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### **► To cite this version:**

David a T Harper, Bertrand Lefebvre, Ian G Percival, Thomas Servais. The Ordovician System: Key concepts, events and its distribution across Europe. A Global Synthesis of the Ordovician System Part 1, 532 (1), pp.1-11, 2023, 978-1-78620-588-9. <10.1144/SP532-2023-8>. <hal-04271110>

**HAL Id: hal-04271110**

**<https://hal.science/hal-04271110v1>**

Submitted on 5 Nov 2023

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Accepted Manuscript

## *Geological Society, London, Special Publications*

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DOI: <https://doi.org/10.1144/SP532-2023-8>

To access the most recent version of this article, please click the DOI URL in the line above. When citing this article please include the above DOI.

Received 13 January 2023

Accepted 25 January 2023

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# The Ordovician System: Key concepts, events and its distribution across Europe

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## Abstract

The Ordovician was a key period in the biological and geological history of the planet. ‘A Global Synthesis of the Ordovician System’ is presented in two volumes of *The Geological Society, Special Publications*. This first volume (SP532) charts the history of the Ordovician System and explores significant advances in our understanding of the period’s biostratigraphy, including more precise calibration of its timescale with tephra chronology and regional alignments using astrochronology and cyclostratigraphy. Changes in the world’s oceans, their shifting currents and sea levels, the biogeography of their biotas and the ambient climate are described and discussed against a background of changing palaeogeography. This first volume also includes syntheses of Ordovician geology of most European countries, including historical key areas, such as the British Isles, Baltoscandia and Bohemia.

For nearly 100 years the Ordovician Period was invisible as Murchison and Sedgwick wrangled over the overlapping ground between their Silurian and Cambrian systems. Ironically, the Ordovician was one of the longest of the geological periods, characterized by major magmatic and tectonic activity, an immense biodiversification, significant fluctuations in climate and sea levels and the first Phanerozoic mass extinction of marine invertebrates. The period was unique, being thalassocratic; epicontinental seas had a wider expanse than during any other geological period. Consequently land areas were restricted to isolated microblocks together archipelagos of various sizes, probably of low relief with rivers traversing gentle gradients, carrying sparse terrigenous material to the coasts (Jaanusson 1984). It is an ancient world with few parallels elsewhere in the Phanerozoic and little in common with Holocene ecosystems and environments. Plate tectonic activity was intense, marked by orogenic and volcanic activity; the roles of microcontinents and volcanic archipelagos were significant in shaping the Ordovician planet and the evolution of its biotas.

This first volume (SP532) of the two in *The Geological Society, Special Publications* series on ‘Global Synthesis of the Ordovician System’ charts the history of the Ordovician System and explores significant advances in our understanding of the period’s biostratigraphy, the calibration of its timescale using astrochronology and cyclostratigraphy, together with tephra chronology. Changes in the world’s oceans, their shifting currents and sea levels, the biogeography of their biotas and the ambient climate are described and discussed against a background of changing palaeogeography. In the second part of this volume, the Ordovician geology of the key areas of the Baltic, Bohemia, Britain and Ireland, Poland, Sardinia, Scandinavia, SE Europe and the Variscan terranes are reviewed and in some cases augmented and revised.

The second volume (SP533) is focused on the Ordovician successions of other parts of the world including North and South America, Greenland, China and adjacent regions of Asia, Australia, New Zealand and Antarctica, North and South Africa together with the Middle East.

## Some key concepts and events

Here we review some key concepts and introduce the relevant chapters in SP532. The first four sections discuss the history of the system, chronostratigraphy and the calibration of Ordovician time; the second three, palaeobiodiversity, palaeogeography together with tectonics and palaeobiogeography; the next climate, ocean circulation and sea level with finally terrestrialization.

### *History of the system*

During the last 50 years the Ordovician has transitioned from its roots in the overlapping unit stratotypes of the British series correlated by Oppel zones (Balini et al. 2017) to a system based on Global Stratotype Sections and Points (GSSP). Successive chairs of the Ordovician Subcommittee have outlined the challenges and progress, from the issues of sustaining the British terminology (Williams 1976; Fortey et al. 1995) to the transition from the British series and importance of radio-isotopic dating (Ross 1984), a road map for progress (Webby 1998), the development of the seven GSSPs (Finney 2005), their completion (Bergström et al. 2009) and their integration with a modern research milieu based on collaboration with IGCP programmes (Harper 2011; Harper et al. 2011), emphasising the importance of an Ordovician Earth System (Finney and Berry 2010). Harper et al. (2023) review the history of the system, its birth out of controversy and evolution into a well-

structured stratotype unit, usefully subdivided and calibrated as key resource for Ordovician researchers. A robust chronostratigraphy has provided a framework for understanding biodiversity changes, but also changing climate and sea-level fluctuations (Fig. 2).

