Palaeoclimatic event at the Lochkovian-Pragian boundary recorded in magnetic susceptibility and gamma-ray spectrometry (Prague Synclinorium, Czech Republic)

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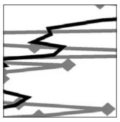

The MS and GRS stratigraphic records of three Lochkovian-Pragian boundary sections representing different depositional conditions have been evaluated. All studied sections are characterized by increased MS magnitudes from Lochkovian to Pragian. Another prominent characteristic is a turnover in the Th/U ratio; the Pragian magnitudes are usually 2–4 times higher than the Lochkovian ones. Based on a combined physical stratigraphic and sedimentological approach a previously reported regressive event at this time interval is ascribed to climate warming accompanied by enhanced carbonate productivity while eustatic sea-level changes probably played only a minor role, which was locally also combined with synsedimentary uplift. • Key words: Devonian, Lochkovian-Pragian boundary, Prague Synclinorium, magnetic susceptibility, gamma-ray spectrometry.

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Physical stratigraphic methods (magnetic susceptibility and gamma-ray spectrometry) have been applied worldwide during last fifteen years in various areas and stratigraphic levels. In the Czech Republic this approach has been used mainly in the Devonian of the Prague Synclinorium (central Bohemia; *e.g*., Slavík *et al.* 2000; Crick *et al*. 1997, 2001; Ellwood *et al*. 2006; Hladil *et al*. 2010b; Koptíková 2010; Koptíková *et al.* 2010a, b; Vacek 2010; Vacek *et al*. 2010) and Moravosilezian Zone (Moravia; *e.g*., Hladil 2002; Hladil *et al.* 2000, 2003a, b, 2006, 2009; Geršl & Hladil 2004; Bábek *et al*. 2007; Boulvain *et al*. 2010). Physical stratigraphic methods have been used for intrabasinal or interregional correlations as well as auxiliary data for characteristics of depositional environments and their evolution, especially in cooperation with sedimentologists and biostratigraphers.

The Prague Synclinorium is a classical area for Devonian System, where several stages have been defined with type sections (Global Boundary Stratotype Section and Point, GSSP). The Pragian Stage was defined by Chlupáč (1981, 1982); its base has been first established at the base of *Eognathodus sulcatus sulcatus* conodont zone at Černá rokle near Kosoř (Weddige 1987). This selection was redefined in 1989 by decision of Subcommission on Devonian Stratigraphy by approval of the Homolka section at Praha-Velká Chuchle as a new GSSP (Chlupáč & Oliver 1989). However, the status of the Pragian Stage has been broadly discussed recently because after the definition of the Pragian-Emsian boundary at Zinzilban Gorge (Uzbekistan) the major part of classical Pragian now correlates with the Emsian (for more details see Slavík *et al*. 2007, Carls *et al*. 2008). Thus, it is necessary to study the type sections by various methods to improve and support their correlation potential for further regional and interregional correlations. Intensive work has been done mainly in conodont stratigraphy (Slavík & Hladil 2004, Slavík *et al*. 2007), but it is also important to support biostratigraphic data by other methods, *e.g.* magnetic susceptibility (MS) and gamma-spectrometric (GRS) stratigraphy or chemostratigraphy. In this particular level several papers have been published dealing with, *e.g.* carbon and oxygen isotopes stratigraphy (Hladíková *et al.* 1997, Gessa & Lécuyer 1998, Buggisch & Mann 2004) or the MS and GRS stratigraphy (Slavík *et al.* 2000; Koptíková *et al.* 2010a, b; Vacek 2010).

Results of studies on the MS and GRS stratigraphy of three type sections, including the Lochkovian-Pragian

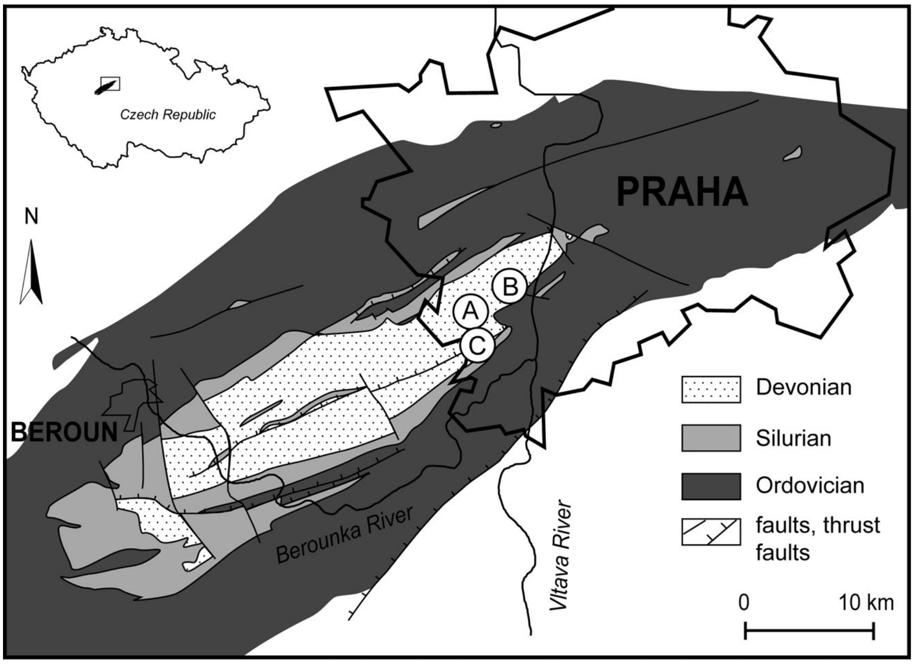

Figure 1. Simplified geological map of the central part of the Prague Synclinorium with position of the studied sections. • A – Cikánka near Praha-Slivenec; B – Homolka near Praha-Velká Chuchle; C – Černá rokle near Kosoř.

