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A journey through the Ordovician System around the World

Thomas Servais¹, David A.T. Harper², Bertrand Lefebvre³ and Ian G. Percival⁴

¹CNRS-Université de Lille, UMR 8198 Evo-Eco-Paleo, F-59000, France

²Palaeoecosystems Group, Department of Earth Sciences, Durham University, Durham
DH1 3LE, UK

³CNRS-Université de Lyon, Lyon 1, ENSL, UMR LGL-TPE, F-69622 Villeurbanne, France

⁴Geological Survey of New South Wales, W.B. Clarke Geoscience Centre, 947-953
Londonderry Road, Londonderry 2753 New South Wales, Australia

TS, 0000-0002-4089-7874

DATH, 0000-0003-1315-9494

BL, 0000-0002-3803-9176

IGP, 0000-0001-5161-2021

Abstract: The Ordovician was a key period in the biological and geological history of the Earth. “A Global Synthesis of the Ordovician System” is presented in two volumes of the Geological Society Special Publications series. The first volume (SP 532) covers general aspects of the Ordovician and also includes the syntheses of the Ordovician successions of Europe. To provide a comprehensive global overview, this second volume (SP 533) represents a journey through the Ordovician System around the World. Reviews of the Ordovician of North America include syntheses of Alaska, Greenland, Canada, the USA and Mexico, whereas the South American Ordovician is summarized in a specific chapter related to Argentina and neighbouring countries. The Ordovician System of Africa is presented in chapters covering the North and the South of the continent where significant Ordovician successions occur. Australia and New Zealand, as well as Antarctica, are visited in separate chapters. Asia provides the most complex Ordovician successions reviewed in chapters covering Turkey and the Levant region, the Middle East, Central Asia, Kazakhstan, India, South-East Asia, China, Korea, and Japan. Our journey covers a great number of locations, but with many successions still to be fully described, the knowledge of the Ordovician of the World remains incomplete.

The Ordovician is one of the longest of the geological periods, characterized by major magmatic and tectonic activity, an immense biodiversification, changing (cooling) climate and increasing sea levels, probably the highest of the Phanerozoic, together with the largest extent of tropical shelves during the entire Phanerozoic (Harper *et al.* 2023a). Plate tectonic activity was intense, with rapidly moving continents (Scotese 2023). The period was marked by strong orogenic and volcanic activity, depositing some of the thickest tephra layers of the Phanerozoic (McLaughlin *et al.* 2023). There was possibly a superplume, for which direct geological evidence is no longer available (Lefebvre *et al.* 2010), because the rocks resulting from a potential Ordovician Large Igneous Province (LIP) have probably been recycled.

Indeed, only a minor fraction of the Ordovician World is still available to the geologist to study. Most Ordovician rocks have been eroded or disappeared during subduction, and of those remaining many are obscured in mountain belts. Nevertheless, there are Ordovician rocks preserved all over the world, on all the continents. From the Geological Map of the World, at scale 1:5M (Sautter *et al.* 2022), the following data are available (Table 1): excluding Antarctica, 1.91 to 4.17 % of the sedimentary rocks on the different continents are Ordovician in age. The varying percentages depend essentially on the mode of calculating, and on the estimation of the age of these rocks. As a result, 4.17 % is the area of sedimentary rocks (potentially 3.5 million km²) that are possibly Ordovician in age (the minimum or maximum age of these rocks is Ordovician). For 1.91 % of the sedimentary rock record (1.6 .5 million km²) of the entire World an Ordovician age is proven (the minimum and maximum ages of these rocks lie within the Ordovician). How much of these areas have been mapped? What is the proportion of these areas where the stratigraphical successions are analysed in detail, with clear definitions of formations, and precise biostratigraphy? Probably only a very small fraction!

From the historical overview (Harper *et al.* 2023b), England and Wales became the centre of early investigations on the Ordovician. The countries with a strong industrial strategy during the 19th Century first developed geological studies and mapping of their respective territories. The impetus for William Smith's geological map of England and Wales, published in 1815, was the establishment of an extensive series of canals dug to facilitate transport of raw materials as the Industrial Revolution advanced in Britain. Most of the Lower Palaeozoic successions were first defined in this region, with the names of the

Ordovician and Silurian based on the names of two ancient tribes of Britain, the Ordovices and Silures. The classification of the Ordovician was first established in Great Britain, with landmark publications as those on works on graptolites (e.g. Elles 1937). Logically, the classical British series were used for many decades globally (Fortey *et al.* 1995, 2000), even if the geological successions around the world are completely different from those of the essentially clastic succession of the historical type-areas of Avalonia (Molyneux *et al.* 2023).

