Stratigraphy and Geological Correlation, Vol. 13, No. 5, 2005, pp. 547–551. Translated from *Stratigrafiya. Geologicheskaya Korrelyatsiya*, Vol. 13, No. 5, 2005, pp. 96–101.

CRITICISM AND DISCUSSION

Nature of the International Stratigraphic Scale and the Volgian Stage (Comments to Paper by V. A. Prozorovsky "To the Problem of the Volgian Stage")

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Received February 24, 2005

Key words: International Stratigraphic Scale, biostratigraphy, Volgian Stage, Tithonian Stage, parallel stages.

The paper by V.A. Prozorovsky "To the Problem of the Volgian Stage" (Prozorovsky, 2005) was published in the Journal *Stratigraphy and Geological Correlation*, Vol. 13, No. 4. Despite a seemingly unifying idea to upgrade persistently the International Stratigraphic Scale (ISS), our opinions in regard to the scale nature are still diverse in principle. Hence, disagreement in assessing the Volgian Stage importance and expediency of parallel stage scales (Zakharov, 2003) is unavoidable. That is why we turn back once more to a more thorough discussion of the ISS principles.

PRINCIPLES OF ELABORATING THE INTERNATIONAL STRATIGRAPHIC SCALE

Prozorovsky recognizes that "paleontological criteria are the most important for dating Phanerozoic rocks," but he actually reduces significance of fossils to a certain physical body, which is comparable in stratigraphic meaning to a rock in the given section. The basic refrain of the Prozorovsky's paper (see introduction to it) is: "a stage is not its fauna." Who would argue against this statement? It is clear that the stage as geological body and fossils buried in that body are not equivalents. Fossils and their host rock represent only a part of the "stage body" or, as Prozorovsky elucidates, "a given sample with organic remains or the respective thin layer" correlated with the ISS unit. Does this mean that a rock sample, say, from the Kimmerigian Stage and large ammonite representing genus *Aulacostephanus* and equal in weight (or volume) to that sample are of similar stratigraphic importance? Stating "biostratigraphic units themselves valid within distribution areas of their fossil assemblages are spatially discrete and characterized by diachronous boundaries," Prozorovsky misses the fact that stratigraphic unit boundaries distinguished by other methods are also diachronous to some extent or another. Recognition of the fact that biostratigraphic units, like taxa determining them, are controlled by facies and taphonomic environments or by diverse opinions of specialists with respect to the taxon range and even by subjective "ability of geologists to find fossils in outcrops" is not a derogation of biostratigraphic method as a tool of chronostratigraphic correlation. Let us imagine incredibility: all the fossils disappeared suddenly from the Earth's layers. What method would be used in this case by geologists to subdivide and correlate (that is of prime importance) the sections composed of different rocks and spaced from each other as far as hundreds or thousands kilometers? For more than 200 years, geologists tested a quantity of methods of determining geological time and correlating sections of the Phanerozoic Erathem. The biostratigraphic method is proved to be the most acceptable. It is effective (precise and reproducible by independent experts), readily working (when urgent decisions, for instance, by drilling are necessary), universal (solves problems of marine and terrestrial stratigraphy), and inexpensive (that is important for this country). We agree with Schindewolf (1975) who assessed stratigraphic value of paleontological method in the following words: "Chronostratigraphy has no its own working method and can be substantiated by biostratigraphic method only."

Fossils are custodians of the event time in geology. The event time is "encoded" in fossils since any biological taxon is characteristic of the time interval it existed in. This is evident from history of d'Orbigny stages and Oppel-zones. At present like at the time of d'Orbigny, a stage is regarded as geological body formed during certain time span. In the ISS, a stage is also regarded as a chronostratigraphic unit. We hold the opinion that "chrono" is imparted to a stage by "bio." A quite different idea is perceptible in Prozorovsky's considerations. He writes that "rapid progress in stratigraphy during the second half of the 20th century" is connected with "new methods (paleomagnetic, geochemical, of cyclic sedimentation, etc.)," which facilitated "reliable correlation of geological sections in different paleobiochores."

In past decades, physicochemical methods actually have been implemented to stratigraphy very actively.