GSSP at Homolka, Praha-Velká Chuchle, are reported in this paper. These results can be used within the Prague Synclinorium (our studied sections and other published data) but may prove useful in interregional correlations as well.

Geological setting

The Prague Synclinorium occupies the central part of the Teplá-Barrandian Zone (Fig. 1). This unit consists of Neoproterozoic to Middle Devonian sedimentary and volcanic sequences, which were deformed and locally metamorphosed during Cadomian and Variscan orogenies (Hajná *et al.* 2010). The Devonian sequences in the Prague Synclinorium are characterized by the predominance of carbonates and a lack of major hiatuses (except for the Koněprusy area, S of Beroun; for more details see Chlupáč *et al*. 1998). Palaeogeographic and palaeomagnetic interpretations place the Prague Synclinorium to the northern margins of Gondwana with close relationship to Armorica (Krs & Pruner 1995, Krs *et al*. 2001, Patočka *et al*. 2003).

The classical Pragian (*sensu* Chlupáč 1981, 1982) approximately corresponds to the Praha Formation (Fm.). The Lochkovian-Pragian (L-P) boundary is close to the upper contact of the Lochkov Formation (approximately corresponding to Lochkovian) with the Praha Formation. Facies development of both formations is characterized by lateral transitions from bioclastic limestone facies in the NW/SW part of the synclinorium to fine-grained limestone/shale facies in the SE. Two contrasting facies are distinguished in the Lochkov Fm. – Kotýs and Radotín Limestone (Chlupáč 1953, 1981). The Kotýs Limestone (Lm.) represents relatively shallow-water deposits of the lower subtidal in contact with storm-wave base (Vacek 2007), whereas the Radotín Lm. was deposited as fine-grained distal calciturbidites on the carbonate slope (Vorel 2006, Vacek 2007).

The Praha Fm. exhibits the most diversified facies of any Devonian unit in the Prague Synclinorium – it includes several members representing the transition from shallow-water carbonates (Koněprusy, Slivenec Lm.) to hemipelagic mudstones (Dvorce-Prokop Lm.; Velebilová & Šarf 1996). In the traditional facies schemes of Chlupáč (1957, 1982) there are several transitional facies types (Loděnice, Řeporyje Lm.) between these two contrasting settings. Shallow-water facies have maximum extent in the lower part of the formation, which reflects the regressive Lochkovian-Pragian boundary event (Chlupáč & Kukal 1988). The overlying sequence reflects gradual deepening and expansion of areas with pelagic facies. These contrasting facies should gradually pass into each other both vertically and laterally. However, Melichar & Hladil (1999) or Melichar (2004) proposed a complicated structural model of the Prague Synclinorium that presumes significant convergence of facies representing a more extensive sedimentary system.

The L-P boundary was defined at the base of *Eognathodus sulcatus sulcatus* Zone at Černá rokle near Kosoř. However, this decision was revised later and a new GSSP at Homolka near Praha-Velká Chuchle was approved by decision of the Subcommission on Devonian Stratigraphy and IUGS at the International Geological Congress in Washington, 1989 (Chlupáč & Oliver 1989). This definition is based on the conodont studies carried out by Weddige (in Chlupáč *et al*. 1985, Weddige 1987). However, his results were revised subsequently by Slavík &

