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Preliminary results of magnetostratigraphic investigations across the Jurassic/Cretaceous boundary strata at Nutzhof, Austria

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(With 9 figures and 2 tables)

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Abstract

The principal aim of detailed magnetostratigraphic and micropalaeontological investigation on the Jurassic/Cretaceous (J/K) boundary is precisely determine the boundaries of magnetozones and narrow reverse subzones, and find global correlation across the J/K boundary. A high resolution study focusing on the detailed biostratigraphy of the limestone-, marly limestone- and marl succession at Nutzhof has been carried out at a new outcrop in the Gresten Klippenbelt of Lower Austria. Eleven magnetic polarity zones, six reverse (R) and five normal (N) polarity – are included in the whole interval (18 m) around J/K boundary of Nutzhof section. The J/K boundary (the Berriasian Stage base), located near *Calpionella* Zone base (REHÁKOVÁ et al. 2008; REHÁKOVÁ et al. this volume) roughly corresponds to magnetozone M19N a succession of M-zones correlative with M17N to M22R. Low-field magnetic susceptibility (k) ranges from -5.9 to 94.9×10^{-6} SI and the intensity of the natural remanent magnetization (NRM) varies between 31 and 615×10^{-6} A/m. The samples display a two- to three-component remanence. The average sampling density for the whole section was around two samples per 1 m of true thickness of limestone strata in these preliminary results. The next step of investigation will be to precisely determine the boundaries of magnetozones M19 and M20 including narrow reverse subzones with the high resolution sampling density for the whole section.

Keywords: Austria, Gresten Klippenbelt, Nutzhof, J/K magnetostratigraphy, magnetomineralogy.

Zusammenfassung

Das primäre Ziel detaillierter magnetostratigrafischer und mikropaläontologischer Untersuchungen der Jura/Kreide (J/K) Grenze ist die genaue Einstufung der Grenzen zwischen Magnetozonen und den engen, reversen Subzonen, sowie die Korrelation mit einer globalen Zonierung rund um die J/K Grenze. Eine hochauflösende Studie, fokusiert auf die detailierte Biostratigrafie der Kalk-, Mergelkalk- und Mergel-Abfolge am Nutzhof wurde an einem neu bearbeiteten Aufschluss in der Grestener Klippenzone in Niederösterreich durchgeführt. Elf magnetische Polritäts-Zonen – sechs reverse (R) und fünf normale (N) – sind im gesamten Intervall (18 m) um die J/K Grenze der Nutzhof Sektion vertreten. Die J/K Grenze (die Basis der Berriasium Stufe), lokalisiert an der Basis der *Calpionella* Zone (REHÁKOVÁ et al. 2008; REHÁKOVÁ et al. dieser Band), stimmt etwa mit der Magnetozone M19N überein, einer Abfolge von M-Zonen vergleichbar

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mit M17N bis M22R. Die schwach-Feld magnetische Suszeptibilität (k) reicht von -5.9 bis 94.9×10^{-6} SI und die Intensität der natürlichen Restmagnetisierung (NRM) variiert von 31 bis 615×10^{-6} A/m. Die Proben zeigen eine zwei- bis drei-Komponenten Remanenz. Die durchschnittliche Zahl der Probennahme des gesamten Abschnittes betrug zwei Proben pro 1 m echter Mächtigkeit der Kalke in diesen vorläufigen Ergebnissen. Der nächste Schritt in den Untersuchungen wird die genaue Fixierung der Magnetozonen M19 and M20 und die exakte Festlegung der reversen Subzonen, durch eine enge Probennahme im gesamten Abschnitt sein.

Schlüsselworte: Österreich, Grestener Klippenzone, Nutzhof, J/K Magnetostratigraphie, Magnetomineralogie

1. Introduction

This study is a continuation of a joint geophysical and palaeontological project focused on detailed magnetostratigraphic and palaeontological studies of the Jurassic/Cretaceous (J/K) boundary. The aims of this project are globally and objectively establish a correlation between biozones around J/K boundary in the Tethyan Realm using global palaeomagnetic events. During the last 30 yers, several magnetostratigraphic investigations across the J/K boundary strata have been reported from the Tethyan Realm (e.g. CIRILLI et al. 1984 or OGG & LOWRIE 1986). The analyses of these sections are typically aimed at the formulation of synoptic charts of normal and reverse magnetozones however, there are not a detailed unity in determination of their boundaries in biostratigraphic terms or a precise definition of subzones close to the J/K boundary. The boundary is placed by different authors at various levels within the range of magnetozones M19–M17. A synoptic magnetostratigraphic profile for Upper Mesozoic rocks from Tunisia was published by NAIRN et al. (1981). LOWRIE & CHANNELL (1983) placed the boundary in the lowermost part of magnetozone M17 in a section through the Maiolica Fm of pelagic limestones in the Bosso Valley, Italy. After the correlation of magnetostratigraphic data with calpionellid zones, MÁRTON (1986) proposed placing the J/K boundary close to the base of M17, as LOWRIE & CHANNELL (1983) had done. The section at Brodno near Žilina, W Slovakia (HOUŠA et al. 1999), was the first section investigated with high-resolution magnetostratigraphy and micropalaeontology in the Carpathians. HOUŠA et al. (1999) detected magnetozones M20r–M17r in the Brodno section near Žilina and, on the basis of calpionellid zonation, placed the J/K boundary at approximately the middle of M19n, between M19r and reverse subzone M19n-1 (the Brodno Subzone). The magnetostratigraphic study was extended to other localities in the Tethyan realm, namely at the Bosso Valley in Umbria, Italy (HOUŠA et al. 2004), in the Tatra Mountains, Poland (Grabowski & Pszczółkowski 2006) and at Puerto Escaño, Spain (HOUŠA et al. 2000), where the magnetostratigraphy and biostratigraphy were well documented. This provided a precise record of polarity changes in the Earth's magnetic and determined their positions precisely relative to the biostratigraphic zonation.

