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The Toarcian (Early Jurassic) Jenkyns Event in Hungary: stratigraphic, geochemical, and fossil records and their global implications

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A toarci (kora jura) Jenkyns-esemény magyarországi rétegtani, geokémiai és őslénytani kutatása és globális vonatkozásai

Összefoglalás

A kora jura során a kora toarciban (~183 Ma) lezajlott Jenkyns-esemény őskörnyezeti és éghajlati változások láncolataként jellemezhető, melyek üledékképződési változásokhoz, a biogeokémiai körforgások zavaraihoz és másodrendű tömeges kihaláshoz vezettek. Ebben a tanulmányban áttekintjük a világszerte kimutatott esemény definícióját, valamint szedimentológiai, rétegtani, őslénytani és geokémiai ismérveit, melyek közül sokat Magyarországról is ismerünk. Alsó toarci rétegek hazánkban két nagyszerkezeti egységben fordulnak elő, melyek az egykori Tethys különböző területeit képviselik. A Dunántúli-középhegységi-egységben kondenzált pelágikus mészkőbe települő, mangántartalmú képződmények, míg a Tiszai-főegységhez tartozó Mecsekben sziliciklasztos-karbonátos rétegsorban megjelenő, szerves anyagban gazdag, fekete pala jelzi az eseményt. A toarci Jenkyns-eseményhez kapcsolódó magyarországi vizsgálatok során számos tanulmány foglalkozott az ehhez köthető rétegtani, üledékföldtani, őslénytani, geokémiai, és ércföldtani vonatkozásokkal. Az ezekből nyert adatok az élővilág, a geokémiai redszerek, a mállás és az üledékképződés változásairól a globális ismereteink bővüléséhez is hozzájárultak. A kutatások hosszú története ellenére a magyarországi toarci rétegsorok folytatódó vizsgálata a Jenkyns-eseménnyel kapcsolatos további gazdag kutatási lehetőségeket kínál. Tanulmányunk egyben tisztelgés GALÁCZ András és VÖRÖS Attila, a hazai jura kutatások kiemelkedő egyéniségei előtt is, akik oktatómunkájukkal és eredményeikkel ifjabb kutatók nemzedékeit indították útnak és inspirálták.

Tárgyszavak: Jenkyns-esemény, toarci, hipertermális események, tömeges kihalás

Abstract

The Early Toarcian (~183 Ma, Early Jurassic) Jenkyns Event is defined as a series of environmental-climatic changes leading to changes in sedimentary regimes, perturbation of biogeochemical cycles, and a second-order mass extinction. Here, we briefly review the definition of this event and how it is recorded in characteristic sedimentary, palaeontological and geochemical signals all over the world, many of which have been documented in Hungary as well. Lower Toarcian strata are known in two tectonic units in Hungary representing different Tethyan environments: (1) in the Transdanubian Range Unit (TRU) manganiferous intercalations occur in a condensed pelagic limestone succession, and (2) in the Mecsek Basin (MB) of the Tisza Mega-unit (TU) in the form of an organic-rich black shale bed-set within a mixed siliciclastic-carbonate succession. Numerous studies of the Hungarian geological record of the Jenkyns Event have focused on its stratigraphy, sedimentology, palaeontology, geochemistry, and economic geology, leading to insights into biotic changes, geochemical perturbations, weathering regimes, and ore-forming processes, adding much relevant information to our understanding of these global phenomena. Despite such a rich history of investigations, the Toarcian successions in Hungary still offer plenty of opportunities for further research on the Jenkyns Event. Spearheading the Jurassic studies in Hungary for the past several decades, András GALÁCZ and Attila VÖRÖS have not only made an immense contribution but also inspired many researchers in their endeavours. This article pays tribute to their outstanding scientific career.

Keywords: Jenkyns Event, Toarcian, hyperthermal events, mass extinction

Introduction

Mesozoic hyperthermal events have been in the focus of a great number of paleoclimatic-environmental research recently, as they provide ample opportunities to study Earth System responses to enhanced greenhouse gas emissions. One prominent example of these events is the Jenkyns Event [or Toarcian Oceanic Anoxic Event (T-OAE)] in the Early Jurassic (~183 Ma) (Jenkyns 1988, Müller et al. 2017, Reolid et al. 2020, Erba et al. 2022, Gambacorta et al. 2023b). Triggered by CO_2 emission related to the emplacement of the Karoo-Ferrar Large Igneous Province (LIP) and associated thermal metamorphism of the vast Karoo Basin coal series, the Jenkyns Event evolved into an interval of pronounced climate changes and perturbations of biogeochemical cycles (*Fig. 1*) (Pálfy & Smith 2000, McElwain et al. 2005, Svensen et al. 2007, Percival et al. 2015, Ruebsam et al. 2020a, Ullmann et al. 2020, Heimdal et al. 2021, Ruhl et al. 2022). Global warming and the accelerated hydrological cycle induced by high atmospheric pCO_2 resulted in increased continental weathering, which altered nutrient cycling and ultimately led to high primary production, oxygen depletion and widespread deposition of organic-rich black shales (*Fig. 1*) (Röhl et al. 2001; Hermoso et al. 2013; Thibault et al. 2018; Suan et al. 2018; McArthur 2019; Kemp et al. 2020, 2022a, b; Ruebsam et al. 2018, 2019, 2020b, c, d; Gambacorta et al. 2023a). Elevated pCO_2 during the Jenkyns Event had a major impact on ocean chemistry, causing a significant decrease in pH and a calcification crisis, which is also reflected in a decrease in carbonate production, often appearing as gaps and condensed sections in carbonate sequences (*Fig. 1*) (Bucefalo-Palliani et al. 2002; Mattioli et al. 2004, 2009; Trecalli et al. 2012; Brame et al. 2019; Krencker et al. 2020; Müller et al. 2020a, b, 2021; Vasseur et al. 2021; Ettinger et al. 2021). This series of climatic-environmental changes eventually led to a biotic crisis manifested in a second-order mass extinction and elevated faunal turnover (*Fig. 1*) (Hallam 1987; Little & Benton 1995; Aberhan & Fursich 2000; Harries & Little 1999; Macchioni & Cecca 2002; Wignall et al. 2006; Dera et al. 2010; García Joral et al. 2011; Caruthers et al. 2014; Baeza-Carratalá et al. 2017;

