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ORDOVICIAN-SILURIAN BIOSTRATIGRAPHY AND PALEOGEOGRAPHY OF THE GORNY ALTAI

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Сенников Н.В. Биостратиграфия и палеогеография ордовика и силура Горного Алтая / **Н.В. Сенников, Е.А. Ёлкин, З.Е. Петрунина, Л.А. Гладких, О.Т. Обут, Н.Г. Изох, Т.П. Киприянова ;** Ред. Н.В. Сенников, А.В. Каныгин ; [Перевод Т.Н. Перепеловой, О.Т. Обут] ; Институт нефтегазовой геологии и геофизики им. А.А. Трофимука СО РАН. – Новосибирск : Издательство СО РАН. – 2008. – 156 с.

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СНИИГГиМС — Siberian Research Institute of Geology, Geophysics & Mineral Resources

СибРМСК — Siberian Regional Interdepartmental Stratigraphic Commission

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This book is an expanded guidebook for a field excursion to the Ordovician-Silurian sections of the Gorny Altai being shown to participants in the International Symposium "Development of Early Paleozoic Biodiversity: Role of Biotic and Abiotic Factors, and Event Correlation", Moscow, 2008. The Symposium is another event in IGCP 503 "Ordovician Palaeogeography and Palaeoclimate" (2004–08) which follows the International Symposium "Palaeogeography and Global Correlation of Ordovician Events" held as part of the same project in 2006 in Novosibirsk, and the accompanying field excursion to the Cambrian-Ordovician section along the Kulyumbe River on the Siberian Platform organized by the Russian team (Palaeogeography..., 2006; Kanygin et al., 2006).

The present guidebook concerns Ordovician and Silurian stratigraphy, paleogeography, lithology, and facies in reference sections in the Gorny Altai, described bed-by-bed.

These data were previously published in part, mainly scattered through various books and papers. This book is a synthesis of present-day knowledge with revisions of the paleontology and age implications. Updating has become possible due to discoveries of graptolite and conodont assemblages of zonal significance; these are presented within the framework of modifications of the International Stratigraphic Chart brought about by introduction of new stages and new boundary definitions of stages, series, and systems. The book is based on abundant biostratigraphic and geological data accumulated over the past 25 years about Ordovician and Silurian deposition in the Gorny Altai. Publication of these data is a necessary step toward broad public discussion of new ideas, a prerequisite for updating the Gorny Altai Ordovician-Silurian stratigraphic charts. Such a discussion is urgent in the context of preparing a new Paleozoic stratigraphic chart of the Altai-Sayan Folded Area.

CONTENTS

INTRODUCTION

Ordovician and Silurian strata are widespread in four major tectonic units of Siberia: in the Altai-Sayan Folded Area, upon the Siberian Craton, in the Taimyr Peninsula, and in the basement of the West Siberian Plate.

The Gorny Altai highland lies in the western Altai-Sayan Folded Area (ASFA), a collage of terranes within the Central Asian orogen. The ASFA comprises several large geologic structures composed of Paleozoic (including Ordovician-Silurian) formations of differing origins. Additional to the Gorny Altai are the Rudny Altai, Salair, Kuznetsky Alatau, Kuznetsk Basin and Gornaya Shoriya in the west, and the Northern and Southern Minusa, West Sayan, and Tuva in the east (Fig. 1). The present tectonic framework of the ASFA (Dobretsov, 2003) has resulted from successive accretion of orogens of different ages to the Siberian craton.

The Ordovician and Silurian sedimentary patterns of the Gorny Altai (Figs 2, 3) consist mainly of rhythmic alternation of terrigenous and carbonate rocks with rare volcanic intercalations. The terrigenous sections occasionally contain limestone lenses. Biohermal carbonates are frequent, mostly as algal buildups. Various facies occur dispersed through the paleobasin; thicknesses vary greatly.

The Gorny Altai territory is completely covered by 1:200 000 geological surveys and much of it by 1:50 000 surveys undertaken during the past 60 to 65 years. Most of the surveys were fulfilled by people from the West Siberian Geological Surveys (currently the Zapsibgeolsyomka Prospecting Company). Large-scale (1:25 000, 1:10 000, 1:5 000) geological surveys for the reference localities of the Ordovician-Silurian rocks in the Gorny Atlai were carried out as special stratigraphic investigations by V.D. Ermikov, L.A. Gladkikh, T.V. Khlebnikova, A.V. Krivchikov, S.A. Kuznetsov, A.N. Mamlin, Z.E. Petrunina, S.S. Podryadchikov, A.A. Puzyrev, N.V. Sennikov, S.P. Shokalsky, E.A. Yolkin, L.L. Zeyfert, V.A. Zybin.

Paleontological and stratigraphical data, analyzed in this monograph were collected during field studies over many years by A.A. Alekseenko, L.S. Bazarova, E.I. Bogashchenko, E.V. Bukolova, E.V. Buyanova, V.D. Ermikov, M.F. Gabova, L.A. Gladkikh, V.I. Ivlicheva, K. Iwata, N.G. Izokh, E.A. Kalinin, T.V. Khlebnikova, A.V. Krivchikov, N.P. Kulkov, M. Kunst, M.I. Mamlina, P. Mannik, O.T. Obut, E.E. Perfilev, Z.E. Petrunina, V.G. Russkikh, N.L. Rybkina, V.R. Savitsky, L.G. Severgina, N.V. Sennikov, E.A. Sharudo, P. Shtorch, Y. Sugai, L. Teller, G.N. Vorotilina, E.V. Yakovleva, E.A. Yolkin, and V.A. Zheltonogova.

Faunal remains included in the present monograph were identified as follows: trilobites – Z.E. Petrunina, E.A. Yolkin; graptolites – N.V. Sennikov, A.M. Obut, V.G. Russkikh, E.V. Bukolova; conodonts – T.A. Moskalenko, A.M. Vorozhbitov, N.G. Izokh, O.T. Obut, P. Mannik; ostracods – L.S. Bazarova, brachiopods – L.G. Severgina, N.P. Kulkov, Ya.M. Gutak,

Fig. 1. Russia with location of the Altai-Sayan Folded Area (ASFA) including Rudny Altai, Gorny Altai, Salair, Kuznetsky Alatau, Kuznetsk basin, Minusa, West Sayan, and Tuva.

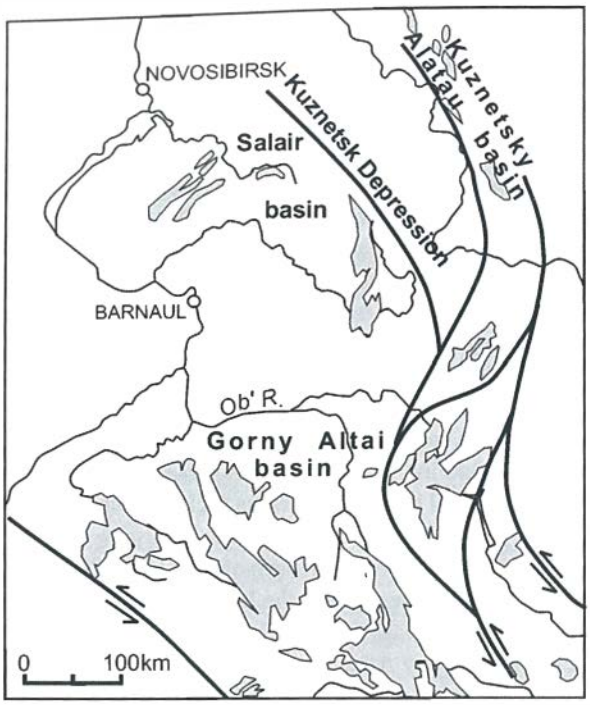


Fig. 2. Sketch map of locations of the Altai-Salair Ordovician deposits with main structural-tectonic elements.

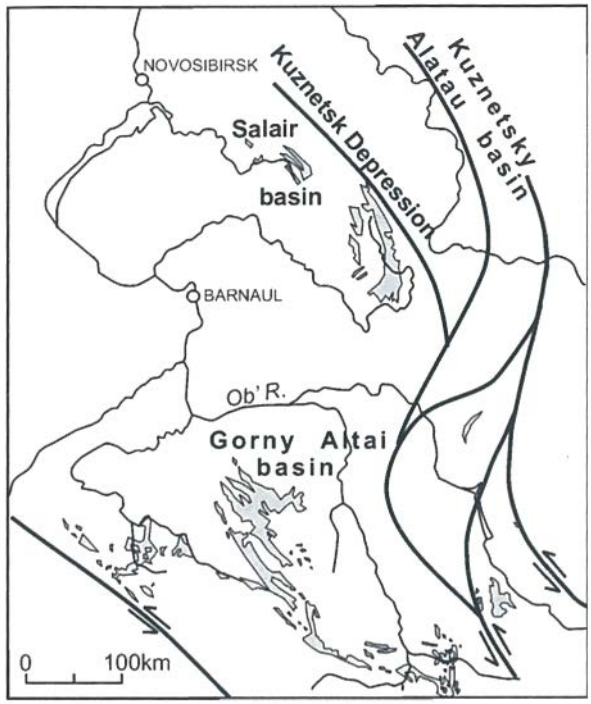


Fig. 3. Sketch map of locations of the Altai-Salair Silurian deposits with main structural-tectonic elements.

V.R. Savitsky; stromatoporoids – V.G. Khromykh; tabulate corals – L.V. Galenko; rugose corals – V.A. Zheltonogova; bryozoans – K.N. Volkova; crinoids – G.A. Stukalina, Yu.A. Dubatolova; gastropods – V.I. Bjalyi; radiolarians – O.T. Obut, K. Iwata; chitinozoans – A.M. Obut, N.M. Zaslavskaya, O.T. Obut.

Photographs illustrated sections and outcrops have been taken by N.V. Sennikov, P. Mannik, O.T. Obut and V.D. Ermikov.

1. ORDOVICIAN AND SILURIAN STRATIGRAPHY OF THE GORNY ALTAI

The Ordovician and Silurian stratigraphic charts of the Gorny Altai have been compiled through the past six decades by joint efforts of prospecting, academic, and educational institutions, namely, All-Russian Geological Institute (VSEGEI, St. Petersburg), Siberian Research Institute of Geology, Geophysics & Mineral Resources (SNIIGGiMS, Novosibirsk), Institute of Geology & Geophysics (currently Trofimuk Institute of Petroleum Geology and Geophysics, Novosibirsk), Zapsibgeologiya (Novokuznetsk), Zapsibgeolsyomka (Elan' Village), Tomsk and Novosibirsk State Universities, Tomsk Technological Institute (currently Tomsk Technological University), Kuzbass Pedagogical Institute (currently Kuzbass Pedagogical Academy, Novokuznetsk), and others.

Among researchers who played important role in the investigation of the Ordovician and Silurian stratigraphy of the Gorny Altai should be noted the following persons (in the alphabetic order): A.F. Abushik, O.N. Andreeva, B.N. Averyanov, D.P. Avrov, N.M. Bartseva, L.S. Bazarova, N.L. Bublichenko, V.D. Chekhovich, S.V. Cherepnina, Yu.A. Dubatolova, P.S. Dzubo, V.D. Ermikov, V.V. Fedyanov, L.V. Galenko, A.B. Gintsinger, L.A. Gladkikh, R.T. Gratsianova, Ya. M. Gutak, G.D. Isaev, A.B. Ivanovsky, N.G. Izokh, V.K. Khalfina, T.V. Khlebnikova, V.G. Khromykh, A.N. Kononov, V.I. Krasnov, A.V. Krivchikov, V.A. Krivchikov, A.V. Krivobodrova, N.P. Kulkov, V.A. Kuznetsov, E.S. Levitsky, V.N. Lyakhnitsky, A.N. Mamlin, E.A. Modzolevskaya, T.A. Moskalenko, V.P. Nekhoroshev, A.A. Nikonov, A.M. Obut, O.T. Obut, Yu.S. Perfilev, Z.E. Petrunina, S.S. Podryadchikov, E.N. Polenova, M.S. Potapova, A.A. Puzyrev, O.A. Rodina, S.A. Rodygin, M.F. Romanenko, A.V. Rozova, V.G. Russkikh, N.I. Savina, V.P. Savirsky, L.G. Severgina, V.M. Sennikov, N.V. Sennikov, G.A. Stukalina, V.I. Tikhonov, N.A. Usov, M.K. Vinkman, E.V. Vladimirovskaya, V.V. Volkov, K.N. Volkova, A.M. Vorozhbitov, I.A. Vyltsan, A.M. Yaroshinskaya. E.A. Yolkin, N.M. Zaslavskaya, L.L. Zeifert, V.A. Zheltonogova.

1.1. Ordovician and Silurian regional stratigraphic units

According to the usual practice in Russia, regional correlation follows chronostratigraphic subdivision into regional stages (called *horizons* in the Russian stratigraphic code). Regional stages comprise regionally spread coeval formations (or their parts) and correspond to stages of regional geological history, and especially to stages in the evolution of marine faunal groups. Regional stages are discussed and approved collectively for further use at special Russian Stratigraphic Workshops held every ten to fifteen years, or sometimes every five or seven years. The succession of regional stages, together with the respective subdivision of the International Stratigraphic Chart (Scale), make basis for correlation of local units (formations and groups) as part of regional charts and for inter-regional correlations.

There are three main steps in synthesis of stratigraphic and biostratigraphic data: (1) subdivision of local sections, (2) correlation of the sections (intra- and partly inter-regional correlations of composite sections from nearby regions), (3) age assignment (correlation among sections from geographically dispersed regions and global correlation, including correlation with the units in the International Stratigraphic Chart). The three objectives are performed with reference to different Ordovician-Silurian faunal groups.

The greatest part of local Ordovician and Silurian sections in the Gorny Altai are correlated mainly according to trilobites and brachiopods. These two groups of benthic organisms occur in diverse complexes of terrigenous, terrigenous-carbonate and purely carbonate compositions and, for this reason, are used in subdivision of local sections and in intra-regional correlation. Trilobites and brachiopods are also of broad use in correlation among sections from the nearby areas of Gorny Altai, Salair, Kuznetsky Alatau, Siberian Platform, Taimyr, Kazakhstan, and Urals.

Other communities besides trilobites and brachiopods used in subdivision of local sections are abundant tabulate and rugose corals, ostracods, fishes, bryozoans, crinoids, nautiloids, gastropods, radiolarians, and chitinozoans. In some cases they may be useful for intra- or, more rarely, inter-regional correlations.

Besides the local subdivision, the succession of trilobite and brachiopod assemblages is the key to Gorny Altai regional Ordovician-Silurian stages, and these, in turn, most often serve as ties in correlation among sections from proximal regions.

Succession of trilobite and graptolie assemblages is regarded as the base for the Altai Ordovician-Silurian regional stages (horizons) as well as a reliable key for the intra-regional correlation. Inter-regional correlation is usually fulfilled on the bases of regional stages (horizons).

Global correlation and dating of the deposits with respect to the International Stratigraphic Chart are made proceeding from pelagic faunas of graptolites and conodonts. Although these faunal groups are less abundant in the Ordovician-Silurian sections of the Gorny Altai than others.

The current Paleozoic stratigraphic charts for Central Siberia were approved at the USSR Workshops on Ordovician-Silurian Stratigraphy of 1956, 1964 and 1979 in Novosibirsk which were three milestones in the history of stratigraphic studies in the Gorny Altai and in the Altai-Sayan Folded Area as a whole. The workshops concerned with unification of regional stratigraphic charts as an outcome of years-long work; the charts were then considered by the USSR Interdepartmental Stratigraphic Committee and ratified to become official guidelines for further use in geological surveys.

The stratigraphic charts approved at the First Siberian Stratigraphic Workshop of 1956 came out as a separate publication in 1959 (Decisions..., 1959). Those approved atthe Second Siberian Stratigraphic Workshop (two sessions in May 1964 and in February 1965) were published only as drafts in 1964 (Documents..., 1964; Correlation..., 1964) and then as a summary in the general Paleozoic chart (Stratigraphy..., 1967).

The work on the charts of 1959 and 1964 was run parallel with synthesizing the available data in a series of books *The Stratigraphy of the USSR*. The volume on the Silurian System came out in 1965 and included the Gorny Altai stratigraphic chart discussed at the Workshop of 1956 with respective later updating. Yet, the volume on the Ordovician System has never been published.

Until today, the Ordovician and Silurian charts for the Gorny Altai (and the whole western Altai-Sayan Folded Area), which were approved at the Stratigraphic Workshop of 1979 in Novosibirsk, ratified by the USSR Interdepartmental Stratigraphic Committee in 1982, and published in 1983 (Decisions..., 1983), have been in official use by geological surveys. The standard stratigraphic chart of the Altai-Sayan Folded Area (including Gorny Altai) comprises the regional stages (horizons) of Dobry, Tayanza, Lebed', Kostinsky, Bugryshikha, Savel'ev, Toga, Chakyr, Dietken, and Orlov in the Ordovician and the Chineta, Polaty, Chagyrka, and Kuimov, and also the Pridoli stage, in the Silurian (Decisions..., 1983).

Several workshops in 2005–2006 aimed at developing new Paleozoic stratigraphic charts of Siberia. Authors of present monograph, are charged with Ordovician and Silurian stratigraphy of the Altai-Sayan Folded Area. In the text

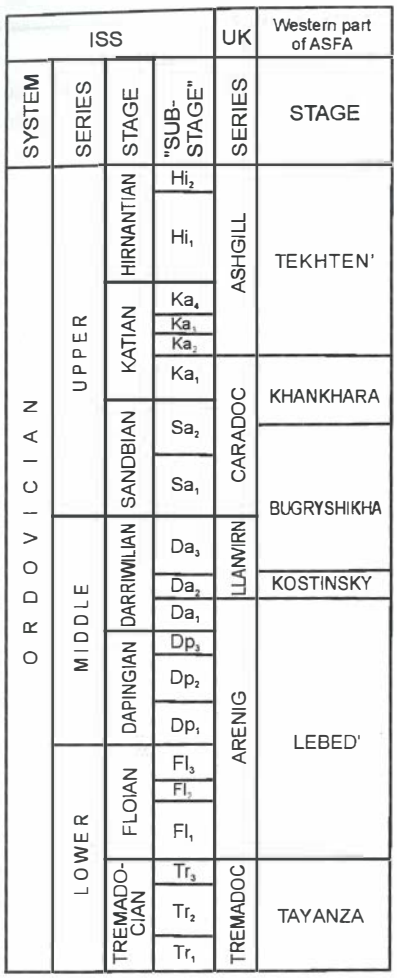


Fig. 4. Alignment of regional stratigraphic chart for the Ordovician of the western part of the ASFA with the International Stratigraphic Scale.

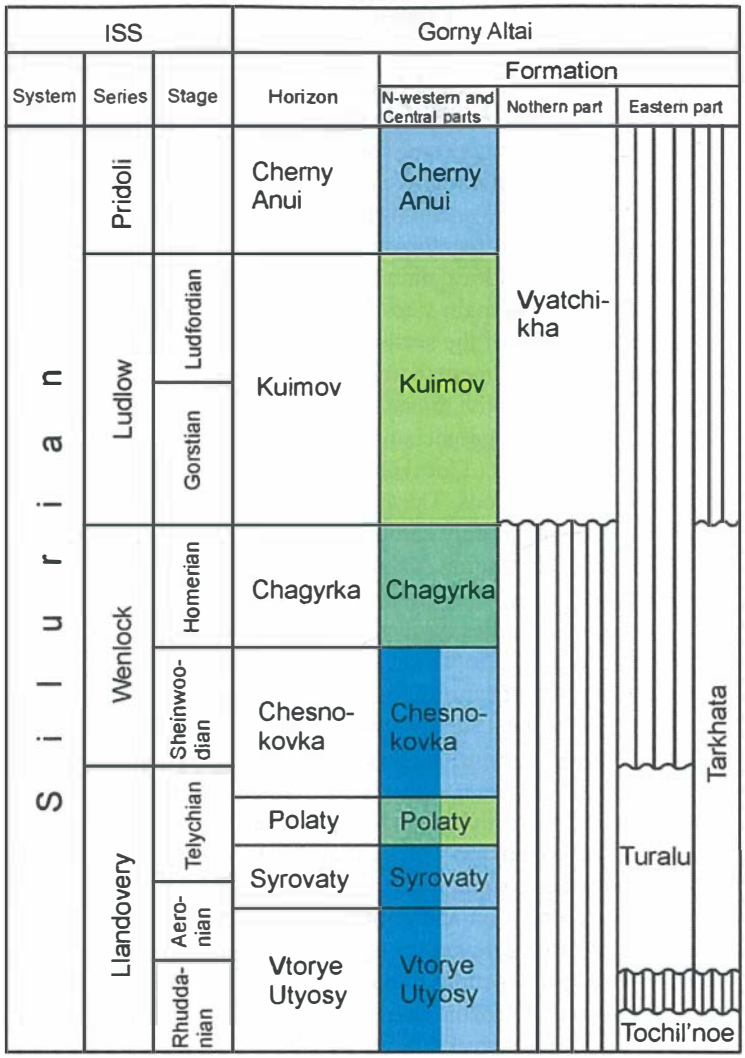


Fig. 5. Alignment of regional and local stratigraphic charts for the Silurian of the Gorny Altai with the International Stratigraphic Scale.

below the provisional new Ordovician and Silurian stratigraphic charts of the Gorny Altai prepared for further consideration and approval are used.

In figures 4 and 5 the Ordovician and Silurian regional stages of the Gorny Altai are correlated to the units of the International Stratigraphic Chart (Scale) on the basis of the respective graptolite, conodont and chitinozoans zones (Figs 6, 7, 8, 9).

1.1.1. Ordovician regional stratigraphic units

Tayanza Regional Stage (Horizon) was defined by Z.E. Petrunina (Decisions..., 1983). It is aligned with whole Tremadocian Stage (Tr_1, Tr_2, Tr_3). It should be noted that the base of the horizon requires specification.

The Tayanza Horizon is subdivided into two subhorizons. Basic fauna for the both subhorizons are trilobites, for the Lower Tayanza Subhorizon - *Apatokephalus bijanus* Petrun., *A. kamlakensis* Petrun., *Koldinioidia anossica* Petrun., *Kaltykelina altaica* Petrun., *Glaphurus kamlakianus* Petrun., and for the Upper Tayanza Subhorizon – *Amzasskiella mirabilis* Polet., *Kaltykelina gracilis* Petrun., *Apatokephalus* ex gr. *serratus* (Sars), *Conophris pusillina* Polet., *Rhadinopleura* (*Sibiriopleura*) *tajansensis* Petrun., *Glaphurus* cf. *coronatus* Z. Max. Brachiopods *Apheoorthis*

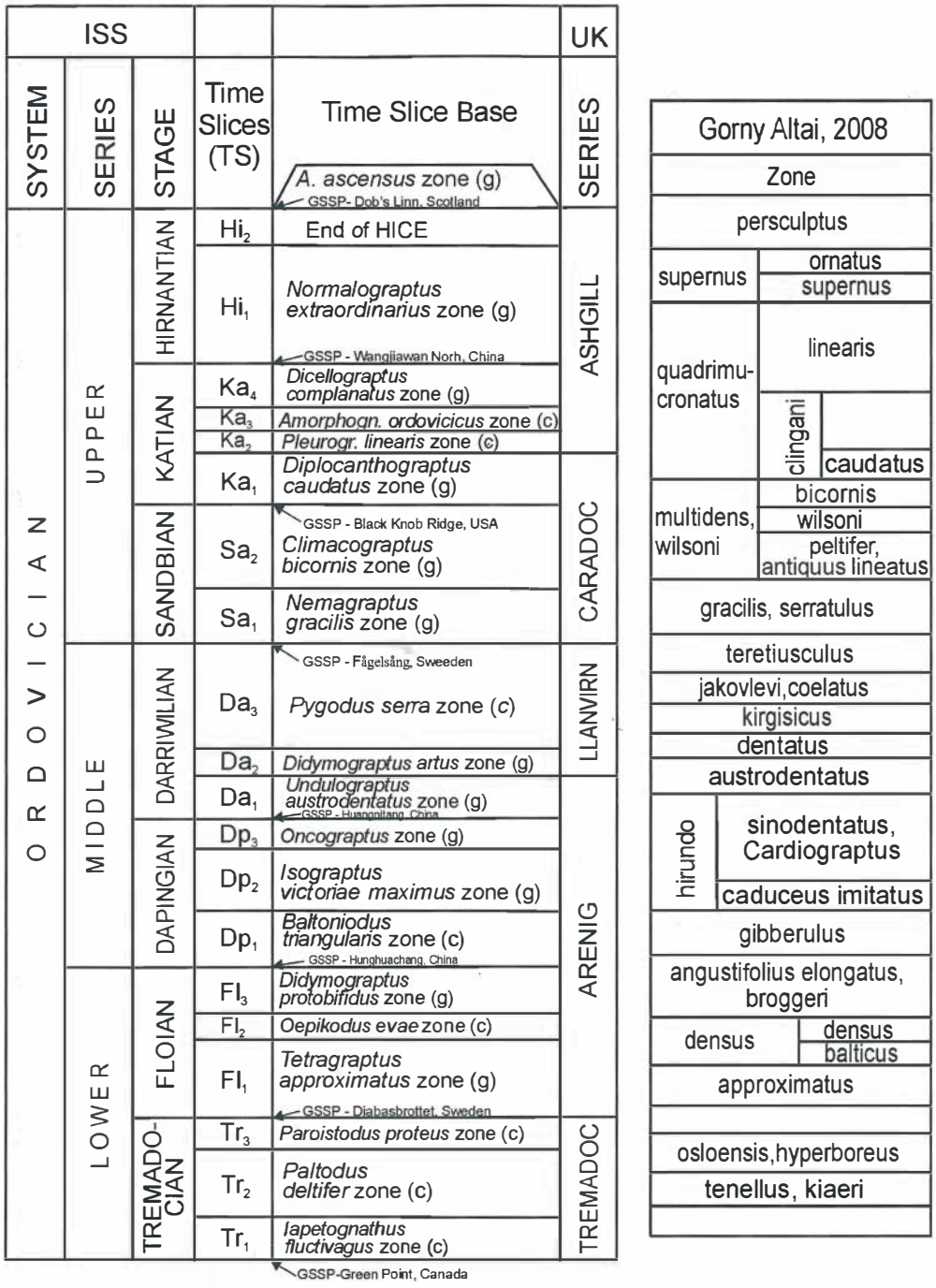


Fig. 6. Time Slice Base International Stratigraphic Ordovician Scale and graptolite zones for the Gorny Altai (modified from Sennikov, 1996, with new additional data).

lineocosta Walcot, *Nanorthis schoriensis* Severg., *Notorthis algainensis* Severg., *Punctolira kondomiensis* Severg. are common for the whole horizon.

Conodonts of the transitional association characteristic for *Cordylodus lindströmi* and *Iapetognathus fluctivagus* zones are known from the Lower Tayanza Subhorizon, whereas the Upper Tayanza Subhorizon is characterized by graptolites of the *osloensis – ramosus* zone.

Lebed' Regional Stage (Horizon) was proposed by N.V. Sennikov (Decisions..., 1983). It is aligned with Floian (Fl_1, Fl_2, Fl_3), Dapingian (Dp_1, Dp_2, Dp_3) and with lower half of Lower Darriwilian (Da_1).

The Lebed' Horizon is subdivided into two subhorizons. The Lower Lebed' Subhorizon is dominated by trilobites *Taidonurus asiaticus* Petrun., *Tersella strobilata* Petrun., *T. altaica* Petrun., *Pytine sibirica* Petrun., *Lapidoperia* ?

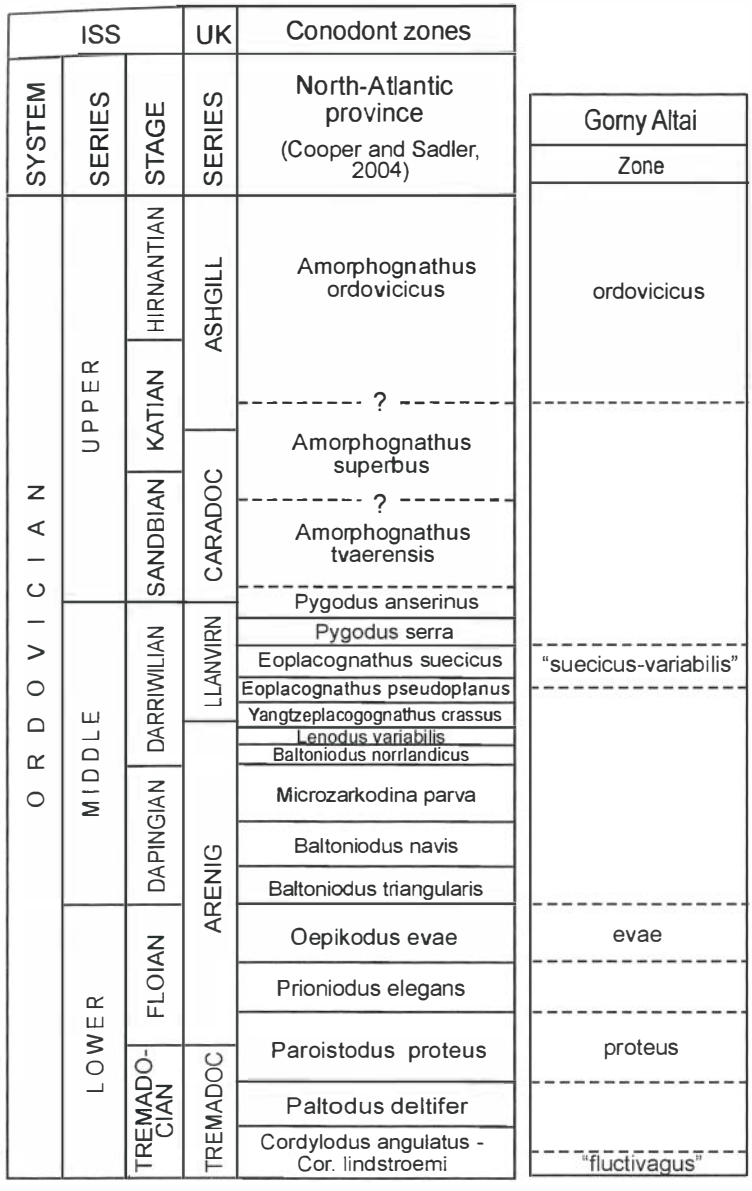


Fig. 7. Ordovician conodont zones for the Gorny Altai (modified from Izokh et al., 2003).

ishpensis Petrun., *Hypermecaspis lebediensis* Petrun., *Conophris tagasensis* Petrun., *Seleneceme improvisa* Petrun., brachiopods *Nanorthis gloriosus* Severg., *Diparelasma minuta* Severg., *Rhyselasma pusilla* Severg., *Akelina akelina* Severg., and the Upper Lebed' Subhorizon – by brachiopods *Archaeorthis sibirica* Severg., *Tritoechia orliniensis* Severg., *Orthis kozhuchiensis* Severg., *Hesperonomia ilovata* Severg., *H. paratylyensis* Severg., *Nanorthis multicostata* Ulr. et Coop.

Basic fauna are graptolites of the *approximatus, densus, angustifolius elongatus, gibberulus* and *austrodentatus-hirundo* zones.

Kostinsky Regional Stage (Horizon) was defined by E.S. Levitsky (Levitsky, 1963; Severgina, 1973; Sennikov et al., 1982; Decisions…, 1983). It is aligned with the upper half of the Lower Darriwilian (Da_1) and Middle Darriwilian (Da_2).

The Kostinsky Horizon is characterized by trilobite fauna *Megalaspides sibirica* Petrun., *Eorobergia compacta* Petrun., *Kolymella* cf. *plana* (Tchug.), *Eccoptochile tchagyrica* Petrun., *Ceraurinella* cf. *frequens* Tchug., and brachiopods *Idiostrophia costata* Cooper, *Chaganella* sp., *Hesperonomia tylyensis* Severg., *Hesperonomiella kuznetskiana* Severg., *Beloviella salairica* Severg., *Trondorthis sibirica* Severg., *Tr. talovskiensis* Severg.

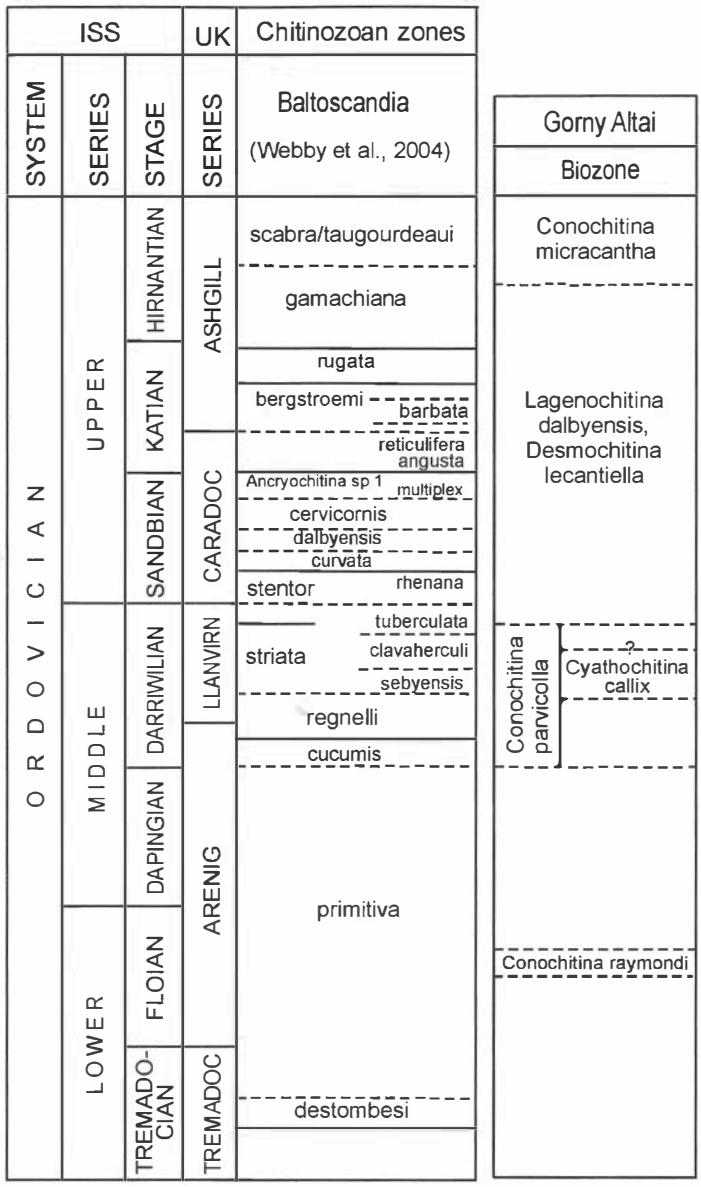


Fig. 8. Ordovician chitinozoan biozones for the Gorny Altai (modified from Sennikov, Obut, 2003).

Graptolites of the *dentatus-kirgisicus* zone are known from the Kostinsky Horizon. Regional *dentatus-kirgisicus* zone is treated as analogue of the *artus* zone of the British zonal scale and the *dentatus* zone of the North-American zonal scale of the International Stratigraphic Scale, that coincides with lower 4b (= Da_2) and transitional 4a/4b (Da_1/Da_2) of the middle part of the Darriwilian Stage (Webby et al., 2004).

Conodonts of the *E. pseudoplanus* zone aligned with upper subzone of the *variabilis* zone from the North-Atlantic zonal scale of the International Stratigraphic Scale (ISS), that coincides with the upper part of 4a (= Da_1) and lower one third of 4b (= Da_2) of the middle part of the Darriwilian Stage (Viira et al., 2001; Webby et al., 2004) are recovered from this horison.

Bugryshikha Regional Stage (Horizon) was proposed by (Levitsky, 1963; Severgina, 1965, 1968, 1972, 1973; Gintsinger, V. Sennikov, 1967; Stratigraphic..., 1975; Decisions..., 1983). This horizon is aligned with upper Darriwilian (Da_3), lower Sandbian (Sa_1) and lower half of upper Sandbian (Sa_2).

The Bugryshikha Horizon is subdivided into three subhorizons. The Lower Bugryshikha Subhorizon is characterized by trilobite fauna *Eorobergia integra* Petrun., *Vogdesia? tuloica* Petrun., *Remopleuridiella altaiensis* Petrun.,

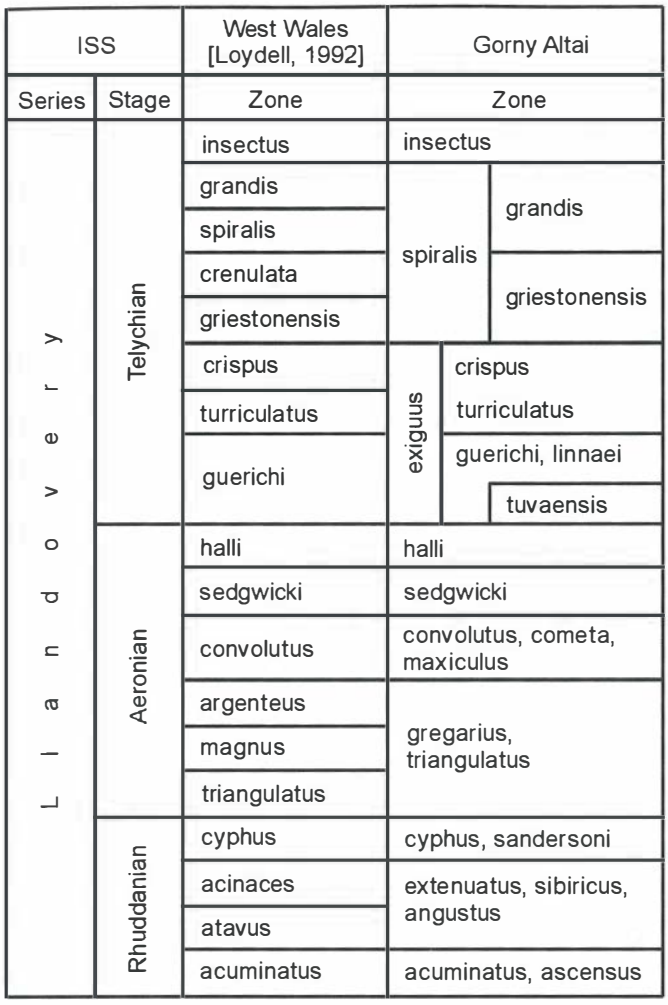


Fig. 9. Silurian graptolite zones for the Gorny Altai (modified from Sennikov, 1996).

Levirobergia oirotica Petrun., and brachiopods *Archaeorthis altaica* Severg., *Idiostrophia tuloviensis* Severg. The Upper Bugryshikha Subhorizon is characterized by trilobites *Pliomerellus latus* Petrun., *Raymondaspis altaicus* Petrun., *Robergiella margofera* Petrun., *Cnemidopyge tuloica* Petrun., *Atractopyge sibirica* Petrun., *Ceraurinella latigenata* Petrun., and brachiopods *Glyptorthis primus* Severg., *Parastrophina bilobata* Cooper, *Beloviella bugryshichiensis* Severg., *Christiania* aff. *subquadrata* Cooper, *Glyptomena karasuensis* Severg.

