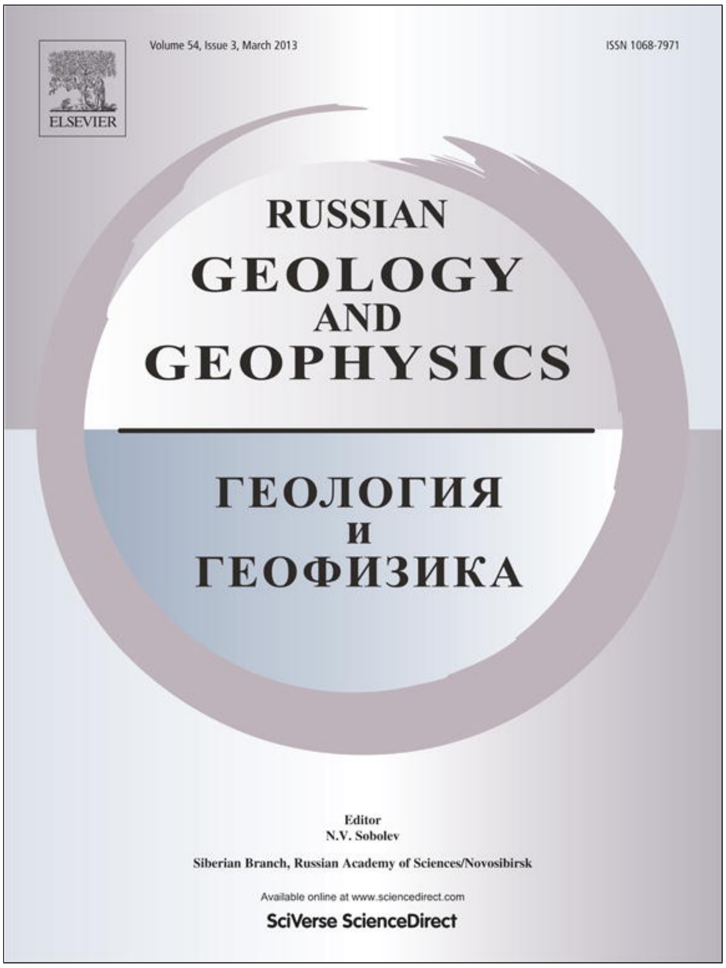
Volume 54, Issue 3, March 2013
ISSN 1068-7971
ELSEVIER
RUSSIAN
GEOLOGY
AND
GEOPHYSICS
ГЕОЛОГИЯ
И
ГЕОФИЗИКА
Editor
N.V. Sobolev
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Available online at www.sciencedirect.com
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SciVerse ScienceDirect
Russian Geology and Geophysics 54 (2013) 349–354
RUSSIAN GEOLOGY AND GEOPHYSICS
www.elsevier.com/locate/rgg

Solving unsolvable problems in stratigraphy (Comments to the paper "New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (*northern East Siberia*)" by V.Yu. Bragin, O.S. Dzyuba, A.Yu. Kazansky, and B.N. Shurygin)

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Received 4 September 2012; accepted 14 September 2012

Abstract

In this study we analyze the importance of new magnetostratigraphic data on the Nordvik section for solving the problem of detailed Tethyan–Boreal correlation around the Jurassic–Cretaceous boundary with a special emphasis on the aspects of interpretation of the paleomagnetic data in magnetostratigraphic studies and the need for the integrated (paleontological and paleomagnetic) approach to recognition of the base of the Berriasian.

Keywords: Jurassic–Cretaceous boundary; biostratigraphy; magnetostratigraphy; Tethyan–Boreal correlation

Introduction

A detailed zone-by-zone bio- and magnetostratigraphic correlation of the Upper Volgian and–Boreal Berriasian with the Tethyan Tithonian–Berriasian faunal zonations proposed by Bragin et al. (2013) can be seen as a preferred alternative for the detailed Tethyan–Boreal correlation of the Jurassic–Cretaceous boundary. This important statement, which is claimed to have found the ultimate solution to the most pressing and long-standing controversies in stratigraphy, including the problems of the Jurassic–Cretaceous boundary (Prozorovskii, 2005; Wimbledon, 2011; Zakharov, 2011; Zakharov and Rogov, 2005, 2008; anothers), deserves careful consideration. Another point of interest in the paper by Bragin et al. (2013) is that it offers an opportunity to explore the stratigraphic implications of paleomagnetic data and describes the influential approach to the acquisition of magnetostratigraphic data.

