The regional stratotype section and point for the base of the Hirnantian Stage (the uppermost Ordovician) at Mirny Creek, Omulev Mountains, Northeast Russia

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Abstract. A complete Hirnantian sequence comprising the *Normalograptus extraordinarius* and *N. persculptus* biozones is well developed at the Mirny Creek section in the Omulev Mountains. The underlying beds are assigned to the *Appendispinograptus supernus* Biozone, and in the overlying strata the lower boundary of the Silurian is precisely defined at the base of the *Akidograptus ascensus* Biozone. Due to the completeness of the sedimentary and palaeontological record, the Mirny Creek section can be considered as a reference section for the Hirnantian Stage. The succession, about 100 m thick, is composed of calcareous siltstones and marls with pebble-shaped limestones, deposited at a high sedimentation rate in shallow shelf settings. The regional stratotype section and point (RSSP) for the lower boundary of the Hirnantian is established at the base of member 68, where *Normalograptus extraordinarius* first appears. This level can be precisely correlated with that at the GSSP section in Yichang and with the sections in Kazakhstan and North America. The position of the Ordovician–Silurian boundary is redefined and placed at the FAD of *A. ascensus* at the base of member 74.

Key words: Hirnantian, regional stratotype, graptolites, brachiopods, NE Russia.

INTRODUCTION

The base of the *Normalograptus extraordinarius* Biozone, chosen by the International Subcommission on Ordovician Stratigraphy (ISOS) for defining the lower boundary of the Hirnantian Stage, is the most reliable level for a global correlation of the uppermost Ordovician. A worldwide review shows that within the upper stage of the Upper Ordovician Series only a small number of stratigraphically continuous sections have been documented in South Scotland, China, and Kazakhstan, that have good graptolite and benthic faunal control at both the base and top of the stage. The Omulev Mountains in Northeast Russia (Fig. 1) are another region with a complete and richly fossiliferous succession of Upper Ordovician shelf deposits, which has been the subject of much study (Oradovskaya & Sobolevskaya 1979; Koren′ et al. 1983; Oradovskaya 1988). The Omulev Mountains are located to the west of the Kolyma River and in the central part of the Chersky Mountain Range (Fig. 1). The best section in the region for studying the detailed biostratigraphy of the Upper Ordovician and Lower Silurian deposits, based on graptolites, brachiopods, and corals, is exposed along Mirny Creek, a tributary of the Ina River. Mirny Creek has a narrow

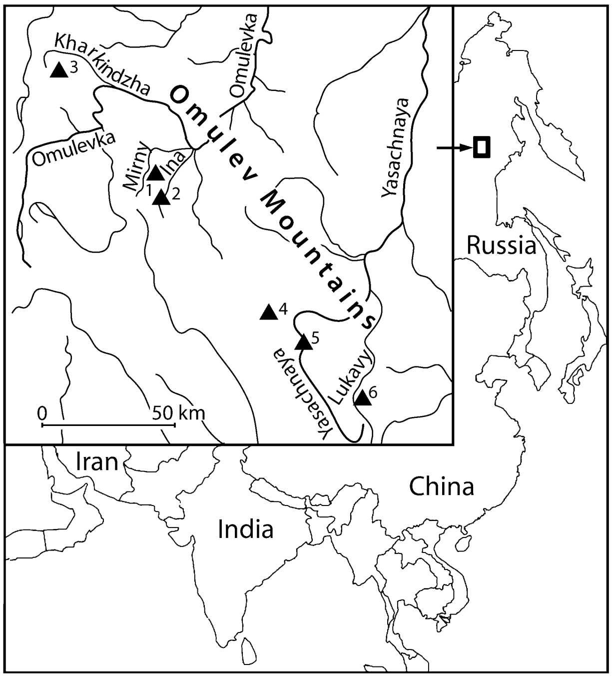

Fig. 1. Schematic map showing locations of the Upper Ordovician sections in the Omulev Mountains, Northeast Russia. 1, Mirny Creek; 2, Ina River; 3, Kharkindzha Mountain; 4, Khekandya River; 5, Yasachnaya River; 6, Lukavy Creek.

valley and cuts the eastern slope of the Omulev Mountains nearly across the strike of their ridges, exposing a section from the Middle Ordovician to the Lower Devonian. The *N. extraordinarius* Biozone was first established as a local biostratigraphic unit within this area (Koren′ & Sobolevskaya 1977, 1979), and the type locality of the zonal species is located on the Ina River (Sobolevskaya 1976).

