA3	Laa/Thaya/Profile	16.411	48.718	Eastern Molasse Zone	K	clay, silt	deep sea	0	0
KHD	Kleinhadersdorf	16.594	48.661	Northern Vienna Basin	B	silt	delta	0	0
GD	Gainfarn	16.176	47.950	Wiener Neustadt Basin	B	silt/clay	shallow sea	359	5
DA	Deutsch-Altenburg 1	16.884	48.129	Hainburg Swell	B	limestone	shallow sea	206	17
RB	Rohrbach	16.435	47.719	Mattersburg Bucht	B	clay	shallow sea	124	30

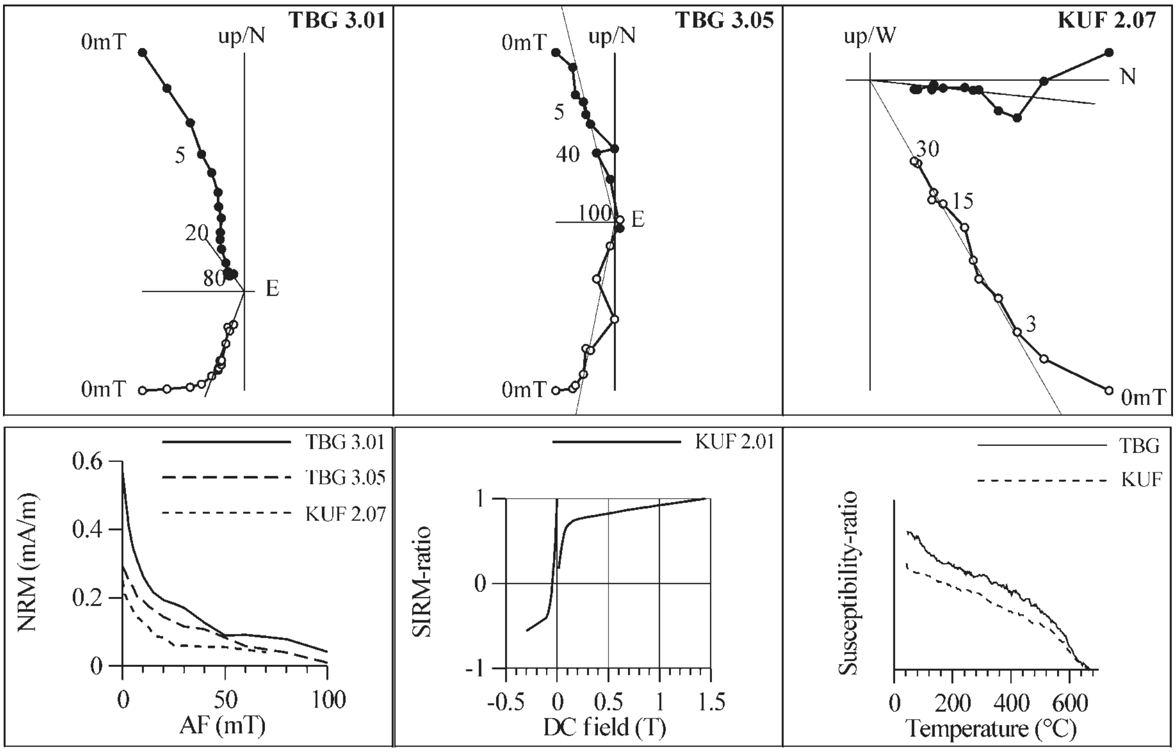

Fig. 2. Demagnetization behaviour and mineral magnetic characterization of samples from the Molasse Zone in Grund (TBG) and Kuffern (KUF). Zijderveld diagrams showing NRM in the horizontal (filled symbols) and vertical plane (open symbols) during demagnetization. Change of NRM during demagnetization, IRM acquisition and backfield, and Curie-point determination.