The role of paleomagnetic data in Tethyan–Boreal correlation

Most previous attempts at correlating the Boreal and Tethyan successions around the Jurassic–Cretaceous boundary have largely relied onthe conventional biostratigraphic data, which,due to increasing biogeographic isolation of the basins, allowed the mutually contradictory interpretations. The situation has changed dramatically, however, as magnetostratographic data became available for the Boreal Upper Volgian–Lower Berriasian section in the Nordvik Peninsula (Houša et al., 2007). These new data have demonstrated the possibilities of the correlation between Jurassic–Cretaceous boundary beds of Northern Siberia and Western Europe on totally independent paleomagnetic arguments. The magnetic polarity time scale was well-documented in dozens of the European sections, as opposed to the Boreal time equivalents (the most comprehensive summary of the published magnetostratigraphic data on the Jurassic–Cretaceous boundary and references see in Grabowski (2011)).

At the time of its publication, the Tethyan–Boreal correlation by Houša et al. (2007) was by farthermost justified of all ever published, because it was independently supported by, and consistent with, the paleomagnetic data, as an additional

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1068-7971/$ - see front matter © 2013, V.S. Sobolev IGM, Siberian Branch of the RAS. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.rgg.2013.02.009

control of biostratigraphic correlations. Looking back at 2007, it should be noted that in Europe, most of the Jurassic–Cretaceous boundary sections studied magnetostratigraphically were previously dated by microfossils. Intercalibration of the Upper Tithonian–Lower Berriasian magnetozones with detailed ammonite biostratigraphy of the composite time scales (Ogg and Ogg, 2004, 2008) has been achieved indirectly. Therefore, Houša et al. (2007) correlated the Boreal ammonite zonation to calpionellid zones.

A calibration of the Tethyan and Boreal ammonite zones ranging from Transitorius to Jacobi and from Variabilis to Sibiricus, respectively (Zakharov et al., 2011, fig. 3) became only possible after the publication of magnetostratigraphic data on the first Tethyan section with well documented ammonite and microfaunal biostratigraphy (at Puerto Escaño, Spain) (Pruner et al., 2010). However, claims about the conclusiveness of this correlation (Zakharov et al., 2011, p. 82) should be viewed with a certain caution.

Based on the reversed polarity (R) microzones, which were documented at Nordvik as corresponding to subchrons M20n.1r (Kysuca) and M.19n.1r (Brodno), the correlation between the base of the Jacobi Zone and the Taimyrensis Zone seems most plausible. Both or either of Kysuca and Brodno sunchrons could potentially be the equivalents of yet unknown subchrons (e.g., within M18n) or may be the result of remagnetization. One way to remove all doubts and improve the conclusiveness of this correlation is by acquiring paleomagnetic data on the remaining Berriasian at Nordvik, which would be completed by magnetostratrigraphy of the Jurassic–Cretaceous boundary in other Boreal sections (lateral stability of R-microzones excludes the possibility of remagnetization). Nevertheless (keeping in mind that we must always strive for the ideal even though it seems unattainable), the correlation independently supported by bio- and magnetostratigraphy should be definitely preferred.

Even more controversial is the equation of R-zone detected within the Sibiricus Zone with M17r (Houša et al., 2007). The analysis of bio- and magnetostratigraphic data on the Berriasian in this case leads to the unlikely conclusion that the Nordvik section seems to either have a hiatus or is condensed, because the Kochi Zone cannot be older than the Dalmasi Subzone (Guzhikov and Baraboshkin, 2008). This contradiction, which was pointed out in our previous study, seemed to be ignored by Zakharov (2011), and the question of the direct correlation of the Sibiricus and the overlying Boreal ammonite zones with their Tethyan equivalents remain unanswered until the recent paper of Bragin et al. (2013). This paper presents a refined paleomagnetic structure of the Nordvik section that contains a new R-zone at the boundary between the Upper Volgian and the Boreal Berriasian. On this basis, the authors identified the equivalents of M17r (at the Chetae Zone boundary), M17n and M16r (at the Kochi Zone boundary) within the Sibiricus Zone. A new bio- and magnetostratigraphic correlation (Fig. 1) proves that the Kochi Zone corresponds to the Tethyan paramimounum Subzone (and that the Kochi Zone is younger than the Dalmasi Subzone), not challenging the sedimentary continuity of the Nordvik section.

