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COMMENTS ON THE DEFINITION OF THE ORDOVICIAN-SILURIAN BOUNDARY

In recent years, progress has been observed in the investigation of the Ordovician-Silurian boundary and correlation of the boundary sections all over the world. Under the guidance of a special working group, discussions on the system boundary are approaching the final stage. As for the definition of the boundary, we are faced with the choice of a faunal group (graptolites or conodonts), zonal level (*persculptus*, *acuminatus*, *oldhamensis*), and stratotype (South Scotland, or Anticosti). Many workers studying the comparative biostratigraphic data use the Kazakhstan evidence concerning the co-occurrences of the benthic association of the *Hirnantia* type and the *persculptus* Zone graptolites, which have been discovered there (Граница ордовика..., 1980). Now some contradictions in estimating data on the Kazakhstan graptolite occurrences have come to light. This fact obliges us to return to that problem and, using likewise the corresponding new evidence on Northeast USSR, clear up some points which seem disputable, and express our opinion on the above boundary.

In 1969 N. Mikhailova identified for the first time *Glyptograptus persculptus* (Salter) from the beds now assigned to the lower part of the Durben Regional Stage (Граница ордовика..., 1980, exp. H-66, Fig. 7). At that time two specimens were sent to R. B. Rickards, who approved the identification (Михайлова, 1970, 1973). Later graptolites were collected from several localities and at different stratigraphical levels within the Durben Regional Stage. When examining all the collections from the lower part of the Durben Regional Stage, from where *G. ? persculptus* was earlier reported (exp. H-66), T. Koren and her colleagues described *G. ? persculptus* forma A and *G. ? aff. persculptus* (Salter) (Граница ордовика..., 1980, Fig. 7). The newly found graptolites from the middle and upper parts of the Durben Regional Stage were assigned to *G. ? persculptus* forma B. There was mentioned «a close morphological similarity in the rhabdosome and thecal shape in *G. ? persculptus* forma A and *Climaeograptus ? extraordinarius* group from the Tirehtjakh Regional Stage in Northeast USSR» (Граница ордовика..., 1980, p. 149). The latter is represented in the Kolyma collections by flattened and often deformed specimens as compared with the 3-D specimens in Kazakhstan. The different state of preservation of the specimens makes it extremely complicated to define these morphologically simple and similar diplograptids with no clear diagnostic features, such as thecal spines, etc.

Using the type material from the Ina River section in Northeast USSR, T. Koren and R. Sobolevskaya concluded the identity of *C. ? extraordinarius* and *G. ? persculptus* forma A as well as *G. ? aff. persculptus*. This enabled them to correlate the lower part of the Durben Regional Stage with the Q member on the Mirny Creek. At the same time the identity of *G. ? persculptus* forma B and *Glyptograptus bohemicus*

Marek was discovered by T. Koren when comparing the Kazakhstan species with the original photographs (type series) and a latex copy of a specimen in relief (Pancrač) of *G. bohemicus* kindly sent by L. Marek. In addition, the study also included numerous specimens of *G. bohemicus* from the type locality (Praha-Nova-Ves), collected by I. Nikitin jointly with L. Marek. Comparison of *G. ? persculptus* forma B and *G. bohemicus* Marek with *G. ? persculptus* (Salter), received on loan from R. B. Rickards (Wales, Abergwesyn) and collected from the Upper Tirekhtjakh Regional Stage allowed the assignment of all the above-mentioned forms to the species *G. ? persculptus* (Salter) (Граница ордовика..., 1980, p. 146, see synonymy). The specimens assigned to *G. bohemicus* Marek and *G. ? persculptus* (Salter) are identical in the thecal shape, degree of genicular curvature and in the inclination of the supragenicular wall, in the position of the base of the median septum and in the rhabdosome size, as well as in thecal frequency. The results of investigations including the identity of *G. ? persculptus* forma A and *C. ? extraordinarius* as well as *G. ? persculptus* forma B, *G. bohemicus* Marek and *G. ? persculptus* (Salter) were demonstrated to R. B. Rickards who agreed to these conclusions (Rickards, Riva, 1981, p. 226). So, the concept of the identity of *G. ? persculptus* in Kazakhstan with *C. ? extraordinarius* (Rickards, 1982, personal communication to T. Koren) is correct only so far as *G. ? persculptus* forma A (Граница ордовика..., 1980, p. 147, Pl. XLII, Figs 3—6; Pl. XLIII, Fig. 1; Pl. XLIV, Figs 1—6; Text-Fig. 44, a—k) and *G. ? aff. persculptus* (p. 151, Pl. XLVII, Figs 1—3) are concerned. The identification of *G. ? persculptus* forma B (Pl. XLV, Figs 1—6; Pl. XLVI, Figs 1—8; Text-Fig. 45 a—ж) and *G. ? persculptus* (Salter) from Great Britain does not arouse any doubt.

