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Taconic orogeny and how it found ground in Bulgaria

Таконската орогенеза и как тя намери почва у нас

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The Taconic orogeny is the first one of three mountain-building events forming the Appalachian Mountains in eastern North America, the Acadian–Neoacadian and Alleghenian orogenies being the second and third events, respectively (Hatcher, 2010). The Taconic orogeny, which involved arc accretion, was not, as traditionally defined, a single orogenic event that occurred at the end of the Ordovician period, but rather a complex series of orogenic episodes or climaxes spread over the larger part of that period (Rodgers, 1971). How did this distant tectonic event find ground in Bulgaria?

Spasov (1960) studied the stratigraphy of the Ordovician and Silurian in the Svoge anticline (Svoge Unit according to Dabovski, Zagorchev, 2009) and has first mentioned Taconic orogeny, trying to explain the absence of the lowermost Silurian *Akidograptus ascensus* and *Parakidograptus acuminatus* graptolite zones. According to him, in order to accept the sandstones at the Ordovician/Silurian boundary (i.e., the Sirman Formation, in Sachanski, 2015, and references therein) as Silurian in age instead of Ordovician, they would have to correspond completely to the mentioned zones, or their absence could be a response of the Taconic tectonic phase. Later on, both zones and the uppermost Ordovician *Metabolograptus persculptus* Zone have been recognized in the black lydites and siliceous shales from the lowermost stratigraphic levels of the Saltar Formation (Sačanski, 1993; Lakova, Sachanski, 2004).

According to Yanev (1992, 1995), the sandstones of the Sirman Formation overlie with angular and metamorphic discordance, or with a seeming concordance, the eroded surface of the Tseretsel Formation, and mark the onset of a new sedimentary cycle, thus meaning an end-Ordovician orogenic phase that has affected this area. The metamorphic discordance was later on rejected by Yanev and Stefanov (2001), who have concluded that the studied fine siliciclastics underwent the same anhymetamorphic changes in their post-sedimentary evolution. Chatalov (2017) in a first detailed sedimentological study of the Sirman Formation recovered a sharp non-erosive basal contact together with a local development of low-amplitude load casts, without manifestation of any tectonic phase across the Ordovician/Silurian boundary. At the end of the Ordovician, however, there was an event which affected the planet globally.

The first of the mass extinctions of the Phanerozoic occurred during the last stage of the Ordovician Period, the Hirnantian, at ca. 440 (Sheehan, 2001, and references therein). The extinction appears to have occurred in two pulses. The first one was associated with a glacio-eustatic sea-level fall of 70–100 m as ice sheets developed on Gondwana, which at the time was situated at the South Pole. Large expanses of tropical to subtropical epicontinental seas replete with carbonate platforms, and diverse benthic and planktonic faunas became subaerially exposed. Marginal anoxic zones became fully oxygenated as oceanic mixing rates apparently intensified. After this first wave of extinction, a more cosmopolitan "Hirnantian" fauna evolved, only to suffer considerable losses at the end of the glaciation as sea-level rose and shelfal anoxia was re-established.

The graptolite record across the Ordovician/Silurian boundary (Fig. 1) shows some specific features in the peri-Gondwanan Europe (Štorch, 1996;