Several working groups of the Russian and International stratigraphical commissions and subcommissions on Ordovician and Silurian stratigraphy (1974, 1979), as well as the participants in the 27th International Geological Congress (1984), have visited the Mirny Creek section. In 1974 the section was considered by the Subcommission on Silurian Stratigraphy as one of the candidates for the global stratotype of the Ordovician–Silurian boundary, defined at the base of the *Akidograptus ascensus–Parakidograptus acuminatus* Biozone. Recently the Mirny Creek section was proposed as one of the candidate sections for the GSSP of the lower boundary of the Hirnantian Stage, marked by the first appearance of the index-species of the *N. extraordinarius* Biozone. This level was chosen by the ISOS as one of the best correlative levels in the Upper Ordovician. It coincides with the *Paraorthograptus pacificus* mass extinction event in graptolite evolution (Melchin & Mitchell 1991; Koren′ 1991) and with critical drop in the diversity of most of the faunal groups due to the last phase of the late Ashgill glaciation (Sheehan 2001). It is worth mentioning that in the late 1970s and early 1980s the base of the *N. extraordinarius* Biozone was considered by the Working Group on the Ordovician–Silurian Boundary as one of three potential levels for defining the base of the Silurian System due to its high correlative value. However, in spite of the complete graptolite sequence the Mirny Creek section contains no typical Hirnantian brachiopod fauna and failed to yield a definitive conodont fauna. In addition, between the levels with the last occurrence of graptolites of the *Appendispinograptus supernus* Biozone and the first occurrence of *N. extraordinarius* at Mirny Creek there is a barren, brecciated limestone about 3 m thick. Furthermore, access to the section is very complicated and expensive.

Recently, the global boundary stratotype section and point for the base of the Hirnantian Stage was defined in the Wangjiawan North section in the Yichang area of China (Chen et al. 2006), which meets all the necessary requirements. Now that the global boundary stratotype section is chosen, it is necessary to trace it in different continents and geological regions using all possible criteria. The designation of regional stratotypes at the most complete and well-studied reference sections in similar sedimentary settings within the main geological provinces will be a next important step. The Mirny Creek section is the most suitable one for the establishment of a regional stratotype section and point (RSSP) for the lower boundary of the Hirnantian Stage within the territory of Russia.

THE MIRNY CREEK SECTION: LOCATION, GEOLOGICAL SETTING, AND LITHOLOGY

The Mirny Creek section can be reached from the city of Magadan by the highway to the city of Seimchan (500 km), and from there 200 km to the northwest by helicopter. The section shows a continuous succession of the Middle Ordovician to Lower Silurian strata exposed on both banks of the creek. The exposure of the Upper Ordovician rocks starts 2 km upstream from the mouth of Mirny Creek and crops out continuously for a distance of 780 m in river-cut cliffs that are approximately 1–4 m high. Detailed studies of the section are possible in the summer season – the best time is in July. The outcrops are easily accessible by walking upstream the creek from a field camp built approximately 1 km from the mouth of the creek.

The succession is structurally simple, sometimes with small folds and unexposed intervals on one of the banks, which do not disturb the continuity of the biostratigraphical succession. The key interval of the lower Hirnantian and lowermost Llandovery is mostly monoclinal and is not affected by faulting. The rocks show no traces of metamorphism.

The Upper Ordovician limestones and carbonaceous shales are assigned to the Tirekhtyakh Regional Stage, which in terms of graptolite biostratigraphy, corresponds to the three following biozones: *Appendispinograptus supernus*, *Normalograptus extraordinarius*, and *N. persculptus* (Fig. 2). The stage also corresponds to the *Tcherskidium unicum* and *Eoplectodonta nesnakomkaensis* and ?*Hirnantia* brachiopod biozones (Koren′ et al. 1983; Oradovskaya 1988).

The upper part of the Tirekhtyakh Regional Stage (units P and Q, the *N. extraordinarius* and *N. persculptus* biozones) is about 100 m thick. The conformably overlying lower Llandovery (Rhuddanian) beds are subdivided into lithostratigraphic units R and S assigned to the Chalmak Regional Stage. In the graptolite sequence they correspond to the *Akidograptus ascensus*, *Parakidograptus acuminatus*, and *Cystograptus vesiculosus* biozones (Koren′ et al. 1983).

