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Report of the restudy of the defined global stratotype of the base of the Silurian System

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The Global Stratotype Section and Point (GSSP) for the base of the Silurian System was defined in 1985. Since that time, a number of researchers have suggested that this section has serious deficiencies for use as a GSSP. As a result, in 2000, the Subcommittee on Silurian Stratigraphy (SSS) proposed undertaking a formal restudy of this GSSP, which was subsequently approved by the International Commission of Stratigraphy (ICS). The result of this restudy was the formal proposal that the current GSSP, at 1.6 m above the base of the Birkhill Shale, at Dob's Linn, Scotland, should be maintained as the same locality and stratigraphic level, but the biostratigraphical definition of the boundary should be revised. The previously defined, basal Silurian graptolite zone, the Parakidograptus acuminatus Zone, should be subdivided into a lower Akidograptus ascensus Zone and a higher P. acuminatus Zone. The base of the A. ascensus Zone, marked by the first appearance of A. ascensus, should be regarded as the biostratigraphic mark for the base of the Silurian. This proposal has now been formally approved by the SSS and ICS, and ratified by International Union of Geological Sciences. This is the first GSSP to undergo formal restudy and redefinition, and the proposal also included a recommended procedure for restudy of GSSPs.

Introduction

A GSSP should be defined at a point in a section that affords the potential for confident, precise, and high-resolution correlation into as many facies worldwide as possible. The GSSPs of the Silurian System were defined in the 1980s (Cocks, 1985; Holland, 1985). Unfortunately, there are serious problems for some of these, mainly because many of the stratotypes have biostratigraphic deficiencies and even lack the key index fossils continuously below and above the boundary. We agree that in order to maintain stability, the whole framework of the Silurian System (Llandovery Series, Wenlock Series, Ludlow Series and their subdivisions, and the Pridoli Series) would best remain as defined for the past two decades (Holland et al., 2003). However, it is our view that maintenance of a poorly defined GSSP does not lead to stability (Melchin, Rong, et al., 2004).

Discussion on a restudy of the base of the Silurian

In the business meeting of the Subcommittee on Silurian Stratigraphy (SSS) held in Orange, Australia on 13 July, 2000, a number of participants suggested that the most important business should be to begin a re-examination of some of the stratotypes of the Silurian System and its subdivisions. Having conscientiously discussed the issues there was a general agreement that two that were specifically named as in need of restudy are the base of the Silurian System and the base of the Wenlock Series. Both the section and the zonation on which the GSSPs are based need to be reconsidered in the process.

Agreement of the restudy within the SSS

Since there were six titular members of the Silurian Subcommittee at the Australia meeting the preliminary suggestion mentioned above went to all titular members for their vote. As a result, this proposal to restudy these GSSPs received no objections from the voting membership of the SSS. Therefore, the SSS decided to restudy these two GSSPs.

Establishment of a joint working group for the restudy

When the subcommittee decided to restudy the base of the Silurian it agreed that a working group for the restudy must be established and scientists from both the Ordovician and Silurian subcommittees should be involved in the group. Dr. Mike Melchin was asked by the Chair of the SSS to organize a joint working group of the SSS and SOS to study this proposal. The working group led by Dr. Mike Melchin, was established in 2002 and include 24 members from Argentina, Australia, Belgium, Canada, China, Denmark, France, Puerto Rico, Russia, UK, and USA ("Silurian Times" No.10). The list of the group membership was sent to the titular membership of the SSS for approval and there are no objections afterwards.

The move to form a working group to restudy of the boundary stratotype for the base of the Silurian System was presented to the executive of the ICS at its meeting in Urbino, Italy in the summer, 2002. The ICS gave its approval for the working group to proceed.