It seems unnecessary to doubt the correctness of the new Tethyan–Boreal correlation around the Jurassic–Cretaceous boundary, because its calibration to magnetostrtaigraphic sections was supported by a tight biostratigraphic control on account of the results from previous studies. There liability of paleomagnetic data obtained by Bragin and Kazansky is directly related to the state-of-art equipment and data processing equipment used in paleomagnetic studies, as well as a comprehensive data set on the rock magnetic properties and magnetic mineralogy, which clearly prove the ancient origin of magnetization.

Sedimentation rates were calculated by Grabowski (2011) in the Nordvik section as a ratio between the thickness of magnetozone and duration of the respective polarity chron (Ogg and Ogg, 2004) based on the sequence of chrons (from M20n to M17r) proposed by Houša at al. (2007). The highest values of the sedimentation rates were calculated for an interval close to the Taimyrensis–Chetae zonal boundary. This is contradicted by the results of Bragin et al. (2013) with references to Zakharov et al. (1993) and Mizera et al. (2010), who demonstrated a decrease of sedimentation rate around the Chetae–Sibiricus boundary coinciding with the onset of the condensed phosphatized limestone layer (so-called iridium anomaly). Variations of sedimentation rates calculated in a similar manner as above in the sequence of chrons proposed by Bragin et al. (2013) produce a more systematic trend: the sedimentation tends to decrease from 9.4–11.4 m/m.y. in the lower okensis Zone to 1.4–1.7 m/m.y. in the top of the Taimyrensis Zone and in the Chetae Zone composed of organic-rich clays, attaining its minimum (~0.5 m/m.y.) at the boundary between Volgian and Boreal Berriasian within the iridium anomaly interval, and then increases to ~12.4 m/m.y within the Sibiricus Zone. Such estimates should be regarded with caution (because they are based on the duration of chrons that cannot be easily verified), but the close agreement of the paleomagnetic and geological data can provide indirect evidence to support the magnetostratigraphic reconstruction of Bragin et al. (2013).

It is worth noting that the proposed bio- and magnetostratigraphic calibration of the Tethyan and Boreal successions suggests a conspicuously short duration for the Kochi Zone compared to the remaining ammonite zones, which seem to be generally comparable in their duration. Such stratigraphic restriction of the Kochi Zone is quite clear since the base of the above zone according to the biostratigraphic criteria cannot be detectably older than the top of the Dalmasi Subzone, whereas the R-zone, which was identified at the boundary between the Kochi and Analogus Zones in the section from the Boyarka River (Guzhikov and Baraboshkin, 2008) and is also correlative with M16r, does not permit the upper boundary of the Kochi Zone to be younger.

However, based on the previous identification of the reversed polarity subchron M16n.1r (Feodosiya) within chron M16n (Bagaeva et al., 2011), it cannot be ruled out that the R-zone confined to the Kochi–Analogus zonal boundary is correlated with M16n.1r (Feodosiya) instead of M16r. In the latter case, the Kochi Zone would be equated almost entirely