It rapidly became evident that the stratigraphical successions from other areas were very different. Several European capitals are built on, or surrounded by, Ordovician rocks. For example, the area around the capital of Norway, Oslo, is of Ordovician age with shale and limestone successions from a succession of rocks that became a regional standard (Nielsen *et al.* 2023). Similarly, the surroundings of the capital of Estonia, Tallinn, provide another succession of Ordovician rocks, typical of the Baltic Region (Meidla *et al.* 2023), that are completely different from the British standard. Also Prague, the capital of the Czech Republic, is partly built on Ordovician rocks (Kraft *et al.* 2023), although the term Pragian is used as the second Global Stage of the Lower Devonian Series. From other continents, Ordovician areas became also classic and world-famous. A good example is the Ordovician of the Cincinnati Arch, with spectacular outcrop areas in Ohio, Kentucky and Indiana, USA. Logically, this succession became a regional standard very early in studies of North American geology (McLaughlin and Stigall 2023). China is today clearly a key area for the Ordovician, although the more intensive studies on the Chinese Ordovician developed comparatively late, with first studies dating back to the 1920s (see summary in Zhang *et al.* 2018, 2023).

After an initial phase of studies in the western world, i.e. western and northern Europe and North America, the Ordovician is today much better known from most other parts of the World. The second volume (SP 533) of “A Global Synthesis of the Ordovician System” is focused on these Ordovician successions from all over the world. In the following paragraphs we summarize this journey through the Ordovician of our planet.

A look at the stratigraphic chart of the Ordovician

Harper *et al.* (2023b) revise the transition from the British ‘standard’ to the modern view on the Ordovician. Webby (1998), as one of the chairs of the Ordovician Subcommittee, illustrated the steps toward the currently adopted global standard of Ordovician stratigraphy,

from the British series towards the development of the seven Global Boundary Stratotype Sections and Points, GSSPs (Finney 2005) and their completion (Bergström *et al.* 2009). Today, the Ordovician is truly global (Fig. 1). From the original British stage names, two have been kept, the first (Tremadocian) and the last (Hirnantian) regional stages are today also the global Stages (Fig. 1).

The GSSPs in the Ordovician are also truly ‘global’ and have not been selected from the classical type area. As illustrated in the Ordovician chronostratigraphic chart (Fig. 1), two GSSPs are defined in North America, i.e. from the palaeocontinent of Laurentia (the base of the Tremadocian and the base of the Katian), two others are defined in Scandinavia, i.e. from the palaeocontinent of Baltica (the base of the Floian and the base of the Sandbian), whereas the three other GSSPs (bases of the Dapingian, Darriwilian and Hirnantian) are described from China.

The names of the global stages of the Ordovician are also of ‘global’ derivation: the Tremadocian derives from the name Tremadog, a town in North Wales, the Floian Stage is named after Flo, a village in Västergötland, southern Sweden. The third Ordovician Stage is the Dapingian, named after Daping, a village near the Dapingian GSSP at Huangnitang, China. The upper stage of the Middle Ordovician is named Darriwilian, that derives from Darriwil, a parish in County of Grant, Victoria, Australia. The Sandbian is the first stage of the Upper Ordovician. The name derives from the village Södra Sandby in the surroundings of the city of Lund, in southern Sweden. The second stage of the Upper Ordovician has again a name from another part of the world: Katy Lake lies in Atoka County, Oklahoma, USA. Finally, the Hirnantian brings the Global Stage name back to the roots of the Ordovician: Cwm Hirnant is a valley that lies south of Bala, in northern Wales.

Ordovician palaeogeography

Examination of a palaeogeographical reconstruction for the Middle Ordovician (Fig. 2) shows the position of the British type areas (Eng = England) between the major continental blocks Laurentia, Baltica and Gondwana (Scotese 2023). Numerous areas have today been documented from all around the world (see abbreviations in the figure legend of Fig. 2). In the present volume many of these areas are described and it is important to place them in their palaeogeographical, and not only modern geographical, context. It becomes evident from the reconstructions that epicontinental shelf areas were widespread, reaching the largest

extent of the entire Phanerozoic (Scotese 2023). Continental dispersal was at its maximum, with immense provincialism observed for many faunas (Harper and Servais 2013; Servais *et al.* 2023). During the Ordovician most palaeocontinents moved into lower latitudes with evident implications for their faunas, as the areas became biodiversity hotspots, and contributed to the Ordovician marine radiation (Harper 2006).