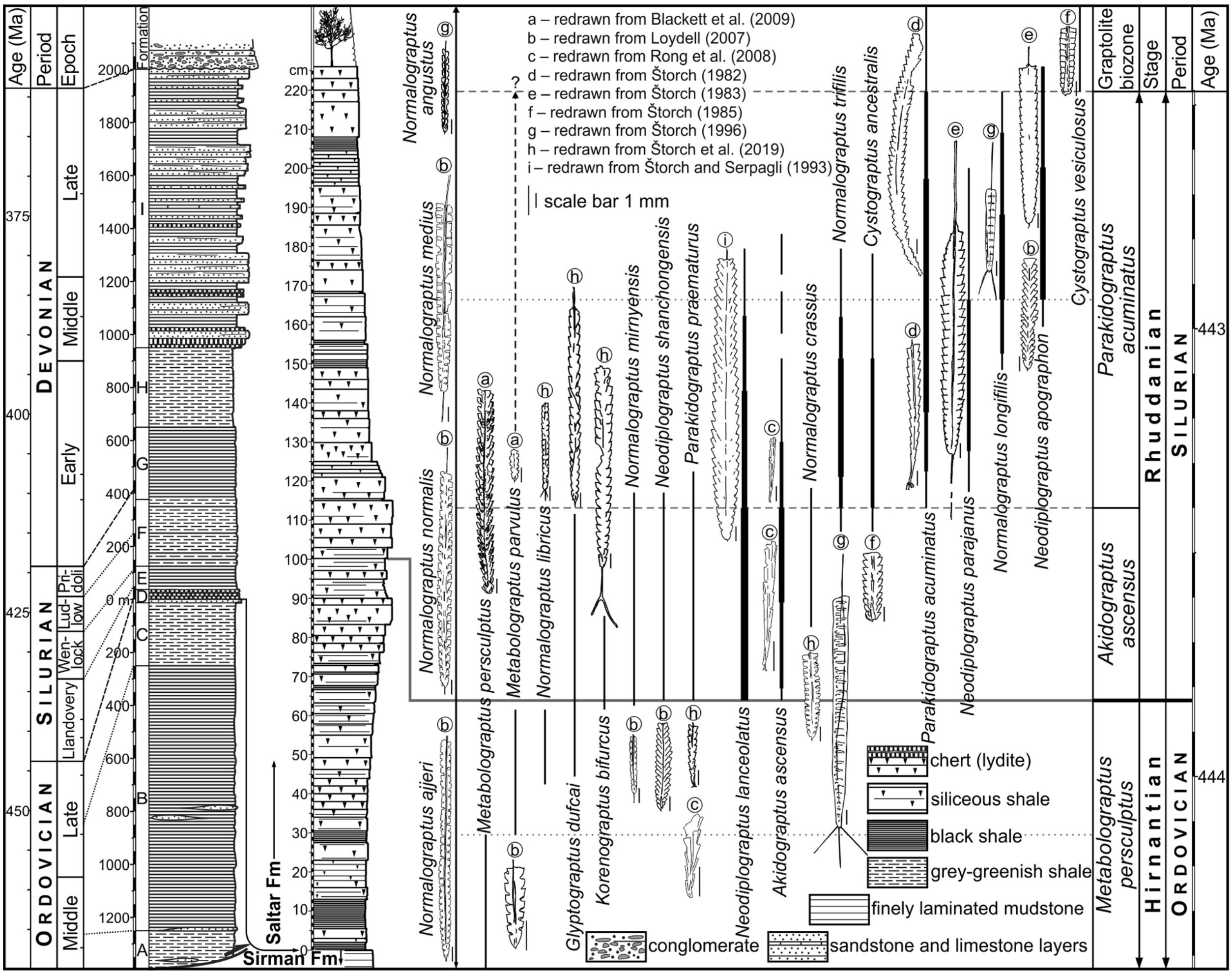

Fig. 1. Generalized lithostratigraphic column of the Palaeozoic in the Svoge Unit (Formations: A – silty-clayey metaformation; B – Grohoten; C – Tseretsel; D – Sirman and Saltar; E – Mala Reka; F – Yabukov Dol; G – Ogradishte; H – Romcha; I – Katina), Upper Hirnantian–Lower Rhuddanian time scale with graptolite biozonation (Cooper et al., 2012; Melchin et al., 2012), and lithostratigraphic column of the Ordovician/Silurian boundary sedimentary succession in Saltarski Dol section with range-chart (Štorch, 1996, Štorch et al., 2019), and illustrations of the typical graptolite species for peri-Gondwanan Europe.