pole to the bedding plane. Magnetic lineation (L = k1/k2) was typically below 1.01, and the average magnetic foliation (F = k2/k3) was 1.016 in Grund and 1.013 in Kuffern (Table 2). The results suggest the presence of a weak or moderate paleocurrent (NNW–SSE) during the time of deposition. During demagnetization, well defined demagnetization paths with up to three components of NRM and a good separation of the unblocking coercivity spectra could be obtained. Typically, the NRM decayed rapidly at low demagnetizing field strengths and the samples were fully demagnetized at 100 mT alternating-field strengths (Fig. 2). Isothermal remanence acquisition curves and backfield experiments indicated the dominance of a low-coercivity magnetic carrier mineral with a remanence coercivity below 50 mT. In some samples, a second magnetic phase with higher coercivity was observed (Fig. 2 — KUF 2.01). Only 25 % of the samples from the locality Grund yielded good results. A well grouped normal polarity component, which decayed towards the origin between 10 and

Table 2: Paleomagnetic results from the Early–Middle Miocene in Northern Austria. AF/TH — number of samples treated with alternating field or thermal demagnetization. Dec b.c., Inc b.c. — declination and inclination of the mean characteristic remanent magnetization vector before bedding correction. K — concentration parameter. conf — α_{95} confidence angle. Dec a.c., Inc a.c. — direction after bedding correction. n — number of results for mean direction. N/R — number of normal and reverse polarity results. k — mean low-field susceptibility (10^{-6} SI units). L — magnetic lineation (k1/k2). F — magnetic foliation (k2/k3). Mol — area mean direction for the sites from the Molasse Zone. V.B. — area mean direction for the sites from the Vienna Basin and subbasins.

ID	AF/TH	Dec b.c.	Inc b.c.	K	conf	Dec a.c.	Inc a.c.	K	conf	n	N/R	k	L	F
TBG	*46/0*	330	48	25	9	330	48	25	9	13	13/0	63	1.001	1.016
KUF	*12/6*	345	52	21	10	350	61	21	10	12	12/0	69	1.008	1.013
ML	*3/3*	146	–42	138	9	145	–47	138	9	4	0/4	16		
LA2	*27/0*	345	51	57	5	345	51	57	5	15	15/0	74	1.011	1.072
LA3	*47/0*	353	60	29	6	353	60	29	6	22	13/9	130		
KHD	*13/0*	343	62	38	12	343	62	38	12	6	6/0	80	1.000	1.000
GD	*9/0*	335	53	65	9	338	49	65	9	6	6/0	98	1.009	1.010
DA	*6/5*	351	53	47	10	331	65	47	10	7	7/0	–3		
RB	*6/0*	325	25	21	16	334	53	21	16	6	6/0	104	1.000	1.000
Mol		338.6	51.0	90.4	9.2	339.2	53.9	86.1	9.4	5				
V.B.		336.7	48.8	27.9	20.6	336.6	57.3	139.1	9.0	4				

100 mT, could be isolated in 13 samples, mainly from profiles F and H (Roetzel & Pervesler 2004). 12 samples from Kuffern yielded demagnetization paths towards the origin between 3 and 50 mT. These components are regarded as the primary characteristic remanence direction vectors.

The samples from Mailberg differed substantially from the results described above. Magnetic susceptibility and NRM intensity were typically very low. The samples could not be demagnetized in alternating fields up to 110 mT. The shape of the IRM (isothermal remanent magnetization) acquisition curves, remanence coercivity values of 400 mT and Curie-points in the range of 620 °C indicate a hematite-like phase as the dominant magnetic carrier (Fig. 3). Thermal demagnetisations yielded scattered demagnetization paths along great circles. Interestingly, the remanence vectors, which reside in the hematite-like phase, represent a very well grouped reverse polarity component. Due to the weak susceptibility values, anisotropy of magnetic susceptibility was insignificant for all samples from Mailberg.