The lower half of the Upper Bugryshikha Subhorizon is dominated by trilobites *Homotelus angustus* Petrun., *Lonchodomas* (*Foliopyge*) *levis* Petrun., *Ampyxella* (*Belaxella*) *infermicostata* Petrun., *Nileus tengriensis* Web., *Telephina mobergi* (Hadd.), and the upper half of the Upper Bugryshikha Subhorizon – by trilobites *Cybelurus planifrons* Weber, *Raymondella bugryshichiensis* Petrun. On a whole brachiopods *Apatomorpha altaica* Severg., *Leptellina tennessensis* Cooper, *Hesperorthis markovae* Rozman are distributed in the Upper Bugryshikha Subhorizon.

Graptolites of the *jakovlevi-coelatus, teretiusculus, gracilis-serratulus, multidens* (subzone of *antiquus lineatus-peltifer* and lower part of subzone *wilsoni*) zones are typical for the Bugryshikha Horizon.

Khankhara Regional Stage (Horizon) is newly proposed in present monograph. It could be aligned with upper half of upper Sandbian (Sa_2) and lower Katian (Ka_1).

The Khankhara Horizon is subdivided into three subhorizons. Trilobites *Chasmopsella unica* Petrun., *Bronteopsis gregaria* Raum., *Jaboganellus gornoaltaicus* Petrun., *Otarionelliana koksoriana* Korol., *Eorobergia lebediensis* Petrun., and brachiopods *Onniella chancharica* Severg., *Plectocamara uscuchiensis* Severg., *Fascifera buraensis* Severg., *Bimuria bugryshichiensis* Severg., *Multicostella* (*Chaulistomella*) *inaequistriata* Cooper, *Eoanostrophia lebediensis* (Severg.) are typical for the Lower Khankhara Subhorizon.

Trilobites *Ceraurinus icarus* (Bill.), *Calyptaulax bellatulus* Petrun., *Paracybeloides loveni* (Linrs.), and brachiopods *Boreadorthis togaensis* Severg., *Multicostella* (*Chaulistomella*) *amzassensis* Severg., *Strophomena lebediensis*

Severg., *Rostricellula ainsliei amzassica* Severg., *Togaella grandis* Severg. are typical for the Middle Khankhara Subhorizon.

Trilobites *Holotrachellus punctillosus* Torng., *Illaenus oviformis* Warb., *Il.* cf. *septentrigonalis* Tchug., *Amphilichas sniatkovi* Weber, *Brontocephalina nuda* (Ang.), *Isocolus sjogreni* Ang., *Chasmops salairicus* Petrun., *Eucrinuroides bobroviensis* Petrun., and brachiopods *Eospirigerina sublevis* Severg., *Austinella lebediensis* Severg., *Salopina uxunaica* (Severg.), *Glyptorthis praepulchra* Severg., *Gl. balclatchiensis* (Dav.), *Hesperorthis lebediensis* Severg., *Dulankarella magna* Ruk., *Salairella salairica* (Severg.) are typical for the Upper Khankhara Subhorizon.

The following graptolite zones are distinguished for the Khankhara Horizon: upper part of *multidens-wilsoni, bicornis, clingani-caudatus* and *linearis.*

Tekhten' Regional Stage (Horizon) was proposed by N.V. Sennikov, Z.E. Petrunina and L.A. Gladkikh (Sennikov et al., 2001a). It is aligned with middle (Ka_2, Ka_3) and upper (Ka_4) Katian, as well as with lower Hirnantian (Hi_1).

The Tekhten' Horizon is subdivided into three subhorizons. The Lower Tekhten' Subhorizon is characterized by brachiopods *Eospirigerina orloviensis* (Severg.), *Oxoplecia platystrophoides* Cooper, *Salairella inensis* Severg., *Catazyga anuensis* Severg., *Eridorthis subinexpecta digna* Severg., *Schizophorella fallax* Salter.

Trilobites *Stenoblepharum warburgae* (Prib.) and brachiopods *Giraldibella vulgaris* (Severg.), *Thebesia thebesensis* Amsden, *Diambonia septata* (Cooper) are typical for the Middle Tekhten' Subhorizon. The Upper Tekhten' Subhorizon is characterized by trilobites *Mucronaspis mucronata* (Brongniart) and brachiopods *Dalmanella testudinaria* (Dalm.), *Alispira praegracilis* Severg., *Streptis altosinuata* (Holt.), *Hirnantia* aff. *noixella* Amsden, *Brevilamnulella gromotuchaensis* Severg.

Tekhten' Horizon is characterised by graptolites of the *linearis, supernus, ornatus, persculptus* zones and by conodonts of *ordovicicus* zone.

Listvyanka Regional stage (Horizon) is newly proposed in present monograph. It is aligned with uppermost upper Hirnantian (Hi_2).

Graptolites of the *persculptus* zone are common for the Listvyanka Horizon. Along with graptolites chitinozoans *Conochitina microcantha* Eisenack have been recovered. Lack of other fauna at this stratigraphic level on the Gorny Altai.

1.1.2. Silurian regional stratigraphic units

Vtorye Utyosy Regional Stage (Horizon) is newly proposed in present monograph. It is aligned with Rhuddanian and lower part of Aeronian.

Trilobites *Stenopareia glochin* How., *St. acymata* How., *Calymene ubquitosus* How., *Warburgella altaica* Yolk., *W. calvata* Yolk. are typical for the Vtorye Utyosy Horizon.

Found graptolites belong to *acuminatus-ascensus, angustus-sibiricus, triangulatus-gregarius* and *convolutus-cometa* zones.

Syrovaty Regional Stage (Horizon) is newly proposed in present monograph. It is aligned with upper part of Aeronian and lower part of Telychian.

Characteristic fauna are brachiopods *Aegiria grayi* (Dav.), *Eoplectodonta* cf. *penkillensis* (Reed), *Protatrypa thorslundi* Bouc. et John., *Dalmanella* cf. *neocrassa* Nikif., *Eospirifer tuvaensis* Tchern.

Graptolites of the *sedgwicki, halli, guerichi* (including lower subzone *tuvaensis*), *turriculatus* and lower part of *griestonensis* zone have been recovered.

Polaty Regional Stage (Horizon) was defined by a group of authors (Decisions..., 1983). It is aligned with upper part of Telychian.

Trilobites *Warburgella kolobovae* Yolk., *W. insperata* Yolk., *Podowrinella straitonensis* Lamont. and brachiopods *Pentameroides exactus* Kulk., *Parastrophinella altaica* Kulk., *Pentamerus kamyschenskiensis* Kulk., *Nalivkinia grunewaldtiaeformis* (Peetz), *Tuvaella rackovskii* Tchern., *Stegerhynchus angaciensis* Tchern., *Atrypa* ex gr. *orbicularis* (Sow.) are typical for the Polaty Horizon.

Graptolites of *griestonensis* zone and conodonts of the *celloni* zone are known.

Chesnokovka Regional Stage (Horizon) is newly proposed in present monograph. It is assigned to uppermost Telychian and Sheinwoodian. Precise alignment of the Chesnokovka Horizon upper boundary with the Sheinwoodian upper boundary requires further investigation.

Chesnokovka Horizon is dominated by trilobites *Warburgella obscura* Yolk., *Bumastus barriensis* Murch., *Sphaerexochus* ex gr. *mirus* Beyr. and brachiopods *Resserella canalis* (Sow.), *Eoplectodonta minuta* (Kulk.), *Ferganella borealis* (Schloth.), *Eospirifer radiatus* (Sow.), *Spirigerina brownsportensis* (Amsden).

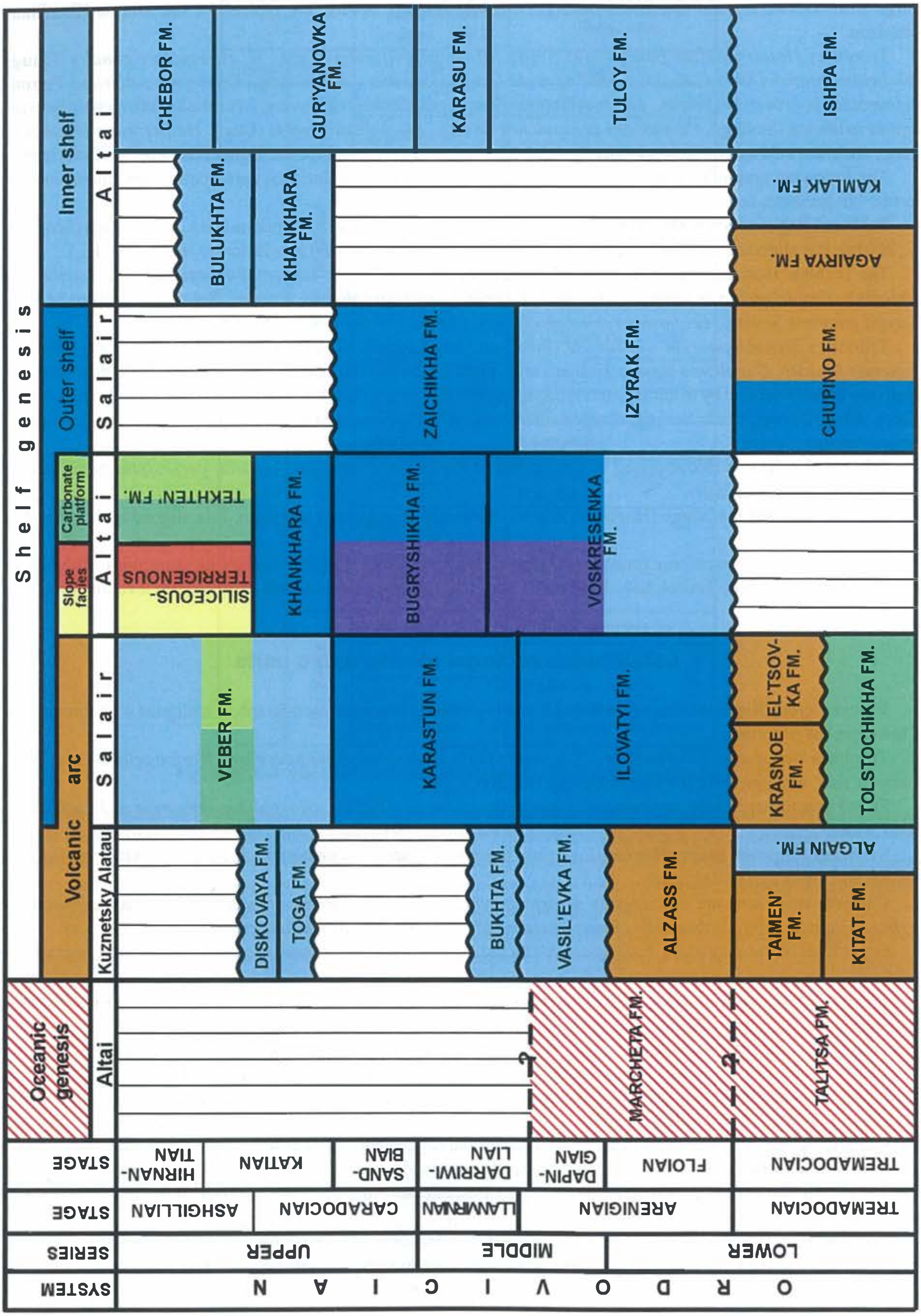


Fig. 10. Intra-regional stratigraphic chart for the Ordovician of the Gorny Altai.

Graptolites of the *spiralis-grandis* and *insectus-centrifugus* zones have been found from the Chesnokovka Horizon. From the upper part of the horizon transitional forms of graptolites *Monograptus priodon* (Bronn) – *Monograptus flemingi* Salter have been collected in Salair. The latter taxa (*Mon. flemingi* Salter) is characteristic for the uppermost Sheinwoodian graptolite zone – *rigidus*, as well as for the lowermost Homerian *lundgreni* zone.

Chagyrka Regional Stage (Horizon) was defined by V.A. Zheltonogova, V.A. Zinchenko, G.S. Kharin (Vladimirskaya, Zheltonogova, 1967; Startigraphic..., 1975; Decisions..., 1983). It is aligned with Homerian. Proper position of the Chagyrka Horizon lower boundary in relation to Sheinwoodian / Homerian boundary requires additional investigation.

Chagyrka Horizon is dominated by trilobites *Warburgella obscura* Yolk., *W. verecunda* Yolk., *Bumastus barriensis* Murch., *Sphaerexochus mirus* Beyr., *Cheirurus beyrichi* Barr. and brachiopods *Trimerella acuminata* Bill., *Resserella canalis* (Sow.), *Harpidium insigne* Kirk., *Cymbidium perpolitus* Kulk., *Gypidula optima* Kulk., *Cliftonia colibri* (Barr.), *Eoplectodonta minuta* (Kulk.), *Ferganella borealis* (Schloth.), *Ancillotoechia subminerva* Kulk., *Atrypella linguata* (Buch.), *At. minuta* Kulk., *Eospirifer radiatus* (Barr.), *Cyrtia exporrecta* (Whal.), *Antirhynchonella exista* (Kulk.).

Kuimov Regional Stage (Horizon) was proposed by N.P. Kulkov and A.B. Ivanovsky (Ivanovsky, Kulkov, 1974; Decisions..., 1983; Stratigraphic..., 1991). It is aligned with Gorstian and Ludfordian. Proper position of the Kuimov Horizon lower boundary with the Gorstian lower boundary requires additional investigation.

Trilobites *Warburgella obscura* Yolk., *W. verecunda* Yolk., *W. stokesii* (Murch.), and brachiopods *Conchidium biloculare* (His.), *Atrypella operosa* Kulk., *Harpidium insigne* Kirk, *Morinorhynchus williamsi* (Kulk.), *Ferganella borealis* (Schloth.), *Howellella elegans* (M.-Wood), *H. complicata* Kulk., *Didymothyris didyma* (Dalm.), *Tannuspirifer posterus* Kulk. are common for the Kuimov Formation.

The discovered conodonts (Kuimov Formation, Pautikha section) point to *O. snajdri* conodont zone, upper part of Ludfordian.

Cherny Anui Regional Stage (Horizon) was distinguished by N.P. Kulkov (Stratigraphic..., 1991). It is aligned with whole Pridolian Stage. Precise alignment of the Cherny Anui lower boundary with lower boundary of Pridolian, and the upper part of this straton with upper Silurian boundary requires further additional investigations, that should be on search of conodonts.

The Cherny Anui Horizon is subdivided into two subhorisons. For the Lower Cherny Anui Subhorizon brachiopods *Atrypella operosa* Kulk., *Lamelliconchidium tschergense* Kulk., *Ferganella borealis* (Schloth.), *Howellella elegans* (M.-Wood), *H. complicata* Kulk., *Didymothyris didyma* (Dalm.), *Tannuspirifer posterus* Kulk. are typical.

Trilobites *Warburgella waigatschensis* (Tschern. et Yak.), and brachiopods *Anastrophia praemagnifica* Kulk., *Alaskaspira* aff. *dunbari* Kirk et Amsd., *Didymothyris didyma* (Dalm.), *Howellella* cf. *elegans* (M.-Wood), *Machaeraria nymphaeformis* (Nikif.), *Pseudocamarotoechia nuculaeformis* Kulk., *Atrypella columbella* (Barr.), *Tannuspirifer kolpakensis* Kulk. are characteristic for the Upper Cherny Anui Subhorizon.

Figures 10 and 5 present intra-regional correlation charts of local Ordovician and Silurian stratigraphic units of the Gorny Altai based mainly on synthetic trilobite and brachiopod data.

1.2. Local Ordovician and Silurian stratigraphic units of the Gorny Altai

1.2.1. Ordovician strata

Ordovician strata in the Gorny Altai occur in two genetically different types of sections that record oceanic and shelf deposition.

1.2.1.1. Oceanic deposition

Oceanic Ordovician sections are known in the western and northwestern Gorny Altai and consist of the following units.

Zasur'ya Group

The Zasur'ya stratigraphic unit was first distinguished as a formation by O.P. Goryainova in 1956 (unpublished evidence). V.I. Tikhonov (1956) in his publication referred to Goryainova's definition but applied the name Zasur'ya to the lower subformation of a variegated formation in the western Gorny Altai. The Zasur'ya unit has no stratotype section and its typical locality is in the area northwest of Krasnoshchekovo Village on the right bank of the Charysh

River, in the catchments of the Zasur'ya, Molchanikha, and Berezovy brooks. Sennikov et al. (2001b, 2003) suggested to distinguish the Zasur'ya unit as a group divided into three formations.

According to the present knowledge, the lithology of the Zasur'ya Group consists of clayey-siliceous schists, jade, chert, mudstone, siltstone, sandstone, tuffaceous sandstone, tuff breccia, and gabbro, gabbro-diabase and diabase dikes, and mafic volcanics. According to the chemistry of basalts, the group was deposited in an ocean (Iwata et al., 1997; Buslov et al., 1999, 2000; Sennikov et al., 2003). Variolite pillow lavas, aphyre or less often plagioclase-pyroxene and pyroxene-plagioclase porphyry basalts and scarce andesites are of low-K oceanic tholeiite affinity and can be classified as mid-ocean ridge (MORB) or ocean-island (OIB) basalts. Basalts are quite rare in the sections of the Zasur'ya Group and are 1 to 10 m thick or thicker layers.

Conodont assemblages in the Zasur'ya Group are localized at two intervals of (i) Late Cambrian (Aksai Stage - Early Batyrbai Substage) and (ii) Early Ordovician (Late Tremadocian Substage – Floian Stage). No transitional Batyrbai-Tremadocian conodont zones in the group have been found so far. All conodonts were extracted by acid dissolution from chert, siliceous mudstone, and other siliceous rocks. The absence of conodont findings from the Cambrian-Ordovician boundary strata in the Zasur'ya Group is implicit evidence that a large part of the sections lack siliceous rocks. This hypothesis is supported by the stacking pattern of the Zasur'ya sections along the Talitsa River where the group shows distinct division into three units, with a purely terrigenous middle unit (the Talitsa Formation) characterized by absence of siliceous sediments.

Listvenny Formation

The Listvenny Formation, 200 to 300 m thick, is the lowermost unit in the Zasur'ya Group (Sennikov et al., 2001b, 2003). Its stratotype section occurs in the Listvenny Brook -Talitsa River divide in the western Gorny Altai. The Listvenny Formation contains, in all its sections, red or more rarely gray siliceous rocks, often with volcanic intercalations, among red and gray terrigenous members. The formation yielded conodonts, radiolarians, and siliceous sponge spicules. The conodont age of the Listvenny Formation is defined at five stratigraphic intervals corresponding to the conodont zones: (1) Aksai age, *W. matsushitai* zone, (2) Aksai age, *M. erectus* zone, (3) earliest Batyrbai age, *P. muelleri* zone, (4) Batyrbai age, *E. notchpeakensis* zone, (5) middle Batyrbai age, *C. minutus* zone. Relationships of the Listvenny Formation with the underlying rocks remain unknown. The formation is conformably overlain by the Talitsa Formation.

Talitsa Formation

The 400-450 m thick Talitsa Formation, the middle unit of the Zasur'ya Group, consists of gray (or less often variegated) terrigenous rocks. Its stratotype is located in the middle reaches of the Talitsa River (right tributary of the Charysh River) in the western Gorny Altai (Sennikov et al, 2001b, 2003). The recovered faunal groups include radiolarians and siliceous sponge spicules. The Talitsa Formation conformably oversteps the Listvenny Formation and is conformably (?) overlain by the Marcheta Formation.

Marcheta Formation

The Marcheta Formation, the upper unit of the Zasur'ya Group, varying in thickness from 600 to 950 m, is composed of alternating red and gray terrigenous and siliceous rocks. The stratotype of the formation was distinguished as two composite sections along the Marcheta River, the left tributary of the Muta River in the northwestern Gorny Altai (Sennikov et al., 2001b, 2003). No reliably proven basalts have been found so far in the paleontologically constrained sections of the Marcheta Formation. The Marcheta rocks include scarce layers of tuff and tuffaceous sandstone. The formation contains conodonts, radiolarians, and siliceous sponge spicules. The conodont age of the Marcheta Formation of the Zasur'ya Group is defined at three stratigraphic intervals corresponding to the conodont zones: (1) Tremadocian-Floian boundary strata, *P. proteus* zone, (2) upper part of the Floian, *P. elegans* zone, and (3) Middle Floian, *O. evae* zone. The Marcheta Formation conformably (?) overlies the Talitsa Formation. The relationship of the formation with the overlying strata remains uncertain.

1.2.1.2. Shelf deposition

Ordovician shelf deposition in the Gorny Altai is known in the western, northwestern, central, northern, northeastern, and eastern parts of the area. There are three main local Ordovician successions that were deposited in different environments of a single basin.

Succession 1 includes the Voskresenka, Bugryshikha, Khankhara, and Tekhten' formations, and the basal layers of the lower Vtorye Utyosy Formation found in the western, northwestern, and central Gorny Altai. The deposition occurred far offshore on a relatively deep outer shelf and on a shallow-marine carbonate platform along the shelf edge at the foot of the continental slope.

Voskresenka Formation

The Voskresenka Formation occupies the western and central parts of the Gorny Altai (Sennikov et al., 1979, 1982; Ermikov et al., 1979; Decisions..., 1983; Stratigraphic..., 1991, Yolkin et al., 2001). Its stratotype section, about 300 m thick, has been documented in the western Gorny Altai at the Barany - Voskresenka brooks divide (left tributaries of the Charysh River) near Ust'-Chagyrka Village. The Voskresenka Formation, 285 to 900 m thick, consists of sandstone, siltstone, mudstone, less often conglomerate and limestone. The rocks contain trilobites, brachiopods, crinoids, gastropods, graptolites, and conodonts. Graptolites include zonal assemblages of the *approximatus, densus, gibberulus, austrodentatus-hirundo*, and *dentatus-kirgisicus* zones (Petrunina et al., 1984; Sennikov, 1996). The *E. pseudoplanus* conodont zone in the upper part of the Voskresenka Formation (Kostinsky Beds) correlates with the upper subzone of the *variabilis* zone in the North Atlantic standard of the ISS: upper part 4a (=Da_1) and lower one third 4b (=Da_2) of the lower and middle Darriwilian (Webby et al., 2004). The formation unconformably overlain different Cambrian units and is conformably overlaid by the Bugryshikha Formation. The Voskresenka Formation is aligned with the Floian, Dapingian, and lower and middle Darriwilian.

Bugryshikha Formation

The Bugryshikha Formation varies in thickness from 140 m to 1600 m and occurs in the Charysh-Inya and Anui-Chuya areas of the Gorny Altai near Bugryshikha Village. The formation was first distinguished as an unnamed unit by A.A. Nikonov (Nikonov, 1931; Usov, 1936; Stratigraphic..., 1956, 1975; Perfiliev, 1959; Sennikov et al., 1959; Decisions..., 1959, 1983; Petrunina, Severgina, 1962; Yolkin et al., 2001); V.A. Kuznetsov (1948) coined the name Bugryshikha Formation. The stratotype of the formation is a composite section near Bugryshikha Village along the Bolshaya and Malaya Uskuchevka rivers, the right tributaries of the Belaya River. The lower part of the formation crops out along the Bugryshikha River (the Belaya left tributary) where it is exposed overlying unconformably variegated terrigenous rocks of the Suetka Formation of the Gorny Altai Group. The Bugryshikha Formation is composed of sandstone, siltstone, or more rarely mudstone and conglomerate. The Bugryshikha strata bear trilobites, brachiopods, and graptolites. The section spans the graptolite zones: *jakovlevi-coelatus, teretiusculus, gracilis-serratulus,* and *multidens* (*antiquus lineatus-peltifer* and lower *wilsoni* subzones). The Bugryshikha Formation conformably overlain the Voskresenka Formation and underlain the Khankhara Formation. It corresponds to upper half of the Darriwilian and the Sandbian.

Khankhara Formation

The Khankhara Formation, with a variable thickness of 60 to 800 m, is found in the western, northwestern, northern and central Gorny Altai. It was distinguished in 1929 by A.A. Nikonov (Usov, 1936; Stratigraphic..., 1956; 1975; Tikhonov, 1956; Sennikov et al., 1959; Decisions..., 1959, 1983; Yolkin et al., 2001). Its stratotype section has been designated on the left bank of the lower Malaya Khankhara River near Chineta Village, and a section on the right bank of the Malaya Uskuchevka River near Bugryshikha Village is its hypostratotype. The Khankhara Formation consists of sandstone, calcareous-argillaceous siltstone, and mudstone with limestone and marl interbeds. The base of the formation is a prominent lithological marker being composed of gray sandy and clayey limestone or often oolitic limestone occasionally grading into limestone conglomerate. The fauna found in the Khankhara section includes tabulate corals, gastropods, crinoids, trilobites, brachiopods, and graptolites.

The graptolite zonation includes the upper *multidens-wilsoni* and *bicornis, clingani-caudatus* and *linearis* zones.

The formation rests conformably upon the Middle Ordovician Bugryshikha Formation and is gradually overlain by the uppermost Ordovician Tekhten' Formation. The Khankhara Formation correlates with the upper Sandbian and the lower half of the Katian.

Tekhten' Formation

The Tekhten' Formation, from 115 m to 700 m thick, occurs in the western, northwestern, and central Gorny Altai. It was distinguished (Sennikov et al., 2001; Yolkin et al., 2001) in Upper Ordovician strata which make up a single complex of carbonate-terrigenous rocks standing out against the strata above and below. The carbonates are most often of reef origin. Terrigenous rocks are found on the periphery of reefal carbonates, where they replace the flanks of the

latter along the strike, as well as inside the carbonate bodies. Reef frameworks are present in different strata but most often are found in the lower and upper parts of the section. Limestones locally predominate throughout the formation thickness (invalid Orlov Formation) or are restricted mainly to the lower layers (invalid Chakyr Formation) while the upper section consists of terrigenous sediments with thin limestone layers (invalid Diekten Formation). In many sections the carbonate-terrigenous proportions are intermediate between the two extremes. The stratotype section of the Tekhten' Formation is located on the right bank of the Tekhten' River (right tributary of the Muta River). The formation is composed of limestone with algal bioherms alternating with calcareous siltstone, sandstone, or less often mudstone. The Tekhten' strata contain tabulate and rugose corals, stromatoporoids, trilobites, brachiopods, ostracods, gastropods, crinoids, graptolites, conodonts, scolecodonts, radiolarians, siliceous sponge spicules, and chitinozoans. The graptolite assemblages correspond to the *supernus* zone with the *supernus* and *ornatus* subzones. The Tekhten' Formation conformably overlain the Khankhara Formation and underlain the Vtorye Utyosy Formation. It is aligned with the upper half of the Katian and with the Hirnantian.

Vtorye Utyosy Formation

For the brief description of the Vtorye Utyosy Formation see 1.2.2. *Silurian* below, because the greatest part of the formation, except for the basal layers marked by the *persculptus* graptolite zone, belongs to the lower Silurian.

Succession 2 of shelf facies includes the Kamlak, Khankhara, and Bulukhta formations found in the northern Gorny Altai. They were deposited at the outer-to-inner shelf transition. Some sections of the local stratigraphic units in succession 2 formed in estuaries of large rivers that most likely flew from mountains.

Kamlak Formation

The Kamlak Formation is found in the northern Gorny Altai and reaches a thickness of 2000 m. It was distinguished as a separate stratigraphic unit (Ermikov et al., 1979; Decisions..., 1983; Petrunina et al., 1984; Petrunina, 1990; Stratigraphic ..., 1991; Yolkin et al., 2001). The composite stratotype section of the formation occurs on the left bank of the Maly Kamlak River and along the Tokoshkin Brook, its left tributary. The Kamlak Formation consists of interbedded sandstone, siltstone, limestone, conglomerate, gravelstone, and mudstone and contains trilobites, brachiopods, graptolites, and conodonts. The conodont age is defined by the *Cordylodus lindströmi - Iapetognathus fluctivagus* zone and graptolites correspond to the *osloensis – ramosus* zone. The formation shows fault contacts with the strata above and below. The Kamlak Formation is divided into three subformations. The Lower Kamlak Subformation (about 120 m thick) is aligned with the upper most Cambrian, the Middle Kamlak Subformation (~440 m) with the lower half of the Tremadocian, and the Upper Kamlak Subformation (up to 1400 m) with the upper half of the Tremadocian.

Khankhara Formation

For data on the Khankhara Formation see above (Succession 1).

Bulukhta Formation

The Bulukhta Formation, about 500 m thick, is known on the northeastern periphery of the Anui-Chuya area of the Gorny Altai (Bulukhta and Sarasa rivers). A.B. Gintsinger (Gintsinger, 1958, 1964; Vinkman, Gintsinger, 1967; Stratigraphic..., 1975; Decisions..., 1983; Sennikov et al., 1995) distinguished it as a separate stratigraphic unit. The formation's stratotype section occurs in the middle reaches of the Bulukhta River (left tributary of the Ulus-Cherga River). It is composed of sandstone, siltstone, mudstone, limestone, and conglomerate and contains tabulate and rugose corals and brachiopods. The formation conformably overlain the Khankhara Formation and is unconformably (?) overlaid by the Vtorye Utyosy Formation. The Bulukhta Formation is aligned with the second half of the Katian.

Succession 3 of Ordovician shelf facies comprises the Ishpa, Tuloi, Karasa, Gur'yanovka, and Chebor formations which occur in the northeastern and eastern Gorny Altai and were deposited on a relatively shallow inner shelf proximal to the shore.

Ishpa Formation

The Ishpa Formation in the northeastern Gorny Altai (Krivchikov et al., 1976; Decisions..., 1983; Stratigraphic..., 1991) reaches a thickness of 1000 m. Its stratotype section is located along the Ishpa River (left tributary of the Biya River) near Verkh-Biysk Village (Petrunina et al., 1984). The basal member of the formation is conglomerate of pebbles and cobbles of sedimentary, volcanic, and intrusive rocks. The Ishpa Formation is generally composed of mudstone,

siltstone, and sandstone, with limestone and conglomerate interbeds. The faunas include algae, trilobites, brachiopods, and graptolites. Graptolite assemblages correspond to the *tenellus – kiaeri* zone. The formation unconformably overlain the Middle-Late Cambrian Tandoshka Formation and underlain the Tuloi Formation with unconformity. Its lower section is aligned with the Upper Cambrian, the middle part - with the Lower Tremadocian, and the upper section - with the Upper Tremadocian.

Tuloi Formation

The Tuloi Formation, up to 2600 m thick, occurs in the northeastern Gorny Altai. It was originally distinguished (Krivchikov et al., 1976; Decisions..., 1983; Petrunina et al., 1984; Stratigraphic..., 1991) as the lower unit of the Stretinka Formation (Group). The formation is represented by its stratotype section on the right bank of the Biya River 2.4 km downstream of the Tuloi inflow and then on the right bank of the lower Tuloi River. The formation consists of interbedded mudstone, siltstone, silty sandstone, and sandstone. Its basal member is composed of coarse conglomerate and sandstone with floating lenses of intrusive, volcanic, and terrigenous pebbles. The Tuloi strata contain trilobites, brachiopods, graptolites, and chitinozoans. According to graptolite zonation, the formation spans the *appoximatus, densus, angustifolius elongatus, gibberulus* and *hirundo* zones. The formation conformably oversteps the Tremadocian Ishpa Formation and is conformably overlaid by the Middle Ordovician Karasa Formation. The Tuloi Formation is aligned with the Floian, the Dapingian, and the lower Darriwilian.

Karasa Formation

The Karasa Formation, 450 m thick, is known in the northeastern Gorny Altai. It was originally recognized (Krivchikov et al., 1976; Decisions..., 1983; Stratigraphic..., 1991) as the upper unit of the Stretinka Formation (Group). Its stratotype section crops out on the right bank of the Tuloi River downstream of the Karasa River mouth. The formation basal member consists of light gray and yellowish-gray quartz sandstone and the full section comprises interbedded mudstone, siltstone, silty sandstone, and sandstone. It contains trilobites, brachiopods, ostracods, crinoids, hyoliths, orthoceratites, gastropods, graptolites, and chitinozoans. There are two graptolite zones: *dentatus* and *teretiusculus*. The formation conformably overlain the Tuloi Formation and is erosively overlain by the Gur'yanovka Formation. The Karasa Formation is aligned with the Darriwilian and the Sandbian.

Gur'yanovka Formation

The Gur'yanovka Formation reaching a thickness of 1000 m occurs in the northeastern Gorny Altai. The formation was recognized by V.M. Sennikov (Sennikov, 1962; Stratigraphic..., 1975; Decisions..., 1983) and is represented by a stratotype section on the right bank of the Lebed' River upstream of the Bura River mouth, near former Gur'yanovka Village. The formation is composed of siltstone, sandstone, limy-clayey mudstone, and limestone, with the basal member of gravelstone and coarse to medium sandstone, or less often of fine conglomerate. The faunas include tabulate and rugose corals, stromatoporoids, trilobites, brachiopods, ostracods, bryozoans, pelecypods, gastropods, orthoceratites, and graptolites. The Gur'yanovka Formation overlain weakly eroded surface of the Middle Ordovician Karasa Formation and is conformably overlaid by the Chebor Formation. The formation is conventionally aligned with the upper Sandbian and the lower Katian.

Chebor Formation

The Chebor Formation, up to 1100 m thick, is known in the northeastern Gorny Altai in the Lebed', Baigol, Biya, and Samysh catchments (northeastern and central Uimen'-Lebed' Synclinorium. The formation was distinguished by V.M. Sennikov (Sennikov, 1962; Stratigraphic..., 1975; Decisions..., 1983) and has its stratotype section on the right bank of the Lebed' River upstream of the Ayugozha mouth, the left Lebed' tributary, near Chebor Mountain. The Chebor section consists of mudstone and siltstone, less abundant sandstone, with thin layers and lenses of gray limestone. The basal member is composed of fine conglomerate and gravelstone with quartz pebble. The recovered fauna are brachiopods and tabulate corals. The formation conformably overlian the Middle Ordovician Gur'yanovka Formation and is unconformably overlaid by the Silurian Tochilny Formation (?). The Chebor Formation is conventionally aligned with the upper Katian.

1.2.2. Silurian strata

Silurian rocks in the Gorny Altai are represented by shelf facies. The succession of local stratigraphic units is the same throughout the region, with the Vtorye Utyosy Formation at the base of the section (its basal layers are uppermost Ordovician) followed successively by the Syrovaty, Polaty, Chesnokovka, Chagyrka and Kuimov formations, and the Cherny Anui Formation at the top of the section. All contacts are conformable.

Vtorye Utyosy Formation

The Vtorye Utyosy Formation, from 40 to 200 m thick, is spread in the western, northwestern, northern, and central Gorny Altai. It was recognized as a separate stratigraphic unit by N.V. Sennikov (Sennikov, 1976; Stratigraphic..., 1991; Yolkin et al., 2001). The formation's stratotype section crops out in the Vtorye Utyosy bluff on the left bank of the Inya River, upstream of Chineta Village. The formation consists of clayey mudstone and siltstone. Its base remains uncertain in the typical section, but occurred mudstone conformably overlain the Tekhten' carbonates northwest of the locality along the Burovlyanka River (left tributary of the Inya R.) and along the Chagyrka River (left bank of the Charysh River). The formation is conformably overlaid by the Middle-Late Llandovery Syrovaty Formation. The section contains numerous graptolite assemblages with index species of the *persculptus, acuminatus-ascensus, extenuatus-sibiricus, cyphus, triangulatus-gregarius* and *convolutus-cometa* zones (Sennikov, 1976, 1996). The benthic fauna includes trilobites and ostracods (Sennikov et al., 1979; Yolkin, 1983; Yolkin et al., 1988). The Vtorye Utyosy Formation is aligned with the Rhuddanian and Aeronian, or the Early-Middle Llandovery (Sennikov, 1996; Yolkin et al., 1997, 2001).

Syrovaty Formation

The Syrovaty Formation, from 90 m to 300 m in thickness, occurs in the Charysh-Inya and Anui-Chuya catchments. It was distinguished as a separate stratigraphic unit (Yolkin et al., 1974; Sennikov, 1976, 1996; Stratigraphic..., 1991). The formation is named after the Syrovaty Log (Russian for Dampish Ravine) on the right bank of the Inya River upstream of Taly Village. Its stratotype section has been documented in the southwestern slope of Rossypnaya Mt. (right bank of the Inya R.), near Taly Village. The Syrovaty Formation overlain the Rhuddanian-Aeronian Vtorye Utyosy Formation and under the upper Telychian Polaty Formation, both along conformable contacts. The Syrovaty section is composed of clayey and clayey-carbonate mudstone and siltstone and bears tabulate and rugose corals, crinoids, brachiopods, algae, trace fossils, graptolites, and chitinozoans. The graptolite age is defined by the *sedgwicki, halli* and *exiguus* zone and the lower part of the *griestonensis* zone. According to graptolites, the Syrovaty Formation may be aligned with to the second half of the Aeronian or to the Telychian (Sennikov, 1996; Yolkin et al., 1997, 2001).

Polaty Formation

The Polaty Formation, varying in thickness from 40 m to over 400 m, is known in the western, northwestern, northern, and central Gorny Altai. It was recognized as a separate stratigraphic unit (Yolkin et al., 1974, 2001; Sennikov, 1976; Decisions..., 1983; Stratigraphic..., 1991) and called after a local name Polaty (Russian for Plank bed) of a surface on Rossypnaya Mountain near Taly Village. The stratotype section of the formation occurs on the southwestern slope of Rossypnaya Mt. and is composed of massive limestone with algal bioherms, laminated limestone, siltstone, and mudstone. The Polaty Formation is the most widespread carbonate unit of reef origin. In some of its sections the formation almost fully consists of algal-biohermal limestone, or algal buildups appear repeatedly in the section intercalating with laminated argillaceous limestone. Terrigenous members in the formation are never too thick being commonly thinner than the carbonate members. Terrigenous sediments are more abundant and carbonates have laminated bedding and slightly to highly clayey compositions in the front and at the back of the carbonate platform rather than in its center. The Polaty section in the frontal part of the carbonate platform bears thin siliceous streaks. Faunas are very unevenly distributed along the section being almost absent from algal-biohermal limestones. Fossils are sporadic and restricted to scarce thin layers of clayey limestone, most often in the lower strata. They are abundant and taxonomically diverse on the periphery of the carbonate platform in the area of coral banks and brachiopod coquina. The formation contains stromatoporoids, tabulate and rugose corals, crinoids, bryozoans, trilobites, brachiopods, ostracods, graptolites and conodonts. The graptolite age is defined by the *griestoniensis* zone and conodonts correspond to the *celloni* zone. The formation conformably overlain the Syrovaty Formation and is overlaid by the Chesnokovka Formation. The Polaty Formation is aligned with the Telychian (Upper Llandoverian).