Geologists are pinning their hopes to magnetostratigraphy. Specialists admit an "instant global" impact of the Earth magnetic field reversals on sedimentary sequences. According to unbiased assessment of the method, the "same" polarity zones could be correlated over vast regions first of all by biostratigraphic methods. For instance, the comprehensive biostratigraphic research combined with paleomagnetic study of the Barremian–Aptian boundary deposits in Eastern Europe showed that boundaries of biostratigraphic units are somewhat time-transgressing relative to Chron M0 (Baraboshkin and Guzhikov, 2004). The heterochronous nature of the Chron M0 "biostratigraphic base" is established therefore based on biostratigraphic data. The diachronous time span is found to be insignificant as compared to stratigraphic range of the Aptian. A priori, "biostratigraphic unit" and "magnetostratigraphic chron" solve the same problem, i. e. they correlate deposits. It is important to remember that a "magnetostratigraphic chron" does not determine the geologic age of rocks. The geologic age of rocks is identified by correlation of successive biostratigraphic units. Chronostratigraphic information is encoded in a "biostratigraphic unit," to be more exact, in a fossil (taxon). Each taxon is specific and represents the only object in a rock that is a carrier of geological time.

All the physicochemical methods do not yield however what supporters of the methods want from them. To put it otherwise, geologists who studied Phanerozoic deposits determined geological ages of rocks even without biostratigraphers. It is pertinent to adduce here the opinion of Schindewolf (1975, p. 90) who commented groundless belief of some stratigraphers in potentialities of physicochemical methods: "...it seems strange that the whole branch of science is based on dreams about fulfillment of wishes".

Prozorovsky believes that discrete distribution of fossils throughout sections is the main disadvantage of biostratigraphic method that makes biostratigraphic units appropriate only for approximate correlation of geological bodies and do not secure isochronism of boundaries between chronostratigraphic subdivisions, i.e., the ISS units. With this belief, Prozorovsky advocates activity of the ISS reformers: "... facts stimulated the International Commission on Stratigraphy (ICS) to change substantially (as compared with former practice) the *principles of the ISC structure*." Where is there progress then? Can one see it in the *calpionella* Zone E "inserted" into continuous succession of ammonite zones in attempt to get the relevant reference point for correlation of the Valanginian base (Bulot, 1996)? It is likely that Zone E facilitates easier correlation between the Caribbean and West Mediterranean sections, but what can we do with it in Boreal regions? It is possible for instance to place the GSSP of the Danian base at the level of iridium anomaly, but in any case one has to prove isochronism of this level in different parts of the Earth by biostratigraphic method only, i.e., by tracing the *Globigerina eugubina* Zone.

The undertaken revision of the ISS brings about chaos. One of the advantages of the ISS—its stability is violated. Who will guarantee that new stages, subsystems, and even systems appearing in the scale would be more effective than former ones, validity of which is proved by longstanding practice over the globe? In this connection, Prozorovsky's criticism of the Kilian Group activity (Hoedemaecker *et al.*, 2003) seems strange. He denounces action of a great international group of specialists on ammonites, because "this group determines stratigraphic ranges of stages by a sum of biostratigraphic zones, often changing therewith the traditional ranges, nomenclature and ranks of biostratigraphic units." The group does not revise however the entire scale of the Lower Cretaceous. The case in point is only the revision of ranges and ranks of biostratigraphic units and verification of their boundaries. It is a common procedure like reconsideration of ranges and boundaries of higher-rank units.

In our opinion, there are no chronozones in the ISS structure. In practice, only zonal standards of different regions (biochores) are under correlation like, for instance, the correlation of ammonite successions in the Tethyan (West Mediterranean) and Boreal (North Siberia) realms. In this case, we may speak about correlation of two independent and equivalent scales. An abstract standard combining biozones of different biochores and successions, which are inadequately correlated, seems to be an impracticable hybrid that cannot be observed in any section. This approach may result in loss of some stratigraphic intervals.

It should be pointed out that idea of the abstract global zonal standard (a stage in "synthetic" stratigraphic succession) is popular among some specialists only in this country. Currently used abroad are the Mediterranean, Submediterranean, and Boreal standards, although the term "standard" is often out of use. In practice, there are scales applicable for the Tethyan, Submediterranean, and Boreal biochores. This practice is quite reasonable, since the range of biostratigraphic zone is usually limited by territory of a particular biochore (Mesezhnikov, 1966). A good example is famous zonal standard of V. J. Arkell "Standard Stages and Ammonite Zones of the Jurassic of Northwestern Europe" (Arkell, 1956, Tables 1 and 2). It is remarkable that the Subboreal but not Tethyan succession is quoted in his book as the standard of Jurassic zones. Prozorovsky (2005) uses the same wording. For instance, in his Table 2 there are Tethyan Realm, General Scale, i.e. the Tethyan standard scale is under consideration. It is the other point that correlation of zones presented in the table is mostly improvable or debatable at the least.