In the two neighbouring sites of the magnetostratigraphic section in Laa/Thaya, we observed different magnetic carrier minerals. Samples from the site LA2 can be described similar to the samples from the site Grund, with a low coercivity magnetic carrier mineral (Fig. 4 — LA2.01) and demagnetization paths towards the origin. Contrastingly, the results of samples from LA3 indicated an interchange of high and low coercivity magnetic carriers in different stratigraphic levels. Curie-point determinations were affected by changes in the magnetic mineralogy of the samples during heating at temperatures above 400 °C, which is usually attributed to a higher concentration of pyrite (Fig. 4). Unfortunately, only 50 % of the studied samples yielded demagnetization paths, that could be used for the calculation of mean directions. Both polarities were present, and the normal and reverse directions were aligned antipodal. However, it has to be mentioned, that the reverse polarity was always residing in the high coercivity phase, and the mean characteristic direction for the reverse polarity group had to be calculated by means of great circle intersection analyses (Fig. 4).

Although there was variability as to the relative contributions of the respective remanence components, mostly the same magnetic mineral associations were present in the sediments from the Vienna Basin system. Samples from Kleinhadersdorf in the Northern Vienna Sub-Basin and Gainfarn in the Wiener Neustadt Sub-Basin are characterized by a relatively uniform demagnetization behaviour and magnetic mineralogy. NRM was typically fully demagnetized at 50 mT alternating field strengths. The majority of the demagnetization paths showed simple two-component systems. A viscose component could be removed with alternating fields of 1 to 10 mT. A second, low coercivity magnetic phase carried a well grouped normal polarity component. During IRM acquisition, magnetic saturation could be reached at low to intermediate fields, and Curie-points were observed at temperatures below 600 °C (Fig. 5).

Results from Deutsch-Altenburg at the Hainburg Swell and from the brickyard Rohrbach located in the Mattersburg Bucht indicated a higher contribution of a high coercivity phase, probably goethite. Some samples could not be fully demagnetized towards the origin by means of alternating field