Chesnokovka Formation

The Chesnokovka Formation, from 50 to 250 m thick, is known in the western, northwestern, and central Gorny

Altai (Yolkin et al., 1974; Sennikov, 1976; Stratigraphic..., 1975, 1991; Decisions..., 1983). It has its stratotype section in the headwaters of the Bolshaya Chesnokovka River, left tributary of the Bolshoi Tigerek River, on the southern slope of Teplaya Mt. The formation is represented by two section types. The stratotype section consists of interbedded sandstone, clayey-carbonate mudstone, siltstone, and clayey limestone. The other type is clayey mudstone, siltstone, with clayey limestone in the upper part. The Chesnokovka strata contain stromatoporoids, tabulate and rugose corals, trilobites, brachiopods, graptolites, and chitinozoans. Graptolites correspond to the *spiralis-grandis* and *insectus-centrifugus* zones. The formation lies, without gaps, over the locally eroded surface of the Polaty Formation and is conformably overlain by the Chagyrka Formation. According to trilobites and brachiopods, the Chesnokovka Formation is aligned with the upper Telychian and Sheinwoodian (Lower Silurian).

Chagyrka Formation

The Chagyrka Formation, from 100 to 300 m thick, is known in the western, northwestern, and central Gorny Altai. It was recognized by N.L. Bublichenko (Bublichenko, 1936; Decisions..., 1959, 1983; Kulkov, 1967; Yolkin et al., 1974, 2001; Ivanovsky, Kulkov, 1974; Stratigraphic..., 1975) and named after the Chagyrka River, left tributary of the Charysh River. The formation's stratotype section occurs on the right bank of the Charysh River opposite Ust'-Chagyrka Village and is composed of reefal limestone, often of algal origin. It contains tabulate and rugose corals, stromatoporoids, trilobites, brachiopods, ostracods, crinoids, and bryozoans. The formation conformably overlain the Chesnokovka Formation and underlain the Kuimov Formation. The Chagyrka Formation is aligned with the second half of the Wenlock (Homerian) (Decisions..., 1983; Yolkin etal., 2001).

Kuimov Formation

The Kuimov Formation, about 200–450 m thick, is spread in the western and northwestern Gorny Altai. N.P. Kulkov (Kulkov, 1966; Yolkin et al., 1974, 2001; Ivanovsky, Kulkov, 1974; Stratigraphic..., 1975; Decisions..., 1983) distinguished it as a unit corresponding to the Upper Chagyrka Subformation, with its specific lithology and Ludlowian faunal assemblages. The stratotype section occurs in the vicinity of Tigerek Village, along the Kuimov spring, right tributary of the Inya River, near former Komsomolets Village. The formation consists of flaggy argillaceous limestone and clayey-carbonate mudstone, with tabulate and rugose corals, trilobites, ostracods, brachiopods, and conodonts. The conodonts correspond to the *O. snajdri* zone. The Kuimov Formation overlain the Chagyrka Formation and underlain the Cherny Anui Formation, with conformable contacts. It is aligned with the Gorstian and the Ludfordian.

Cherny Anui Formation

The 260 m thick Cherny Anui Formation found in the northwestern Gorny Altai was distinguished by N.P. Kulkov (Kulkov, 1966, 1967; Yolkin et al., 1974, 2001; Ivanovsky, Kulkov, 1974; Stratigraphic..., 1975, 1991; Decisions..., 1983; Gutak et al., 2000). Its stratotype section has been documented near Cherny Anui Village on the left bank of the Cherga River, the Anui right tributary. The formation is composed of fine conglomerate, gravelstone, sandstone (locally calcareous sandstone), siltstone, and scarce layers of sandy limestone, with stromatoporoids, tabulate and rugose corals, trilobites, brachiopods, ostracods, bryozoans, and conodonts. The Cherny Anui Formation rests conformably overlain the Kuimov Formation and is unconformably overlaid by Lower Devonian strata. The formation is aligned with the Pridoli Stage of the Upper Silurian.

2. PALEOGEOGRAPHY OF THE WESTERN ALTAI-SAYAN FOLDED AREA (ORDOVICIAN-SILURIAN ALTAI-SALAIR BASIN)

2.1. Sedimentary types and biota of the Altai-Salair Ordovician-Silurian basin

The Altai-Salair Ordovician basin represented shelf continental-margin basin of the Siberian Craton. The so-called Paleo-Asian Ocean was directly linked with the Altai-Salair shelf basin. Its separate fragments could be observed as tectonic blocks in the Gorny Altai area.

Local lithostratigraphic subdivisions (formations) in the Altai-Salair Ordovician basin characterize wide range of sedimentary facies: from shelf to oceanic genesis. Formations could be subdivided into two groups. First group is represented by only one rocks association, for example, sandstone and siltstone, confined to a single specific facies.

The second group includes formations represented by the diverse rock associations, for example, limestone, mudstone, siltstone and sandstone. Such rocks in the various sections characterize relatively same facies that on the other hand could be assigned to the different paleogeographic environments.

Oceanic genesis

1. ***Volcanic-siliceous-terrigenous sedimentary type*** (massive, coarse-laminated tuff, tuff sandstone, chert, siliceous mudstone, siltstone, sandstone yielded numerous siliceous sponge spicules, radiolarians and rare conodonts). As an example: Marcheta Formation (Marcheta-2 and Talitsa sections) – Late Tremadocian –Floian.

2. ***Siliceous-terrigenous sedimentary type*** (massive, coarse-laminated chert, siliceous mudstone, siltstone, sandstone with numerous siliceous sponge spicules, radiolarians and rare conodonts). As an example: Marcheta Formation (Kamyshenka and Charysh sections) – Late Tremadocian – Floian.

Continental slope genesis

1. ***Terrigenous flysch sedimentary type*** (coarse-laminated rhythmic sandstone, siltstone, mudstone, with rare but taxonomically diverse trilobites, brachiopods, single poor graptolites). As an example: Bugryshikha Formation (Malaya Uskuchevka and Pichuzhikha-2 sections) – Late Darriwilian – Early Sandbian.

2. ***Terrigenous underwater-sliding (gravitation-mixtitic) sedimentary type*** (non-bedded, often lense with landslide traces and small isolated sphere jointing in terrigeneous rocks ("twisting"), chert, siliceous mudstone, siltstone, with rare unvaried radiolarians and rare siliceous sponge spicules). As an example: siliceous-terrigenous sequence (Suetka section) – Early Hirnantian.

3. ***Siliceous-terrigenous (gravitational-mixtitic) sedimentary type*** (fine-laminated, often lenses with traces of sliding and isolated sphere jointing in terrigeneous rocks ("twisting"), chert, siliceous mudstone, siltstone with few and taxonomically monotonous radiolarians and rare siliceous sponge spicules). As an example: siliceous-terrigenous sequence (Suetka section) – Early Hirnantian.

Shelf genesis

1. ***Volcanic-terrigenous sedimentary type*** (volcanic islands and arcs)

A. Volcanoes slope facies (porphyrite, tuff, sandstone lenses and rare limestone lenses with single trilobites and brachiopods). As an example: Krasnoe Formation (Krasnoe section), El'tsovka Formation (El'tsovka section) – Tremadocian.

B. Facies distant from the volcanic arc (porphyrite, tuff, beds and lenses of sandstone, siltstone and limestone with few taxonomically diverse trilobites and brachiopods). As an example: Agayra Formation (Anossection) – Tremadocian.

2. ***Siliceous-terrigenous sedimentary type***

A. Facies of the distant from shore deep shelf (chert, siliceous mudstone, siltstone with taxonomically diverse radiolarians and rare taxonomically diverse conodonts siliceous sponge spicules). As an example: Tekhten' Formation (Tachalov and Barany sections), siliceous-terrigenous sequence (Suetka section) - Early Hirnantian.

B. Facies of the shelf foreland, near continental slope edge (sandstone, siltstone, siliceous mudstone with few poor graptolites). As an example: Tekhten' Formation (Rudovozy section) – Early Hirnantian.

3. ***Terrigenous sedimentary type***

A. Avandelta front of the mountain river (varicolored conglomerate and sandstone). As an example: Upper Subformation of the Kamlak Formation (Kakoshkin section) – Late Tremadocian; Bulukhta Formation (Boriskin Log section) – Early Hirnantian.

B. Riverside facies

a) location close to cliffy (iron-bound) desiccated river bank (beds and lenses of the well-rounded and well-sorted conglometare, gravelstone, sandstone). As an example: lower basal bed of the Tuloi Formation (Mengalevsky, Ishpa sections) – Early Floian.

b) location close to relatively plane bank (massive, well-sorted and well-rounded sandstone). As an example: lower basal bed of the Karasu Formation (Tuloi section) – Middle Darriwilian.

C. Facies distant from the bank (siltstone, mudstone, rarely sandstone with taxonomically diverse graptolites, trilobites and brachiopods). As an example: middle and upper parts of the Tuloi Formation (Stretenka, Tagaza, Tandoshka sections) – Floian; Bugryshikha Formation (Maralikha section) – Late Darriwilian – Early Sandbian; Khankhara Formation (Ebogon section) – Late Sandbian – Early Katian; Ilovaty Formation (Ilovaty, Cheremshanka sections) – Floian – Early Darriwilian; Karastun Formation (Korovy section) – Middle Darriwilian – Sandbian; Izyrak Formation (Izyrak section) – Floian – Early Darriwilian; Vtorye Utyosy Formation (Vtorye Utyosy, Burovlyanka, Tekhten', Voskresenka-

4, Rossypnaya Mountain and Generalka sections) – Rhuddanian, Aeronian; Syrovaty Formation (Vtorye Utyosy, Chernaya Mountain, Rossypnaya Mountain, Generalka sections) – Early Telychian; Chesnokovka Formation (Rossypnaya, Shpil', Syrovaty, Mayak sections) – Late Telychian – Sheinwoodian.

D. Facies of the underwater highs tops (fine-platy and cross-laminating mudstone with traces of maceration and yielded abundant taxonomically diverse graptolites). As an example: Voskresenka Formation (Pichuzhikha section) – Floian.

E. Facies of the underwater highs bottoms (gravitation-mixtite) (coarse-laminated sandstone and siltstone with the middle size isolated sphere jointing in terrigeneous rocks ("twisting"), up to 0.2–0.3 m in diameter, with rare taxonomically monotonous graptolites). As an example: Voskresenka Formation (Maralikha section) – Lower Darriwilian; Syrovaty Formation (Chernaya Mountain, Pervye Utyosy sections) – Telychian.

4. ***Carbonate-terrigenous sedimentary type***

A. Facies slightly distant from the shore (carbonate mudstone, marl, clayey limestone with rare taxonomically poor corals and brachiopods). As an example: Diskovaya Formation (Algain section) – Early Katian.

B. Facies distant from the shore (intercalation of prevailed carbonate mudstone and siltstone, with the secondary in amount middle-laminated clayey limestone yielded few taxonomically diverse brachiopods and trilobites, rare taxonomically poor corals and graptolites). As an example: Khankhara Formation (Verkhnyaya Karasu, Nizhnyaya Karasu, Marcheta-4 sections) – Early Katian; Syrovaty Formation (Turata section) – Telychian.

5. ***Terrigenous-carbonate sedimentary type***

A. Facies distant from the shore (intercalation of prevailed fine-laminated carbonate clayey limestone with the secondary in amount of carbonate mudstone and siltstone yielded abundant taxonomically diverse brachiopods and trilobites, rare taxonomically monotonous corals). As an example: Khankhara Formation (Marinikha, Kholmogorikha sections) – Early Katian; Syrovaty Formation (Tekhten'section) – Telychian.

B. Facies adjacent to distant parts of the reefs (middle and fine-laminated clayey limestone with intercalates of carbonaceous mudstone with abundant diverse corals, trilobites, brachiopods). As an example: Tekhten' Formation (Elanda section) – Late Katian; Polaty Formation (Syrovaty, Mayak sections) – Telychian.

C. Facies of bays on the reef edges (lenses of the algae bioherms small in size, to 1–2 m in diameter, in the siltstone-mudstone matrix with rare taxonomically monotonous brachiopods and graptolites). As an example: Tekhten' Formation (Burovlyanka section) – Early Hirnantian.

6. ***Carbonate (reef) sedimentary type***

A. Facies of the groups of large reefs (up to 2–3 km in diameter) on the carbonate platform at shelf edge:

a) central parts of separate reefs (massive, un-laminated limestone with large algae bioherms up 20–30 m, with rare taxonomically monotonous corals). As an example: Tekhten' Formation (Orlov, Burovlyanka, Generalka, Marcheta-4, Tekhten', Chakyr, Muta, Bely Bom sections) – Late Katian – Early Hirnantian; Polaty Formation (Rossypnaya, Generalka, Inya, Chuya, Yaloman-2 sections) – Telychian; Chagyrka Formation (Rossypnaya, Mayak sections) – Homerian.

b) marginal part of the separate reefs (coarse- and middle laminated limestone, with large taxonomically diverse corals). As an example: Tekhten' Formation (Tekhten', Muta sections) – Late Katian; Polaty Formation (Chichka section) – Telychian.

B. Facies of middle-sized reefs (0.5–1 km in diameter) on the slopes of fade volcanoes (massive, un-laminated limestone, with abundant taxonomically diverse trilobites, as well as rare taxonomically poor brachiopods and conodonts). As an example: Tolstochikha Formation (Orlinaya section) – Tremadocian.

C. Facies of separate, small (0.05–0.1 km in diameter), isolated reefs (patch-reef). As an example: Tekhten' Formation (Tachalov, Burovlyanka sections) – Early Hirnantian; Veber Formation (Spornaya Sopka section) – Early Hirnantian; Kuimov Formation (Tigerek section) – Ludfordian.

D. Shallow-water distant from shore facies (middle-laminated oolitic limestone, with rare brachiopod and trilobite fragments). As an example: basal bed of the Khankhara Formation (Malaya Uskuchevka, Ebogon, Belaya sections) – Late Sandbian.

2.2. Key events in the evolution of the Western Altai-Salair Ordovician-Silurian basin (paleogeography and biota)

Previous stratigraphic studies in the western Altai-Sayan Folded Area (Yolkin et al., 1994; Yolkin et al., 1997; Yolkin, Sennikov, 1998; Sennikov et al., 2000) provided an insight into the patterns of deposition environments and cyclicity, trends of global transgression-regression events (Fig. 11), biota evolution, and spatial relationships between faunas and facies. This study concerns especially with the deposition and biota events in the Ordovician-Silurian Altai-Salair basin history that appear to be of regional relevance. The reason is that the regional events record the origin and

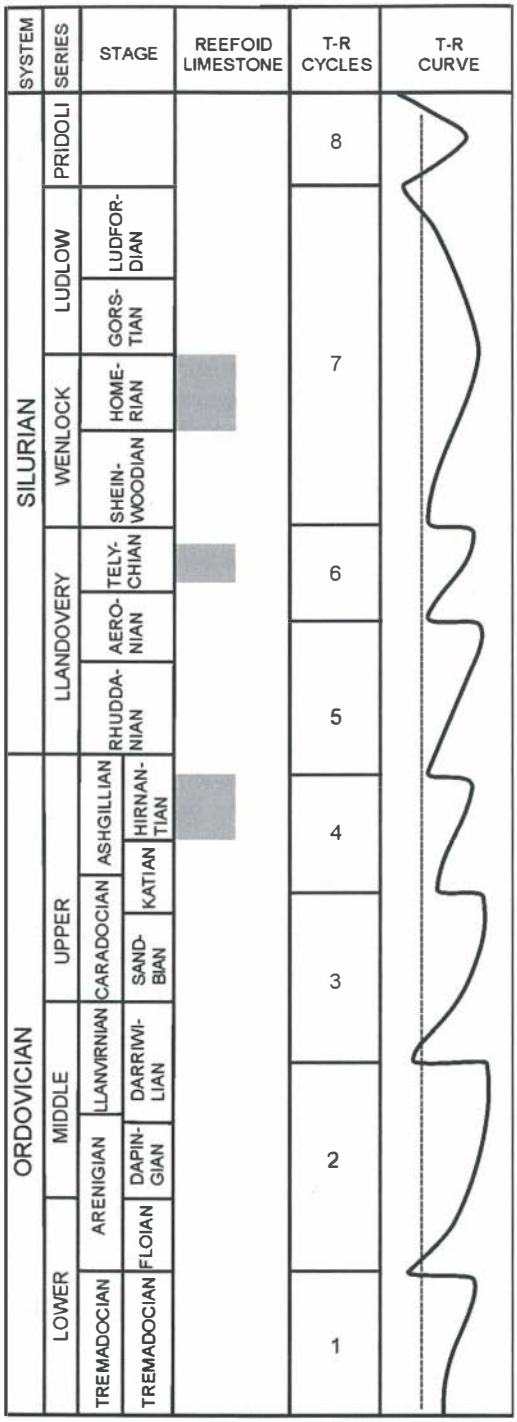


Fig. 11. Ordovician and Silurian eustatic curve and transgressive-regressive cycles for the western part of the ASFA showing the stratigraphical position of reef limestones (modified from Yokin et al., 1997, with new additional data).

evolution of large geological structures, such as volcanic arcs, back-arc basins, terranes, and microcontinents, and their interaction with one another and with the Siberian continent.

All lithological markers recognized in the Ordovician-Silurian Altai-Salair basin were dated according to faunal groups. We used independent conodont, graptolite, trilobite, chitinozoan (See figs 6–9), and other zonal scales developed through many years of studies in the area (Sennikov, 1996; Yolkin, Izokh, 1999; Sennikov, Obut, 2002, 2003; Izokh et al., 2005). The zone-scale age resolution allowed reliable ties for the synchronicity of geological events behind a deposition event, for the duration of the latter in the lithological record, and for the respective responses of biota.

According to the present knowledge, the key events in the Ordovician-Silurian basin history were as follows. Some events were detailed in our previous publications (Yolkin et al., 1997; Yolkin, Sennikov, 1998; Sennikov, 1998, 2003, 2006a, b).

1. **Cambrian–Ordovician boundary:** partial (Salair) and then complete (Kuznetsk-Salair) degradation of a Late Cambrian-Early Ordovician volcanic arc (Sennikov, 2006a, b) in latest Batyrbai – earliest Tremadocian time. Stop in growth of the arc resulted in chain of seamounts which became covered with small carcassless reef-like algal buildups (Tolstochikha Formation). That was the time when the Altai-Salair basin turned toward a passive-margin evolution. Carbonate deposition in the basin occurred near the shore and on the slopes of the degraded volcanic arc through the Tremadocian and alternated with coarse terrigenous deposition without any spatial regularity. Marine biota did not suffer any drastic overturn. It evolved in steady favorable conditions indicated by high abundances, densities, and taxonomic diversity of populations (especially in trilobites) rather than responded to geological or climate events.

2. **Late Tremadocian:** first Ordovician orogenic phase associated with complete accretion of the Kuznetsk-Salair volcanic arc (Gorny Altai, Salair, Kuznetsky Alatau) to Siberia. The phase was quite long and spanned the second half of the Tremadocian and the earliest Floian. Its onset was distinguished at the Lower-Upper Tremadoacian boundary (basal layers of Upper Kamlak and Upper Agaira subformations, middle part of the Ishpa Formation in Gorny Altai, middle part of the Chupino Formation and lower part of the Krasnoe Formation in Salair, basal layers of Upper Algain Subformation and Taimenka Formation in Kuznetsky Alatau). The event became marked by (i) basal conglomerate with pebble of intrusives and (ii) change in position and orientation of basins. Activity resumed at the end of the orogenic phase as a final episode at the Upper Tremadocian-Floian boundary and was recognized in the basal layers of the Voskresenka and Tuloi formations in the Gorny Altai, of the Alzass Formation in the Kuznetsky Alatau, and of the Ilovaty Formation in the Salair (Petrunina et al., 1984). Lithological and paleogeographic evidence of the final event at the end of the orogenic phase at the Tremadocain-Floian boundary shows up as (i) polymictic basal conglomerate with pebble of intrusives, (ii) azimuthal and angular unconformities, (iii) change in general basin geometry, (iv) change in position and orientation of basins, (v) greater depths and steeper sides of basins, (vi) appearance of seamounts, etc.

3. **Floian – Dapingian:** transition from active to passive continental margin (Gorny Altai, Salair, Kuznetsky Alatau). The Floian and Dapingian stages were transitional in terms of composition and distribution of facies. Although the active-margin environment persisted in some areas (Kuznetsky Alatau) which experienced volcanic activity (Alzass Formation), the whole Gorny Altai and Salair territory (Voskresenka, Tuloi, Ilovaty, and Izyrak formations) evolved already in a single amagmatic shelf basin. Unlike the older basins where facies made a mosaic pattern, the facies in the shelf basin were regularly distributed in nearly parallel belts following the shoreline contours. The Floian-Dopingian sea in the Gorny Altai and the Salair occupied a smaller total area than the younger Middle Ordovician basin. Therefore, the beginning and the end of the Floian-Dapingian transition between the active- and passive-margin environments were marked by two orogenic events (see above).

The two stages corresponded to faunistic overturns. The basin was inhabited mainly by pelagic communities of graptolites and chitinozoans. Numerous graptolite communities formed taxonomically diverse and dense populations. Chitinozoans occurred more sporadically and their assemblages consisted of few taxa. Benthic populations were few, small, and poorly diverse (commonly 3–5 taxa in trilobites and 2–3 taxa in brachiopods).

4. **Early/Middle Darriwilian boundary:** another episode of carbonate deposition after the respective Tremadocian event. Carbonate deposition of that time produced a belt of light-color pure massive limestone along the outer edge of the outer shelf which coexisted with the parallel terrigenous belts that followed the shoreline contours. The limestones built the upper part of the Voskresenka Formation (Kostinsky Beds) (sections Barany-1, Batun, etc.).

5. **Middle/Late Darriwilian boundary:** second Ordovician orogenic phase. It was a single episode recorded in the lower Bugryshikha Formation and at the base of the Karasa Formation in the Gorny Altai and at the base of the Zaichikha and Karastun formations in the Salair (Sennikov, Petrunina, 2000; Sennikov, 2006a, b) as (i) basal conglomerate or gravelly sandstone, (ii) changes in position and orientation of basins, (iii) considerable broadening of deposition area (especially in northern and central Gorny Altai), (iv) transition from area of marine deposition in Kuznetsky Alatau to a continental denudation area.

6. **Late Darriwilian:** responses of marine biota to the second orogenic phase. The pelagic communities of graptolites and chitinozoans reduced strongly in number, population density, and taxonomic diversity. Benthic communities (brachiopods and trilobites) changed notably their composition toward assemblages of a greater taxonomic diversity with abundant endemic forms besides cosmopolite taxa; benthic populations became quite numerous and dense.

7. **Early Sandbian:** slowdown of general subsidence of the Gorny Altai segment of the Siberian continental margin. Deposition on the inner shelf not compensated by subsidence leveled up the sea floor. Large-scale seafloor levelling, which is recorded in oolitic limestone layers at the base of the Khankhara Formation, occurred in a tectonically quiet environment at shallow-marine depths (less than 10 m of fair-weather wave base).

8. **Late Sandbian:** change from mainly terrigenous to mixed terrigenous-carbonate deposition under accelerated subsidence. The deposition environments became more diverse. Carbonate-terrigenous and carbonate (to reefal) facies developed and spread progressively over greater areas in addition to coarse and fine terrigenous facies. The belts of different facies were separated by linear zones of transitional facies.

The biota responded by a dramatic change in the structure of benthic communities (especially, trilobite and brachiopod assemblages), increasing density and taxonomic diversity of benthic populations, and inception of reef dwellers and builders (algae, tabulate corals, stromatoporoids, bryozoans, and crinoids). Pelagic communities of graptolites and chitinozoans were sporadic, of low population density and poor diversity (no more than 2–5 taxa). Since the Caradocian, the basins of the Gorny Altai and Salair were inhabited by diverse marine organisms from nekton and plankton (conodonts, nautiloids, graptolites, chitinozoans, and radiolarians) to benthic (trilobites, brachiopods, ostracods, crinoids, gastropods, bryozoans, tabulate and rugose corals, stromatoporoids, etc.) groups.

9. **Sandbian/Katian boundary:** a short spell of coarse clastic deposition, possibly, caused by an unknown single orogenic event or by a global sealevel rise (transgression and ensuing rapid erosion in the provenance). The coarse clastic material was deposited as conglomerate in the middle strata of the Khankhara, Bulukhta, and Veber formations; Tremadocian sediments in Gornaya Shoriya became overlain, with a large gap, by the basal conglomerate of the Toga Formation. However, no evidence of paleogeographic, facies, or biotic responses to the third orogenic phase has been found so far.

10. **Early Hirnantian (latest Ordovician):** differentiation of general shelf subsidence. The shelf inner part subsided more rapidly than its outer edge and the latter became the place where large reef systems of carbonate-platform type appeared in the Late Ashgillian. *Carbonate platform* is commonly meant as an elongate zone of barrier and marginal reefs which often merge in reef massifs or long chains.

The current large reef systems, especially the Great Barrier Reef (GBR) in the Coral Sea at the Australian eastern coast, are used for reference in paleoenvironment reconstructions as a model of a warm sea with rapid biogenic carbonate deposition. By analogy with the current systems, Paleozoic reef-like systems on carbonate platforms can have formed at paleolatitudes from 10° to 20–25° N or S in the conditions of optimum temperatures between +18° and +30° all yearround, normal salinity (about 35‰), clear water, and shallow sea depths (0 to 10–20 m, less often 40 m).

In the latest Ordovician (Late Ashgillian), the first Altai carcassless algal-biohermal reef buildup formed on the shelf edge. It was found (Sennikov et al., 2001a; Sennikov, 2006a, b) extending in an over 100 km long chain in outcrops of the Tekhten' Formation (Orlov, Burovlyanka, Muta, Bely Bom and other reefs). The Late Ashgillian carbonate deposition produced 150 to 700 m thick Tekhten' sections most often composed of massive pure limestone with algal bioherms (to 10–15 m in diameter), rare corals, trilobites, and brachiopods. The Altai-Salair reef may have reached a total length of 700 km (in the present frame of reference, here and below) and a width of 3–5 km, i.e., it was comparable with the today's Great Barrier Reef. The size was estimated from the geographic extent of the Tekhten' Formation taking into account its continuation into the Salair inferred from outcrops of the Veber Formation (Bobrovka and other reefs). The thickness of reef buildups in this stratigraphic interval is up to 500 m.

Since the end of the Ordovician, shelf deposition had been associated with steady formation of facies that made a regular pattern of belts spread for tens to few hundreds of kilometers off the shore. They were, namely, coarse terrigenous (narrowest belt), fine terrigenous (narrow belt), mixed terrigenous-carbonate (widest belt), carbonate and (or) reef (wide belt), terrigenous-carbonate (narrow belt) facies, and terrigenous-carbonate slope deposits with an olistostrome component (thin belt). The facies boundaries were rather sharp, and transitional facies occupied relatively narrow zones. Therefore, the Altai-Salair basin of that time evolved in a stable passive continental margin environment.

11. **Early Hirnantian:** local and relatively rapid biogenic silica deposition, with a minor chemogenic component. The deposition produced the upper Tekhten' Formation and siliceous-terrigenous strata in the Tachalov, Suetka, and Barany-2 section. Biota included siliceous sponges as a benthic component and a pelagic component of taxonomically diverse conodont and radiolarian assemblages, with population densities as high as to form radiolarite.

12. **Middle part of Late Hirnantian:** at least 100 m basin deepening as a result of a transgression at the base of the *persculptus* graptolite zone (Yolkin et al., 1997; Sennikov, 1998). The transgression, attendant rapid black shale deposition, remained recorded in the Late Hirnantian lower Vtorye Utyosy section as a lithology change from light gray massive reef limestone (or more rarely from dark gray slightly clayey thick-bedded dalmanitid limestone) to black mudstone deposited in anoxic conditions (judging by the presence of pyrite). That was a global event corresponding to a great extinction event in Paleozoic marine biota. After that event, through the Rhuddanian and Aeronian, the Altai-Salair marine biota consisted almost entirely of pelagic graptolite and chitinozoan communities of high population density and taxonomic diversity; benthic assemblages were restricted to sporadic and taxonomically poor trilobites, ostracods, and brachiopods.

13. **Convolutus-cometa/sedgwicki boundary:** another transgression pulse and another 100 m sealevel rise (Yolkin et al., 1997). Pelagic faunas consisted of medium-density and taxonomically uniform graptolite populations. Benthic communities were sporadic brachiopods and trilobites of low diversity. Trilobites experienced considerable morphological changes (Yolkin, 1983).

14. **Late Telychian:** formation of the second algal-coral reef framework which became the largest Ordovician-Silurian reef system (Yolkin et al., 1994, 1997; Yolkin, Sennikov, 1998). That deposition event produced the Polaty Formation (Rossypnaya, Chichka, Inya, Chuya, Yaloman and other reefs) in the Gorny Altai and the Baskuskan Formation (Vetokhino and other reefs) in the Salair composed of massive pure limestone with few thin interbeds of mudrocks with 30–50 m algal bioherms and abundant tabulate and rugose corals, stromatoporoids, bryozoans and other benthic communities of reef builders and dwellers. The terrigenous input reduced notably and was limited to sporadic pulses.

The Late Telychian carbonate platform in the basin may have reached a length of 700 km and a width of 10–25 km. The Late Telychian reef deposition lasted for 350-400 kyr and produced 200–450 m thick layers. The reefs grew at a rate of 1.3–1.5 m/kyr, i.e., only slightly slower than the current reefs (2 m/kyr).

The relatively shallow-marine (sea depths from 0–5 m to 10–50 m) outer edge of the carbonate platform in the central Altai was bordered by a narrow zone of a deeper (100-200 m) fore-reef shelf. The relatively deepwater deposition area of clastic laminated limestone neighbored an area of siliceous deposition on the outer shelf edge or already on the continental slope at a sea depth of 200 to 250–300 m or deeper.

15. **End of Telychian – Early Sheinwoodian:** rapid basin deepening and black shale deposition. Lithologycally it is distinguished by drastic change from massive light-color reef limestone of the Polaty Formation and its equivalents

to black mudstone of the Chesnokovka Formation and its equivalents, which often have cavernous eroded base layers. Carbonate deposition continued but at a much slower rate over a smaller area and became localized. The terrigenous input reduced progressively through the Sheinwoodian while carbonate deposition slowly increased. Biota was dominated by pelagic communities of graptolites and chitinozoans; brachiopods, trilobites, and corals were sporadic and poorly diverse. The benthic component of biota likewise became ever more significant in the Sheinwoodian.

16. **Sheinwoodian/Homerian boundary:** onset of an algal-coral reef framework, the third reef system. The reef deposition produced the Chagyrka Formation (Rossypnaya, Shpil', Nebo, Mayak and other reefs) in the Gorny Altai and the Potapovka Formation in the Salair composed of 225 m massive pure limestone with 10–20 m algal bioherms containing abundant tabulate and rugose corals, stromatoporoids, bryozoans, and other reef-building and reef-dwelling benthic communities. The terrigenous input almost ceased. The Homerian carbonate platform may have reached a length of 600 km and a width of 5–15 km.

17. **Homerian/Gorstian boundary:** onset of regular terrigenous input, with occasional peaks, in addition to continuing large-scale steady carbonate deposition. As a result, deposition of pure light-color massive reef limestone (Chagyrka Formation) changed to deposition of laminated often clayey limestone layers alternating with one another or with rare thin calcareous mudstone or less often siltstone interbeds (Kuimov Formation). Biota experienced no significant overturns.

18. **Ludfordian:** appearance of patch reefs (Tigerek Section) along the basin margin, within a belt that evolved from the carbonate platform zone of Telychian and Homerian reefs. The patch reefs formed while the carbonate deposition with a terrigenous component (upper Kuimov Formation, Gorny Altai) continued and minor siliceous deposition began on the shelf outer edge. Siliceous deposits underwent later diagenetic and post-diagenetic changes which caused, for instance, silicification of skeletons in different benthic groups found in the upper Kuimov Formation (Tigerek section).

19. **Ludfordian/Pridoli boundary:** onset of mainly terrigenous redbed deposition recorded in the basal layers of the Cherny Anui Formation in the Gorny Altai (Cherga and Cherny Anui sections). The Cherny Anui basal sand member contains lenses and thin layers of conglomerate and gravelstone. The benthic component of biota lost much in density and diversity of populations, and the pelagic component was restricted to rare conodonts. All faunas were found in limestone in the middle Cherny Anui Formation (middle Pridolian).

To sum up, the biota evolution in the Late Ordovician-Silurian history of the Altai-Salair basin had the following features. The basin was inhabited by almost all known groups of benthic, plankton and nekton organisms that possessed quite a high taxonomic diversity and high (often maximum) population density. The organisms were involved with complex symbiotic links and long food chains.

Production (total numbers of individuals in species) and biodiversity in benthic communities were the highest in reef systems but very low in near-shore ecosystems. Production and diversity in both benthic and pelagic communities were medium in back-reef basins and slightly lower in slope and fore-reef environments.

The pelagic component of biota reached the greatest possible density in the Aeronian only, judging by numerous findings of taxonomically diverse graptolite assemblages in the upper Vtorye Utyosy Formation (Gorny Altai). Late Katian and Early Hirnantian basins in the area were second largest in density of pelagic populations with diverse graptolite, conodont, and radiolarian assemblages.

2.3. Paleogeographic reconstruction of the Ordovician-Silurian Altai-Salair basin

This study is the first systematic synthesis of successive changes in paleogeography and contours of the Ordovician-Silurian Altai-Salair basin (Fig. 12). The synthesis is based on a series of stage- (and substage)-scale paleogeographic maps for the whole Ordovician-Silurian basin history which have been compiled and partly published by today (Yolkin et al., 1994; Sennikov, 2006a, b).

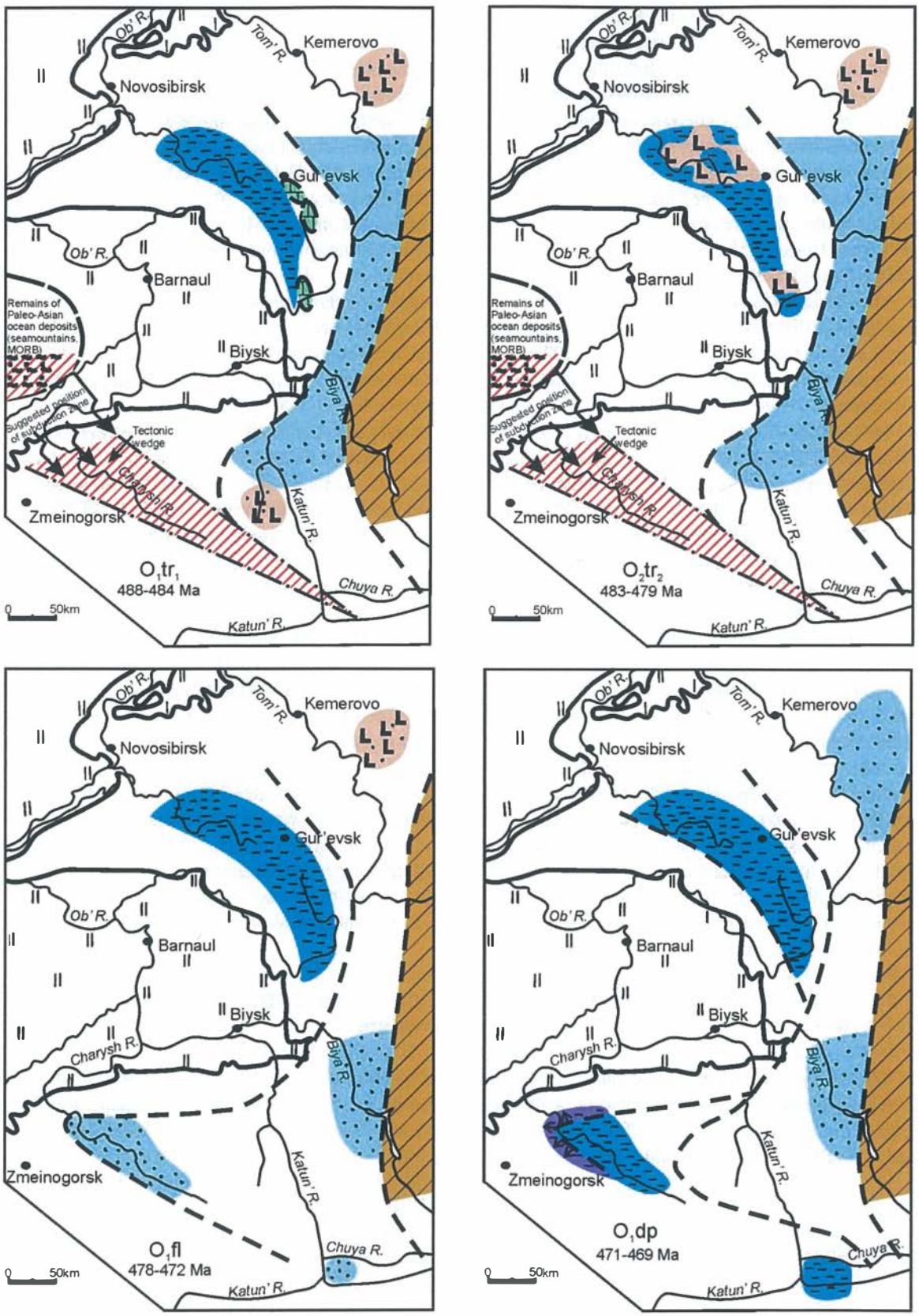


Fig. 12. Paleographic environments of western part ASFA through Ordovician-Silurian (modified from Yokin et al., 1994; Sennikov, 2006a, with new data).