### *Ordovician biostratigraphy*

The biostratigraphy of the Ordovician was founded on graptolites that permitted the construction of Oppel zones through the system (Lapworth 1879, 1880). Other groups such as brachiopods and trilobites, though of regional importance, were considered supplementary to a graptolite zonation (Elles 1937). During the later part of the 20th Century, with advanced acid-etching techniques, conodonts were established as an essential tool for correlation and the basis for an additional zonal scheme. Both conodonts and graptolites are the preferred taxa for the correlation of the Ordovician GSSPs. There have been many iterations of Ordovician zonal schemes. Goldman et al. (2022) review the major subdivisions of the Ordovician System, their GSSPs and the stratigraphic levels that define their bases. These authors include a detailed set of correlation charts illustrating relationships among most of the regional graptolite, conodont and chitinozoan successions across the world.

### *Ordovician cyclostratigraphy and astrochronology*

Cyclostratigraphy links rhythmic changes in strata with Milankovitch cycles, permitting successions to be orbitally tuned using the tools of astrochronology (Strasser et al. 2007). Quaternary geologists first demonstrated that Holocene climate changes were aligned with cycles of astronomical change (Hays et al. 1976). Such short-term patterns, termed Milankovitch cycles, recognise eccentricity (variation in the shape of the Earth's orbit from nearly circular to elliptical; 100 kyr cycle), obliquity (wobble of the Earth's axis; 41 kyr cycle) and precession (change in direction of the Earth's axis relative to the sun; 23 kyr cycle). Throughout the stratigraphic record there are many successions of rhythmically alternating lithologies, for example limestones and marls, possibly controlled by Milankovitch processes, although not all of these modulations were constant in deep time. Furthermore, some cycles have been demonstrated to be of diagenetic origin, and therefore not related to cycles of astronomical change (Westphal et al. 2004). Apart from their obvious value for correlation, such rhythms possibly also effected changes in biotic community compositions and structures together with the extinction and origination of taxa. Over 100 sections ranging in age from the Quaternary to the Triassic have already been reliably tuned in this way. However, deeper in time, in particular in the Paleozoic, the tuning with astronomical cycles becomes more and more difficult.

Sinnesael (2023) reviews the status of Ordovician cyclostratigraphy and astrochronology and suggests that Ordovician astronomically-driven climate dynamics influenced processes such as glacial dynamics, sea-level variations and changes in biodiversity. Ordovician cyclostratigraphic studies can form the basis of high-resolution numerical time scales, ideally in combination with high-quality radio-isotopic dating. Clearly, cyclostratigraphy is becoming increasingly important in integrated stratigraphic studies to understand Ordovician stratigraphy and palaeoenvironmental change.

## *Ordovician tephra chronology*

Chronostratigraphy is traditionally calibrated by numerical ages provided by radio-isotopes (Harper et al. 2022) which can be used to develop a timescale (Hounslow et al. 2022). Some of the early attempts (see Ross 1984 for discussion) lacked accuracy and precision and some were simply erroneous. Radio-isotope techniques require the availability of igneous material, usually tephra, containing zircon crystals. McLaughlin et al. (2023) review in detail the use of tephrochronology, emphasizing the pioneering research on Ordovician rocks, including chemical fingerprinting, to improve precision in dating. Tephra ages provide an unequaled precision in constraining the rates of biological and geological processes through all seven global stages from across many of the Ordovician regions, globally.

## *Ordovician biodiversity*

The Ordovician is marked by the successive appearance and massive diversification of many new groups of taxa (Webby et al. 2004) during and after the gradual transition from the Cambrian to Paleozoic evolutionary faunas, culminating in the Tremadocian (Saleh et al. 2022; see Fig. 1). In the pelagic realm micro-organisms, mostly representing microplankton, were already diversifying in the late Cambrian forming the basis for the Plankton Revolution (Servais et al. 2008). They were joined by radiolarians forming chert units throughout the Ordovician. In the benthos, the Porifera and Cnidaria, i.e., sponges, stromatoporoids and corals, were variably distributed during the Early and Middle Ordovician but all three groups diversified during the Late Ordovician coincident with the widespread development of carbonate platforms at this time. Nevertheless the Ordovician benthos was dominated by suspension-feeding lophotrochozoans. Within the Brachiopoda, the most abundant (in number of specimens and species) fossil group, the dalmanellidines, plectambonitoids, strophomenoids, rhynchonellides and atrypides evolved and diversified during the period, becoming the dominant sessile benthos of the Paleozoic. Bryozoans although now known from the Cambrian, radiated during the Ordovician peaking in the Late Ordovician with the establishment of eight of the key groups including the cyclostomes, cryptostomes and fenestrates. Gastropods initially diversified during the Middle and early Late Ordovician but although taxonomically diverse remained a relatively minor part of the Ordovician fauna, common in near-shore carbonate environments. Bivalves first radiated at high latitudes during the Early Ordovician but expanded their taxon numbers substantially when they migrated to the low-latitude carbonate platforms during the Late Ordovician. Cephalopods were already diverse during the Early Ordovician; they were mainly predators occupying a range of depths, but are most common in carbonate facies. Their diversity fluctuated during the period peaking in the Late Ordovician.