Hence, Prozorovsky discredits the key significance of biostratigraphic method for solving problems of chronology of geological events. Nevertheless, he refers to biostratigraphy trying to confirm his views on certain stratigraphic problems. Let us consider this using the Volgian Stage as an example.

THE VOLGIAN STAGE AND ITS POSITION IN THE ISS

Enclosing the word "stage" into inverted commas in his paper title, Prozorovsky (2005) already deprives the Volgian Stage of possibility to be in the ISS. Adherents of this "Russian" stage immediately feel temptation to refer to opinions of violent and competent defenders of "national" Kimmeridgian, Bolonian and Portlandian stages (Cope, 1984, 1993, 1996; Abbink *et al.*, 2001) and, consequently, of our Volgian Stage. Feeling of "novelty in denial" is likely hard to overcome psychologically, since it is impossible to explain otherwise the disregarding of many scientific arguments we have already advanced in defense of the Volgian Stage (Zakharov, 2003).

Discussing stratigraphic ranges of the interval from the lower boundary of terminal stages of the Jurassic to the lower boundary of the Valanginian in the Pan-Boreal and Tethyan–Panthalassa biogeographic superrealms, Prozorovsky refers first to biostratigraphic data, although they are disputable. To prove isochronism of lower boundaries of the Tithonian and Volgian stages, he states that "boundaries of stratigraphic interval under consideration are almost isochronous. The lower boundary corresponds the base of *Gravesia gravesiana* Beds and the upper one to the base of the *Thurmanniceras otopeta* Chronozone. Two stratigraphic levels mentioned above are readily traceable in many marine sections of the Northern Hemisphere." However, species *Gravesia gravesiana* appears not at the base of the Tithonian but in the upper part of its lower zone (Hantzpergue, 1989; Schweigert, 1993). In sections of Swabia and Ardesh, which are regarded currently as candidates for establishing the GSSP of the Tithonian base, *Gravesia* forms are rare or missing. Basal levels of the *Hybonotum* and *Klimovi* ammonite zones do coincide, but their correlation is primarily based on succession of haploceratids and on disappearance of *Aulacostephanus* at this level (Rogov, 2004).

Similar claims can be made against the Valanginian base correlation suggested by Prozorovsky. The idea to place the Berriasian–Valanginian boundary at the top of the *Otopeta* ammonite zone is not of Hoedemaecker only; it is widely accepted at present as reasonable (though disputable) variant of the boundary position. Changes in ammonite assemblages across the Berriasian–Valanginian boundary interval are gradual. First representatives of Valanginian ammonite genera appear in the *alpinensis* Subzone, although *boissieri* forms still occur in the *Otopeta* Zone (Aguardo *et al.*, 2000; Wippich, 2003). Nevertheless, neither the Berriasian nor Valanginian GSSP has been established yet. A good correlation between Submediterranean and Boreal sequences at the level in question would not suffer irrespective of the boundary position at the base or top of the *Otopeta* Zone.

In support of his own standpoint, Prozorovsky quotes words of G.Ya. Krymholts: "The acceptance of two stages (Tithonian and Volgian, *V.Z.* and *M.R.*) with identical levels of lower and upper boundaries, but containing fossils of different composition, is methodically incorrect, admissible only temporarily." These words of Krymholts do not support the standpoint of Prozorovsky. Krymholts assumed identical ranges of the Tithonian and Volgian stages, whereas Prozorovsky is of the other opinion. He writes about mismatch of the Volgian and Tithonian boundaries! Let us quote Krymholts (1982, p. 171): "A specific feature of the national stage scale for the Jurassic System is discrimination of the Volgian Stage in vast areas that belonged to the Boreal biogeographic realm in the Jurassic. We believe this stage can be temporarily retained parallel to the Tithonian, and likely a plenty of time will elapse prior to proper elaboration of the Tithonian zonal scale and accomplished Tithonian–Volgian zonal correlation." It is untimely to speak now about zone-by-zone correlation of the Volgian and Tithonian and about possibility to define substage boundaries of one stage within the other. Analysis of Boreal and Tethyan ammonites jointly occurring in the Volgian and Tithonian stages shows that boundaries well distinguishable within one stage are not traceable within the other. In Subboreal sequences for instance, boundary between the lower and middle Tithonian is likely situated close to the base of the *Tenuicostata* Subzone (Rogov, 2004), and boundary between the middle and upper Tithonian is probably close to the base of *regularis* faunal horizon of the *Panderi* Zone. None of these levels is traceable in the Boreal (Siberian) zonal scale. The middle–upper Volgian boundary is well traceable in distribution areas of Boreal deposits, but there is no strong evidence that this level corresponds to the Tithonian–Berriasian boundary in Tethyan sections. According to most recent data, basal interval of the Ryazanian Stage (the *Rjasanensis* Hyperzone) may correspond to the lower Berriasian, probably, to the *Grandis* Zone (Mitta, 2005). This suggests that at least the greater part of the upper Volgian Substage is correlative with the Tithonian. Thus, the problem of Boreal–Tethyan zonal correlation within the Jurassic–Cretaceous boundary interval remains to be solved.