Štorch et al., 2019). The Ordovician–Silurian sequences in the Svoge Unit were parts of this space. There were over 40 sections examined in order to establish a continuous stratigraphic succession in this interval. Although based on geological maps for the area opportunities extend beyond 100 km (Sachanski, 2015, Fig. 1), till now the only one suitable section remains that in Saltarski Dol near Batuliya Village (Sačanski, 1993; Lakova, Sachanski, 2004). In most cases, this boundary interval is covered by deluvium, often the contact is tectonically disturbed and/or dominated by lydites, from which it is difficult, if not impossible, to extract identifiable graptolites. The first occurrence (FO) of *Ak. ascensus* has been recorded 1 m above the boundary between the Sirman and Saltar formations, together with the FOs of *Neodiplograptus lanceolatus* and *Normalograptus trifilis*. The latter species are characteristic of the uppermost part of the *Ak. ascensus* graptolite zone and the lower part of *Par. acuminatus* graptolite zone. *M. persculptus* has been recorded 50 cm below them, and the FO of *Par. acuminatus* is 20 cm higher. A number of species confined to peri-Gondwanan Europe have not yet been identified and others like *Par. praematurus*, *M. persculptus*, *N. normalis*, and *N. medius* should be revised according to new concepts of these species (see Štorch et al., 2019 for the former and Loydell, 2007 for the latter three).

And yet, whether the echo of Taconic orogenesis (Spasov, 1960) has reached our lands and not only them? The Earth's climate cooled through the Ordovician Period leading up to the Hirnantian glaciation. Increased weatherability of silicate rocks associated with topography generated on the Appalachian margin during the Taconic orogeny has been proposed (Kump et al., 1999; Swanson-Hysell, Macdonald, 2017; Macdonald et al., 2019) as a mechanism for Ordovician cooling. According to this weathering hypothesis, atmospheric pCO_2 fell prior to and during the initial phases of ice-sheet growth, but then rose during glacial maximum times because of reduced weathering. Eventually, the greenhouse effect of CO_2 overcame the cooling albedo effect of glacial ice, and the glaciation ended. These events leave a mark on the development of organisms and the nature of sedimentary sequences around the world.

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References

Blackett, E., A. Page, J. Zalasiewicz, M. Williams, B. Rickards, J. Davies. 2009. A refined graptolite biostratigraphy for the Late Ordovician–early Silurian of central Wales. – *Lethaia*, *42*, 83–96.

Chatalov, A. 2017. Sedimentology of Hirnantian glaciomarine deposits in the Balkan Terrane, western Bulgaria: Fixing a piece of the north peri-Gondwana jigsaw puzzle. – *Sedimentary Geol.*, *350*, 1–22.

Cooper, R. A., P. M. Sadler, O. Hammer, F. M. Gradstein. 2012. The Ordovician Period. – In: Gradstein, F. M., J. G. Ogg, M. D. Schmitz, M. D. Ogg (Eds.). *The Geologic Time Scale 2012*. Oxford, Elsevier, 489–523.

Dabovski, H., I. Zagorchev. 2009. Introduction: Mesozoic evolution and Alpine structure. Alpine structure. – In: Zagorchev, I., H. Dabovski, T. Nikolov, (Eds.), *Geology of Bulgaria. Vol. II. Mesozoic Geology*. Sofia, "Prof. M. Drinov" Academic Press, 30–37 (in Bulgarian with English abstract).

Hatcher, R. D. Jr. 2010. The Appalachian orogen: A brief summary. – *The Geological Society of America Memoir*, *206*, 1–19.

Kump, L. R., M. Arthur, M. E. Patzkowsky, M. E. Gibbs, M. T. Pinkus, P. M. Sheehan. 1999. A weathering hypothesis for glaciation at high atmospheric pCO_2 during the Late Ordovician. – *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, *152*, 173–187.

Lakova, I., V. Sachanski. 2004. Cryptospores and trilite spores in oceanic graptolite-bearing sediments (Saltar Formation) across the Ordovician–Silurian boundary in the West Balkan Mountains, Bulgaria. – *Rev. Bulg. Geol. Soc.*, *65*, 1–3, 151–156.

Loydell, D. K. 2007. Graptolites from the Upper Ordovician and lower Silurian of Jordan. – *Special Papers in Palaeontology*, *78*, 1–66.