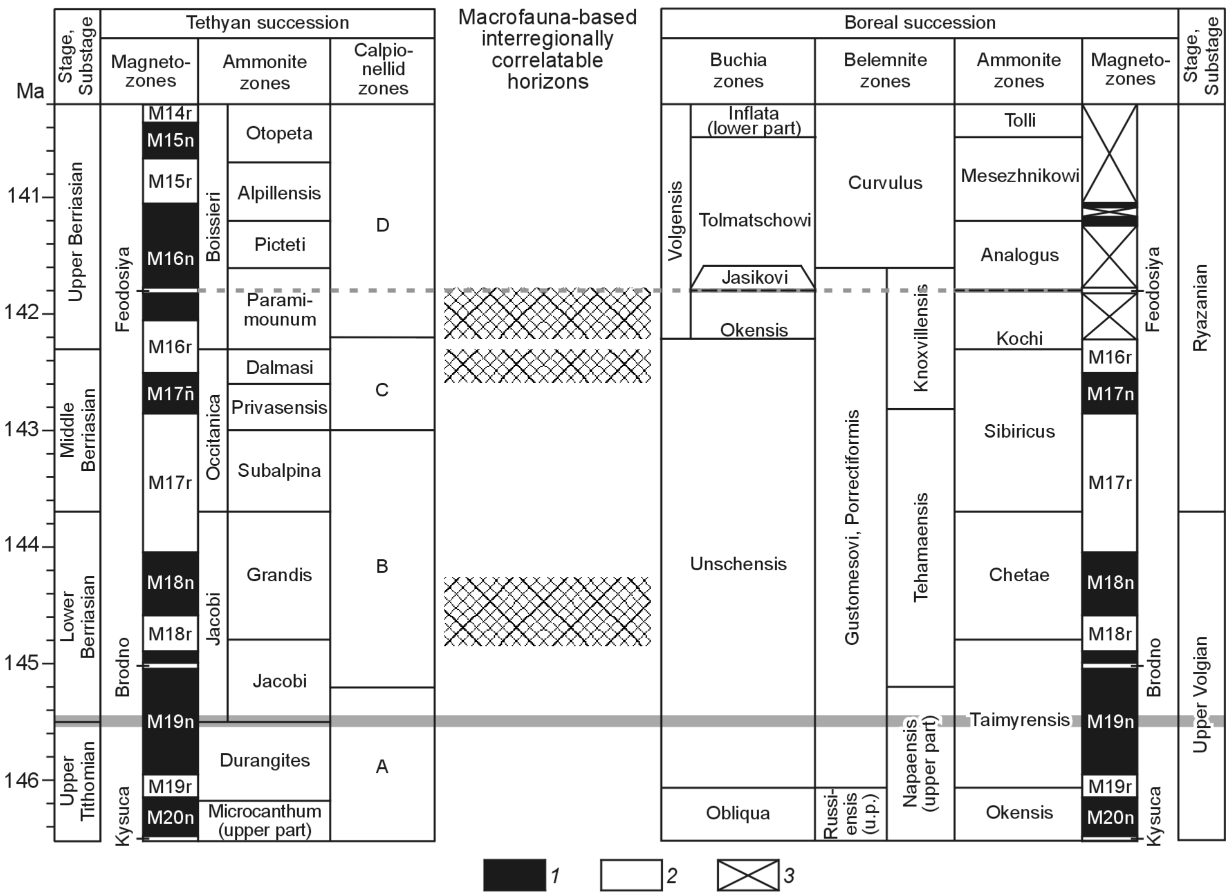

Fig. 1. Tethyan–Boreal correlation of the Jurassic–Cretaceous boundary interval based on bio- and magnetostratigraphy (modified after Bragin et al. (2013) using the data on subchron M16n.1r Feodosiya (Bagaeva et al., 2011). Geomagnetic polarity: *1*, normal; *2*, reversed; *3*, no sampling.

with the Paramimounum Subzone, and its duration would be consistent with that of the other Northern Siberian phases of the Berriasian (Fig. 1). Subchron M16n.1r has not yet been included in the geologic time scale (Ogg and Ogg, 2008), but it has now been found within the Paramimounum Subzone and in the Berriasian stratotype (Galbrun, 1985), in the Crimea (Bagaeva et al., 2011), and also with a sequence of linear magnetic anomalies (Tominaga and Sager, 2010).

Some aspects of the magnetic polarity interpretation of the paleomagnetic data

The magnetic polarity columns for the Nordvik section, derived independently by different authors, are almost similar, except for the interval characterized by an iridium anomaly and the presence of newly identified R-zone. This reproducibility gave us confidence about the objectivity of the polarity pattern of the section. However, the omission of reversed polarity zone at the Chetae–Sibiricus zonal boundary, as identified by Houša et al. (2007), needs aplausible explanation. Although a brief discussion of possible reasons for the omission of M17 requivalent was given in the work of Bragin et al. (2013), this issue should be considered in greater detail, as it is related to different approaches to the magnetostratigraphic interpretation of principal component analyses (PCA) data and will be of interest not only to paleomagneticians, but also to stratigraphers who can use geomagnetic polarity data in their reconstructions.

It is still a common belief that paleomagnetic vectors used in magnetic polarity determination must positively pass the statistical and field tests, otherwise they cannot be considered reliable. It is, however, clear that under such conditions the paleomagnetic methods would be of little use in practical stratigraphy since a magnetic polarity sequence could only be developed from datasets on the representative number of stratigraphic levels, more or less uniformly acquired throughout the section. However, intervals, in which most (if not all) of the samples exhibit magnetic stability, are rarely observable in nature. By contrast, most of stratotypes and stratigraphic reference sections, most important for the solution of stratigraphic problems, are pretty often (probably sticking to Murphy's Law) unsuitable for paleomagnetic studies, because a ChRM could not be completely isolated. Consequently, this may result in the poor precision parameters and negative reversal test. The fold and conglomerate tests could not be applicable in this case based on geologic considerations, etc.