PARALLEL STAGES AT THE JURASSIC–CRETACEOUS BOUNDARY LEVEL: FEASIBLE SOLUTION OF THE PROBLEM

Paper by Prozorovsky dedicated to the Volgian "Stage" concerns the Berriasian as well. He states that it is "unreasonable to use such notions as the Berriasian and Boreal Berriasian." Since it is untimely to speak about coincidence of Boreal and Tethyan ranges of the Berriasian Stage, the conference of International Working Group on Jurassic–Cretaceous Boundary recommended to add the term "Boreal" to the name of the Cretaceous lower stage (Zakharov, 1988). If range coincidence of the Ryazanian Horizon and Berriasian Stage would be proved, then we should return to the Ryazanian Stage instead of the "Boreal Berriasian" in distribution areas of Boreal deposits. As the convincing

correlation of Jurassic–Cretaceous boundary intervals is unavailable, we believe that parallel stages should be admitted for use in the high-rank biochores. The idea to replace the "Volgian Stage" by the "Tithonian Stage" in the Boreal realm is misleading, as we think. Let us consider, for example, the Explanatory Note to the sheet R-(45)-47, Norilsk, of the State Geological Map of Russia, scale 1:1 000 000 (Semerikov, 2000). According to ISC recommendations, local geologists have to distinguish the Tithonian and Berriasian instead of Volgian and Ryazanian stages (or Boreal Berriasian) in the area, where Tithonian and Berriasian fossils are missing! They place the Tithonian–Berriasian boundary above the upper Volgian Substage. We agree with Prozorovsky who states regarding the stage nomenclature: "To avoid possible confusion, units of each category should be designated by their own names different from the others." However, we cannot agree with him, when he suggests that the Volgian Stage should be replaced by the Tithonian right now in all the stratigraphic schemes of Russia. We think that until solution of the problem of zonal Boreal–Tethyan correlation of Jurassic–Cretaceous boundary deposits, the Tithonian and Berriasian stages of the ISS should be retained for the Tethyan–Panthalassa superrealm parallel to the Volgian and Ryazanian stages applicable in the Pan-Boreal superrealm.

The ISS is a chronostratigraphic standard in geology usable for correlation of the stratisphere segments and enabling relative timing of geological events (earlier, later, simultaneously), if they left "traces" recorded in particular (real) sections. It seems unreasonable therefore to introduce a new category of interregional stratigraphic units in addition to the ISS stages, as Prozorovsky suggests. In any case, it is unclear why the suggested procedure "will make the entire stratigraphic nomenclature more flexible, disagreements unnecessary, and correlation of sections more reliable and detailed." Introduction of new category of stratigraphic units can hardly enhance validity of correlation, to put it mildly. Undoubtedly the innovation will bring about a further confusion.

It should be noted that idea to operate with parallel stages in separate spacious biochores likely originated in Russia (Yuferev, 1969). A similar suggestion with regard to the Kimmeridgian Stage less problematic than the Volgian Stage was expressed recently. In open letter to members of the Working Group, March 19, 2004, J. Callomon, well-known expert on biostratigraphy and Jurassic ammonites, suggested to retain the Kimmeridgian in the Subboreal scale only and recommended to use the Boreal Kimmeridgian and Sequanian in other regions.

