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Warsaw Remarks – Berriasian Progress

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As it meets for its Warsaw 2013 (9–12 October) workshop, the ISCS's Berriasian Working Group, though busy with all aspects of the stage, is preoccupied with the documentation and selection of a GSSP for the Berriasian. And we have discussed this much in our workshop in Poland. That GSSP datum needs to be readily correlatable, and traceable as much as possible around the World. It is always a matter of finding markers with the widest utility, but for this particular interval it is an impossibility to settle on a single global or even remotely global indicator. For this is the stratigraphic interval that is most fraught with difficulties, because of issues of contrasting facies, geographical barriers and the endemism of its biotas. With this interval we are forced to work with a core group of markers in the largest geographical unit, Tethys, and use proxies (including magnetozones) to achieve correlations to other, sometimes more problematic, regions. It is probably fair to say that the problems are exaggerated, for if we use multidisciplinary methods the J/K boundary is seen as far less problematic than some other boundaries. For instance, some Upper Cretaceous stage boundaries where the biotas are less diverse and the available biotic markers are far less plentiful.

The reasons why this is the very last system base to be tackled by the ICS and its subcommissions have already been much discussed (Wimbledon, 2008; Wimbledon *et al*., 2011). Removal by mid-Cretaceous erosion over large regions, faunal separation into tethyan, austral, boreal marine regions, isolation of individual basins within these, and the prevalence in wide regions of non-marine sequences across the boundary have combined to afford a correlative enigma for geologists since the start of stratigraphical study. However, at least there has never been any doubt that Berriasian is the obvious name, and the name with priority, for the first stage/age of the Cretaceous.

Ironically, work on fixing a J/K boundary was held back for decades by concentration on single fossil groups with limited correlation potential (Remane, 1991), and by rather nationalistic and sterile arguments over the priority of stage names for the final Jurassic stage. This was ended when the name Tithonian was selected by the International Jurassic Subcommission of ISC as the only global term, and all other stage names (and even d'Orbigny's senior name of Portlandian) were suppressed (Sarjeant, Wimbledon, 2000; Cope, 2013). Now the focus is not on stage nomenclature, but on detailed correlation and calibration of useful fossil and other markers.

The focus on the definition of a base for the Berriasian is still on the interval between the base of the Jacobi Zone and the base of the Grandis Zone, but nowadays with ever increasing precision. Defining a boundary for the base of the Berriasian is more straightforward in the biotic core area of western Tethys (Morocco, Tunisia, Iberia, France, Italy, Central Europe, Turkey, Bulgaria, Ukraine, Iran) to north Atlantic 'Tethys' and the Caribbean (Cuba, Mexico), and on to California. This becomes less straightforward beyond Iran into eastern Tethys (Tibet, Australasia, Russian Far East, and Japan), with parts of the Upper Tithonian and Lower Berriasian represented, but no continuity and no complete sequences.

The idea that mythical ammonites could afford a global scale or markers and provide correlation at about the J/K boundary has over the years undergone some rigorous examination, and now has rather faded. No ammonite species, or any other alternative single fossil, provides a marker that

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has anything remotely approaching a global distribution. Even in Tethys it has never proved possible to define and apply a single biozonal scheme. Thus it is clear why for at least three decades a multiplicity of complementary or alternative fossils have been applied: calpionellids, nannofossils, palynomorphs, belemnites, radiolaria, forams, bivalves *etc etc*. For some years an integrated approach has been seen as the best, the only, way forward in the definition of a J/K boundary.

Workers on marine sequences sometimes overlook the fact that in J/K boundary times across wide regions no marine sedimentation took place. Extensive non-marine deposits typify large areas globally (*e.g*. USA, UK-Poland, Mongolia, and China). Here, of course, marine fossils are a rarity and we must rely for stratigraphic purposes on spores and pollen and limited dinoflagellates and ostracods, though magnetostratigraphy has, so far, rarely been applied. Palaeomagnetism and ostracod stratigraphy are currently the subject of new studies on the non-marine Tithonian-Lower Valanginian of southern England.

In non-Mediterraean Gondwana and, loosely, the Austral/Pacific (Argentina, Chile, Yemen, Madagascar, and Iraq) mostly endemic macrofaunas require separate zonal definition (*e.g*. Zeiss, Leanza, 2011; Vennari *et al*., 2013; Howarth, 1992; Howarth, Morris, 1998). Elements of the distinct J/K ammonite assemblage of Argentina have been infrequently identified in Tethys, and Argentine "*Berriasella*" are not Tethyan species: however, well-defined nannofossils are becoming important correlative tools. Argentina and Iraq have a few ammonites (*Groebericeras*, *Chigaroceras*…) in common, but it is the calpionellids and nannofossils newly discovered in Iraq that promise much more precise correlations with western Tethys and North America. Of all the recent discoveries made, the potential revealed by the discovery of calpionellids in the Neuquen basin must be one of the most important, and one deserving of strenuous effort in further investigation.