The detailed biostratigraphy of the limestone-, marly limestone- and marl succession at Nutzhof has been studied at a new outcrop in the Gresten Klippenbelt of Lower Austria (Fig. 1). The cross-section at Nutzhof contains 18 m of overturned layers, which are 1 to 50 cm thick. At the 7th meter lies the Jurassic-Cretaceous boundary located near *Calpionella* Zone base (REHÁKOVÁ et al. 2008). The stratigraphic investigation of the micro- and nannofauna revealed that the Nutzhof section comprises sedimentary sequence of Early Tithonian to Middle Berriasian in age. The ammonites from the lower

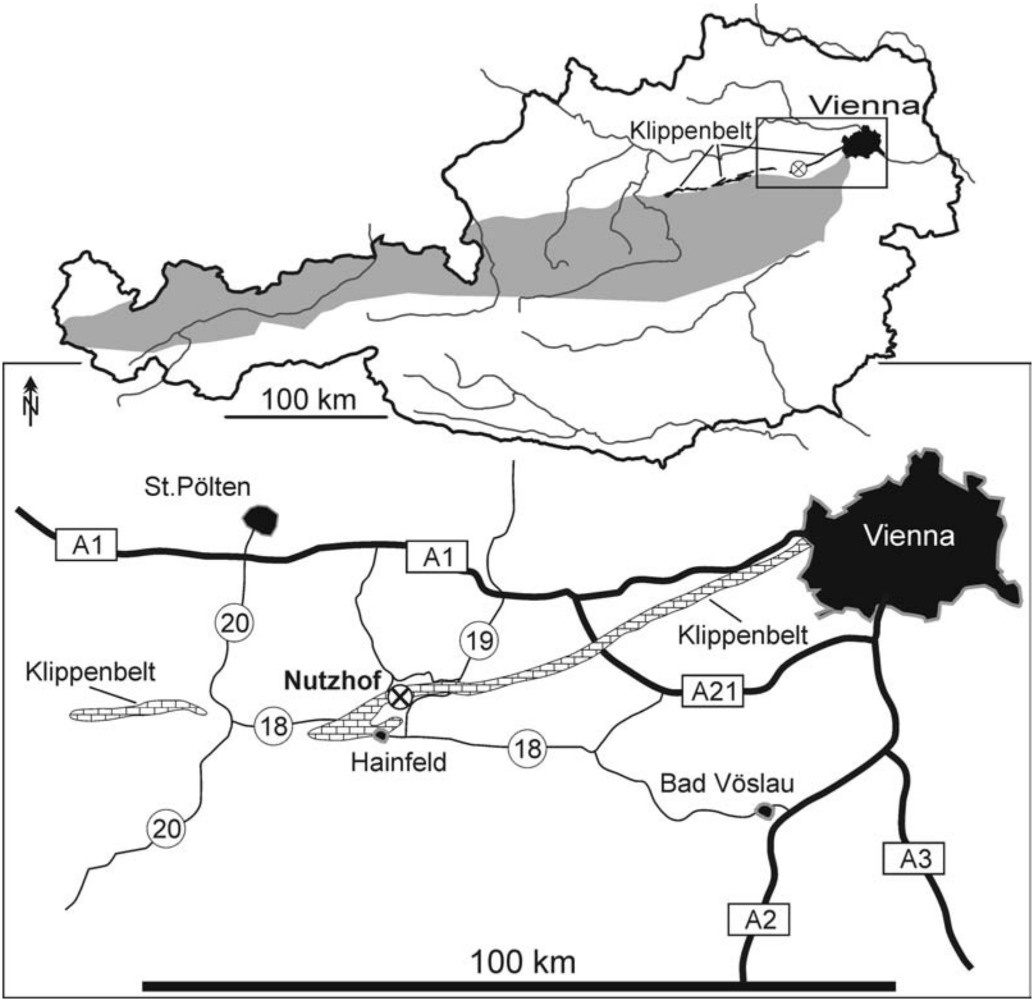

Fig. 1: Location map of the Nutzhof area (Lower Austria) from LUKENEDER (this volume).

part strengthen these results. The upper part shows aptychi but is barren of ammonites. The fact that the Jurassic-Cretaceous boundary is detected in this outcrop by detailed biostratigraphy makes magnetostratigraphic study reasonable.