Let us try to answer the question whether stratigraphic units of the ISS are natural or artificial. At present, there are supporters of both viewpoints. "Geological (read stratigraphic, *V. Z.* and *M. R.*) subdivisions represent only artificial units distinguished for convenience of research" (Renevier, cited after Leonov, 1973, p. 48). "Stratigraphic units represent formally established segments of an ideal section of the Earth's crust", echoes Prozorovsky to the above saying (from his letter of February 19, 2004, to Zakharov). However, if the ISS stratigraphic units were formal, the Phanerozoic scale would be divided into identical segments (for convenience) like a metric ruler. In the ISS, even stratigraphic subdivisions of the same rank are not equal in duration and enclose different number of subordinate units. For instance, erathems are not equal in range and have not identical number of systems, which in turn consist of two, three or even four series. The latter are divided into unequal number of stages, which include different number of zones and, as it is getting clear now, different stratigraphic ranges are typical not only of stages but of adjacent phylozones as well. The Phanerozoic stage scale is surely synthetic but not formal at all. Since the moment of creation, it was based on stages of biota development. These stages first established practically in one region (Western Europe) have been traced with time (during 150 years) in subglobal regions or over the globe by means of biostratigraphic method. Thus, efficiency of biostratigraphic method for the Phanerozoic global correlation is established empirically. Exactly this approach is used to establish chronology of all the Phanerozoic events and hierarchy of the ISS stratigraphic units. The stage is interpreted therewith as an elementary chronostratigraphic unit (*International...*, 1976, 1978, 1994, 1999, 2002). Each particular stage is determined in any region of the Earth primarily by the sum of biostratigraphic zones enclosed in it. Sokolov (1971) wrote: "At all the levels of hierarchical system of the Phanerozoic stratigraphy, boundaries of units should be determined only by the taxon-range zones... Only this principle secures integrity and stability of the chronostratigraphic scale".

The Earth's biosphere evolved under influence of outer and inner factors. The biosphere evolution, like all the processes on the Earth, progressed irregularly and periodically. Evolutionary stages of biota recorded in the Earth's strata impart key significance to paleontological method, when we divide sedimentary sequences into stratigraphic units. As the evolution rate of biota has been irregular, stratigraphic units are naturally uneven in range. This does not mean that biostratigraphic method cannot function as a tool of geologic age determination. This method is not exhausted so far. Biostratigraphic basis is principal one in current development of detailed stratigraphy (subdivision of zones and subzones into biohorizons and distant correlations based on the latter), and this is the main point.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 03-05-64297.

