Geologica Acta, Vol.3, Nº4, 2005, 309-316
Available online at www.geologica-acta.com

geologica acta

Global Series and Stages for the Ordovician System: A Progress Report

S. FINNEY

Department of Geological Sciences, California State University at Long Beach
Long Beach, CA, USA 90840. E-mail: scfinney@csulb.edu

ABSTRACT

There is no global standard set of chronostratigraphic/geochronologic subdivisions for the Ordovician System/Period. British series/epochs are often used as *de facto* nomenclature on stratigraphic correlation charts and geologic time scales. However, they were not widely adopted outside of the British Isles because the high degree of biogeographic provincialism and ecologic differentiation of Ordovician faunas prevent the British series from being correlated with precision and high resolution. As a result, several independent and very different regional sets of series and constituent stages were established for the Ordovician System with each generally applicable to a different paleoplate or modern continent. Of course, this has greatly confused Ordovician chronostratigraphy/geochronology and often results in imprecise correlations of Ordovician stratigraphic successions. An example is the Argentine Precordillera where British series are traditionally used to correlate Ordovician strata that contain faunas of predominately Laurentian affinity. The Subcommission on Ordovician Stratigraphy of the International Commission on Stratigraphy is addressing this problem by developing a standard set of Global Series and Stages for the Ordovician System. The Subcommission has made considerable progress, but it must complete its work expeditiously. The new global standard will facilitate reliable global correlation. It will provide a common language for discussing Ordovician strata, fossils, and geologic events. It will be of fundamental importance in advancing research on Ordovician rocks worldwide.

KEYWORDS **Ordovician. Chronostratigraphy. Precordillera. Argentina**

INTRODUCTION

The Ordovician System has an exceptionally diverse and rich fossil record. Land plants and animals were virtually non-existent during the Ordovician Period, yet a great radiation occurred in the marine realm (Webby, 2004), while several continents were at low and mid paleolatitudes and extensively covered by warm, shallow epeiric seas (Fig. 1). Benthic faunas were dominated by trilobites, brachiopods, corals, bryozoans, sponges, bivalves, gastropods, and ostracods. Common pelagic organisms included the planktic graptolites, chitinozoans, and acritarchs and the nektic conodonts, nautiloid cephalopods, phyllocarid crustaceans, and some trilobites. Given the widespread distribution of fossil-rich strata, biostratigraphy should provide a reliable means for precise, high resolution correlations between Ordovician stratigraphic successions worldwide. It does, but the situation is very complicated.

Ordovician continents ranged in size from microcontinents to the super-continent of Gondwana and were distributed across a wide range of paleolatitude (Fig. 1). As a result, Ordovician faunas show a high degree of biogeographic provincialism in addition to ecologic differentiation. Benthic faunas display considerable endemism, and thus generally are useful only for regional correlations. Planktic graptolites are considered to be cosmopolitan and are the primary index fossil for global correlations (fig. 2.1 in Webby et al., 2004), yet they were differentiated into distinct Atlantic (high latitude) and Pacific (low latitude) paleobiogeographic provinces during the Late Early and Mid Ordovician (Finney and Chen, 1990). In addition, their biostratigraphic usefulness generally is restricted to strata deposited on continental margins (outer shelf, slope, and rise) and in ocean basins (Finney and Berry, 1997). Conodonts are the most useful fossils for correlation of platform deposits, in particular those rich in endemic benthic faunas, but their potential for global correlation is also limited by their differentiation into pelagic and nektobenthic habitats and deep/cold and shallow/warm water biofacies. As a result the succession of Ordovician conodonts is expressed in terms of two very different conodont zonations – the North American Midcontinent Province zonation and the North Atlantic Province zonation (fig. 2.2 in Webby et al., 2004).

Accordingly, there is no single zonation that can be used for global correlation of Ordovician successions. For the same reason, there has been no global standard set of chronostratigraphic/geochronologic units for the Ordovician System/Period. British series are often used, because of historical priority, as *de facto* nomenclature on geologic time scale and stratigraphic correlation charts. However, they were not widely adopted outside of the British Isles because the British series can not be correlated with precision and high resolution. Instead, several independent and very different regional sets of series and constituent stages were established, each generally applicable to a different paleoplate or modern continent (Webby, 1998), e.g. Laurentia, Baltica, Avalonia (Britain), North Gondwana, Australia, China (Fig. 1). Of course, this has greatly complicated Ordovician chronostratigraphy/geochronology, and confused those who do not have expertise with Ordovician chronostratigraphy yet wish to study tectonics, paleogeography, and other geologic aspects of Ordovician rocks. Consequently, the Subcommission on Ordovician Stratigraphy of the International Commission on Stratigraphy was established with the primary goal of establishing a single, standard framework of Series and Stages for use in global correlation to the highest resolution possible. The process began with the formal definition of lower and upper boundaries to the Ordovician System and is being followed with determination of Series and Stages and their boundaries. This paper is a progress report on the work of the Ordovician Subcommission, and