Unlike in Great Britain, the *Hirnantia* fauna in the Ordovician-Silurian boundary sections in Kazakhstan and Northeast USSR is not confined to the *extraordinarius* Zone alone, but goes through the whole *persculptus* Zone. It is worth mentioning that the richest and most typical *Hirnantia* fauna occurs in association with *G. ? persculptus* (Salter) (= *G. ? persculptus* forma B; Граница ордовика..., 1980, Fig. 7, exp. 287) but not with *C. ? extraordinarius* (Sob.) (= *G. ? persculptus* forma A and *G. ? aff. persculptus*, 1980).

In the sections studied in Northeast USSR (Граница ордовика..., in print), the stratigraphical interval of the *Hirnantia* beds (member Q on the Mirny Creek) coincides with two graptolite zones — *extraordinarius* and *persculptus*, as established by M. Oradovskaya. On the Mirny Creek and Neznakomka River, the highest-lying *Hirnantia* fauna was found at 3—5 m below the base of the *acuminatus-ascensus* Zone. Along the Mirny Creek the richest *Hirnantia* fauna is associated with *G. ? persculptus* in the lower part of the eponymous Zone, 27 m thick. In the uppermost part of this zone, 15 m thick, as well as in the underlying *extraordinarius* Zone, there occur single representatives of the characteristic brachiopod assemblage. The boundary of the *Hirnantia* and *Skenidioides* beds coincides with that of *persculptus* and *acuminatus* (Граница ордовика..., in print).

Within the *extraordinarius* and *persculptus* Zones trilobites belonging to *Dalmanitina* and *Mucronaspis* were identified by M. Apollonov and M. Chugayeva. They are typical of the late Ordovician *Dalmanitina* association and unknown in the section studied from both underlying and overlying beds. In the Mirny Creek and Kharkindzha River sections, the highest occurrences of *Dalmanitina olini* Temple and *Dalmanitina* sp. indet. are 1—3 m below the base of the *acuminatus-ascensus* Zone, together with the last *G. ? persculptus* (Salter). A new trilobite *Acer-*

naspis fauna was found for the first time 0.2—0.3 m above the base of the *acuminatus-ascensus* Zone coinciding with the lower boundary of the Chalmak Regional Stage.

Many researchers assume that one of the zonal boundaries in the graptolite sequence should be used in defining the level of the standard boundary of the systems. If the base of the *persculptus* Zone is used as the Ordovician-Silurian boundary, its definition according to the appearance of zonal species will present great difficulties. Species *Glyptograptus* ? *ojsuensis* Kor. et Mikh. (the uppermost part of the *supernus* Zone), *C.* ? *extraordinarius* (Sob.), *C.* ? ex gr. *extraordinarius* (the eponymous Zone), and *G.* ? *persculptus* occur in chronological succession in Northeast USSR and in Kazakhstan. In China, *G.* ? *ojsuensis*, *C.* ? *extraordinarius* (open nomenclature), and *Diplograptus orientalis* seem to have broader stratigraphical ranges in the Ordovician-Silurian boundary sections, having been recorded from the uppermost *Diceratograptus-Paraorthograptus*, *bohemicus*, and *persculptus* Zones. The latter two are characterized by almost identical graptolite assemblages. Such contradictions have most probably been caused by the different mode of preservation of specimens and different taxonomic approach in the identification of morphologically similar diplograptids. The graptolites known from the *extraordinarius* and *persculptus* Zones badly need a taxonomic revision. Their identifications made in different regions show that one and the same form can be assigned to different species, to say nothing of their generic assignment: *Glyptograptus*, *Climatograptus* or *Diplograptus*. With the above in view, Acad. B. Sokolov suggested during the Ordovician-Silurian boundary meeting held in Khabarovsk in 1979 that R. B. Rickards and T. Koren might make such a revision; however, that revision has not yet been completed. So now it is premature to make any definite time correlations of the *G.* ? *persculptus* beds in different regions in anticipation of a good potential for the further subdivision of the eponymous zone in the long turn.

Today only a general correlation of beds assigned to the *persculptus* Zone in different regions is possible. There is a limited number of sections with an exactly known range of *G.* ? *persculptus*, where a continuous succession with the underlying *extraordinarius* Zone can be established. If we take into account the experience of the Silurian-Devonian boundary definition and consider the geographical extent of the level chosen as an important criterion, then the zonal boundary between the *extraordinarius* and *persculptus* Zones does not seem to fit the definition both in the graptolite and the shelly strata.