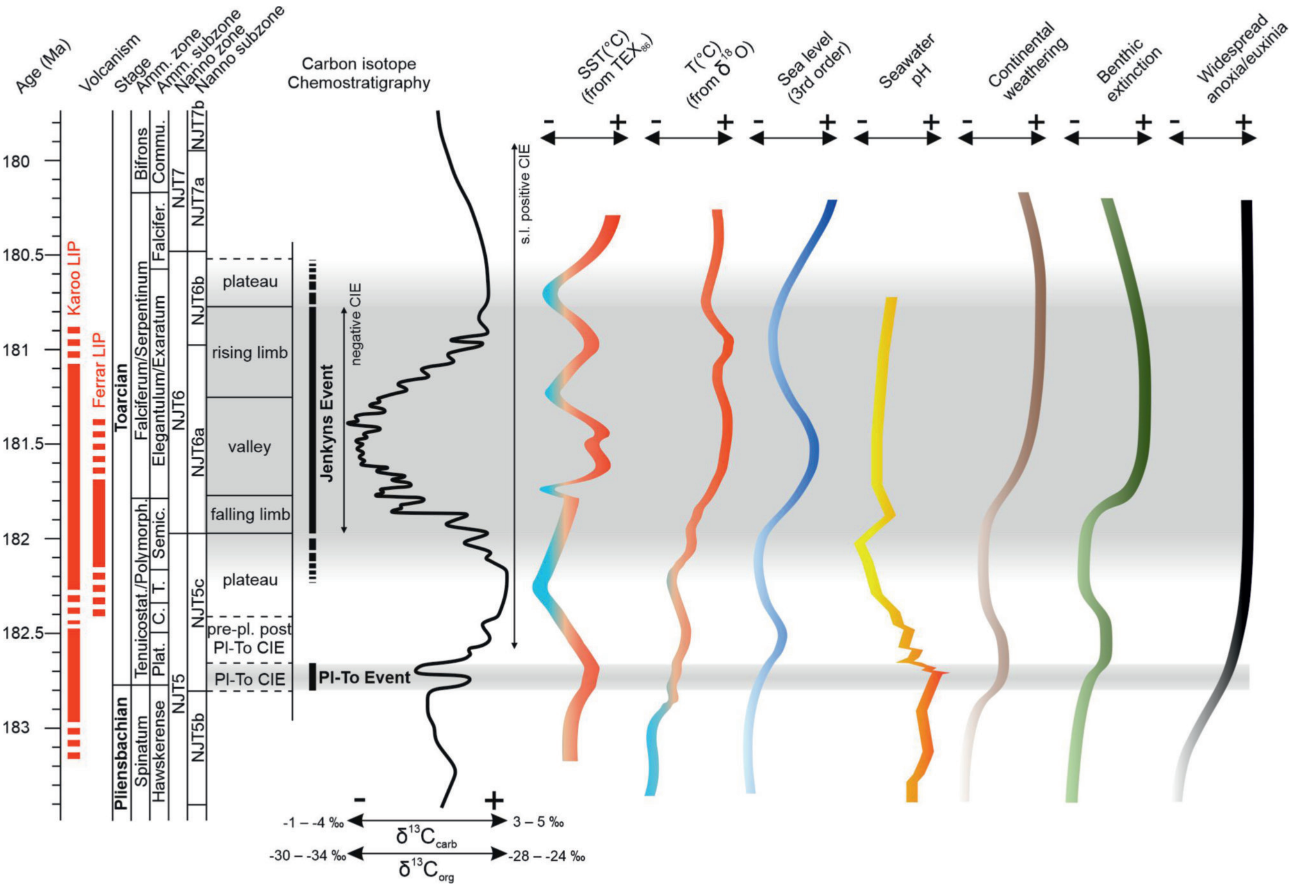

Figure 1. Integrated bio-, chrono, and chemostratigraphy and subdivisions of a composite carbon isotope curve of the early Toarcian (with typical ranges of maximum and minimum values of carbonate and organic carbon derived carbon isotope curves) (based on Ruebsam & Al-Husseini 2020, Ferreira et al. 2019, Al-Suwaidi et al. 2022 and Bodin et al. 2023), together with a schematic illustration of environmental changes associated with the Jenkyns Event (after Caswell et al. 2009; Ruebsam et al. 2019, 2022; Müller et al. 2020a; Hallam 1997; Percival et al. 2016; Ruhl et al. 2023)

***1. ábra.** Kora toarci integrált bio-, krono- és kemosztratigráfia a szakaszokra bontott összegzett szénizotóp-görbével (a jellemző minimum és maximum karbonát, valamint szervesanyag-fázis értékekkel) (Ruebsam & Al-Husseini 2020, Ferreira et al. 2019, Al-Suwaidi et al. 2022 és Bodin et al. 2023 alapján), valamint a Jenkyns-eseményhez kapcsolódó környezeti változások sematikus ábrázolása (after Caswell et al. 2009; Ruebsam et al. 2019, 2022; Müller et al. 2020a; Hallam 1997; Percival et al. 2016; Ruhl et al. 2023 nyomán)*

REOLID et al. 2019; DANISE et al. 2013; VÖRÖS 2002; VÖRÖS et al. 2016, 2019; VASSEUR et al. 2021; REOLID et al. 2022). Perturbation of the carbon cycle is characterised by carbon isotope excursions (CIE), typically exhibiting a ~2-4‰ negative CIE around the Pliensbachian–Toarcian boundary, followed by a prolonged positive CIE in the early Toarcian, which is interrupted by a large negative CIE by 4-6‰ in the latest Tenuicostatum and early Falciferum biochrons. These anomalies and trends are well recognised in marine and terrestrial organic matter as well as in biogenic and bulk marine carbonates (*Fig. 1*) (JENKYNS & CLAYTON 1997; HESSELBO et al. 2000, 2007; HESSELBO & PIEŃKOWSKI 2011; SUAN et al. 2008a, 2010, 2015; XU et al. 2017, 2018; MÜLLER et al. 2017, 2020b; FANTASIA et al. 2019; ULLMANN et al. 2014, 2020; ERBA et al. 2022). The positive CIE is generally explained by high primary production and enhanced burial of ^{12}C, while the negative CIE is considered a result of additional ^{12}C input from either volcanic sources or methane liberated during the thermal metamorphism of coal, or methane-hydrate dissociation from marine or terrestrial reservoirs (HESSELBO et al. 2000, SVENSEN et al. 2007, JENKYNS 2010, RUEBSAM et al. 2019). A composite early Toarcian $\delta^{13}C$ record is summarised by RUEBSAM & AL-HUSSEINI (2020) who identified characteristic segments of the curve based on its distinctive trend sand hinge points, thereby developing a system that offers an effective chemostratigraphic correlation tool (*Fig. 1*).

Within Hungary, two major tectonic units represent different depositional environments in the Early Jurassic. One of them, the Transdanubian Range Unit (TRU), which is part of the larger ALCAPA (AL – Alpine, CA – Carpathian, PA – Pannonian) Mega-unit was located south of its current position as part of the Neotethys margin of the Adria microplate (Gondwana /Africa/-related domain). The other one, the Tisza Mega-unit belonged to the NW European margin of the Neotethys (GÉCZY 1973, HAAS & PÉRÓ 2004, CSONTOS & VÖRÖS 2004, CSÁSZÁR et al. 2013) (*Figs. 2* and *3*). Within the Transdanubian Range Unit, a number of stratigraphic sections record the Jenkyns Event, predominantly in a pelagic carbonate depositional setting (GALÁCZ 1988, JENKYNS et al. 1991, VÖRÖS & GALÁCZ 1998, CSÁSZÁR et al. 1998, HAAS 2012, POLGÁRI et al. 2016, MÜLLER et al. 2021). In contrast, within the Tisza Mega-unit, the event is only recorded in the Mecsek Basin (MB) (western Mecsek nappe or Mecsek zone) (*Figs. 2* and *3*) where high sedimentation rate and mixed siliciclastic-carbonate deposition prevailed during this time (JENKYNS 1988; GALÁCZ 1991; DULAI et al. 1992; VARGA et al. 2007; RAUCSIK & VARGA 2008a, b; VARGA et al. 2009; MÜLLER et al. 2017).

The Toarcian stratigraphic record of Hungary has attracted considerable interest and has been studied for more than a century, providing valuable localities for research concerning the Jenkyns Event. A common lithological marker of the Jenkyns Event is the occurrence of organic-rich black shales, which are particularly widespread and often expanded in the NW European basins. Well-studied units of these black shale are known locally as *Jet Rock* (Cleveland Basin, United Kingdom), *Posidonienschiefer* (SW Germany) and *Schistes Carton* (Paris Basin, France), to which the black shale occurrences of the MB in Hungary show close similarities (e.g., HALLAM 1967, RÖHL et al. 2001, EMMANUEL et al. 2006, DULAI et al. 1992, VARGA et al. 2007). In the Mediterranean Lower Jurassic, black shales are less common and relatively organic-lean compared to their NW European correlatives; the *Livello a Pesci* (Lombardian Basin, N Italy) is regarded as a typical example (CASELLATO & ERBA 2015, ERBA et al. 2022). Additionally, the Mediterranean records of the Jenkyns Event are often characterised by considerable manganese enrichment, e.g., in Bächental (Austria) or Monte Mangart (Italy–Slovenia) (NEUMEISTER et al. 2015, SABATINO et al. 2011). In the TRU there are several localities with comparable features, including moderate TOC enrichment and high manganese concentrations, the latter with major economic importance (VETŐ et al. 1997; POLGÁRI et al. 2012, 2016; HAAS 2012).

The present review aims to comprehensively summarise our current knowledge of the stratigraphic, geochemical, and fossil record of the Jenkyns Event in Hungary. In addition, we also highlight the potential for further research that could contribute to our understanding of this remarkable global change event in deep time. For the two major tectonic units in Hungary with contrasting features, here we briefly provide a paleogeographic background and review of their sedimentary basin evolution to provide context for the Toarcian units that record the Jenkyns Event. We focus on the key localities, their litho- and biostratigraphy, with particular emphasis on the ammonite and nannofossil zonations. Data on the macro- and microfauna, as well as results of geochemical studies are reviewed, with the aim to enable the reader to follow up on the details using the sources listed here. As a pre-requisite to a meaningful summary of the various local records of the Jenkyns Event, we first review the evolving usage of this term.

