

The problem of the Precambrian–Cambrian boundary

A. Yu. ROZANOV & B. S. SOKOLOV

In the last few years the problem of the lower boundary of the Cambrian has been dealt with in dozens of works which considered not only the history of the question but all the current material available. It is a subject discussed at many national and international symposia. Although great progress has been achieved in drawing together the points of view on the position of the boundary (compare the results of the symposia held in Paris in 1958 with that in 1974), the range of different opinions still remains wide, particularly with regard to the zonal scales (for example, in Siberia, from the base of the Nemakit–Daldyn horizon up to the base of the beds with *Fallotaspis*). First, therefore, we give consideration to those questions which often constitute a stumbling block. It seems necessary to make a reservation that some of the difficulties arising may undoubtedly be referred to as purely psychological.

Considerable progress in selecting approaches to the solution of the Precambrian–Cambrian boundary problem was stimulated by a rejection of the principle of using abiotic historical geological methods (such as palaeoclimatology, tectonics and the like) and a firm preference being given to biostratigraphy as the discipline which justified itself in the solution of Phanerozoic problems.

However, even such a strictly definite approach has not saved us from a considerable divergence of views: first, the biostratigraphic data themselves are still not used uniformly (for example appraisal of the first appearance of various forms); secondly, a tendency is still strong to consider the trilobites as the ‘orthostratigraphic’ group of the Cambrian for solving this problem; thirdly, on the one hand, a skeletalized fauna is made a fetish, on the other hand, this notion is interpreted quite differently.

It is the usage of the notion ‘skeletalized fauna’ that constitutes one of the most complex questions. Though a mutual understanding of different points of view is not necessarily a key to the solution of the problem, it could certainly be a means of eliminating seemingly important disagreements.

In fact, some investigators use the term ‘skeletalized fauna’ for any hard form of tubular or shell-like dwelling-place as well as for spicules of sponges and tests or shells of protistids. If we followed this interpretation, we could naturally confirm the existence of ‘skeletalized fauna’ in the Vendian and the Judoma complex, or at least in their upper parts.

Those who reject the tubes of polychaetes and analogous forms as a physiologically based hard shell skeleton, point to the absence or extreme scarcity of normal skeletalized forms of invertebrates in the Vendian. But it is remarkable that the investigators of either group cite the same lists of fossils in the upper Vendian bed (Yudomian). For these upper Vendian beds, including the Nemakit–Daldyn horizon (Manykai as termed by other authors), both groups of researchers listed usually sabelliditids, angustiocreids (*Anabarites*) and very peculiar *Protohertzina*. Thus, in actual fact we have no contrasting faunal groups here, the point is that some consider the most abundant tubular organisms as a specific group comparable with other skeletalized organisms of the Phanerozoic.

A lot of confusion was caused by the notion ‘sudden appearance of the skeletalized fauna’. The supporters of the view that different groups of organisms developed their capacity to build skeletons gradually point to the later appearance, for example, of trilobites and some other organisms, forgetting that it was those same investigators who drew attention to the known ‘suddenness’ of the origin of the true skeletalized fauna who demonstrated both the late occurrence of trilobites and the early appearance of tubular organisms (*Anabarites*,

sabelliditids) and problematic *Protohertzina*. But these two aforementioned assumptions do not refute the third one: namely, that the wide ability for skeleton-building appears as a fact among whole series of organisms at more or less the same time, in a geological sense. It is this well known fact that has caused the widespread notion of the early Cambrian 'population explosion'.

Accepting the Phanerozoic principle for the determination of the Precambrian–Cambrian boundary, we should not neglect the fact that the organic world developed in a very specific way, during this transitional early stage of formation of the Phanerozoic faunas, and it requires a particularly non-standard approach for consideration of the whole problem. The peculiar character of the faunas during the transitional period from late Precambrian to Cambrian, may be interpreted differently, as has been done by V. E. Savitsky *et al.* (1972, 1975). A. Yu. Rozanov (1976) and others, but it is impossible not to see this specific character of the Vendian–Cambrian stage.