Units P and Q are exposed in a series of small outcrops. Unit P was observed for a distance of about 16 m along the left bank of Mirny Creek, 30 m upstream from

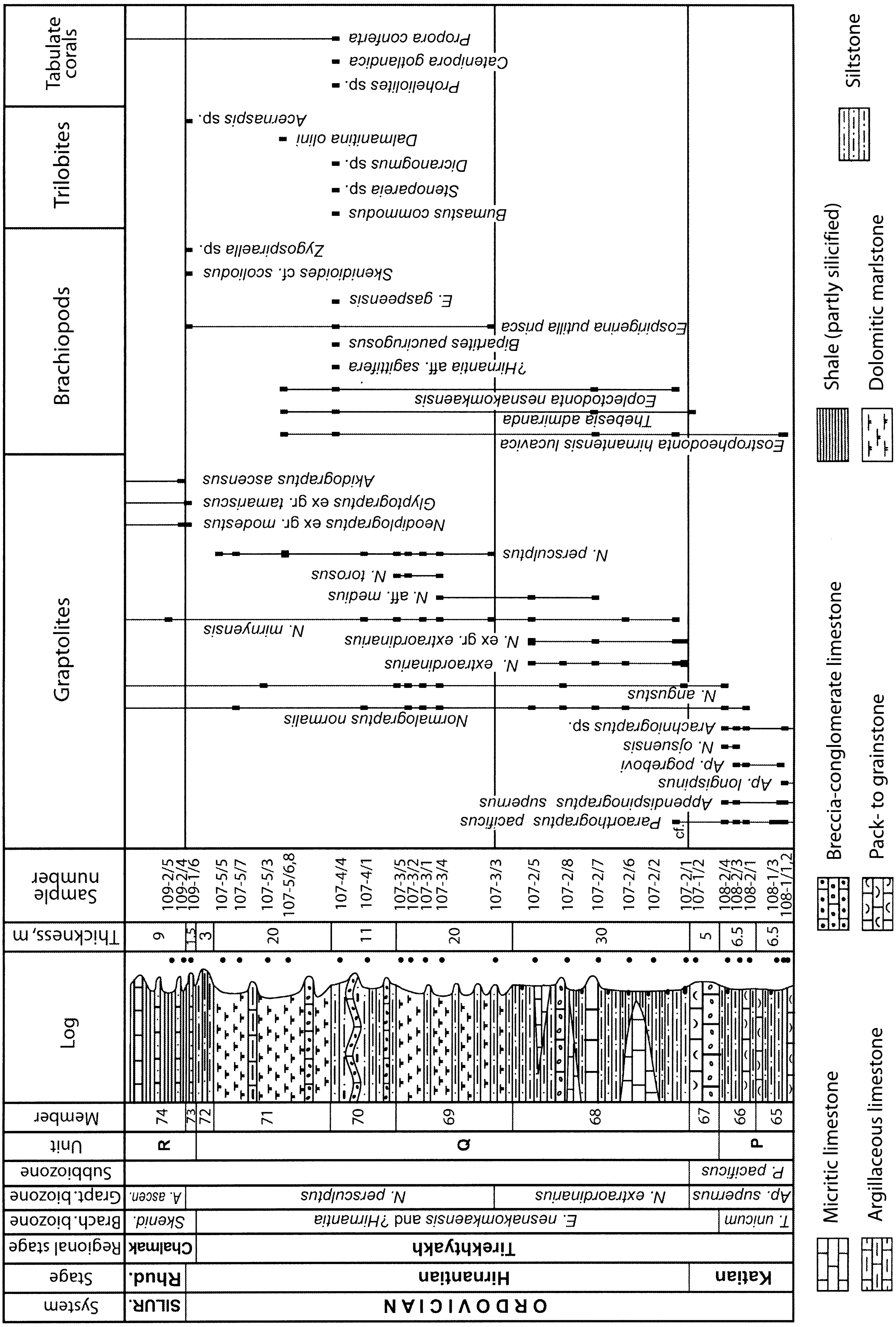

Fig. 2. Mirny Creek section showing ranges of graptolites, selected brahiopods, trilobites, and tabulate corals. Thickness of bars shows a relative numerical abundance of specimens in each sample. Abbreviations: Rhud. = Rhuddanian, Silur. = Silurian. Biostratigraphical names occur in full in the text.

the mouth of Kravchun Creek. Units P and Q are similar in lithology. Unit P is composed of bedded calcareous, detrital siltstones of brownish and dark grey colour, with trilobite, ostracode, bryozoan, and crinoid fragments. Brownish to dark grey calcareous organic-rich siltstones yielding trilobites, ostracodes, and crinoids, light grey marls, with some layers of thick brecciated (pebble-like) limestones of slump origin, are the main components of unit Q. In the upper part of the unit sediments show traces of bioturbation. Graptolites are quite numerous in the lower part of unit Q, whereas in the upper part brachiopods and trilobites dominate alongside with rare graptolites, crinoids, and bryozoans.

The Tirekhtyakh Regional Stage corresponds to the regressive phase of the Kolyma Basin evolution and shows a shallowing upward succession. The algal biohermal facies of the outer part of shallow shelf are typical of the *N. extraordinarius* Biozone, whereas the *N. persculptus* Biozone is represented by the algal limestones and dolomites formed in shoal settings (Oradovskaya 1988). This explains the irregular distribution of graptolites: mass occurrences of normalograptids are confined to some carbonaceous siltstone interbeds within the *N. extraordinarius* Biozone and only a few rhabdosomes were found in light yellow-greyish marls of the *N. persculptus* Biozone in association with the *Dalmanitina*–?*Hirnantia* aff. *sagittifera* benthic fauna. The sharp lithological transition from light-coloured marls to black carbonaceous shales yielding numerous graptolites corresponds to the base of the Chalmak Regional Stage (unit R, member 73) and mark the beginning of the transgression.