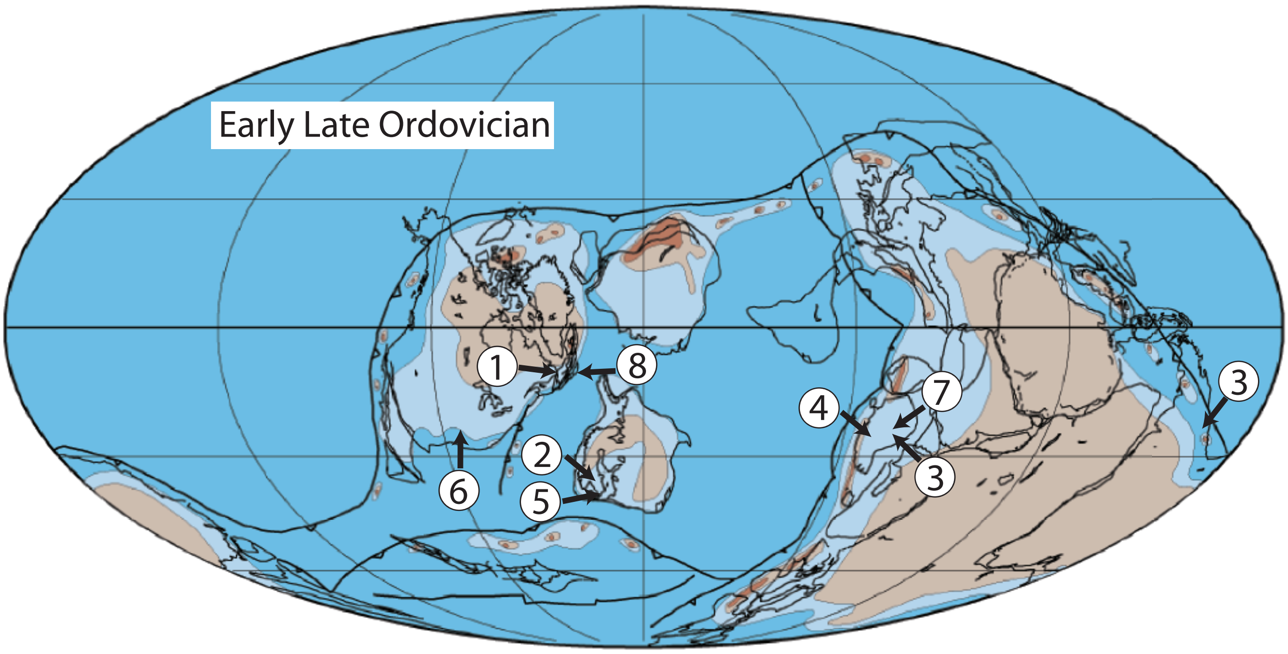

FIGURE 1 **Christopher Scotese's global paleogeographic reconstruction for Early Late Ordovician time showing the distribution of major lithospheric plates, plate boundaries, continents, oceans, shallow epeiric seas, exposed land, and mountains. Numbered arrows indicate locations of stratotype sections for 1) base of Ordovician System, Lower Ordovician Series, and Tremadoc Stage at Green Point, Newfoundland, Fig. 3A; 2) Base of Second Stage at Diabasbrottet, Sweden, Fig. 3B; 3) Possible bases of Middle Ordovician Series and Third Stage at either Huanghuachang, China or Niquivil, Argentina; 4) Base of Darrwilian Stage at Huangnitang, China, Fig. 3C; 5) Base of Upper Ordovician Series and Fifth Stage at Fågelsång, Sweden, Fig. 3D; 6) base of Sixth Stage at Black Knob Ridge, USA; 7) base of Hirnantian Stage at Wangjiawan, China, Fig. 3E; 8) base of Silurian System (top of Ordovician System) at Dob's Linn, Scotland. See Fig. 2 for futher detail on the selected biohorizons.**

it offers the Ordovician stratigraphy of the Precordillera of northwestern Argentina as an example of the need for the Subcommission to complete its work expeditiously.