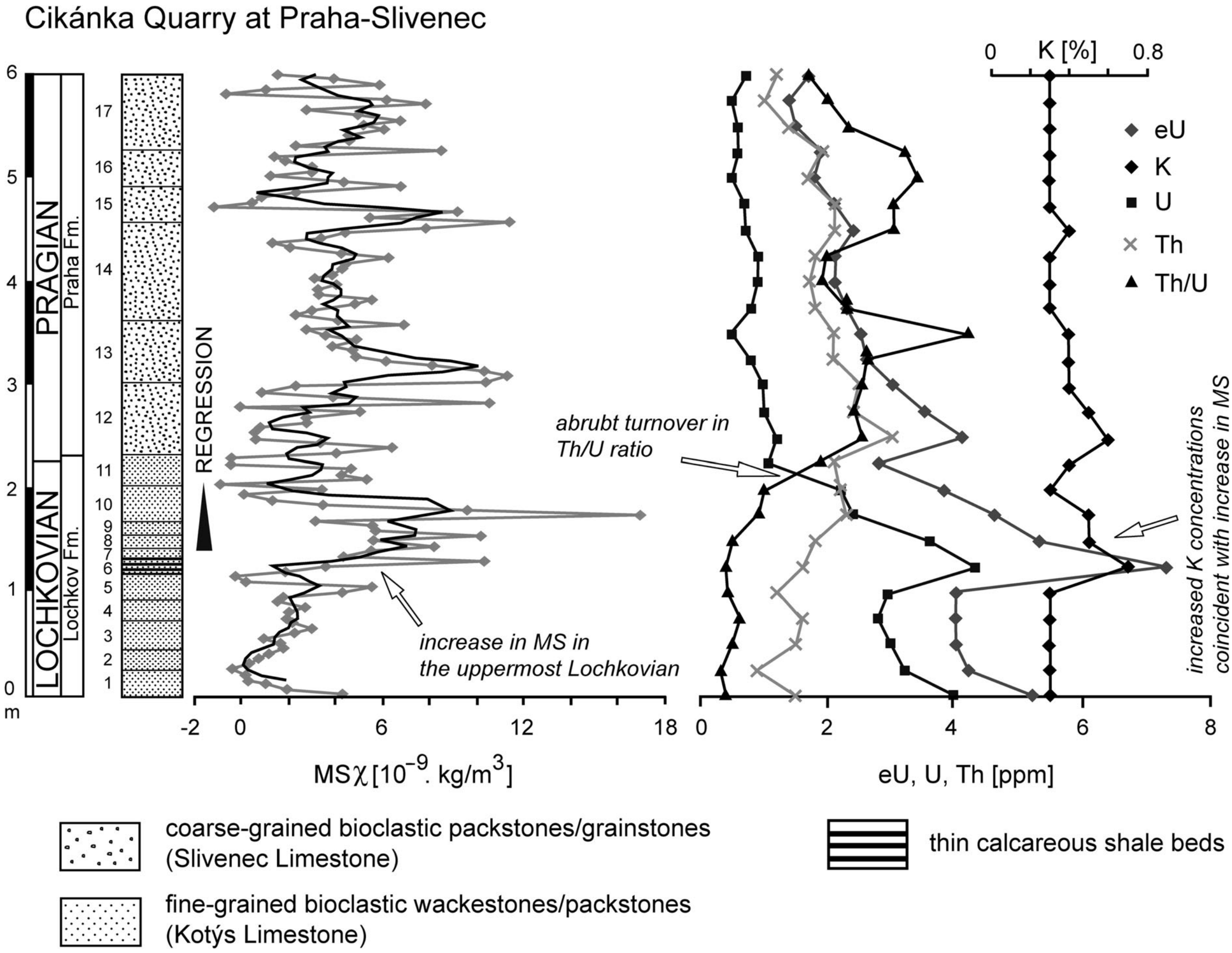

Figure 2. Magnetosusceptibility and gamma-ray spectrometric logs of the Cikánka section (bed numbers after Chlupáč *et al.* 1985). Grey MS curve represents raw values; black curve has been smoothed using four-point running average method.

Hladil (2004) and Slavík *et al.* (2007), who reported the first occurrence of index taxa more definitively than in the previous studies.

Study sections

Lithology, sedimentology, biostratigraphy, and other aspects of the studied sections have been described in many previous papers (*e.g.*, Chlupáč *et al.* 1985, Hladíková *et al.* 1997, Chlupáč 2000, Čáp *et al.* 2003, Vorel 2006, Slavík & Hladil 2004, Slavík *et al.* 2007). Thus, only brief descriptions of the sampled intervals are given here.

The Cikánka section is situated in an abandoned quarry near Praha-Slivenec (N 50° 0´ 5.168˝, E 14° 19´ 34.742˝; Fig. 1 – locality A). The studied interval comprises beds 1–17 (thickness 6.05 m; 122 MS samples, 25 GRS measurements). It is characterized by predominance of massive, medium- to coarse-grained bioclastic packstones to grainstones. The lower part of the section (beds 1–11; Fig. 2) belongs to the uppermost part of the Lochkov Fm. (Kotýs Lm. – grey coloured medium-grained packstones/grainstones). The overlying beds of pink coarse-grained packstones/grainstones belong to the base of the Praha Fm. (Slivenec Lm.). The L-P boundary occurs in the upper part of bed 11 (Slavík et al. 2007).

The Homolka section is situated at Praha-Velká Chuchle (N 50° 0´ 52.959˝, E 14° 22´ 20.822˝; Fig. 1 – locality B). The studied interval comprises beds 1–37 (thickness 5.9 m; 119 MS samples, 25 GRS measurements). The uppermost part of the Lochkov Fm. (beds 1–26; Fig. 3) consists of thin beds of fine- to medium-grained wackestones to packstones separated by thin shale intercalations. The overlying succession comprises fine-grained nodular mudstones (Dvorce-Prokop Lm.) of the basal part of the Praha Fm. (beds 27–37; Fig. 3). The L-P boundary is defined by the first appearance of index conodont *Eognathodus sulcatus "eosulcatus"* in bed 12 (Slavík & Hladil 2004).