What's to be done in such situations? Should we discard all directional data that do not meet a set of strict criteria and tend to affect the paleomagnetic statistics? And this seems to have been the choice of Czech researchers, as was already rightly assumed by Bragin et al. (2013), whose resulting data sets *"do not include 108 samples (~ 30% of the total number of samples), which are probably shallow inclination samples (cf. (compare Figs. 8 and 9 in Houša et al. (2007))."* So what then was the outcome? It was, most probably, the omission of reversed polarity zone, which is critical for valid identification of the polarity column of the section with a sequence of magnetic chrons and, consequently, ambiguous correlation of zonal scales for different paleobiogeographic provinces.

Is there any alternative approach? Yes, but it would require a rational use of anomalous NRM directions for polarity determinations. This approach was used by the authors of the paper under discussion, *"Note that the statistical parameters of the distribution of ChRM directional data for both the reversed and normal polarity groups, and for the entire population, are lower than those reported by Houša et al. (2007). Moreover, the study revealed paleopoles at low latitudes (Table), which can be probably explained by different selection criteria show all directions found in this study (83 ChRM directions for 83 hand samples), as compared to 209 ChRM directions for 317 samples used in the previous magnetostratigraphic study (Houša et al., 2007)... ."*

Bragin et al. (2013) definitely demonstrated that the anomalous NRM directions appear to reflect a polarity change and thus have to be used in the magnetostratigraphy; a dataset that fails a reversals test could not be rejected if most samples proved to have a significant secondary component of NRM; the anomalous directions forma tight cluster in the section, rather than being scattered in narrow intervals; a reproducible polarity pattern (the observed polarity zones justified by the data contaminated by a secondary remanence are well consistent with known magnetostrtaigraphic results from other coeval sections). Compete isolation of the primary component (undistorted) should be sought, if possible.

Indeed, this approach is well-known to magnetostrtaigraphers and was cited, implicitly or explicitly, in many Russian and Western papers (Guzhikov et al., 2012; Przybylski et al., 2010).

The question then becomes which approach is more valid? This question is rhetorical, on account of the equivalent of chron M17 convincingly detected by Bragin et al (2013) within the Sibiricus Zone, which is of crucial importance for Tethyan–Boreal correlation.

The role of paleomagnetic criteria in contraining the Jurassic–Cretaceous boundary

Significant advances in global correlation cannot be expected using biostratigraphic data alone, but requires testing by an independent correlative tool (nonpaleontological). The importance of paleomagnetic data for the calibration of biozones around the Jurassic–Cretaceous boundary interval in Western Europe and Siberia and their use as decisive evidence for correlating the most Upper Volgian with the Tithonian, rather than the Berriasian, have been emphasized in earlier studies (Wimbledon, 2011; Zakharov, 2011) and seem not to be questioned at present.

However, the call for utilization of the paleomagnetic criteria for constraining the Jurassic–Cretaceous boundary remains overlooked by some researchers. Although I agree with the opinion that "*...the base of the Berriasian should be defined based on an important phyletic event, e.g., the appearance of the index taxon, which will be selected to be ammonites"* (Zakharov, 2011, p. 81), we cannot but mention that the role of paleomagnetic data is not fully appreciated as a decisive tool for the solution of the problem.

Paleomagnetic markers have long proved useful in constraining the Quaternary stratigraphic subdivision, e.g., the Brunhes–Matuyama reversal was used to identify the Eo- and Neopleistocene of the General Stratigraphic Scale (Lower and Middle Pleistocene of the Global Stratigraphic Scale) (Supplements, 2000). The base of chron M0 was recommended by the Aptian Stage Working Group asone of markers for the Barremian–Aptian boundary (Erba et al., 1996). The significance of paleomagnetic data in fixing stage and substage boundaries was convincingly demonstrated later in a paper by Guzhikov and Baraboshkin (2006). The proposals on using the base of chron as a workable indicator of the basal Cretaceous (base of M18r as a most likely marker) have been voiced repeatedly in the literature (Channell et al., 2010; Guzhikov et al., 2012; and others), and in a number of All-Russian meetings, such as Cretaceous System of Russia (Ulyanovsk-2010), Jurassic System of Russia (St. Petersburg, 2011), as well as the Berriasian Working Group workshops (Smolenice, 2010; Sofia, 2011).