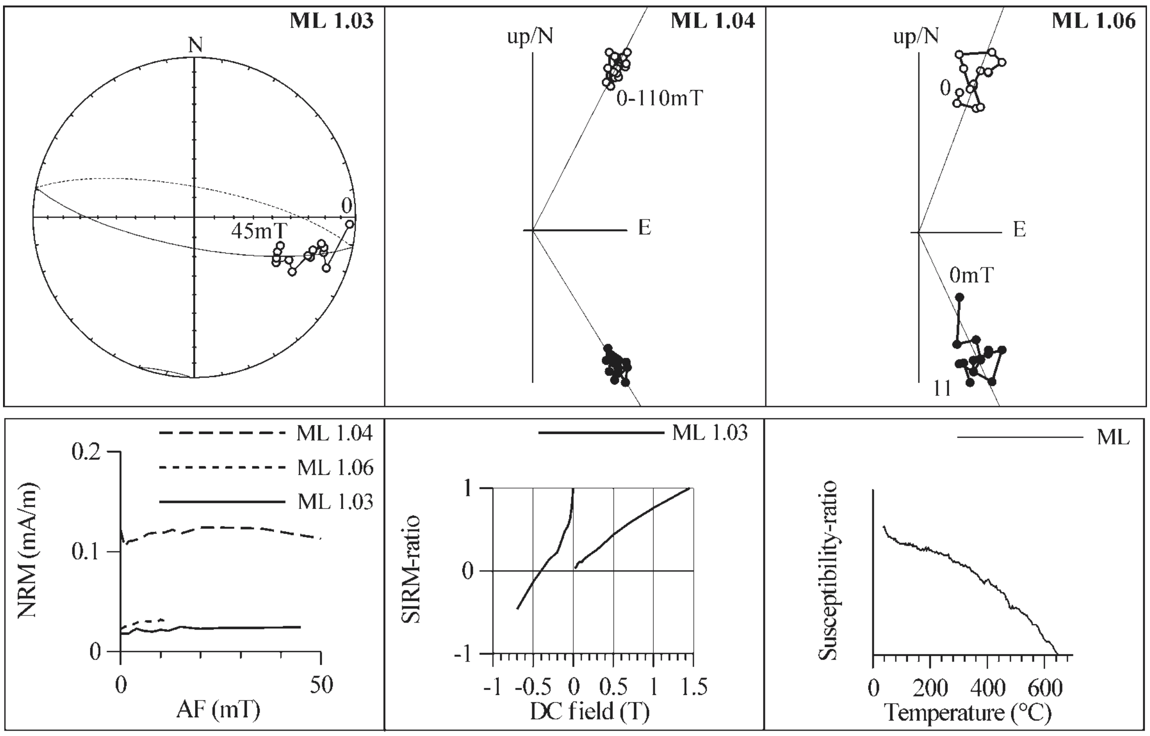

Fig. 3. Demagnetization behaviour and mineral magnetic characterization of samples from the Molasse Zone in Mailberg (ML). Stereographic projection and Zijderveld diagrams showing NRM in the horizontal (filled symbols) and vertical plane (open symbols) during demagnetization. Change of NRM during demagnetization, IRM acquisition and backfield, and Curie-point determination.

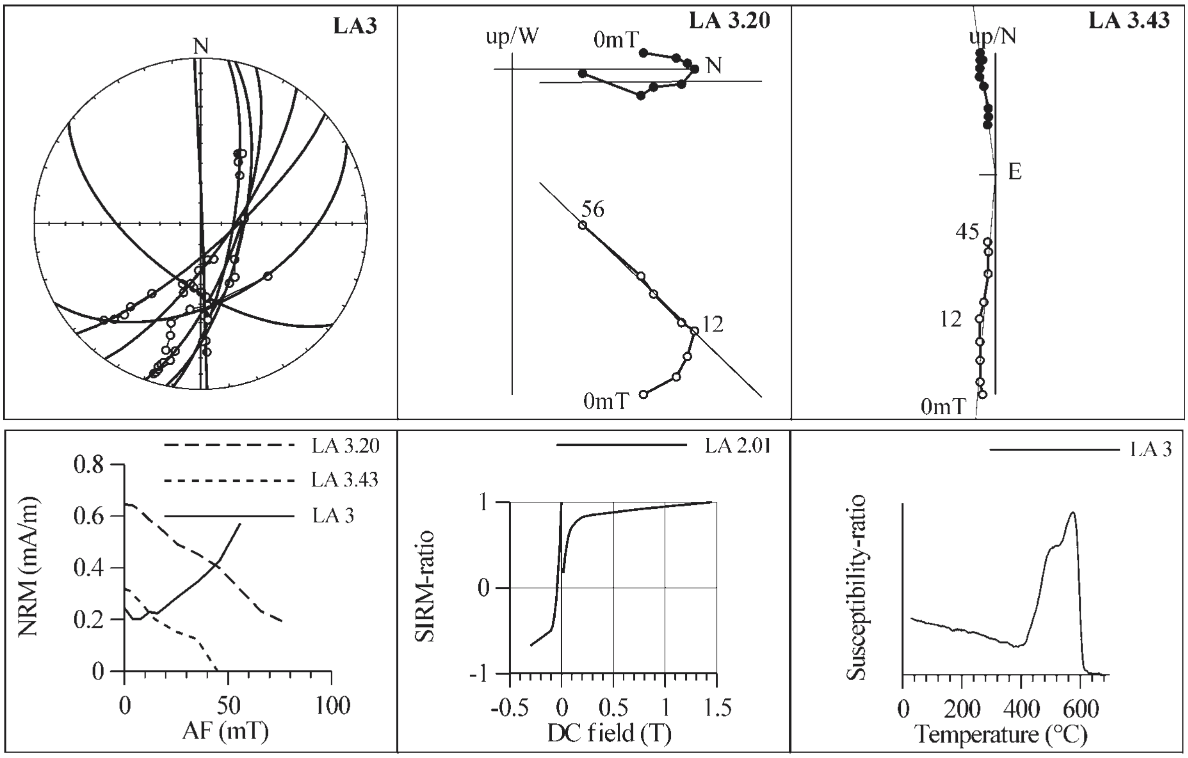

Fig. 4. Demagnetization behaviour and mineral magnetic characterization of samples from the Molasse Zone in Laa/Thaya (LA). Stereographic projection and Zijderveld diagrams showing NRM in the horizontal (filled symbols) and vertical plane (open symbols) during demagnetization. Change of NRM during demagnetization, IRM acquisition and backfield, and Curie-point determination.