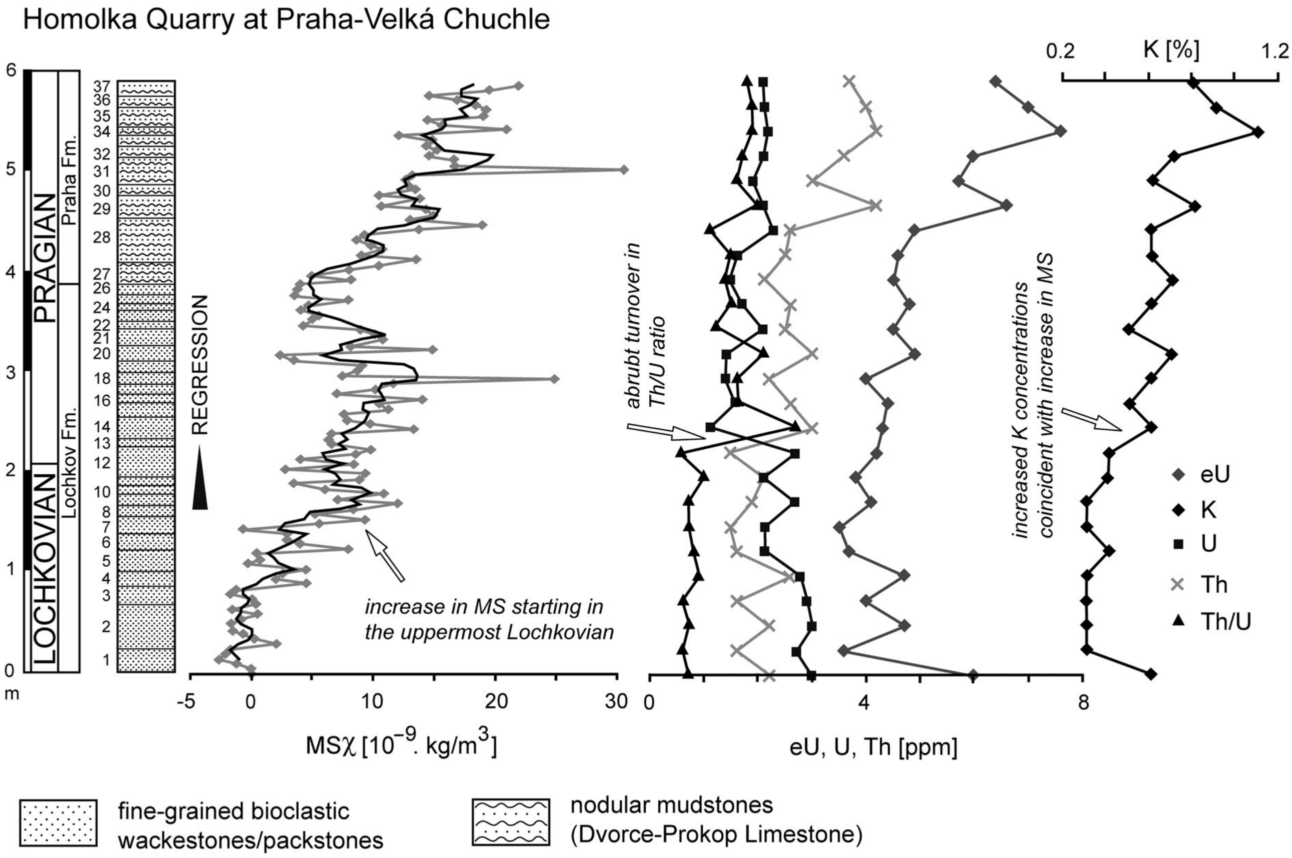

Figure 3. Magnetosusceptibility and gamma-ray spectrometric logs of the Homolka section (bed numbers after Chlupáč *et al.* 1985). Grey MS curve represents raw values; black curve has been smoothed using four-point running average method.

The sampled interval at Černá rokle near Kosoř (N 49° 59´ 22.932˝, E 14° 20´ 17.405˝; Fig. 1 – locality C) is 6 m thick (121 MS samples, 25 GRS measurements). The uppermost part of the Lochkov Fm. is characterized by rhythmic alternation of fine-grained mudstones/wackestones and shales (Radotín Lm.; beds 60–86; Fig. 4). The base of the Praha Fm. is characterized by nodular mudstones (Dvorce-Prokop Lm.; bed. 87; Fig. 4). The L-P boundary is situated in bed 76 (Slavík *et al*. 2007).

Methods

Although all studied sections had been depicted in many papers they have been re-measured for our purposes to avoid any ambiguities. All three sections have been sampled and measured in thickness of approximately 6 m. Sampling for the MS study was carried out in steps of 0.05 m.

Small cubic or slice rock samples (20–50 g) were collected for study of stratigraphic variations in MS. Only fresh rock samples were taken (*i.e*. avoiding calcite veins, visible pyrite or limonite aggregates, spots with suspected dolomitization and shear-deformed parts of the rock).

Measurements were carried out in the Laboratory of Geological Processes (Institute of Geology, Academy of Sciences of the Czech Republic, v.v.i., Prague) on a Kappa Bridge KLY-2 (produced by Agico Ltd. Brno; for technical details, refer to www.agico.com). Raw MS data obtained from the instrument have been recalculated to mass-specific susceptibility (χ) expressed in $m^3/kg \times 10^{-9}$ (in descriptions of magnetic signals in the studied sections and the following discussion, this is reported simply as MS without units). Raw MS curves have been smoothed using four-point running average method in order to visualize better trends in MS (Figs 2–4).