North America

The complex Ordovician geology of Alaska is reviewed by Dumoulin *et al.* (2023). Shallow- and deep-water deposits along the northwestern Laurentian margin occur in east-central Alaska (Yukon River area). Elsewhere in Alaska, Ordovician strata occupy parts of continental or island arc fragments that, as indicated by faunal and detrital zircon data, originated as crustal fragments situated in the palaeo-Arctic between Laurentia, Baltica, and Siberia during the early Palaeozoic before being variously displaced. In northern Alaska, Ordovician rocks are found in the Arctic Alaska–Chukotka Microplate (AACM), a composite tectonic entity with a complex history. Some Ordovician strata in the AACM (parts of the North Slope subterrane) represent displaced fragments of the northern Laurentian margin. Coeval strata in southwestern parts of the AACM (York and Seward terranes, Hammond subterrane) share distinctive lithologic and biotic features with Ordovician rocks in interior Alaska (Farewell and related terranes). The Alexander terrane in southeastern Alaska is another composite crustal fragment with Ordovician rocks that accumulated in a complex arc system.

Greenland is the largest of the world's islands, exposing Ordovician rocks around its margins in North Greenland and northern East Greenland; loose blocks containing Ordovician fossils are also recorded from the craton of West Greenland. Stouge *et al.* (2023) have described in detail successions from western North Greenland (Franklinian Basin), eastern North Greenland (the north-eastern corner of Laurentia) and northern East Greenland (part of the Caledonian platform of northern Europe and the Appalachians). Greenland occupied a subtropical to tropical position during the Ordovician with faunas typical of Laurentia. A prominent faunal peak of diversification occurred in the Late Ordovician. This chapter summarizes the stratigraphical succession of Greenland and its age relationships are discussed with reference to its fossil record; correlations within and beyond Greenland are provided.

Ordovician rocks extend over a large area of the North American Craton and its margins in Canada. The areas are vast and the contrasts between successions significant. Desrochers *et al.* (2023) have documented the Ordovician in the Canadian Arctic Islands, Eastern Canada, Western Canada and the Canadian Interior, highlighting their depositional and geographic settings. During much of the period, Laurentia straddled the palaeoequator, flooded by epicontinental seas, characterized by high temperatures and high faunal diversities. Substantial tectonic activity was largely restricted to the Taconic Orogeny affecting the Appalachians and the Pearya composite terrane. The Hudson Bay and Williston basins and some smaller satellite basins cover the cratonic interior of Canada. These shallow-water basins, dominated by carbonates with some evaporites, are the remnants of a more extensive sea, episodically connected to the adjacent platform. The GSSP for the base of the Ordovician system is defined at Green Point, western Newfoundland, whereas the Ordovician–Silurian boundary interval is well exposed on Anticosti Island, Québec.

McLaughlin and Stigall (2023) outline the Ordovician history of the conterminous United States (USA) which spans multiple ancient basins on the palaeocontinent of Laurentia. This region occupied a relatively stable and isolated position in the southern tropics during the Ordovician. Lower Ordovician rocks on the epicontinental platform mostly consist of fine-grained carbonates termed the “Great American Carbonate Bank”. Distal ribbon carbonates and graptolitic shales are preserved in allochthonous fragments of the continental margin. Middle Ordovician strata include sandstones of the inner detrital belt, mostly overlying the Sauk-Tippecanoe unconformity. Upper Ordovician strata show the greatest lithologic and faunal diversity, reflecting steepening topography resulting from regional compression along the south Laurentian (Appalachian) margin. The GSSP for the Katian Stage is defined in Oklahoma. Recent advances in the interpretation of the USA are primarily from study of carbon and oxygen stable isotopes, sequence stratigraphy, palaeoecology, tephrochronology, redox geochemistry, strontium isotopes, and geochronology.