2. Geographical and geological setting

The assembled outcrop is located about 20 km south of Böheimkirchen and 5 km north of Hainfeld. The surrounding area is called Kleindurlas and the locality itself Nutzhof. The Gresten Klippenbelt is in this area a small band of Upper Jurassic to Lower Cretaceous sediments from 200-500 m breadth. It is surrounded by sediments of the Rhenodanubian Flysch Zone. Tectonically, the outcrop is situated only 5 km north of the main border between the Rhenodanubian Flysch Zone and Northern Calcareous Alps. Lithological, sedimentological and palaeoecological studies of the succession uncovered rich spectra of Tithonian to Berriasian macro- and microfaunal elements. The evaluation of the thin sections and washed samples indicates a change from a saccocomid facies to a calpionellid facies within the succession.

3. Rockmagnetic investigation

Isothermal remanent magnetization (IRM) to saturation was measured to identify coercivity spectra of the magnetically active minerals. The whole rock samples were magnetized on the Pulse Magnetizer MMPM 10, demagnetized on LDA-3 AF Demagnetizer and measured on JR6 a magnetometer. The used field range was 10 to 2900 mT. IRM curves demonstrated in Fig. 2 show two different magnetic minerals. Graph a) demonstrates magnetically soft magnetite and graph b) shows samples with magnetically hard goethite and negligible amount of magnetite.

4. Methods

Oriented hand samples (38) from the Nutzhof section were cut to 111 laboratory specimens. Remanent magnetization (RM) of the rocks was easily measured using JR-5A spinner magnetometer or Liquid helium-free Superconducting Rock Magnetometer, type 755 4K SRM and the magnetic susceptibility of the samples was measured using a KLY-4 Kappabridge (Jelínek 1966, 1973). Mean values of the modulus of natural RM

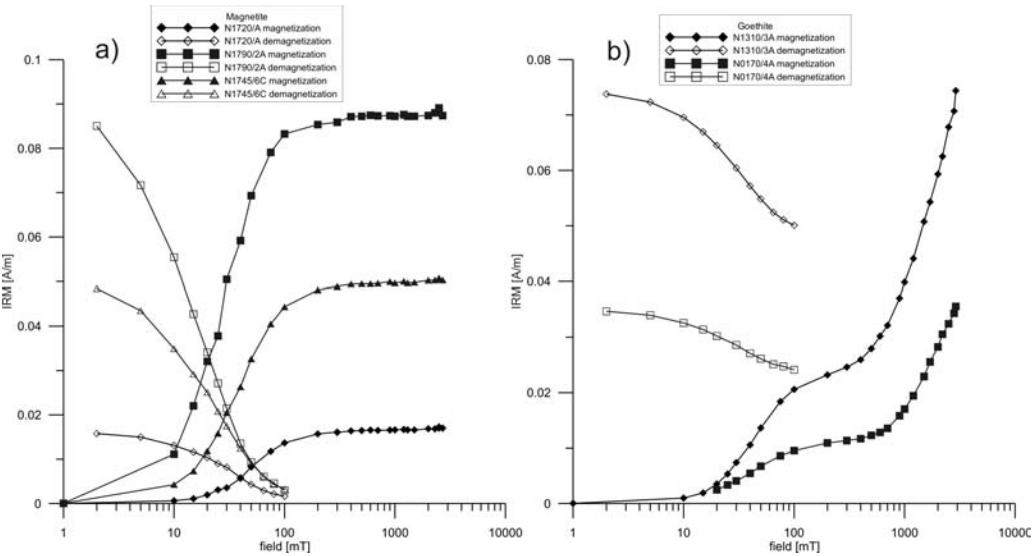

Fig. 2: Examples of IRM acquisition and AF demagnetization curves, limestone samples: a) samples with magnetically soft magnetite and b) samples with magnetically hard goethite and negligible amount of magnetite.

(Jn) and of volume magnetic susceptibility (kn) for 111 samples of upper Tithonian and lower Berriasian limestones are shown in Table 1. These data given in the magnetostratigraphic profile indicate a significant jump of remanent magnetization and magnetic susceptibility, in the meter 10. The reason of this jump is change in lithology, from meter 0 to 10 prevailing limestones and from meter 10 started siltstones. Several pilot samples were experimentally subjected to alternating field (AF) demagnetization using a LDA -3A demagnetizer. The method of progressive thermal demagnetization (TD) using the MAVACS demagnetizer (PŘÍHODA et al. 1989) gave considerably better results. Each of the 86 samples studied was subjected to TD or AF demagnetization in 11–12 temperatures or fields. As a result, the individual components could be precisely established in the vast majority of samples using the multicomponent analysis of remanence (KIRSCHVINK 1980). Zijderveld diagrams and diagrams of Mt/Mn values vs. laboratory thermal demagnetizing field t (°C) were constructed for all samples.

Table 1: Basic magnetic parameters and statistical properties of the physical quantities in the basic groups of samples from the Nutzhof.

Age	Magnetozone	Number of samples	Modulus of natural remanent magnetization M [10^{-6} A/m]		Volume magnetic susceptibility k [10^{-6} SI]	
			Mean value	Standard deviation	Mean value	Standard deviation
Early Berriasian	N+R	19	108	42	3.2	2.4
Late Tithonian	N+R	92	224	112	58	12

Limestone beds at the Nutzhof display uniform overturned bedding-plane orientation, with the mean strike of 151°±30° and the mean dip angle of 44°±22°. From paleomagnetic point of view the mean strike is 331°±30° and the mean dip angle is 136°±22°. The uniform bedding plane orientation is also responsible for the equal dispersions of the mean directions of remanence components in situ (not corrected for tectonic dip) and those corrected for tectonic dip. According these values we used tilt test, the fold test was not possible to apply in this case.