Magnetic susceptibility is a material property related to amount of magnetizable minerals in a rock sample, which become magnetized in magnetic fields. Limestones have generally very low MS values as their rock-forming constituents (calcite and aragonite) have diamagnetic behaviour and very weak negative MS magnitudes. The enhanced MS signal in limestones is induced by presence of non-carbonate impurities including various ferromagnetic (*sensu lato*) minerals (magnetite, maghemite, hematite), and also weakly magnetic but much more abundant paramagnetic minerals (clay minerals, pyroxene, amphibole, biotite, chlorite, pyrite, chalcopyrite, a.o.). The basic con-

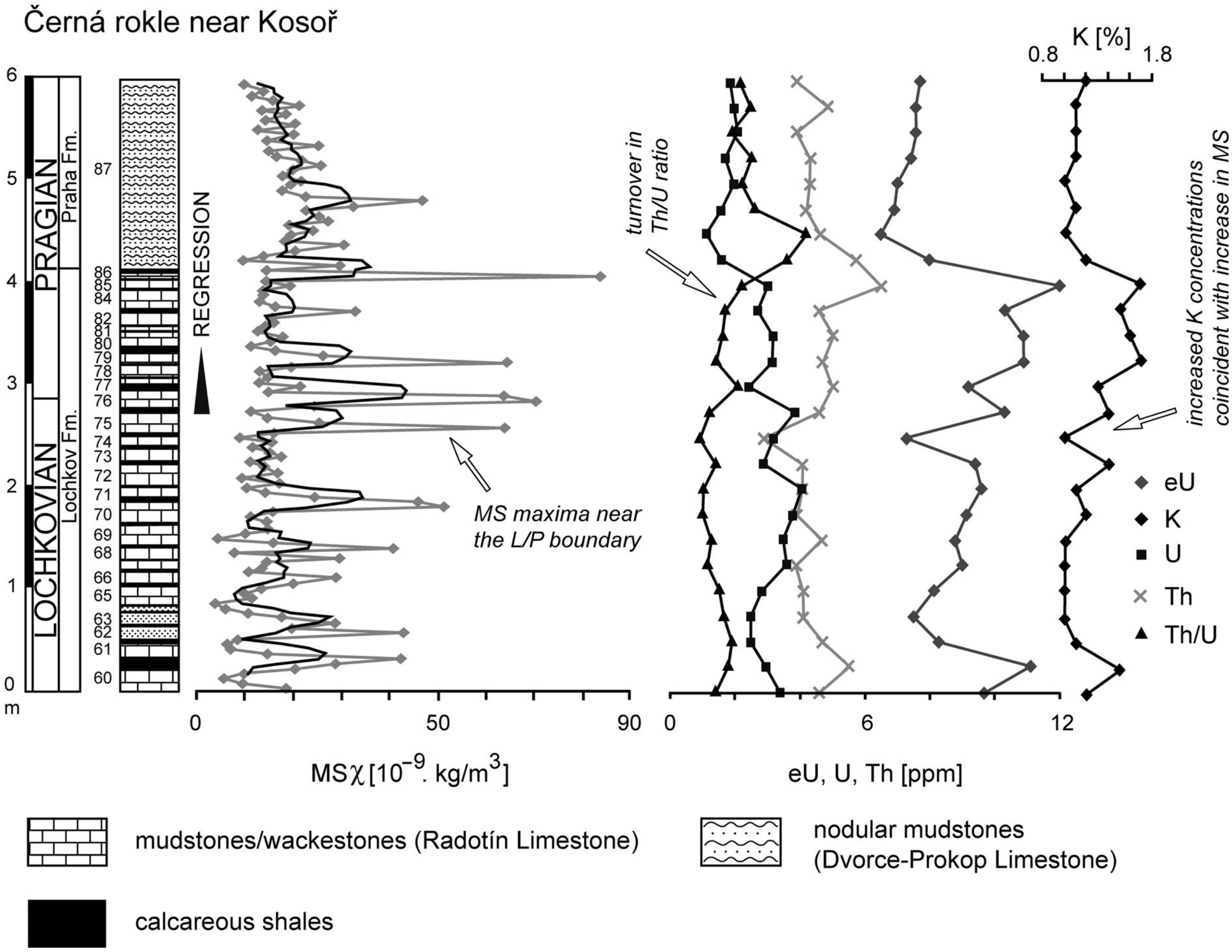

Figure 4. Magnetosusceptibility and gamma-ray spectrometric logs of the Černá rokle section (bed numbers after Chlupáč *et al.* 1985). Grey MS curve represents raw values; black curve has been smoothed using four-point running average method.