Western Canada and California have boreal *Buchia*, but also share some non-boreal ammonites close to the J/K boundary, supposedly "late Tithonian"(*Paradontoceras, Substeueroceras*) or "early Berriasian" (*Spiticeras*) (Imlay, Jones, 1970; Jeletsky, 1984). They are ammonites that are less well known in Tethys. Whereas belemnites, tethyan calcareous nannofossil species and palynomorphs in California offer better correlative possibilities: and integration of these with *Buchia* faunas in Asia may prove to be very useful. Much more problematic is the more isolated Siberia where there are no calpionellids, and though nannofossils are present (Zanin *et al*., 2012), they have not really been exploited thus far. There is no ammonite in Siberia (or other boreal areas – the Russian Platform, UK or Greenland) that makes possible a correlation with any part of the traditional J/K boundary interval in any section in Tethys, though, again, *Buchia* and belemnites can help the situation.

Of course, in fixing a boundary, we are constrained by the history of research, by international consensus and conventions, by the decisions of two international symposia which voted on the issue, innumerable publications (some cited above and below), and by the decisions made in the last five years by the Berriasian Working Group of the ISCS. For several generations, apart from occasional aberrations, definitions of a J/K boundary have focussed on the *Berriasella jacobi* (Jacobi) Zone: but in the last forty years the focus, more and more, has been on calpionellids, on the widespread and more precisely and consistently recognised turnover from *Crassicollaria* assemblages to small *Calpionella* (*e.g.* Remane, 1963, 1986; Le Hégarat, Remane, 1968; Pop, 1976; Altiner, Özkan, 1991; Lakova, 1993; Benzaggagh, Atrops, 1997; Reháková, Michalik, 1997; Skourtsis-Coroneou, Solakius, 1999; Houša *et al*., 1999, 2004; Pszczółkowski *et al*., 2005; Boughdiri *et al*., 2006; Michalik *et al*., 2009; Grabowski *et al*., 2010a; Benzaggagh *et al*., 2012; Lakova, Petrova, 2013; López-Martínez *et al*., 2013a, b). Latterly this has been widely reinforced by the use of calcareous nannofossil FADs (references in Casellato, 2010). Much more work is in progress and is still needed on the detailed calibration of nannofossils with calpionellids, ammonites and magnetostratigraphy, so as to complete a more perfect matrix. Notably more work to realise their potential in those areas where nannofossils have already been identified, such as Argentina, Tibet (Liu *et al*., 2013) and in Mexico and California (Bralower *et al*., 1990). In the last, the existing results for radiolarians (Pessagno *et al*., 2009) could usefully be integrated with datums of other fossil groups. The specific identifications and correlative contradictions in the account of Liu *et al*. (2013) are greatly in need of attention. And all these regions, thus far, have been without palaeomagnetic study. Recent years have seen the expansion of the area with calpionellids, to Mexico westwards and to Australasia in the east; with, since the formation of the Berriasian group, new finds extend their range to Iraq and to Argentina.

Magnetostratigraphy has advanced greatly in the last thirty years, and become an essential tool in Tithonian-Berriasian stratigraphy, in both marine and non-marine facies (*e.g*. Lowrie, Channell, 1983; Ogg *et al*., 1984, 1991, 1994; Galbrun, 1985; Ogg, Lowrie, 1986; Houša *et al*., 1999, 2004, 2007; Grabowski, Pszczółkowski, 2006; Grabowski *et al*., 2010b; Pruner *et al*., 2010; Channell *et al*., 2010; Wimbledon *et al*., 2011, 2013; Guzhikov *et al*., 2012; Bragin *et al*., 2013; Bakhmutov *et al*., 2014 – in press). The numerous J/K sections studied for palaeomagnetism in western Tethys are noteworthy in that they constitute a larger data set than exists for most previously selected GSSPs and boundary intervals. Thus we are indeed fortunate to have the constraints imposed on biostratigraphy that magnetozones can afford.

And this tool has made a great difference with our ability to derive better correlations with the more problematic and, biotically, more impoverished regions. Nordvik is in one of these, in the Siberian embayment, that part of the boreal furthest removed from Tethys. Siberia has its own ammonite scale, as its ammonites around the Tithonian/Berriasian boundary level are different to the other boreal regions, for instance, Greenland, UK or Canada. Matching of ammonite zones in Siberia to zones in Tethys, lacking ammonite in common, has been, at best, approximate – straddling as much as 2.5 my and three local ammonite zones (Schnabl *et al*., 2014 – in press). Intensive studies of magnetostratigraphy at Nordvik (Houša *et al*., 2007; Bragin *et al*., 2013) have greatly improved this situation.