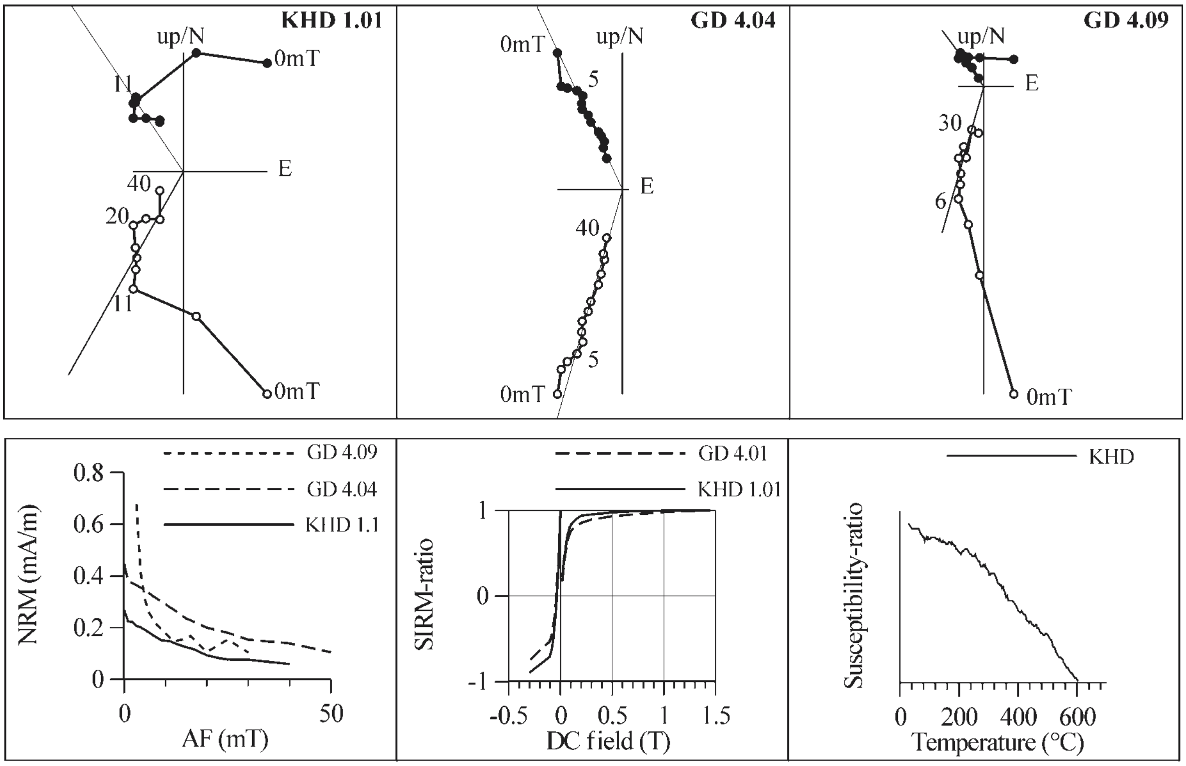

Fig. 5. Demagnetization behaviour and mineral magnetic characterization of samples from the Vienna Basin system in Kleinhadersdorf (KHD) and Gainfarn (GD). Zijderveld diagrams showing NRM in the horizontal (filled symbols) and vertical plane (open symbols) during demagnetization. Change of NRM during demagnetization, IRM acquisition and backfield, and Curie-point determination.

demagnetization, but showed demagnetization paths towards an irremovable second vector component. In accordance with this observation, the respective IRM acquisition curves showed influence from a higher coercivity phase (Fig. 6). However, isolated difference vectors in such samples yielded significant grouping together with the results from samples that were fully demagnetized. Curie-point determinations were again affected by changes in the magnetic mineralogy of the samples due to a higher concentration of pyrite (Fig. 6).

