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First record of the early Sheinwoodian carbon isotope excursion (ESCIE) from the Barrandian area of northwestern peri-Gondwana

Jiri Frýda[a,b], Oliver Lehnert[c–e] and Michael Joachimski[c]

[a] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6 – Suchdol, 165 21, Czech Republic
[b] Czech Geological Survey, Klárov 3/131, 118 21 Prague 1, Czech Republic; bellerophon@seznam.cz
[c] GeoZentrum Nordbayern, Universität Erlangen, Schlossgarten 5, D-91054 Erlangen, Germany; oliver.lehnert@fau.de, michael.joachimski@fau.de
[d] Department of Geology, Lund University, Sölvegatan 12, 223 62 Lund, Sweden; oliver.lehnert@geol.lu.se
[e] Institute of Geology at Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia

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Abstract. The $\delta^{13}C$ record from an early Sheinwoodian limestone unit in the Prague Basin suggests its deposition during the time of the early Sheinwoodian carbon isotope excursion (ESCIE). The geochemical data set represents the first evidence for the ESCIE in the Prague Basin which was located in high latitudes on the northwestern peri-Gondwana shelf during early Silurian times.

Key words: Silurian, early Sheinwoodian, carbon isotope excursion, northern peri-Gondwana, Barrandian area, Prague Basin, Czech Republic.

INTRODUCTION

The early Sheinwoodian carbon isotope excursion (ESCIE) is known from several palaeocontinents in the Silurian tropics and subtropics (Lehnert et al. 2010, with references therein). Most records are documented from different parts of Laurussia, including its Laurentian part (e.g., Saltzman 2001; Brand et al. 2006), the Baltoscandian Basin (e.g., Munnecke et al. 2003; Kaljo et al. 2007; Racki et al. 2012) and the Avalonian part of Laurussia (e.g., Loydell & Frýda 2007). There is one study from tropical Gondwana (New South Wales; Talent et al. 1993) and only two records from higher latitudes of peri-Gondwana and Gondwana (Wenzel 1997; Vecoli et al. 2009).

From the Prague Basin, all the other major Silurian $\delta^{13}C$ excursions associated with different bioevents such as the late Aeronian *sedgwickii* Event, the Homerian Mulde Event, the Ludfordian Lau Event or *kozlowskii* Event and the Silurian/Devonian boundary event have been reported (Frýda & Frýdová 2014, with references therein).

In this short paper, we report the first $\delta^{13}C$ record of the ESCIE from an early Sheinwoodian limestone unit in the Prague Basin. Oxygen isotope data from the Eastern Baltic (Lehnert et al. 2010) suggest a strong shift into icehouse conditions during the event and represent, beside coeval diamictites in western peri-Gondwana, an evidence of an early Silurian glaciation. The expression of this glacial in the Prague Basin has already been discussed with respect to the deposition of early Sheinwoodian limestones during a glacially-driven major sea level drop (Lehnert et al. 2010).

GEOLOGICAL SETTING

The Lower Silurian successions in the Prague Basin (northern peri-Gondwana) are exclusively composed of fine-grained siliciclastics (Kříž 1998). The oldest Silurian carbonate deposition occurs in the middle part of the *Stimulograptus sedgwicki* graptolite Biozone (Aeronian, Llandovery) during a rapid sea level drop associated with the late Aeronian carbon isotope excursion (Štorch & Frýda 2012, with references therein). The first lenses and beds of micritic and bioclastic limestones younger than Llandovery in age, with abundant fossils of the *Niorhynx* Community of Havlíček & Štorch (1990), occur in the *Cyrtograptus murchisoni* and *Monograptus riccartonensis* biozones. This signal, indicating warmer conditions or a sea level drop in the Prague Basin, has been documented near Prague by Bouček (1937, Řeporyje area) and Havlíček & Štorch (1990, Malá Chuchle area). In the Central Segment of the Prague Basin comparable bioclastic limestones formed during the *C. murchisoni* Biozone (Svatý Jan area, Kříž 1991).