THE ORDOVICIAN SYSTEM IN BRITAIN

In its type area in Britain, the Ordovician System has traditionally been divided into six series : Tremadoc, Arenig, Llanvirn, Llandeilo, Caradoc, and Ashgill. As originally defined, the British series were based on local stratigraphic successions and their contained benthic faunas, which were highly endemic, except for one series, the Llanvirn, which was based on Atlantic province graptolites. The series were defined on unit stratotypes in geographically separate areas and with their boundaries marked by major unconformities or stratigraphic changes (Williams et al., 1976; Fortey et al., 1995). British workers have actively promoted the Anglo-Welsh series for global chronostratigraphy to the extent of informally redefining them in terms of the graptolite zonation (Fortey et al., 1995, 2000). Doing so has demonstrated significant gaps and overlaps between successive series (Fig. 2), as originally defined (Fortey et al., 1995). As a result, the biostratigraphic extent of the original series has been substantially modified (Fig. 2). The number of series was reduced to five by combining the Llanvirn and lower Llandeilo series into a single Llanvirn Series, and the boundaries of some series, in particular the base of the Caradoc, were significantly changed. With such substantial modification, the historical precedence of the British series must be questioned. Furthermore, the redefinition of the British series has been largely conceptual rather than real. Because graptolites are uncommon in type areas of most British series, the boundaries of these series are not defined on graptolite occurrences in stratigraphic sections. Instead, series boundaries are correlated into graptolite successions elsewhere in the world, which often is not precise, or a graptolite zonal level that correlates into an unconformity at the base of a series is chosen as the boundary even though the succession in the type area does not extend as low as that zonal level.

The base of the Llanvirn is defined on graptolites of the Atlantic province fauna that was restricted to high latitudes; thus it cannot be correlated with precision into

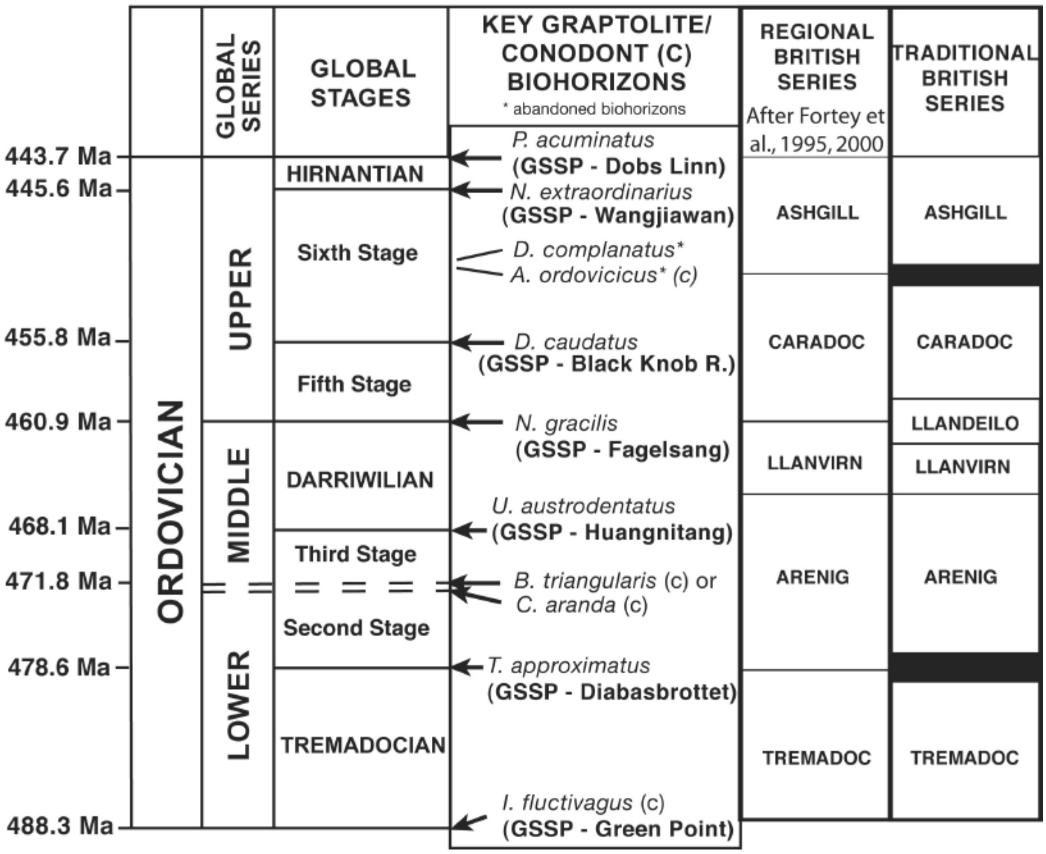

FIGURE 2| **Ordovician chronostratigraphic chart showing global Series and Stages, both those defined and those proposed; GSSPs that have been defined and biohorizons under consideration or abandoned for boundaries still to be defined; and correlation to global Series and Stages of regional British series, as redefined by Fortey et al. (1995, 2000), and traditional British Series. For ease of communication, Stages without names can be referred to informally by their position, for example, Lower Middle Ordovician, Lower Upper Ordovician, and Middle Upper Ordovician. Corresponding Ages are, respectively, Early Mid Ordovician, Early Late Ordovician, and Mid Late Ordovician.**