GRAPTOLITE BIOSTRATIGRAPHY

The Tirekhtyakh Regional Stage is subdivided into the *Ap. supernus* Biozone (including the *Ap. longispinus* and *P. pacificus* subbiozones) and the *N. extraordinarius* and *N. persculptus* biozones. Together they have yielded no more than 30 species, which is much less than reported from the contemporaneous assemblages in China (e.g. Chen et al. 2000). The lower Tirekhtyakh graptolites (units M to P, the *Ap. supernus* Biozone; Koren′ et al. 1983) are comparatively diverse and numerically abundant, representing outer shelf to upper slope environments (the “margin-dweller biotope” of Finney & Berry 1998). After the extinction event at the end of the *Ap. supernus* Biozone (*P. pacificus* Subbiozone) the Hirnantian graptolite assemblages show a substantial species turnover. However, they do not show a dramatic drop in diversity, typical of shallow-water graptolite biofacies distributed in the low-middle latitude realm (Chen et al. 2000, 2003, 2005, 2007).

The relatively low diversity (ten species) Hirnantian graptolite assemblages are dominated by the geographically widely distributed, diagnostic normalograptid fauna, which is relatively rich in specimens. The preservation is usually quite good and most taxa are represented by flattened specimens at different astogenetic stages. Within the studied succession graptolites are most abundant in the *N. extraordinarius* Biozone (Fig. 3). They are less numerous and occur only at some stratigraphic levels within the uppermost part of the *Ap. longispinus* Subbiozone and *N. persculptus* Biozone, because the lithologies are unsuitable for their preservation in many intervals.

In the upper part of the *P. pacificus* Subbiozone (unit P), graptolites occur in member 65 (samples 108-1/1, 2, 3) and at three levels within member 66: at 1.5 m and in 3 m above the base (samples 108-2/1 and 2/3), and 2 m below the base of the limestone bed of member 67 (sample 108-2/4) (Fig. 2). The assemblage includes *Appendispinograptus longispinus* (T. Hall), *Ap. supernus* (Elles & Wood), *Ap. pogrebovi* (Koren′ & Sobolevskaya), *Normalograptus normalis* (Lapworth), *N. angustus* (Perner), *N. ojsuensis* (Koren′ & Mikhaylova), and *Arachniograptus* sp. In the other sections known in the Omulev Mountains, such as the Ina River (the type locality of *N. extraordinarius* Sobolevskaya, 1976), Orlinaya River, and the Rovny Creek section, *N. ojsuensis* is also typical of the upper part of the *P. pacificus* Subbiozone. *Normalograptus ojsuensis* is considered to be a possible ancestral form for *N. extraordinarius* due to the close morphological affinities and stratigraphically earlier appearance (Koren′ et al. 1983). The *N. extraordinarius* assemblage is much less diverse than graptolites recorded from units N and O (the *Ap. longispinus* Subbiozone, Koren′ et al. 1983). However, in spite of the low taxonomic diversity of the late Katian (eight species) and early Hirnantian graptolites (four species), the extinction event at the base of the *N. extraordinarius* Biozone is well recognizable in the Kolyma Region (Koren′ et al. 1983).

The boundary between units P and Q is marked by lithological transition from light grey horizontally bedded siltstone with graptolites to thick-bedded brecciated limestone (5 m thick) with numerous fragments of brachiopods, trilobites, rugose and tabulate corals, and other benthic fauna (member 67, sample 107-1/2). This level shows a distinctive regressive episode and one can suggest that it correlates with the base of the Hirnantian in other regions, for example in South Kazakhstan (Appolonov et al. 1988). As no graptolites were found in limestone beds (as it is shown by mistake in Koren′

