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The role of the Secondary Standard in stratigraphy

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Abstract

The development of a series of internationally acceptable chronostratigraphical units initially grew up through agreed use. Today's requirement of endorsement by the International Commission on Stratigraphy has resulted in the official rejection of names which are perfectly valid and still essential in the parts of the world for which they were introduced. Recognition of this fact is urged, by the acceptance of the Secondary Standards as locally defined chronostratigraphical units pending possible future correlation with the primary standard.

The geological time-scale has been developed piecemeal over almost two centuries. Initial work was concerned with the naming of formations – in English geological literature usually referred to as 'strata'; these were often adaptations of quarrymen's terms, such as we find in William Smith's contribution to Townsend's (1813) table of strata which listed formations between the Coal Measures and the Chalk. This was developed from earlier manuscript versions – the first of which, dealing with the formations around Bath, dates from 1797. 'Strata' were then grouped together as a result of syntheses of earlier work into 'formations' or into 'series'. Thus Smith's Jurassic stratal terms were grouped into an Oolite Formation (Buckland, 1818) or an Oolite Series (Conybeare & Phillips, 1822). These terms were compared with the Jura Limestone of Humboldt (1795) and following Brogniart's introduction of the term 'Jurassic' (1829) the Oolite Series of Conybeare & Phillips was soon widely referred to as Jurassic in Britain. The underlying Lias strata were still referred to separately and it was not until Wright (1872) compared the British succession with that of the Côte d'Or that the term Jurassic was used to embrace the Lias strata in addition to the Oolite strata (Torrens *in* Cope, 1980).

During the 1820s and 1830s there was similarly developed a succession of names which were a grouping together of what we now consider formations. Examples during this interval include the Carboniferous (Conybeare & Phillips, 1822), Cretaceous (d'Halloy, 1822), Silurian (Murchison, 1835), Cambrian (Sedgwick *in* Sedgwick & Murchison, 1835) and Devonian (Sedgwick & Murchison, 1839), each of which were introduced as 'natural' groupings of strata, each characterized by its own fossils. This principle was carried forward by d'Orbigny (1842–51) who perceived that local stratal names were proliferating, resulting in much confusion, but that the faunas could provide correlation between them. He thus proposed a series of divisions, stages, which could be identified by their fauna. These were divisions based on the extinction of some species and their replacement by others. They were seen by d'Orbigny as divisions which 'nature has delineated with bold strokes across the whole earth' (Arkell, 1933).

This concept of 'natural' divisions was one of the criteria which helped define the boundaries of many of the emerging geological systems. In particular, major lithological changes or unconformities often provided the ideal criterion for drawing a boundary at a particular place. Thus the base of the Cambrian is well defined, at most places in Britain, by a basal unconformity. Paradoxically, in the type area of North Wales, the basal boundary may be conformable on the underlying Precambrian (Cowie, Rushton & Stubblefield, 1972). The base of the Carboniferous was drawn where marine limestones succeeded Old Red Sandstone fluviatile sediments; the lithological base of the Old Red Sandstone was equated with the base of the Devonian. Only when problems began to emerge was there debate about procedure. As early as the Second International Geological Congress in Bologna (1880) there were moves towards a standardization in stratigraphy (Dewalque, 1882), but it was not until the second half of the present century that such ideas were developed into guides to stratigraphical practice.

One of the first truths to emerge was that as time is continuous, there is a theoretical possibility that the geological record is also continuous. Thus in an unbroken section across a chronostratigraphical boundary, the identification of that boundary may prove difficult, but at least there is the knowledge that the boundary is identified by sound criteria and not because of a local break in the succession which could cut out important events. As Ager (1984) said, 'the best level at which to place a boundary is, paradoxically, the level at which it is least obvious'. One other principle to emerge during the 1960s was that all chronostratigraphical units should be defined by means of their bases only, the tops being defined automatically by the base of the succeeding unit (this precludes the difficulties resulting from the discovery of strata or faunas which fall into a 'gap'). There was also the distinction made, consciously for the first time, into lithostratigraphy, biostratigraphy and chronostratigraphy. Here, what happened was on occasion at variance with some previous practices.

One of the first codes to have wide application was the *International Stratigraphic Guide* (Hedberg, 1976) which, being largely American in origin and concept, used the accepted American hierarchy of lithostratigraphical nomenclature. Thus the basic unit, the formation, could be divisible into members and beds. Formations were combined into groups, and groups into supergroups. This found wide and ready acceptance in most parts of the world. However, in other ways the *International Stratigraphic Guide* caused major problems. In particular, the stage, seen by d'Orbigny as being characterized by different faunas, was defined as a chronostratigraphical unit. As Hancock (1977, p.19) said 'if Hedberg were not the gentleman I know him to be, I should be tempted to accuse him of a form of scientific theft'. This hi-jacking of a biostratigraphical term as a chronostratigraphical term has not, however, had major long-term consequences, as many stratigraphers realise that although there is an important distinction to be made, between

biostratigraphy and chronostratigraphy, *in practice* there is little difference between chronostratigraphy and carefully chosen biostratigraphy (Torrens *in* Cope, 1980).