Proceeding from the accepted principle and the subject of this paper, it appears possible to formulate the following thesis:

only the lower boundary of a real well-correlated zone (oppelzone), distinguished on the basis of skeletalized faunas, may be taken as a Precambrian–Cambrian boundary.

This thesis follows inevitably from the sum of the data accumulated so far for Phanerozoic stratigraphy. In this connection, understanding of the real value of previously established zonal units of the basal Cambrian (and the top of the Precambrian), is undoubtedly of paramount importance.

There are probably no reasons to doubt the different ranks and different correlation values of such notions as the generalized biochronological zone '*Pteridinium simplex*–*Dicksonia costata*' in the Vendian on the one hand, and '*Dokidocyathus regularis*' zone traced in numerous Cambrian sections of the stratotypical region in Siberia, on the other hand. This is a very important fact, for only by descending from the top of the stratigraphic section downwards from the well-established accurate short-timed zones can we rest our attention on the base of one of the oldest zones, and, only then does it become evident that it is this zone that can be taken as a true boundary standard providing a maximum accuracy of correlation. A principle of mutual agreement may be attained here rather easily because the number of key points in a section cannot at this level be large. It is, thus, unlikely that a selection from key points within a continuous sequence of Tommotian zonal faunas (for example, between the *sunmaginicus* and *regularis* zones) will be practicable. Furthermore, it might introduce error to assign the abundant and undoubtedly 'Cambrian' fossils into the 'Precambrian'. Besides, experience accumulated so far shows that we have established this minutely subdivided zonal scheme of the pre-trilobite beds only in the Siberian Platform. This, naturally, places boundaries between the zones of the Tommotian stage into the category of regional boundaries and reduces their correlation value for remote areas almost to nothing. In this case, we will most likely fail to establish criteria clear enough to determine these inter-zonal Tommotian boundaries in other regions.

The supporters of the establishment of the Precambrian–Cambrian boundary within a continuous trilobite succession could suggest a boundary between the *Profallotaspis* and *Fallotaspis* zones. But this suggestion is unlikely to be accepted either. First, in Siberia this boundary may be established only in a few places; secondly, and most important, all the pre-fallotaspid Tommotian fauna is typically 'Cambrian'. Thus the boundary would appear artificial, though formally it is connected with a transition in one group of organisms.

A lot of agitation has been aroused recently by B. B. Shishkin and later by N. P. Meshkova and others, who found pre-Tommotian faunas in the sections of the Western

Anabar district. Here, the typically Yudomian (Vendian) Starotretchenskaya Formation is overlain by a characteristic two-member section. V. E. Savitsky called the lower succession of rocks the Nemakit–Daldyn horizon. V. V. Missarzhevsky found the top of this succession to contain a marker horizon of grey limestones called by him the Koril member. Even at the time of this discovery A. Yu. Rozanov, V. V. Missarzhevsky and others (1969) pointed to the presence of sabelliditids and *Anabarites trisulcatus* in the Nemakit–Daldyn zone, which somewhat later were supplemented by *Protohertzina* (Missarzhevsky, 1973). The beds beginning from the top of the Koril member were referred to the *Aldanocyathus sunnaginicus* Zone and were naturally supposed to be the base of the Tommotian stage in the sense that it was accepted for the S of the platform (Rozanov & Missarzhevsky, 1966; Rozanov & Missarzhevsky *et al.* 1969).

The findings of Shishkin and others led some investigators to the conclusion that this represented the discovery of a new abundant assemblage of pre-Tommotian skeletalized fossils. But in fact, these findings only give additional palaeontological characteristics to the Nemakit–Daldyn horizon. I. T. Zhuravleva (1975) contended that the Nemakit–Daldyn horizon had to be an analogue (complete or partial) of the *Al. sunnaginicus* Zone. This point of view awaits analysis. It might turn out that the correlation between the N and S sections of the Siberian platform is to some extent erroneous. The solution of this question is to a certain extent the key for real appraisal of the significance of the level of the *sunnaginicus* Zone base.