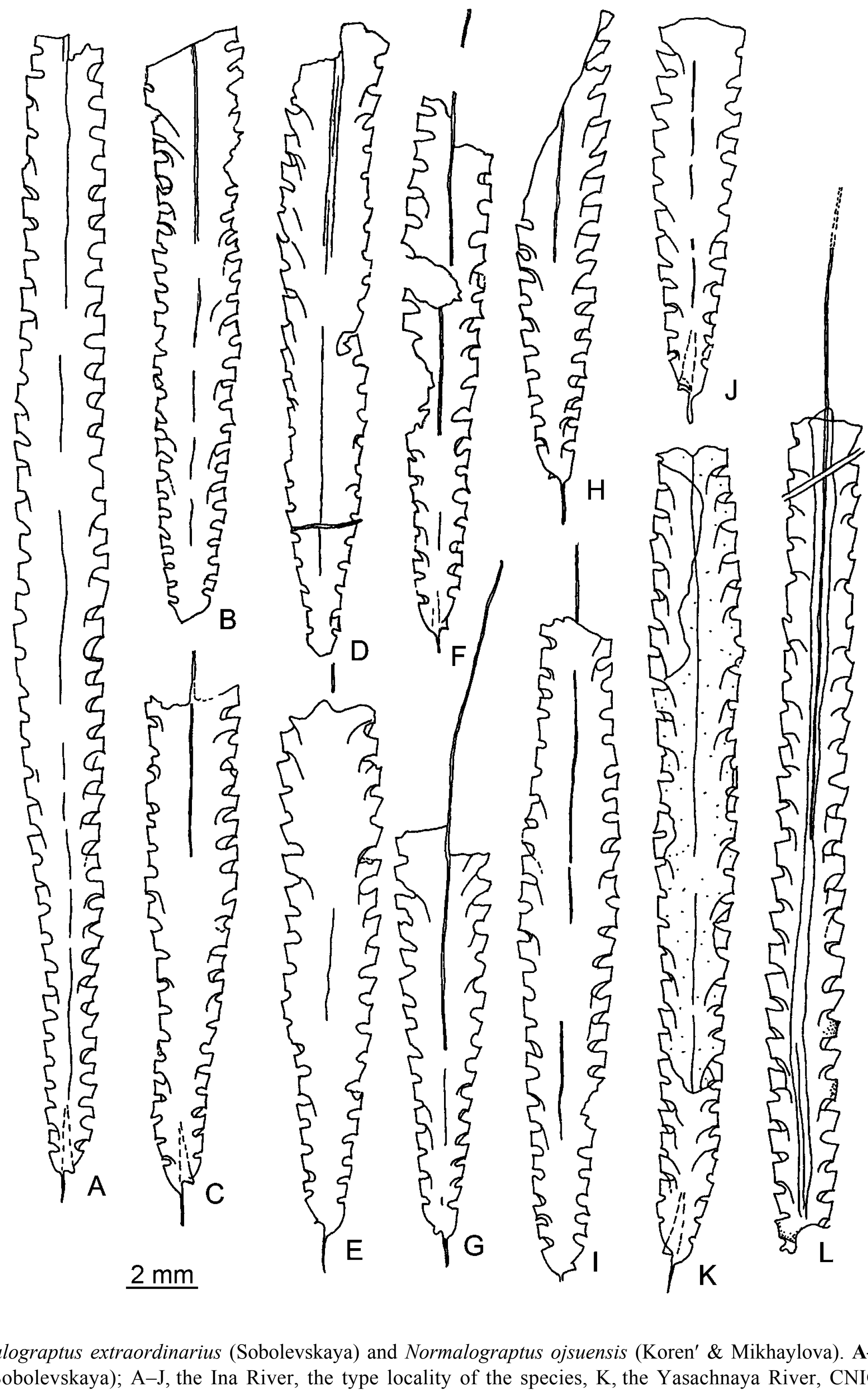

Fig. 3. *Normalograptus extraordinarius* (Sobolevskaya) and *Normalograptus ojsuensis* (Koren′ & Mikhaylova). **A–K**, *N. extraordinarius* (Sobolevskaya); A–J, the Ina River, the type locality of the species, K, the Yasachnaya River, CNIGR Museum 65/11433, 61/11433, 62/11433, 67/11433–69/11433, 60/11433, 63/11433, 67/11433, 59/11433, 284/11433. **L**, *N. ojsuensis* (Koren′ & Mikhaylova), the Yasachnaya River, CNIGR Museum, 285/11433.

et al. 1983, p. 13, fig. 62), the lower boundary of the *N. extraordinarius* Biozone is defined by the first appearance of the index-species at the base of member 68 (Fig. 2, sample 107-1/1). *Normalograptus mirnyensis* (Obut & Sobolevskaya) first appears slightly higher (in sample 107-2/1). It is worth mentioning that in the same sample a single specimen of *Paraorthograptus* cf. *pacificus* (Ruedeman) (first identified by R. Sobolevskaya as *Paraclimacograptus* sp.; pers. comm.) was found. This species is the only representative of the Dicranograptidae–Diplograptidae–Orthograptidae (DDO) Fauna that appears to have persisted into the *N. extraordinarius* Biozone in this region. Other associated species *N. angustus* (Perner), *N. normalis* (Lapworth), and *N.* aff. *medius* (Törnquist) extend through the overlying *N. persculptus* Biozone and into the lowermost Llandovery. Seven levels with graptolites were recognized within the *N. extraordinarius* Biozone (member 68), which is 30 m thick. At some levels the index species is characterized by the high abundance of individuals, which is especially characteristic of the type locality of *N. extraordinarius* on the Ina River (Sobolevskaya 1976).