The chronostratigraphical hierarchy of erathem, system, series and stage is now universally accepted. What is also accepted is that these members of the hierarchy have to be unambiguously defined. This is now achieved by international agreement on a reference section, which becomes the standard. The ultimate goal is to define a Global Stratotype Section and Point (GSSP) for the base of each unit. The base of each unit is defined in terms of the unit of next lowest rank, so that the base of the Devonian System is defined by the base of the Lochkovian Stage, which in turn is defined at a point ('the golden spike') at the base of the *Monograptus uniformis* Biozone at Klonk in the Czech Republic (McLaren, 1977).

The procedure for the establishment of a basal boundary GSSP for each stage, series or system depends upon publication of detailed litho- and biostratigraphy of the section, together with accurate maps and locality information and an assessment of the site's permanent accessibility. Working groups of interested specialists are set up by the appropriate Subcommission of the International Commission on Stratigraphy (ICS) which is answerable to the International Union of Geological Sciences (IUGS). There is a subcommission appointed for each Phanerozoic system. The working groups ideally visit each of the possible candidate GSSPs and then make recommendations to their respective subcommission. This subcommission in turn reports to the ICS and the decision goes to the next International Geological Congress for ratification. By this means, GSSPs have now been confirmed for the bases of the Silurian, Devonian, Carboniferous, Paleocene and Pleistocene. Series and stages have also been defined, but it is only in the Silurian and Devonian that system, series and stage boundaries have all been defined. Why is this? It is not that the Silurian and Devonian workers have 'got their act together' more efficiently than other subcommissions (but it must be admitted that some subcommissions have been very lax in this direction). The basic reason that agreement has been relatively easy to obtain for the Silurian and Devonian systems is the essentially cosmopolitan nature of their faunas and absence of provincialism which is the bugbear of international correlations for so many other geological periods.

There is now international agreement on what constitute the principal divisions of the Phanerozoic eras, the systems. The last obstacle to this was the United States' recognition of two separate systems, the Mississippian and Pennsylvanian, for what was elsewhere regarded as Carboniferous; now it has been internationally agreed that there shall be a single system, the Carboniferous. However, system boundaries, dependent on the fixing of basal boundary stratotypes, have yet to be agreed for many systems. But at least working groups are active on these boundary problems.

Because chronostratigraphical subdivisions, such as stages, are, as explained above, based on faunal changes, different series and stages have been introduced for separate areas. Under existing ICS procedures, only a single series or stage is permitted for each time interval. This, however, raises problems, because in many areas stage or series names have been duplicated for the simple reason that faunas are so different that correlation between one faunal realm and another is totally impossible at present. This of course does not defend the duplication of stage names as local expedients. For example, in the Jurassic, eleven stages are now internationally recognized. Arkell (1933, 1956) listed 126 stage names applied to the Jurassic; no doubt more have been introduced since 1956. The latest to gain acceptance as an international standard was the Tithonian, ratified by the Jurassic Subcommission in 1991.

The Tithonian illustrates the other problem, that of a standard stage being inapplicable to some areas because of a lack of characteristic faunas in those areas. The Tithonian is one of three stage names used for the terminal Jurassic stage (the Purbeckian of d'Orbigny is no longer used as it is merely a facies term). In addition to Tithonian, the other stage names in use are Portlandian and Volgian. The Portlandian, being a d'Orbigny stage, was advanced as the international standard by Arkell (1946); he disavowed the use of Tithonian as it was not named after a place (as is normal for stage names) but after a demi-god, although he subsequently admitted (1956, p.8) that it had been used for so long that it could never be abandoned.

The Portlandian, however, has been subject to two interpretations since its ambiguous definition by d'Orbigny (1842-51). In his founding of the stage, he stated that he named it after the Isle of Portland in Dorset, and that it was equivalent to the Portland Sand and Portland Stone of Fitton (1836). However, in his list of fossils characteristic of the stage, he named *Ammonites irius, A. gigas* and *A. gravesiana* as typical species. None of these species occurs in the Portland Sand or Stone; instead they occur some hundreds of metres lower in the Dorset succession in the middle part of the Kimmeridge Clay. Thus French palaeontologists, using ammonite faunas, drew their basal Portlandian boundary much lower than the British geologists did on the basis of lithostratigraphy. The problem was not immediately recognized, but J.F.Blake (1880, 1881) was the first to identify the problem and to predict the level of these ammonites in the Dorset sections. He proposed the stage name "Bolonian" to embrace what was the upper part of the Kimmeridgian *sensu anglico* and the lower part of the Portlandian *sensu gallico*. Salfeld (1913) was the first to find the ammonites (now included in the genus *Gravesia*) in the Dorset succession, thus confirming Blake's ideas. Cope (1993, 1995) has recently advocated the re-introduction of the Bolonian Stage to avoid further confusion over the interpretations of Kimmeridgian and Portlandian.