The ecdysozoans were mainly (in numerical terms) represented by the arthropods, specifically the prolific trilobites. There is a marked difference between the diverse trilobite faunas of the Cambrian and those of the Ordovician, characterised by significant changes in feeding strategies and life styles. Their diversification patterns have been described in terms of three successive faunas culminating in the highest diversity during the Late Ordovician. Other arthropods such as the eurypterids, phyllocarids and ostracodes also diversified during the Ordovician.

The deuterostomes included the echinoderms, graptolites and vertebrates *sensu lato*.

Planktic graptolites radiated from a benthic ancestor in the late Cambrian to occupy a variety of depth zones and provinces from the early Tremadocian. All five extant classes of echinoderms appeared and crinoids diversified rapidly, to become one of the major components of the Paleozoic Evolutionary Fauna. Conodonts expanded their distributions across depths, facies and provinces. Finally fishes, i.e., vertebrates, were generally confined to Gondwana during the Early Ordovician, diversifying around Baltica, Laurentia and Siberia during the Late Ordovician. The Ordovician was clearly the period when the entire marine water column, from the seabed to the surface, was colonized and the numbers of megaguilds and their memberships expanded. Less numerically dominant groups such as the conulariids, worms, worm-like and sclerite-bearing taxa were locally important but nevertheless significant parts of the Ordovician biota.

The Great Ordovician Biodiversification has provided a focus on the diachronous appearance and radiation of these biotas in phylogenies, time and space during the period. Much has been written in the last few decades researching and recognising this period-long event (Sepkoski 1995; Harper 2006). Mention should be made of the landmark publication of Webby et al. (2004), together with some subsequent thematic studies (e.g. Harper and Servais 2013 and Zhang et al. 2019). There have been a number of recent reviews of the ‘event’ (Kröger et al. 2019; Harper et al. 2020, 2021; Servais et al. 2021, 2023a; Lefebvre et al. 2022) and the substance of these papers is not repeated here. Many of the individual regional chapters contain biodiversity data, supplemented by graphs, providing further opportunities to analyse and reassess the existing taxonomic compilations for the period.

### *Ordovician palaeogeography and tectonics*

The Ordovician was one of the most magmatic and tectonically active periods of the Phanerozoic. In terms of geological activity, the Ordovician has been compared with the Cretaceous, a period with marked magmatism and volcanicity, warm climates and high sea levels (Crame and Owen, 2002). There have been many iterations of global geographic maps for the period. The initial mismatch between biogeographic and palaeomagnetic data, apparent in some studies during the 1980s, was solved with more reliable palaeomagnetic data (see e.g. Torsvik et al. 1991; Harper et al. 1996). During the last 25 years there have been many global maps reconstructed for the Phanerozoic using a variety of methodologies for their assembly. In a step change in reconstructing palaeogeography, Scotese (2023) presents maps for nine Ordovician time slices, illustrating the positions of mountain belts, land areas, shallow seas and deep basins. Plate modelling has involved calculating the changing age of the seafloor and thus the volume of the oceans and episodes of continental flooding. The fluctuating sea level during the Ordovician is graphically illustrated. With the exception of South China, the palaeocontinents all moved into lower latitudes during the period (Fig. 3) with implications for their faunas. Most interestingly, the Ordovician is significant in having the greatest proportion of tropical epicontinental shelves during the entire Phanerozoic.