A report outlining the results of this work

The Rhuddanian Stage, the lowest stage of the Silurian System, is named for the Cefn-Rhuddan Farm in the Llandovery area. How-

ever, its lower boundary stratotype section and point are located at Dob's Linn in the southern uplands of Scotland. It was defined at a point 1.6 m above the base of the Birkhill Shale in the Linn Branch Trench section (Williams, 1983, 1988). This point was regarded as coincident with the local base of the *Parakidograptus acuminatus* Zone (Cocks, 1985), marked by the first appearances of *P. acuminatus* s.l. and *Akidograptus ascensus* (Williams, 1983). However, in several other regions where both taxa occur, *A. ascensus* first appears below *P. acuminatus*, and some authors have marked the base of the Silurian as occurring at the first appearance of the former whereas others have used the latter to define the base of the Silurian. Therefore, this has not been a "stable" situation, with different workers using different and conflicting criteria to define the boundary in their respective regions.

Resampling and systematic revisions have shown that *A. ascensus* first appears at the level of the GSSP at Dob's Linn, and that *P. acuminatus* s.s. first occurs 1.5 m higher in the section (Melchin and Williams, 2000) (Figures 1, 2). Therefore, they proposed that the graptolite zonation at Dob's Linn be revised to include a lower *A. ascensus* Zone and a higher *P. acuminatus* Zone. The base of the *A. ascensus* Zone, marked by the first occurrences of *A. ascensus* and *Parakidograptus praematurus* [the latter was identified by Williams (1983) as *P. acuminatus* sensu lato], should be regarded as the biostratigraphic horizon that marks the base of the Silurian System.

Akidograptus ascensus is a species known from several different paleocontinents and paleolatitudes (Figure 3, see Appendix 1). It has been reported from Kazakhstan (Koren' et al., 1980), northeastern Siberia (Koren' et al., 1983), several regions within peri-Gondwanan Europe (Storch, 1996) and Sweden (Koren' et al., 2003). It has been widely recorded in many places of the South China Plate, such as Guizhou (Chen and Lin, 1978; Chen et al., 2000; Rong et al., 2002), Hubei (Mu et al., 1984; Chen et al., 1999, 2000), Jiangxi (Fang et al., 1990), Anhui (Li and Ge, 1981; Yang et al., 1983; Li, 1999), Jiangsu (Zhang and Jiao, 1985; Chen et al., 1988), Zhejiang (Yang 1964; Yang et al., 1983), Shaanxi (Yu et al., 1988; Fu and Song, 1986) and Yunnan (Ni, 1983), and in Xainza, northern Xizang (Mu and Ni, 1983). Therefore, this species has a very high value for global biostratigraphic correlation. In addition, the occurrence of additional taxa at and just above the GSSP level, particularly *Normalograptus lubricus*, permit correlation with some regions that lack akidograptids, such as Arctic Canada (Melchin et al., 1991) and Uzbekistan (Koren' and Melchin, 2000), where *A. ascensus* is delayed in its first appearance or absent as a result of biofacies controls. This restudy has also shown that the graptolite faunas are significantly more diverse in both the *N. persculptus* and *A. ascensus* zones than previously suspected.

Sampling for palynomorphs has shown that biostratigraphically useful chitinozoans occur in the GSSP interval, which can be used for correlation between graptolitic shale and carbonate shelf biofacies (Vernier et al., 2005; Verniers and Vandenbroucke, 2006).

As a result of three years of work, the working group has agreed that the current GSSP, at 1.6 m above the base of the Birkhill Shale, at Dob's Linn, Scotland, should be maintained as the GSSP, but the biostratigraphical definition of the boundary needs to be revised. The GSSP should be regarded as coinciding with the first appearance of *A. ascensus*, defining the base of the *A. ascensus* Biozone at that GSSP section.

It is important to note that this proposal is only for a change in the biostratigraphic definition of the GSSP. The location and strati-

Figure 1 1, 2. *Parakidograptus praematurus* (Davies, 1929) (= *P. acuminatus* s.l., Williams, 1983): 1. Holotype, SM A10023; 2. specimen from the GSSP level, GLAHM C13911. 3, 4. *Akidograptus ascensus* (Davies, 1929). 3. holotype, SM A10021; 4. specimen from the GSSP level, GLAHM C13913. 5, 6. *Parakidograptus acuminatus* (Nicholson, 1867). 5. holotype, BMNH Q1310; 6. specimen from 1.5 m above the GSSP level, the base of the *Parakidograptus acuminatus* Zone, GLAHM 134349. Scale bars are 1 mm. SM—Sedgwick Museum; GLAHM—Hunterian Museum, Glasgow; BMNH—British Museum of Natural History.

graphic level will not change, nor will its age with respect to the radiometric time scale (Melchin et al., 2004).