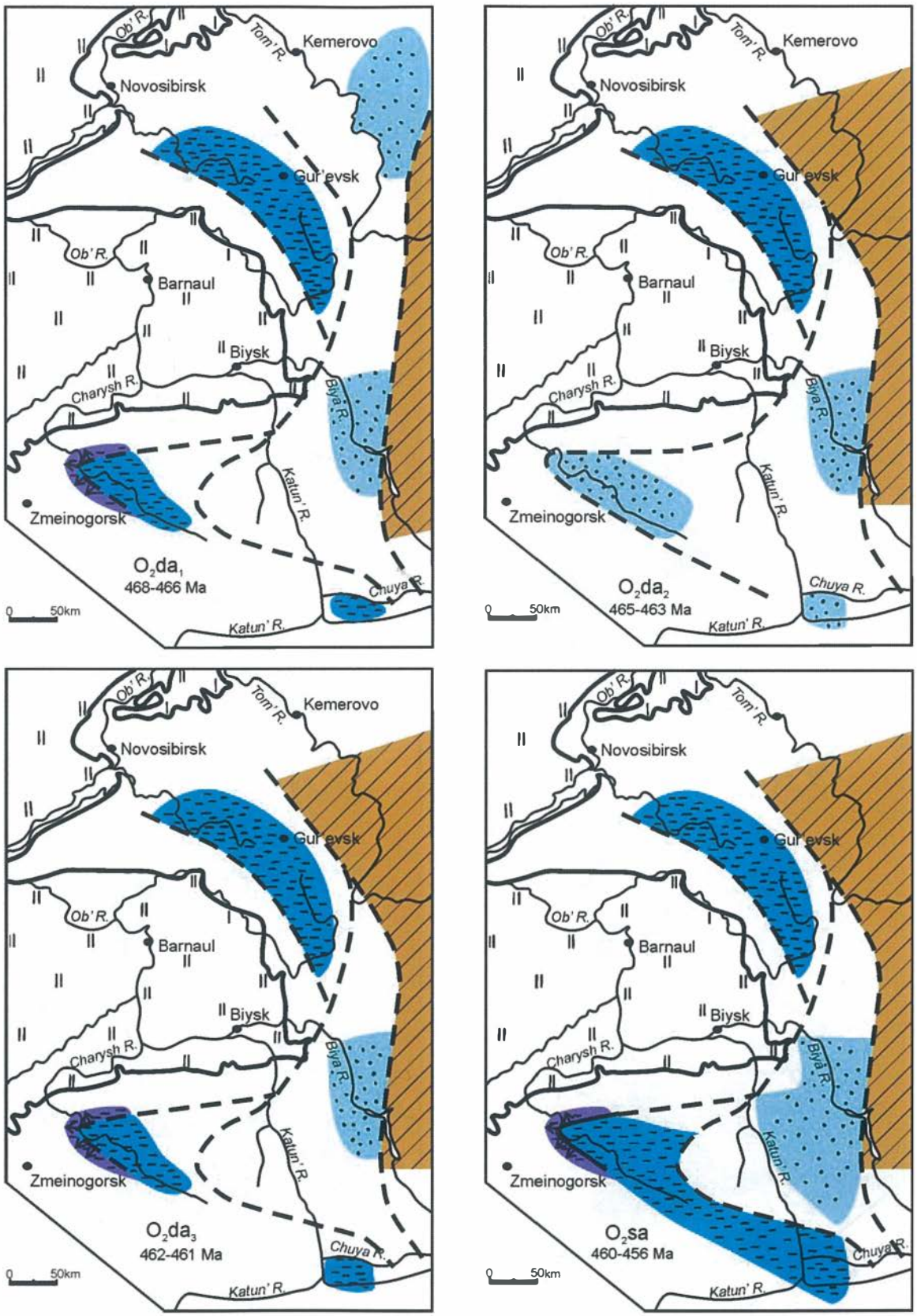
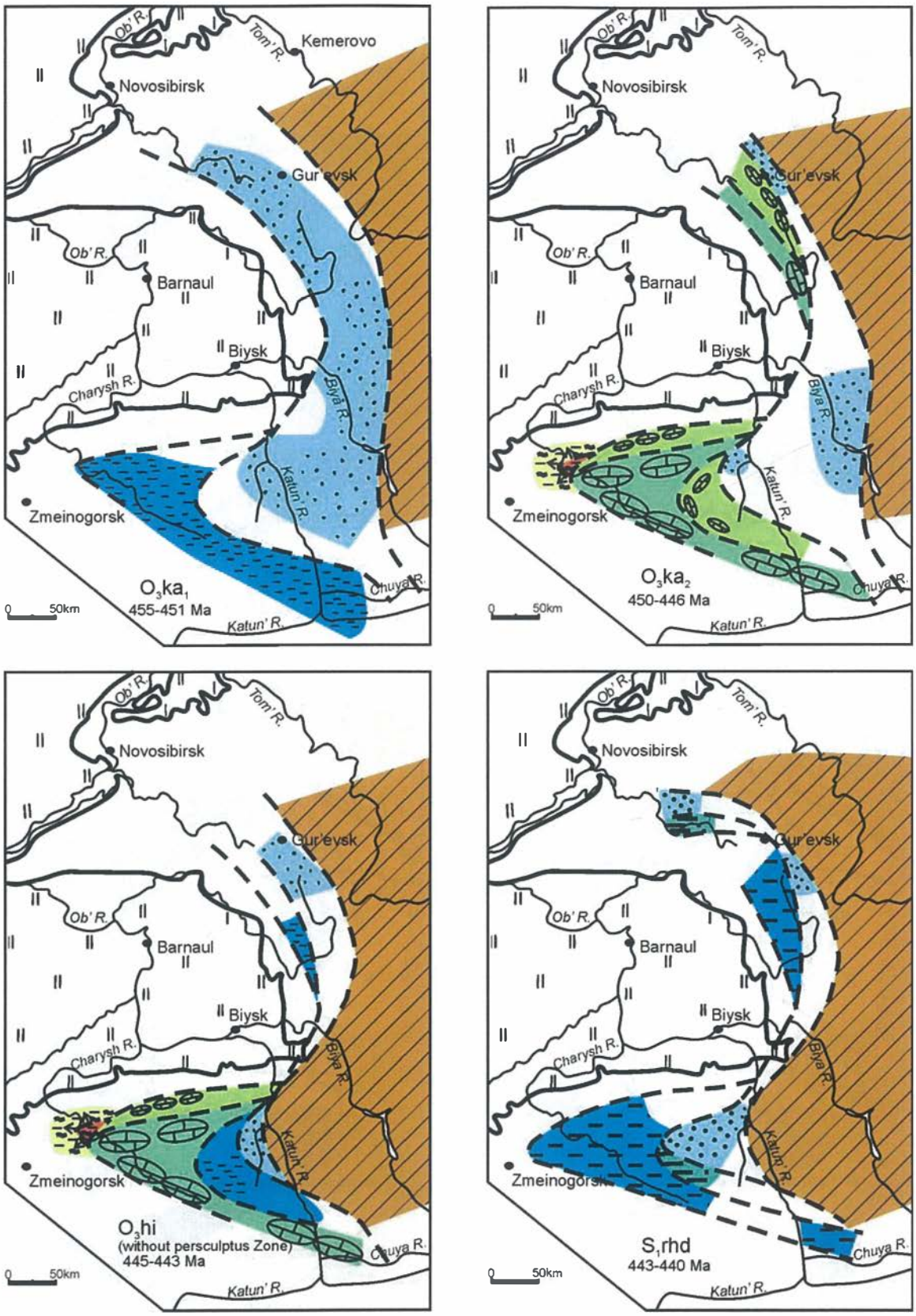


Fig. 12. Continued.



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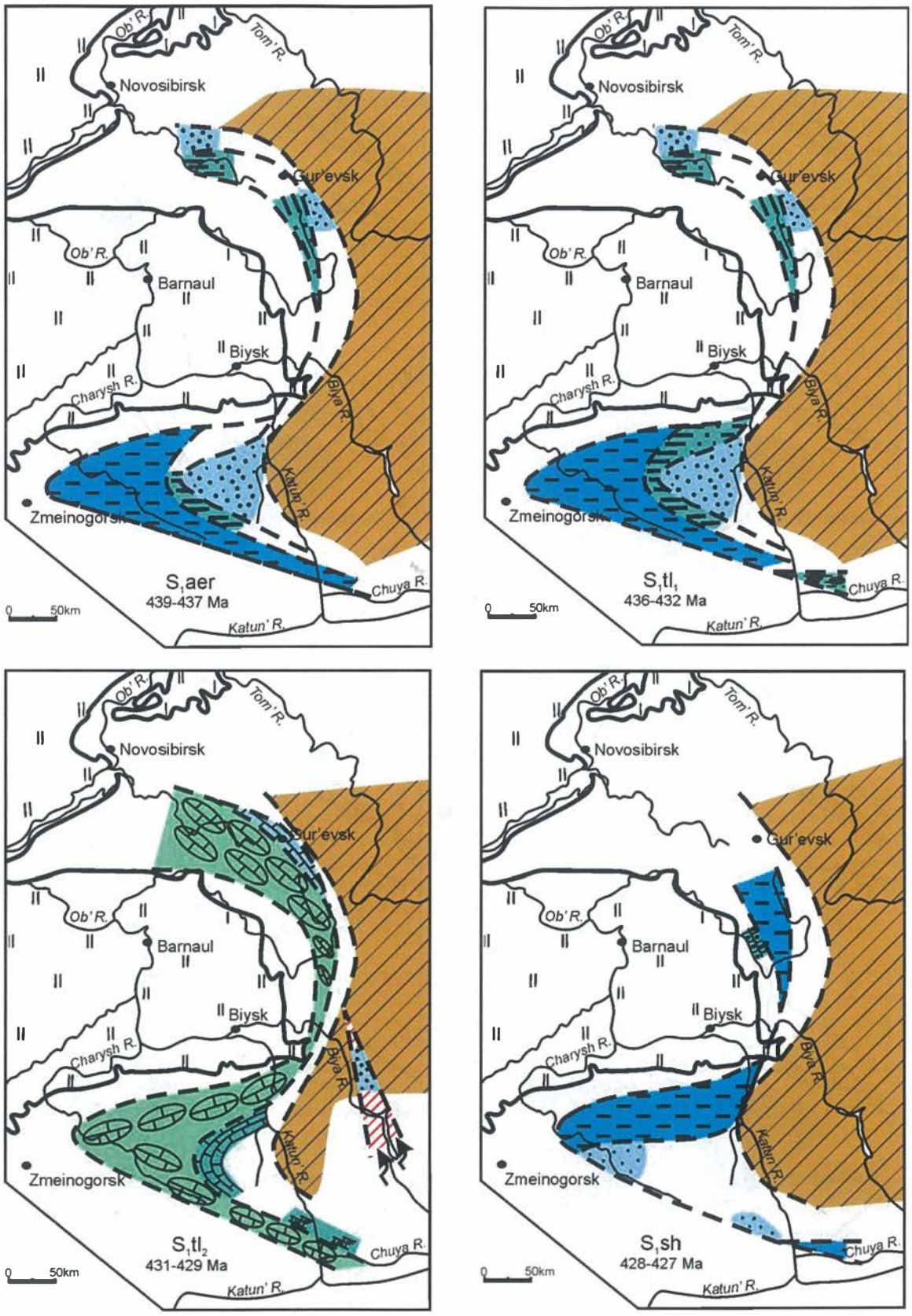


Fig. 12. Continued.

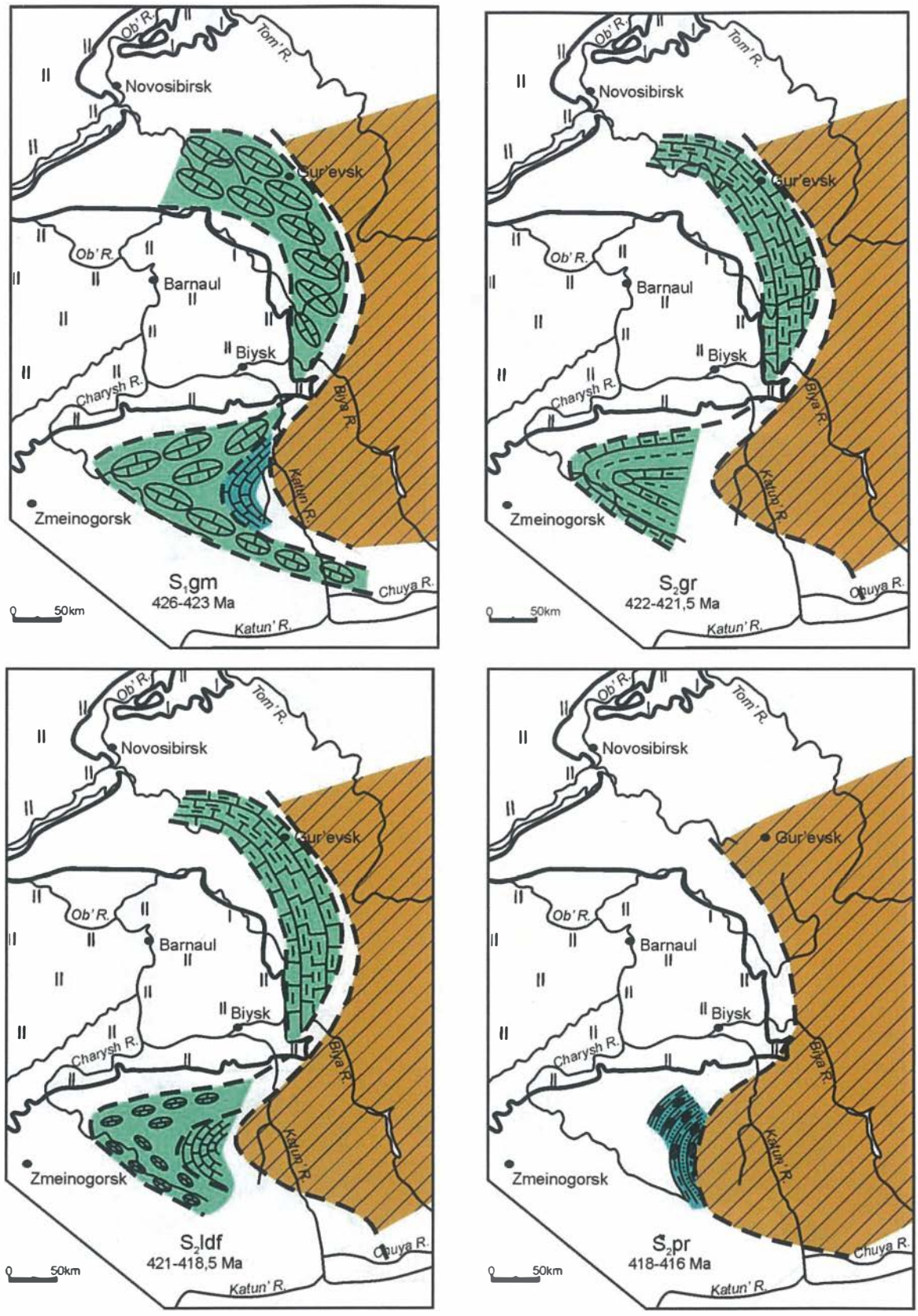

Ob' R.
Tom' R.
Novosibirsk
Gur'evsk
Barnaul
Biysk
Charysh R.
Biya R.
Katun' R.
Zmeinogorsk
Chuya R.
S1gm
426-423 Ma
S2gr
422-421,5 Ma
S2ldf
421-418,5 Ma
S2pr
418-416 Ma
0 50km

Fig. 12. End.

3. ORDOVICIAN AND SILURIAN REFERENCE SECTIONS IN THE GORNY ALTAI

The described sections are grouped geographically into areas of the western, northwestern, central, northern and northeastern Gorny Altai. The member subdivision and bed-by-bed description of the sections have been the responsibility of N.V. Sennikov, E.A. Yolkin, Z.E. Petrunina, L.A. Gladkikh, N.G. Izokh, A.V. Krivchikov, V.G. Russkikh and A.A. Puzyrev. The section symbols are keyed as follows. The letters stand for author's name (e.g., Yo – for Yolkin, S – for Sennikov, P – for Puzyrev, R – for Russkikh in Yo-7039, S-78115, P-78032-1/12, and R-7812) or for location (LSS for location from succession of sections, F – for faunal location, H – for hole (excavation)). Two first numerals after hyphen denote the year when the description was made (70 for 1970, 78 for 1978, etc.) and the following digits before hyphen are section or locality numbers (39, 115, 032); numerals after second hyphen are member numbers (-1 for first member), and numerals after slash mark the sampling depth in meters above the member base (/12 means that the sample was collected at 12 m above the base of the member).

3.1. Western Gorny Altai

3.1.1. Area of Ust'-Chagyrka Village

Barany-1 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: ? Tremadocian, Floian, Dapingian, Darriwilian.

Regional stratigraphic subdivisions: Tayanza, Lebed' and Bugryshikha regional stages (horizons).

Local lithostratigraphic subdivisions: Suetka, Voskresenka and Bugryshikha formations.

Fauna: trilobites, brachiopods, gastropods, chitinozoans.

The Voskresenka Formation in the vicinity of Ust'-Chagyrka Village crops out along the Barany, Voskresenka, and Tachalov brooks, the left tributaries of the Chagyrka River (Fig. 13). An outcrop on the right bank of the Barany Brook (Fig. 14), 300 m from 500.3 m mountain at azimuth 235° exposes lilac to red siltstone and sandstone of the Suetka Formation (Gorny Altai Group) overstepped, with a sharp angular unconformity, by (stratotype section of Voskresenka Formation, P-78032) (Fig. 15):

Thickness, m

1. Siltstone: green, massive, with scarce floating sandstone pebble; green siltstone gives way along strike (right bank of the Tachalov Brook) to lilac-red, violet, green, and yellowish-gray siltstone with lenses and thin layers of medium to boulder conglomerate with pebbles mostly of Gorny Altai Group rocks or sporadically fine red quartzite; calcareous siltstone, at 6 m above member base (loc. P-78032-1/6) contains brachiopods *Idiostophia* cf. *coctata* Ulr. et Coop., and stratigraphically 6 meters upwards (loc. P-78032-1/12) brachiopods *Idiostophia* sp., *Archaeorthis altaica* Severg. 40

3. Siltstone: yellowish greenish-gray, flaggy, with fragments of trilobites *Illaenus* Dalm. (loc. S-7915) and undefinable brachiopods 25

4. Sandstone: limy, grading along strike into sandy limestone 2

5. Siltstone: greenish-gray and yellowish-gray, sandy, laminated, flaggy, with fauna (loc. S-7913), possibly, graptolites . 205

6. Limestone: gray and dark gray, sandy, laminated, flaggy; with trilobites (loc. S-7914) *Ceraurinella frequiens* Tchug., *Eorobergia bipunctata* Tchug., *Bathyurellus nonnufus* Tchug., *Glaphurus altaicus* Web., *Kolymella plana* (Tchug.), *Pliomerullus amplissimus* Petrun. sp. n., *Pliomerops parasiensis* Petrun. sp. n., *Eccoptochile tchagyrica* Petrun. sp. n., brachiopods *Plectocamara constata* Coop., *Archaeorthis altaica* Severg., *Atelelasma batunensis* Severg., *Idiostophia coctata* Ulr. et Coop. 8

7. Sodded interval; talus bears rare clasts of greenish-gray and yellowish-gray siltstone 90

8. Sodded interval; talus bears fine conglomerate of light gray (to 80 %) well rounded pebble and dark gray (to 20 %) quartzite 5

The member top is truncated by a fault. The total thickness of the section is about 380 m.

Members 1 through 6 belong to the Voskresenka Formation and members 7 and 8 belong to the overlying Bugryshikha Formation. The Voskresenka Formation in the Barany section is 285 m thick and the Bugryshikha Formation is 95 m (incomplete thickness).

Gastropods and crinoids were collected from sandy limestone equivalent to member 4 on the right bank of the Tachalov Brook (loc. S-7736) and gastropods were found on the right bank of the Voskresenka Brook (loc. S-7726). Chitinozoans extracted by acid dissolution of rocks were identified as *Desmochitina minor* Eisenack and *Desmochitina*

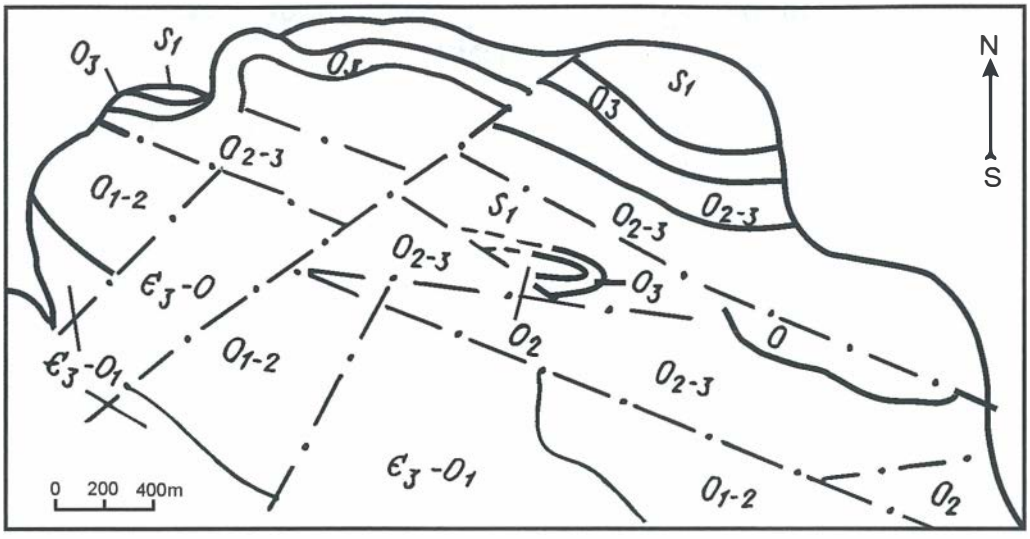


Fig. 13. Sketch map of Chagyrka Brook, left bank, near Ust'-Chagyrka Village (modified from Yolkin et al., 1988).

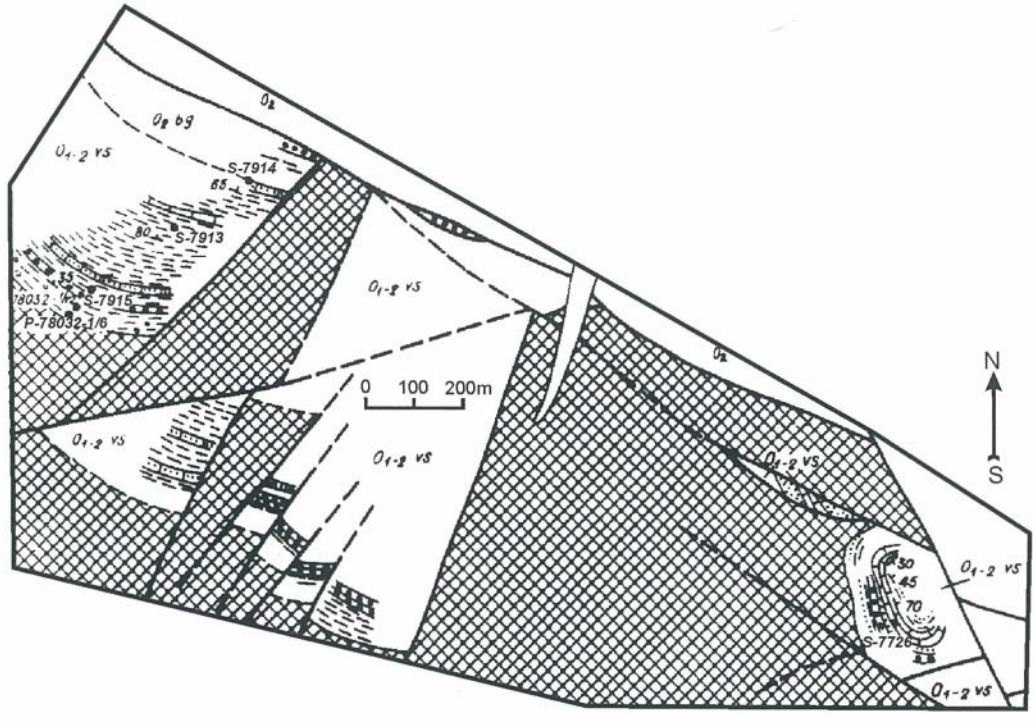


Fig. 14. Sketch map of Barany Brook (modified from Sennikov et al., 1982).

sp. at loc. S-7726 and *Desmochitina rhenana* Eisenack and *Conochitina* sp. at loc. S-7736. These species indicate an Ordovician age of the host sediment (most likely Tremadocian-Darriwilian, judging by their distribution in the Gorny Altai). Gastropods from S-7726 identified as *Temnodicus* sp. are similar, according to V.I. Bjaly, to the *Temnodiscus* sp. known from the variegated member of the Lugovoi Formation in the Biryusa River catchment (Siberian craton) correlated with the Nyaya regional stage (Early Tremdocian). Thus, the fauna-bearing sandy limestone can be conventionally assigned a Tremadocian age.

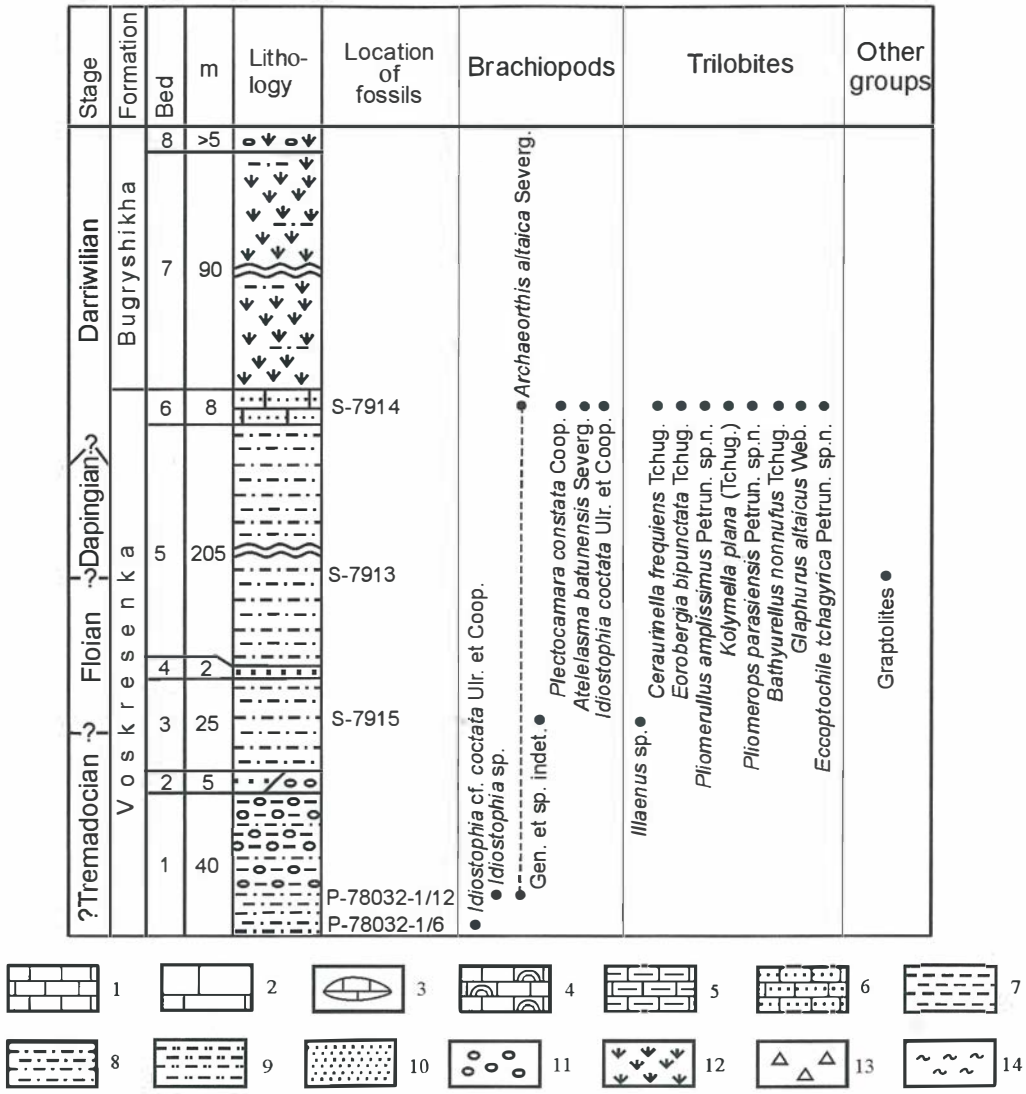


Fig. 15. Ranges of fossil taxa from Barany-1 section.
The legend: 1 – limestones, 2 – massive limestones, 3 – lenses, 4 – algal limestones, 5 – clayey limestones, 6 – sandy limestones, 7 – mudstones, 8 – siltstones, 9 – aleuro-sandstones, 10 – sandstones, 11 – conglomerates, 12 – sodded interval, 13 – breccia, 14 – cherts.

Voskresenka-1 Section

Chronostratigraphic subdivisions of the International Startigraphic Scale: Darriwilian, Sandbian, Katian, Hirnantian.
Regional stratigraphic subdivisions: Bugryshikha, Khankhara and Tekhten'regional stages (horizons).
Local lithostratigraphic subdivisions: Bugryshikha, Khankhara and Tekhten' formations.
Zones: *coelatus, teretiusculus, serratulus, multidens* graptolite zones .
Fauna: tabulate corals, trilobites, brachiopods, ostracods, crinoids, bryozoans, gastropods, graptolites, polychaets, siliceous sponges, conodonts.

The most complete and stratigraphically continuous Ordovician section crops out of near Ust'-Chagyrka Village, in the Tachalov/Voskresenka brook divide (Fig. 16), 200 m from 530.3 m mountain at azimuth 15° and on northeastward down the divide. The rocks show monoclinal bedding to a dip of 75–80°. The section (S-78115) consists of (Fig. 17):

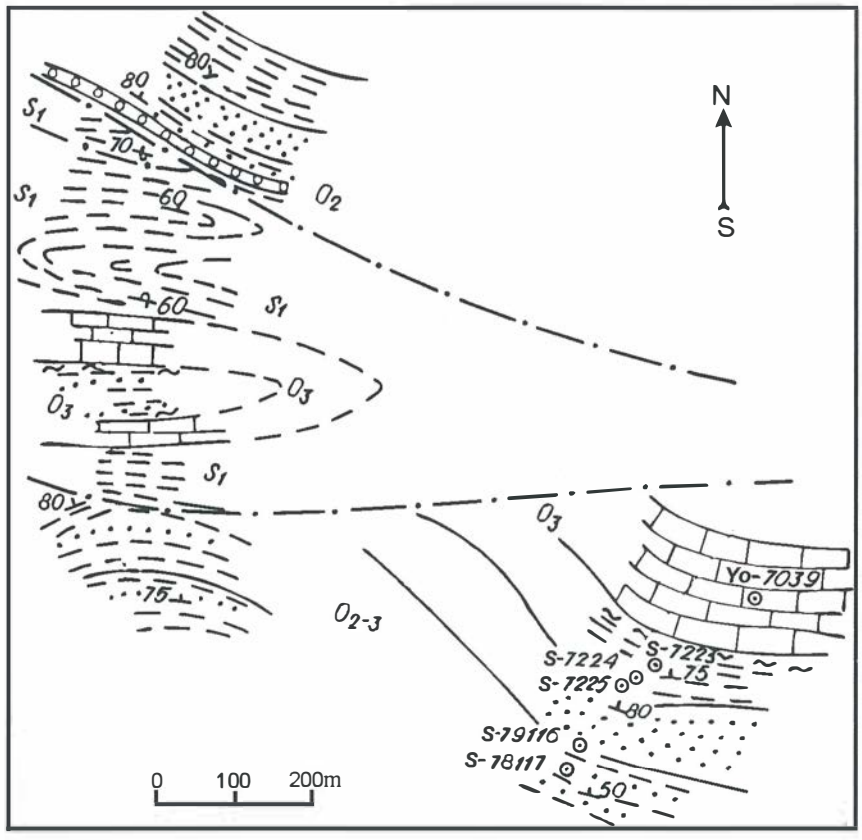


Fig. 16. Sketch map of the watershed of the Voskresenka and Tachalov brooks (modified from Sennikov et al., 1979).

Thickness, m

1. Siltstone, dirty yellow and greenish-gray, thinly (3–5 cm) interbedded with mudstone or less often with fine polymictic sandstone, with sporadic floating quartz and quartzite pebble of 1–3 cm in diameter ..... at least 10

2. Conglomerate: brown and dark gray, fine to medium, with well rounded quartz and quartzite pebble of 1–3 cm to 5 – 7 cm in diameter (Fig. 18) 7

3. Sandstone: dirty yellow, rather quartz, medium and coarse, with well rounded floating quartz and quartzite pebble of 3–5 cm in diameter; siliceous-clayey cement 0.5

4. Sandstone: dirty yellow, rather quartz, medium and coarse, clayey cement 1

5. Sandstone: dirty yellow, rather quartz, medium and coarse, clayey-carbonate cement 2

6. Interbedded fine clayey sandstone and siltstone, yellowish-gray or greenish-gray; with graptolites (2 m above member base): *Dicellograptus* aff. *moffatensis* Carruthers; at 3rd m - scolecodonts; at 17th m -graptolites *Cryptograptus tricornis insectiformis* Ruedemann, *Amplexograptus coelatus* (Lapworth); at 45th m - graptolites *Amplexograptus* sp., *Cryptograptus tricornis insectiformis* Ruedemann, *Glossograptus fimbriatus* (Hopkinson); at 46th m - graptolites *Pterograptus* sp., *Isograptus* sp., *Hustedograptus teretiusculus* (Hisinger) 52

7. Siltstone: black or locally gray, clayey, with uneven shear surfaces; with graptolites (4 m meter above member base): *Hustedograptus teretiusculus* (Hisinger), *Cryptograptus tricornis* (Carruthers); at 14th m – graptolites *Cryptograptus* sp., *Amplexograptus perexcavatus* (Lapworth), *Glossograptus hincksi* (Hopkinson), *Pseudoclimacograptus* (*Pseudoclimacograptus*) sp., *Acrograptus serratulus* (Hall), *Climacograptus* aff. *brevis* Elles et Wood 8

8. Siltstone: pale yellowish-green or gray, clayey, strongly foliated; with graptolites (1 m above member base): *Pseudoclimacograptus scharenbergi* (Lapworth), *Amplexograptus perexcavatus* (Lapworth), *Diplograptus multidens* Elles et Wood 22

9. Sandstone: dirty brown, fine to medium; with brachiopods (5 and 18 meters above member base): *Rostricellula* ex gr. *lenaensis* (Nikif.) and gastropods 20

10. Clayey mudstone and siltstone, gray or greenish-gray; with brachiopods (1 m above member base): *Skenidioides* sp., *Isophragma* sp., ostracods, bryozoans and gastropods 4.5

11. Limestone: gray or dark gray, crystalline; with brachiopods (2 m above member base): *Hesperorthis* ex gr. *markovae* Rozm., *Leptellina* sp., trilobites *Pliomerops* sp., tabulate corals, gastropods and crinoids 5

12. Siltstone: black, clayey, strongly foliated 16

13. Mudstone: clayey, and siltstone, dark gray or greenish-gray; with graptolites (8 meter above member base): *Leptograptus* sp., *Cryptograptus tricornis* (Carruthers), *Orthograptus* ex gr. *truncatus* (Lapworth), *Orthograptus quadrimucronatus* (Hall), *Climacograptus* sp.; at 18th m of this bed brachiopods *Plectorthis* aff. *altaicus* Severg., *Leptellina* cf. *tennesiensis* Ulr. et Coop., *Anophambonites grayae sibirica* Severg., *Hesperorthis* sp. and trilobites *Lonchodomas (Foliopyge)* cf. *tardus* Petrun., *Lonchodomas* aff. *tchakyrensis* Petrun., *Bronteopsis* sp., *Remopleurides* sp., *Encrinuroides* sp., *Calyptaulax* sp., *Nileus* sp. have been collected from the fine-grained carbonate sandstone 22

14. Silty sandstone and clayey siltstone, greenish-gray; with trilobites (2 m above member base): *Nileus* sp., graptolites *Amplexograptus* aff. *perexcavatus* (Lapworth), *Climacograptus* sp., Dicellograptidae, as well as brachiopods, ostracods, gastropods 18

15. Sandstone: gray or dirty yellow to gray, rather quartz, fine, with rare thin (1-5 cm) interbeds of clayey siltstone; with graptolites at 15 (*Climacograptus* sp.) and 40 (Dicellograptidae) meters above member base 90

16. Silicite (chert): greenish-yellow or greenish-gray, massive, locally thinly banded (1–3 cm); with well or quite well preserved radiolarians, siliceous sponge spicules, and conodonts 10

17. Limestone: gray or dark gray, massive, with crinoids ..... ~25

Members 1 through 10 in S-78115 belong to the Bugryshikha Formation, members 11 through 14 belong to the Khankhara Formation, and members 15 through 17 belong to the Tekhten' Formation. Thus, the Bugryshikha Formation in the Voskresenka-1 section totals a thickness of about 140 m, the Khankhara Formation is more than 60 m thick, and the Tekhten' Formation is over 115 m.

The following graptolite zones are recognized in the section S-78115: *coelatus* (lower half of member 6), *teretiusculus* (upper half of member 6 and lower half of member 7), *serratulus* (upper half of member 7), and *multidens* (member 8).

Tachalov Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian.
Regional stratigraphic subdivisions: Khankhara and Tekhten' regional stages (horizons).
Local lithostratigraphic subdivisions: Khankhara and Tekhten' formations.
Zones: *bicornis* and *supernus* (lower *supernus* and upper *ornatus* subzones) graptolite zones, *A. ordovicicus* conodont zones.
Fauna: tabulate corals, brachiopods, graptolites, polychaetes, conodonts, radiolarians, and chitinozoans.

The section occurs on the left bank of the Tachalov Brook, left tributary of the Chagyrka River, near Ust'-Chagyrka Village where equivalents of the upper Voskresenka-1 Section (members 15 through 17) are exposed, namely (Fig. 19):

Thickness, m

1a. Silty sandstone and sandstone: rather quartz, fine, greenish to dark olive-gray; with *bicornis* graptolite zone (first meter above member base, loc. S-78117): *Climacograptus* ex gr. *bicornis* (Hall), *Orthograptus* ex gr. *quadrimucronatus* (Hall) 15

1b. Sandstone: dirty yellowish-gray, rather quartz, fine, with layers of siltstone and 5–10 cm thick and up to 10 m long lenses of detrital limestone; member contains graptolites (first meter above member base, loc. S-78116): *Climacograptus* aff. *hastatus* T.S. Hall, *Xylonograptus regularis* Sennikov; at 46th m (loc. S-7225) – graptolites *Paraorthograptus* sp.; at 57th m (loc. S-7224) graptolites of the *supernus* zone (subzone *supernus*) *Climacograptus longispinus supernus* Elles et Wood, chitinozoans *Conochitina micracantha* Eis., *Tanuchitina ontariensis* Jans., *Cyatochitina* sp. and scolecodonts have been collected; at 73rd m (loc. S-7223) graptolites of the *supernus* zone (subzone *ornatus*) – *Dicellograptus ornatus minor* Toghill, *Climacograptus longispinus supernus* Elles et Wood, *Climacograptus hastatus hastatus* T.S.Hall, *Glyptograptus posterus* Koren' et Mikh., *Xylonograptus regularis* Sennikov, *Inocaulis* sp., *Glyptograptus* sp., conodonts of the *A. ordovicicus* zone - *Acodus similaris* Rhodes, *Ambolodus triangularis* Branson et Mehl, *Amorphognathus* cf. *duftonus* Rhodes, *Belodina* sp., *Drepanodus* sp., *Hibbardella* (?) *diminuta* (Rhodes), *Oistodus* sp., *Panderodus intermedius* (Branson, Mehl et Branson), *Panderodus* cf. *unicostatus* (Branson et Mehl), *Phragmodus insculptus* Branson et Mehl, scolecodonts *Paulinites* sp. and ostracods 75

2. Silicite (chert): greenish-gray, dirty gray, or purple; less often lilac-red mudstone; with well preserved radiolarians in gray and greenish-gray siliceous mudstone (loc. 98080406): *Secuicollacta cassa* Naz. et Orm., *S. sceptri* McDonald, *Kalimnasphaera* cf. *maculosa* Web. et Bl., *Entactinia subulata* Web. et Bl., *Secuicollacta* cf. *esthonica* (Naz.) ..... ~15

3. Limestone: gray or light gray, massive; with tabulate corals (loc. Yo-7039): *Catenipora workmanae* Flower, *Rhabdotetradium* sp. and brachiopods *Vaga* (?) sp., *Brevilamnuella* aff. *thebesensis* (Savage) ..... at least 40

Basal member 1a of the section belongs to the Khankhara Formation and members 1b through 3 belong to the Tekhten' Formation. The latter has an incomplete thickness of 130 m in the section.