The difficulties which occurred when a key point was taken at the base of the *sunnaginicus* Zone in the Ulakhan–Sulugur section (the Aldan River), (Cowie & Rozanov, 1973) brought about many doubts as to the possibility of using the Lena–Aldan region as a type region for the Precambrian–Cambrian boundary, since there is a break between the ‘Pestrosvet’ (many-coloured) and Yudomian Formations. However, it seems to have been disregarded that the Precambrian–Cambrian Boundary Working Group (I.U.G.S.–I.G.C.P.) recommended the study of four (not one) working reference points (including two from the Aldan) and, furthermore, the recommended points included one from the Ulakhan–Sulugur section, at the base of the *sunnaginicus* Zone. This decision was dictated by fairly understandable reasons. First, the Working Group field excursions could not be long enough to make a comprehensive assessment of the origin of the key ‘layer No. 8’; secondly, the break observed at the base of the ‘Pestrosvet’ (many-coloured) Formation may not be so important if the fauna from ‘layer No. 8’ is *in situ*, and lastly the presence of a fauna in the dolomite ‘beds 9–11’ (also of the Yudoma Formation) cannot be interpreted otherwise than grounds for further studies of the Ulakhan–Sulugur section with an attempt to use it as a possible standard even at the level of the base of the *sunnaginicus* Zone.

However, the absence of unique recommendations after the Precambrian–Cambrian Boundary Working Group’s visit in 1973 brought about a natural wish to try to find other approaches to the solution of the problem of the Precambrian–Cambrian boundary. One of the approaches, according to B. M. Keller, is a search for a section containing both the Ediacarian and Tommotian faunas. But it is clear that, first, these biota represent quite different ecological types; second, they fail to have an evolutionary association since they represent different taxonomic types and classes. Whatever is the relation between the Ediacarian and Tommotian biotas, the position of the boundary cannot change as the problem should be solved on quite a different basis. If the base of the *sunnaginicus* Zone, like any other zone evidenced by a skeletalized fauna, is formally taken as the Precambrian–Cambrian boundary, the presence of an Ediacarian fauna in beds either above or below this zone, would not change the position of the boundary. In that case the relationship of these two biotas is of great significance only for determination of the age of the Ediacarian

and other Vendian biotas and their correlation. Formulated in this way (pursuing the search for the combined presence of Ediacarian, Vendian and Tommotian biotas) we have confusion of two problems – the one of stratigraphical division and the establishment of the boundary standard and the other of correlation. It is quite another thing if we make an attempt to find the boundary within a sequence of rocks characterized by non-skeletalized fossils. In principle this formulation of the problem is acceptable. However, we know of no sections in the world which contain the required sequence of non-skeletalized invertebrates.

Thus if we restrict ourselves to the Siberian model of the Precambrian–Cambrian (Vendian–Cambrian) boundary, the most acceptable boundary solution would be the base of the ‘complete’ *sunaginicus* Zone as termed by one of the authors of this paper (Sokolov, 1974) and we are approaching this level of exactness now (see the review of opinions by V. V. Khomentovsky in 1976). However, the problem of the stratigraphic position of the Nemakit–Daldyn horizon remains to be solved. We believe it to be pre-*sunaginicus*. Its correlation, on the basis of sabelliditids (tubular organic mineralized structures) and of vendotenids resembling *Tyrasetaenia*, with the Rovno horizon of the Baltic series of the Russian platform necessitates a further discussion of the possibility of drawing the Vendian–Cambrian boundary at the base of or within the limits of the Nemakit–Daldyn horizon. Non-equivalence between the basal parts of the Baltic state of the Russian platform and the Tommotian stage of the Siberian platform is more evident now than it was before, however. This question has already no significance in principle for the final choice of the Precambrian–Cambrian boundary on the basis of Phanerozoic stratigraphical concepts.

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Palaeontological Institute of U.S.S.R. Academy of Sciences
Maronovsky per 26
Moscow B-49
U.S.S.R.