The overlying *N. persculptus* Biozone of the upper Hirnantian (the upper part of unit Q) is established by the occurrence of the eponymous species at nine stratigraphic levels within members 69–71, which total 51 m in thickness. The lower beds of member 69 (10 m thick) are not well exposed and the first specimen of *N. persculptus* is documented in sample 107-3/3 (Fig. 2). The *persculptus* fauna includes *N. normalis* (Lapworth), *N. angustus* (Perner), *N. mirnyensis* (Obut & Sobolevskaya), *N. torosus* (Koren′ & Sobolevskaya), and *N.* aff. *medius* (Törnquist).

A well-exposed boundary between the Tirekhtyakh and Chalmak horizons (units Q and R) coincides with the facies changes from light-coloured siltstones and marls to black calcareous shales and argillaceous limestones. The basal beds, 1.5 m thick (member 73), bear numerous graptolites, sometimes covering the bedding surfaces. Among them *Neodiplograptus* ex gr. *modestus* (Lapworth), *Glyptograptus* ex gr. *tamariscus* (Lapworth) and numerous, but not well preserved normalograptids were identified. *Akidograptus ascensus* Davies, marking the Ordovician and Silurian boundary (Rong et al. 2007), first appears at the base of member 74.

RECORD OF BENTHIC FAUNA

The Tirekhtyakh Regional Stage is well defined biostratigraphically not only by graptolites. At some stratigraphic intervals it contains rich benthic fauna, including numerous brachiopods (about 40 species), corals (22 species), as well as rare trilobites, gastropods, and ostracodes.

Two brachiopod biozones have been established in the Tirekhtyakh Regional Stage: *Tcherskidium unicum* (units M, upper part, N, O, P), and *Eoplectodonta nesnakomkaensis* and ?*Hirnantia* (unit Q; Oradovskaya 1988). In the Mirny Creek section (Fig. 2) *Eostropheodonta hirnantensis lucavica* and rare cheirurid trilobites occur in the lower part of unit P (samples 108-1/1, 2). Brachiopods assigned to *Thebesia admiranda* are found together with *N. extraordinarius* (sample 107-1/2). At higher levels (samples 107-2/1, 7, 4/4, 5/6, 8) *T. admiranda*, *Eostropheodonta hirnantensis lucavica*, *Eoplectodonta nesnakomkaensis*, and a single cranidium of an illaenid trilobite were collected.

In the Omulev Mountains the *Eoplectodonta nesnakomkaensis* and ?*Hirnantia* Biozone contains about 30 brachiopod species (Oradovskaya 1988), including *Eoplectodonta nesnakomkaensis*, *Thebesia admiranda*, and *Eospirigerina putilla prisca*. ?*Hirnantia* aff. *sagittifera* occurs only in the Mirny Creek section.

The tabulate coral fauna of the Tirekhtyakh Regional Stage is richest in the limestones of the middle part of unit O in the Mirny Creek section and contains mostly endemic species of *Agetolites*, *Paleofavosites*, *Mesofavosites*, *Catenipora*, *Heliolites*, *Plasmoporella*, *Rhaphidophyllum*, *Propora*, and other genera (Preobrazhenskij 1966; Koren′ et al. 1983). They are associated with the oldest pentamerid brachiopods, *Tcherskidium unicum* (A. Nikolaev) and *Holorhynchus* ex gr. *giganteus* Kiaer, as well as with rare ostracodes of the genera *Leperditella*, *Laccochilina* (*Eochilina*), *Primitiella*, and *Platybolbina*. A rich coral and trilobite fauna is characteristic of member 70 of unit Q. Among corals, *Proheliolites* sp., *Catenipora gotlandica* (Yabe), and *Propora conferta* (Edwards & Haime) are found (samples 107-4/4). Within the same beds the following brachiopods are most common: *Dalmanella* cf. *testudinaria* (Dalman), *Girardella* aff. *bella* (Bergström), *Bipartites paucirugosus* Amsden, *Thebesia admiranda* (Oradovskaya), *Eospirigerina putilla prisca* Oradovskaya, *E. gaspeensis* (Cooper) (Koren′ et al. 1983). Among trilobites, *Bumastus commodus* Apollonov and some species of the genera *Stenoporeia* and *Dicranogmus* occur. *Dalmanitina olini* Temple appears first in member 71 (Fig. 2, samples 107-5/6, 8).