Clarifying the definition of the Jenkyns Event

The term "oceanic anoxic events" was coined, and their interpretation was first developed using Cretaceous examples (SCHLANGER & JENKYNS 1976). Later, the recognition of widespread occurrence of black shales in the Falciferum Zone in Lower Toarcian successions led to the assumption of global significance of this phenomenon and the introduction of the term Toarcian Oceanic Anoxic Event (T-OAE) (JENKYNS 1988). Alternatively, the name "*Posidonienchiefer* Event" (JENKYNS 1999) was also used to refer to the T-OAE. At first, lithological characters of oxygen-depleted facies were the key markers of the event. Subsequently, however, chemostratigraphic features such as the carbon isotope anomalies were used to complement the definition, more specifically a prominent negative CIE that interrupts the broad early Toarcian positive CIE (JENKYNS & CLAYTON 1997, JENKYNS 2010, BOULILA & HINNOV 2017, THIBAULT et al. 2018, RUEBSAM et al. 2019). Since the 1990's and 2000's,

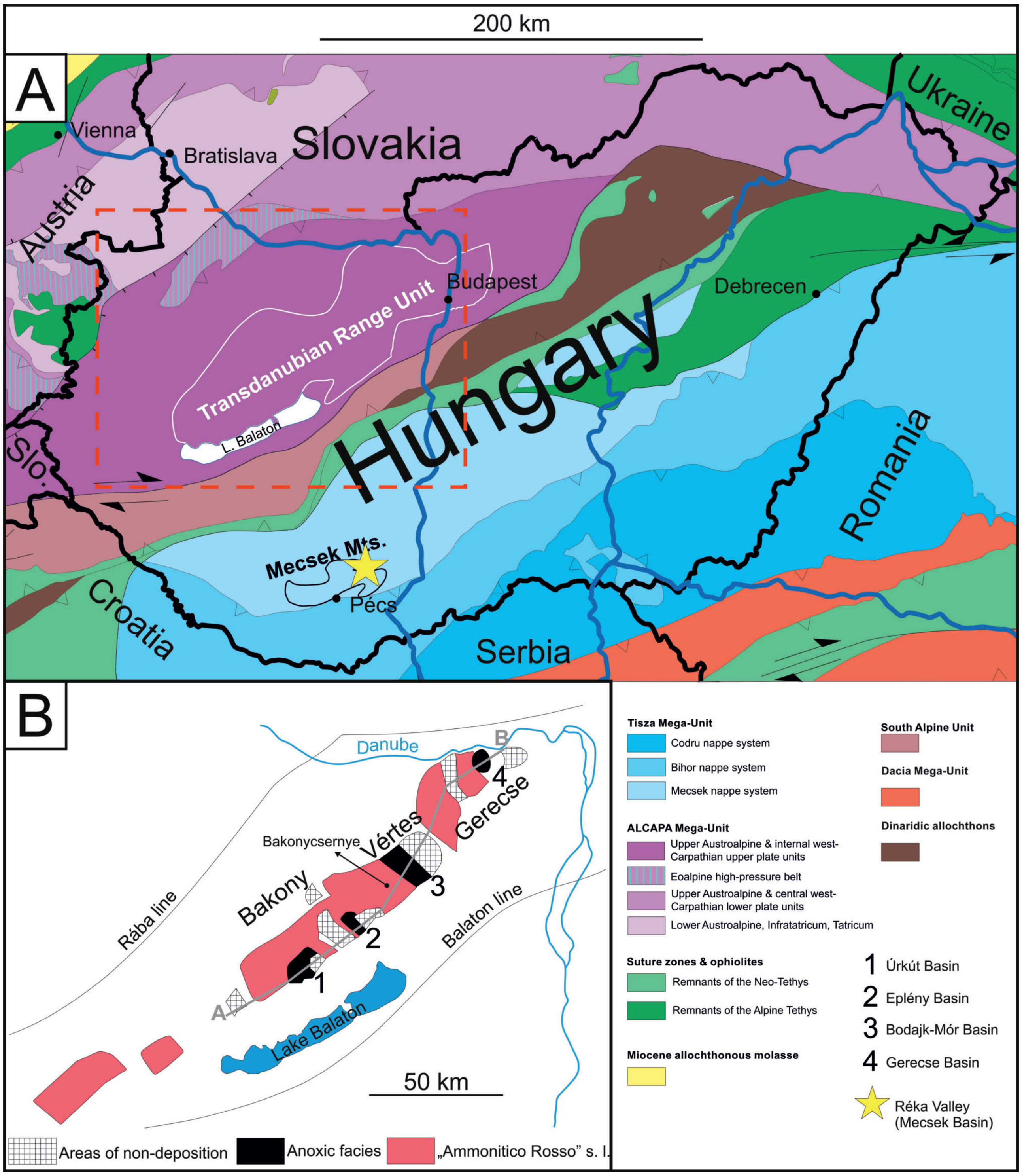

Figure 2. A: Tectonic map of Hungary and its surroundings (modified from SCHMID et al. 2020). B: Sedimentary basins and facies distribution in the Transdanubian Range Unit during the early Toarcian (after VÖRÖS & GALÁCZ 1998). For the cross-section along the grey line between A and B, see *Fig. 3C*

2. ábra. *A: Magyarország és a környező területek nagyszerkezeti egységeinek áttekintő térképe (SCHMID et al. 2020 után módosítva). B: A Dunántúli-középhegységi-egység üledékes medencéi és a fáciesek eloszlása a kora toarciban (VÖRÖS & GALÁCZ 1998 nyomán). Az A-B vonalnak megfelelő keresztszelvényt a* 3, C ábra *mutatja*

a growing number of studies revealed the complexity of this event, expressed by coeval paleontological, environmental, climatic and ocean chemistry changes (LITTLE & BENTON 1995; HESSELBO et al. 2000; KEMP et al. 2005; COHEN et al. 2004, 2007; MATTIOLI et al. 2008; DERA & DONNADIEU 2012; GILL et al. 2011; TRECALLI et al. 2012; MONTERO-SERRANO et al. 2015; PERCIVAL et al. 2016), creating the need for a more inclusive term for the event. MÜLLER et al. (2017) proposed renaming the T-OAE as "Jenkyns Event", honouring the seminal and pioneering work of Professor Hugh Jenkyns. Following that, REOLID et al. (2020) suggested a definition for the Jenkyns Event that refers to the sum of the coeval

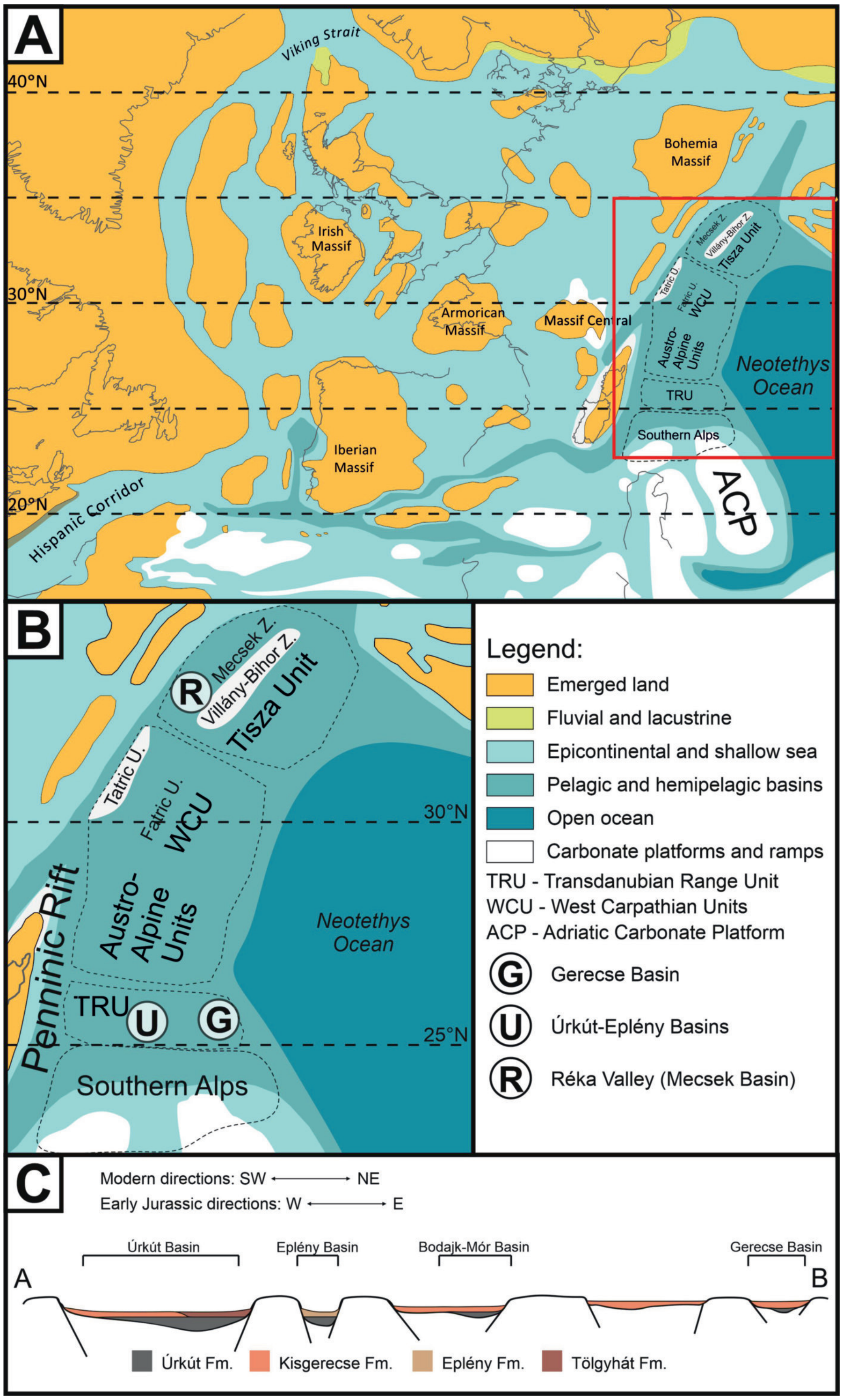

Figure 3. A: Palaeogeographic map of Europe and the NW Tethys during the Early Jurassic (modified from THIERRY & BARRIER 2000). Supposed position of the NW Tethyan tectonic units (Southers Alps, Transdanubian Range Unit, Austro-Alpine Units, Western Carpathian Units, and Tisza Unit) are marked with a dashed line (after MÜLLER et al. 2021, based on HÄUSLER et al. 1993 and HAAS 2012). B: Close-up of the palaeogeography NW Neoethys margin during the Early Jurassic, showing the position of sedimentary basins discussed in the text. C: Cross section of the Transdanubian Range Unit along the A-B line in *Fig. 2B.*