### *Changing palaeobiogeography*

The Ordovician Period was characterized by extreme biogeographic differentiation amongst its biota; all groups were affected, particularly the benthos and to a lesser degree the nekton and plankton. Though provinciality of Ordovician faunas was apparent to several late 19th Century geologists and palaeontologists (e.g. Nicholson and Etheridge 1880), research intensified during the 1960s when

biogeographic data formed a key part of emerging plate tectonic models for the period, particularly those for the North Atlantic region (e.g. Wilson 1966). Much of the data were derived from Europe and North America and many reconstructions have been based on these datasets (e.g., McKerrow and Scotese 1990; Harper and Servais 2013). During the last two decades, supported by a series of IGCP programmes, new data from within and beyond the North Atlantic region are greatly enhancing existing global and regional databases. Bioregional patterns are now well established for many biotic groups, particularly the invertebrates. Servais et al. (2023b) chart this progress, focusing on the potential to describe and predict the location and pace of speciation. Future modelling will help pinpoint diversity hot spots, species pumps and diversity gradients, shedding more light on the causes and consequences of the Great Ordovician Biodiversification and its termination in the Late Ordovician Mass Extinction.

### *Ordovician climate*

The Ordovician Period witnessed the development of more modern climate regimes. Data from isotope studies and modelling suggest that atmospheric carbon dioxide levels were about 15 times higher than those today, with higher temperatures releasing water from ice sheets. Widespread volcanicity during the period may have also contributed to these high levels by displacing oceanic water onto the extensive shelves and platform areas. The lack of widespread vegetation on land suppressed the weathering of silicate rocks, a key means of scrubbing carbon dioxide from the atmosphere. Warm temperatures in the tropics encouraged the extensive deposition of Ordovician carbonates. There were, however, a number of ice ages during the period increasing in intensity from the Middle Ordovician onwards and culminating in the Hirnantian glaciation associated with the Late Ordovician Mass Extinction. Initial studies by Spjeldnæs (1961) on Ordovician climate and climatic zones based mainly on biotas and sediment types, have been superseded by interpretations enhanced by isotopic data and more accurate palaeogeographic maps (e.g. Munnecke and Servais 2007; Munnecke et al. 2010).

Young et al. (2023) track climate and environments through the period using direct geochemical proxy datasets and/or numerical modelling approaches. New insights are offered on the timing and potential causes of the major radiation of Ordovician marine life, changes in weathering and the transition from a greenhouse-to-icehouse state and cooling and (de)oxygenation during the end-Ordovician Glaciation. Technical improvements in the collection and analysis of data for palaeotemperature (oxygen isotopes), palaeoredox (sulphur isotopes) and weathering proxy records (strontium and neodymium isotopes), complement the development of new palaeoenvironmental proxies (e.g. clumped, uranium, molybdenum and thallium isotopes; iodine, iron, trace metal geochemistry).

### *Ordovician ocean circulation*

A great deal is now known about the changing continental and terrane configurations during the Ordovician Period but relatively little has been published on oceanic circulation patterns. Earlier attempts (e.g. Wilde et al. 1991; Christiansen and Stouge 1999; Pohl et al. 2016) have used a number of techniques to model water circulation, whereas Pohl et al. (2018) attempted to understand the impact on the primary productivity in Ordovician oceans. The main obstacle in defining and refining the track of ancient oceanic currents is the lack of direct evidence of their movements in the rock record.



Pohl et al. (2022) have applied general circulation models that provide independent, robust insights into the relationship between climate change and ocean circulation. These integrated approaches based on the use of geological data in numerical models are supported by a literature review and updated synthesis of the current understanding of the Ordovician ocean circulation.

### *Ordovician sea level*

Sea level fluctuations during the Ordovician, as featured in the much-cited global curves by Vail et al. (1977 - aka the Exxon Curve) and Haq and Schutter (2008), have been the focus of much research by specialist groups. Global curves presuppose global mechanisms mediating sea levels, such as the waxing and waning of ice caps and sheets or massive seafloor spreading displacing water onto continental shelves. Ordovician ice ages and prolonged active magmatism were both clearly contributory factors to global sea-level fluctuations. Local tectonism is also a key factor and has contributed to the difficulty in constructing a unique global curve, applicable to all continents. These data, nevertheless, together with biotic and isotope information, are now forming the basis for an integrated Ordovician stratigraphy (Zhang et al. 2018).

Fluctuating sea level has also controlled many processes such as biodiversifications and the distribution of sedimentary magnafacies. Fortey (1984) noted the importance of sea-level change in the initial definitions of the Ordovician (British) series. Transgressions were responsible for the flooding of offshore sites on the periphery of continents; these facies may have hosted progenitor taxa. Regressions, however, encouraged the development of offshore islands and archipelagos, the habitats for both progenitor and relict species. The link of biodiversity with marine transgressions has been known for some time (see e.g. Servais et al. 2009).

The fundamental studies on sea-level curves from North America (Ross and Ross 1992) and Baltoscandia (Nielsen 2004) provided some prospect for establishment of a global curve albeit with some regional variations. Scotese (2023) has provided a new global sea-level curve. Many authors have included regional sea-level curves in their chapters, with such curves available for Bohemia (Kraft et al. 2023), East Baltic (Meidla et al. 2022), western France (Lefebvre et al. 2023), the Laurentian margin in Scotland (Molyneux et al. 2023) and Sardinia (Loi et al. 2022).