I believe that the use of paleomagnetic indicators in defining the Jurassic–Cretaceous boundary will inevitably gain wide acceptance. This assertion by no means seeks to diminish the priority of the biostratigraphic criteria, because a paleomagnetic indicator cannot be seen as a substitute for the paleontological indicators and is not, and cannot, be involved in the initial definition of the Cretaceous boundary. However, for methodological purposes, it is misleading to view the paleomagnetic method as a mere correlative tool, without regard to the definition of a boundary. The base of the Berriasian, as is the case with other stage boundaries, should be defined using a combination of methods (paleontological and nonpaleontological), and this can be easily proved true by admitting the following facts.

1. The boundaries of all biostratigraphic units are diachronous to a lesser or greater extent and none of the paleontological markers are globally applicable, merely because of a strong facies control.

Integrated bio- and magnetostratigraphic correlations confirmed diachronism of macro- and microfossil-based stratigraphic boundaries within the Lower Cretaceous (Channell et al., 2010; Guzhikov and Baraboshkin, 2008; and others). This marked diachronism (about 1 Ma, judging from the duration of magnetic chrons) of nannoplankton zones was identified in sections some 150 km apart from each other (Channell et al., 2010; and others). (The ammonite zonal boundaries show a limited amount of diachronism. Therefore, we have to agree with Zakharov (2011) in that ammonite markers should become a preferred alternative in identifying the boundary instead of calpionellids and nannoconids, as recently suggested by Wimbledon et al. (2011)).

2. Since modern stratigraphy attempts to achieve interregional infrazonal correlations, enabling the comparison of subdivisions with the duration of a few hundreds of thousands of years, then a reasonable assumption we must rely on is that diachronism of stratigraphic boundaries could not exceed the duration of correlatable divisions. Since the boundaries of stages, divisions, and systems become the boundaries of finer-time subdivisions (zones and subzones), the same diachronism requirements continue to be applicable to them.

At the same time, interchangeability of paleontological indicators, unavoidable in long-range correlations, may result in the increased time shift of fossil-based boundaries, on the order of million(s) of years (Guzhikov and Baraboshkin, 2006). This may result in different sets of zones and none of these can be considered a preferred alternative. A classic example is the problem of Tethyan–Boreal correlation of the Jurassic–Cretaceous boundary interval, which cannot be resolved without a paleontologically-independent scale (and the paleomagnetic scale is the best candidate thus far).

3. However hard we try to preserve the key significance of ammonites for long-range correlations, we cannot ignore facts: e.g., summary data on Western Europe presented by Grabowski (2011) show that only 2 sections (out of a total of 23) with well-resolved polarity patterns across the Jurassic–Cretaceous boundary are dated by ammonites. Therefore, in reality, the position of the basal Berrisianin any section is impossible to fix precisely using ammonites alone, even within a single region (e.g., Western Europe). Alternatively, the boundary is to be defined using tintinnids or nannoplankton tied to the ammonite succession of key sections. However, because the macrofaunal and palynological subdivisions are time-transgressive, the time shift of ammonite-based boundary may be too large and exceed the duration of a chronozone.

The integrated biostratigraphic control offers good prospects for recognition of magnetozone boundaries on a regional as well as global scale. And this was clearly demonstrated in the paper of Bragin et al. (2013). Paleomagnetic boundaries appear to be globally isochronous owing to the nature of magnetic reversals. Thus, the paleomagnetic indicator could be a useful marker for the base of the Berriasian, but first we need to constrain biostratigraphically the stage boundaries and then select a geomagnetic polarity reversal closest to the level reflecting a change in the ammonite fauna in the reference section.

The paleomagnetic datum (base of M18r or base of M17r) to fix the Jurassic–Cretaceous boundary could be recommended depending on the choice by biostratigraphers of the basal Berrisian (base of the Jacobi Zone or base of the Occitanica Zone). Despite the fact that the position of Brodno subchron at Puerto Escaño (Pruner et al., 2010) is closer to the base of the Jacobi Zone than that of the base of M18r, it seems unreasonable to use Brodno as a paleomagnetic maker to recognize the boundary, because of its short duration.

The equation of the base of the Berriasian with the base of the Occitanica Zone seems to be a preferred alternative, since in this case the whole Upper Volgian excepting the uppermost part of the Chetae Zone would correspond to the Tithonian (Fig. 1).