Characteristic remanence directions

The directions of the primary components, which were used for the magnetostratigraphic zonation and calculation of paleomagnetic mean directions, are presented in a stereographic projection in Fig. 7, and in Table 2. Characteristic remanent magnetization directions (ChRM) for single samples were determined by principal component analyses of the magnetization components observed during thermal or alternating-field demagnetization. The quality of the demagnetization data varied strongly in accordance with the different rock types. 91 results from a total of 183 processed samples were suitable for further analyses. The majority yielded consistent demagnetization paths towards the origin, which indicated a low coercivity carrier mineral, most probably magnetite, as the primary carrier of the remanence. The second, smaller group represents results from well defined difference vectors, where demagnetization paths did not show decay towards the origin.

The sites in the Molasse Zone were characterized by mostly flat lying sedimentary bedding planes, disabling the application of a paleomagnetic fold test to prove the relative age of the remanence acquisition. However, the occurrence of normal and antipodal reverse directions (in Mailberg, as well as within the magnetostratigraphic section in Laa/Thaya) gives evidence for a primary nature of the magnetization vectors. For instance, marls of Badenian age from the locality Mailberg in the Eastern Molasse Zone yielded a reverse component (Dec = 145°, Inc = –47°), that is antipodal within the statistical confidence limits to the normal vector direction observed in Grund (Dec = 330; Inc = 48).

In contrast, only normal polarity results were obtained from the sites in the Vienna Basin system, but the pre-tectonic origin of the magnetization directions could be proved by a significant area-scale fold test (Table 2). The concentration parameter of the area-mean direction for 4 studied sites in the Vienna Basin system before and after bedding correction improves from K = 27.9 to K = 139.1. The mean directions for the Middle Miocene in the Molasse Zone (Dec = 339.2; Inc = 53.9) and the Vienna Basin system (Dec = 336.6; Inc = 57.3) in Northern Austria are indistinguishable from each other within statistical limits (Table 2).