### *Terrestrialization*

The colonizations of land by plants together with invertebrate and vertebrate animals are key events in the history of life. The Ordovician radiation, now generally called Great Ordovician Biodiversity Event (GOBE), was first recognized in the 1970s, mostly based on recognition of a rapid diversification of the marine shelly fauna. The importance of microfossils (conodonts, acritarchs, chitinozoans, miospores, etc.) in the Ordovician came much later with the development of the study of these groups in the second half of the 20th century (and the strong demand from the oil industry). Biodiversifications on land during the Ordovician have received relatively little attention, compared to the intensive studies on marine organisms, in particular marine invertebrates. Nevertheless, the Ordovician was also a key period for the development of terrestrial organisms: microbial and fungal organisms, land plants, and animals contributed to terrestrialization during the Ordovician, making it obvious that there was also a 'GOBE' on land (Servais et al. 2019).

Wellman et al. (2022) review the data available and point out that during the Ordovician a transition from a microbial soil-vegetation system to one with the first land-plants occurred. The microfossil

record (cryptospores and miospores) indicates a sustained biodiversification of land plants during the Ordovician. True (bryophytic) land plants appeared in the Middle Ordovician after a long algal-land plant transition. The first vascular land plants had possibly appeared by the end of the Ordovician.

## **The Ordovician in Europe**

The present-day continent of Europe is a complex amalgamation of continental plates, terranes and volcanic arcs; it is also a continent of many cultures, languages and some different approaches to the development and use of fundamental geological concepts. Valuable geological literature from many countries is understandably published in the language of the country, driving the need for reviews written in more globally recognised languages, usually English. Publications on the Ordovician System are no exception. Many of our colleagues have provided such reviews.

The geological history of Europe is rich in classic areas, especially those exposing Ordovician rocks and fossils. Stille (1924) classified Europe into Palaeo-Europa, Meso-Europa and Neo-Europa, broadly the Caledonian, Variscan and Alpine belts of the continent. Ordovician rocks crop out in all three belts in various styles of deformation and grades of metamorphism. The most pristine successions are located on the Baltic or Fennoscandian platform, east of the Caledonian front. In this volume the Ordovician is described from all four areas.

### *Britain and Ireland*

Wales and the Welsh Borderlands together with NW England (Avalonia) provided type sections for the unit stratotypes of the British chronostratigraphic units. The use of these units for correlations was expanded to the whole of Britain and the island of Ireland under the auspices of the Geological Survey of Great Britain and Ireland. The work of colonial geological surveys aided the global spread of this terminology throughout much of the known world and many countries still adhere to the British series. The Geological Society has published two comprehensive reports on the Ordovician of Britain and Ireland (Williams et al. 1972; Fortey et al. 2000). Molyneux et al. (2023) provide a substantial revision of the British and Irish Ordovician, based on much new data and analysis, mapped onto the complex tectonic zones of this part of the European margin.

### *Scandinavia*

The Ordovician successions of Scandinavia (i.e. Denmark, Norway and Sweden) are quite different from those of the Baltic States and the western part of Russia. The former developed adjacent to an evolving orogen, the Scandinavian Caledonides, whereas the latter were generally condensed and deposited on an extensive carbonate platform and ramp. The contrasting geological settings have provided challenges in applying first the regional chronostratigraphic scheme of the East Baltic and historically the British chronostratigraphic units established on Avalonia. The revised stage classification for Scandinavia reflects the uniqueness of these Ordovician successions, providing a greater facility to correlate across the Scandinavian countries and directly with the global chronostratigraphy for the system (Nielsen et al. 2023).

### *Baltic palaeobasin*

The mainly condensed, carbonate successions of the Baltic palaeobasin have been researched for some two hundred years. Meidla et al. (2022) present the current knowledge on the biostratigraphy, correlation, palaeontology, sea-level change, together with climate history and isotopic geochemistry

in an area extending from the southern margin of the Fennoscandian Shield to the western margin of the Ukrainian Shield. A two-part correlation chart indicating the classic regional chronostratigraphic standard in ten areas is correlated with the global stages of the Ordovician System, flagging bioevents and gaps in the stratigraphic record.