***3. ábra.** A: Európa és az ÉNy-i Tethys ősföldrajzi térképe a kora jurában (THIERRY & BARRIER (2000) nyomán módosítva). Az ÉNy-i tethysi szerkezeti egységek (Déli-Alpok, Dunántúli-középhegységi-egység, Ausztroalpi egységek, Nyugati-Kárpáti egységek, Tisza-egység) feltételezett helyzetét szaggatott vonal jelzi (MÜLLER et al. 2021 nyomán, HÄUSLER et al. 1993 és HAAS 2012 alapján). B: Az ÉNy-i Tethys peremének nagyított ősföldrajzi térképe a kora jurában, feltüntetve a szövegben tárgyalt üledékes medencék helyzetét. C: A Dunántúli-középhegységi-egység keresztszelvénye a* 2, B *ábrán jelölt A-B vonal mentén* global biotic, environmental, climatic and ocean chemistry changes. Additionally, these authors kept the term T-OAE and recommended using it exclusively for marine sedimentary records where there is clear evidence of oxygen-depleted conditions. Alternative definitions for the Jenkyns Event and T-OAE were also considered, where the term T-OAE was applied to the early Toarcian positive CIE and Jenkyns Event for the interrupting negative CIE (Erba et al. 2022). Building on the growing number of published high-resolution early Toarcian carbon isotope records, combined with the increasingly sophisticated biostratigraphic framework, a detailed subdivision of this interval is now feasible. Such an integrated stratigraphic scheme employs a subdivision based on the hinge points of the carbon isotope record (Ruebsam & Al-Husseini 2020). This scheme was also adopted by Gambacorta et al. (2023b) who supplemented it with the pre-negative CIE interval (*Fig. 1*). These authors summarised our knowledge of the Jenkyns Event in great detail, and also proposed to use the T-OAE and the Jenkyns Event as synonyms that include the entire early Toarcian positive CIE.

In this paper, we also use the term Jenkyns Event as a synonym for the T-OAE as suggested by Gambacorta et al. (2023b). However, we prefer the name Jenkyns Event and argue that the historic usage of T-OAE should be discontinued as it may mistakenly imply its exclusivity to marine phenomena whereas this was a complex global event resulting in Earth system-wide changes that affected both the oceans and the continental realm (Xu et al. 2017). Considering both the complexity and diachrony of the biotic and environmental changes occurring over this time interval (*Fig. 1*), we prefer not to rigidly fix the chronostratigraphic position of the Jenkyns Event. The main phase of the event is best regarded contemporaneous with the negative CIE (solid line on *Fig. 1*) but the diachrony of the observed changes warrants the inclusion of a transition zone with the most positive carbon isotope values before and after the negative CIE (dashed lines on *Fig. 1*) similarly as suggested by Gambacorta et al. (2023b).

Records of the Jenkyns Event in the Transdanubian Range Unit

Forming part of the broad shelf of the western Neotethys in the Late Triassic, extensive carbonate platforms developed in the TRU, the site of deposition of the Dachstein Fm. (Haas & Budai 1995; Haas 2002, 2004). Combined effects of the latest Rhaetian tectonic disruption, platform drowning (Haas 1995), and environmental changes related to the end-Triassic mass extinction (Pálfy et al. 2021) led to a significant hiatus throughout the TRU except in the Csővár Basin (NE extremity of the TRU), where sedimentation was continuous across the Triassic-Jurassic boundary (Pálfy et al. 2001, Haas et al. 2010, Vallner et al. 2023). Sedimentation on shallow marine carbonate ramps resumed in the Hettangian, resulting in the deposition of thick-bedded, locally oncoidal limestone (Kardosrét Fm.) (*Fig. 4*) (Vörös & Galácz 1998). Continuous extensional tectonism in the TRU in the Sinemurian–Pliensbachian led to topographic differentiation, formation of submarine highs and fault-controlled basins. Condensed successions with gaps and hardgrounds typically formed on the highs, crinoidal-brachiopdal limestones (Hierlatz Fm.) at the toe of the steep slopes, and *ammonitico rosso*-type limestones (Pisznice Fm., Kishát Fm., Tűzkövesárok Fm.) were deposited in the basins (*Fig. 4*) (Konda 1970; Galácz 1988; Császár et al. 1998; Vörös & Galácz 1998; Knauer 2012a, b). A marked change in the sedimentation occurred in the early Toarcian. In deeper parts of some basins, manganese-rich carbonates with black shale interbeds were deposited, which are assigned to the Úrkút Fm. (*Fig. 4*) (Polgári et al. 2000, Vörös & Galácz 1998, Haas 2012, Szabó 2012). In other basins, deposition of red pelagic marls and argillaceous limestones occurred, known as the Kisgerecse Fm. (Vörös & Galácz 1998, Császár et al. 1998). In the middle-late Toarcian, deposition of pelagic *ammonitico rosso*-type limestone resumed (Eplény Fm., Tölgyhát Fm.) (*Fig. 4*) (Vörös & Galácz 1998).

In the TRU, sedimentary records of the Jenkyns Event can be studied in several small fault-controlled basins; from SW to NE, they are the Úrkút and Eplény basins, the Bodajk–Mór Basin, and the Gerecse Basin (*Figs. 2B* and *3C*).

In the vicinity of the village of Úrkút in the Bakony Mts., the Jenkyns Event is expressed in a unique sedimentary succession of the manganese ore- (Mn-carbonate and -oxide) and pyritic black shale-bearing Úrkút Fm. The occurrence was first described by Böckh (1874), and subsequently it was subject to numerous studies concerning mainly its ore geology, mineralogy, and geochemistry (e.g., Sidó & Síkabonyi 1952, Grasselly & Cseh Németh 1961, Cseh Németh 1967, Polgári 1993, Polgári et al. 2012, Molnár et al. 2017, Leskó et al. 2019). The deposit had great economic significance, underground mining of the ore spanned 100 years between 1917–2016 (Polgári et al. 2017). In terms of lithology and facies, the succession is exceptionally diverse in the Úrkút Basin. Overlying pelagic limestones of the upper Pliensbachian Kishát and Isztimér Fm., the Úrkút Fm. typically starts with a ~0.5 m thick Mn-oxide bed. It is followed by a ~1 m of black shale and ~8–14 m of manganese carbonate on top (Ore bed 1). The latter is composed of very fine-grained green, brown, black, and light-coloured, banded facies, dominated by authigenic Mn-carbonates and clays (Bíró 2014; Polgári et al. 2013, 2016). Ore bed 1 is overlain by another ~10 m thick black shale deposit, which in turn is followed by the ~4–5m thick Ore bed 2 that consists of Mn-carbonate-rich brown marl with a black shale intercalation (Bíró 2014). On top of the Úrkút Fm. and a thin chert bed (formally named as the Cservár Chert Bed), ~2–3 m of reddish nodular marl of the Kisgerecse Fm. occurs, which is overlain by nodular limestone of the Eplény Fm. (Bíró 2014). A peculiar occurrence of primary Mn-oxides can be found at Úrkút around the Csárda Hill (Bíró & Pál-Molnár 2015).