First documented about 120 years ago, Ordovician successions and faunas remain incompletely known in Mexico. Cuen Romero *et al.* (2023) provide an extensive and up-to-date overview of Mexican Ordovician biostratigraphy, based mostly on conodonts and graptolites. The most complete and best-known Ordovician successions are exposed in the Sonora Province. Those occurring in other regions are also described and comprise only Tremadocian (Oaxaca), Floian (Baja California) and Upper Ordovician (Chihuahua) rocks. In northern Mexico (Baja California, Chihuahua and Sonora), Ordovician assemblages display

clear Laurentian affinities, in good agreement with palaeogeographic reconstructions, suggesting that this region was then part of the southwestern margin of the North American craton. In marked contrast, Ordovician faunas from southern Mexico (Oaxaca) exhibit strong Gondwanan affinities, supporting the view that this region was then possibly next to, or part of, the northern margin of modern South America.

South America

The southern part of South America (Argentina, Bolivia, Brazil, Chile and Paraguay) represents a substantial portion of Gondwana. Waisfeld *et al.* (2023) describe the thick, extensive and unequally investigated Ordovician successions occurring in four main areas. The intracratonic Paraná Basin yielded siliciclastic and glacio-marine Upper Ordovician deposits. In the Central Andean Basin (Cordillera Oriental of Argentina, Cordillera Oriental of Bolivia and Sierras Subandinas), Ordovician successions consist of widespread, particularly thick (up to 5,000 m), shallow marine siliciclastic deposits. In this area, Ordovician biostratigraphy was mostly investigated in the Cordillera Oriental of Argentina and relies on conodonts, graptolites, palynomorphs and trilobites. In the Puna-Famatina region, Ordovician rocks were deposited in volcano-sedimentary basins related to the subduction zone along the proto-Andean margin of Gondwana. In marked contrast with all other areas in South America, Lower Ordovician successions from the Precordillera Basin of western Argentina are dominated by shallow marine carbonates yielding abundant tropical Laurentian faunas. Increasing Gondwanan faunal affinities during the Middle and Late Ordovician suggest that this region was probably a terrane (Cuyania) drifting away from Laurentia towards Gondwana. Finally, South American regional patterns of biodiversity for marine metazoans, trace fossils and land plants are discussed and compared with other areas.

Africa

The Ordovician rocks and fossils of South Africa provide a unique, low-latitude window on Earth surface processes along the southern margin of Gondwana. Penn-Clarke *et al.* (2023) review existing and new research on the extensive Ordovician outcrops in South Africa. These rocks cover large areas of the Northern, Western and Eastern Cape provinces within the Cape Fold Belt as well as the KwaZulu-Natal Province. The rocks are mainly

metasiliciclastic sediments and are normally unfossiliferous except for the world-class fossil deposits of the Cedarberg Formation and important trace fossil localities in the Graafwater, Peninsula and Pakhuis formations. Nevertheless age constraints for many Ordovician successions remain challenging and it is difficult to correlate the majority of units with global Ordovician chronostratigraphic frameworks.

North and West Africa includes some very large Ordovician outcrop areas as well as extensive subsurface Ordovician sediments, of which only a small fraction is known in some detail so far. Morocco surely holds a key position, with famous sequences and Lagerstätten, such as the Fezouata and Tafilalt biotas (Lefebvre *et al.* 2018, 2022). Ghienne *et al.* (2023) summarize the main patterns of Ordovician geology of North and West Africa. Morocco, Algeria, Tunisia and Lybia have partly been well studied in terms of petroleum exploration, with robust biostratigraphical frameworks provided by graptolites, brachiopods, trilobites and palynomorphs. On the other hand, in other areas, such as Mauritania, Senegal, Guinea, Ghana, Niger, Chad, and other countries, most of the Ordovician sequences still need to be fully described. Many of these North African countries show sedimentary archives of the maxima of the end-Ordovician glaciation, i.e. from Hirnantian glaciers.

Asia

Elicki *et al.* (2023) investigate the Ordovician of the Levant region (Middle East) and Turkey. They present a summary of the current knowledge on the mainly siliciclastic Ordovician rock sequences from Jordan, Syria and southern Turkey. An increasing amount of data enables correlation across the southern parts of the Arabian Plate to southern Turkey, and with the greater Gondwanan regions, but also with southwestern Europe and northern Africa. Data from zircon-based provenance analysis clearly implicate the Arabian Shield as the main source of the sediments within the Ordovician succession of this area that still represents a huge potential for further research.