The following graptolite zones were distinguished: *bicornis* and *supernus* (with lower *supernus* and upper *ornatus* subzones) and *A. ordovicicus* conodont zone.

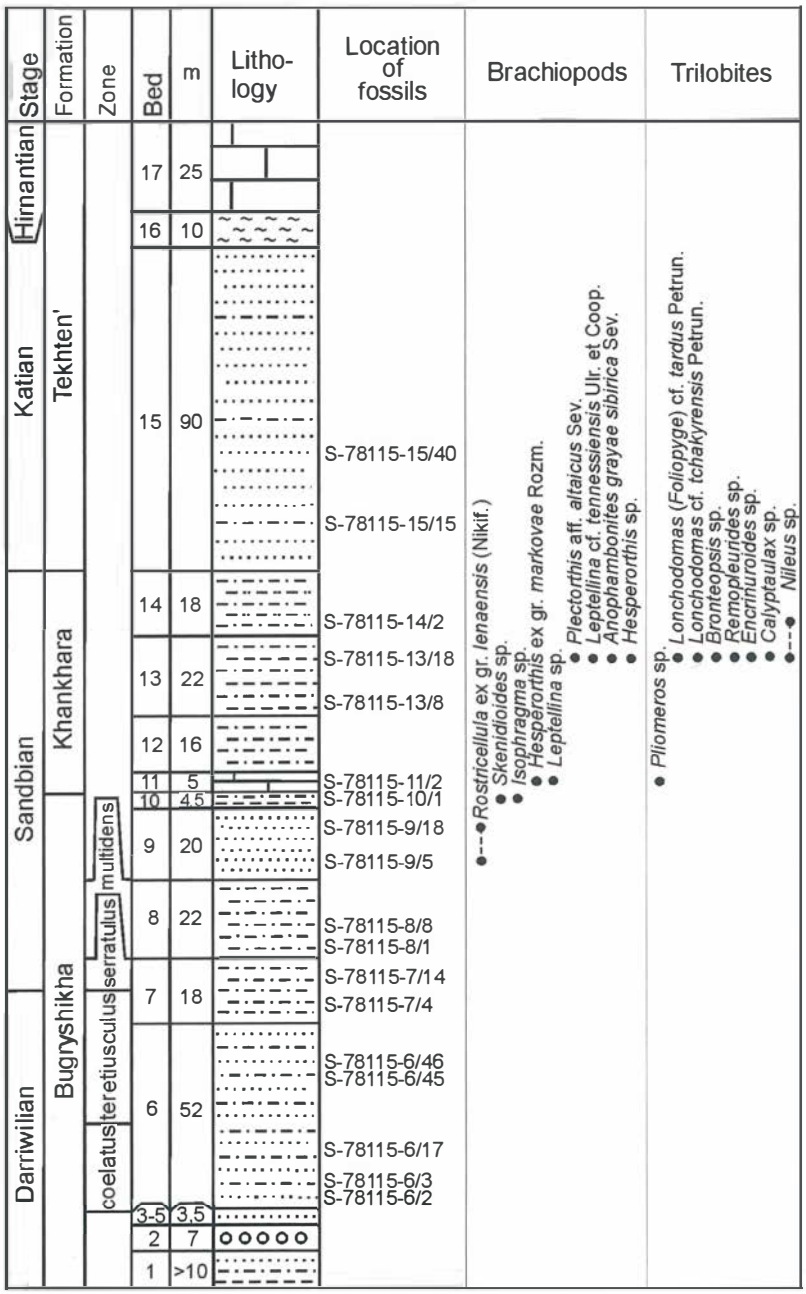


Fig. 17. Ranges of fossil taxa from Voskresenka-1 section.

Voskresenka-2 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian.
Regional stratigraphic subdivisions: Khankhara Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Khankhara Formation.
Zones: *caudatus* graptolite zone .
Fauna: graptolites.

Dirty yellow-gray fine sandstone of member 1 in the Tachalov section extend along strike to the right bank of the Voskresenka Brook where the Voskresenka-2 section, stratigraphically higher than S-78117 and lower than S-7225, consists of:

Thickness, m

1. Silty sandstone: pale yellow-greenish-gray; with graptolites (loc. S-7718): *Climacograptus caudatus* Lapworth, *Orthograptus* ex gr. *quadrimucronatus* (Hall), *Orthograptus* ex gr. *truncatus* (Lapworth), *Glyptograptus* sp. ..... > 15

The Voskresenka-2 section belongs to the Khankhara Formation and corresponds the *caudatus* conodont zone.

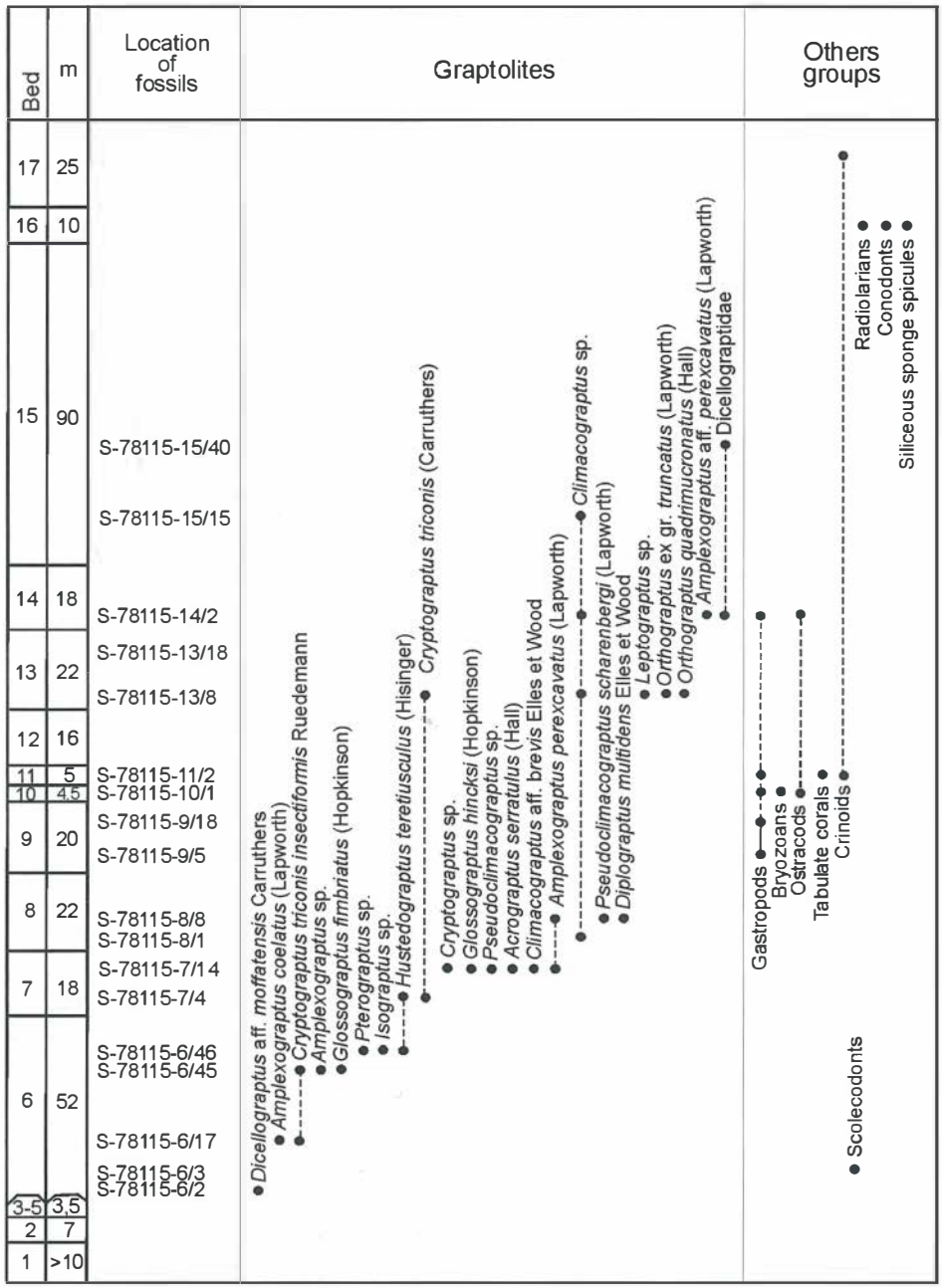


Fig. 17. End.

Voskresenka-3 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Hirnantian.
Regional stratigraphic subdivisions: Tekhten' Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Tekhten' Formation.
Fauna: trilobites, brachiopods, tabulate corals.

Light-color massive limestone exposed in the right bank of the Voskresenka Brook is equivalent to limestones of member 3 in the Tachalov Section and contains trilobites (loc. 170): *Illaensis* sp., brachiopods – *Alispira praegracilis* Severg., *Brevilamnulella* ex gr. *thebesensis* (Savage), *Thebesia* sp., *Prostricklandia* sp., tabulate corals - *Catenipora workmanae* Flower, *Rhabdotetradium* sp. The entire Voskresenka-3 section belongs to the Tekhten' Formation.

Fig. 18. Conglomerates from the basal member of the Ordovician Bugryshikha Formation; Voskresenka-1 section, member 2.

Fig. 21. Massive cherts of the Ordovician Tekhten' Formation; Barany-2 section, member 4.

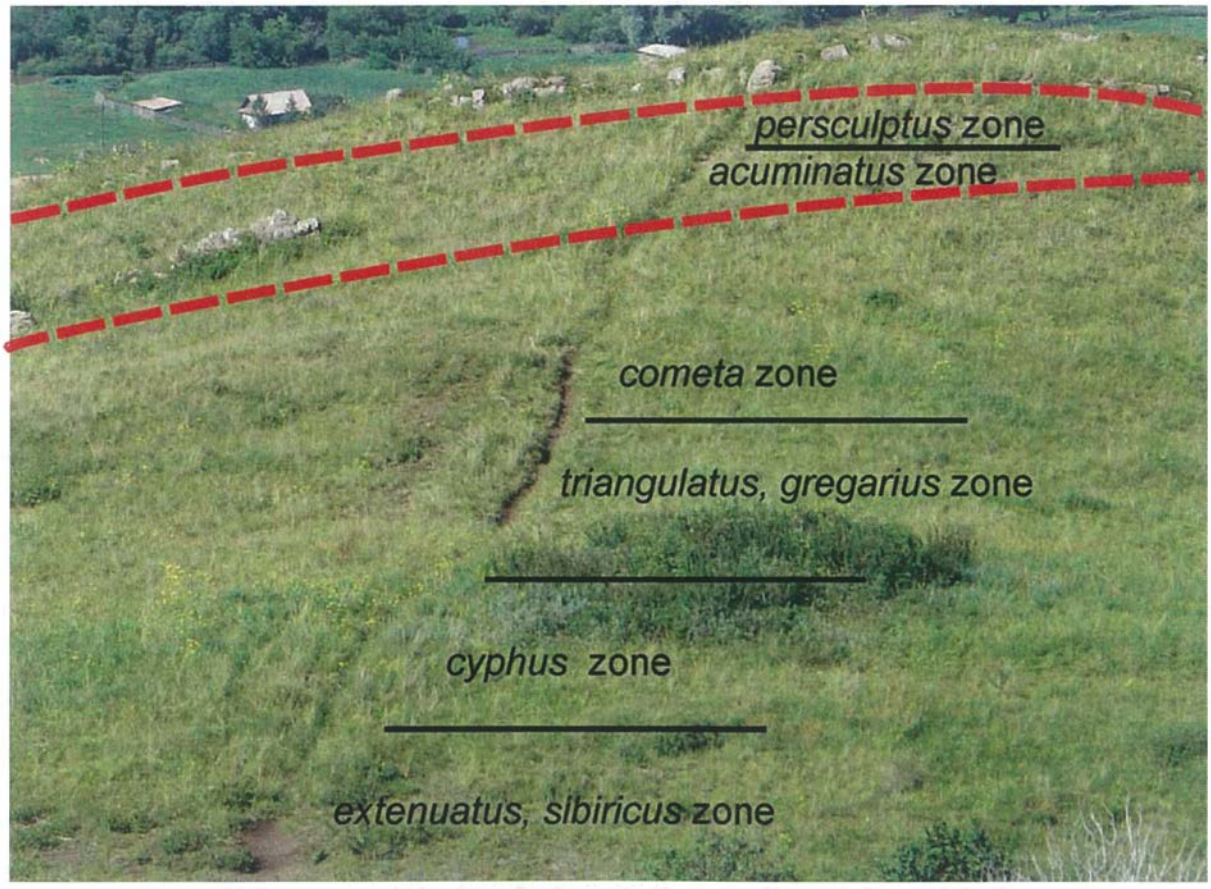


Fig. 23. General view of the trench with outcrop of Voskresenka-4 section.

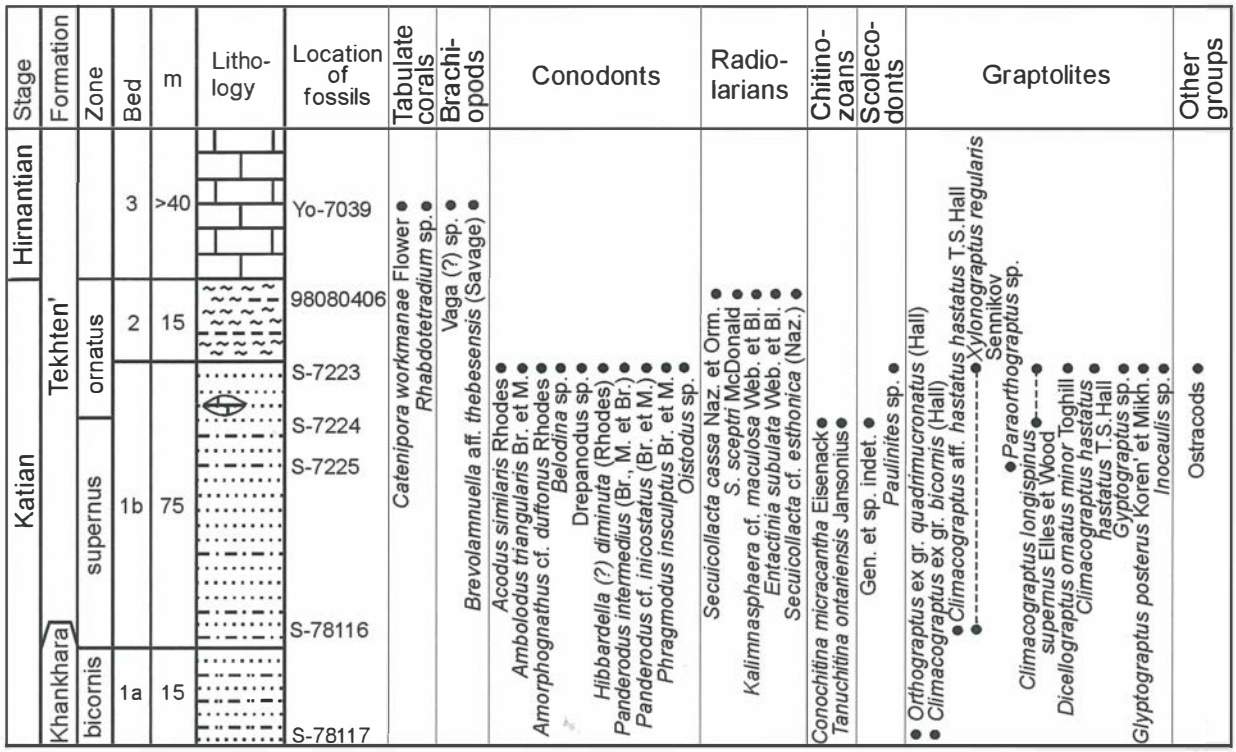
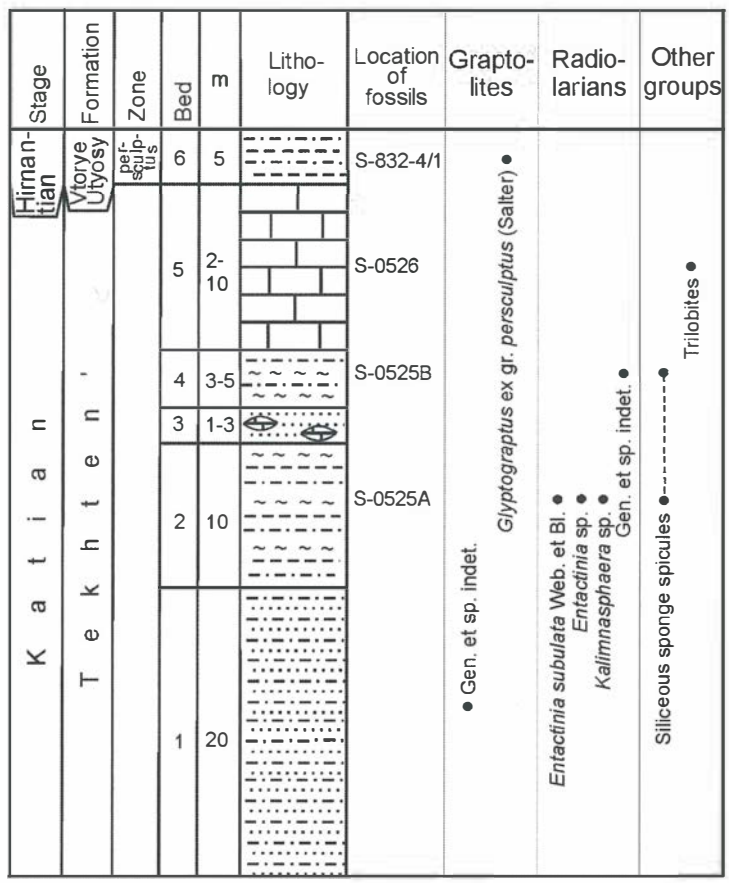


Fig. 19. Ranges of fossil taxa from Tachalov section.

Fig. 20. Ranges of fossil taxa from Barany-2 section.



Barany-2 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian.
Regional stratigraphic subdivisions: Tekhten' and Vtorye Utyosy regional stages (horizons).
Local lithostratigraphic subdivisions: Tekhten' and Vtorye Utyosy formations.
Zones: *persculptus* graptolite zone.
Fauna: trilobites, graptolites, radiolarians, siliceous sponges.

The Barany-2 section (S-832 = S-0525) is located near Ust'-Chagyrka Village, on the right bank of the lower Barany Brook where it enters the Charysh River valley. The section includes (Fig. 20):

Thickness, m

1. Sandstone and siltstone: gray or dark olive-greenish-gray, polymictic, fine, with indefinable graptolites.....~ 20

2. Siltstone and mudstone: dirty green or gray, alternating with gray or greenish-gray silicite (chert); siliceous rocks (loc. S-0525a) contain moderately well preserved radiolarians *Entactinia subulata* Web. et Bl., *Entactinia* sp., *Kalimnasphaera* sp. and siliceous sponge spicules.....10

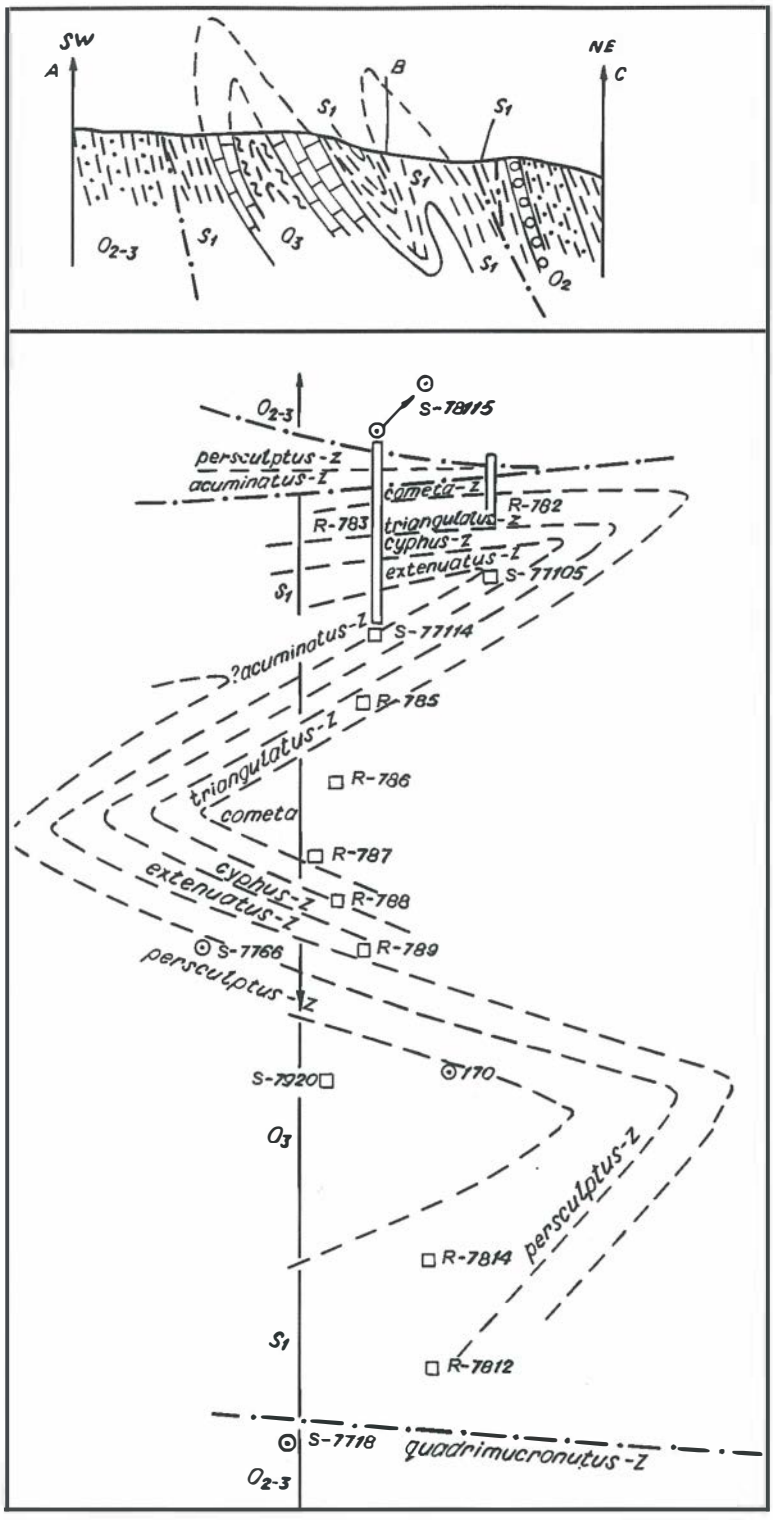


Fig. 22. Sketch map and profile of the Voskresenka-4 section (modified from Sennikov, Russkikh, 1982).

3. Sandstone: dirty green-gray, polymictic, fine, including flat 3–5 cm thick and 20–30 cm long loaf-shaped lenses of gray or dark gray fine-grained bioclastic limestone; member is lens-shaped and pinches out 1–3

4. Silicite (chert): greenish-gray, gray, brown, or yellowish-dirty gray, banded, alternating with dirty gray or silver-gray siltstone; siliceous rocks (loc. S-0525b) contain quite well preserved radiolarians and siliceous sponge spicules (Fig. 21) 3–5

5. Limestone: gray, massive; with trilobites found in a lens-shaped layer of 15 cm thick and 30 cm long (loc. S-0526). Thickness is 10 m decreasing to 2–3 m along the strike at 40 m away from the site 2–10

6. Siltstone and mudstone: dark silver-gray, foliated; with graptolites (loc. S-832-4/1) of *persculptus* zone (Upper Hirnant or Upper Ashgill): *Persculptograptus* ex gr. *persculptus* (Salter) ..... ~ 5

Members 1 through 5 belong to the Tekhten' Formation and member 6 belongs to the Vtorye Utyosy Formation. The incomplete thickness of the Tekhten' Formation in the section is about 20 m.

Voskresenka-4 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Hirnantian, Ruddanian, Aeronian.

Regional stratigraphic subdivisions: Vtorye Utyosy Regional stage (Horizon).

Local lithostratigraphic subdivisions: Vtorye Utyosy Formation.

Zones: *persculptus, acuminatus-ascensus, extenuatus-sibiricus, cyphus, triangulatus-gregarius, cometa* graptolite zones .

Fauna: tabulate corals, trilobites, ostracods, crinoids, brachiopods, graptolites.

Upper Ordovician (Upper Hirnantian) and Lower Silurian (Rhuddanian-Aeronian) strata near Ust'-Chagyrka Village at 25 to 200 m from 530.3 m mountain at azimuth 15° make up a fault block (Fig. 22). One fault zone involves a tectonic (?) lens of Upper Ordovician (Sandbian or Caradocian) limestone. The strata are folded in overturned isoclinal folds with their limbs dipping at 60–90°.

Ditch R-783 runs southward from the line of conglomerate in section S-78115-2 (Fig. 23), roughly across the strike of rocks. The exposed thickness of the strata may approximately correspond to their true thickness in view of their steep dip at 60–90°. All intervals are measured from the base of conglomerate. The Silurian section begins with interval 15.5–21 m (R-783) where exposed are (Fig. 24):

Thickness, m

1. Mudstone: dark olive-green, limy-clayey, foliated, flaggy, fine. At four levels from interval 16,5–17,5 m graptolites of the youngest Ordovician zone *persculptus* (Late Hirnantian) (Late Ashgillian) have been obtained - (loc. S-7785 = R-783-2/16,50-16,55) *Persculptograptus persculptus* (Salter), *Glyptograptus* sp., *Diplograptus* (s.l.) sp., (loc. R-783-2/16,65-16,70) *Metaclimacograptus hughesi* (Nicholson), *Persculptograptus persculptus* (Salter), (loc. R-783-2/17,15-17,20) *Metaclimacograptus hughesi* (Nicholson), *Hedrograptus* sp., (loc. R-783-17,35-17.40) *Normalograptus scalaris* (Hisinger), *Persculptograptus persculptus* (Salter).

At six levels from interval 17.5–21.0 m graptolites of the most ancient Silurian *acuminatus* zone (Lower Ruddanian), (Lower Llandoverian) have been recovered - (loc. S-7786 = R-783-3/17,55-17,60) *Normalograptus scalaris* (Hisinger), *Hedrograptus* sp., *Glyptograptus* sp., *Parakidograptus acuminatus* (Nicholson), *Parakidograptus* cf. *acuminatus* (Nicholson), *Rhaphidograptus* sp., (loc. R-783-3/18,25-18,30) *Persculptograptus* ex gr. *persculptus* (Salter), *Diplograptus* sp., (loc. S-7787 = R-783-3/18,65-18,70) *Hedrograptus* sp., *Persculptograptus* ex gr. *persculptus* (Salter), *Glyptograptus* sp., (loc. R-783-3/19,20-19,50), *Glyptograptus* sp., (loc. R-783-3/19,70-19,80) *Normalograptus scalaris* (Hisinger), (loc. R-783-5/20,40-20,50) *Glyptograptus* sp. ..... at least 5.5

The member is truncated by faults at the base and at the top which separate it, respectively, from the Ordovician strata of S-78115-1 and from 2 m thick (interval 21–23 m) fault lens of Upper Ordovician Sandbian (Caradocian) gray massive limestone (possibly, equivalent of member 11 Voskresenka-1 section), with trilobites *Remopleurides* sp., brachiopods *Parastrophinella* (?) sp. indet. and tabulate corals *Plasmoporella plana* Bondarenko.

Member 1 is overlain successively by

2. Siltstone: dark gray to black, locally with yellowish hue, clayey, strongly foliated; gray, crystalline limestone exposed at 58–57.9 m 22

At seven levels from interval 79,3–57,25 m graptolites of the *extenuatus-sibiricus* zone (Middle Ruddanian) (Lower Llandoverian) - (loc. Yo-7047 = R-783-8/57,60-58,00) *Metaclimacograptus hughesi* (Nicholson), *Met. orientalis* Obut et Sob., *Normalograptus normalis* (Lapworth), *Hedrograptus rectangularis* (McCoy), *Metabolograptus sibiricus* (Obut), *Cystograptus tumidicaulus* (Hsu), *Dimorphograptus extenuatus* Elles et Wood, *Monograptus* (s.l.) sp., scolecodonts - *Paulinites* sp. and indetermined ostracods and crinoids, (loc. S-77109 = R-783-8/58,20-58,30) *Metaclimacograptus hughesi* (Nicholson), *Hedrograptus rectangularis* (McCoy), *Hedrograptus* sp., *Metabolograptus sibiricus* (Obut), *Dimorphograptus extenuatus* Elles et Wood, *Coronograptus* sp., (loc. R-783-8/58,60-58,70) *Glyptograptus* sp., *Monograptus* (s.l.) sp., (loc. S-77110 = R-783-8/58,90-59,00) *Metaclimacograptus hughesi* (Nicholson), *Hedrograptus* sp., *Metabolograptus sibiricus* (Obut), *Glyptograptus* sp., *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Monograptus* (s.l.) sp., *Dimorphograptus extenuatus* Elles et Wood, (loc. S-77111 = R-783-8/59,60-59,70) *Diplograptus* (s.l.) sp., *Dimorphograptus extenuatus* Elles et Wood, (loc. S-77112 = R-783-8/62,50-62,60) *Diplograptus* (s.l.) sp., (loc. S-77113 = R-783-8/65,80-65,90) *Diplograptus* (s.l.) sp. indet.

3. Siltstone: dark olive-green, yellowish-gray or gray, with clayey and limy-clayey alternation; "loaves" of gray massive limestone occupy 10 to 80 % of intervals 55–54.7 m, 53.2–53.0 m, 50.6–49.8 m, 49.4–47.4 m, 45.3–44.9 m, and 24.3–23.9 m; member contains trilobites found at 57,2-53,5 m: ostracods, brachiopods and crinoids.

At twenty one levels from interval 57,25-45,3 m graptolites of the *cyphus* zone (upper part of Ruddanian) (upper part of the Lower Llandoverian) - (loc. R-783-7/45,65–45,70) *Glyptograptus tamariscus* (Nicholson), *Orthograptus mutabilis* (Elles et Wood), *Coronograptus cyphus* (Lapworth), *Monograptus* (s.l.) sp., (loc. S-77101 = R-783-7/45,80-45,90) *Hedrograptus janishewskyi* Obut, *Paraclimacograptus innotatus* (Nicholson), *Glyptograptus* sp., *Coronograptus cyphus* (Lapworth), (loc. R-783-7/46,10-46,20: *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Coronograptus cyphus* (Lapworth), (loc. S-77102 = R-783-7/47,00-47,10) *Hedrograptus* sp., (loc. R-783-7/47,40-47,50) *Metaclimacograptus orientalis* Obut et Sob., *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Coronograptus cyphus* (Lapworth); (loc. S-77103 = R-783-7/48,65-48,7) *Hedrograptus* sp., *Coronograptus cyphus* (Lapworth), (loc. S-77104 = R-783-7/49,05-49,10) *Paraclimacograptus* sp., *Hedrograptus* sp., *Glyptograptus* sp., *Coronograptus cyphus* (Lapworth), (loc. R-783-7/49,80-49,90) *Normalograptus scalaris* (Hisinger), *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Coronograptus* sp., (loc. R-783-7/50,30-50,40) *Glyptograptus tamariscus* (Nicholson), *Monograptus* (s.l.) sp., (loc. R-783-7/51,00-51,10) *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Coronograptus cyphus* (Lapworth), (loc. R-783-7/51,65-51,70) *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Coronograptus cyphus* (Lapworth), *Monograptus* (s.l.) sp., *Pribylograptus sandersoni* (Lapworth), (loc. R-783-7/52,10-52,20) *Coronograptus cyphus* (Lapworth), (loc. R-783-7/52,30-52,40) *Coronograptus cyphus* (Lapworth), (loc. R-783-8/52,50-52,60) *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Coronograptus cyphus* (Lapworth), *Dimorphograptus swanstoni* Lapworth, (loc. S-77106 = R-783-8/53,50-53,60) *Metaclimacograptus orientalis* Obut et Sob., *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Dimorphograptoides*) aff. *physophora* (Nicholson), *Pernerograptus* sp., *Coronograptus cyphus* (Lapworth), (loc. S-77107 = R-783-8/54,15-54,20) *Metaclimacograptus hughesi* (Nicholson), *Hedrograptus* sp., *Diplograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Glyptograptus* sp., *Orthograptus mutabilis* (Elles et Wood), (loc. R-783-8/54,50-54,60) *Glyptograptus tamariscus* (Nicholson), (loc. R-783-8/55,10–55,20) *Metaclimacograptus orientalis* Obut et Sob., *Paraclimacograptus innotatus* (Nicholson), *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Coronograptus cyphus* (Lapworth), Dendrograptidae,

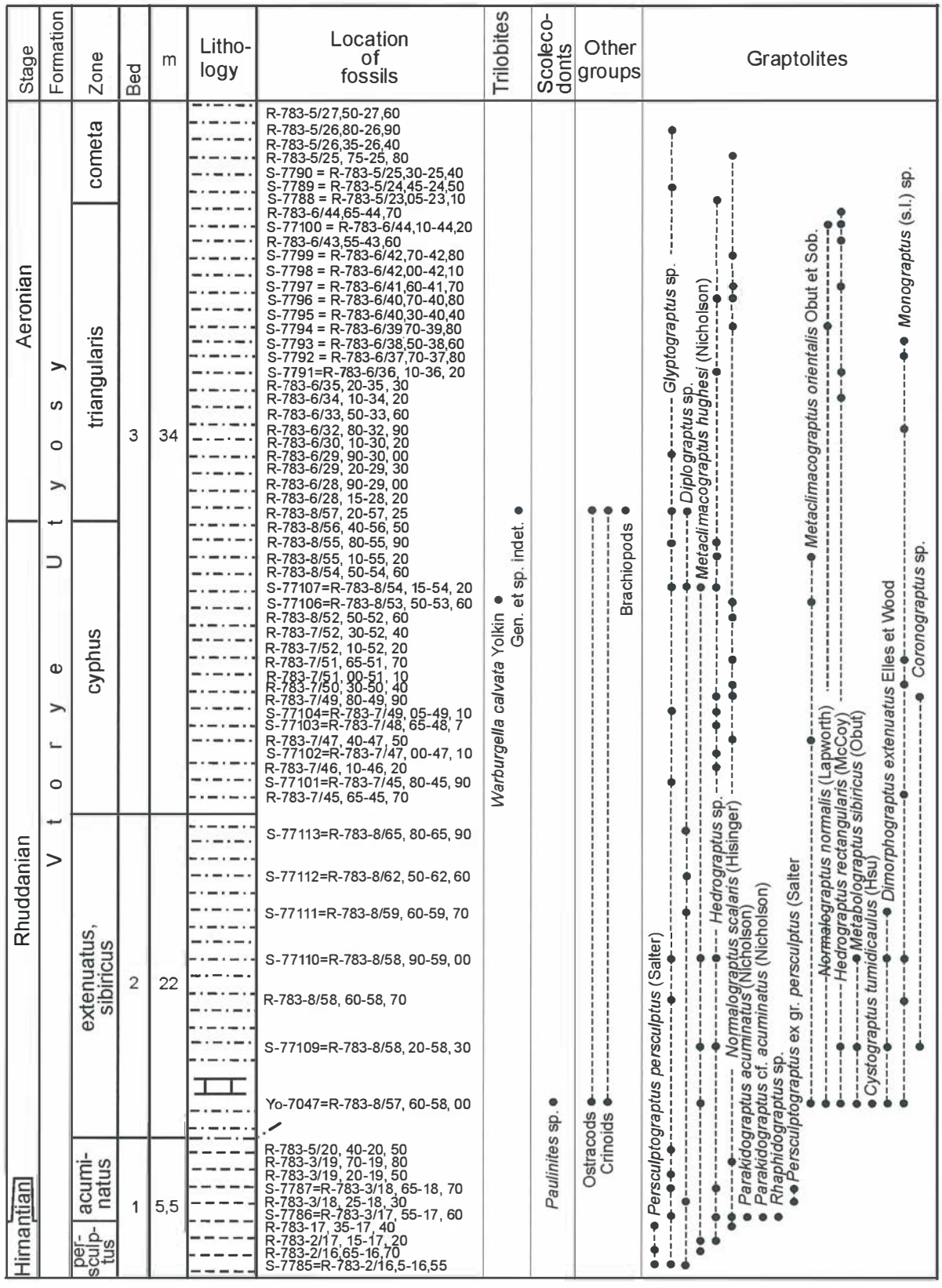
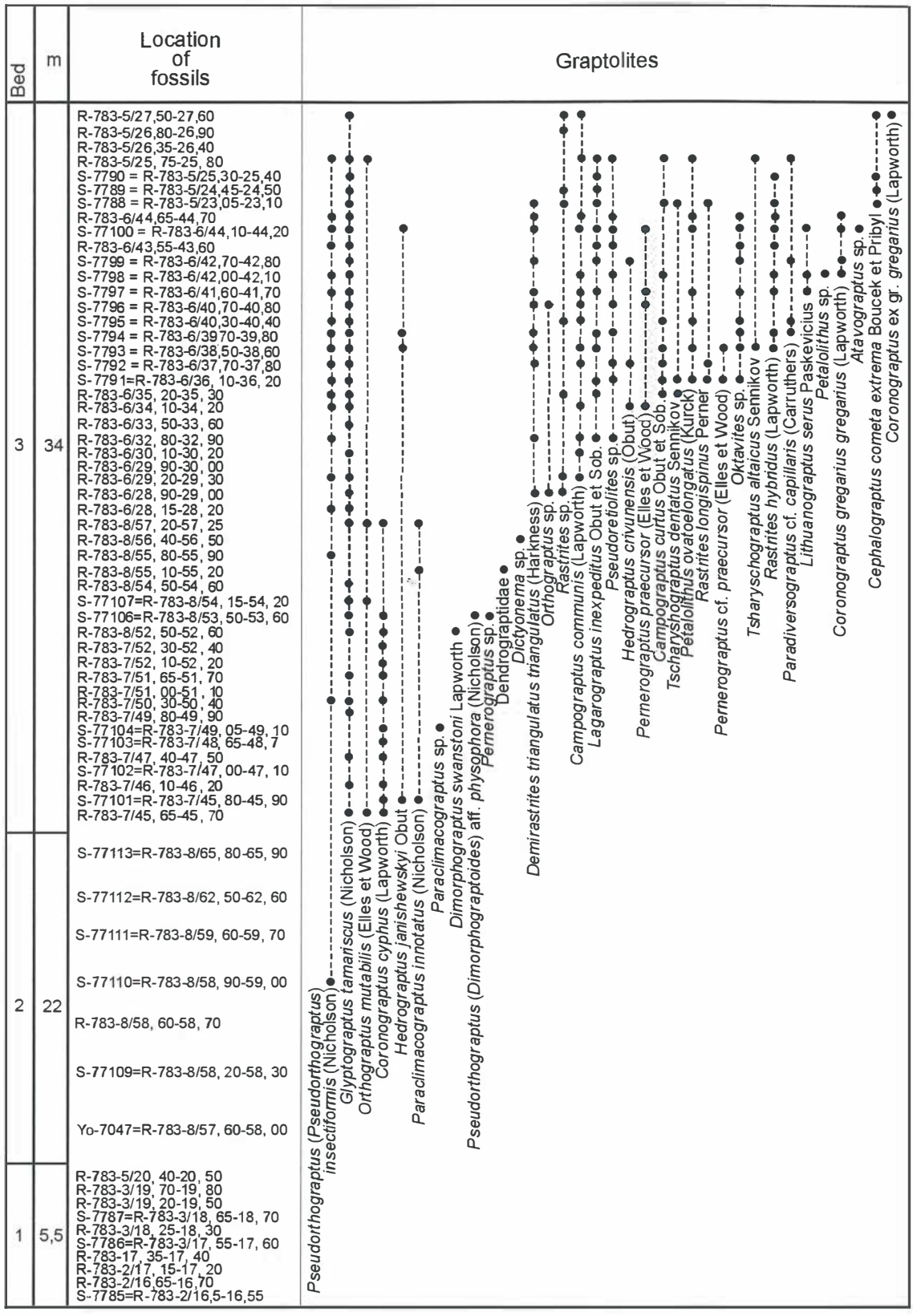


Fig. 24. Ranges of fossil taxa from Voskresenka-4 section.