5. Analysis of magnetic and palaeomagnetic properties

Results of AF and TD demagnetization procedures are displayed in Figures 3–4. They refer to two limestone samples with normal palaeomagnetic directions (sample N 0720-1 from M19N of the magnetostratigraphic profile and sample N 1720-3B from M22N) and two limestone samples with reverse palaeomagnetic directions (sample N 0430i1 from M17R of the magnetostratigraphic profile and sample N 1280-3 from M20R). Analogous results were obtained for most samples from the whole Nutzhof section. The remanent magnetization directions shown in the projections are corrected for the dip of strata. Results of the multi-component analysis of remanence show that the rock samples from Nutzhof display a three-component remanent magnetization. The A-component is undoubtedly of viscous origin and is demagnetizable in the temperature range of 20–

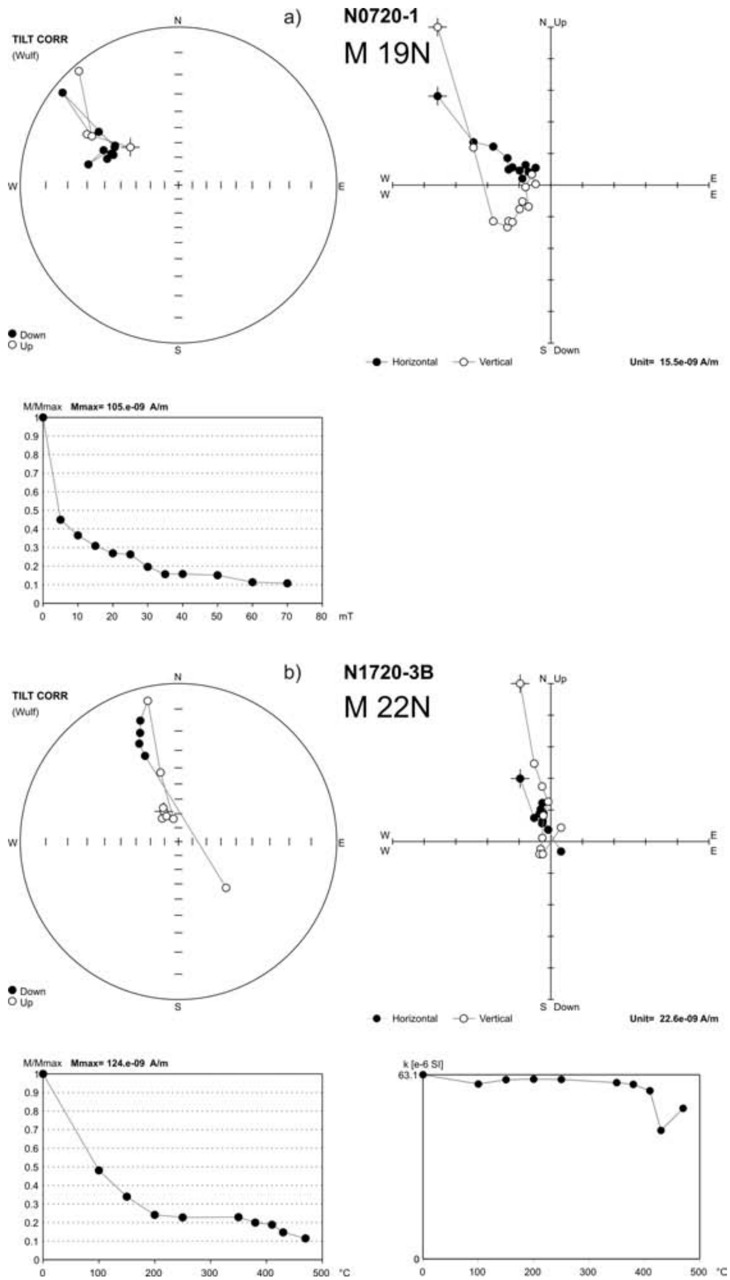

Fig. 3: Results of AF and TD demagnetization of two limestone samples (a – N0720-1; b – N1720-3B) with normal palaeomagnetic polarity. Top left: Stereographic projection of NRM vector variations during AF (a) and TD (b) demagnetization, solid and open circles denote projections of NRM vectors on the lower and upper hemispheres, respectively. Top right: Zijderveld diagram, solid circles represent projection on the horizontal plane (XY), open circles represent projections on the north–south vertical plane (XZ). NRM module (M) as dependent on AF intensity (a) and TD field (b). A graph of volume magnetic susceptibility as dependent on TD field (b).