A synthesis of the Ordovician of the Middle East (Iran, Afghanistan and Pakistan) is presented by Ghobadi Pour and Popov (2023). Most of the Iranian terranes are now reasonably well studied and show a palaeogeographical proximity to temperate latitude Gondwana, but the biogeographical links of Alborz and Kopet-Dagh with South China prevailed during the Early and Middle Ordovician. In Pakistan, Ordovician deposits are present in the Karakorum block (Chitral), whereas the available information on the

Ordovician of Afghanistan is so far mostly based on reconnaissance studies performed almost half a century ago, and many areas need to be investigated in detail.

Ordovician geology of the region of Kyrgyzstan, Tajikistan and Uzbekistan in central Asia is relatively poorly known, both on the ground and from accessible geological literature, and the review provided by Ghobadi Pour *et al.* (2023) is a significant advance towards remedying this situation. Five first-order tectonic units with an Early Palaeozoic sedimentary record are recognised, comprising North Tien Shan, Karatau Naryn, Turkestan–Alai, Zeravshan–Hissar and the Central Pamirs. The first three of these were possibly separate microcontinents, located in low southern latitudes throughout the Ordovician in relative proximity to the western Gondwana margin. Zeravshan–Hissar and the Central Pamirs were also parts of the Gondwana supercontinent but were located in temperate latitudes. The extensive geological literature on the Ordovician of the region is assessed to provide an updated palaeontological record, outline of lithostratigraphy, and synthesis of biostratigraphic correlation which is mainly graptolite-based but discontinuous.

Popov *et al.* (2023) provide a comprehensive review of the complex mosaic of Ordovician rocks in Kazakhstan, based on an extensive bibliography of literature that is largely inaccessible to many researchers. The archipelago model is considered most appropriate for reconstruction of inferred Kazakh volcanic island arcs and microcontinents in the Ordovician Period. Kazakh Ordovician benthic faunas show strongest affinities to those of Tarim, South and North China and to a lesser degree the Australian sector of Gondwana, whereas biogeographical connections with Siberia and Baltica were negligible. During the Sandbian to Katian, a loose cluster of Kazakh microcontinents and island arcs located in low latitudes on both sides of the equator became a major biodiversity hotspot. Radiolarian cherts from accretionary complexes preserve an almost complete record of biogenic sedimentation spanning at least 30 myr from the Furongian to Darriwilian, providing a unique opportunity to study biotas and environments in Ordovician oceans.

As documented by Myrow *et al.* (2023), Ordovician rocks of the Indian Tethyan Himalaya are initially represented by strata of terrestrial origin overlying a conspicuous angular unconformity with Cambrian strata, recording the widespread Kurgiak Orogeny. The widespread absence of pre-Katian strata on the Indian subcontinent is due to erosion associated with the Kurghiak Orogeny and delayed onlap onto topographically high areas. No fossils diagnostic of any Ordovician ages prior to the Katian Stage are known from India. The Pin Formation in the Spiti Valley provides a high-resolution record of the depositional history, palaeontology, and isotope geochemistry of Late Ordovician events, extending into

the lower Silurian (Llandovery). Significant events recognized in this interval include the late Katian Boda warming event, the Paroveja positive excursion (the last major excursion of the Katian), and a “lower HICE” or KaH excursion of the Katian–Hirnantian boundary interval.

In the Ordovician, China comprised several independent tectonic palaeoplates or terranes and parts of other blocks, including South China, North China, Tarim, Qaidam, Junggar, Qiangtang-Qamdo, Lhasa, and partially Himalaya, Sibumasu and Indochina, as well as the Altay-Xing’an and Songpan-Garze fold belts, which were discrete but near-adjacent. Twelve stratigraphic megaregions bounded by tectonic sutures or major fault zones are recognized. Zhang *et al.* (2023) summarize the biostratigraphic framework enabling correlation across these stratigraphic megaregions and regions, based on 33 graptolite biozones and 27 conodont biozones, together with supplementary biozones, communities or associations of brachiopods, trilobites, cephalopods, chitinozoans, acritarchs and radiolarians. Documenting constraints provided by integrative chronostratigraphy, biostratigraphy, chemostratigraphy, cyclostratigraphy and magnetostratigraphy, and geochronology, our understanding of the temporal and spatial distribution of the Ordovician lithostratigraphic units on these major blocks composing China is significantly advanced by this comprehensive synthesis.