A minimum discrepancy between the ammonite and paleomagnetic markers would require that the Jurassic–Cretaceous boundary to be equated with the base of the grand is Subzone closest to the reversal level, the base of chron M18r. In the Boreal realm, this level approximately corresponds to the base of the Chetae Zone (Fig. 1).

It is important to note, in summary, that in ever meant to use the pun in the title of my paper, I only wanted to put more emphasison the impossibility of solving several stratigraphic problems (especially for the epochs of the maximum isolation of paleobasins) using paleontology alone, without the help of independent (nonpaleontological) methods, and magnetostratigraphy can be of utmost importance. This assertion is not an attempt to challenge the role of biostratigraphy. Paleontological methods, like many others, have their own limitations and, at a certain stage, often need to be integrated with physicochemical data in order to keep up with the requirements of current stratigraphic techniques attempting mode detailed interregional and global correlations. It should be remembered that the paleomagnetic method itself is generally incapable of giving us the age of a rock, and it only proves effective being augmented by bio- and magnetostratigraphic data. This notion can be firmly confirmed by the study of Bragin et al. (2013), which presented the results of Tethyan–Boreal correlation around the Jurassic–Cretaceous boundary intervals on the basis of paleomagnetic data that otherwise would be useless without biostratigraphic data.

This study was supported by the Russian Foundaion for Basic Research (project no. 11-05-00405-a).

References

Bagaeva, M.I., Arkadiev, V.V., Baraboshkin, E.Yu., Gorbenko, E.Yu., Guzhikov, A.Yu., Manikin, A.G., Perminov, V.A., 2011. New data on bio- and magnetostratigraphy of the Berrisian–Valanginian boundary sediments in eastern Crimea, in: Shurygin, B.N., Lebedeva, N.K., Goryacheva, A.A. (Eds.), Paleontology, Stratigraphy and Paleogeography of the Boreal Mesozoic and Cenozoic: Proc. Meet. (April 18–22, 2011) in 2 vols. Volume I: Mesozoic. INGG SO RAN, Novosibirsk, pp. 23–26.

Bragin, V.Yu., Dzyuba, O.S., Kazansky, A.Yu., Shurygin, B.N., 2013. New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia). Russian Geology and Geophysics (Geologiya i Geofizika) 54 (3), 335–348 (438–455).

Channell, J.E.T., Casellato, C.E., Muttoni, G., Erba, E., 2010. Magnetostratigraphy, nannofossil stratigraphy and apparent polar wander for Adria-Africa in the Jurassic–Cretaceous boundary interval. Palaeogeogr., Palaeoclimat., Palaeoecol. 293, 51–75.

Erba, E., Aguado, R., Avram, E., Baraboschkin, E.J., Bergen, J.A., Bralower, T.J., Cecca, F., Channell, J.E.T., Coccioni, R., Company, M., Delanoy, G., Erbacher, J., Herbert, T.D., Hoedemaeker, P.J., Kakabadze, M., Leereveld, H., Lini, A., Mikhailova, I.A., Mutterlose, J., 1996. The Aptian Stage. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre 66 (Suppl.), 31–43.

Galbrun, B., 1985. Magnetostratigraphy of the Berriasian stratotype section (Berrias, France). Earth Planet. Sci. Lett. 74, 130–136.

Grabowski, J., 2011. Magnetostratigraphy of the Jurassic/Cretaceous boundary interval in the Western Tethys and its correlations with other regions: a review. Volumina Jurassica 9, 105–128.

Guzhikov, A.Yu., Baraboshkin, E.Yu., 2006. Assessment of diachronism of biostratigraphic boundaries by magnetochronological calibration of zonal scales for the Lower Cretaceous of the Tethyan and Boreal belts. Dokl. Earth Sci. 409A (3), 843–846 (365–368).

Guzhikov, A.Yu., Baraboshkin, E.Yu., 2008. New magnetostratigraphic data on the Boreal Neocomian key section of the Boyarka River (northern Siberia), in: Dzyuba, O.S., Zakharov, V.A., Shurygin, B.N. (Eds.), Cretaceous System of Russia and FSU: Problems of Stratigraphy and Paleogeography. Proc. 4th All-Russian Meet. (Novosibirsk, September 19–23, 2008) [in Russian]. Izd. SO RAN, Novosibirsk, pp. 66–69.