graptolite successions elsewhere that contain Pacific province faunas (e.g. Australia, North America, Argentine Precordillera). The base of the Arenig Series is defined on the graptolite *Tetragraptus approximatus*, which does not occur in Britain. Instead, the base of the type Arenig in Britain is an unconformity, and the first appearance of *T. approximatus* in Baltica is interpreted to correlate into this unconformity (Fortey et al., 1995). And, on the basis of graptolites from the lower Rawtheyan Stage of the type Ashgill Series, Rickards (2002) recently proposed that a substantial part of the lower Ashgill Series is substantially older (two graptolite zones) than previously considered. In fact, it may correlate with the upper Caradoc Series.

NEW APPROACH TO ORDOVICIAN CHRONOSTRATIGRAPHY

Because no single set of regional Series and Stage divisions was adequate for precise global correlation, the Subcommission on Ordovician Stratigraphy eventually chose a new course of action by resolving to 1) find the best biohorizons for most useful subdivisions and precise global correlation using graptolites and/or conodonts, 2) select global stratotype sections for these biohorizons, and 3) define new global chronostratigraphic units with boundaries defined on these biohorizons.

In 1995 at the 7th International Symposium on the Ordovician System, held in Las Vegas, Nevada, USA, the Ordovician Subcommission decided to adopt a three-fold global Series subdivision with the names Lower, Middle, and Upper Ordovician and with each Series divided into two stages. This scheme required the selection of six GSSPs for defining Series and Stage boundaries, with the lower boundary of each Series serving also as the lower boundary of the lowest Stage in that Series (Figs. 2 and 3). Six biohorizons were identified for evaluation, with one being the biohorizon that would also define the base of the Ordovician System. Although emended British Series names (e.g. "Caradocian") initially were attached to some of the proposed Stages, most Subcommission members are of the opinion that a name should be chosen only after the extent of the Stage has been determined by selection of GSSPs for both lower and upper boundaries. Until that time, the Stages are referred to by informal names (First, Second, Third in ascending order, or Lower Lower Ordovician, Upper Lower Ordovician, Lower Middle Ordovician, respectively; Fig. 2). Corresponding geochronologic units can be referred to simply as Early Early Ordovician, Late Early Ordovician, Early Mid Ordovician, respectively.

In 1996, the Darriwillian Stage was ratified as the upper Stage of the Middle Ordovician Series with the GSSP defined in the Huangnitang section in China at the first appearance datum (FAD) of the graptolite *Undulograptus austrodentatus* (Mitchell et al., 1997; Figs. 1 and 3C). Because the biohorizon proposed for the upper boundary of this Stage, the FAD of the graptolite *Nemagraptus gracilis*, was considered one of the best, most reliable biohorizons in the Ordovician System for global correlation, Subcommission members were of the opinion that the full extent of the Stage was known and, thus, it could be named. The name Darriwillian was taken from the Australian regional stage that spanned the same biostratigraphic interval as the global Stage.

In 2000, a GSSP was ratified for the base of the Ordovician System (the Cambrian/Ordovician boundary) at the Green Point section, Newfoundland, on the FAD of the conodont *Iapetognathus fluctivagus* (Cooper et al., 2001). This GSSP also defines the lower boundary of the Lower Ordovician Series and of its lowest Stage (Figs. 1 and 3A). The name Tremadocian was subsequently approved for this first Stage of the Ordovician System because selection of the GSSP for the lower boundary of the overlying Stage was nearing approval and the biostratigraphic extent of the Stage seemed certain and was equivalent to that accorded to the British Tremadoc series. The top of the Ordovician System had been formalized in 1984 with approval of the GSSP for the base of the Silurian System, which was placed at the FAD of the graptolite *Parakidograptus acuminatus* in the section at Dob's Linn, Scotland (Cocks, 1985; Figs. 1 and 2).