Macdonald, F. A., N. L. Swanson-Hysell, Y. Park, L. Lisiecki, O. Jagoutz. 2019. Arc-continent collisions in the tropics set Earth's climate state. – *Science*, *364*, 181–184.

Melchin, M. J., P. M. Sadler, B. D. Cramer, R. A. Cooper, F. M. Gradstein, O. Hammer. 2012. The Silurian Period. – In: Gradstein, F. M., J.G. Ogg, M. D. Schmitz, G. M. Ogg (Eds.). *The Geologic Time Scale 2012*. Oxford, Elsevier, 525–558.

Rodgers, J. 1971. The Taconic orogeny. – *Geol. Soc. Am. Bull.*, *82*, 1141–1177.

Rong, J., M. J. Melchin, S. H. Williams, T. N. Koren, J. Verniers. 2008. Report of the restudy of the defined global stratotype of the base of the Silurian System. – *Episodes*, *31*, 315–318.

Sačanski, V. 1993. Boundaries of Silurian System in Bulgaria defined by graptolites. – *Geologica Balc., 23*, 1, 25–33.

Sachanski, V. 2015. The Silurian in the West Balkan Mts. (Svoge Unit, Srednogorie Zone) – 110 years later. – *Geologica Balc.*, *44*, 1–3, 3–15.

Sheehan P. M. 2001. The Late Ordovician mass extinction. – *Annual Review of Earth and Planetary Sciences*, *29*, 331–364.

Spasov, C. 1960. Stratigraphie des Ordoviziums und Silurs im Kern der Svoge-Antiklinale. – *Travaux sur la Géologie de Bulgarie, Série Stratigraphie et Tectonique*, *1*, 161–202 (in Bulgarian with Russian and German abstracts).

Štorch, P. 1982. Ordovician–Silurian boundary in the northernmost part of the Prague Basin (Barrandian, Bohemia). – *Věstník Ústředního ústavu geologického*, *57*, 231–236.

Štorch, P. 1983. The genus Diplograptus (Graptolithina) from the lower Silurian of Bohemia. – *Věstník Ústředního ústavu geologického*, *58*, 159–170.

Štorch, P. 1985. Orthograptus s.l. and Cystograptus (Graptolithina) from the Bohemian lower Silurian. – *Věstník Ústředního ústavu geologického*, *60*, 87–99.

Štorch, P. 1996. The basal Silurian *Akidograptus ascensus–Parakidograptus acuminatus* Biozone in peri-Gondwanan Europe: graptolite assemblages, stratigraphical ranges and palaeobiography. – *Věstník Ústředního ústavu geologického*, *71*, 177–188.

Štorch, P., E. Serpagli. 1993. Lower Silurian graptolites from southwestern Sardinia. – *Bollettino della Società Paleontologica Italiana*, *32*, 3–57.

Štorch, P., J. Roqué Bernal, J. C. Gutiérrez-Marco. 2019. A graptolite-rich Ordovician–Silurian boundary section in the south-central Pyrenees, Spain: stratigraphical and palaeobiogeographical significance. – *Geol. Mag.*, *156*, 6, 1069–1091.

Swanson-Hysell, N. L., F. A. Macdonald. 2017. Tropical weathering of the Taconic orogeny as a driver for Ordovician cooling. – *Geol.*, *45*, 719–722.

Yanev, S. 1992. Contribution to the elucidation of pre-Alpine evolution in Bulgaria (based on sedimentological data from the marine Paleozoic). – *Geologica Balc.*, *22,* 2, 3–31.

Yanev, S. 1995. Silurian system. – In: Yanev, S. (Ed.). *Explanatory Note to the Geological Map of Bulgaria on Scale 1:100 000, Sofia Map Sheet. Sofia*, Committee on Geology and Mineral Resources, "Geology & Geophysics" Corp., 17–27 (in Bulgarian with English abstract).

Yanev, S., D. Stefanov. 2001. Paleozoic politic rocks in Bulgaria. I. Composition, genesis and postsedimentary evolution of the pelitic rocks in Western Stara Planina. – *Rev. Bulg. Geol. Soc.*, *62*, 1–3. 3–10 (in Bulgarian with English abstract).