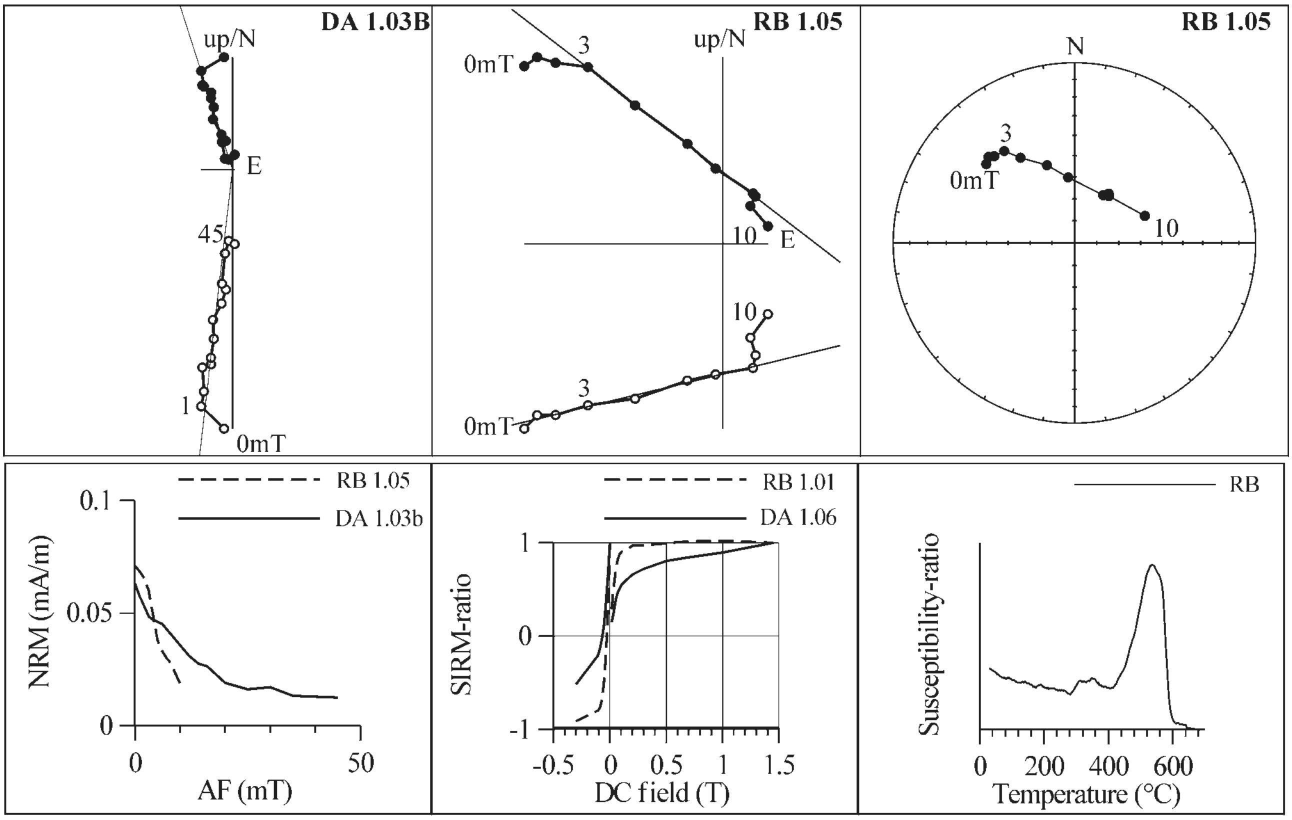

Fig. 6. Demagnetization behaviour and mineral magnetic characterization of samples from the Vienna Basin system in Deutsch-Altenburg (DA) and Rohrbach (RB). Zijderveld diagrams showing NRM in the horizontal (filled symbols) and vertical plane (open symbols) and stereographic projection during demagnetization. Change of NRM during demagnetization, IRM acquisition and backfield, and Curie-point determination.