Two additional GSSPs were ratified in 2001 and ceremonially inaugurated in 2003. The FAD of the graptolite *Tetragraptus approximatus* in the Diabasbrottet section, Sweden is the GSSP for the base of the Second Stage (Figs. 1 and 3B) and serves as the upper boundary of the Tremadocian Stage (Bergström et al., 2004). The upper boundary of the Second Stage is the base of the Middle Ordovician Series and the Third Stage, but selection of a GSSP for this boundary has been delayed because of deficiencies discovered in the primary biohorizon and stratotype section under consideration. Because the biostratigraphic extent of the Second Stage is not yet known, a formal name will not be chosen until its upper boundary has been determined. The FAD of the graptolite *Nemagraptus gracilis* in the Fågelsång section, Sweden (Figs. 1 and 3D) is the GSSP for the base of the Upper Ordovician Series and the base of the Fifth Stage (Bergström et al., 2000). And the Fifth Stage will not be formally named until the GSSP for the overlying stage has been approved (Fig. 2).

The 9th International Symposium on the Ordovician System, sponsored by the Ordovician Subcommission, was held in San Juan, Argentina, in August 2003. It provided many, varied opportunities (technical presentations, business meetings, field inspection of stratigraphic suc-

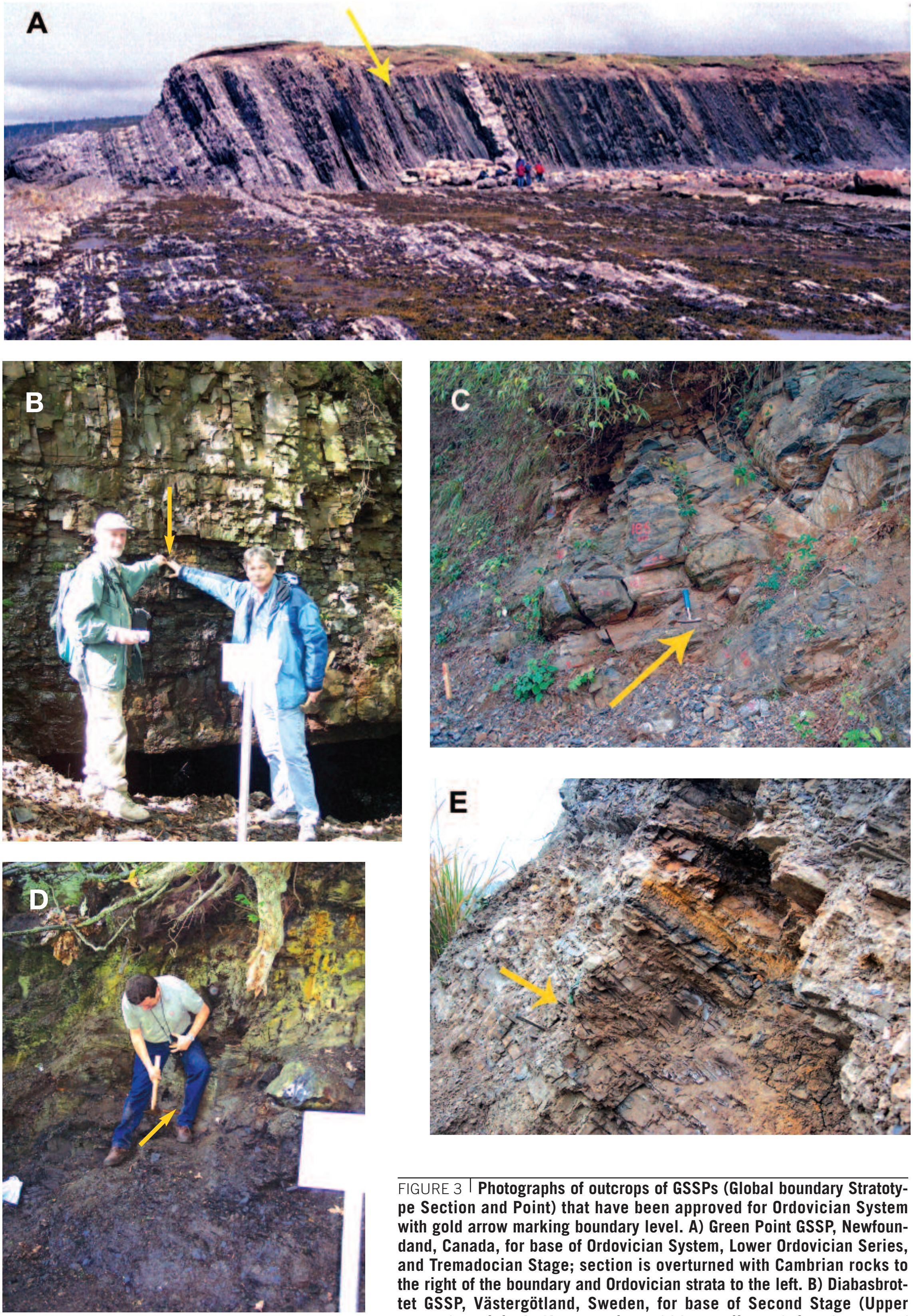

FIGURE 3 | **Photographs of outcrops of GSSPs (Global boundary Stratotype Section and Point) that have been approved for Ordovician System with gold arrow marking boundary level. A) Green Point GSSP, Newfoundand, Canada, for base of Ordovician System, Lower Ordovician Series, and Tremadocian Stage; section is overturned with Cambrian rocks to the right of the boundary and Ordovician strata to the left. B) Diabasbrottet GSSP, Västergötland, Sweden, for base of Second Stage (Upper Lower Ordovician). C) Huangnitang GSSP, Zhejiang, China, for base of Darriwilian Stage. D) Fågelsång GSSP, Scania, Sweden, for base of Upper Ordovician Series and Fifth Stage (Lower Upper Ordovician). E) Wangjiawan North GSSP, Hubei, China, for base of Hirnanatian Stage. All have been approved by Subcommission on Ordovician Stratigraphy and International Commission on Stratigraphy (ICS) and ratified by International Union of Geological Sciences, except for Wangjiawan North, which has been approved by Ordovician Subcommission and is presently under consideration by ICS.**

cessions, informal discussions) to make important progress. Most significantly, the Subcommission voted to abandon its goal of subdividing the Upper Ordovician Series into two stages. Since 1995, the Subcommission had been evaluating potential stratotype sections for two different biohorizons on which to define the base of the upper stage of the Upper Ordovician Series and thus to subdivide the series into two stage. These were the base of the *Dicellograptus complanatus* graptolite zone and the base of the *Amorphognathus ordovicicus* conodont zone (Fig. 2). However, after evaluation of many sections worldwide, the Subcommission could not find any known section to be an adequate stratotype for either boundary level. At the 9th ISOS, Subcommission members decided upon a new approach, a three-fold subdivision of the Upper Ordovician Series. Recent research by Goldman (2003) indicated that the FAD of the graptolite *Diplacanthograptus caudatus* was a reliable biohorizon for precise, global