The Sheinwoodian (early Wenlock) strata in the Prague Basin are represented by the lower part of the Motol Formation which comprises the uppermost Telychian (Llandovery) through the entire Wenlock (Kříž 1975). This lower part of the formation is sedimentologically more uniform and mainly consists of calcareous clayey shales. In its middle and upper parts volcanic rocks and limestones are significant. Facies distribution was strongly influenced by synsedimentary tectonics and volcanic activity in the upper Motol Formation (Bouček 1934, 1953; Horný 1955, 1960; Kříž 1991). Its thickness varies from 80 to 300 m (Kříž 1998).

The section described in this paper (49°57′29.533″N, 14°5′48.190″E, section No. 566 by Kříž 1992) is located on the left (north) bank of the Berounka River, south of the village of Lištice near Beroun (Fig. 1). It is located in the Northern Segment of the Prague Basin (NW of Tachlovice fault) which had a lower subsidence rate than the adjacent Central Segment. The thickness of the Motol Formation reaches here only about 100 m (Kříž 1998).

The studied section starts in laminated siliceous graptolitic shales of the *Oktavites spiralis* graptolite Biozone (Horný 1955). The top of this shale succession shows an irregular erosional surface covered by an about 2 m thick limestone unit (Fig. 2A). The front part of this limestone shows megaslab internal deformation, brecciation and folding, as well as soft sediment deformation in the shale matrix. In the backpart, where the megaslab was partly disrupted (Fig. 2B) and represents some badly sorted megabreccia, less and less limestone beds are preserved until one last bed is disappearing upslope towards the volcanic centre. The matrix of the huge limestone slab is mainly some brown-green tuffite. Horný (1955) suggested a transport of limestone blocks from the present-day north or northeast to the south. The limestone succession is dominated by extremely fine-grained, laminated grainstones with intercalated coarser-grained bioclastic pack- to grainstones with brachiopods and crinoids as well as some thin brachiopod layers (Fig. 2C). Some parts, especially close to the top of the limestone unit, contain a high admixture of volcanoclastic components (Fig. 2D). Kříž (1992) noted that this succession is represented by two types of limestones, one bearing mainly brachiopods (*Niorhynx niobe*, *Cyrtia spiriferoides*, *Hirciniscа rhynchonelliformis*, *Bleshidium papalas* and *Gladiostrophia mixta*), the other one mainly trilobites (*Trochurus speciosus*, *Planiscutellum planum*, *Staurocephalus murchisoni*, *Cheirurus insignis* and *Decoroproetus decorus*). Horný (1955) found *Cyrtograptus* cf. *murchisoni* in limestone clasts within the redeposited unit. Later, Dufka (1992) discovered the abundant occurrence of the biostratigraphically significant chitinozoan *Margachitina margaritana*. The limestones are covered by a shale succession with rare, thinly laminated limestone beds corresponding to the *Monograptus belophorus* to *Cyrtograptus perneri–C. ramosus* biozones (Horný 1962; Kříž 1992).

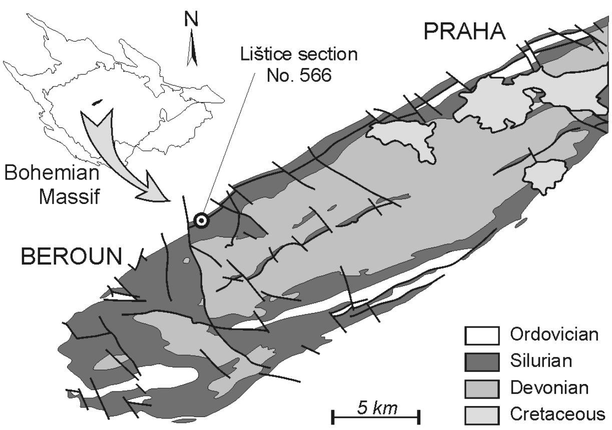

Fig. 1. Distribution of Silurian rocks in the Barrandian area (Perunica), including the position of the studied section (modified after Kříž 1992).