The lowermost Silurian strata of the Chalmak Regional Stage bear rare brachiopods *Skenidioides* and rare specimens of the trilobite *Acernaspis* in thin limestone layers occurring within the graptolite sequence (Koren′ et al. 1983).

OTHER SECTIONS

Within the Omulev Mountains and upper Yasachnaya River ten sections of the Katian and Hirnantian strata were measured and studied biostratigraphically (Koren′ et al. 1983). In many of them the Hirnantian interval (unit Q) is not well exposed or preserved. However, the sections along the Ina, Rovnaya, and Orlinaya rivers, as well as in Kharkindzha Mountain, have a well-preserved *N. extraordinarius* fauna (Fig. 3), but the base of the eponymous biozone is either unexposed or marked by an unconformity. In all sections studied graptolite assemblages are strongly dominated by the index-species associated with some long-ranging normalograptids. In the Ina River section siltstones of unit P contain *N. ojsuensis* (Koren′ & Mikhaylova) in association with *Normalograptus angustus* (Perner), *N. normalis* (Lapworth), and *Paraorthograptus pacificus pacificus* (Ruedeman) (Koren′ et al. 1983).

CORRELATION

In the shallow-water sections of the Yangtze Region, South Kazakhstan, and Northeast Russia, as well as in the deeper-water sections at Dob's Linn and central Nevada, the base of the *N. extraordinarius* Biozone is defined by the FAD of *N. extraordinarius*, a morphologically well-defined and taxonomically clear species. In the definition of the GSSP in the Wangjiawan North section a slightly earlier first appearance of *N. ojsuensis* (Koren′ & Mikhaylova) was noted among the secondary markers (Chen et al. 2006). The presence of both phylogenetically related species in continuous graptolite sequences permits a high-precision correlation of the lower boundary of the Hirnantian. This level is one of the best bioevent markers for a global correlation within the Ashgill succession because of a sharp drop in biodiversity or species turnover as a result of the *pacificus* extinction event. The shallow-water Hirnantian graptolite succession in the Omulev Mountains can be precisely correlated with those of the Wangjiawan North and Wangjiawan South sections of China, as well as with deep-water sections at Dob's Linn and central Nevada (Vinini).

Recently conodonts from the Mirny Creek and Ina River sections were described (Zhang & Barnes 2007). The faunal record within unit Q proved to be very scarce in spite of close sampling, however, the zonal species *Amorphognathus ordovicicus* Branson & Mehl was found in the lower part of unit Q (Zhang & Barnes 2007, fig. 5). Numerous conodonts occur in member 66 of unit P together with the last graptolites of the *P. pacificus* Subbiozone. The presence of *Gamachigraptus ensifer* McCracken, Nowlan & Barnes in the assemblage supports a correlation of these beds with the uppermost Richmondian of North America. *Hamarodus europaeus* (Serpagli), found in member 66, is well known from the uppermost Katian successions of Europe. The basal Silurian strata lack conodonts in spite of close sampling and the first relatively abundant and diverse Silurian fauna was recovered from the top of member 74 of unit R in the *A. ascensus* Biozone.

The Katian, Hirnantian, and lower Llandovery beds with graptolites and benthic fauna were studied in detail in the sections near the Ojsu and Durben wells in the Chu-Ili Mountains in southern Kazakhstan (Koren′ et al. 1979; Apollonov et al. 1980). There, a very similar succession of the *Ap. supernus*, *N. extraordinarius*, *N. persculptus*, and *A. ascensus* biozones was recognized. The Ojsu section is the type locality of *Normalograptus ojsuensis* (Koren′ & Mikhaylova) (Koren′ et al., in Apollonov et al. 1980; fig. 3, sample 1053). In this section *N. ojsuensis* was found in the upper part of the Chokpar Regional Stage, assigned to the upper *Ap. supernus* Biozone. It is associated with *Orthograptus amplexicaulis amplexicaulis* J. Hall and *Paraorthograptus pacificus affinis*. In the overlying sandstones of the Zhalair Formation (the basal part of the Durben Regional Stage or the Hirnantian Stage) *Normalograptus extraordinarius* (Sobolevskaya) (= *Glyptograptus*? *persculptus* forma A, *Glyptograptus* aff. *persculptus*, Koren′ et al., in Apollonov et al. 1980, p. 151; Koren′ & Nikitin 1983), *N. angustus*, *N.* cf. *normalis* (Lapworth), and *Pseudoclimacograptus* sp. were found. The Hirnantian and lowermost Llandovery deposits were formed in a restricted shallow-water basin, which continued to exist by the beginning of the Silurian within South Kazakhstan. A suggestion made by Chen et al. (2003, p. 143) that the graptolite diversity in Kazakhstan could be artificially low due to the difficulty of making large collections in this region could be true. This can be attributed to the limited distributional area and complex geological structure of the Ordovician–Silurian boundary beds in the available exposures within the Chu-Ili Mountains (Apollonov et al. 1988).