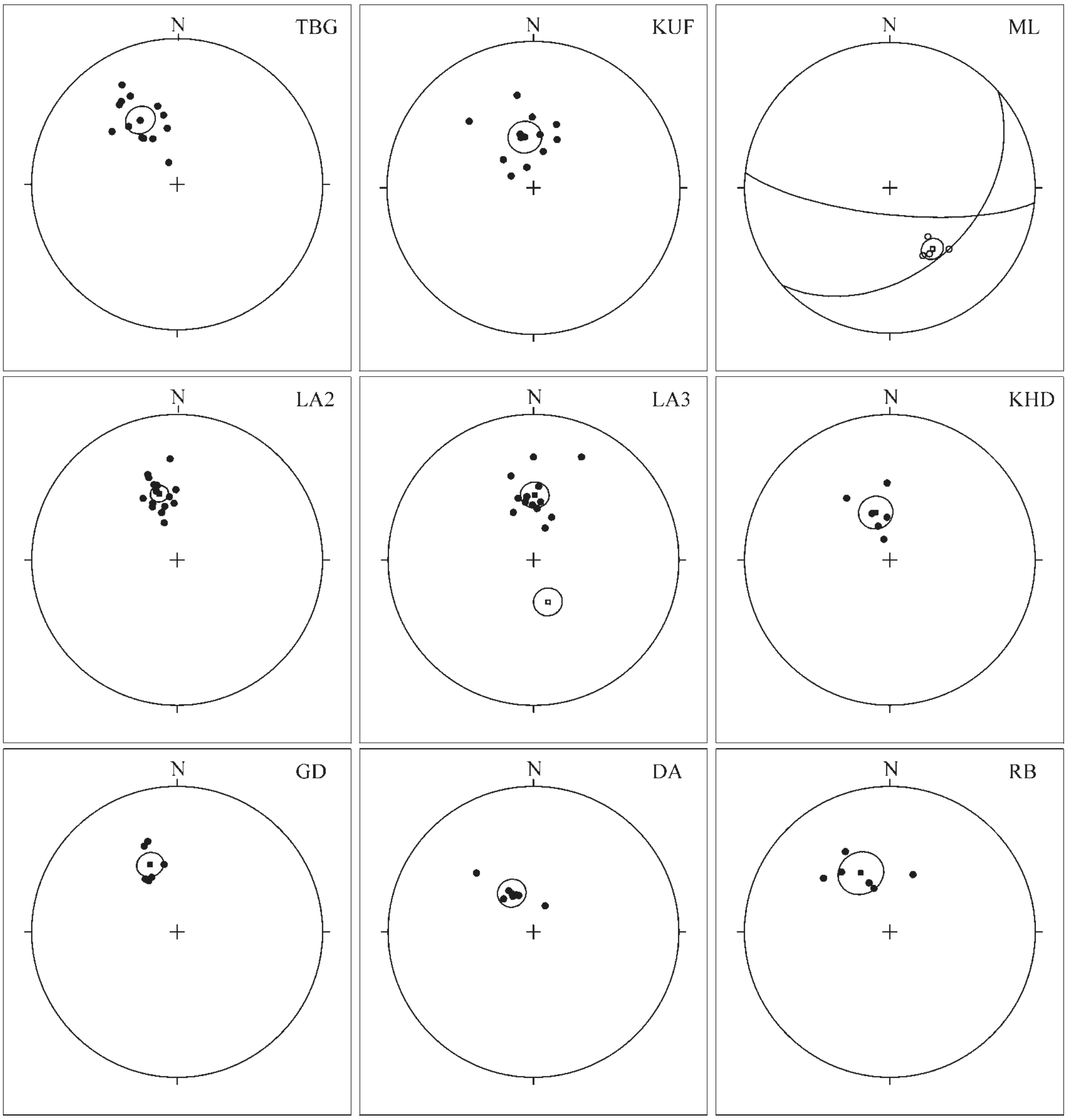

Fig. 7. Stereographic projection of the characteristic remanence magnetization directions after bedding correction. Equal area projection with full symbols for lower hemisphere and open symbols for upper hemisphere. Mean values for normal and reverse polarity are shown with α_{95} confidence intervals. The demagnetization planes shown for the Site Mailberg (ML) are not included in the mean value. See also Table 2.

Conclusion

In the localities Grund and Kuffern well grouped normal polarity components could be isolated, which are regarded as the primary characteristic remanence direction vectors. Only normal polarity was observed in both sites. The results from Mailberg yielded a very well grouped reverse polarity component in samples from a 20 cm marl layer, while no paleomagnetic results could be obtained from the diamagnetic Leitha limestone in the hanging wall and footwall of this layer. In the profile in Laa/Thaya (brickyard), both polarities were present, and the normal and reverse directions were aligned antipodal. The lower part of the sequence (3.20 m) was characterized by reverse polarity, the upper part (6.10 m) yielded only normal polarity results. Compared with the stratigraphic time scale of Berggren et al. (1995), the reverse is assigned to Chron C5Cr and the normal to Chron C5Cn.2n (16.327–16.488 Ma). The normal chron also comprises the upper part of the Karpatian as measured in the Korneuburg Formation (Ćorić et al. 2004). Only normal polarity is found in the sediments of Badenian age from Kleinhadersdorf in the Northern Vienna Basin, Gainfarn in the Wiener Neustadt Basin, Deutsch-Altenburg at the Hainburg Swell and Rohrbach in the Mattersburg Bucht.

The new results from Middle Miocene basin sediments (Karpatian and Badenian Stages) located North and East of the Eastern Alpine Basement in Northern Austria show a general trend for synsedimentary counterclockwise rotations of some 20 degrees with respect to the present North direction (according to 30° rotation with respect to the stable European continent). The observed rotation values and paleo-inclinations are in accordance with previous paleomagnetic results from Karpatian deposits in Teiritzberg (Dec = 340°, Inc = 49°) and Obergänserndorf (Dec = 336°; Inc = 56°) in the Korneuburg Basin (Scholger 1998). This pattern of rotations is in accordance with paleomagnetic results from other parts of the Alpine-Carpathian Foredeep (e.g. Márton et al. 2001).

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