Vote in favor of the new proposal within the subcommission

The report outlining the results of the restudy work was submitted to the titular membership of the SSS for a vote to accept this proposal. The votes from the titular members were organized in late 2005. By the middle of March 2006 all titular members voted in favor of Mike

Figure 2 Diagram showing stratigraphic ranges of main graptolite taxa through the Ordovician-Silurian Boundary at Dob's Linn, Moffat District, Scotland provided by Williams (1983, 1988) at left side and the result of the restudy done by Melchin and Williams (2000) at right side.

Figure 3 Showing geographical distribution of *Akidograptus ascensus* on the world reconstruction map (after Rong and Harper 1988).

Melchin's proposal for the revision of the biostratigraphic definition of the base of the Silurian at Dob's Linn. No one was opposed, no one abstained. Thus, it is widely agreed among the titular membership of the SSS. This restudy will move forward our better understanding of the stratigraphy of the boundary interval and improve the resolution with which it can be correlated globally.

Report to ICS and IUGS for ratification

Having been approved by the SSS membership, this report with the results of the votes and final conclusion has been approved by the ICS and then ratified by IUGS.

Suggestions for a procedure proposed for the restudy of a GSSP

This is the first effort ever to formally restudy a defined GSSP, and, as a result, there are no formal procedures in place. The following preliminary procedure for further discussion may be applicable.

First, there should be a general agreement that a particular defined stratotype is in a real need of restudy. A working group to restudy the boundary should be created, and given the task of undertaking this research and preparing a report to the relevant subcommission(s).

Second, a report outlining the results of the restudy work should be submitted to the restudy working group and then to the titular membership of the SSS for a vote to accept this proposal. The voting should take place first within the boundary restudy working group, and then within the voting membership of the ICS subcommission for the particular system.

Third, the results of these votes should then be forwarded to the ICS for consideration and approval (see *Silurian Times* No.11, p. 11; Mike Melchin with contributions from Jiayu Rong, David Loydell, Felix Gradstein and Stan Finney).

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Appendix 1: Geographical distribution of *Akidograptus ascensus*:

1. Dob's Linn, Scotland (Williams, 1983; Melchin and Williams, 2000)
2. Anhui, E China (Li and Ge, 1981; Yang et al., 1983; Li, 1999)
3. Bohemia (Storch, 1996)
4. Bulgaria (Storch, 1996)
5. England (Hutt, 1974; Harper and Williams, 2002)
6. Gornyi Altai (Yolkin et al., 1988)
7. Guizhou, SW China (Chen and Lin, 1978; Mu, 1988; Chen et al., 2000; Rong et al., 2002)
8. Hubei, Central China (Mu et al., 1984; Mu, 1988; Chen et al., 1999, 2000)
9. Jiangsu, E China (Zhang and Jiao, 1985; Chen et al., 1988)
10. Jiangxi, E China (Fang et al., 1990)
11. Kazakhstan (Koren et al., 1979; in Apollonov et al., 1980; Koren' and Rickards, 1996)
12. Kolyma (Koren et al., 1983)
13. Poland (Teller, 1969)
14. Portugal (Gutierrez-Marco et al., 1998)
15. Sardinia, Italy (Storch, 1996)
16. Scania, Sweden (Koren et al., 2003)
17. Shaanxi, W China (Yu et al., 1988; Fu and Song, 1986)
18. Spain (Gutierrez-Marco et al., 1998)
19. Thuringia, Germany (Jaeger, 1988)
20. Uzbekistan (Koren' and Melchin, 2000)
21. Wales (Zalasiewicz and Tunncliff, 1994)
22. Xainza, Xizang (Mu and Ni, 1983; Mu, 1988)
23. Yunnan SW China (Ni, 1983)
24. Zhejiang, E China (Yang, 1964; Yang et al., 1983)

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