The Ordovician succession of the Korean Peninsula is part of the Cambrian-Ordovician Joseon Supergroup, exposed in the Taebaeksan Basin of South Korea and the Pyeongnam Basin of North Korea. The review by Lee *et al.* (2023) summarizes advances in the study of these Ordovician successions over the past two decades, focusing on the Taebaeksan Basin which comprises the Taebaek, Yeongwol, Yongtan, Pyeongchang and Mungyeong groups. The Taebaek and Yeongwol groups have been studied in detail and comprise mixed carbonate–siliciclastic deposits formed in peritidal to deep-subtidal environments. Whereas Ordovician strata in the Taebaek Group are generally similar to those of the Pyeongnam Basin and North China, palaeontological affinities of the two Korean basins are closer to those of South China.

Only remnants of Ordovician Japan remain available for study. Isozaki (2023) places these in the context of the Neoproterozoic to Cenozoic history of the Greater South China (GSC) continental block. The GSC, which consists of South China, the East China Sea, SW-NE Japan, and the Khanka-Jiamusi-Bureya megablock, became separated from Rodinia in the Neoproterozoic, and its Proto-Japan segment has evolved as a collision-free subduction margin for nearly 500 myr since the mid-Cambrian. The Ordovician crust of Proto-Japan was part of an active continental margin on the Palaeo-Pacific margin of the GSC and comprises

arc-related rocks such as granitoids, supra-subduction zone ophiolite, and fore-arc basin strata, most of which are considerably fragmented. Ordovician fossils from Japan are limited to a single occurrence in the Hida marginal–Nagato belt; these rare conodonts suggest that Proto-Japan was positioned in the low-latitude domains of the Paleo-Pacific Ocean.

Agematsu and Oo (2023) describe the Ordovician stratigraphy of the Sibumasu Block of southeast Asia, which formed part of equatorial peri-Gondwana during the early Palaeozoic. Palaeobiogeographical data suggest that the Sibumasu Block was adjacent to Western Australia throughout the early Palaeozoic, while Late Ordovician fossil assemblages from Sibumasu and South China are closely similar. Lower Ordovician strata include fine-grained clastic rocks in the Shan Plateau of Myanmar, shallow-marine clastic rocks in northern to western Thailand, and shallow-marine carbonate rocks in southern Thailand and northwestern Malaysia. Middle Ordovician strata consist almost entirely of shallow- to deeper-water carbonate rocks, with turbidites in western Malaysia. Upper Ordovician rocks reflect an overall deeper environment, and the uppermost Ordovician consisting of deeper-water fine-grained clastic rocks. Upper Cambrian rhyolitic rocks in the Shan Plateau and Lower to Middle Ordovician volcanics in midwestern Malaysia likely formed during subduction of the Proto-Tethys Ocean plate beneath the northern Gondwanan margin.

Australia, New Zealand and Antarctica

The stratigraphic overview presented for the Ordovician rocks of Australia and New Zealand (Percival *et al.* 2023a) substantially updates and revises the last major review published forty years ago. In the western two-thirds of Australia, Lower and Middle Ordovician shallow marine successions are restricted to intracratonic basins of which the Canning Basin (Western Australia) and Amadeus Basin (central Australia) are the best known. The eastern third of the continent consists of multiple orogens (i.e. Delamarian, Lachlan, New England, Thomson, Mossman) that accreted to the East Gondwana margin, with an extensive volcanic and intrusive rock record as well as sedimentary facies extending from shoreline to basinal depths. In the Lachlan Orogen the well-known Pacific Graptolite zonation (31 biozones spanning the entire Ordovician) is supplemented in deep-water siliceous sedimentary rocks by a newly defined set of 12 conodont biozones, and the conodont biozonation developed for shallow-water carbonate rocks is further refined. Ordovician rocks in the Buller Terrane of

New Zealand share a palaeogeographic link with the Bendigo Zone of the western Lachlan Orogen.