Bed
m
Location of fossils
Graptolites
3
34
2
22
1
5,5
R-783-5/27,50-27,60
R-783-5/26,80-26,90
R-783-5/26,35-26,40
R-783-5/25, 75-25, 80
S-7790 = R-783-5/25,30-25,40
S-7789 = R-783-5/24,45-24,50
S-7788 = R-783-5/23,05-23,10
R-783-6/44,65-44,70
S-77100 = R-783-6/44,10-44,20
R-783-6/43,55-43,60
S-7799 = R-783-6/42,70-42,80
S-7798 = R-783-6/42,00-42,10
S-7797 = R-783-6/41,60-41,70
S-7796 = R-783-6/40,70-40,80
S-7795 = R-783-6/40,30-40,40
S-7794 = R-783-6/3970-39,80
S-7793 = R-783-6/38,50-38,60
S-7792 = R-783-6/37,70-37,80
S-7791=R-783-6/36, 10-36, 20
R-783-6/35, 20-35, 30
R-783-6/34, 10-34, 20
R-783-6/33, 50-33, 60
R-783-6/32, 80-32, 90
R-783-6/30, 10-30, 20
R-783-6/29, 90-30, 00
R-783-6/29, 20-29, 30
R-783-6/28, 90-29, 00
R-783-6/28, 15-28, 20
R-783-8/57, 20-57, 25
R-783-8/56, 40-56, 50
R-783-8/55, 80-55, 90
R-783-8/55, 10-55, 20
R-783-8/54, 50-54, 60
S-77107=R-783-8/54, 15-54, 20
S-77106=R-783-8/53, 50-53, 60
R-783-8/52, 50-52, 60
R-783-7/52, 30-52, 40
R-783-7/52, 10-52, 20
R-783-7/51, 65-51, 70
R-783-7/51, 00-51, 10
R-783-7/50, 30-50, 40
R-783-7/49, 80-49, 90
S-77104=R-783-7/49, 05-49, 10
S-77103=R-783-7/48, 65-48, 7
R-783-7/47, 40-47, 50
S-77102=R-783-7/47, 00-47, 10
R-783-7/46, 10-46, 20
S-77101=R-783-7/45, 80-45, 90
R-783-7/45, 65-45, 70
S-77113=R-783-8/65, 80-65, 90
S-77112=R-783-8/62, 50-62, 60
S-77111=R-783-8/59, 60-59, 70
S-77110=R-783-8/58, 90-59, 00
R-783-8/58, 60-58, 70
S-77109=R-783-8/58, 20-58, 30
Yo-7047=R-783-8/57, 60-58, 00
R-783-5/20, 40-20, 50
R-783-3/19, 70-19, 80
R-783-3/19, 20-19, 50
S-7787=R-783-3/18, 65-18, 70
R-783-3/18, 25-18, 30
S-7786=R-783-3/17, 55-17, 60
R-783-17, 35-17, 40
R-783-2/17, 15-17, 20
R-783-2/16,65-16,70
S-7785=R-783-2/16,5-16,55
Pseudorthograptus (Pseudorthograptus) insectiformis (Nicholson)
Glyptograptus tamariscus (Nicholson)
Orthograptus mutabilis (Elles et Wood)
Coronograptus cyphus (Lapworth)
Hedrograptus janishewskyi Obut
Paraclimacograptus innotatus (Nicholson)
Paraclimacograptus sp.
Dimorphograptus swanstoni Lapworth
Pseudorthograptus (Dimorphograptoides) aff. physophora (Nicholson)
Pernerograptus sp.
Dendrograptidae
Dictyonema sp.
Demirastrites triangulatus triangulatus (Harkness)
Orthograptus sp.
Rastrites sp.
Campograptus communis (Lapworth)
Lagarograptus inexpeditus Obut et Sob.
Pseudoretiolites sp.
Hedrograptus crivunensis (Obut)
Pernerograptus praecursor (Elles et Wood)
Campograptus curtus Obut et Sob.
Tscharyshograptus dentatus Sennikov
Petalolithus ovatoelongatus (Kurck)
Rastrites longispinus Perner
Pernerograptus cf. praecursor (Elles et Wood)
Oktavites sp.
Tsharyschograptus altaicus Sennikov
Rastrites hybridus (Lapworth)
Paradiversograptus cf. capillaris (Carruthers)
Lithuanograptus serus Paskevicius
Petalolithus sp.
Coronograptus gregarius gregarius (Lapworth)
Atavograptus sp.
Cephalograptus cometa extrema Boucek et Pribyl
Coronograptus ex gr. gregarius (Lapworth)

(loc. R-783-8/55,80–55,90) *Hedrograptus* sp., *Glyptograptus* sp., *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), (loc. R-783-8/56,40-56,50) *Dictyonema* sp., (loc. R-783-8/57,20-57,25) *Paraclimacograptus innotatus* (Nicholson), *Glyptograptus tamariscus* (Nicholson), *Glyptograptus* sp., *Diplograptus* sp., *Orthograptus mutabilis* (Elles et Wood), *Coronograptus cyphus* (Lapworth) were identified.

From loc. S-77106 = R-783-8/53,50-53,60 trilobites *Warburgella calvata* Yolk. have been found together with graptolites.

At twenty one levels from interval 45,3-27,8 m graptolites of the *triangulatus, gregarius* zone (lower part of Aeronian) (lower part of Middle Llandoverian) were recovered – (loc. R-783-6/28,15-28,20) *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Demirastrites triangulatus triangulatus* (Harkness), (loc. R-783-6/28,90-29,00) *Glyptograptus tamariscus* (Nicholson), *Orthograptus* sp., *Rastrites* sp., (loc. R-783-6/29,20-29,30) *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Campograptus communis* (Lapworth), *Rastrites* sp., (loc. R-783-6/29,90-30,00) *Glyptograptus* sp., (loc. R-783-6/30,10-30,20) *Glyptograptus tamariscus* (Nicholson), *Campograptus communis* (Lapworth), (loc. R-783-6/32,80-32,90) *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Campograptus communis* (Nicholson), *Demirastrites triangulatus triangulatus* (Harkness), *Pseudoretiolites* sp., *Monograptus* (s.l.) sp., (loc. R-783-6/33,50-33,60) *Glyptograptus tamariscus* (Nicholson), (loc. R-783-6/34,10-34,20) *Hedrograptus crivunensis* (Obut), *Hedrograptus rectangularis* (McCoy), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Campograptus communis* (Lapworth), *Pernerograptus praecursor* (Elles et Wood), (loc. R-783-6/35,20–35,30) *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Campograptus curtus* Obut et Sob., *Rastrites* sp., *Tscharyshograptus dentatus* Sennikov, (loc. S-7791 = R-783-6/36,10-36,20) *Tsharyschograptus dentatus* Sennikov, *Hedrograptus rectangularis* (McCoy), *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Lagarograptus inexpeditus* Obut et Sob., *Campograptus curtus* Obut et Sob., *Rastrites longispinus* Perner, *Pernerograptus* cf. *praecursor* (Elles et Wood), *Pseudoretiolites* sp., *Oktavites* sp. (loc. S-7792 = R-783-6/37,70-37,80) *Hedrograptus krivunensis* (Obut), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Campograptus communis* (Lapworth), *Campograptus curtus* Obut et Sob., *Rastrites longispinus* Perner, *Demirastrites triangulatus triangulatus* (Harkness), *Monograptus* (s.l.) sp., *Pseudoretiolites* sp., (loc. S-7793 = R-783-6/38,50-38,60) *Tsharyschograptus altaicus* Sennikov, *Hedrograptus janishewskyi* Obut, *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Lagarograptus inexpeditus* Obut et Sob., *Pernerograptus* cf. *praecursor* (Elles et Wood), *Monograptus* (s.l.) sp., *Campograptus communis* (Lapworth), *Campograptus curtus* Obut et Sob., Oktavites sp., *Demirastrites triangulatus triangulatus* (Harkness), *Rastrites hybridus* (Lapworth), (loc. S-7794 = R-783-6/39 70-39,80) *Hedrograptus janishewskyi* Obut, *Normalograptus scalaris* (Hisinger), *Normalograptus normalis* (Lapworth), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Demirastrites triangulatus triangulatus* (Harkness), *Rastrites hybridus* Lapworth, *Paradiversograptus* cf. *capillaris* (Carruthers), *Pseudoretiolites* sp., *Oktavites* sp., (loc. S-7795 = R-783-6/40,30-40,40) *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Campograptus communis* (Lapworth), *Campograptus curtus* Obut et Sob., *Paradiversograptus capillaris* (Carruthers), *Rastrites* sp., *Oktavites* sp., (loc. S-7796 = R-783-6/40,70-40,80) *Normalograptus scalaris* (Hisinger), *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Orthograptus* sp., *Campograptus communis* (Lapworth), *Demirastrites triangulatus triangulatus* (Harkness), *Pernerograptus praecursor* (Elles et Wood), *Monograptus* (s.l.) sp., *Pseudoretiolites* sp., (loc. S-7797 = R-783-6/41,60-41,70) *Lithuanograptus serus* Paskevicius, *Hedrograptus rectangularis* (McCoy), *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Petalolithus ovatoelongatus* (Kurck), *Demirastrites triangulatus triangulatus* (Harkness), *Pernerograptus praecursor* (Elles et Wood), *Campograptus communis* (Lapworth), *Rastrites hybridus* Lapworth, *Oktavites* sp., (loc. S-7798 = R-783-6/42,00-42,10) *Lithuanograptus serus* Paskevicius, *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus* sp., *Campograptus communis* (Lapworth), *Campograptus curtus* Obut et Sob., *Coronograptus gregarius gregarius* (Lapworth), *Rastrites hybridus* Lapworth, *Pseudoretiolites* sp., (loc. S-7799 = R-783-6/42,70-42,80) *Normalograptus scalaris* (Hisinger), *Hedrograptus krivunensis* (Obut), *Glyptograptus tamariscus* (Nicholson), *Coronograptus gregarius gregarius* (Lapworth), *Lagarograptus inexpeditus* Obut et Sob., *Demirastrites triangulatus triangulatus* (Harkness), *Paradiversograptus capillaris* (Carruthers), *Oktavites* sp., (loc. R-783-6/43,55-43,60) *Hedrograptus rectangularis* (McCoy), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Lagarograptus inexpeditus* Obut et Sob., *Rastrites hybridus* (Lapworth.), *Oktavites* sp., *Pseudoretiolites* sp., (loc. S-77100 = R-783-6/44,10-44,20) *Metaclimacograptus hughesi* (Nicholson), *Lithuanograptus serus* Paskevicius, *Normalograptus normalis* (Lapworth), *Hedrograptus janishewskyi* Obut, *Hedrograptus rectangularis* (McCoy), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Lagarograptus inexpeditus* Obut et Sob., *Coronograptus gregarius gregarius* (Lapworth), *Pernerograptus praecursor* (Elles et Wood), *Campograptus communis* (Lapworth), *Demirastrites triangulatus triangulatus* (Harkness), *Rastrites hybridus* Lapworth, *Oktavites* sp., *Pseudoretiolites* sp., *Atavograptus* sp., (loc. R-783-6/44,65-44,70) *Hedrograptus rectangularis* (McCoy), *Glyptograptus tamariscus* (Nicholson), *Pseudorthograptus*

(*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Coronograptus gregarius gregarius* (Lapworth), *Campograptus communis* (Lapworth), *Demirastrites triangulatus triangulatus* (Harkness), *Rastrites hybridus* Lapworth, *Pseudoretiolites* sp., *Oktavites* sp.

At six levels from interval 27,8–23 m graptolites of the *cometa* zone (Middle Aeronian) (upper part of Middle Llandoverian) have been obtained – (loc. S-7788 = R-783-5/23,05-23,10) *Tsharyschograptus dentatus* Sennikov, *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Cephalograptus cometa extrema* Boucek et Pribyl, *Lagarograptus inexpeditus* Obut et Sob., *Campograptus curtus* Obut et Sob., *Demirastrites triangulatus triangulatus* (Harkness), *Demirastrites* sp., *Rastrites hybridus* Lapworth, *Rastrites longispinus* Perner, *Rastrites* sp., (loc. S-7789 = R-783-5/24,45-24,50) *Glyptograptus tamariscus* (Nicholson), *Cephalograptus cometa extrema* Boucek et Pribyl, *Lagarograptus inexpeditus* Obut et Sob., (loc. S-7790 = R-783-5/25,30-25,40) *Glyptograptus* sp., *Rastrites* sp., (loc. R-783-5/25,75-25,80) *Glyptograptus tamariscus* (Nicholson), *Cephalograptus cometa extrema* Boucek et Pribyl, *Lagarograptus inexpeditus* Obut et Sob., *Rastrites hybridus* Lapworth, (loc. R-783-5/26,35-26,40) *Tsharyschograptus altaicus* Sennikov, *Normalograptus scalaris* (Hisinger), *Glyptograptus tamariscus* (Nicholson), *Orthograptus mutabilis* (Elles et Wood), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Petalolithus ovatoelongatus* (Kurck), *Lagarograptus inexpeditus* Obut et Sob., *Campograptus communis* (Lapworth), *Campograptus curtus* Obut et Sob., *Paradiversograptus capillaris* (Carruthers), *Pseudoretiolites* sp., (loc. R-783-5/26,80-26,90) *Glyptograptus* sp., *Rastrites* sp., (loc. R-783-5/27,50-27,60) *Glyptograptus tamariscus* (Nicholson), *Cephalograptus cometa extrema* Boucek et Pribyl, *Coronograptus* ex gr. *gregarius* (Lapworth), *Campograptus communis* (Lapworth.), *Rastrites* sp. ..... ~34

The base of member 2 is unexposed and the top of member 3 is truncated by a fault which separates it from the fault lens of Sandbian (Caradocian) limestone. The lower part of member 2, not constrained by faunas, may be older than the *extenuatus* zone and may be correlated with the *acuminatus-ascensus* zone.

All members of the section belong to the Vtorye Utyosy Formation which has an incomplete total thickness of more than 60 m.

Ditches R-785, R-786, R-787, R-788, and R-789 dug at every 20–30 m from the end of cut R-783 (79.3 m) toward 530.3 m mountain expose Silurian rocks of the Voskresenka-4 section; section contains graptolites of the *triangulatus* zone collected at R-785: *Pseudoretiolites* sp., *Campograptus curtus* Obut et Sob., R-786 – graptolites of the *cometa* zone *Cephalograptus cometa* (Geinitz) and from R-787 – *cometa* zone *Cephalograptus cometa* (Geinitz), R-788 – *cyphus* zone *Glyptograptus* sp., *Hedrograptus* sp., *Coronograptus cyphus* (Lapworth), R-789 – *extenuatus* zone *Glyptograptus* sp., *Metabolograptus sibiricus* (Obut).

In the ditch R-788 trilobites *Warburgella altaica* Yolk., *Warburgella calvata* Yolk., ostracods *Spinobolbina bispina* Abushik were recovered along with graptolites; graptolites of the *acuminatus-ascensus* zone (Lower Rhuddanian) found 70 m downhill from point 530.3 m toward the Voskresenka Brook headwaters (a small cut, loc. S-7766): *Akidograptus ascensus* Davies, *Persculptograptus* ex gr. *persculptus* (Salter); and graptolites *Metaclimacograptus orientalis* Obut et Sob. found 100 m south of point 530.3 m at R-7812.

3.1.2. Area of Maralikha Village

Pichuzhikha Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Floian, Dapingian.
Regional stratigraphic subdivisions: Lebed' Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Voskresenka Formation.
Zones: *densus, gibberulus* graptolite zones.
Fauna: graptolites.

Stratigraphically younger strata of the Voskresenka Formation crop out on the right bank of the Pichuzhikha Brook, 200 m far from the place where it enters the Charysh River terrace (Fig.25). The section from the water surface upwards includes (Fig. 26):

Thickness, m

1. Siltstone: greenish-dark gray, thinly interbedded with fine sandstone; with graptolites *Eotetragraptus* sp. in upper layers (loc. S-8211-1/5) 5

2. Siltstone: silver-gray, with sporadic thin layers of fine sandstone; with graptolites (5 m above member base, loc. S-8211-2/5): *Phyllograptus ilicifolius glaber* Monsen, *Expansograptus* sp. 30

Thickness, m

3. Interbedded dark gray, almost black siltstone and fine sandstone. At 10m from the base of the bed (loc. 3206 = S-8211-3/10) graptolites *Expansograptus* ex gr. *extensus* (Hall), *Expansograptus suecicus* (Tullberg), *Tristichograptus ensiformis* (Hall), *Phyllograptus ilicifolius glaber* Monsen were collected. At 30th m of the bed (loc. S-8211-3/30 = 3207) graptolites *Phyllograptus densus opulentus* Monsen, *Ph. densus densus* Tornquist, *Ph. ilicifolius glaber* Monsen, *Pseudophyllograptus* ex gr. *angustifolius* Hall, *Glyptograptus* cf. *dentatus* (Brongniart) were recovered 65

4. Siltstones black and yellow-grey. At 20 m from the base of the bed (loc. S-8211-4/20) graptolites *Expansograptus suecicus suecicus* (Tullberq), *Eotetragraptus harti* (Hall) were found. At 52-m (loc. S-8211-4/52) graptolites *Isograptus gibberulus* (Nicholson) were collected 70

5. Limestone: gray or black, flaggy. 10

6. Scattered siltstone debris and shale: black and silver-gray 20

The top of the section is truncated by a fault. Member 1 conventionally corresponds to the *approximatus* zone; member 2 and lower 20 m, member 3 – with the *balticus* subzone of the *densus* zone; upper 45 m, member 3 make up the *densus* subzone of the *densus* zone; lower 30 m, member 4 conventionally correlated with the *angustifolius elongatus* zone and its upper 40 m form the *gibberulus* zone; member 5 may correspond to the top of the Voskresenka Formation and may be assigned to Middle Darriwilian by analogy with the stratotype section of the Voskresenka Formation near Ust'-Chagyrka Village. Members 1 through 5 belong to the Voskresenka Formation and member 6 may belong to the Bugryshikha Formation. The total thickness of the Voskresenka Formation in the Pichuzhikha Section is 180 m.

Maralikha Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Dapingian, Darriwilian.
Regional stratigraphic subdivisions: Lebed' Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Voskresenka Formation.
Zones: *caduceus imitatus*, *hirundo, Cardiograptus, sinodentatus*, *austrodentatus* graptolite zones.
Fauna: graptolites, nautiloids, crinoids, trilobites and brachiopods.

Section representing upper part of the Voskresenka Formation is cropped out on the right bank of the Charysh River Valley, near alt 352, 1 m. It is represented by specific rocks formed as a result of the under-water sliding. Stratigraphically upward are observed (section S-8212 – Maralikha) (Fig. 27):

Thickness, m

1. Alternation of greenish-gray siltstone and fine-grained polymictic sandstone. In 5 m from the top of the bed (loc. S-8212-1/20) following graptolites have been found: *Tristichograptus* cf. *ensiformis* (Hall), *Trigonograptus* sp., *Glossograptus* aff. *acanthus* Elles et Wood 25

2. Siltstone: vesicular with "twisting" (from 3 cm to 1 m) siltstone and fine-grained sandstone, non oriented, occupied up 50 % of rock 5

3. Alternation of the vesicular siltstone and fine-grained polymictic bedded sandstone 25

4. Alternation of gray fine-grained polymictic mudstone and sandstone. In 5 m from the member base (loc. S-8212-4/5) graptolites *Acrograptus cognatus* (Harris et Thomas), *Pendeograptus* cf. *pendens* (Elles), *Glyptograptus* sp., *Expansograptus suecicus suecicus* (Tullberg), *Ex. extensus* (Hall), *Glossograptus* aff. *acanthus* Elles et Wood have been obtained. In 20 m from the member base (loc. S-0512=S-812-4/20) graptolites *Expansograptus suecicus suecicus* (Tullberg), *Glossograptus acanthus* Elles et Wood, *Isograptus caduceus imitatus* Harris, *Pseudoclimacograptus* sp., ?*Undulograptus* sp. have been found. In 30 m (loc. S-8212-4/30) graptolites *Undulograptus sinodentatus* (Mu et Lee), *Undulograptus* sp., *Cardiograptus* sp., *Acrograptus cognatus* (Harris et Thomas), *Loganograptus logani* (Hall) were recovered. In 60 m from the member base (loc. S-8212-4/60) graptolites *Expansograptus taimyrensis* Obut et Sob., *Ex. hirundo* (Salter), *Expansograptus* sp., *Tristichogratus* sp., *Glossograptus* sp., *Undulograptus sinodentatus* (Mu et Lee) have been obtained. From the top of the member (loc. S-0522=S-8212-4/65) *Expansograptus* (?) sp., *Phyllograptus anna anna* Hall were collected 65

5. Conglomerate: gray with middle to coarse pebbles and nodules. Pebbles are 2–5 cm rarely up to 12 cm in diameter. Pebbles are sorted due to clasts size, round, oriented by flatten surfaces according to bedding, other orientation was not observed. Pebbles occupied up to 80 % of rock. In composition pebbles are represented by 50 % dark-gray limestone, 35 % siltstones and 15 % mudstones. Mudstone are also observed as fragments of the "folded" intercalates (10–15 cm length, thickness 1–3 cm). Matrix consisted of fine-middle-grained sandstone and siltstone. Fragments of crinoids, trilobites and brachiopods could be found in matrix 0.5–1

6. Siltstone: gray with single fine (5–7 cm, rarely 10 cm) light-gray to light-greenish gray, fine-grained polymictic sandstone intercalates (Fig. 28). Siltstone possess fine cross-bedding. In 5 m from the member base (loc. S-072 = S-8112-6/5) graptolites *Undulograptus austrodentatus* (Harris et Keble), *Undulograptus sinodentatus* (Mu et Lee), *Undulograptus* aff. *sinicus* (Mu et Lee) *Undulograptus* sp. have been recovered from sandstones. In 15 m from the member base (loc S-0523=S-8212-6/15) *Undulograptus*

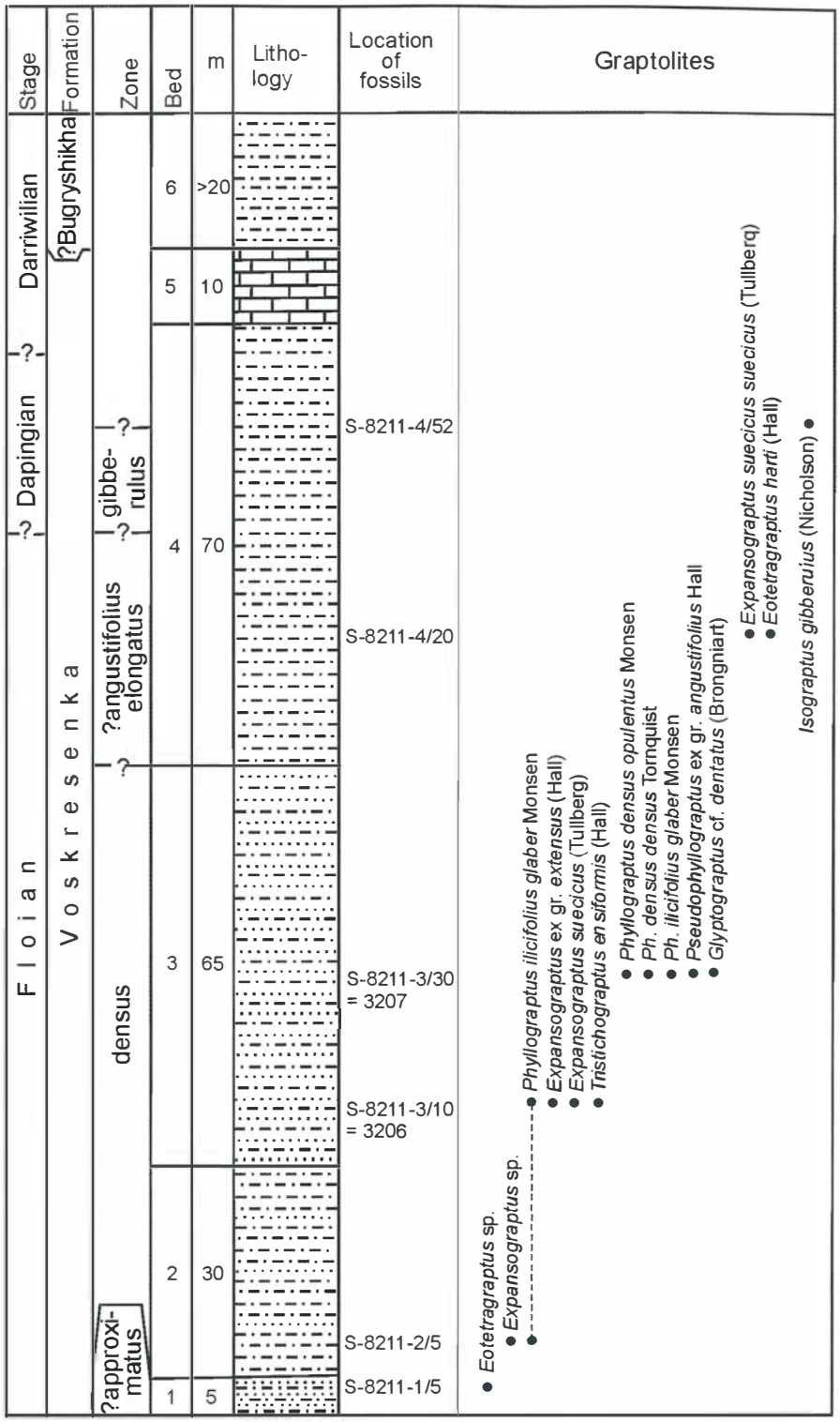


Fig. 26. Ranges of fossil taxa from Pichuzhikha section.

austrodentatus (Harris et Keble), *Undulograptus sinodentatus* (Mu et Lee) were found and in 65m from the member base – indet. graptolites and trilobites have been collected ..... ~80

7. Siltstone: gray, fine schistose into large plates 20

8. Siltstone: vesicular with "twisting" structures of the same composition, occupied up to 50% of the rock. Their size in the

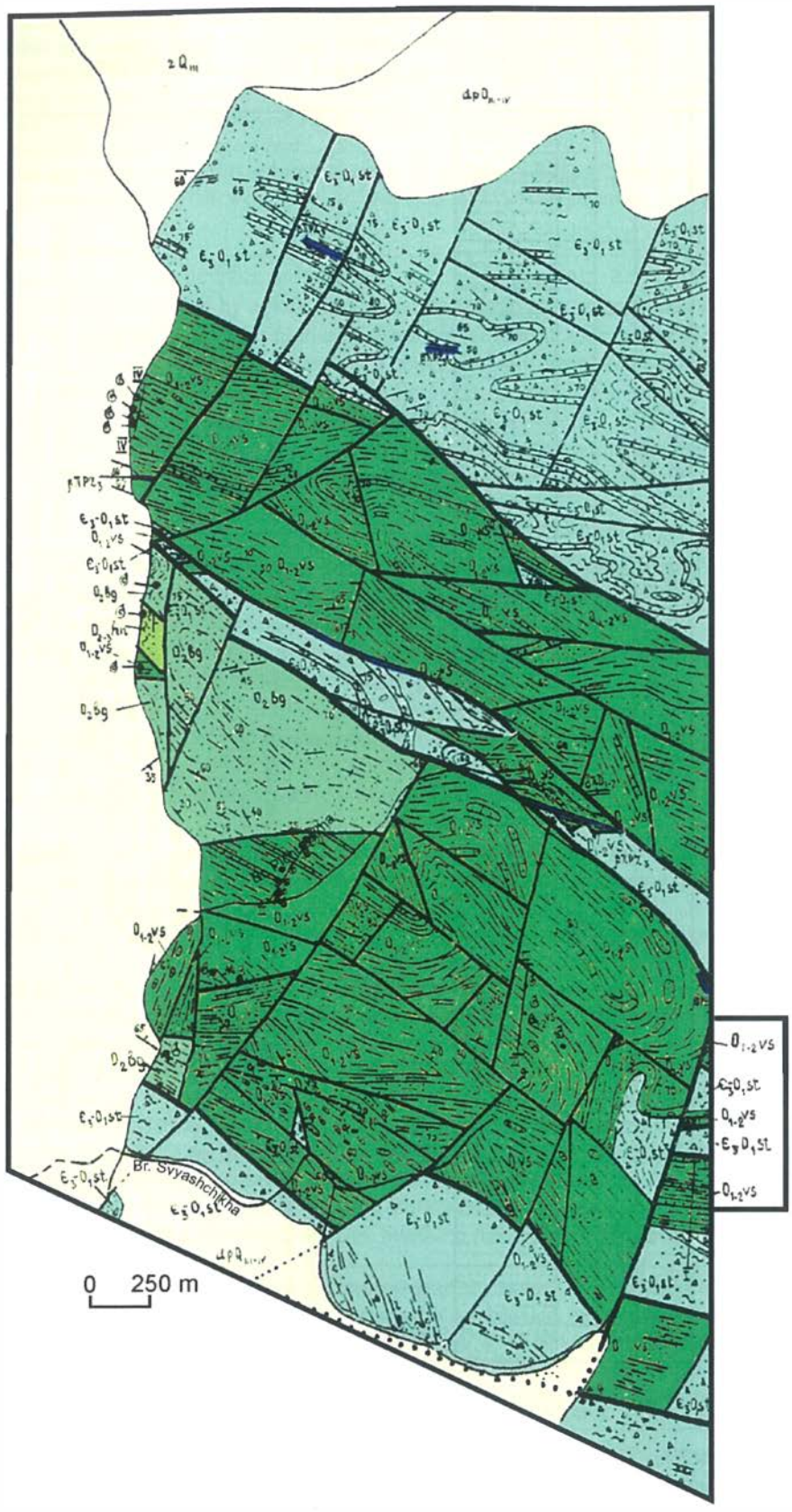


Fig. 25. Sketch map of the Charysh River, right bank, upstream from Maralikha Village.

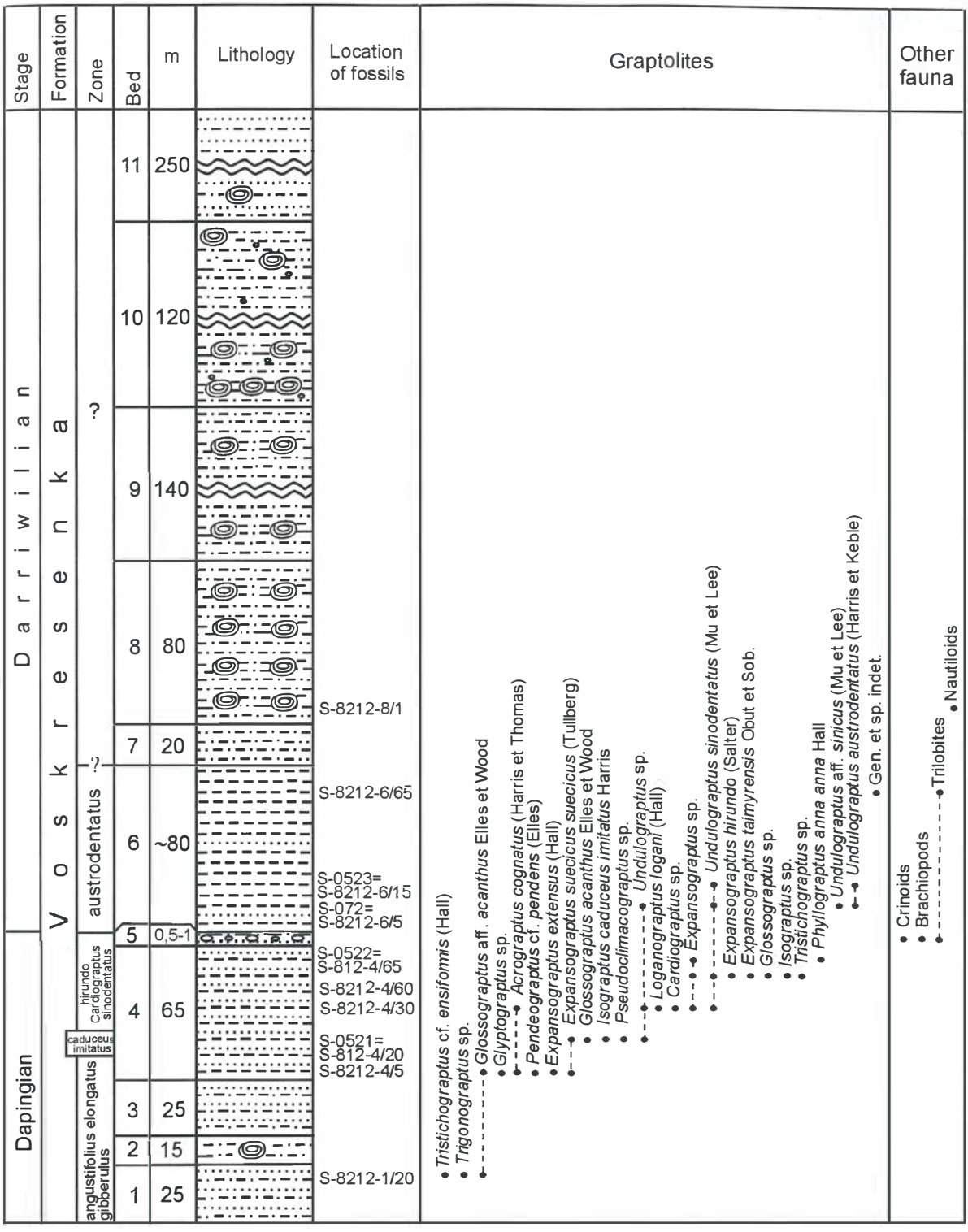


Fig. 27. Ranges of fossil taxa from Maralikha section.

lower part of the member 1–3 cm to 0,5 m, gradually enlarged to up to 1–3 m the top (Figs 29, 30). Rare angular white and bull quartz pebbles (up to 1 cm in diameter) were observed. Nautiloides have been recovered from the memer base (loc. S-8212-8/1) 80

9. Siltstone: greenish and gray vesicular with "twisting" siltstone and fine-grained sandstone occupied up to 50 % of rock. Pebbles (from 5 to 15 cm in diameter) of fine-gained quartz sandstone have been observed 140

Fig. 28. Rhythmical alternation of mudstones and fine-grained sandstones in the Ordovician Voskresenka Formation, Maralikha section, member 6.

Fig. 31. Underwater-sliding structures (diameter up to 20 cm) in siltstones in the Ordovician Voskresenka Formation, Maralikha section, member 10.

Fig. 29. Giant underwater-sliding structures (diameter up to 7–8 m) in siltstones in the Ordovician Voskresenka Formation, Maralikha section, analogues of member 8.

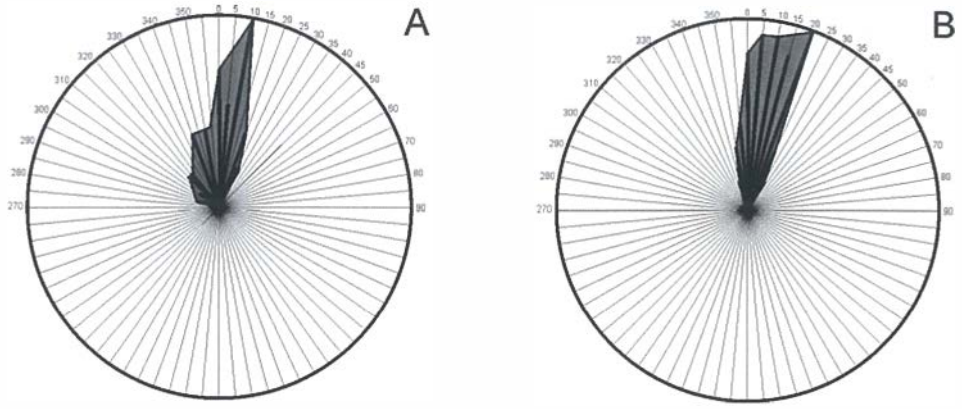


Fig. 30. Diagram (in modern coordinates) for directions of non-lithified movement during underwater sliding in Maralikha section (A- member 6, B – member 8).

10. Siltstone: gray vesicular with "twisting" structures occupied up to 90 % (Fig. 31) of rock, upwards to the top of the member reduced to 10 %. Rare coarse-grained quartz sandstone pebbles were observed 120

11. Alternation of the siltstones and greenish-gray fine-grained sandstone. 50 % of rocks are vesicular, with rare "twisting" sandy-siltstones comprised 3–5 % of rock 250

A tectonic dislocation binds the top of the section.

Beds 1–3, as well as lower 20 m of the bed 4 of the Maralikha section could be aligned with *angustifolius elongatus* and *gibberulus* zones according to the collected graptolites. Interval from the 20 to 29 m of the bed 4 coincides with *I. caduceus imitatus* zone. Interval from the 30 m up to the top of the bed 4 and provisionally bed 5 of the section were aligned with *hirundo, Cardiograptus, sinodentatus* zone. Base of the 6 bed is aligned with lower Darriwilian boundary, overlain by *austrodentatus* zone.

All beds of the Maralikha section are assigned to Voskresenka Formation. Total thickness of the Voskresenka Formation within this section is more than 800 m.