The sedimentary record of the Eplény Basin reveals another characteristic and commercially exploited develop-

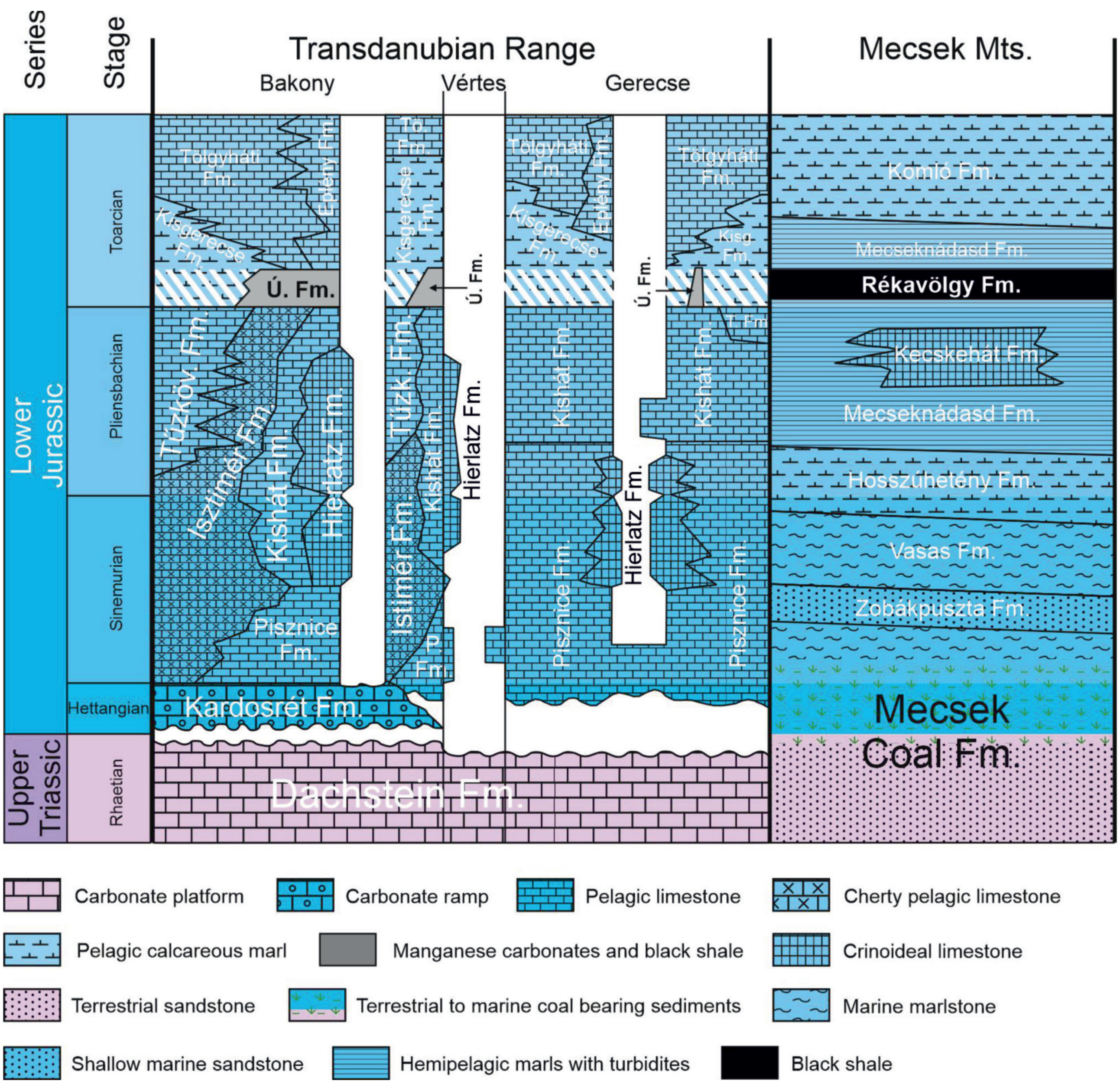

Figure 4. Upper Triassic–Lower Jurassic lithostratigraphy of the Transdanubian Range Unit (TRU) and the Mecsek Basin (after BABINSZKI et al. 2023). Triassic–Jurassic boundary modified after PÁLFY et al. (2021). White stripes indicate common stratigraphic gaps in the Lower Toarcian of the TRU

Abbreviations: Ú. Fm. – Úrkút Formation; P. Fm. – Pisznice Formation; Tűzköv. Fm., Tűzk. Fm., T. Fm. – Tűzkövesárok Formation; Kisg. Fm. – Kisgerecse Formation; Tö. Fm. – Tölgyhát Formation

4. ábra. *A Dunántúli-középhegységi-egység és a Mecsek felső triász – alsó jura litosztratigráfiája (BABINSZKI et al. 2023 nyomán). A triász–jura határ módosítva PÁLFY et al. (2021) alapján*

Rövidítések: Ú. Fm. – Úrkúti Formáció; P. Fm. – Pisznicei Formáció; Tűzköv. Fm., Tűzk. Fm., T. Fm. – Tűzkövesárki Formáció; Kisg. Fm. – Kisgerecsei Formáció; Tö. Fm. – Tölgyháti Formáció

ment of manganese oxide ores and black shale assigned to the Úrkút Fm. (DRUBINA-SZABÓ 1961, CSEH NÉMETH 1967, GRASSELLY et al. 1969). Other lower Toarcian strongly condensed strata with manganese ore indications and thin (a few tens of cm) black shale occurrences were reported from the surroundings of the Eplény Basin at the Lókút Hill, Kávás Hill, Kericser, and Eperjes Hill localities (KONDA 1970, GÉCZY 1971, GALÁCZ 1988, CSÁSZÁR et al. 2008). Farther to the east, ~7 m of upper Liassic manganiferous black shale akin to that in the Úrkút and Eplény basins was explored in a borehole near Balinka in the Bodajk–Mór Basin (KONDA 1970). The easternmost occurrence of this lower Jurassic black shale is known in the Gerecse Basin from a single locality, where a 10-30-cm-thick condensed shale bed is exposed in the Tölgyhát quarry (KONDA 1988, SASVÁRI et al. 2009, SZENTE 2017, MÜLLER et al. 2021). The lower part of the pelagic reddish-yellow nodular marl and calcareous marl of the Kisgerecse Fm. also records the Jenkyns event, albeit its late phase (JENKYNS et al. 1991, MÜLLER et al. 2021). This unit is ~0.6–3.5 m thick, reaching its maximum thickness in the Bodajk–Mór and the Gerecse basins (KNAUER 2012c).

On the basis of ammonite biostratigraphy, the lower ore bed in the Úrkút Basin was assigned to the Tenuicostatum Zone, the overlying black shale to the Serpentinum Zone, whereas the Kisgerecse Fm. to the Bifrons Zone (GÉCZY 1966a, b; 1968) (*Fig. 5*). Elsewhere, the manganiferous facies and black shale occurrences generally lack ammonites and their age is assumed based on the sharp differences in lithology relative to the under- and overlying strata, and the lithological resemblance to the Úrkút succession (KONDA 1970, GÉCZY 1971). Calcareous nannofossil data tentatively suggest the presence of the lower Toarcian NJT5 zone in the lower half of the lower ore bed and NJT6 zone in the upper half of the lower ore bed and the overlying black shale (*Fig. 5*) (SUAN et al. 2016). A significant stratigraphic gap is commonly inferred at the base of the lower Toarcian Kisgerecse Fm. at localities where the Úrkút Fm. is missing. This facies starts in the upper Serpentinum Zone at most localities. There is no record of the Tenuicostatum Zone, except for a few centimer-thick beds at the base of the formation at Bakonycsernye (west of the Bodajk–Mór Basin) and at Kisgerecse (the type section of the formation) in the Gerecse Basin (*Fig. 5*) (GÉCZY 1984, 1985; GÉCZY & SZENTE 2006; GALÁCZ et al. 2008, 2010, 2012; KOVÁCS 2012). Calcareous nannofossils from the Tölgyhát quarry indicate the presence of the lower Toarcian NJ6b and NJT7a subzones that allow correlation with the late phase of the Jenkyns Event (*Fig. 5*) (MÜLLER et al. 2021).

The Úrkút Fm. contains only scarce macrofauna. The finely laminated facies is devoid of bioturbation and benthic fossils (POLGÁRI et al. 1991). Ammonites were described by GÉCZY (1966a, 1966b, 1968), and other invertebrates are rare. Vertebrate remains, fish scales and bones occur sporadically. Entire articulated fish skeletons in phosphoritic nodules were found in the underground Úrkút mine (CSEH NÉMETH 1966, PÁSZTI 2004), and a nearly complete specimen of *Dapedium* sp. was recently reported (SZABÓ & PÁLFY 2020). Abundant fish teeth were encountered from the ~10-30-cm-thick black shale of the Tölgyhát quarry in the Gerecse Basin (VADÁSZ 1913, VÍGH 1925). Petrified and coalified fossil wood fragments occur in the Úrkút Fm., primarily in the black shale interval above the lower ore bed in the Úrkút mines (GREGUSS 1974, POLGÁRI et al. 2005). Abundant radiolarians were reported from the black shale in the Úrkút Basin (DRUBINA-SZABÓ 1959). Palynological analyses from the Úrkút mine revealed diverse and successive assemblages of different compositions and diversity that also contained several new nominal taxa of Jurassic sporomorphs (KEDVES 1990). Calcareous nannofossil assemblages are taxonomically diverse, dominated by *Schizosphaerella* spp., albeit various species of the genus *Lotharingius* are also common (SUAN et al. 2016). Scarce occurrences of *Bositra sp.*, echinoderm fragments, benthic forams and ostracods were also observed in the Úrkút succession (LANTOS et al. 2003). The red nodular marly facies of the Kisgerecse Fm. yielded a diverse early Toarcian ammonite fauna of great abundance, especially at localities near the village of Bakonycsernye (west of the Bodajk–Mór Basin) and in the Gerecse Basin (e.g., GÉCZY 1966c, 1967, 1984, 1985; GÉCZY & SZENTE 2006; GALÁCZ et al. 2008, 2010, 2012; KOVÁCS 2010, 2012, 2014; KOVÁCS et al. 2020). A diverse and unique foraminifera assemblage was recovered from the Kisgerecse Fm. from the area of Bakonycsernye (GÖRÖG & ZSIBORÁS 2020). Calcareous nannofossils were reported from the Tölgyhát quarry in the Kisgerecse Fm. in the Gerecse Basin (MÜLLER et al. 2021). The Kisgerecse Fm. also yielded an extraordinary vertebrate fossil find, a partial skeleton of a marine crocodile assigned to a new genus and species, *Magyarosuchus fitosi* (ŐSI et al. 2018), in addition to ichthyosaur remains that were also discovered at the same stratigraphic level (DUNAI 2012, ŐSI & MÉSZÁROS 2020). A synoptic study of brachiopod faunas in the TRU pointed out a significant reduction in species-level diversity during the Jenkyns Event, which is thought to reflect unfavourable conditions and less successful adaptation of the group to environmental changes (VÖRÖS & DULAI 2007).