cepts of MS stratigraphy described by Ellwood *et al.* (2000, 2001) are based on the assumption that the major part of the magnetic material is of terrigeneous origin (*i.e.*, has been delivered to marine environments from land). According to this assumption, the supply with terrigeneous material is driven by fluctuations in sea-level, which control erosion in coastal areas and the delivery of weathering products to the sea. The maximum input of terrigeneous detritus should correspond to intensive erosion during the lowstand of sea-level and conversely, the delivery from land should be limited during highstands. Major events expressed in the MS are considered to be recognizable on both regional and global scales because of the synchronous variations in global erosion controlled by eustasy (Ellwood *et al.* 2000, 2001). However, there are many factors playing against this general assumption such as local synsedimentary tectonics or biotic events with enhanced carbonate productivity leading to lowering of the MS in major carbonate mass (Vacek *et al.* 2010) or eolian transport of non-carbonate material (Hladil 2002; Hladil *et al.* 2006, 2010a; Koptíková 2010b). Magnetite can also be of biogenic origin, produced by magnetotactic bacteria or algae. Many examples of this have been described in shallow-water conditions commonly associated with restricted circulation (for broad description and discussion on the primary and secondary magnetic minerals in carbonates see da Silva *et al.* 2009). However, some authors believe that biogenic magnetite contributes only very little to bulk MS as it does not respond to low inducing fields produced in measuring instruments (Ellwood *et al.* 2000).

The GRS measurements were performed using a field spectrometer Geofyzika-SatisGeo GS-512 with 0.25 m step at time of 240 s. Numbers of detected radiogenic emissions have been automatically calculated to element concentrations of K (%), U (mg/kg = ppm) and Th (ppm). The total natural gamma-ray variation has been inferred from selected energy windows, all above 720 keV. This instrument also provides an additional automatically displayed parameter set to notional uranium equivalent contents (eU, mg/kg or ppm). However, this may be used only for rough estimates of total gamma activity of the analyzed rocks (for discussion see Geršl & Hladil 2004).

Detected concentrations of K, U, and Th are mostly related to amount of feldspars, micas, and clay minerals, a.o. However, uranium is also known to be preferentially trapped in organic matter (*e.g*., Durrance 1986) and might be highly mobile during diagenetic processes. Therefore, its variations are mostly excluded from any environmental interpretations related to depositional processes. On the other hand, higher concentrations of K and Th should reflect increased amounts of non-carbonate mineral impurities in limestones that are caused by terrigeneous detrital influx.

Main characteristics of the MS and GRS records

The Cikánka section is characterized by relatively low MS values in the Lochkovian and Pragian parts of the section (see Table 1). A slightly upwards increasing trend can be seen (average magnitude for Lochkovian is 3.3, for Pragian 4.3). MS curve shows relatively high variations in both parts (standard deviations, SD, are 3.0 and 2.8). The uppermost Lochkovian is characterized by clearly upwards increasing trend in MS (see smoothed curve in Fig. 2), it is followed by a drop near the L-P boundary. The overlying Pragian sequence has also a progressive trend in MS (Fig. 2). Total gamma-activity of the measured rocks is also relatively low and tends to decrease upwards as along with U concentrations (Fig. 2). The Th/U ratio has distinctive progressive trend (its average value for Lochkovian is 0.7, for Pragian it is 2.6; see Fig. 2 and Table 1). Average magnitudes for K and Th remain relatively stable throughout whole section, concentrations of both elements show relatively low variations (see Table 1 for standard deviations). However, increased K and Th values, which correlate with increase in MS, can be seen near the L-P boundary (see Fig. 2). The eU is mostly related to variations in U content (R^2 = 0.9) and covariance with K and Th is very low (R^2 = 0.6 and 0.05).

The MS curve of the Homolka section displays a pronounced increasing trend (see smoothed curve in Fig. 3). The average magnitude for the Lochkovian is 2.7, and 11.5 for the Pragian (there is relatively high variation of the MS values in both parts, SD are 3.9 and 5.3, respectively; see Table 1). An increasing trend is also observable for eU, K, and Th. Coincident with this trend for eU, K and Th is an upward decreasing trend for U concentrations (see Fig. 3 and Table 1 for average concentrations and SD). Similar to the previous section, the Th/U ratio clearly shows an upward increasing trend (average magnitude for Lochkovian is 0.7, for Pragian it is 1.6). Trends in total gamma activity (eU) can be mostly related to variations in K and Th (R^2 = 0.84 and 0.88). Conversely, the covariance between eU and U is very low (R^2 = 0.02).

In the Černá rokle section a slight increase in the MS is observable from the Lochkovian to the Pragian (average magnitudes are 18.0 and 21.9, MS in both parts shows high variations, SD are 12.2. and 14.1; Table 1). The eU and U curves show a slightly decreasing trend upward. The K and Th contents tend to slightly increase upwards. Concentrations of all three elements show only low or moderate variations in both distinguished segments (see Table 1 for average concentrations and SD). The highest concentrations of K and Th correspond to MS maxima near the base of Pragian (Fig. 4). The enhancement in Th concentrations is expressed also in the progressive trend in the Th/U ratio (average value for Lochkovian is 1.4, for Pragian it is 2.3). The eU magnitudes depend mostly on K (R^2 = 0.85), while covariance with U and Th remains low (R^2 = 0.65 and 0.54).

There is a remarkable difference in the trends of the GRS-detected elements at the transition from the uppermost part of the Lochkov Fm. (platy limestone/shales) to the basal Praha Fm. (nodular mudstones) between Homolka and Černá rokle sections. In the Homolka section K, U, and Th concentrations clearly show an increasing trend however, the Černá rokle section is characterized by the opposite tendency developed in similar facies (see Figs 3 and 4).