## *Poland*

In Poland, Ordovician sedimentary rocks are exposed only in the Holy Cross Mountains and the Sudetes, but they have also been recognized in the subsurface of several other areas (e.g. drill cores in the East European Craton and in the Pomeranian, Łysogóry, Małopolska and Upper Silesian blocks). Trela (2022) describes the geology, correlations (based on bentonites and biostratigraphy) and sea-level changes in each major tectonic unit of Poland. Three main comparable depositional sequences reflecting major eustatic events in Baltica, are identified in both northeastern (Polish part of the East European Craton) and southeastern (Łysogóry and Małopolska blocks) regions. In Pomerania (NW Poland). The sedimentary succession is strongly affected by the docking of Baltica with Avalonia in the Late Ordovician. Finally, the Ordovician rocks exposed in the Sudetes (SW Poland) are part of the Bohemian Massif, and were more or less strongly metamorphosed during the Variscan orogeny.

## *Variscan chain in France and adjacent countries*

Lefebvre et al. (2023) have reported in detail on the current status of the Ordovician in France and adjacent territories, exposed with the Variscan mountain chain. Ordovician successions of Belgium (Brabant Massif, Condroz and Ardenne inliers) and Germany (Rhenish massif and Rügen area) contain the same three megasequences related to rift, drift and docking of Avalonia with Baltica. Other areas with Ordovician rocks include the Armorican Massif sharing a Furongian–Early Ordovician gap (Toledanian or Norman gap) with the Ordovician of the Iberian Peninsula, together with continuous Mid–Late Ordovician shelf sedimentation. The Occitan Domain (Montagne Noire and Mouthoumet massifs), eastern Pyrenees and northwestern Corsica together with southwestern Sardinia show continuous shelf sedimentation in the Early Ordovician, and a Mid Ordovician ‘Sardic gap’. The Maures Massif was probably part of this zone. The Vosges and Schwarzwald massifs expose comparable, poorly preserved Ordovician successions, similar to those of the Teplá-Barrandian and/or Moldanubian zones of Central Europe.

Detailed revisions of the Ordovician of Spain have been published previously by Gutiérrez-Marco et al. (2002, 2015). The Iberian Peninsula is not covered here in detail but the chronostratigraphy has been published in Bergström et al. (2009) under the heading Mediterranean and N Gondwana and similarities are drawn here with the successions in the Armorican Massif.

## *Sardinia*

Loi et al. (2022) discuss and illustrate the stratigraphy and structures in the External and Nappe zones of the Variscan basement. The Ordovician successions are characterized by unconformities related to tectonic events ascribed to the Sardic and Sarrabese phases. The External and Nappe zones had different tectonic settings and geographic locations during the Ordovician, implying they were amalgamated only during the Variscan orogeny. The history of the high-grade metamorphic Inner Zone is less clear.

## *Bohemia*

The Bohemian Massif is a classic area for geological and palaeontological research with a long-standing tradition of Ordovician research dating back to the eighteenth century, highlighted by the extensive studies of Joachim Barrande (see also Harper et al. 2023). Kraft et al. (2023) describe and discuss the geology and palaeontology of this key area. The Ordovician rocks rest on a Cadomian basement on the northern margins of Gondwana. These Ordovician strata with Gondwanan shelf affinities can be traced along the Variscan belt from Spain to central Europe, using a stratigraphic scale based mainly on the classic succession in the Prague Basin. The Ordovician fill of this basin, together with relics of another in the Schwarzburg Anticline (SE Germany), are the main exposures in the greater Bohemian Massif. The rocks and fossils of this region together provide a cool-water stratigraphic standard for the Ordovician System.

### *South-eastern Europe*

Southeastern Europe exposes a range of sedimentary environments, from shallow water to basinal settings, located in different palaeogeographic regions. The Ordovician stratigraphy of southeastern Europe with its diverse successions and biotas is revised by Ferretti et al. (2023) and integrated with new multidisciplinary data, aligned with global events during the Ordovician Period. The geology of the Carnic Alps is well known but others that extend discontinuously across this belt, are less well known.

### **Acknowledgements**

Harper thanks the Leverhulme Trust for support. We thank the reviewers for their insightful comments.