One of the unique features of the sedimentary record of the Jenkyns Event of the TRU, which is restricted to the central Bakony Mts, is the remarkably high rate of manganese mineral accumulation. In the Úrkút Basin, the average MnO concentration is ~24 wt% in Ore bed 1 and ~15 wt% in Ore bed 2 (SZABÓ & GRASSELLY 1980). The formation of the manganese carbonates is considered to be microbially mediated under suboxic conditions through bacterial Mn reduction during organic matter oxidation (POLGÁRI et al. 1991, 2012). Manganese is assumed to have originated from hydrothermal vent systems (POLGÁRI et al. 2012). However, the strict stratigraphic determination of the manganese-rich successions (as observed in similar occurrences regionally in the Southern Alps and Eastern Alps (SABATINO et al. 2011, NEUMEISTER et al. 2015, SUAN et al. 2016)) contradicts this hypothesis and suggests that environmental changes related to the event favour the bacterially mediated Mn-mineral formation scenario (HAAS 2012). Black shale samples yielded TOC values of ~2–3 wt% from the Úrkút Basin (VETŐ et al. 1997) and 2.68 wt% from the thin black shale in the Tölgyhát quarry (POLGÁRI 2000). Rock-Eval analyses provide low T_{max} values of immature organic matter in the black shale from Úrkút and suggest a mixed terigenous and marine source (POLGÁRI et al. 2016). Geochemical analysis of minor, trace and rare earth elements on the manganese ore and black shale facies at Úrkút (e.g., POLGÁRI 1993, GRASSELLY & PANTÓ 1988) indicate that suboxic to anoxic conditions were prevailing during the Jenkyns Event (BÍRÓ et al. 2015). Carbonate carbon isotope ($\delta^{13}C_{carb}$) data from Úrkút show extremely negative values (~–10 – –30‰) in the ore beds that are unlikely to be explained by changes in the global carbon cycle, hampering the possibility of chemostratigraphic use. Nevertheless, they further support the hypothesis of degradation of organic matter via manganese carbonate formation (POLGÁRI et al. 1991). Organic carbon isotope values ($\delta^{13}C_{org}$), on the other hand, display anomalies that likely reflect global changes (*Fig. 5*) (VETŐ et al. 1997, POLGÁRI et al. 2016). Strongly negative $\delta^{13}C_{org}$ values in the lower ~3 m of the Úr-

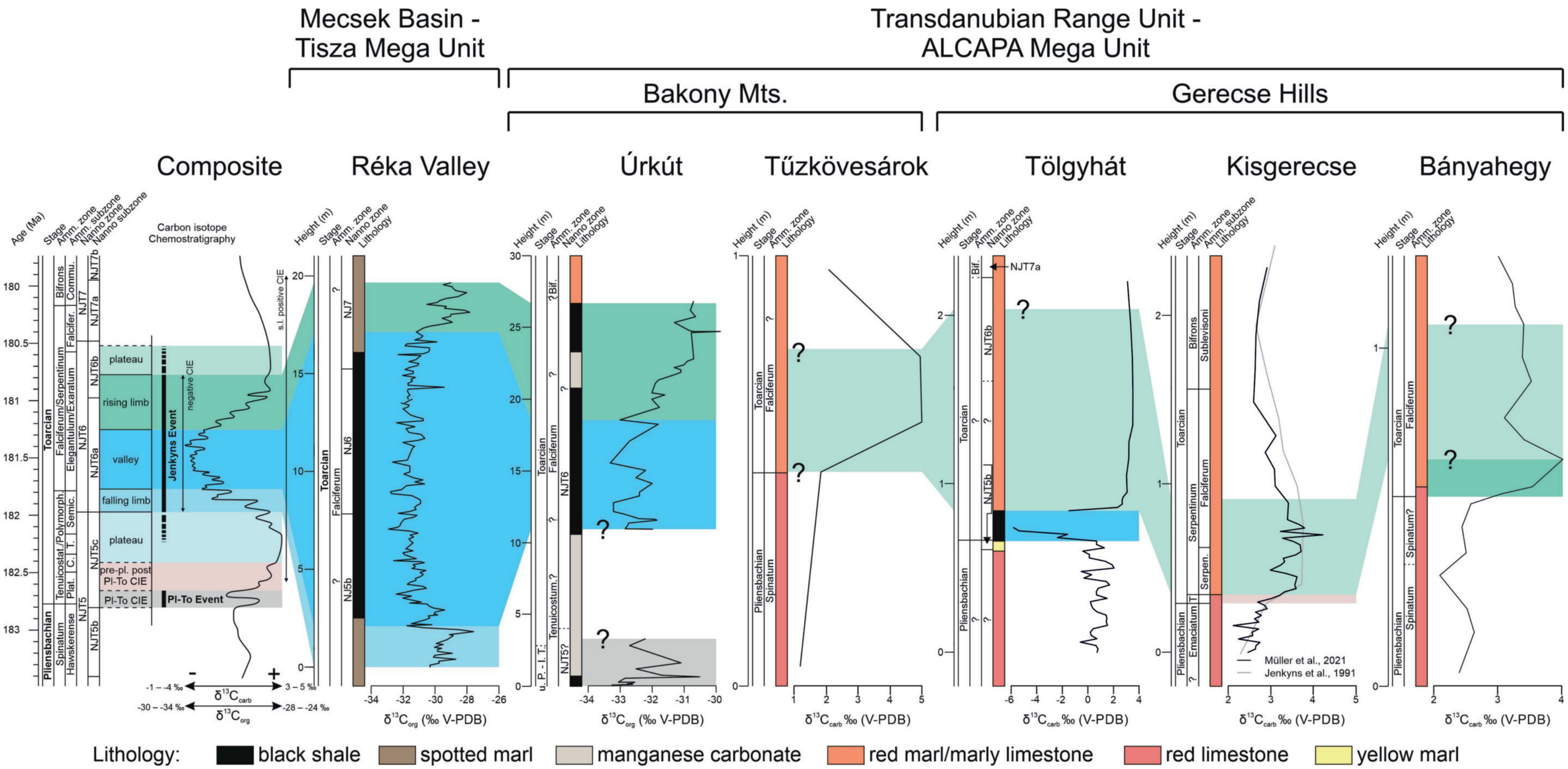

Figure 5. Integrated stratigraphy and carbon isotope chemostratigraphic correlation of key sections from Hungary with records of the Jenkyns Event (MÜLLER et al. 2017, 2021; POLGÁRI et al. 2016; GÉCZY 1966a, b, 1968; SUAN et al. 2016; JENKYNS et al. 1991; JENKYNS & CLAYTON 1986). For sources of the integrated stratigraphic framework, see the caption of *Fig. 1*