An occurrence of *N. extraordinarius* is reported from the *Dicellograptus ornatus*–*Ap. supernus* Biozone of

Gornyj Altaj (Sennikov in Kaljo & Koren′ 1976, pl. 3, fig. 9). However, the figured specimen does not look like *N. extraordinarius* and should most probably be assigned to *N. ojsuensis* (Koren′ & Mikhaylova).

In the late 1970s in the Kolyma Region the Silurian System boundary was drawn at the base of the combined *A. ascensus–P. acuminatus* graptolite Biozone, defined by the appearance of the first representatives of the *Normalograptus modestus* and *Glyptograptus tamariscus* groups that were considered as typical Silurian graptolites at that time (Koren′ et al. 1983). This level corresponds to the base of member 73 and the Chalmak Regional Stage, well marked by the beginning of the post-glacial transgression and incoming of black shale sedimentation.

During the last two decades much new data on graptolite taxonomy and species ranges in the Ordovician–Silurian boundary beds have been published. The post-*persculptus* and pre-*ascensus* diplograptid fauna lacking akidograptids was recently studied in Arctic Canada, Algerian Sahara, South Kazakhstan, Uzbekistan, and Sweden (Melchin et al. 1998; Koren′ & Melchin 2000; Koren′ et al. 2003). The restudy of the global stratotype of the base of the Silurian System was undertaken (Melchin & Williams 2000). As a result, the base of the *A. ascensus* Biozone, marked by the first occurrences of the zonal species, is now regarded as the biostratigraphic horizon that marks the base of the Silurian System. The new definition was ratified by the International Commission on Stratigraphy (Rong et al. 2007).

In this paper, according to the current knowledge, the base of the Silurian System in the Mirny Creek section is redefined. It is placed at the FAD of *A. ascensus* at the base of member 74 within a continuous succession of graptolite shales and 1.5 m above the level of incoming of the post-glacial transgression (Fig. 2). This allows a precise global correlation with the Dob's Linn stratotype section and other sections of the world.

In conclusion, the Mirny Creek succession of the upper Tirekhtyakh Regional Stage is the best candidate of the regional stratotype section and point (RSSP) for the lower boundary of the Hirnantian Stage within the Asian part of Russia. The *N. extraordinarius* regional Biozone was first recognized in this region, based on detailed palaeontological and biostratigraphic studies. Within the continuous sequence of shelf deposits the underlying beds were assigned to the *Ap. supernus* Biozone and the overlying strata to the *N. persculptus* Biozone with a precisely defined lower boundary (Koren′ & Sobolevskaya 1977; Koren′ et al. 1983). The *N. extraordinarius* Biozone has since been recognized in many parts of the world (Kazakhstan, Southern Scotland, China, and Central Nevada) and a complete succession of the standard Hirnantian graptolite biozones, comprising the *N. extraordinarius* and *N. persculptus* biozones, has been established (Cooper & Sadler 2004).

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Ülem-Ordoviitsiumi Hirnantia lademe alumise piiri regionaalne stratotüüp ja tase Mirnõi oja ääres Omulevi mäestikus Kirde-Venemaal

Tatjana N. Koren ja Rimma F. Sobolevskaya

Hirnantia lademe täielik läbilõige, mis jaotub *Normalograptus extraordinarius*'e ja *N. persculptus*'e biotsooniks, paljandub Mirnõi oja kallastel Omulevi mäestikus. Lamavad kihid kuuluvad *Appendispinograptus supernus*'e biotsooni ja lasum Silurisse, mille alumise piiri määratleb *Akidograptus ascensus*'e biotsooni algus. Arvestades Mirnõi läbilõike sedimentoloogilist ja biostratigraafilist täielikkust, soovitatakse seda kasutada Hirnantia lademe alumise piiri regionaalse stratotüübina Venemaa Aasia-osas. Läbilõige koosneb lubjakatest aleuroliitidest ja merglitest ning madalaveelistest lubjakividest. Lademe paksus on umbes 100 m, mis näitab väga suurt settimiskiirust. Hirnantia lademe alumise piiri tasemeks peetakse 68. kihistiku alumist piiri, kus ilmub esmakordselt *Normalograptus extraordinarius*. See tase korreleerub hästi nimetatud piiriga globaalses stratotüübis (Yichang, Hiina), aga samuti vastavates läbilõigetes Kasahstanis ja Põhja-Ameerikas. Ordoviitsiumi ja Siluri täpsustatud piir (*Akidograptus ascensus*'e esmailmumise tase) paikneb Mirnõi läbilõikes 74. kihistiku alguses.