correlation, and two sections (Black Knob Ridge in Oklahoma, USA, and Hartfell Score in Scotland, UK) offered great potential as stratotype sections. GSSP proposals were submitted for these sections and subject to internet-hosted discussion. In subsequent voting in April and May 2005, the Oklahoma section (Fig. 1) was approved, receiving an overwhelming majority of votes. Because this boundary level results in two stages of very unequal duration (Fig. 2), the suggestion that the Upper Ordovician Series be subdivided into three stages was overwhelming approved. The immediate acceptance of a third or uppermost stage was due to the fact that it would correspond to the informal, but widely used, Hirnantian Stage with its lower boundary defined at a level corresponding to the base of the *Normalograptus extraordinarius* graptolite zone. The Wangjiawan North GSSP near Yichang, China (Figs. 1 and 3E), defining the base of the Hirnantian Stage, was approved unanimously by the Subcommission in August 2004. It is expected that both the Black Knob Ridge and Wangjiawan GSSP proposals will be approved by the International Commission on Stratigraphy and ratified by IUGS in 2005.

The new global chronostratigraphic classification for the Ordovician System is rapidly approaching completion. The last boundary to be defined, the base of the Middle Ordovician Series and its lower stage, will be the sole focus of the Ordovician Subcommission from mid 2005 until it is approved and sent forward for approval by ICS and ratification by IUGS. Two different biohorizons and stratotype sections are presently under study for the base of the Middle Ordovician Series and the Third Stage: the FAD of the conodont *Baltoniodus*? *triangularis* in the section at Huanghuachang in China, and the FAD of the conodont *Cooperignathus aranda* in the section at Niquivil in Argentina (Figs. 1 and 2). With selection of this final GSSP, the Ordovician System will consist of three global Series and seven global Stages, that in turn will be used to define corresponding Period, Epochs, and Ages. The seven stages will each be defined by a GSSP that determines its lower boundary and also serves as the upper boundary of the underlying stage. Each stage boundary will be defined such that in the stratotype section it will coincide with the level of first appearance of a key graptolite or conodont species that has shown to provide the greatest potential possible for precise global correlation. Each boundary will also be characterized by secondary markers that will aid greatly in correlation of the boundary into stratigraphic sections worldwide and into the widest range of facies and geographic areas possible. These secondary markers include biostratigraphy of additional species and other fossil groups, chemostratigraphy, and sequence stratigraphy in the boundary interval. With lower boundaries defined by GSSPs, successive stages will not overlap and will not be separated by gaps. The stages themselves will each include distinctive stratigraphic and faunal successions that can be correlated worldwide and record significant events that occurred during various intervals of the Ordovician Period. The faunal successions, in particular those of graptolites and conodonts, are already well established (Webby et al., 2004); they were used extensively to determine the extent of stages and the stratigraphic levels of their boundaries.