5. ábra. *A Jenkyns-eseményt rögzítő legfontosabb magyarországi szelvények integrált rétegtani és szénizotóp-kemosztratigráfiai korrelációja (MÜLLER et al. 2017, 2021; POLGÁRI et al. 2016; GÉCZY 1966a, b, 1968; SUAN et al. 2016; JENKYNS et al. 1991; JENKYNS & CLAYTON 1986). Az integrált rétegtani keret forrásait ld. az* 1. *ábránál* kút profile, assigned to the lower Toarcian NJT5 nannozone, suggest the influence of the Pliensbachian–Toarcian boundary event (*Fig. 5*). Data from the black shale above the lower ore bed, up to ~18–19 m in the profile, show the lowest values and a fluctuating pattern. These features and the biostratigraphic assignment to the Falciferum and NJT6 zones indicate an interval corresponding to the *valley* phase in the carbon isotope stratigraphy (*Fig. 5*). Above the hinge point around ~18–19 m on the $\delta^{13}C_{org}$ curve, a ~8–9 m interval that includes the upper ore bed and the overlying black shale can be fitted to the *rising limb* (*Fig. 5*). Thus, chemostratigraphic correlation of the Úrkút data suggests that oxygen depletion in the basin already started before the Jenkyns Event at the Pliensbachian–Toarcian (Pl–To) boundary and then, later on, prevailed during the Jenkyns Event. The formation of Ore bed 1 likely preceded the main phase of the Jenkyns Event, although additional analyses and higher resolution of $\delta^{13}C_{org}$ data will be needed for a more accurate assessment and a reliable stratigraphic subdivision of the Úrkút sedimentary record. Jenkyns et al. (1991) presented a low-resolution $\delta^{13}C_{carb}$ record from the condensed Tűzkövesárok section near Bakonycsernye (west of the Bodajk–Mór Basin, Bakony Mts). These few datapoints, however, show very positive values (~4–5‰), directly above the upper Pliensbachian limestones in the first ~0.5 m of the marly facies of the Toarcian Kisgerecse Fm. The presence of the Falciferum Zone together with the positive values correlates this interval with the upper *plateau*, which implies a ~2 Myr gap at this locality (*Fig. 5*). Published $\delta^{13}C_{carb}$ data from the Gerecse Basin exist from three sections: the Tölgyhát quarry (Müller et al. 2021), Kisgerecse (Jenkyns et al. 1991, Müller et al. 2021), and Bányahegy (Jenkyns & Clayton 1986). Among these, the negative CIE is only detected at Tölgyhát, in the 10–30 cm black shale layer that can be correlated with the *valley* interval (*Fig. 5*). At Kisgerecse, a ~5 cm bed yielded ammonites of the Tenuicostatum Zone (Géczy 1985) and $\delta^{13}C_{carb}$ value of 2.5‰; thus, this bed can be correlated with the *pre-plateau* above the Pl-To CIE (*Fig. 5*). Higher levels at Tölgyhát and Kisgerecse (the marly facies of the Kisgerecse Fm.) represent the latest phase of the Jenkyns Event, correlated with the upper *plateau* (*Fig. 5*). Thus, our correlation suggests a significant gap at Tölgyhát below and above the black shale, and in Kisgerecse above and below the Tenuicostatum Zone bed (*Fig. 5*). At the condensed Bányahegy section, the first ~20–30 cm of the lower Toarcian might be correlated with higher part of the *falling limb* and the overlying ~0.5 m with the upper *plateau* (*Fig. 5*), also suggesting that the interrupted sedimentation resumed during the late phase of the Jenkyns Event.

In the predominantly carbonate sequence of the Jurassic in the TRU condensed successions and gaps in the pelagic *ammonitico rosso*-type facies are not uncommon and are related to sub-basin-scale tectonic, sedimentary and bottom current changes (Galácz & Vörös 1972). In several lower Toarcian successions in the TRU, especially in the Gerecse Basin, the occurrence of gaps, condensation, hardgrounds, and the near-complete lack of the lower Toarcian Tenuicostatum Zone and probably also the lowermost Falciferum Zone appears to be systematic (Konda 1970, Jenkyns et al. 1991, Cronan et al. 1991, Vörös & Galácz 1998, Galácz et al. 2008). This observation suggests that, besides local factors, changes in seawater chemistry related to the Jenkyns Event likely had, at least in part, a negative impact on the carbonate sedimentation in the TRU (Müller et al. 2021). Since terrigenous influx was extremely reduced during the Early Jurassic in the TRU (Vörös & Galácz 1998), global sea level rise and fluctuation during the Jenkyns Event (Hallam 1997, Pittet et al. 2014, Ruebsam et al. 2019) could also have played a role in the sedimentological expression of the event (Müller et al. 2021).

Record of the Jenkyns Event in the Mecsek Basin

Early Jurassic sedimentation in the Mecsek Basin was controlled by an active half-graben system resulting in a very high sedimentation rate due to sustained deepening of the basin and enhanced clastic input. The thickness of the Lower Jurassic strata increases southward, reaching ~1700 m (Némedi Varga 1995, 1998; Császár et al. 2013). The upper Rhaetian to lower Sinemurian Mecsek Coal Fm. consists of siliciclastic coal-bearing, terrestrial to coastal marine deposits (Nagy 1968). Later in the Sinemurian to Pliensbachian, a thick series of mixed siliciclastics and carbonates indicate rapid deepening from shallow marine (Zobákpuszta and Vasas Fm.) to deep marine (Hosszúhetény Fm.; Mecseknádasd Fm. (Raucsik 2012a, b) depositional environments. Monotonous deep marine hemipelagic marls with turbidite interbeds (Mecseknádasd Fm.) dominate the lower Toarcian succession of the Mecsek Basin (Némedi Varga 1998, Raucsik & Merényi 2000, Raucsik 2012b). Within this succession, a distinctive ~13 m thick black shale unit was designated as the Rékavölgy Formation and is considered as a lithological expression of the Jenkyns Event (Dulai et al. 1992, Varga et al. 2007, Raucsik 2012c). (Note that previously, the lower Toarcian part of the Mecseknádasd Fm., also including the Rékavölgy Fm., was assigned to the Óbánya Fm. (Hetényi 1966, Némedi Varga 1998).) The middle and upper Toarcian deposits constitute a thick series of rhythmically bedded hemipelagic calcareous marls (Komló Fm.) (Raucsik 1997, 2012d) (*Fig. 4*). Together, the Toarcian deposits can reach up to ~160 m in the Mecsek Mts. (Hetényi 1996).

The Rékavölgy Fm. crops out at only a few localities in the western Mecsek Mts. Some exposures exist at Cseresnyák in the vicinity of the town of Komló but the best outcrop where the entire succession can be best studied, including the under- and overlying strata, is situated in the Réka Valley, in a ravine opening to the north from the main valley (~2 km south of the village of Óbánya). Peters (1862) was the first to report the occurrence of black shale in the Réka Valley and already recognised its similarity to the *Posido-*

nienschiefer in the SW German (Schwabian) Basin. Later, VADÁSZ (1935) published the first faunal list with identified ammonite taxa and gave a detailed description of the succession. In the subsurface, this unit is known to occur in a SW-NW striking belt under the thick Neogene basin fill of the Great Hungarian Plain, and it was penetrated as a potential source rock by numerous boreholes for hydrocarbon exploration (BADICS & VETŐ 2012).

In the Réka Valley, the lower Toarcian part of the Mecseknádasd Fm., directly underlying the black shale succession, comprises grey to brown spotted marls (commonly referred to elsewhere as "Allgäu beds" or "Fleckenmergel") with up to ~60-cm-thick siliciclastic or carbonate turbidite intercalations. Bioturbation suggests fluctuating oxic to suboxic conditions during deposition. The Rékavölgy Fm. consists of dark grey, finely laminated, commonly micaceous and bituminous shales and paper shales with siliciclastic turbidite intercalations. This sedimentary facies is indicative of severely oxygen-depleted bottom conditions. Higher upsection, the spotted marl facies returns with gradually increasing carbonate content and less common turbidite intercalations, suggesting improving oxygenation. Petrographic and heavy mineral analyses of the Réka Valley succession pointed to metamorphic and felsic magmatic sources for the detrital component of the turbiditic beds (GALÁCZ 1991; DULAI et al. 1992; VARGA et al. 2007, 2009; RAUCSIK & VARGA 2008a, b).

Following the discovery and early study of ammonites (PETERS 1862, VADÁSZ 1935), the assignment of this black shale to the Falciferum Zone was accepted (FÜLÖP 1971, HETÉNYI *in* FÜLÖP 1978). Subsequently, new findings confirmed the age of the black shale as Falciferum Zone on the basis of specimens of *Hildaites* spp. (*Fig. 5*) and suggested the presence of the Bifrons Zone in the overlying strata (GALÁCZ 1991, DULAI et al. 1992). Recently, a review of the extensive and previously undocumented collection of Rudolf HETÉNYI from multiple localities and drill cores proved the existence of all standard NW European Toarcian ammonite chronozones in the Mecsek Mts (KOVÁCS et al. 2023). This study not only added further support for the presence of Serpentinum Zone (equivalent of Falciferum Zone by various authors) but also suggested the possibility of its subdivision into the older Elegantulum Subzone (with *Cleviceras exaratum*) and the younger Falciferum Subzone (with *Orthodactylites* sp., *Nodicoeloceras crassoides*, *Harpoceras serpentinum*, *H.* cf. *pseudoserpentinum*, *H. falciferum*, *Hildaites murleyi*, *H. serpentiniformis*, and *H.* cf. *subserpentinus*). Nevertheless, a detailed ammonite biostratigraphic study of the Réka Valley section is still needed. The first calcareous nannofossil studies from the Réka Valley established a broad correlation with the Tenuicosatatum and Falciferum ammonite zones; however, it was found to be difficult to define a more precise age (BALDANZA et al. 1995, VARGA et al. 2009). In a later study, the lower Toarcian NJT5b nannozone (based on the co-occurrence of *Lotharingius sigillatus, Biscutum finchii* and *Crepidolithus impontus*) was identified in the uppermost ~3 m of the spotted marl and the lower ~5 m of the black shale, NJ6 zone (with its base drawn at the first occurrence of *Carinolithus superbus*) for most of the upper part of the black shale, and NJ7 (marked by the first occurrence of *Discorhabdus striatus* and the last occurrence of *B. finchii*) for the uppermost ~1 m of the black shale and the lowermost ~5 m for the overlying spotted marl (*Fig. 5*) (MÜLLER et al. 2017).