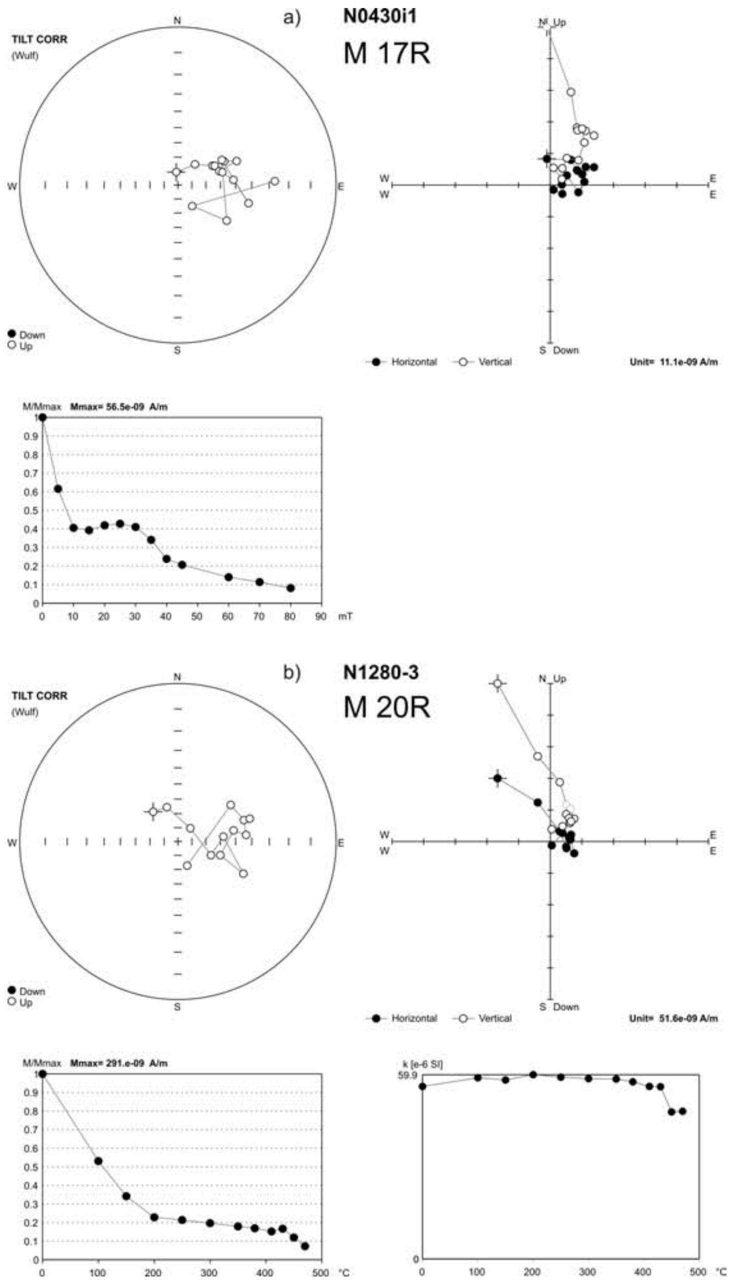

Fig. 4: Results of AF and TD demagnetization of two limestone samples (a – N0430i1; b – N1280-3) with reverse palaeomagnetic polarity. See caption for Fig. 3.

100 °C (or AF 0-5 mT); the B-component is also of secondary origin but shows harder magnetic properties being demagnetizable in temperature range of 100–200 °C (or AF 5-20 mT); the C-component is the most stable, being demagnetizable in temperature-range of *c*. 350–500 °C (or AF 30-100 mT). The origin of the B-component was studied by statistical processing of a larger set of data and is discussed below (section 6). The mean directions and dispersions of components were calculated using Fisher's statistics (FISHER 1953) and were displayed on Wulf stereographic projection. They are marked either by full or empty crossed circles with a confidence circle circumscribed around the mean direction at the 95 % probability level. Low-field magnetic susceptibility (k) ranges from -5.9 to 94.9×10^{-6} SI and the intensity of the natural remanent magnetization (NRM) varies between 31 and 615×10^{-6} A/m.

6. Discussion of the main results

The paleomagnetic data given in the magnetostratigraphic profile indicate a significant jump of remanent magnetization and magnetic susceptibility, in the meter 10. The reason of this change is lithology, from meter 0 to 10 prevailing limestones and from meter 10 started siltstones. The mean B-component directions of the sets of rocks, upper Tithonian and lower Berriasian display a somewhat higher dispersion, see Table 2. Inclination of the field of theoretical co-axial geocentric magnetic dipole for the Nutzhof is 64.2°; the mean inclination of B-component (secondary or "present day" component) calculated from our data set is higher (73°), the B-component is considered without correction for the dip of strata (in situ directions), see Fig 5. These components were undoubtedly imprinted in the near past during normal polarity of the Earth's magnetic field, most probably in the Neogene, after Alpine folding. Both magnetic polarities are present in C-component directions, but the directions are highly scattered (Table 2). Consequently, the mean direction for samples with normal polarity is D=314.7°, I=32.0°, α_{95}=12.5° (Fig 6).