Guzhikov, A.Yu., Arkadiev, V.V., Baraboshkin, E.Yu., Bagaeva, M.I., Piskunov, V.K., Rud'ko, S.V., Perminov, V.A., Manikin, A.G., 2012. New sedimentological, bio-, and magnetostratigraphic data on the Jurassic–Cretaceous boundary interval of Eastern Crimea (Feodosiya). Stratigrafiya. Geologicheskaya Korrelatsiya (Stratigraphy and Geological Correlation) 20 (3), 35–71 (261–294).

Houša, V., Pruner, P., Zakharov, V.A., Kostak, M., Chadima, M., Rogov, M.A., Šlechta, S., Mazuch, M., 2007. Boreal–Tethyan correlation of the Jurassic–Cretaceous boundary interval by magneto- and biostratigraphy. Stratigrafiya. Geologicheskaya Korrelatsiya (Stratigraphy and Geological Correlation) 15 (3), 63–76 (297–309).

Mizera, J., Randa, Z., Košt'ák, M., 2010. Neutron activation analysis in geochemical characterization of Jurassic–Cretaceous sedimentary rocks from the Nordvik Peninsula. J. Radioanal. Nucl. Chem. 284, 211–219.

Ogg, J., Ogg, G., 2004. Jurassic Time Scale. URL: http://nhm2.uio.no/norges/timescale/Fig17.1_Jur_colA.pdf.

Ogg, J., Ogg, G., 2008. Late Jurassic (139–169 Ma time-slice). URL: http://www.nhm.uio.no/norges/timescale/5_JurCret_Sept08.pdf.

Prozorovskii, V.A., 2005. To the problem of the Volgian Stage. Stratigrafiya. Geologicheskaya Korrelatsiya (Stratigraphy and Geological Correlation) 13 (4), 101–108 (430–437).

Pruner, P., Houša ,V., Olóriz, F., Košt'ák, M., Krs, M., Man, O., Schnabl, P., Venhodová, D., Tavera, J.M., Mazuch, M., 2010. High-resolution magnetostratigraphy and biostratigraphic zonation of the Jurassic/Cretaceous boundary strata in the Puerto Escaño section (southern Spain). Cretaceous Res. 31, 192–206.

Przybylski, P.A., Glowniak, E., Ogg, J.G., Ziólkowski, P., Sidorczuk, M., Gutowski, J., Lewandowski, M., 2010.Oxfordian magnetostratigraphy of Poland and its correlation to Sub-Mediterranean ammonite zones and marine magnetic anomalies. Earth Planet. Sci. Lett. 289, 417–432.

Supplements to the Stratigraphic Code of Russia [in Russian], 2000. VSEGEI, St. Petersburg.

Tominaga, M., Sager, W.W., 2010. Revised Pacific M-anomaly geomagnetic polarity timescale. Geophys. J. Int. 182, 203–232.

Wimbledon, W.A.P., Casellato, C.E., Reháková, D., Bulot, L.G., Erba, E., Gardin, S., Verreussel, R.M.C.H., Munsterman, D.K., Hunt, C.O., 2011. Fixing a basal Berriasian and Jurassic/Cretaceous (J/K) boundary—is there perhaps some light at the end of the tunnel? Riv. It. Paleont. Strat. 117 (2), 295–307.

Zakharov, V.A., 2011. Jurassic–Cretaceous boundary and Berriasian GSSP: is there light at the end of the tunnel? (Comments to proposals on the Jurassic–Cretaceous boundary by Berriasian Working Group). News on paleonotology and stratigraphy, Issues 16–17, Supplement to journal Russian Geology and Geophysics 52, pp. 69–866.

Zakharov, V.A., Rogov, M.A., 2005. Nature of the International Stratigraphical Scale and the Volgian Stage (Comments to paper by V.A. Prozorovsky "To the problem of the Volgian Stage"). Stratigrafiya. Geologicheskaya Korrelatsiya (Stratigraphy and Geological Correlation) 13 (5), 129–134 (547–551).

Zakharov, V.A., Rogov, M.A., 2008. Let the Volgian Stage stay in the Jurassic. Russian Geology and Geophysics (Geologiya i Geofizika) 49 (6), 408–412 (541–546).

Zakharov, V.A., Lapukhov, A.S., Shenfil, O.V., 1993. Iridium anomaly at the Jurassic and Cretaceous boundary in northern Siberia. Geologiya i Geofizika (Russian Geology and Geophysics) 34 (1), 102–109 (83–90).

Editorial responsibility: N.V. Sennikov