Macrofauna is not abundant in the Réka Valley section. Although ammonites are moderately frequent finds, they are poorly preserved, mostly as flattened internal moulds. Their assemblage shows a NW European affinity (GALÁCZ 1991, DULAI et al. 1992, KOVÁCS et al. 2023). Fish scales and skeletal remains are common in the black shale, complete fish skeletons (e.g., *Leptolepis normandica*) are also known (DULAI et al. 1992, FŐZY & SZENTE 2014). A recent study of the bivalve assemblage found *Parainoceramya*? *dubia* as the most common taxon, accompanied by rare *Solemya voltzii*, *Liostrea hisingeri* and a few other species, whereas an apparent lack of *Bositra* (="*Posidonia*", "*Posidonomya*") was noted (SZENTE 2015), despite earlier reports of its presence (VADÁSZ 1935). The echinoid *Diademopsis*? cf. *crinifera* represents a unique find from the Rékavölgy Fm. (SZENTE 2015), whereas we found other echinoids and belemnites sporadically in the underlying spotted marl. Macroplant remains assigned to *Pagiophyllum*? sp. were encountered in the black shale (SZENTE 2015). Palynomophs are abundant in the back shale in Réka Valley (BUCEFALO PALLIANI et al. 1997). A detailed palynological and palynofacies study described diverse phytoplankton assemblages from the Réka Valley and interpreted their successive changes as the response to the environmental changes during the Jenkyns Event (BARANYI et al. 2016). The authors distinguished five intervals based on palynomorph assemblages, of which Interval 3, which corresponds to the ~13 m black shale, is characterised by a dinoflagellate cyst "blackout" (profound reduction of dinoflagellate cyst relative abundance) and prasinophyte bloom, marking the most severe phase of the environmental crisis during the Jenkyns Event. Among the microfauna, diverse Late Pliensbachian and Early Toarcian ostracod assemblages were reported from Réka Valley (MONOSTORI 2008). Notably, the black shale is barren of ostracods and marks the disappearance of Healdidae and the rise of Cytheridae to dominance. In addition, unpublished studies hint at the utility of foraminifera fauna in characterising the Pliensbachian–Toarcian evolution of the Mecsek basin and the effects of the Jenkyns Event (GÖRÖG 2004).

Investigation of clay mineral assemblages of the Réka Valley succession revealed a change to higher kaolinite dominance in the black shale strata and no indication of diagenetic overprint. Thus, variation in the clay mineral composition suggests a sharp change to a more humid and warmer climate, with a very high water/rock ratio in the hinterland during weathering that coincided with the Jenkyns Event (RAUCSIK & MERÉNYI 2000, VARGA et al. 2007, RAUCSIK & VARGA 2008). Analysis of K_2O/Al element ratio further confirmed episodes of extremely intense continental weathering during the deposition of the black shale (MÜLLER et al. 2017). Notably, the black shale yielded very high TOC values up to ~15 wt%. Based on hydrogen and oxygen indices, the organic matter composition shifts from a mixed terrestrial-marine source in the underlying spotted marl to a predominantly marine source in the black shale. These observations and the high pyrite content suggest highly eutrophic conditions and anoxic bottom waters during deposition (DULAI et al. 1992, VARGA et al. 2007, RUEBSAM et al. 2018). The first low-resolution stable isotope geochemical study from the Réka Valley section (VARGA et al. 2007) obtained very negative $\delta^{13}C_{org}$ and $\delta^{13}C_{carb}$ values from the black shale that are typical for the valley of the negative CIE (*Fig. 5*) (RUEBSAM & AL-HUSSEINI 2020). However, the $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ record was considered diagenetically overprinted. Subsequently, two independent suites of high-resolution $\delta^{13}C_{org}$ data were obtained, displaying congruent isotope curves with very negative values (~–27 to –33‰) (MÜLLER et al. 2017, RUEBSAM et al. 2018). The data revealed a stepped and fluctuating negative carbon isotope excursion, which is widely regarded as the hallmark of the Jenkyns Event. Correlation of the Réka Valley $\delta^{13}C_{org}$ curve with an integrated stratigraphic framework suggests that the entire black shale spans the *valley* segment of the isotope reference curve, whereas the *falling limb* and the *rising limb* correspond to the underlying and overlying spotted marl, respectively (*Fig. 5*). A comparison with other high-resolution $\delta^{13}C_{org}$ curves suggests an uninterrupted depositional regime and a complete record in the Réka Valley (MÜLLER et al. 2017). Cyclostratigraphic analyses on the basis of $\delta^{13}C_{org}$, $CaCO_3$ and CH2 FTIR provided alternative estimations for the duration of the negative CIE. Assuming Milankovitch control, estimations imply the duration of the CIE as 200 kyr, 350 kyr or 1 Myr, depending on the possible dominance of either precession, obliquity or short eccentricity forcing, respectively (MÜLLER et al. 2017). Results of organic geochemical investigations found evidence of the expansion of H_2S-rich waters into the photic zone, as suggested by the occurrence of the *Chlorobiaceae*-derived isorenieratane biomarker which is ascribed to intensified bacterial sulphate reduction (RUEBSAM et al. 2018). A positive nitrogen isotope anomaly in the black shale provides evidence of local perturbation of the nitrogen cycle as a result of intense bioavailable nitrogen uptake and denitrification (RUEBSAM et al. 2018). Additionally, molecular geochemical evidence of normal marine salinity was found using methylated chromanes, leading to a conclusion that oxygen-depleted conditions during the Jenkyns Event in the Mecsek Basin were not promoted by seawater stratification owing to freshwater inflow (RUEBSAM et al. 2018).

Summary and conclusions

The Early Toarcian Jenkyns Event is one of the archetypal Mesozoic global change events, when profound climato-environmental perturbations triggered by intense LIP volcanism led to significant changes in the depositional patterns in marine basins and a second-order mass extinction. Ocean deoxygenation promoted widespread black shale accumulation. Increased CO_2 input into the ocean-atmosphere system altered seawater chemistry, affecting carbonate sedimentation. In Hungary, stratigraphic, paleontological, and geochemical expressions of the Jenkyns Event are well recorded and have a long history of study both in the basins of the Transdanubian Range Unit (TRU) (part of the southern /Adria/ Neotethys margin of the Neoethys) and in the Mecsek Basin (part of the NW /European/ Neotethys margin). In the SW part of TRU (Úrkút, Eplény) the sedimentary record of the manganiferous Úrkút Formation coincides with the main phase of the Jenkyns Event. The black shale deposition here is preceded by manganese carbonate accumulation which presumably occurred during the early phase of the event. In the central (Bakonycsernye) and NE part of TRU (Gerecse), deposition of pelagic marls of the Kisgerecse Formation occurred after a significant hiatus at the base of the succession. At these localities, the lowermost Toarcian is typically missing, and only the late phase of the Jenkyns Event is captured. In the Mecsek Basin, during the Early and early Middle Jurassic, siliciclastic-carbonate sedimentation took place with a high accumulation rate. The geochemical and litho- and biofacies characteristics of the ~13 m thick black shale of the Rékavölgy Fm. suggest the development of anoxic conditions in the main phase of the Jenkyns Event when euxinia might have reached the photic zone. Comparing the geological record of the Mecsek Basin and the TRU basins reveals that besides the sedimentation mode, the main difference was in the organic carbon accumulation. In the Mecsek Basin conditions were more favourable for organic matter preservation despite the higher sedimentation rate, albeit this is restricted to the main phase of the event. On the other hand, oxygen depletion may have started earlier in the Úrkút Basin of the TRU, with suboxic conditions prevailing during the early phase of the Jenkyns Event and anoxia probably occurring only during the main phase, resulting in moderate organic matter accumulation. Carbon isotope data of bulk organic carbon show the presence of the main negative CIE in the two stratigraphically most extended records, in the Réka Valley section and in the Úrkút succession. In addition, the strongly condensed development at Tölgyhát (Gerecse Basin) also captures the negative CIE in bulk carbonate. At all three localities, the negative CIE cooccurs within organic-rich facies. At Bakonycsernye and in most of the Gerecse successions carbon isotope chemostratigraphy reveals a major gap with a duration of up to ~ 2Myr.

This review summarises our current knowledge of the sedimentary, geochemical, and fossil record of the Jenkyns Event in Hungary and highlights possibilities for future research to enhance our understanding of one of the prominent hyperthermal events in the Mesozoic.

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