There is much potential for work in Siberia. At numerous sites in Tethys the Tithonian/Berriasian (J/K) boundary interval has been identified in magnetozone M19n, and at Nordvik M19 is placed within the *Craspedites taimyrensis* (Taimyrensis) Zone. No doubt more finds will be made, but currently at Nordvik the bases of the magnetozones M19r, M19n, M18r, M17r and M16r all lie in intervals with no ammonites. This suggests the need to find accurate and repeatable biostratigraphic markers here and perhaps in alternative Siberian sites, sites that might then be considered for sampling for palaeomagnetism. It is excellent to have the same magnetozones identified as at the Puerto Escano, Le Chouet and St Bertrands Spring (Les Combes) *etc*, but it is critical to have biotic markers also. New belemnite studies (Dzyuba, 2012) have afforded wider correlations and exciting possibilities. Importantly, the first appearance of the Californian species *Arctoteuthis tehamaensis* in Siberia (in the middle of M19n.2n) provides a proxy for the base of the *Calpionella alpina* (Alpina) Zone, and the short-ranging *Lagonibelus gustomesovi* marking the top of M19r. The biotic connections between California and Siberia appear now to have considerable significance in the wider correlative context. And the urgent need for more magnetostratigraphic studies in Siberia is clear.

It is possible to suggest a magnetostratigraphic primary marker for the Tithonian/Berriasian boundary, but any such level would need to be tightly 'sandwiched' between consistent and widespread fossil markers. There is no possibility of ignoring numerous and widely used biostratigraphic datums, and simply choosing a magnetozone far removed from accepted traditional levels. Past suggestions that the base of M18r was a suitable contender for a J/K boundary (Ogg, Lowrie, 1986) were in our minds when we had the first Berriasian WG meetings. In earlier times, the suggestion was based on the belief that the boundary lay "in the middle of various biostratigraphic definitions" of the boundary in Tethys. But the idea has not subsequently been supported by biostratigraphic data. The decision of a new Berriasian WG, at its first meeting, to concentrate study on the base of the Jacobi Subzone as a primary boundary contender was strongly endorsed by various distinguished workers. At its third workshop in Milan, the group considered the potential of *all* possible biotic markers and levels for a GSSP, always combined with magnetostratigraphy, in the Jacobi Subzone. This interval, the upward sequence in M19n.2n, M19n.1r and M19.1n, in particular, provides several closely spaced markers (Wimbledon *et al.*, 2011; though it was recognised that M19n.1r was too short an interval to be a recognisable and repeatable marker, especially in shallow marine and non-marine facies). Study in the last few years has suggested that the bases of the Alpina and Jacobi biozones are not coincident (as has been stated in the past), and neither of them is now seen to lie close to the base of M18r (*e.g.* Wimbledon *et al*., 2013). Similarly, no FAD of a nannofossil species coincides with the base of M18r. Considering ammonites, calpionellids and nannofossils, the particular focus has shifted: to documentation of useful markers within M19n.2n.

The definition of the magnetozones that straddle the Tithonian/Berriasian interval and their essential calibration with fossil markers (calpionellids, calcareous nannofossils, ammonites, palynomorphs, radiolaria, belemnites, forams, buchiids *etc*) is a task that many colleagues, including the Berriasian WG, have valuably addressed in recent times. A string of papers has been published on French, Italian, Polish, Czech, Slovak, Hungarian, Bulgarian, and Ukrainian sections. Some key 'old' localities are under re-investigation, including of calpionellid studies at Fonte del Giordano and Fiume Bosso. Publication of new integrated ammonite and nannofossil data is anticipated from Berende in Bulgaria, as well as magnetostratigraphy, ammonites, calpionellid and nannofossils from Barlya. The first nannofossils from Sidi Khalif, in mid Tunisia, offer excellent prospects, and are some of the best preserved for this group. New palaeomagnetic results from Beni Kleb in Tunisia, the first in North Africa, and for Crimea (Theodosia), for the last combined with new nannofossil data, are in the pipeline. As stated, new and unique results for calpionellids have been recorded recently in Iraq and Argentina, as well as being anticipated in new projects under way in California (on nannofossils, palynomorphs, belemnites, *Buchia*, and ammonites). A new project is being started on the marine palynology of Tibet, and a fresh search has been initiated for calpionellid-bearing units in northern Australia.

The consensus amongst researchers for more than a generation has been that the final selection of a GSSP for the Berriasian Stage will be at a locality in Tethys (Remane, 1991; Wimbledon *et al*., 2011: Michalik, Rehakova, 2011; Schnabl *et al*., 2014 – in press). Tethys was the largest geographical unit in Tithonian and Berriasian times, with the clearest consistency in its biotas. Our discussions in Warsaw were very useful in canvassing opinion on prospective levels for a J/K boundary. After a free and wide-ranging discussion, there was a clear consensus, in fact with no dissent at all, that, on current knowledge, the base of the *Calpionella alpina* (Alpina) Subzone provides the most widespread and consistent candidate for a primary boundary marker. Therefore our work in coming months is to test this suggestion, and to continue efforts on calibrating *all* biotic and other markers around the levels of the bases of the subzones of *Berriasella jacobi* (Jacobi), *Calpionella alpina* (Alpina) and *Pseudosubplanites grandis* (Grandis).

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