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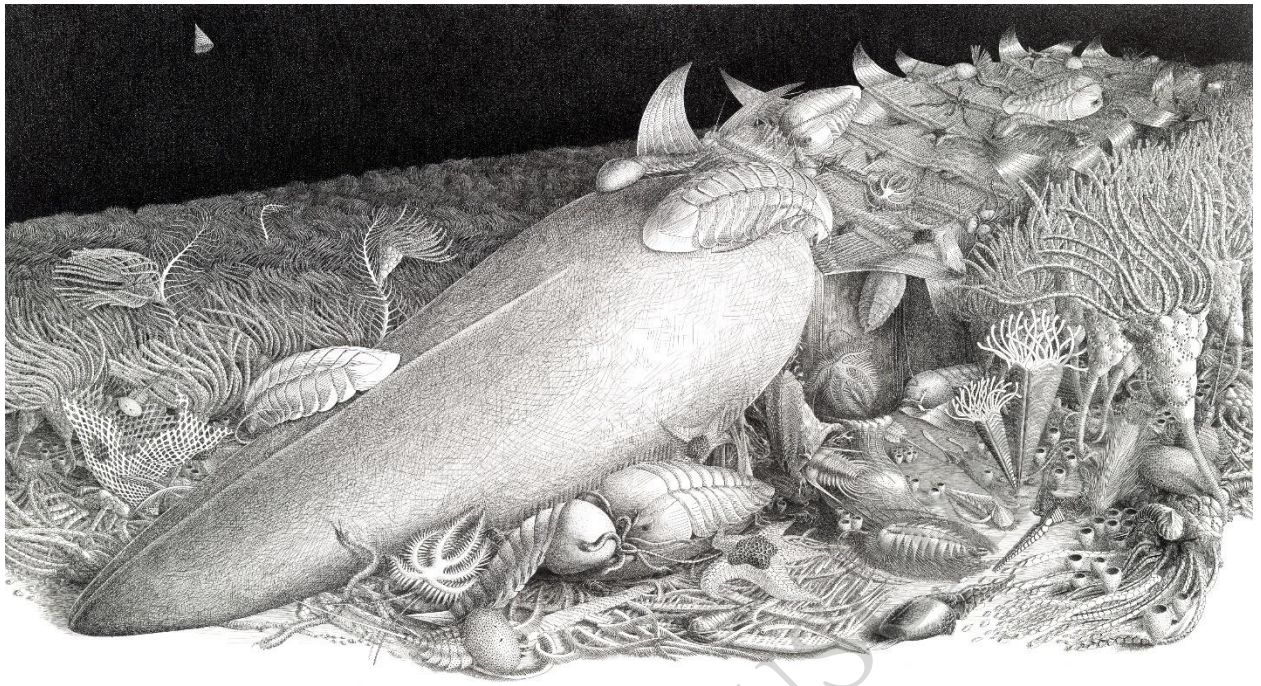
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## Figure Captions

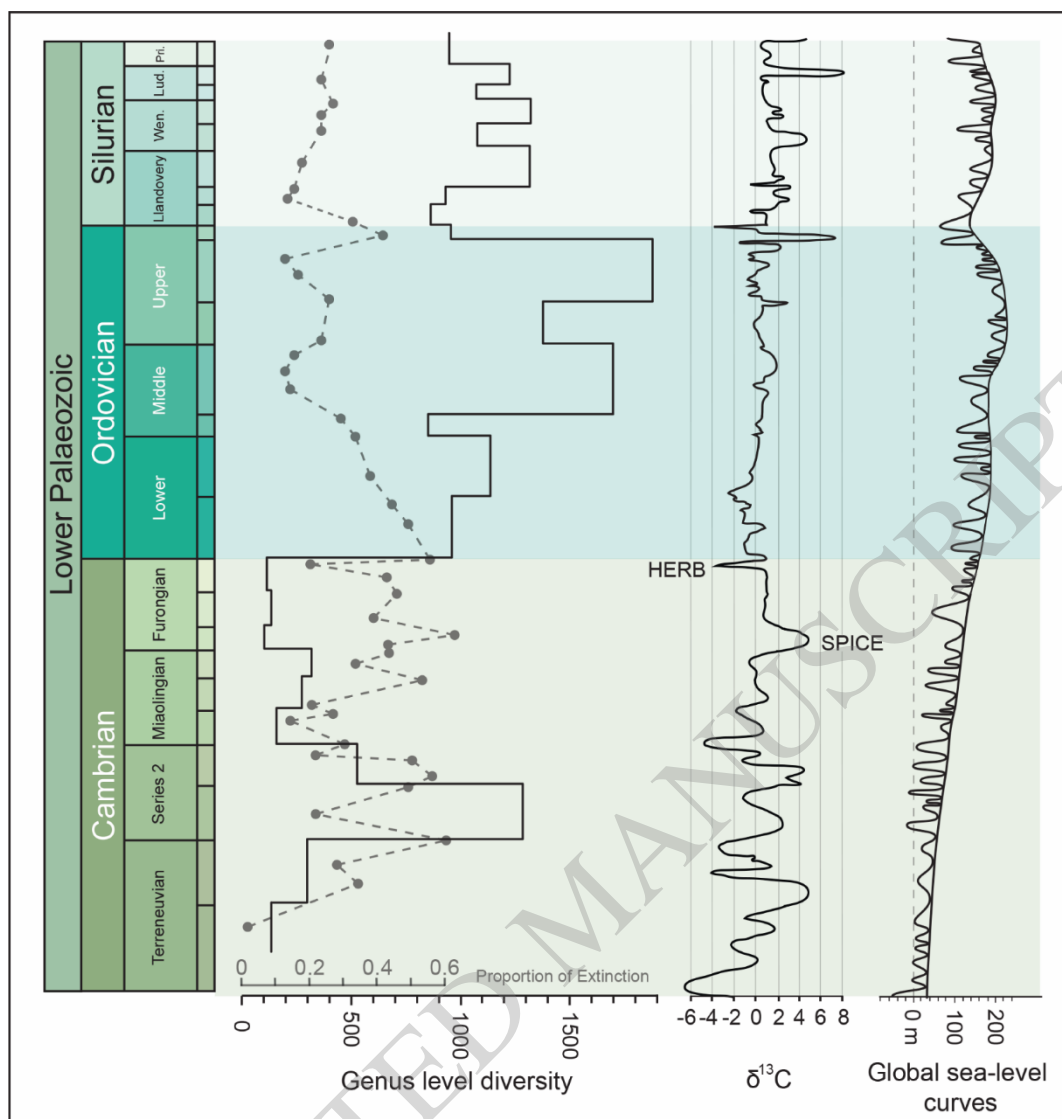
Figure 1. Artistic reconstruction of the Fezouata Biota (late Tremadocian, Morocco) by Madmeg. The extremely diverse benthic and nektobenthic communities recovered from this Lagerstätte document a relatively continuous, smooth transition between the Cambrian and Palaeozoic evolutionary faunas (from Lefebvre et al. 2016).