Reviewers Yu.B. Gladenkov and K.I. Kuznetsova

REFERENCES

1. O. A. Abbink, J. H. Callomon, J. B. Riding, *et al.*, "Biostratigraphy of Jurassic–Cretaceous Boundary Strata in the Terschelling Basin, the Netherlands," Proceed. Yorkshire Geol. Soc. **53**, Pt. 4, 275–302 (2001).
2. R. Aguado, M. Company, and J. M. Tavera, "The Berriasian/Valanginian Boundary in the Mediterranean Region: New Data from the Caravaca and Cehegin Sections, SE Spain," Cretaceous Res., No. 21, 1–21 (2000).
3. W. J. Arkell, *Jurassic Geology of the World* (Oliver et Boyd, Oxford, 1956).
4. E. Yu. Baraboshkin and A. Yu. Guzhikov, "Boreal and Tethyan Cretaceous: Problems of Isochronism of Biostratigraphic Boundaries and Elaboration of General Stratigraphic Scale," in *Proceedings of the Second All-Russia Conference on the Cretaceous System of Russia: Problems of Stratigraphy and Paleogeography, St. Petersburg, Russia, 2004* (St. Petersburg State University, St. Petersburg, 2004), p. 11 [in Russian].
5. L. Bulot, "The Valanginian Stage," Bull. Inst. Roy. Sci. Natur. Belgique Sci. d.1. Terre, No. 66, 7–10 (1996).
6. J. C. W. Cope, "The Terminal Jurassic Stage," in *Intern. Symp. Jurassic Stratigr., Erlanger, Denmark*, 1984 (Geol. Surv. Denmark, Copenhagen, 1984), pp. 445–456.
7. J. C. W. Cope, "The Bolonian Stage: an Old Answer to an Old Problem," Newsl. Stratigr., No. 28, 151–156 (1993).
8. J. C. W. Cope, "The Role of the Second Standard in Stratigraphy," Geol. Mag. **133** (1), 107–110 (1996).
9. P. Hantzpergue, *Les Ammonites kimméridgiennes du haut-fond d'Europe occidentale. Biochronologie, Systématique, Evolution, Paléobiogéographie. Cahiers de Paléontologie* (C.N.R.S., 1989).
10. Ph. J. Hoedemaecker, S. Reboulet, M. B. Aguirre-Urreta, *et al.*, "Report on the First International Workshop of the IUGS Lower Cretaceous Ammonite Working Group, the 'Kilian Group'," Cretaceous Res., No. 24, 89–94 (2003).
11. *International Stratigraphic Guide*, Ed. by H. D. Hedberg (J. Willey & Sons, New York, 1976).
12. *International Stratigraphic Guide*, Ed. by H. Hedberg (Mir, Moscow, 1978; J. Willey & Sons, New York, 1976).
13. *International Stratigraphic Guide. Second Edition*, Ed. by A. Salvador (IUGS, Geol. Soc. America, Colorado, 1994).
14. *International Stratigraphic Guide*, Ed. by M. Murphy and A. Salvador, Episodes **2** (4), 255–271 (1999).
15. *International Stratigraphic Guide*, Ed. by Yu. B. Gladenkov (GEOS, Moscow, 2002) [in Russian].
16. G. Ya. Krymholts, "Conclusion: Zones of Jurassic System in the USSR," Tr. Interdep. Stratigr. Comm., No. 10, 170–174 (1982).
17. G. P. Leonov, *Fundamentals of Stratigraphy* (MGU, Moscow, 1973) [in Russian].
18. M. S. Mesezhnikov, "Zonal Subdivision of Lower Kimmeridgian of the Arctic Region," Doklady Akad. Nauk SSSR **178** (4), 912 (1968).
19. V. V. Mitta, "New Data on the Age of the Ryazanian Stage Lower Boundary," Stratigr. Geol. Korrelyatsiya **13** (5) (in press).
20. V. A. Prozorovsky, "To the Problem of the Volgian 'Stage'," Stratigr. Geol. Korrelyatsiya **13** (4) (in press).
21. M. A. Rogov, "Ammonite-Based Correlation of the Lower and (*Panderi* Zone) Volgian Substages with the Tithonian Stage," Stratigr, Geol. Korrelyatsiya **12** (1), 41–66 (2004) [Stratigr. Geol. Correlation **12** (1), 35–57 (2004)].
22. M. A. Rogov, "The Russian Platform as a Key Region for Volgian/Tithonian Correlation: A Review of the Mediterranean Faunal Elements and Ammonite Biostratigraphy of the Volgian Stage," Riv. Itali. Paleontol. e Stratigrafi. **110** (1), 321–328 (2004).
23. G. Schweigert, "Die Ammonitengattungen *Gravesia* Salfeld und *Tolvericeras* Hantzpergue und ihre bedeutung für den Grenzbereich Oberkimmeridgium/Untertithonium im Schwäbischen Jura," Geol. Bl. NO-Bayern. **43** (1–3), 167–186 (1993).
24. O. H. Schindewolf, *Stratigraphie und Stratotypus*, (Akademie Wiss. Literatur, Mainz, 1970; Mir, Moscow, 1975).
25. A. A. Semerikov, "Jurassic System," in *State Geological Map of the Russian Federation, Sheet R-(45)-47, Norilsk, Scale 1 : 1 000 000. Explanatory Notes* (VSEGEI, St. Petersburg, 2000), pp. 116–123.
26. B. S. Sokolov, "Biochronology and Stratigraphic Boundaries," in *Problems of General Regional Geology* (Nauka, Novosibirsk, 1971), pp. 155–178.
27. M. G. E. Wippich, "Valanginian (Early Cretaceous) Ammonite Fauna from the Western High Atlas, Morocco, and the Recognition of Western Mediterranean 'Standard' Zones," Cretaceous Res., No. 24, 357–374 (2003).
28. O. V. Yuferev, "Paleobiogeographic Belts and Units of the Stage Scale," Izv. Akad. Nauk SSSR. Ser, Geol., No. 5, 77–84 (1969).
29. V. A. Zakharov, "Problems of the Jurassic–Cretaceous Boundary," Geol. Geofiz. **38** (4), 140–141 (1988).
30. V. A. Zakharov, "In Defense of the Volgian Stage," Stratigr. Geol. Korrelyatsiya **11** (6), 58 (2003) [Stratigr. Geol. Correlation **11** (6), 585–593 (2003)].