ORDOVICIAN CHRONOSTRATIGRAPHY FOR THE PRECORDILLERA OF ARGENTINA

The Ordovician geology of Argentina has received considerable attention in recent years because of the most interesting hypothesis that the Cuyania terrane, represented primarily by the stratigraphic successions in the Argentine Precordillera, rifted from Laurentia in the late Early Cambrian, drifted across the Iapetus Ocean as a microcontinent, and accreted to the proto-Andean margin of Gondwana during the Mid to Late Ordovician (Finney et al., in this issue). Discussions of the Ordovician history of this paleogeographic and geotectonic event have employed the British series/epochs almost exclusively, as have virtually all stratigraphic and paleontologic publications on Ordovician strata and fossils in Argentina (e.g., Astini et al., 1995; Keller, 1999; Albanesi and Ortega, 2002). No doubt, this reflects the history of geologist studying the geology of South American. Europeans were the first. Naturally, they employed European and, thus, British Ordovician stratigraphic nomenclature. The British series are used without serious problems in Ordovician successions deposited in basins that were located along the margin of Gondwana, i.e., in the Famatina volcanic belt and in the Central Andean basin. The biogeographic affinity of faunas in those basins - graptolites, trilobites, and brachiopods - are closest to faunas of peri-Gondwana (southern Europe, Avalonia) and Baltica, where British series are widely used. In the

Argentine Precordillera, however, Ordovician faunas have strong biogeographic affinity to Laurentian faunas or to those from widespread low-latitude (tropical) faunal provinces. Laurentian taxa dominate benthic shelly faunas in Lower Ordovician strata and remain common in Middle Ordovician strata, but Avalonian taxa, on which most British series were originally defined, are absent. In fact, the set of British stages, recently redefined in order to subdivide better the British Series (Fortey et al., 1995, 2000), cannot be recognized at all in the Precordillera because they are based on benthic shelly faunas endemic to Avalonia. Graptolites are key index fossils that occur in Middle and lower Upper Ordovician strata in the Precordillera, and they represent the Pacific province, in contrast to the Atlantic province graptolites found in British successions. Conodont faunas in the Ordovician strata of the Precordillera include a mixture of species from both the North American Midcontinent province and the North Atlantic province. However, zones for the conodont succession of the North Atlantic province were developed in Baltica, not in Avalonia, and their correlation to the British series is not exact at all levels. Given the strong Laurentian faunal affinities of Ordovician faunas in the Precordillera, North American (Laurentian) series and stages can be used in the Precordillera with considerable precision and accuracy, whereas British Series can only be used by first approximating their correlation into the graptolite zonation of the Pacific Province and into the conodont zonations for the North American Midcontinent and the North Atlantic provinces. In addition, except for the Hirnantian, British stages are useless for correlation in the Precordillera. Further complicating the problem are that attempts to redefine British Series, in terms, of the graptolite zonation has been unsuccessful in some instances (e.g., Caradoc and Ashgill series may overlap substantially), and concepts of some British series (e.g. Caradoc and Llanvirn) have been substantially revised recently, and one series, the Llandeilo, has been eliminated. Clearly, this is confusing to geologists who study the paleogeographic and geotectonic history of Argentina, who are not specialists in stratigraphic nomenclature, and who generally use the traditional six-fold set of British series.

CONCLUSIONS

The first global stage to be defined, the Darriwilian Stage, is already widely used by Ordovician specialists worldwide. Yet, for the rest of the Ordovician System, a great variety of nomenclatures is used. Some stratigraphers retain the British Arenig series, but also include the Darrwilian as the succeeding chronostratigraphic unit, even though there is appreciable overlap between the two. Some use the five new, redefined British series, but others retain the traditional six series. Those working with graptolite successions tend to use the Australian regional stages, and those working in North America use the Laurentian series and stages. Given this complexity, it is imperative that the new global classification of the Ordovician System be completed expeditiously. Once it is established, when the last GSSP is approved and all stages are given formal names, it will be widely accepted and extensively used. It will provide clearly defined chronostratigraphic and associated geochronologic units of global extent with precisely defined boundaries. It will facilitate reliable global correlation, and it will provide a common language for discussing Ordovician strata, fossils, and geologic events. It will be adopted for studies of Ordovician rocks not only in Argentina, but also in Laurentia, Baltica, China, and, in fact, worldwide. It will be of fundamental importance in advancing research on Ordovician rocks worldwide.