The sparse Ordovician rock record in Antarctica, restricted to the Lower Ordovician, is reviewed by Percival *et al.* (2023b). In East Antarctica, Lower Ordovician rocks are best known from the Ross Orogen, postdating the 495-489 Ma Ross Orogeny, and include the ~490-475 Ma Granite Harbour Intrusives. Few fossils are known. The Robertson Bay Terrane in northern Victoria Land includes allochthonous limestones of the Handler Formation (Robertson Bay Group) with latest Cambrian to earliest Ordovician conodonts and microbrachiopods. Trace fossils of probable Early Ordovician age are present in the Camp Ridge Quartzite (Leap Year Group) in the Bowers Terrane. In West Antarctica, the Blaiklock Glacier Group in the Shackleton Range of Coats Land contains a diverse ichnofossil fauna of probable Ordovician age associated with undescribed bivalved arthropods and segmented crustacea. The Swanson Formation of the Ross Province in Marie Byrd Land (correlated with the Robertson Bay Group of the Ross Orogen) is a turbiditic unit dominated by quartz-rich sandstones.

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Figure and Table Captions

Fig. 1. Chart showing proposed correlation between the new global series and stages and regional chronostratigraphic units recognized in major outcrop areas of Ordovician rocks. Also shown are the stratigraphic positions of the stage slices (SS). The Siberian and Mediterranean/N. Gondwanan columns were compiled by Andrei Dronov and Juan Carlos Gutiérrez-Marco, respectively. The Global Boundary Stratotype Section and Point (GSSP) boxes in the North American column refer to the base of the Ordovician System and the base of the Katian Stage, respectively; those in the Baltoscandian column to the bases of the Floian and Sandbian stages, respectively; and those in the Chinese column to the bases of the Dapingian, Darriwilian, and Hirnantian stages, respectively.

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Figure 2. Middle Ordovician Index Map (Scotese 2023, fig. 1). AA = Apulia-Adria, Alex = Alexander terrane, A-M = Atsu-Mointy island arc, Arm = Armorica, B = Bronson Hill island arc, Bal = Ballantrae island arc, Bar = Barents Sea, BM = Bohemian Massif, Br = Brabant Massif, B-T-S = Boshchekul-Tarbagatay-Selety island arc, Bu = Burma, CFB = Cape Fold Belt, Ch-NT = Chu Ili–North Tianshan island arc, Chuk = Chukotka, Cuy = Cuyania, Eng = England, FAM = Famatinian ranges, Fara = Farah terrane, Fl = Florida, Grn = Greenland, GTI = Greater India, Ib = Iberia, Indch = Indochina, Jp = Japan, K = Korea, K-K-S = Kalmyk Kol-Kokchetav-Stepnyak island arc, K-O = Kolyma-Omolon, KW = Karawanken terrane, L = Lush's Bight island arc, Lh = Lhasa terrane, Mal = Malaysia, MC = Maritime Canada, Md = Madagascar, Mex = Mexico, Mol = Moldanubian Zone, Mor = Morocco, NG = New Guinea, N. Mong = North Mongolia, NE = New England, NSI = New Siberian Islands, NvZ = Novaya Zemlya, QT = Qiangtang terrane, S. Mong = South Mongolia, Sct = Scotland, Sis = Sistan terrane, SSJ = Sanandaj Sirjan, Sum = Sumatra, SV = Sierra de la Ventana ranges, Svl = Svalbard, T = Tetagouche volcanic arc, Tim = Timan-Pechora basin, T-M-R = Tisia-Moesia-Rhodope terrane, TS = Tornquist Sea, WSL = West Siberian Lowlands, Yc = Yucatan, Z = Zealandia. Tectonic elements along the Indo-Australian margin of Gondwana have been outlined in white for greater clarity; red lettering indicates orogenic belts; shades of blue in the ocean basins indicate bathymetry; light blue shading on the continents are shallow seas; light brown shading is lowlands, brown shading indicates uplands.

Table 1. Proportion of Ordovician sedimentary rocks from the Global Geological Map at 5M. All data are extracted from the Geological Map of the World at 5M. This geological database contains 138756 polygons (excluding Antarctica) characterized by different attributes (Min Age, Max Age, lithology, rock type, etc.). The data are more or less complete and precise, depending on the location, and they are the result of regional interpretations and correlations on a continental scale. A large proportion of the polygons therefore have little or no associated information and their ages are imprecise. For further information see Sautter et al. (2022).