The Volgian Stage was introduced by Nikitin (1881) for the uppermost Jurassic beds of the Volga Basin. The stage was originally equivalent to the uppermost part of the Kimmeridgian and Portlandian *sensu anglico*. However, the basal boundary was moved downwards by Gerassimov & Michailov (1966) to a point approximately coincident with the top of the Kimmeridgian *sensu gallico*, and thus closely coincident in its basal age to the Tithonian. This was widely interpreted as a move which was prompted by a wish to put forward the Volgian as the international Standard Stage for the terminal Jurassic. It was soon shown, however, that at its type section at Gorodische on the Volga, it was very incomplete and highly condensed, being only about one twentieth of the thickness of the corresponding beds in Dorset (Wimbledon, 1985). This major deficiency soon led to the abandonment of the Volgian as a candidate Standard Stage for the terminal Jurassic.

The acceptance of the Tithonian as the international standard for the terminal Jurassic was primarily because faunas of that age can be recognized in most parts of the world. It is only in the very much more geographically restricted areas of the Boreal Realm that the Volgian and Portlandian faunas can be recognized. However, in these Boreal regions, it is unrealistic to imply that we can recognize anything more than approximate equivalence to the Tithonian. For the foreseeable future, it will be necessary to use the Volgian (for Russia and Poland) and the Portlandian (for Britain, northern France and Greenland). Why should not the international community recognize this fact and accept secondary (local) standard stages? This point was made by Cope (1993) when he proposed that for the British area Bolonian and Portlandian be recognized as Secondary Standard Stages, whilst for Russia, Volgian should be similarly recognized.

There is a strong case for accepting Secondary Standard Stages (hereinafter SSS) for use in those cases where faunal differences make correlation by all normal means impossible, at least in the present state of knowledge. If the principle of the SSS was accepted, then it is a relatively easy matter to agree what shall be the primary standard, as long as terms in other countries can be used as secondary standards for as long as they are needed. Ultimately the aim must be to use only the primary standard, but the acceptance of the SSS would provide an immediate answer in many cases and would undoubtedly speed up the proposals and acceptances of the primary GSSPs.

In so many cases, one feels that nationalism has been allowed to enter the scientific debate. One hesitates to accuse stratigraphers of nationalistic prejudice in their views, but a little more honest self-appraisal would possibly allow them to admit that their proposals were not always entirely altruistic. On occasion it would seem that the best way to defend one's corner, is to advance the local stage names as the standard, in order that they may be preserved. Introduction of Secondary Standard Stages would ensure preservation of local names where they have a genuine usefulness, defuse any nationalistic prejudice, and ensure a greater scientific objectivity in selection of GSSPs.

Another example where the introduction of the SSS may help resolve difficulties is in the case of the Ordovician. At present there is no agreement on a global standard for series of the Ordovician. Proponents of the British, North American and Scandinavian series and stages are at loggerheads. Fortey *et al.* (1995) have recently published new proposals for international standard series and stages for the Ordovician. These are based on sections in the historical type area and involve a re-appraisal of the classical British subdivisions of the Ordovician System, some of which go back as far as Murchison (1839). Notwithstanding this, the Ordovician Subcommission meeting in Las Vegas in June 1995 voted to opt instead for the American Ordovician series, during a debate which became at times extremely heated (R.A.Fortey, pers. comm.). Here, as in other cases, the discussions have broken into national factions. This is a source of concern, as in the final analysis decisions may depend upon which country has the greatest numbers of Titular (voting) Members of the relevant subcommission. Should rival proposals be equally scientifically sound, those produced by a country with the largest membership of the Subcommission at that time, stand a better chance of approval simply because of the fact that delegates from country A outnumber those of country B at a meeting. Although theoretically there is a world-wide representation on each subcommission, the location of a meeting in a particular part of the world will obviously have an effect on which delegates can be present.

Such problems are not restricted to the Ordovician, but this type of situation could be immediately obviated if official sanction came from the ICS for approval of a series of Secondary Standards where it is clear that they are the best short-term solution. A Secondary Standard would be an internationally acceptable name which could be applied as local requirements dictate and acknowledges that the primary standard, to which the GSSP is applied, shall act as the ultimate standard of reference. Secondary Standards should be accepted as necessary expedients in cases where correlation with the primary standard is at present difficult (or even impossible); they obviously need to be rigorously defined in just the same way that each primary standard is. They should be defined in a similar manner with their own Secondary Stratotype Section and Point (SSSP) so that correlation problems between primary and secondary standards may be ultimately resolved. Such a scheme was followed with the Bolonian Secondary Standard Stage by Cope (1993) who defined the base of the Stage at a particular point in a section in Dorset.

The fact that a series of Secondary Standards exists need not divert us from the ultimate quest for the best series of chronostratigraphical divisions, but one immediate advantage would accrue. Once stratigraphers realized that their locally-cherished names need not necessarily be deemed unacceptable by the ICS, but could well continue as Secondary Standards, there will be a more honest and open debate on the Primary Standard. This debate will then no longer be coloured by national prejudice or decisions taken in the course of defence of one's corner, but will become scientifically more objective and thus more likely to produce decisions which are simultaneously internationally acceptable and scientifically defensible.

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