3.1.3. Area of Bugryshikha Village

Altai Mountain Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Darriwilian.
Regional stratigraphic subdivisions: Bugryshikha Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Bugryshikha Formation.
Fauna: trilobites, brachiopods.

Middle Ordovician strata in the lower part of the composite stratotype section of the Bugryshikha Formation crop out near Bugryshikha Village, on the left bank of the Belaya River and along the right and left banks of the lower Bugryshikha River (left tributary of the Belaya River). The lowermost member of the Bugryshikha Formation is exposed on Altai Mt. (Fig. 32) that descends in a bluff into the Belaya River on its left bank below the Bugryshikha inflow. The documented section (S-071) includes the following members, listed downstream (Fig.33):

Thickness, m

1. Mudstone, siltstone, and less often fine sandstone, gray; with trilobites and brachiopods ..... ~100

2. Syndepositional breccia (size of clasts 1-2 cm, rarely 3 cm) of siltstone, mudstone, and fine sandstone in a siltstone matrix; clasts occupy up to 80 % of rock volume 0.2

3. Mudstone and siltstone: gray, slightly calcareous, with conglomerate-like layers (lenses) with few floating carbonate concretions (3–5 cm in diameter) of dark gray clayey limestone; with trilobites and brachiopods (Fig. 34) ..... ~50

4. Silty sandstone and siltstone: silver-gray or dark gray, lumpy, with traces of soft sediment slumping (up to 2-3 cm long and 1 cm wide tongues) ..... over 10

5. Mudstone and siltstone: dark gray or black, thin-bedded; frequent pyrite crystals indicate deposition in anoxic conditions; siltstone contains small (5 cm long and 2 cm thick) mudstone lenses ..... ~40

6. Siltstone and sandstone: fine, lumpy, wave-bedded ..... over 100

From the first and third beds of the Altai Mountain section directly in the coastal cliff of Belaya River (loc. 216 and 216a) trilobites – *Lonchodomas sagittatus* Levit., *Nileus tengriensis* Web., *Homotelus angustus* Petrun., brachiopods

Fig. 32. General view of the exposure along left bank of Belaya River, Altai Mountains.

Fig. 34. Massive mudstones and siltstones of the Ordovician Bugryshikha Formation, Altai Mountain section, member 3.

Archaeorthis altaica Severg., *Glyptorthis primus* Severg., *Atelelasma subdorsokonvexum* Severg., *Ujukites tarlykensis* Andreeva have been found. From the rocks analogue to the third bed of the described section, on the flatten top of the Altai Mt. (loc. 803) brachiopods – *Ujukites tarlykensis* Andreeva were collected, and at the western slope of the Altai Mt., near Bugryshikha Village (loc. 178) brachiopods – *Glyptorthis primus* Severg. Possibly at the same stratigraphic level on the right bank of the Bugryshikha River, near Bugryshikha Village (loc. F-10) brachiopods *Atelelasma subdorsoconvexum* Severg. in Rozman. have been recovered.

All members, of a total thickness of 300 m, belong to the lower Bugryshikha Formation.

The Altai Mountain section is extended upwards with the Bugryshikha Section, 1.5 km far to the northwest, on the other side of the same synclinal fold.

Bugryshikha Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Darriwilian.
Regional stratigraphic subdivisions: Bugryshikha Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Bugryshikha Formation.
Zones: *teretiusculus* graptolite zone.
Fauna: trilobites, brachiopods, graptolites.

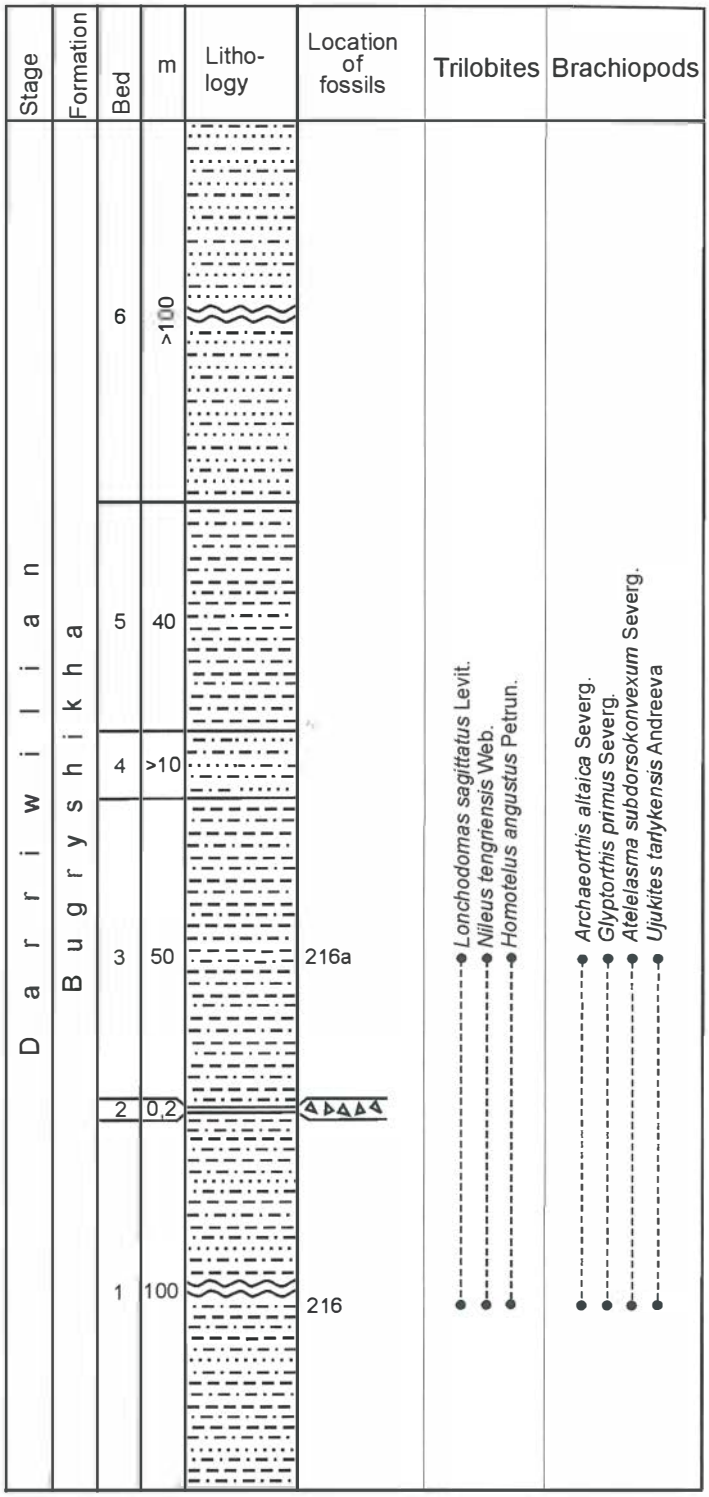


Fig. 33. Ranges of fossil taxa from Altai Mountain section.

The Bugryshikha section occurs northwest of the Altai Mountain section, 150 m from 580.8 m mountain at azimuth 190°. The documented section includes the following members, listed downhill toward Bugryshikha Village (Fig. 35):

Thickness, m

1. Siltstone and mudstone, variegated 20
2. Sodded interval 5

3. Sandstone and siltstone: dark green to light green or brown, fine 145
4. Sodded interval 5
5. Sandstone and siltstone: light gray, polymictic, fine, gray. At the bottom of the bed (loc. S-78126) graptolites *Hustedograptus teretiusculus* (Hisinger), *Amplexograptus perexcavatus* (Lapwrth), *Pseudoclimacograptus sharenbergi* (Lapworth), *Glossograptus hincksi* (Hopkinson), *Cryptograptus tricornis* (Carruthers), *Acrograptus* sp. were found. Trilobites and brachiopods *Glyptorthis primus* Severg., *Ujukites tarlykensis* Andreeva, *Eodalmanella* aff. *socialis* (Barr.) have been recovered (locs. 180a, 180b, 180c, 180 d) 30
6. Sandstone and fine siltstone: dark gray or black, more rarely greenish-gray; with graptolites *Diplograptus* sp. (member top, loc. S-78127) 22
7. Siltstone: dark green to dark gray 20
8. Sodded interval 35
9. Mudstone and siltstone: black, clayey ..... over 5
10. Sandstone: light gray, fine; with brachiopods, ostracods, and crinoids (at member base, loc. 181) 20
11. Interbedded siltstone and black fine sandstone 50
12. Siltstone: dark gray; with graptolites *Glyptograptus* sp. (member top, loc. S-78128) 20
13. Siltstone: brownish, greenish or dark olive-gray 65
14. Siltstone or less often fine sandstone: light greenish-gray. At the lower third of the bed the following fauna was collected: (loc. S-78130) graptolites *Diplograptus* sp., (loc. 182 and 183) trilobites. At the middle of the bed (loc. 184) - trilobites, brachiopods, (loc. 185) trilobites 390
15. Siltstone: black; with graptolites (at member base, loc. S-78131) *Climacograptus* sp., *Glyptograptus* sp. At the top of the bed (loc. S-78132) graptolites *Climacograptus* sp., *Diplograptus* sp., *Leptograptus* sp. were collected 24

All members belong to the lower half of the Bugryshikha Formation. The section is 850 m thick, and the total thickness of the composite stratotype section of the Bugryshikha Formation is 1000 m (without the lowermost and uppermost strata). Findings of graptolites in member 5 correspond to the *teretiusculus* zone. According to graptolite, trilobite, and brachiopod assemblages, the Bugryshikha Formation in its stratotype section is aligned with the Upper Darriwilian-Lower Sandbian (Middle-Upper Llanvirnian – Lower Caradocian).

The Altai Mountain section is extended upwards by the Malaya Uskuchevka section located 1 km far to the southeast on the other side of the same anticlinal fold, on the right bank of the Belaya River.

Malaya Uskuchevka Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Darriwilian, Sandbian.
Regional stratigraphic subdivisions: Bugryshikha and Khankhara regional stages (horizons).
Local lithostratigraphic subdivisions: Bugryshikha and Khankhara formations.
Zones: *multidens* (subzones *antiquus lineatus, wilsoni*) graptolite zone.
Fauna: trilobites, brachiopods, graptolites.

A large part of the Bugryshikha and Khankhara formations crops out on the right bank of the Malaya Uskuchevka River (right tributary of the Belaya River), uphill from the roadway. The section (S-8351) may be considered a parastratotype of the Khankhara Formation as its members exactly match those in the parastratotype section along the Bolshaya Uskuchevka River (Fig. 36):

1. Siltstone: gray, light gray or locally bluish, clayey. At the upper part of the bed (loc. 6) the following trilobites fauna was found - *Trinodus* sp., *Bronteopsis transversalis* Petrun., *Eoroberqia striata* Petrun., *Eorobergia urceolata* Petrun., *Nileus tengriensis* Weber, *Remopleurides uscutchevensis* Petrun., *Lonchodomas* cf. *laevisculus* (Bill.), *Lonchodomas* cf. *semicostatus* (Bill.), *Telephina möbergi* Hadding ..... over 50
2. Siltstone: light gray or gray dark gray in upper layers, with black interbeds, clayey. At the lower part of the bed (loc. 8a) brachiopods *Eodalmanella* aff. *socialis* (Barrande) were distinguished, as well as (loc. S-7645) trilobites *Cybelurus planus* Levit., graptolites *Geitonograptus gavia* Sinnikov, *Diplograptus multidens* Elles et Wood, *Climacograptus antiquus lineatus* Elles et Wood, *Climacograptus* sp., (loc. S-7745) *Geitonograptus* sp., *Diplograptus* sp., (loc. S-7746) trilobites *Cybelurus planus* Lev., *Lonchodomas* cf. *semicostatus* (Bill.), graptolites *Dicranograptus* sp., *Climacograptus* ex gr. *wilsoni* (Lapworth), *Dicellograptus* sp., *Diplograptus* sp. ..... about 70
3. Siltstone: dark silver-gray, nearly black, thick-bedded (10–20 cm), often massive, with scarce light bluish-gray interbeds. In the middle part of the bed (loc. S-7747) trilobites *Lonchodomas* cf. *semicostatus* (Bill.), *Lonchodomas* cf. *laevisculus* (Bill.) were obtained 200
4. Mudstone: bluish-gray, clayey, massive, locally cavernous. At the upper part of the bed (loc. S-7748) trilobites *Lonchodomas* sp., *Homotelus* sp., *Nileus tengriensis* Weber and graptolites *Dicellograptus* aff. *divaricatus rigidus* Lapworth, *Diplograptus* ex. gr. *multidens* Elles et Wood, *Dicranograptus* sp. were found 150
5. Interbedded siltstone and dark gray clayey mudstone 70

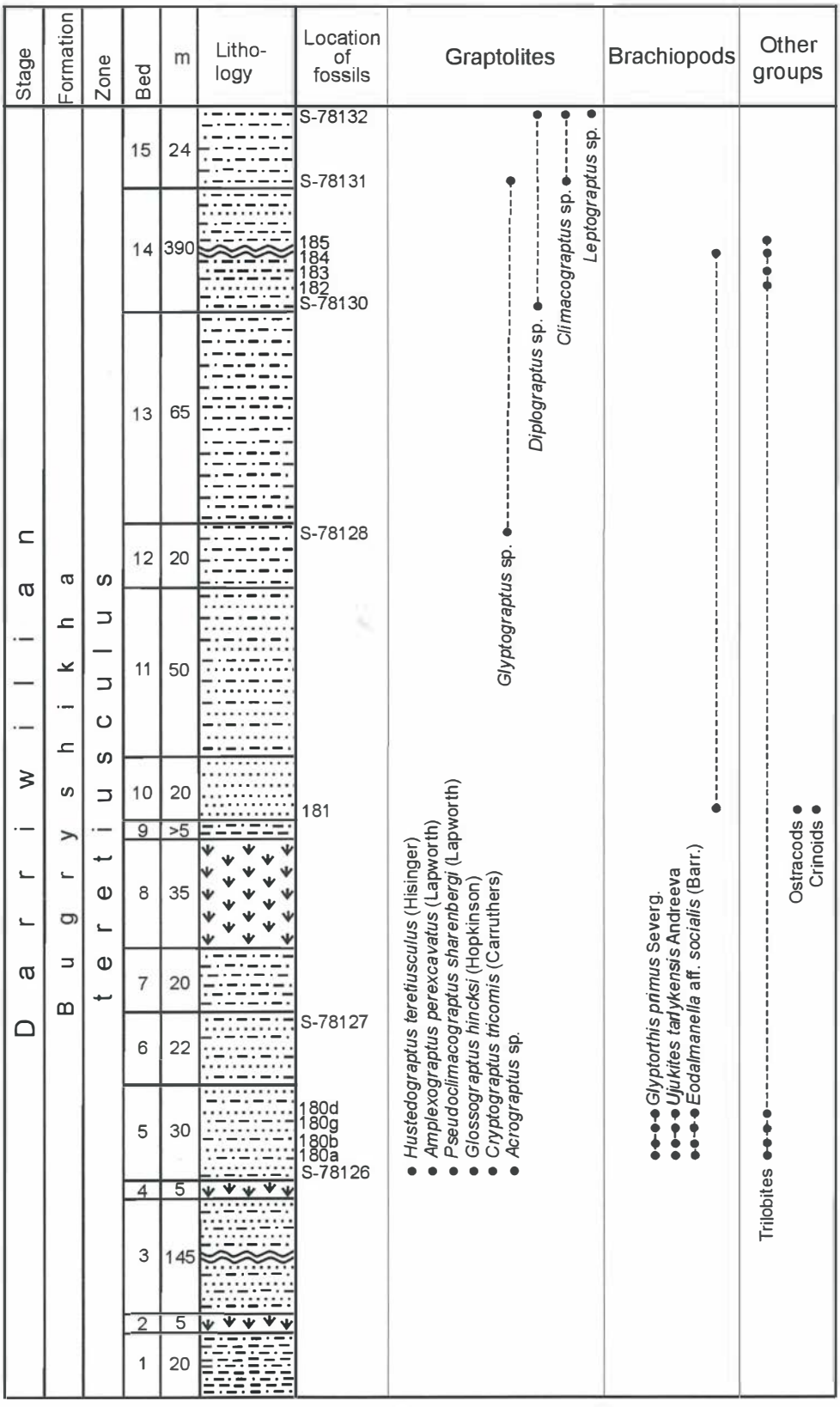


Fig. 35. Ranges of fossil taxa from Bugryshikha section.

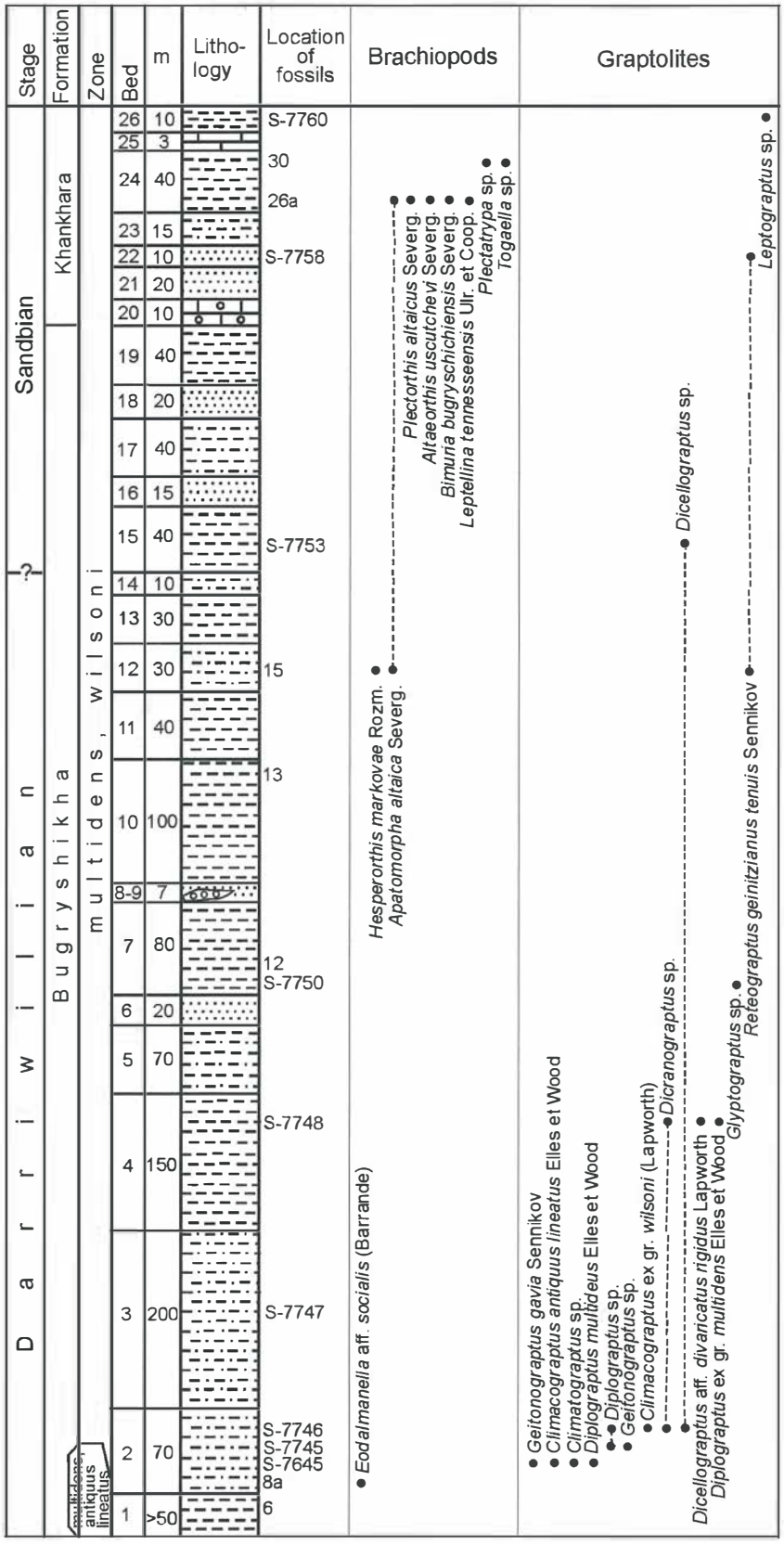
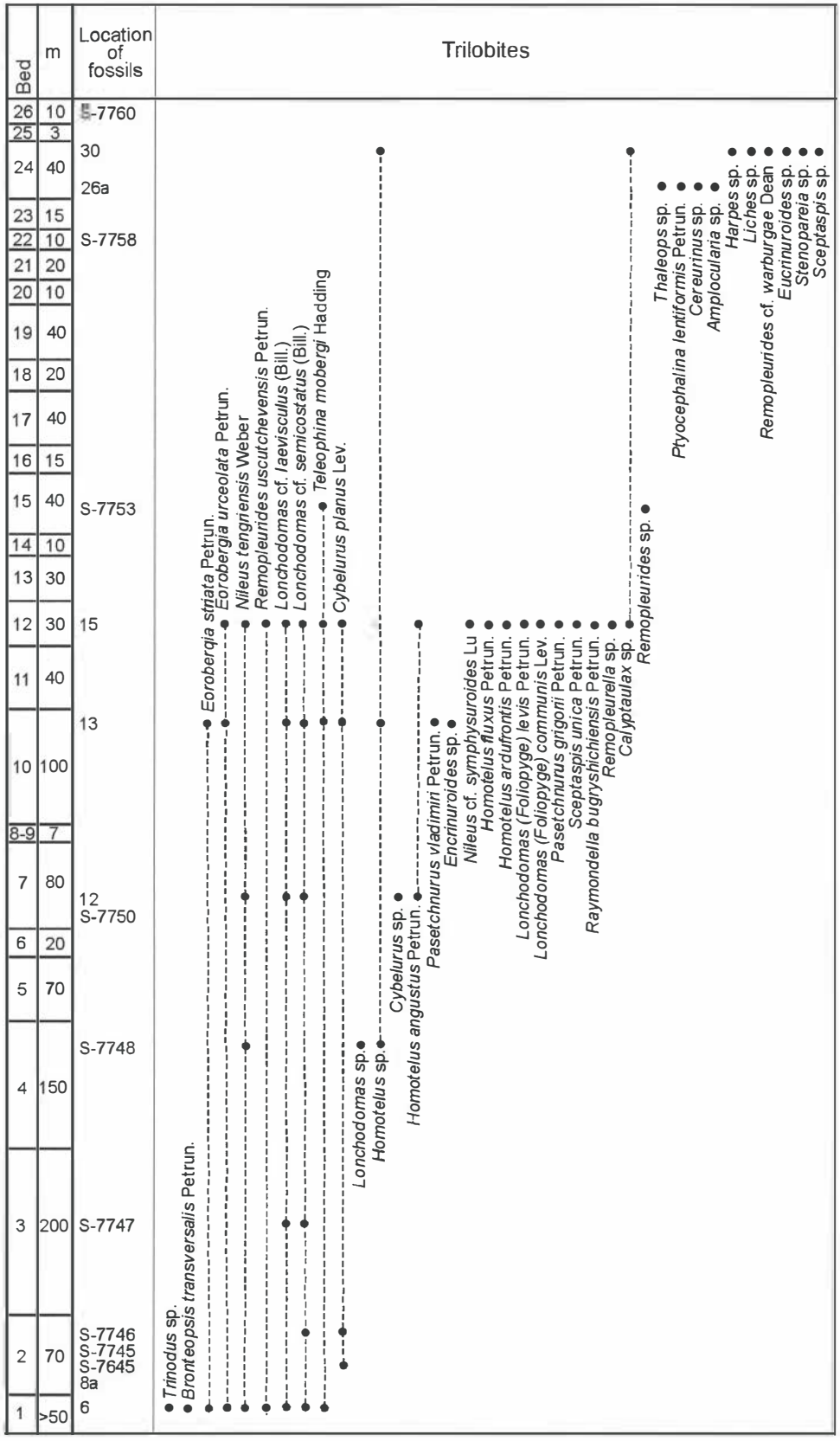


Fig. 36. Ranges of fossil taxa from Malaya Uskuchyovka section.


Bed
m
Location of fossils
Trilobites
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
8-9
7
6
5
4
3
2
1
10
3
40
30
26a
15
S-7758
20
10
40
20
40
15
40
S-7753
10
30
15
40
13
100
7
80
12
S-7750
20
70
S-7748
150
S-7747
200
S-7746
S-7745
S-7645
8a
70
6
>50
Trinodus sp.
Bronteopsis transversalis Petrun.
Eorobergia striata Petrun.
Eorobergia urceolata Petrun.
Nileus tengriensis Weber
Remopleurides uscutchevensis Petrun.
Lonchodomas cf. laevisculus (Bill.)
Lonchodomas cf. semicostatus (Bill.)
Teleophina mobergi Hadding
Cybelurus planus Lev.
Lonchodomas sp.
Homotelus sp.
Cybelurus sp.
Homotelus angustus Petrun.
Pasetchnurus vladimiri Petrun.
Encrinuroides sp.
Nileus cf. symphysuroides Lu
Homotelus fluxus Petrun.
Homotelus arduifrontis Petrun.
Lonchodomas (Foliopyge) levis Petrun.
Lonchodomas (Foliopyge) communis Lev.
Pasetchnurus grigorii Petrun.
Sceptaspis unica Petrun.
Raymondella bugryshichiensis Petrun.
Remopleurella sp.
Calyptaulax sp.
Remopleurides sp.
Thaleops sp.
Ptyocephalina lentiformis Petrun.
Cereurinus sp.
Amplocularia sp.
Harpes sp.
Liches sp.
Remopleurides cf. warburgae Dean
Eucrinuroides sp.
Stenopareia sp.
Sceptaspis sp.

6. Sandstone: greenish-gray, polymictic, fine 25

7. Mudstone: dark gray, locally almost black, clayey. At the lower part of the bed (loc. S-7750) graptolites *Glyptograptus* sp., (loc. 12) trilobites *Cybelurus* sp., *Nileus tengriensis* Weber, *Lonchodomas* cf. *laevisculus* (Bill.), *Lonchodomas* cf. *semicostatus* (Bill.), *Homotelus angustus* Petrun. have been recovered 80

8. Conglomerate: fine to medium, unsorted, with 0.5 to 3 cm, rarely to 5 cm quartz or quartzite pebbles of medium roundness that occupy 10-20 % to 60-70 % of rock volume in fine-medium quartz sandstone cement; conglomerate occurs as a 15 m long lens and is replaced by sandstone of member 9 as the lens pinches out ..... over 1

9. Sandstone: rather quartz, medium-grained, polymictic, with sporadic 1 cm floating quartz pebble of low or medium roundness ..... ~ 6

10. Mudstone: bluish-gray, clayey. At the upper part of the bed (loc. 13) trilobites *Pasetchnurus vladimiri* Petrun., *Homotelus* sp., *Telephina möbergi* Hadding, *Eoroberqia striata* Petrun., *Eorobergia urceolata* Petrun., *Cybelurus planus* Levit., *Encrinuroides* sp., *Lonchodomas* cf. *laevisculus* (Bill.), *Lonchodomas* cf. *semicostatus* (Bill.) were collected 100

11. Mudstone: silver-gray clayey 40

12. Siltstone: greenish-dirty gray to yellowish-gray; clayey cement. In the middle part (loc. 15) the following fauna was recovered: trilobites *Lonchodomas* cf. *laevisculus* (Bill.), *Lonchodomas* cf. *semicostatus* (Bill.), *Lonchodomas* (*Foliopyge*) *levis* Petrun., *Lonchodomas* (*Foliopyge*) *communis* Levit., *Pasetchnurus grigorii* Petrun., *Sceptaspis unica* Petrun., *Raymondella bugryshichiensis* Petrun., *Calyptaulax* sp., *Nileus* cf. *symphysuroides* Lu, *Nileus tengriensis* Weber, *Homotelus fluxus* Petrun., *Homotelus angustus* Petrun., *Homotelus ardufrontis* Petrun., *Cybelurus planus* Levit., *Remopleurella* sp., *Eorobergia urceolata* Petrun., *Remopleurides uscutchevensis* Petrun., *Telephina möbergi* Hadding, brachiopods *Apatomorpha altaica* Severg., *Hesperorthis markovae* Rozm., as well as graptolites *Reteograptus geinitzianus tenuis* Sennikov 30

13. Mudstone: dark gray, clayey 30

14. Siltstone: light gray 10

15. Mudstone: greenish-gray, locally dark gray, clayey, strongly foliated. In the middle part of the bed (loc. S-7753) trilobites *Remopleurides* sp., *Telephina möbergi* Hadding and graptolites *Dicellograptus* sp. were collected 40

16. Sandstone: greenish-gray, rather quartz, polymictic, fine 15

17. Interbedded greenish-gray siltstone and clayey mudstone 40

18. Sandstone: greenish-gray, rather quartz, polymictic, fine, with rare (at 1–3 m) clayey siltstone interbeds 20

19. Mudstone: bluish-gray, clayey, slightly calcareous, with "loaves" of gray limestone, from 3-5 cm to 10-15 cm in diameter, in lower layers 40

20. Limestone: gray, oolitic (oolites of <1 mm in diameter), flaggy in lower layers and massive in upper layers 10

21. Sandstone: yellowish-dirty gray, slightly calcareous, polymictic, with rare gray limestone concretions (to 5 cm in diameter) in upper layers 20

22. Sandstone: greenish-gray, highly calcareous, fine. In the middle part of the bed (loc. S-7758) graptolites *Reteograptus geinitzianus tenuis* Sennikov were obtained 10

23. Siltstone: yellowish-dirty gray; limy cement 15

24. Mudstone: silver-gray, limy, strongly foliated. In the lower half of the bed (loc. 26a) trilobites *Thaleops* sp., *Ptyocephalina lentiformis* Petrun., *Cereurinus* sp., *Amplocularia* sp., brachiopods – *Apatomorpha altaica* Severg., *Plectorthis altaicus* Severg., *Altaeorthis uscutchevi* Severg., *Bimuria bugryschichiensis* Severg., *Leptellina tennesseensis* Ulr. et Coop. were found, and in the upper half of the bed (loc. 30) - trilobites *Harpes* sp., *Liches* sp., *Remopleurides* cf. *warburgae* Dean, *Eucrinuroides* sp., *Stenopareia* sp., *Sceptaspis* sp., *Homotelus* sp., *Calyptaulax* sp. and brachiopods *Plectatrypa* sp., *Togaella* sp. were collected 40

25. Limestone: gray and dark gray, slightly argillaceous 3

26. Mudstone: greenish-gray, limy, with sporadic carbonate concretions (to 0.5 mm in diameter); with graptolites *Leptograptus* sp. (middle layers, loc. S-7760) 10

The section is followed, toward the headwaters of the Malaya Uskuchevka River, by a more than 300 m thick unexposed interval overlain by a succession of limestone, calcareous siltstone, and silty sandstone equivalent to members 21 through 26 in S-8351 (see above). From the middle part of section the Bolshaya Uskuchevka/Malaya Uskuchevka watershed trilobites (loc. 39) *Calliops* sp., *Homotelus* sp., *Lonchodomas* sp., *Bronteopsis* cf. *gregaria* Raymond, *Carrickia chancharensis* Petrun., *Illaenus* sp., brachiopods *Orthambonites jaboganicum* Severg., *Altaeorthis uscutchevi* Severg., (loc. 39a) brachiopods *Plectorthis altaicus* Severg., *Paurorthis sibirica* Severg., *Onniella chancharica* Severeg., *Titanambonites elandicus* Severg., *Sowerbyella* (*Sowerbyella*) *sibirica* Severg., *Bimuria bugrychiensis* Severg., *Plectocamara uscuchiensis* Severg. In the same area at the same stratigraphic level (loc. 3008, 3512) brachiopods *Boreadorthis togaensis* Severg., *Multicostella* (*Chaulistomella*) *amzassensis* Severg. have been identified.

Members 1 through 19 belong to the Bugryshikha Formation; members 20 through 26 belong to the Khankhara Formation. The incomplete thickness of the Bugryshikha Formation in the section is 980 m (without basal layers) and that of the Khankhara Formation exceeds 110 m. Trilobite and brachiopod assemblages indicate a Late Darriwilian and Early Sandbian (Llandelian and Early Caradocian) age of the section. Graptolites correspond to the *multidens* zone, including the *antiquus lineatus* subzone at loc. S-7645 and the *wilsoni* subzone at other localities.

3.1.4. Area of Krasnoshchekovo Village

Suetka Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian.
Local lithostratigraphic subdivisions: Siliceous-terrigenous sequence and Syrovaty Formation.
Zones: *supernus* graptolite zone.
Fauna: graptolites, radiolarians.

The Suetka section (loc. S-8223=S-0515-0518) occurs on the right bank of the Suetka River, 2 km upstream of Suetka Village, on the southern slope of 323.6 m mountain (Fig. 37). The section consists of (Fig. 38):

Thickness, m

1. Mudstone: dark silver-gray, thick-bedded (10-15 cm to 20-25 cm), interlayered with yellowish- and greenish-gray silicite (chert), often wavy-bedded, and with black or gray massive limestone, quite often granular; limestone occupies about 30 % of member volume, chert is up to 15 %, and mudstone is over 50 %; limestone occurs as silicified layers (up to 20 cm thick) or lenses that contain, in turn, microscopic layers and lenses of yellow siliceous mudstone; there are locally structures among limestone (up to 80 % vol.) including 1-3 cm thick and <0.5 m long layers folded in small current folds (with 0.3-0.5 m cores) which is signature of gravity-mixtite (olistostrome) origin of limestone (Fig. 39). Mudstone layers contain graptolites of the Middle Katian (Middle Ashgill) *supernus* zone (loc. 1801/1=S-8223): *Climacograptus longispinus supernus* Elles et Wood, *Climacograptus* ex gr. *longispinus* T.S.Hall, *Orthograptus amplexicaulis* (Hall).; silicites contain poorly preserved radiolarians (loc. S-0516): *Entactinia* sp. ..... over 10
2. Mudstone: gray or dark silver-gray, clayey and silicified ..... ≈70
3. Silicite (chert), dark silver-gray; with poor-preserved (loc. S-0517) radiolarians *Entactinia subulata* Web. et Bl., *Entactinia* sp. ..... over 3
4. Mudstone: gray or dark silver-gray, silicified. ..... over 50
5. Silicite (chert): dark silver-gray; with abundant well preserved radiolarians (loc. S-0518): *Entactinia subulata* Web. et Bl., *Entactinia* sp. ..... over 1

The whole section, with a total thickness of about 70 m, belongs to the siliceous-terrigenous sequence and spans the *supernus* graptolite zone.

In the northwest the section borders, along a fault, black and dark silver-gray mudstone containing graptolites *Cohlograptus veles* (Richter) and brachiopods (loc. S-9021) is exposed. The described section fragment belongs to the Syrovaty Formation.

Pautikha Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: ?Gorstian, Ludfordian.
Regional stratigraphic subdivisions: Kuimov Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Kuimov Formation.
Zone: *O. snajdri* conodont zone.
Fauna: tabulate corals, trilobites, brachiopods, conodonts.

An Upper Silurian (Ludlowian) section corresponding to the Kuimov Formation occurs south of Krasnoshchekovo Village, on the right bank of the Pautikha River near its confluence with the Zemlyanushka River (Fig. 40). Detailed bed-by-bed description of the section at the Pautikha site is impossible because of quite poor exposure. The exposed part of the Kuimov Formation comprises two large members (Fig. 41):

Thickness, m

1. Alternating 0.1 to 1.5 m layers of (a) limestone, gray or dark gray, clayey, platy (1–3 cm) and massive, bioclastic; (b) sandstone, dark olive-gray, polymictic, fine to medium, with limy cement; (c) siltstone and mudstone, brown and dark olive-gray, limy-clayey.

1a. In limestones at the lower part of the bed (loc. 3209) brachiopods *Spirigerina supramarginalis* (Khalf.), (loc. 3210) brachiopods *Lissatrypa minuta* Kulk., *Ferganella* cf. *borealis* (Schloth.) were collected.

1b. At the middle part of the bed (loc. 3211) brachiopods *Lissatrypa minuta* Kulk., *Spirigerina* sp., crinoids *Mediocrinus* sp., *Tolenicrinus* sp., (loc. 3212) brachiopods *Lissatrypa minuta* Kulk., *Spirigerina supramarginalis* (Khalf.), *Ferganella* sp., (loc. I-984) conodonts *Spathognathodus inclinatus inclinatus* (Rhodes) [element *Ozarkodina excavata excavata* (Branson et Mehl), *Pelekysgnathus dubius* Jeppsson were recovered.

1c. At the upper part of the bed the following fauna was found: (loc. 3213) brachiopods *Lissatrypa minuta* Kulk., *Spirigerina supramarginalis* (Khalf.), *Harpidium insigna* Kirk., *Tannuspirifer pedaschenkoi* Tchern., *Atrypa* sp., *Dalmanella* sp., trilobites *Warburgella stokesii* (Murch.), *War. verecunda* Yolk., *Scharyia micropyga micropyga* (H. et C.), *Prionopeltis* sp., Encrinuridae, Calymenidae, Scutelluidae, Phacopidae, Proetidae, (loc. 3208) brachiopods *Spirigerina supramarginalis* (Khalf.), *Lissatrypa minuta* Kulk., *Schellwienella* ? sp. ind., *Hesperorthis* ? sp. ..... over 150

2. Limestone: alternating 1–1.5 m thick layers of gray and dark gray, bioclastic, with floating coarse and medium sand grains and mudstone, brown and dark olive-gray, limy-clayey, and siltstone.