Interpretation and discussion

Numerous studies on the relationship between palaeoenvironmental changes and MS stratigraphic variations have been published in recent years. These interpretations come from the general assumption that there is a relationship between the amount of terrigeneous supply responsible for increased MS values and eustasy (Ellwood *et al*. 2000). However, there are also various factors which play against this generalization (*e.g*., Hladil *et al*. 2006, 2009; Da Silva *et al*. 2009; Vacek *et al*. 2010). The MS signal may be strongly modified by secondary processes such as magnetite neomorphism during diagenesis or secondary remagnetization (see *e.g*., Riquier *et al*. 2010), which certainly devalues interpretations that the primary MS record reflects depositional conditions and processes. Vacek *et al.* (2010) and Koptíková *et al.* (2010b), who studied analogous facies from this stratigraphic level in other sections in the Prague Synclinorium, ascribed the major effect on the MS signal to changing amounts of various paramagnetic minerals (pyroxenes, amphiboles, micas, chlorite, a.o.) whereas ferromagnetic components (mainly magnetite, hematite, and goethite) have been present only subordinately and have had only limited influence on the bulk MS. Therefore, we may assume that the MS record mainly reflects

Table 1. Average magnitudes of the MS and GRS-based parameters in the studied sections, standard deviations for average values are given in brackets. Abbreviation: *Lo* – Lochkovian; *Pg* – Pragian.

Sections/their segments	MS_χ [10^{-9} m^3/kg]	eU [ppm]	K [%]	U [ppm]	Th [ppm]	Th/U
Cikánka *Lo* (0.0–2.25 m)	3.3 (3.0)	4.5 (1.1)	0.4 (0.1)	1.7 (0.9)	1.7 (0.4)	0.7 (0.5)
Cikánka *Pg* (2.25–6.05 m)	4.3 (2.8)	2.3 (0.7)	0.4 (0.1)	1.9 (0.2)	1.9 (0.5)	2.6 (0.6)
Homolka *Lo* (0.0–2.15 m)	2.7 (3.9)	4.2 (0.7)	0.4 (0.1)	2.6 (0.4)	1.9 (0.4)	0.7 (0.1)
Homolka *Pg* (2.15–5.9 m)	11.5 (5.3)	5.3 (1.1)	0.7 (0.2)	1.9 (0.4)	3.0 (0.8)	1.6 (0.5)
Černá rokle *Lo* (0.0–2.8 m)	18.0 (12.2)	8.9 (1.1)	1.1 (0.2)	3.2 (0.5)	4.2 (0.6)	1.4 (0.3)
Černá rokle *Pg* (2.8–6.0 m)	21.9 (14.1)	8.7 (1.7)	1.3 (0.2)	2.3 (0.6)	4.7 (0.7)	2.3 (0.7)

primary conditions and can be used for further environmental interpretations.

There is a more or less distinctive progressive trend in the MS from Lochkovian to Pragian in all three studied sections (see Table 1). This trend is apparent in the Cikánka and Homolka sections (see smoothed curves in Figs 2 and 3). In the Černá rokle sections numerous MS peaks related to alternation of limestone and shale beds may cloak the overall trend (Fig. 4). As these MS peaks mostly correspond to limestone beds, this pattern is related to increased delivery of magnetic particles by calciturbidites to the carbonate slope environment with prevailing hemipelagic sedimentation (see Vacek *et al*. 2010).

A similar, slightly upward increasing trend holds for K and Th which also may reflect enhanced amounts of detrital material in Pragian parts of all sections. This increase starts near the base of Pragian in all sections even if it is still situated in the "Lochkovian" facies (see Figs 2–4). Similar patterns of MS and GRS stratigraphic variations at the L-P boundary have been also described from other sections in this area (*e.g.*, Požáry Quarry near Praha-Řeporyje in the NW part of the Prague Synclinorium; Koptíková *et al.* 2010a, b).

If we apply the basic concept of MS stratigraphy (Ellwood *et al.* 2000, 2001) to our sections, we could conclude that the increased amount of non-carbonate impurities at the L-P transition reflects a regressive event. This is in accordance with the traditional idea based on faunal changes that the L-P boundary event is regressive (Chlupáč & Kukal 1988). Regressive conditions also may be supported by the facies changes in the shallow-water settings (*e.g.*, Cikánka section) where grey-coloured Kotýs Lm. in the uppermost Lochkovian (bioclastic wackestones/packstones) is replaced in the lowermost Pragian by pink-coloured Slivenec Lm. (coarse-grained bioclastic grainstones; Čáp *et al.* 2003, Vorel 2006). On the other hand, facies changes at the transition from the Lochkovian to Pragian in the carbonate slope environment rather suggest an opposite trend – nodular mudstones (Dvorce-Prokop Lm.) at the base of the Praha Fm. are considered deposits of highstand conditions (Vorel 2006).