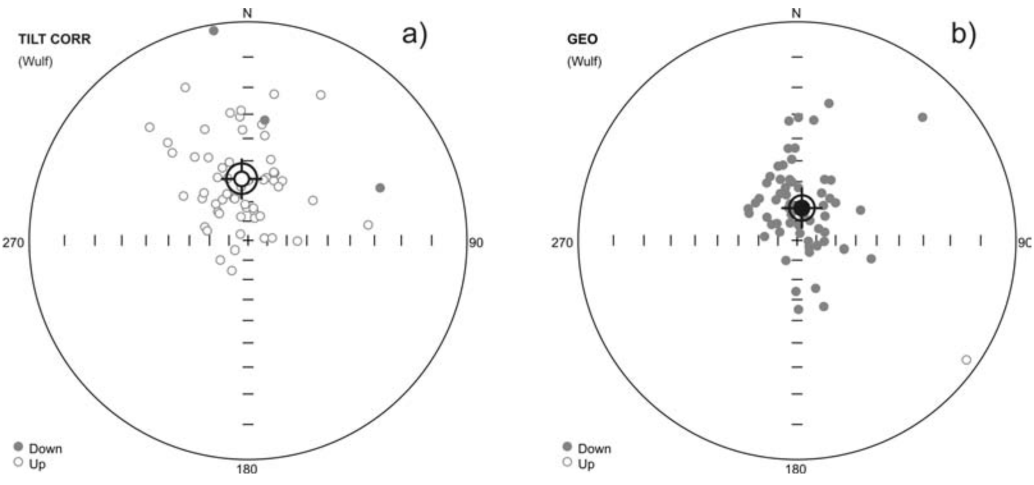

Fig. 5: J/K limestones and marls, directions of B-components of RM corrected (a) and not corrected (b) for dip of strata. Stereographic projection, full (open) small circles represent projection onto the lower (upper) hemisphere.

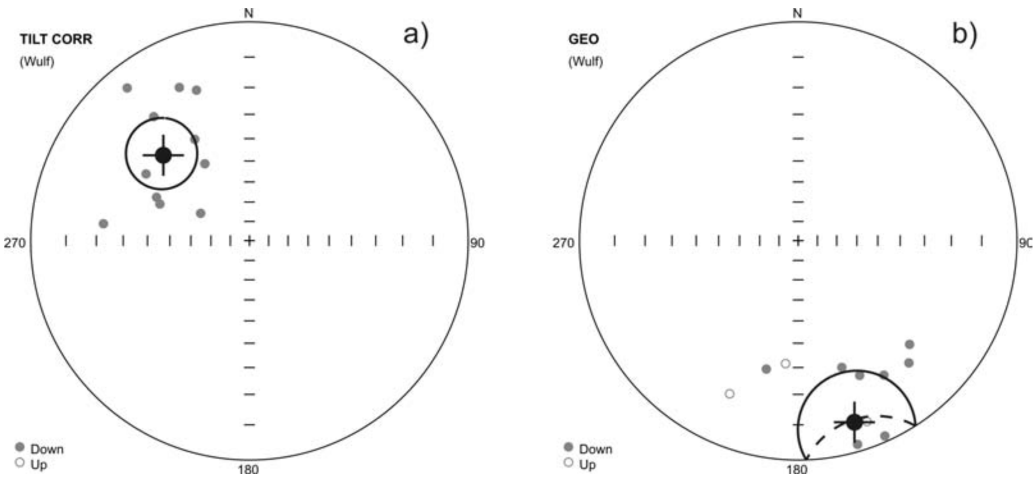

Fig. 6: J/K limestones and marls, directions (N polarity) of C-components of RM corrected (a) and not corrected (b) for dip of strata. See caption for Fig. 5.

For reverse polarity we obtained two groups, the first (R1) is D=76.1°, I=-39.3°, α_{95} =8.4° and the second (R2) is D=192.8°, I=-45.2°, α_{95} =14.5° (Figs 7 and 8). This normal polarity direction is in agreement with the magnetic field for the J/K, but the reverse polarity presents high difference of declination. Table 2 shows that the dispersions of C-componet directions are always wider for rocks in situ (not corrected for dip of strata) than dispersions of directions corrected for dip of strata. The mean values of C-component of normal polarity directions are anomalous, having been affected by counterclockwise paleotectonic rotation. An analogous palaeotectonic rotation has been reported for Cretaceous and

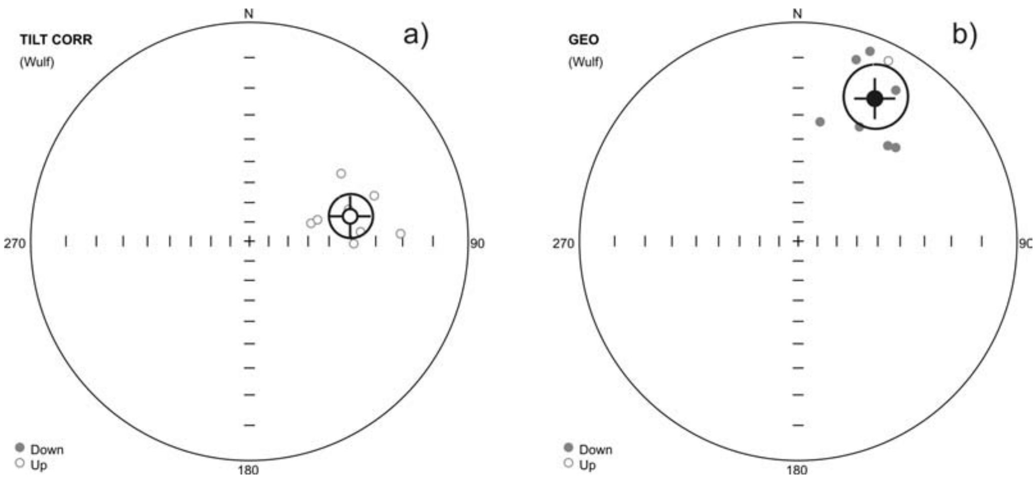

Fig. 7: J/K limestones and marls, directions (R1 polarity) of C-components of RM corrected (a) and not corrected (b) for dip of strata. See caption for Fig. 5.