METHOD AND RESULTS

The parauthochthonous section throughout the limestone unit in the Lištice section No. 566 has been sampled about 15 m behind its deformed front (Fig. 2A) where the beds still seem to be intact and tectonically undisturbed. Most of the limestone beds are partly silicified and show an admixture of volcanoclastic components (Fig. 2D). A total of 55 carbonate samples were analysed for δ^{13}C. Forty-two samples originate from the measured section (Fig. 2A), five samples from thinly laminated limestone beds of the mostly tuffitic shale succession overlying the limestone unit and eight samples from the base and top of the megaslab along the whole outcrop, collected to analyse the spatial distribution of δ^{13}C values in its more disrupted parts.

Carbonate powders were reacted with 103% phosphoric acid at 70 °C using a Gasbench II connected to a ThermoFinnigan Five Plus mass spectrometer. All values are reported in per mil relative to V-PDB by assigning a δ^{13}C +1.95‰ to NBS19. Accuracy and precision were controlled by replicate measurements of laboratory standards and were better than ±0.1‰ for the carbon isotope data.

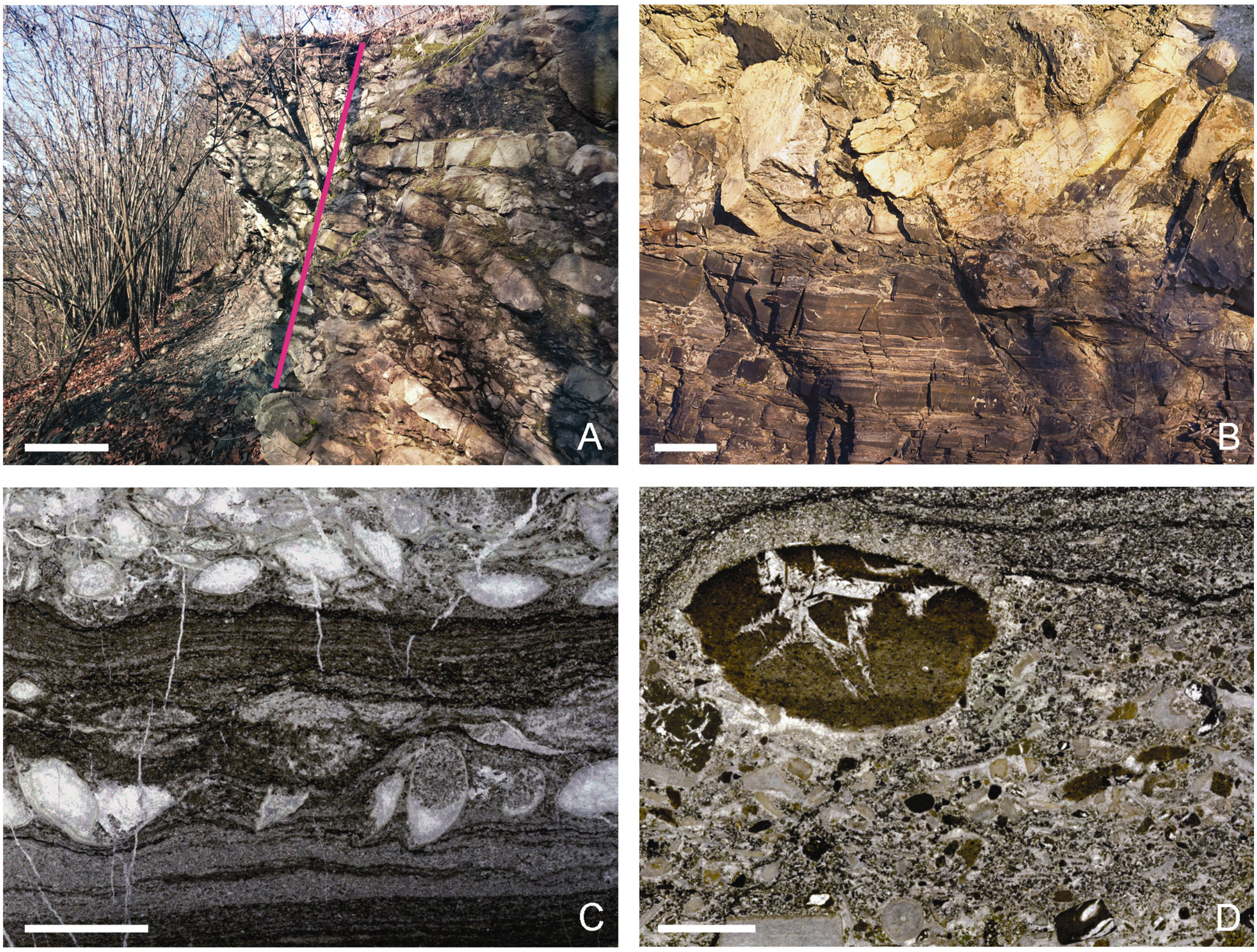

Fig. 2. A, general view of the Lištice limestone megaslab (section No. 566 of Kříž 1992) showing the position of the measured section; the scale bar is 0.5 m; **B**, basal part of the Lištice section showing the laminated siliceous graptolitic shales of the *Oktavites spiralis* Biozone with the irregular erosional surface at their top, covered by brecciated limestones in the more distal and stretched part of the megaslab, which in relation to its origin at the volcanic centre reflects the most proximal end of this limestone body; the scale bar is 0.1 m; **C**, fine-grained, laminated