Figure 2. Contextualizing the Ordovician Period. Chronostratigraphy, biodiversity, isotope curve and sea level through the Ordovician (from Harper et al. 2019).

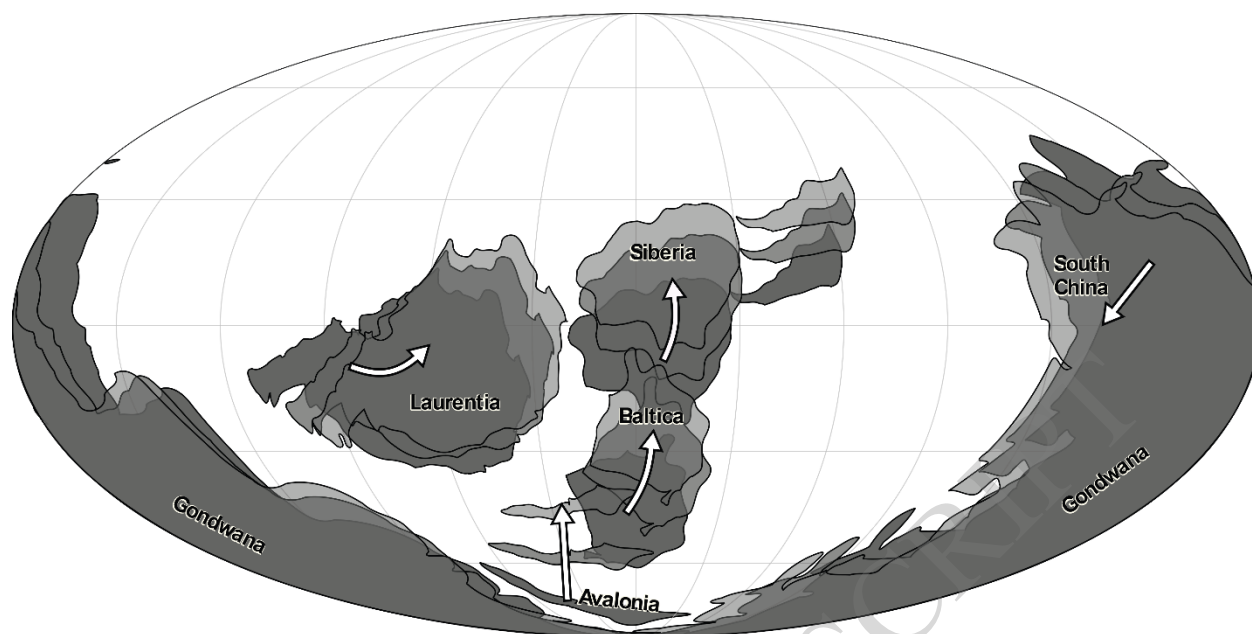
Figure 3. Movement of continents to lower latitudes during the Ordovician (from Harper et al. 2021).



**Figure 1**



**Figure 2**



**Figure 3**