Data (All World without Antarctica)	Area (km²)	Percentage
All rocks	131,888,369.90	
All World 5M Sedimentary rocks	84,847,001.60	100
All Ordovician Sedimentary rocks (Age Max + Age Min)	3,537,567.20	4.17
Restricted Ordovician (Age confirmed)	1,620,531.50	1.91



ORDOVICIAN CHRONOSTRATIGRAPHIC CHART

International Subcommission on Ordovician Stratigraphy



GLOBAL			UNITED KINGDOM		NORTH AMERICA		BALTOSCANDIA		AUSTRALIA		CHINA		SIBERIA		MEDITERRANEAN & N.GONDWANA		Stage Slices (SS)						
SYSTEM	SERIES	STAGE	SERIES	STAGE	SERIES	STAGE	SERIES	STAGE	SERIES	STAGE	SERIES	STAGE	SERIES	STAGE	STAGE								
ORDOVICIAN	UPPER ORDOVICIAN	HIRNANTIAN	ASHGILL	HIRNANTIAN	CINCINNATIAN	GAMACHIAN	HARJU	PORKUNI	UPPER	BOLINDIAN	UPPER	HIRNANTIAN	UPPER	Not distinguished	HIRNANTIAN (=KOSOVIAN)	H2							
				RAWTHEYAN CAUTLEYAN PUSGILLIAN		RICHMONDIAN MAYSVILLIAN EDENIAN		PIRGU VORMSI NARALA KARVERE OAJDLU KELA				CHIENTANGKIANGIAN		BURIAN NIRUNDIAN DOLBORIAN		Ka4							
		SANDBIAN	CARADOC	STREFFORDIAN CHENEYAN		MOHAWKIAN		CHATFIELDIAN		VIRU		HALJALA	UPPER	EASTONIAN	NEICHIASHANIAN	UPPER	BAKSIAN	BEROUNIAN	U.	Ka3			
				BURRELLIAN				TURINIAN				KUKRUSE							GISBORNIAN	CHERTOVSKIAN	M.	Ka2	
		LANVIER	ARENIG	AURELUCIAN		WHITEROCKIAN		CHAZYAN		OELAND		UHAKU	MIDDLE	DARRIWILIAN		MIDDLE	MIDDLE	KIMAIAN	DOBROTIVIAN	U.	Sa2		
				LLANDEILIAN				Not distinguished				LASNAMAGI ASERI KUNDA								CHERTOVSKIAN	CHERTOVSKIAN	L.	Sa1
	DAPINGIAN	ARENIG	ABEREIDDIAN	WHITEROCKIAN	RANGERIAN		OELAND	VOLKHOV	MIDDLE		YAPEENIAN	MIDDLE		MIDDLE			KIMAIAN	DOBROTIVIAN	U.	Dw3			
			FENNIAN		Not distinguished			CASTLEMANIAN			DARRIWILIAN								KIRENSKO-KUDRINIAN VOLGINIAN	U.	Dw2		
	TREMADOCIAN	ARENIG	WHITLANDIAN		WHITEROCKIAN			BLACK HILLSIAN			OELAND			BILLINGEN	LOWER		CHEWTONIAN BENDIGONIAN	LOWER	LOWER	UGORIAN	ARENIGIAN	U.	Dp3
			MORIDUNIAN					RANGERIAN						HUNNEBERG			DAPIINGIAN					MUKTEIAN VIKHOREVIAN	U.
	TREMADOCIAN	ARENIG	MIGNEINTIAN			WHITEROCKIAN		TULEAN		OELAND			VARANGU	LOWER		FLOIAN	LOWER		LOWER	UGORIAN	ARENIGIAN	M.	Dp1
			CRESSAGIAN					STAIRSIAN SKULLROCKIAN					PAKERORT			TREMADOCIAN						NYAIAN	L.
	TREMADOCIAN	ARENIG	CRESSAGIAN	WHITEROCKIAN			IBEXIAN	OELAND	PAKERORT			LOWER	TREMADOCIAN			LOWER			LOWER	UGORIAN	ARENIGIAN	L.	F2
							IBEXIAN		IBEXIAN				TREMADOCIAN									NYAIAN	U.
	TREMADOCIAN	ARENIG			WHITEROCKIAN		IBEXIAN		OELAND				LOWER					LOWER	LOWER	UGORIAN	ARENIGIAN	U.	Tr3
							IBEXIAN				IBEXIAN				TREMADOCIAN							NYAIAN	L.
TREMADOCIAN	ARENIG		WHITEROCKIAN			IBEXIAN	OELAND				LOWER				LOWER		LOWER		UGORIAN	ARENIGIAN	L.	Tr1	
						IBEXIAN				IBEXIAN				TREMADOCIAN							NYAIAN		

Figure 2