As far as evolutionary changes in graptolites are concerned, the importance of the zonal boundary is inferior to that of the base of both the *extraordinarius* and *acuminatus* Zones. The *persculptus* Zone assemblage is not richer than the assemblage in the preceding *extraordinarius* Zone, and it is dominated by transient graptolite species. A single occurrence of *Monograptus ceryx* Rick. et Hutt (Rickards, Hutt, 1970), considered now as the oldest monograptid (in the *persculptus* Zone) cannot confirm the conclusion that this zone heralds the subsequent Llandovery evolutionary explosion. Monograptids are extremely rare in the succeeding *acuminatus* Zone, and they become an important element of graptolite associations starting from the base of the *vesiculosus* Zone, earlier discussed (Elles, 1922) as a possible Ordovician-Silurian boundary level.

There is no doubt as to the reliable definition of the base of the *acuminatus* Zone owing to the clear-cut evolutionary and morphological changes in graptolite associations traceable almost throughout the world. This is marked by the synchronous appearance of *Akidograptus ascensus*

and *Parakidograptus acuminatus* in the sections (Kazakhstan, Central Asia and other areas). The beginning of akidograptid successions either with *A. ascensus* or with *P. acuminatus* in some sections does not imply the different chronological appearance of these diagnostic akidograptid species, and can most probably be explained by the incompleteness of sampling.

A peculiar assemblage of shelly fossils was recently discovered in Northeast USSR at the base of the *acuminatus-ascensus* Zone (the base of the Chalmak Regional Stage, beds with *Skenidioides* and *Acernaspis*; Орадовская, Соболевская, 1979; Корень et al., 1979; Граница ордовика..., in print). The representative shelly fauna dated by the *acuminatus* Zone graptolites is unknown elsewhere. However, in the *persculptus* Zone J. E. Hutt (1974) referred to the occurrences of abundant shelly fauna (brachiopods, trilobites, crinoids, etc.) in the western English Lake District, Yewdale Beck section including *Kaysrerella* (sensu Temple), *Kinnella*, *Ravozetina* and *Paromalomena* (Brenchley, Cocks, 1982). *Kaysrerella* also occurs in the Ojsu limestones in Kazakhstan as *Enteletacea* gen. et sp. indet., the uppermost part of the *supernus* Zone (Граница ордовика..., 1980, p. 44, Pl. X, Figs 13—15).

Conclusions and recommendations

A. Up to now there are no new data which cast doubt on the coincidence of the *Dalmanitina-Hirnantia* stratigraphical range with the *extraordinarius* and *persculptus* Zones, established in Kazakhstan and Northeast USSR.

B. The advantages of the base of the *acuminatus* Zone as a boundary of the Silurian system are obvious from the point of view of evolutionary, morphological and geographical criteria. Its practical use within extensive areas is not to be discarded.

C. The boundary between *extraordinarius* and *persculptus* Zones should not be proposed for a boundary of systems on the following grounds: 1) it is known from single continuous graptolite sequences; 2) it provides difficulties in definition due to the ambiguity of morphological criteria and similarity in the composition of *extraordinarius* and *persculptus* zonal assemblages; 3) it involves no representative shelly fauna.

D. A choice of a stratotype with zonal graptolite control is quite enough for the present detailed correlation of sections represented by different facies. The preference should be given to Dob's Linn section, where new graptolite and shelly faunas have been recently found by J. K. Ingham. The Mirny Creek section in Northeast USSR is proposed as a hypostratotype. The final decision concerning the level and stratotype of the Ordovician-Silurian boundary is to be made together with the definition of the name and type area of the first Silurian series. In this case the traditionally used Llandovery of Great Britain seems to be most preferable.

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KOMMENTAARE ORDOVIITSIUMI JA SILURI PIIRI MÄÄRAMISE KOHTA

Ordoviitsiumi ja siluri piiri määramise variantidest — konodontitsoon *oldhamensis* või graptoliiditsoonide *extraordinarius*, *persculptus* või *acuminatus* alumine piir — peetakse parimaks viimast. Selle valiku kasuks kõneleb nii piiri määramiseks kasutatavate graptoliitide taksonoomiline selgus kui ka laialdane levik.

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КОММЕНТАРИИ К ОПРЕДЕЛЕНИЮ ГРАНИЦЫ ОРДОВИКА И СИЛУРА

В качестве границы ордовика и силура разными авторами предложены подошвы конодонтовой зоны *oldhamensis*, граптолитовых зон *extraordinarius*, *persculptus* и *acuminatus*. Из них наиболее подходящим положением границы считается последнее, четко определяемое по зональной ассоциации, хорошо изученное во многих регионах мира.