grainstones with intercalations of thin brachiopod layers; the scale bar is 1 cm; **D**, coarse-grained and poorly sorted bioclastic grainstone, with high admixture of volcanoclastic components overlain by fine-grained and laminated grainstones close to the top of the limestone succession; the scale bar is 0.5 cm.

The $\delta^{13}C$ analysis of the 42 samples from the measured section revealed a high variability of values up to 4.10‰ (Fig. 3). Similar $\delta^{13}C$ values (from 1.72‰ to 3.22‰) were found in eight samples from limestone blocks in the more disrupted part of the megaslab. The $\delta^{13}C$ values of five samples from thin laminated limestone beds within the tuffitic shale succession covering the limestones are much lower and range from –2.66‰ to –1.23‰.

STRATIGRAPHIC FRAMEWORK AND CONCLUSIONS

The abundant occurrence of *Margachitina margaritana*, a chitinozoan zonal index for the base of the Sheinwoodian (Wenlock; Loydell 2012), in the limestones at Lištice (Fig. 3) might be equivalent to the *C. murchisoni* graptolite Biozone, but the taxon occurs also in the Telychian *O. spiralis* graptolite Biozone (Loydell & Nestor 2005). The limestone megaslab covers the irregular erosional surface on top of the shales of the *O. spiralis* graptolite Biozone (Figs 2B, 3). Horný (1955) and Kříž (1992) mentioned *C. murchisoni* from the limestone of the megaslab, hitherto the most exact biostratigraphic marker. The first appearance (FAD) of *C. murchisoni* is considered to indicate the base of the Wenlock Series and represents the index of the basal zone of the Sheinwoodian (Loydell 2012), followed by *M. riccartonensis*. However, the last occurrence of *C. murchisoni* is complicated. In many areas *C. murchisoni* disappears just before the FAD of