REFERENCES

Albanesi, G.L., Ortega, G., 2002. Advances on Conodont-Graptolite Biostratigraphy of the Ordovician System of Argentina. In: Aceñolaza, F.G. (ed.). Aspects of the Ordovician System in Argentina. INSUGEO, Serie Correlación Geológica, 16, 143-166.

Astini, R.A., Benedetto, J.L., Vaccari, N.E., 1995. The early Paleozoic evolution of the Argentine Precordillera as a Laurentian rifted, drifted, and collided terrane: Ageodynamic model. Geological Society of America Bulletin, 107, 253-273.

Bergström, S.M., Finney, S.C., Chen Xu, Pålsson, C., Wang Zhi-hao, Grahn, Y., 2000. A proposed global boundary stratotype for the base of the Upper Series of the Ordovician System: The Fågelsång section, Scania, southern Sweden. Episodes, 23, 102-109.

Bergström, S.M., Maletz, J., Löfgren, A., 2004. The GSSP of the Second (Upper) Stage of the Lower Ordovician Series: Diabasbrottet at Hunneberg, Province of Västergötland, Southwestern Sweden. Episodes, 27(4), 265-272.

Cocks, L.R.M., 1985. The Ordovician-Silurian Boundary. Episodes, 8, 98-100.

Cooper, R.A., Nowlan, G.S., Williams, S.H., 2001. Global Stratotype Section and Point for base of the Ordovician System. Episodes, 24, 19-28.

Finney, S.C., Berry, W.B.N., 1997. New perspectives on graptolite distributions and their use as indicators of platform margin dynamics. Geology, 25(10), 919-922.

Finney, S.C., Chen, X., 1990. The relationship of Ordovician graptolite provincialism to palaeogeography. In: McKerrow, W.S., Scotese, C.R. (eds.). Palaeozoic Palaeogeography and Biogeography. Geological Society Memoir No. 12, 122-128.

Finney, S., Peralta, S., Gehrels, G., Marsaglia, K. 2005. The Early Paleozoic history of the Cuyania (greater Precordillera) terrane of western Argentina: evidence from geochronology of detrital zircons from Middle Cambrian sandstones. Geologica Acta, 3, 339-354.

Fortey, R.A., Harper, D.A.T., Ingham, J.K., Owen, A.W., Rushton, A.W.A., 1995. A revision of Ordovician series and stages from the historical ype area. Geological Magazine, 132, 15-30.

Fortey, R.A., Harper, D.A.T., Ingham, J.K., Owen, A.W., Parkes, M.A., Rushton, A.W.A., Woodcock, N.H., 2000. A Revised Correlation of Ordovician Rocks in the British Isles. The Geological Society Special Report No. 24, 83 pp.

Goldman, D., 2003. The *Diplacanthograptus caudatus* Zone: a proposal for a new, globally recognizable, Upper Ordovician graptolite zone. In: Albenesi, G.L., Beresi, M.S., Peralta, S.H. (eds.). Ordovician From The Andes, INSUGEO, Serie Correlación Geológica, 17, 65-70.

Keller, M., 1999. Argentine Precordillera: Sedimentary and Plate Tectonic History of a Laurentian Crustal Fragment in South America. Geological Society of America Special Paper 341, 1-131.

Mitchell, C.E., Chen X., Bergström, S.M., Zhang Y., Wang Z., Webby, B.D., Finney, S.C., 1997. Definition of a global boundary stratotype for the Darriwilian Stage of the Ordovician System. Episodes, 20, 158-166.

Rickards, R.B., 2002. The graptolitic age of the type Ashgill Series (Ordovician), Cumbria, UK. Proceedings of the Yorkshire Geological Society, 54(1), 1-16.

Webby, B.D., 1998. Steps toward a global standard for Ordovician stratigraphy. Newsletters in Stratigraphy, 36, 1-33.

Webby, B.D., 2004. Introduction. In: Webby, B.D., Paris, F., Droser, M.L., Percival, I.G. (eds.). The Great Ordovician Biodiversification Event. New York, Columbia University Press, 1-37.

Webby, B.D., Cooper, R.A., Bergström, S.M., Paris, F., 2004. Stratigraphic Framework and Time Slices. In: Webby, B.D., Paris, F., Droser, M.L., Percival, I.G. (eds.). The Great Ordovician Biodiversification Event. New York, Columbia University Press. 41-47.

Williams, A., Strachan, I., Bassett, D.A., Dean, W.T., Ingham, J.K., Wright, A.D., Whittington, H.B., 1976. A Correlation of the Ordovician rocks in the British Isles. Geological Society of London Special Report No. 3, 74 pp.

**Manuscript received March 2005;
revision accepted June 2005.**