The L-P transition in all our sections as well as in other sections described in literature (*e.g.*, Slavík *et al*. 2000; Hladil *et al*. 2008; Koptíková *et al*. 2010 a, b) is characterized by an abrupt turnover in Th/U ratio. The Pragian magnitudes are usually 2–4× higher than Lochkovian values. According to Ruffell & Worden (2000) the Th/U ratio may have palaeoclimatic implications. It is known that U and K are more soluble than Th. Content of Th increases with weathering on land during hot and humid climatic phases. Thus, low magnitudes of Th/U should correspond to colder climate and higher values to warm climatic conditions, with enhanced amounts of Th delivered from land to sea. Applying these premises to our studied sections, we interpret the abrupt change in Th/U at the L-P boundary as a result of warming (see also Hladil *et al*. 2008, Vacek 2010 or Koptíková *et al.* 2010b). It is notable that this Th/U trend has been recorded across the Prague Synclinorium in various facies. This presumed palaeoclimatic event coincides with the facies change at the base of the Praha Fm. (see above). In deeper-water environments, distal calciturbidites with shales are replaced by hemipelagic mudstones. This change has been explained as a result of se-level rise (Vorel 2006). This interpretation might be in accordance with presumed palaeoclimate warming which caused glaciers melting and sea-level rise. This might be expressed in enhanced carbonate productivity during transgression and highstand (highstand shedding effect of Schlager *et al.* 1994) and disappearance of shales with lower carbonate content (Vacek 2010). This interpretation is supported by the progressive trend in $CaCO_3$ content from the Lochkovian to Pragian described by Koptíková *et al.* (2010b). However, it contradicts the shallowing-trend observable in shallow-water facies (see above in the text). Thus, these general assumptions would lead to a completely opposite interpretation of the facies change at the L-P boundary in different settings. However, these changes need not be a result of a significant sea-level fluctuation, but rather result from a climatic event. As described by Vacek *et al.* (2010), synsedimentary tectonics also might have caused short-term facies changes, which might be confused with effects of minor eustatic sea-level changes. The widespread distribution of shallow-water facies (including reef facies in the Koněprusy area, SW part of the Prague Synclinorium) in the lower part of the Praha Fm. also suggests a regressive trend during this time interval.

However, the regression might be modified locally by synsedimentary uplift, with eustasy playing only a minor role. The synsedimentary uplift in this time interval is best documented in the Koněprusy area (SW part of the Prague Synclinorium), where it is expressed in a stratigraphic gap in the upper Lochkovian (Chlupáč 2003).

Originally defined on paleontological and lithological data, the regressive event at the L-P boundary has been analysed by various other methods, *e.g.* by isotopic studies. Hladíková *et al.* (1997) described a gradual increasing trend in $\delta^{13}C$ both in the Lochkovian and Pragian parts of the Homolka section. They explained this increase as a result of enhanced bioproductivity during the Lochovian-Pragian regressive phase or increased burial of organic matter. Buggisch & Mann (2004) provided evidence for a sharp increase in $\delta^{13}C$ at the L-P boundary in other sections from the Prague Synclinorium (including the Černá rokle section) as well as from other regions of Europe (Carnic Alps and Cantabrian Mountains). Buggisch & Mann (2004) also ascribed this increase to the effects of a drop in sea-level during the Lochkovian-Pragian interval. These effects have been also reported from other parts of the world as well, *e.g.* central Asia (Koren *et al.* 2007), Northern America (Johnson & Murphy 1984, Johnson *et al.* 1985), Australia (Talent & Yolkin 1987) or Northern Africa (Chlupáč *et al*. 1988, Lubeseder 2008) indicating that the event is probably global in nature. Results of studies on carbon and oxygen isotopes published by Buggisch & Mann (2004) and Saltzman (2005) suggest a pronounced global event in palaeooceanographic conditions related to climate warming. While the Silurian to Lochkovian period has been characterized by cool-water conditions, the succeeding Pragian to Givetian interval was distinguished by higher temperatures of the oceans. However, Joachimski *et al.* (2009) concluded from oxygen isotopes from conodont apatite that Lochkovian was a period of warm tropical climate, which was followed by cooling in Pragian characterized by intermediate temperatures.

As described above our data and interpretations contribute to the palaeonvironmental image of this time interval in the Devonian type area. Our results are consistent with various data published previously, but they are in contradiction with other theories such as that of Joachimski *et al*. (2009).

Conclusions

The MS and GRS stratigraphic records of three L-P boundary sections representing different depositional conditions have been evaluated. The boundary interval is characterized by facies change in all studied sections. All sections display an increase in MS that coincides with increased K and Th concentrations from uppermost Lochkovian to Pragian. This may reflect increased delivery of terrigeneous material as a result of a regressive trend (*e.g.*, the previously defined Lochkovian-Pragian boundary event). Another prominent characteristic in these sections is a turnover in the Th/U ratio with the Pragian magnitudes 2–4× higher than the Lochkovian values. Based on combined physical stratigraphic and sedimentological approach, the previously reported regressive event during this time interval is ascribed to climatic warming accompanied by enhanced carbonate productivity (as documented by the increasing amount of $CaCO_3$ in limestones in the lower part of the Praha Fm. and the isotopic data reported in the literature). Eustatic sea-level changes probably played only a subordinate role in the L-P boundary event and local synsedimentary uplift such as that documented in various parts of the Prague Synclinorium may enhance or mask this eustatic signal.

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