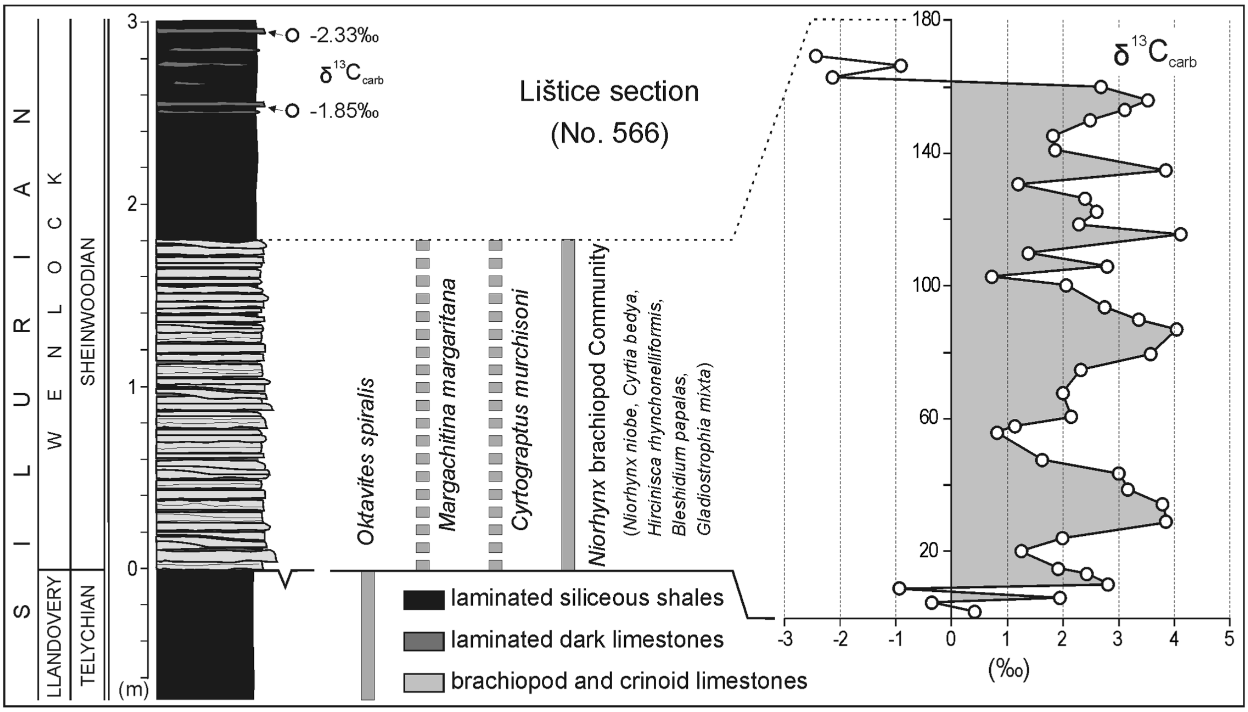

Fig. 3. Faunal occurrences and $\delta^{13}C$ record of the ESCIE in the Lištice section (section No. 566 of Kříž 1992) of the Motol Formation.

M. riccartonensis. However, in the Prague Basin *C. murchisoni* occurs also in the lower *M. riccartonensis* Biozone as the subspecies *C. murchisoni bohemicus* (Štorch 1994, 1995; Williams & Zalasiewicz 2004). Therefore, the most likely age of the limestone succession is early Sheinwoodian (*C. murchisoni* to the lower part of the *M. riccartonensis* biozones).

The 42 samples from the measured section reveal a high variability in $\delta^{13}C$ values (Fig. 3). This fact, together with possible internal deformation and brecciation in parts of the redeposited unit, suggests that duplications or gaps may occur within the section. On the other hand, the $\delta^{13}C$ values, showing rather a repeating non-random pattern (Fig. 3) than a random sawtooth pattern of chaos, may represent a real record. A similar degree of variation for the ESCIE was documented in the eastern Appalachian Basin (McLaughlin et al. 2012, fig. 3).

The $\delta^{13}C$ values of up to 4.10‰ are far above the early Sheinwoodian $\delta^{13}C$ background values of about 1‰ (e.g., Cramer et al. 2011). The high $\delta^{13}C$ values suggest carbonate deposition during a positive $\delta^{13}C$ anomaly in the global marine carbon cycle. If we take the most likely biostratigraphic age of the limestone succession (*C. murchisoni* to lower *M. riccartonensis* biozones) into account, the sedimentation of the limestones at Lištice clearly took place during the ESCIE.

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