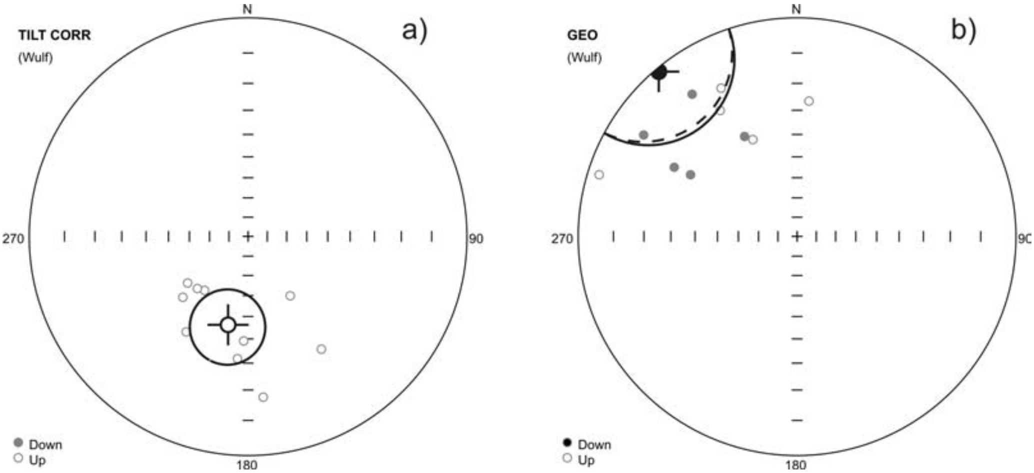

Fig. 8: J/K limestones and marls, directions (R2 polarity) of C-components of RM corrected (a) and not corrected (b) for dip of strata.See caption for Fig. 5.

Jurassic rocks in a broader region of the Eastern Alps. The nearest profiles that had been palaeomagneticaly studied are in Eastern Alps intramontane basins filled with Miocene sediments; it shows counter-clockwise rotations from 27° to 59° (Márton et al. 2000). On the contrary the second closest sets of profiles, the Gossau sediments (upper Cretaceous), shows clockwise rotations from 26° to 59° (Mauritsch & Becke 1987).

Table 2: Mean directions of B (LFC or LTD) and C-components (HFC or HTD) corrected and not corrected for structural tilt.

Age of rocks	Component of remanence	Polarity	Structural tilt correction				No structural tilt correction (in-situ directions)				n	See Figure
			Mean directions		α_{95} [°]	k	Mean directions		α_{95} [°]	k		
			Decl. [°]	Incl. [°]			Decl. [°]	Incl. [°]				
L. Tith.+ E.Berr.	B	R	354.1	-58.4	6.8	6.9	8.5	73.0	6.0	8.7	62	5
L. Tith.+ E.Berr.	C	N	314.7	32.0	12.5	11.4	162.7	8.2	17.2	8.0	11	6
L. Tith.+ E.Berr.	C	R1	76.1	-39.3	8.4	31.1	28.3	17.0	9.6	23.7	9	7
L. Tith.+ E.Berr.	C	R2	192.8	-45.2	14.5	9.3	320.0	0.9	18.3	5.9	10	8

N, R, normal, reverse polarity

7. Magnetostratigraphic profile

The section at Nutzhof complies with our aims in three fundamental criteria: (a) continuous sedimentation not interrupted by marked diastems; (b) rich fossil associations (calpionellids, amonites) allowing a detailed biostratigraphic division; and (c) rocks with magnetic properties that are favourable for reliable determination of palaeomagnetic polarity. The calpionellid associations are very well preserved and highly diversified (REHÁKOVÁ et al. 2008). The log at Nutzhof contains 18 m of inverse, cm to dm beds showing at meter 7 the Jurassic-Cretaceous boundary (REHÁKOVÁ et al. this volume).

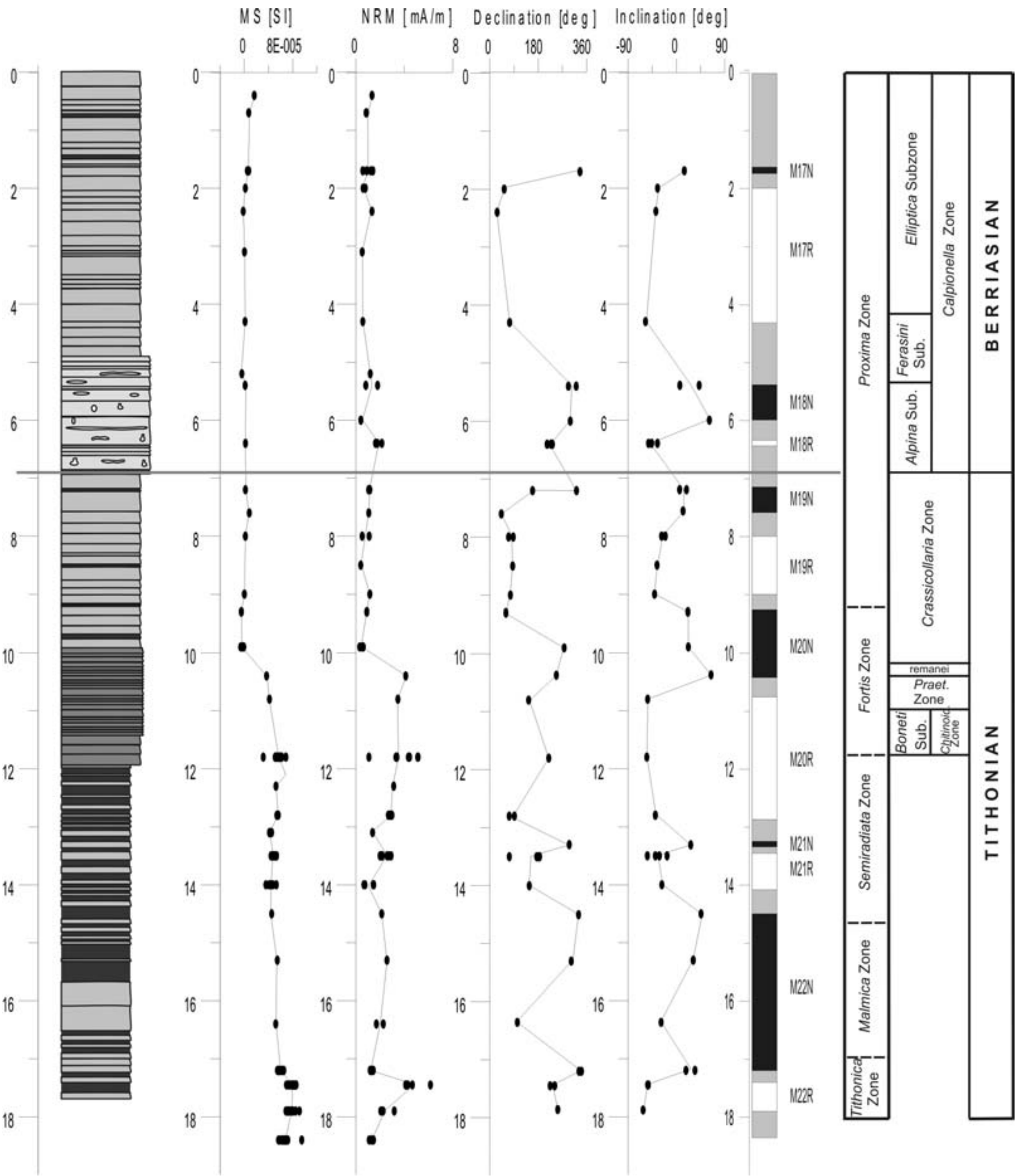

Fig. 9: Magnetostratigraphic profile across the Nutzhof J/K boundary strata, preliminary results of magnetic, palaeomagnetic and lithostratigraphic data. M – NRM in the natural state; k – value of volume magnetic susceptibility in the natural state; D – declination; I – inclination. Normal magnetozones are denoted in black, reverse in white and unknown in grey. Calpionellid biostratigraphy from REHÁKOVÁ et al. (this volume).

Our study concentrated on the investigation of the basal 18-m thick portion of the section, on the limestone strata around the J/K boundary, to preliminarily determine the boundaries of magnetozones M17N to M22R (six reverse and six normal zones), see Fig. 9. In order to identify the detected polarity zones against the M-sequence of polarity intervals given by the GPTS (GRADSTEIN et al. 2004).

The localities in the Tethyan realm include the J/K sections at Brodno near Žilina (Western Carpathians, W Slovakia), the Tatra Mountains (central Western Carpathians, Poland), the Bosso Valley (Umbria, central Italy) and at Puerto Escaño (Province of Cordóba, S Spain). These localities provided very detailed to high-resolution magnetostratigraphic data across the J/K boundary. The reverse subzones were precisely localized in all the sections in analogous relative positions in magnetozones M20N (Kysuca Subzone) and M19N (Brodno Subzone), respectively. Identification of the magnetozones enables a rough estimation of sedimentation rates for these studied sections. The average sedimentation rate in our section (Nutzhof) is around 2.5 m/Ma. The average sampling density of the whole section was around two samples per 1 m of true thickness of limestone strata. The value of sedimentation rate for the Nutzhof section corresponds to an average sedimentation rate of 2.27 m/Ma in Brodno and 2.88 m/Ma in Puerto Escaño. Relatively low value (1 m/Ma) are recorded in Bosso Valley, but mostly higher values (3-20 m/Ma) are given by GRABOWSKI & PSZCZÓŁKOWSKI (2006) for sections in the Tatra Mountains.

8. Conclusions

The magnetostratigraphic study concentrated on the investigation of the basal 18 m thick portion of the Nutzhof section, on the limestone strata around the J/K boundary, to preliminarily determine the boundaries of magnetozones M17N to M22R (according correlation with GPTS), it means six reverse and six normal zones. The directions of B-component (LFC and LTC) are most probably secondary origin (the Neogene), after the rocks had been folded. Both magnetic polarities are present of C-component (HFC and HTC) directions, but the directions are highly scattered. This normal polarity direction is in agreement with the magnetic field for the J/K, but the reverse polarity presents two groups with difference in declination. The next step of magnetostratigraphic investigation will be to determine the boundaries of magnetozones M19 and M20, the average sampling density for the whole section must be around 5 to 8 samples per 1 m and 20 and more samples per 1 m in critical portions of the section.

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