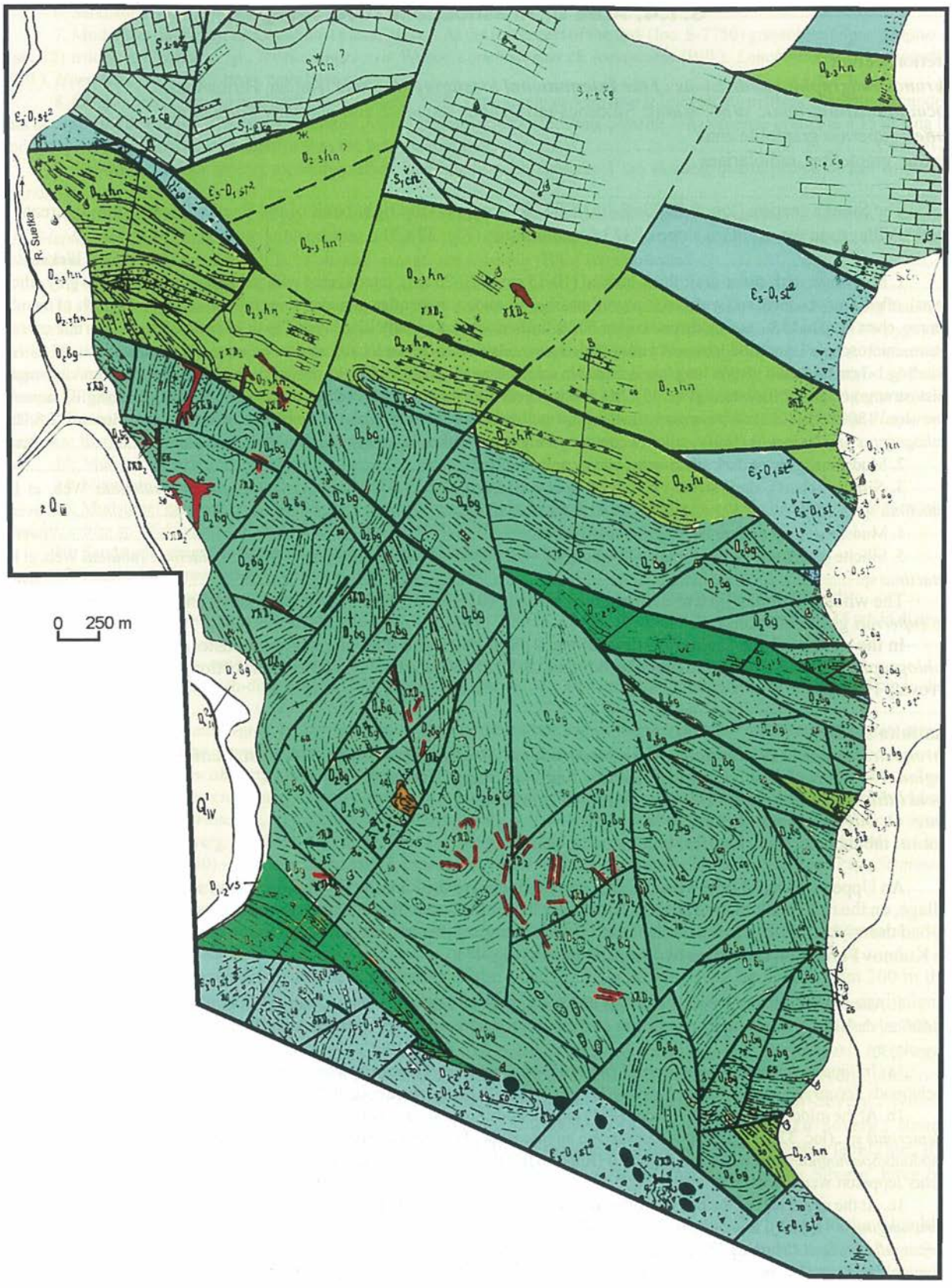
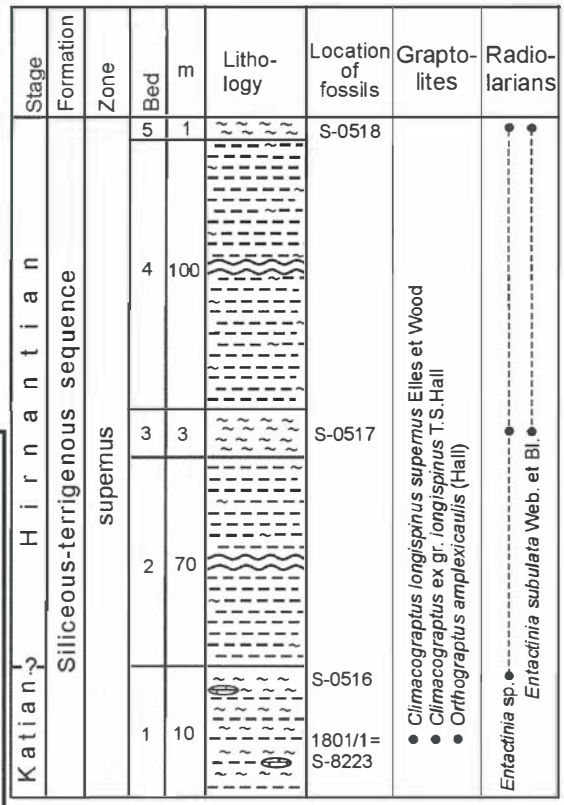


Fig. 37. Sketch map of the Charysh River, left bank, upstream from Maralikha Village.

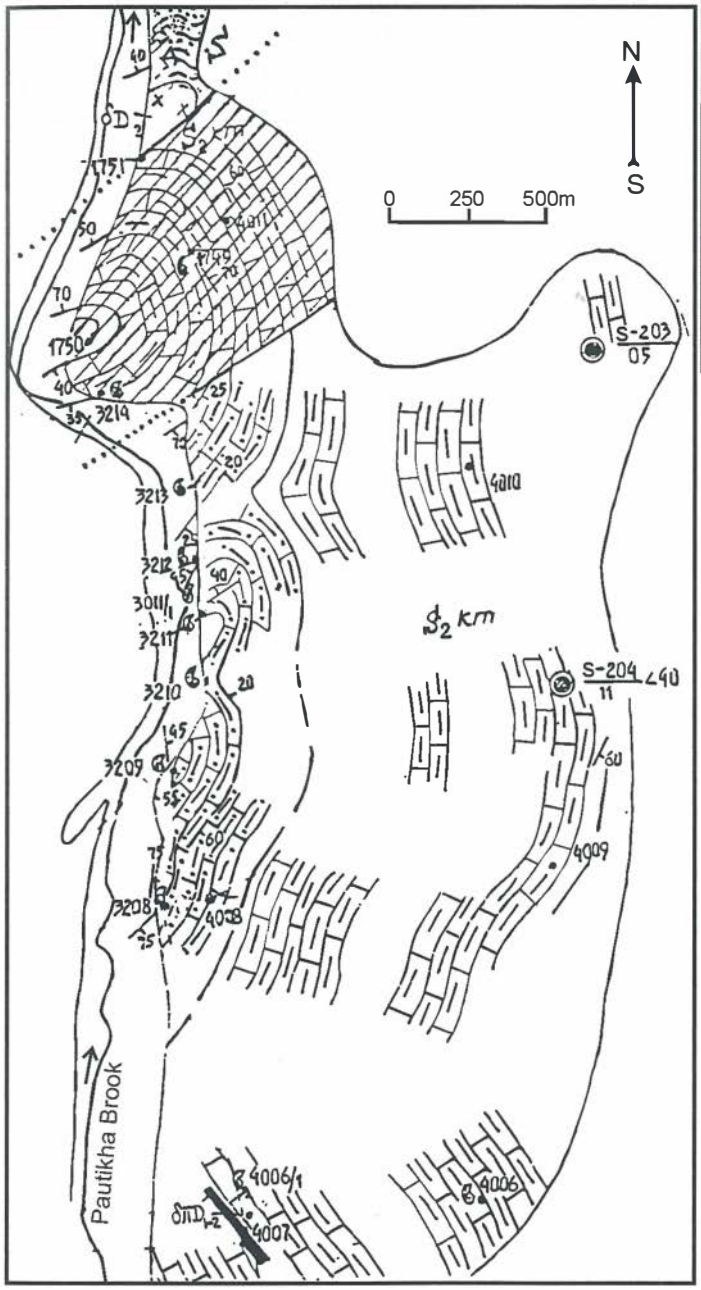
Fig. 38. Ranges of fossil taxa from Suetka section.



Thickness, m

2a. In limestones at the lower part of the bed (loc. 3214) trilobites Phacopidae, Proetidae, (loc. 4006/1) brachiopods *Lissatrypa minuta* Kulk., *Spirigerina supramarginalis* (Khalf.), *Strophonella* ex gr. *raricosta* (Northerp), *Leptaena* sp., *Eospirifer* sp., trilobites *Warburgella stokesii* (Murch.), *Ananaspis* sp., Otarionidae, Calymenidae, Cheiruridae have been collected.

2b. In the middle part of the bed (loc. 1749) brachiopods *Eospirifer* ex gr. *radiatus* (Sow.), *Stropheodonta* sp., *Atrypa* sp.



2c. At the upper part of the bed – (loc. 4006) brachiopods *Lissatrypa minuta* Kulk., *Spirigerina supramarginalis* (Khalf.), *Eospirifer* ex gr. *parvus* Kulk., *Ferganella* ex gr. *borealis* (Schloth.), *Schellwienella* ? sp., trilobites *Warburgella stokesii* (Murch.), *War. verecunda* Yolk., *Prionopeltis* sp., Cheiruridae, Calymenidae, tabulate corals *Favosites gothlandicus* Lam.

By joint findings of conodonts *Pelekysgnathus dubius* Jeppsson, *Ozarkodina excavata* (Branson et Mehl) in the middle part of the first bed (loc. I-984) zone *O. snajdri* could be distinguished. It is aligned with upper part of Ludfordian (Kritz et al., 2003; Talent et al., 2003; Rong et al., 2003) ..... ~300

The total thickness of the Kuimov Formation in the section is 450 m.

Fig. 40. Sketch map of the location on right bank of Pautikha River (modified from Yolkin et al., 2001).

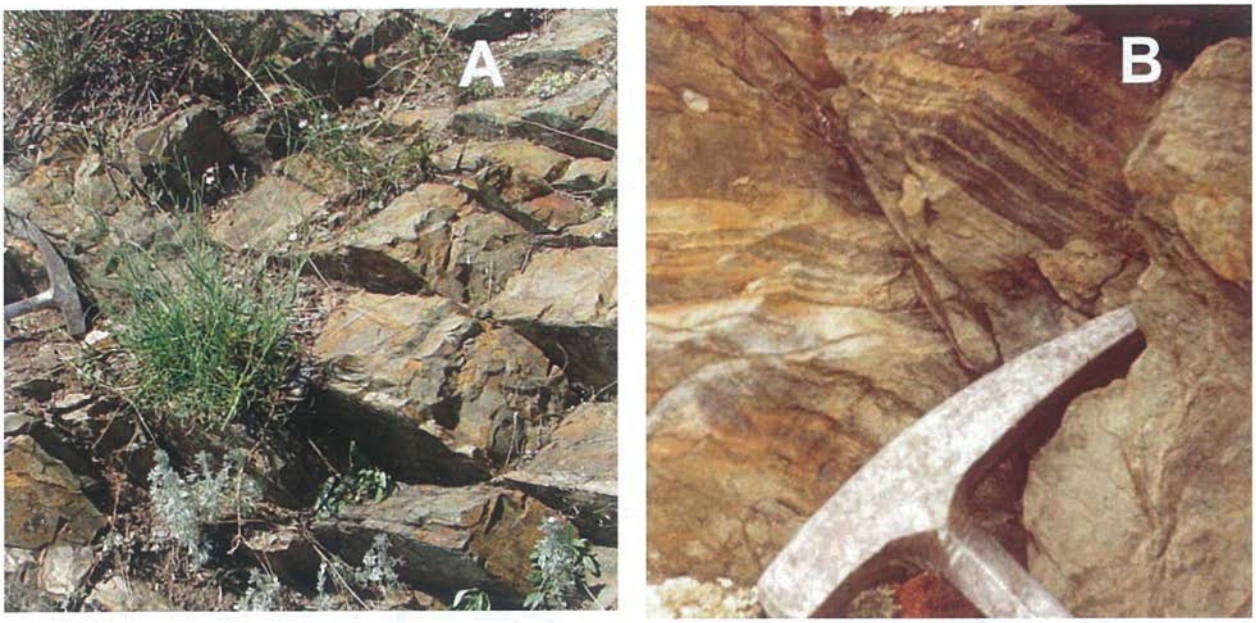


Fig. 39. First member of the siliceous-terrigenous strata in Suetka section: A– massive siliceous mudstones, B – cherts with ribbon structure.

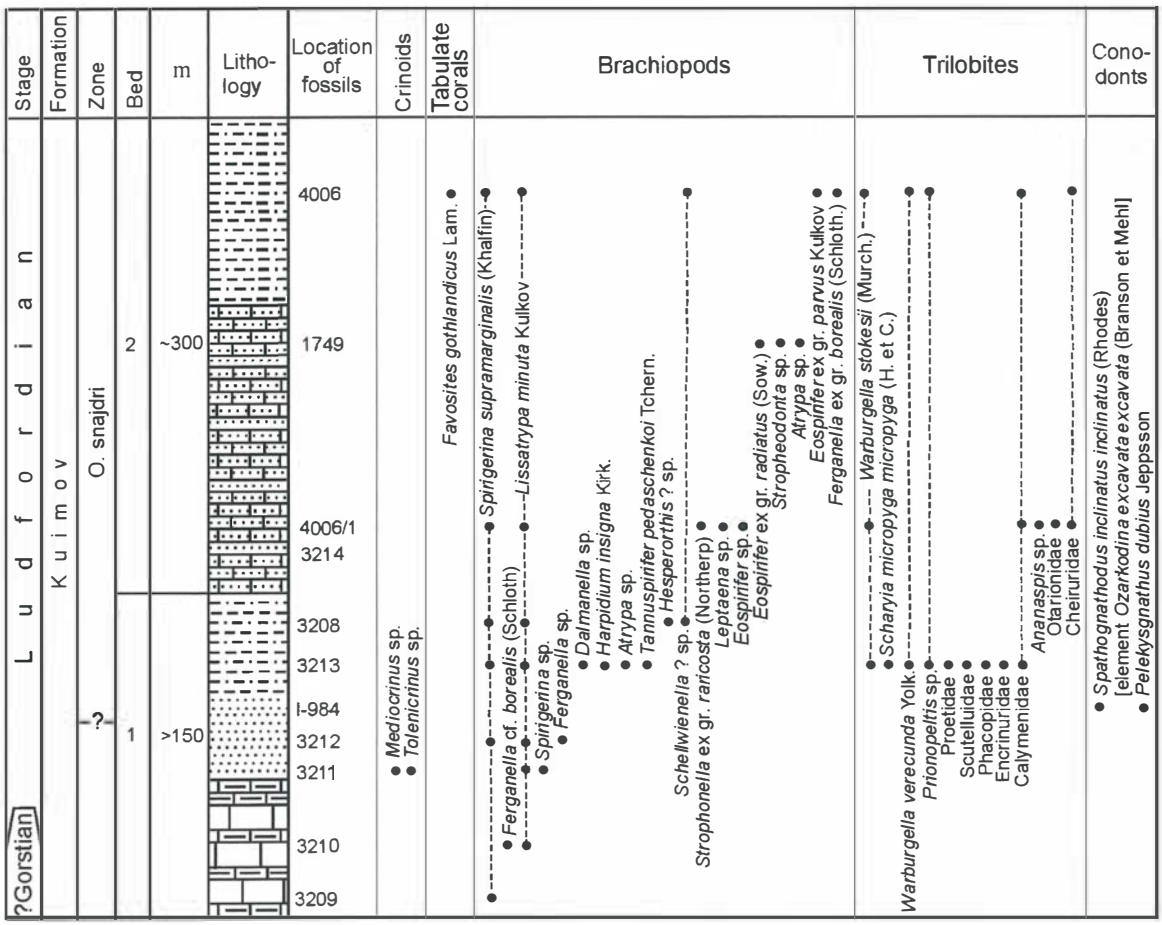


Fig. 41. Ranges of fossil taxa from Pautikha section.

3.1.5. Area of Chineta Village

Chineta Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Sandbian, Katian, Rhuddanian.
Regional stratigraphic subdivisions: Bugryshikha, Khankhara, Tekhten' and Vtorye Utyosy regional stages (horizons).
Local lithostratigraphic subdivisions: Bugryshikha, Khankhara, Tekhten' and Vtorye Utyosy formations.
Zones: *teretiusculus, wilsoni* and *clingani* graptolite zones.
Fauna: trilobites, brachiopods, graptolites, conodonts.

A section that spans the Middle-Upper Ordovician Bugryshikha, Khankhara, and Tekhten' formations and the Lower Silurian Vtorye Utyosy Formation crops out at the northeastern end of Chineta Village, on the right bank of the Inya River (Fig. 42). The documented section includes the following members, listed down the southern slope of 609.3 m mountain (Fig. 43):

Thickness, m

1. Interbedded mudstone, siltstone, and less often fine sandstone, bluish-greenish- and silver-gray ..... ~100

2. Interbedded mudstone and siltstone, bluish-greenish and silver-gray. In 30 m from the bottom of the bed (loc. 2304) graptolites *Metaclimacograptus* sp. trilobites, brachiopods were found, and in 20 m stratigraphically upward (loc. 2305) – trilobites *Ceraurinus* sp., *Kinderlania* sp., Ptiomeridae. In 30 m from the top of the bed in 1m layer of greenish-grey mudstones (loc. S-795 - 350 m by azimuth 210° from height 609,3 m) graptolites *Hustedograptus* ex gr. *teretiusculus* (Hisinger), *Climacograptus* sp., *Dicranograptus* sp., m. 120

3. Sandstone, light gray, limy, grading into san 3

4. Mudstone and siltstone, less often fine sandstone: silver-gray or brownish, slightly calcareous and clayey, with sporadic 0.5 m thick layers of highly calcareous siltstone grading into clayey-sandy limestone; bluish-greenish-gray siltstone contains trilobites (20 m above member base, loc. 211 = 2306/1 – 450, at azimuth 215° from point 609.3 m): *Tretaspis* sp., *Lonchodomas (Poliopyge) levis* Petrun. sp. n., *Eorobergia* sp., *Trinodus* sp., Raphiophoridae, Pterygometopinae. In 30 m stratigraphically upward (loc. 2307) graptolites *Diplograptus* sp., *Climacograptus* sp., *Orthograptus* sp., *Leptograptus* sp., trilobites *Calliops* sp., brachiopods. In the middle part of the bed (loc. 2308) graptolites *Climacograptus* sp., *Diplograptus compactus* Elles et Wood, *Leptograptus* sp., *Glyptograptus euglyphus* (Lapworth) were collected, and in 20-30 m from the top of the bed (loc. 2308/1) – graptolites *Diplograptus compactus* Elles et Wood, *Climacograptus tubiliferus* Lapworth, *Dicellograptus* sp., *Leptograptus* sp. ..... ~120

5. Limestone: gray, massives ..... ~40

The top of member 6 is truncated by a fault.

6. Mudstone: silver-gray or black, clayey ..... ~30

On the southern slope of 609.3 m mountain, the section is extended with a repetition of member 4 (see above), at least 100 m thick, composed of interbedded siltstone and fine sandstone, quite often slightly calcareous; in upper part there is an interbed of light gray fine to medium limy sandstone grading into sandy limestone; limestone contains trilobites and brachiopods (loc. S-812, 90 m far from point 609.3 m at azimuth 145°).

Equivalents of member 2 on the other side of the fold north of point 609.3 m contain graptolites *Diplograptus* sp., *Dicellograptus* sp. (loc. 2302/1).

Members 1 and 2 belong to the Bugryshikha Formation, members 3 through 4 belong to the Khankhara Formation, member 5 marks the base of the Tekhten' Formation, and member 6 correlates with the Vtorye Utyosy Formation.

Loc. S-795 in member 2 may correspond to the *teretiusculus* graptolite zone and loc. 2308 and 2308/1 in member 4 apparently belongs to the *wilsoni* and *clingani* zones.

The incomplete thickness of the Bugryshikha Formation in the section is at least 220 m, the Khankhara Formation is more than 120 m thick, the incomplete thickness of the Tekhten' Formation is at least 40 m, and that of the Vtorye Utyosy Formation exceeds 30 m.

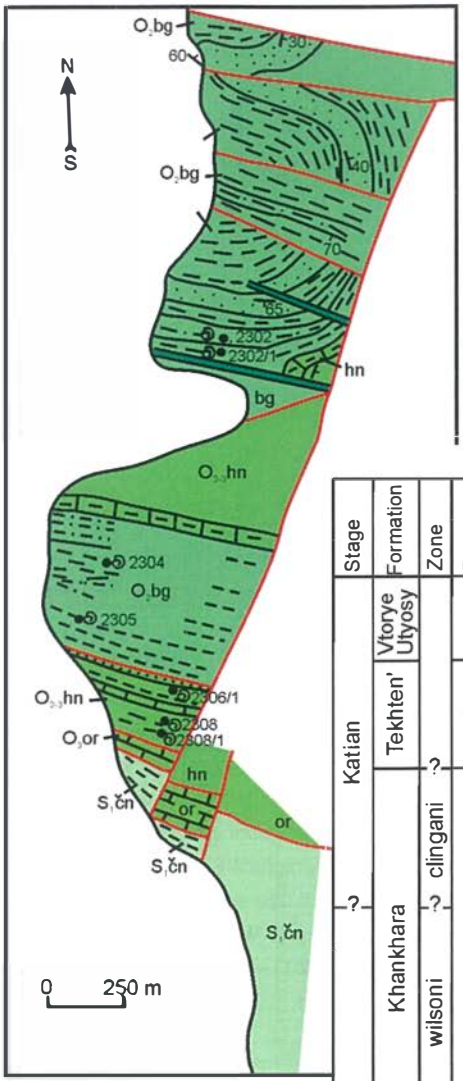
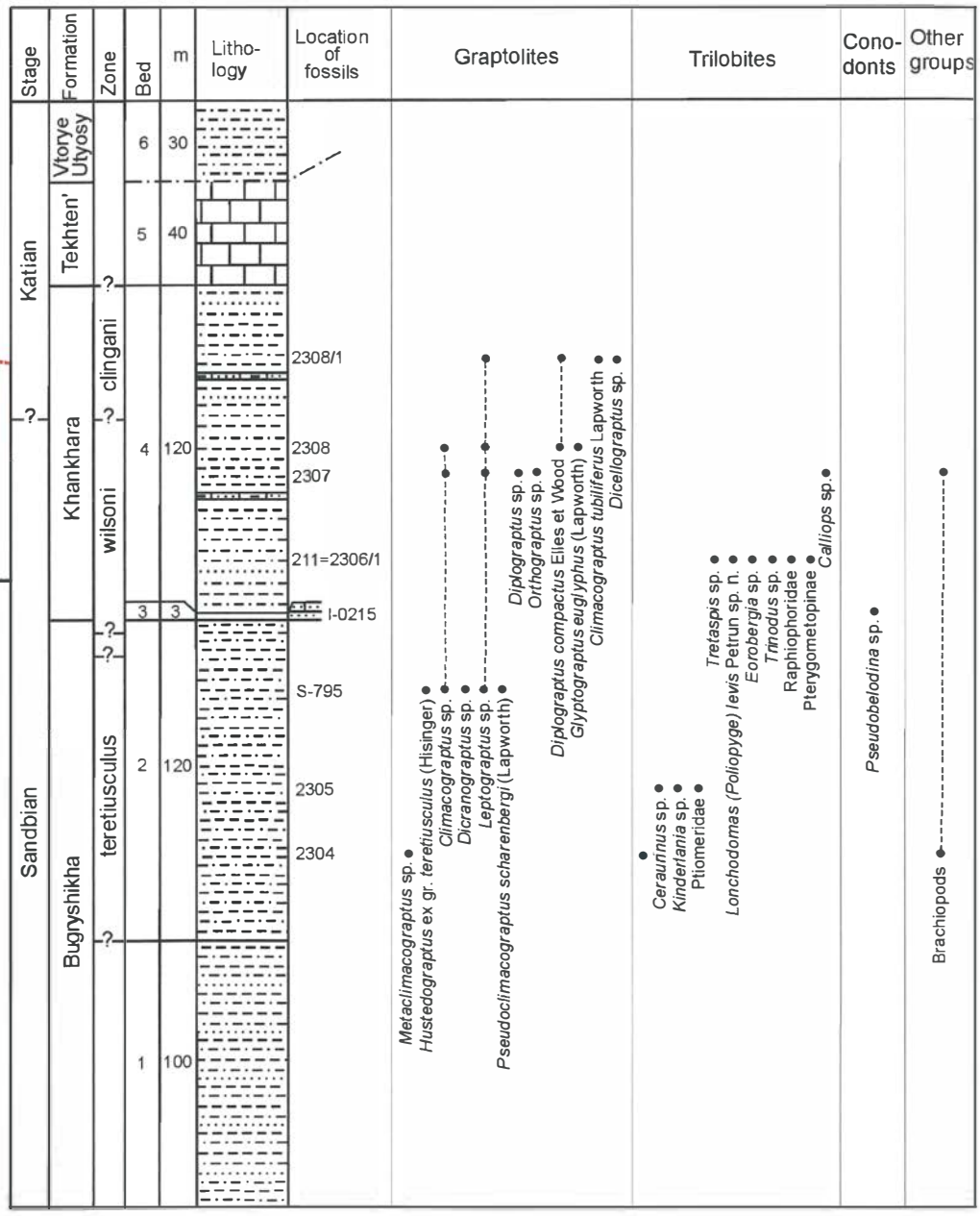


Fig. 42. Sketch map of the location on the right bank of Inya River, near Chineta Village.

Fig. 43. Ranges of fossil taxa from Chineta section.



Burovlyanka Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian, Rhuddanian, Aeronian, Telychian.

Regional stratigraphic subdivisions: Tekhten', Vtorye Utyosy and Syrovaty regional stages (horizons).

Local lithostratigraphic subdivisions: Tekhten', Vtorye Utyosy, Syrovaty formations.

Zones: *supernus* (subzone *ornatus*), *persculptus, acuminatus, angustus-sibiricus, triangulatus-gregarius, convolutus, halli, guerichi* graptolite zones.

Fauna: trilobites, brachiopods, graptolites.

Upper Ordovician and Lower Silurian strata crop out on the left bank of the Inya River opposite Chineta Village, on the divide of the Burovlyanka and Listvyanka brooks (Inya left tributaries) and along the left side of the Listvyanka Brook (Fig. 44). The fragment of section S-822 exposed on the southern slope of 591 m mountain, right upward from the Burovlyanka floodplain includes (Fig. 45):

Thickness, m

1. Limestone: gray or light gray, massive, with sporadic poorly preserved crinoids in upper layers ..... over 250
2. Limestone: gray, algal-biohermal, with mud patches ; 3×5 m bioherms occupy 80–90 % of member volume and occur in massive limestone 10
3. Limestone: gray, algal-biohermal, in a greenish-gray silt-sandstone matrix; 1×2 m carbonate bioherms occupy 80–90 % of member volume (Fig. 46) 2
4. Siltstone, silty sandstone, and fine limy-clayey sandstone, greenish-gray, locally black; member contains graptolites of the *supernus* zone, *ornatus* subzone (2, 4, and 48 m above member base): *Dicellograptus ornatus ornatus* (Elles et Wood), *Climacograptus longispinus supernus* Elles et Wood, *Glyptograptus* cf. *ojsuensis* Koren et Mikh., *Gl. lorrainensis* (Rued.), *Pseudoclimacograptus* sp. In the middle part of the bed brachiopods were collected 50
5. Limestone: gray or black, clayey, flaggy; with trilobites *Mucronaspis mucronata* (Brongniart) in middle layers 20
6. Siltstone and silty sandstone, clayey, greenish-dark gray; with poorly preserved graptolites (5 m above member base) ... . over 20

Section S-833 runs parallel to S-822 on the southwestern slope of 635.4 m mountain, from the Burovlyanka Brook floodplain toward the Burovlyanka/Listvyanka divide, and consists of:

1. Limestone: light gray, massive ..... over 100
2. Siltstone and silty sandstone, clayey, dark silver-gray 90
3. Limestone: dark or light gray, clayey; clay material produces a flaggy pattern of 5 to 30 cm thick plates; member contains graptolites (2 m above member base): *Glyptograptus* sp. and trilobites *Mucronaspis mucronata* (Brong.) 3

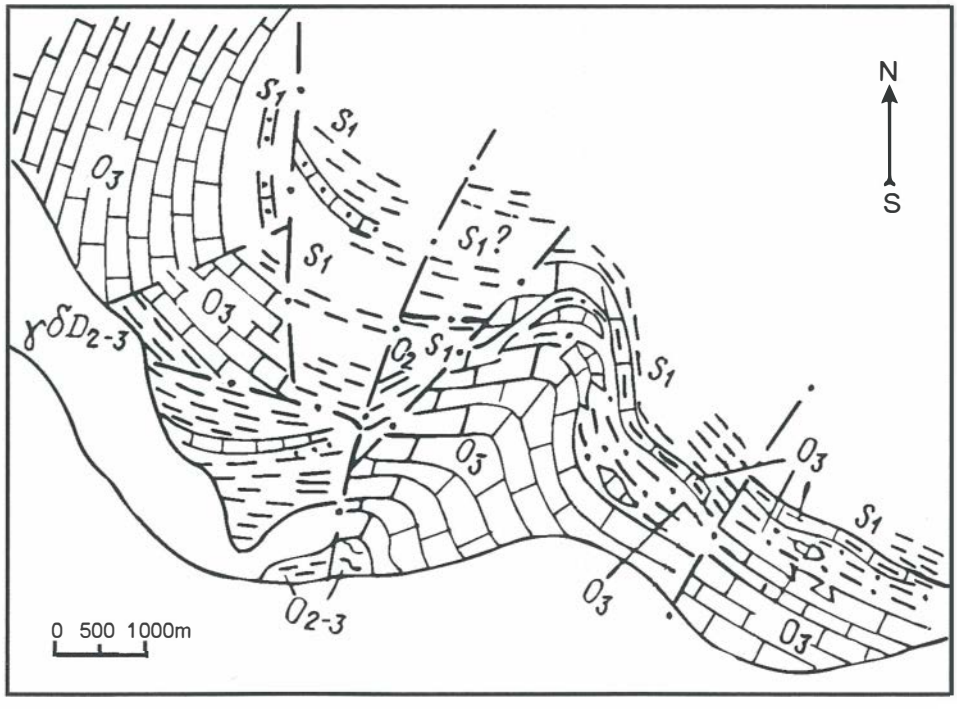


Fig. 44. Sketch map of the location on the watershed of Burovlyanka and Listvyanka Rivers (modified from Sennikov et al., 1984).

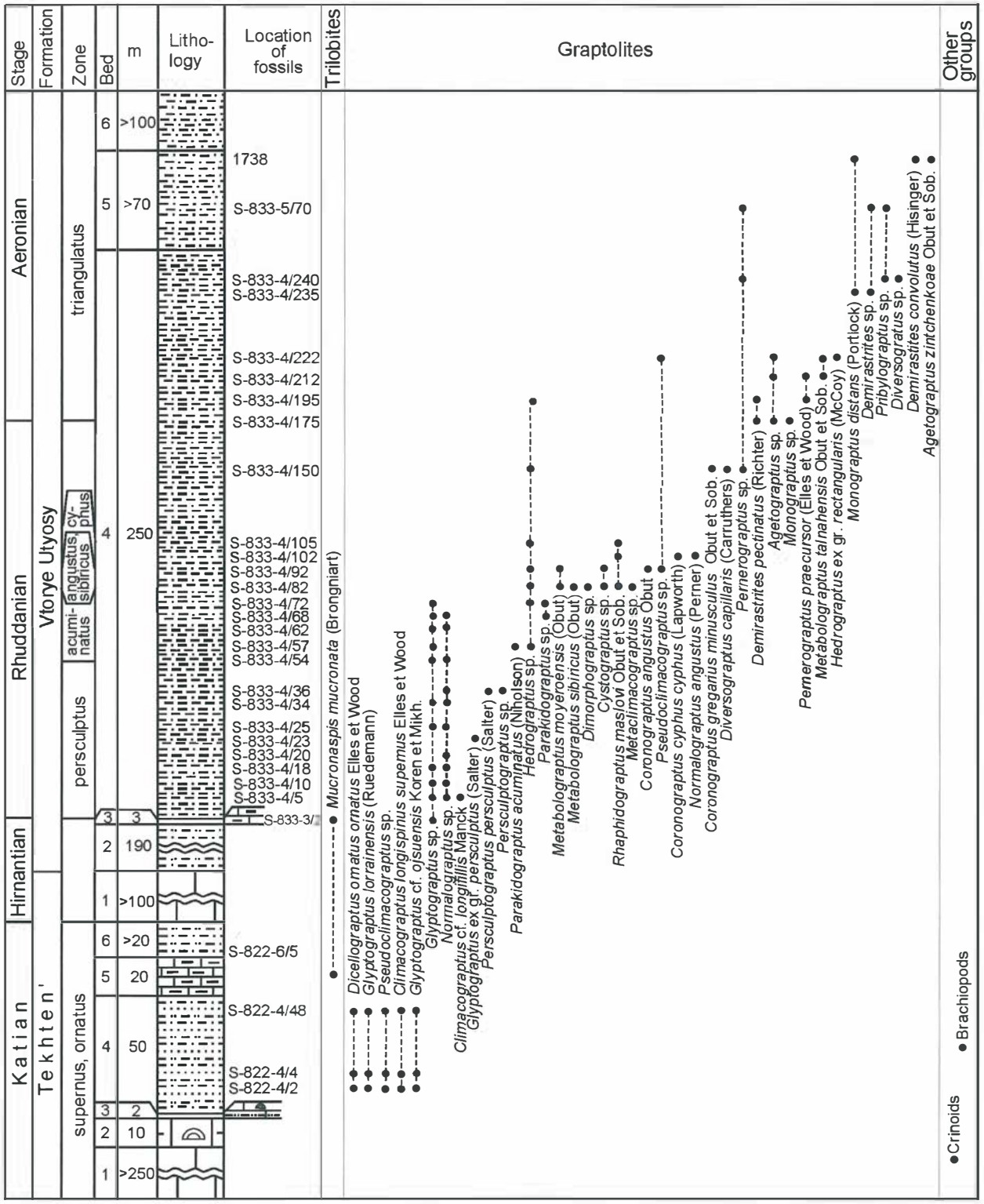


Fig. 45. Ranges of fossil taxa from Burovlyanka section.

4. Siltstone and mudstone: dark greenish-yellowish-gray, foliated; member contains graptolites at different depths, including graptolites of the *persculptus* zone in 0–36 m interval above member base: at 5th m from the base of the bed *Glyptograptus* sp., *Normalograptus* sp., *Climacograptus* cf. *longifillis* Manck; at 10th m – *Normalograptus* sp., *Glyptograptus* sp.; at 18th m – *Normalograptus* sp., *Glyptograptus* sp.; at 20th m – *Normalograptus* sp.; at 23d m – *Glyptograptus* ex. gr. *persculptus* (Salter); at 25th m – *Normalograptus* sp., *Glyptograptus* sp.; at 34th m – *Normalograptus* sp., *Glyptograptus* sp.; at 36th m – *Persculptograptus persculptus* (Salter), *Persculptograptus* sp., *Normalograptus* sp.

In 54–72 m interval from the base of the bed *acuminatus* zone graptolites were collected: at 54th m – *Normalograptus* sp., *Glyptograptus* sp., at 57th m – *Parakidograptus acuminatus* (Nicholson), *Glyptograptus* sp., *Hedrograptus* sp., at 62nd m – *Glyptograptus* sp., *Normalograptus* sp.; at 68th m – *Parakidograptus* sp., *Glyptograptus* sp., *Normalograptus* sp., at 72nd m – *Parakidograptus* sp., *Glyptograptus* sp., *Hedrograptus* sp.

In 82–92 m interval from the base of the bed *angustus, sibiricus* zone graptolites were found: at 82nd m – *Metabolograptus sibiricus* (Obut), *Metabolograptus moyeroensis* (Obut), *Dimorphograptus* sp., *Cystograptus* sp., *Hedrograptus* sp., *Metaclimacograptus* sp., *Rhaphidograptus maslovi* Obut et Sob., at 92nd m – *Metabolograptus moyeroensis* (Obut), *Coronograptus angustus* (Obut), *Pseudoclimacograptus* sp., *Cystograptus* sp., *Hedrograptus* sp.

In 102–105 m interval from the base of the bed *cyphus* zone graptolites have been collected: at 102nd m – *Coronograptus cyphus cyphus* (Lapworth), *Rhaphidograptus maslovi* Obut et Sob., *Normalograptus angustus* (Perner), at 105th m – *Rhaphidoraptus maslovi* Obut et Sob., *Hedrograptus* sp.

In 150–240 m interval from the base of the bed *triangulatus, gregarius* zone graptolites have been found: at 150 m – *Coronograptus gregarius minusculus* Obut et Sob., *Diversograptus capillaris* (Carruthers), *Hedrograptus* sp., *Pernerograptus* sp., at 175th m – *Demirastrites pectinatus* (Richter), *Agetograptus* sp., *Monograptus* sp., at 195th m – *Demirastrites pectinatus* (Richter), *Pernerograptus praecursor* (Elles et Wood), *Hedrograptus* sp., at 212th m – *Metabolograptus talnahensis* Obut et Sob., *Pernerograptus praecursor* (Elles et Wood), *Agetograptus* sp., at 222 m – *Metabolograptus talnahensis* Obut et Sob., *Hedrograptus* ex gr. *rectangularis* (McCoy), *Pseudoclimacograptus* sp., *Agetograptus* sp., at 235 m – *Monograptus distans* (Portlock), *Demirastrites* sp., at 240 m – *Diversogratus* sp., *Pernerograptus* sp., *Pribylograptus* sp. 250

On the left bank of the Listvyanka Brook, in 700 m upstream from its mouth from the equivalent of the upper part of member 4 from S-833 section represented by siltstones (loc. S-824-2/10) Middle Llandoverian *triangulatus, gregarius* zone graptolites were identified. Among them – *Demirastrites triangulatus* (Harkness), *Hedrograptus rectangularis* (McCoy). *Hedrograptus* sp., *Rastrites longispinus* Perner, *Monograptus* sp.

5. Siltstone: dark gray, clayey, cavernous, with conchoidal cleavage; with Middle Llandoverian graptolites *Demirastrites* sp., *Pernerograptus* sp., *Pribylograptus* sp. (70 m above member base) and graptolites of the Middle Llandovery *convolutus* zone (1 km northwest, in the same interval, loc. 1738): *Demirastrites convolutus* (Hisinger), *Agetograptus zintchenkoae* Obut et Sob., *Monograptus distans* (Portlock). ..... over 70

6. Siltstone: gray and silver-gray, clayey; member (section top) occurs in the core of a synclinal fold ..... over 100

Siltstone in equivalents of member 6 of S-833 on the left bank of the Listvyanka Brook, 500 m upstream of its mouth, contains Upper Llandoverian graptolites of the *halli* zone (loc. S-824-1/1), 120 m stratigraphically higher than loc. S-824-2/10 with graptolites of the *triangulatus* and *gregarius* zones: *Stimulograptus halli* (Barrande), *Monograptus* sp., *Paradiversograptus capillaris* (Carruthers), *Glyptograptus tamariscus* (Niholson).

Siltstone in equivalents of member 6 of S-833 on the left bank of the Inya River, 100 m upstream of an island near the Listvyanka Brook inflow (loc. S-8341) contains graptolites of the Upper Llandoverian *guerichi* zone: *Spirograptus guerichi* Loydell, Storch et Melchin, *Rastrites* sp., *Stimulograptus halli* (Barrande), *Oktavites planus* (Barrande), *Paradiversograptus runcinatus* (Lapworth), *Paradiversograptus capillaris* (Carruthers), *Agetograptus tenuissimus* Sennikov, *Hedrograptus* sp., *Petalograptus* sp.

All six members of S-822 section and members 1–3 of S-833 section belong to Tekhten' Formation, and members 4 and 5 of S-833 section – to Vtorye Utyosy Formation, member 6 of S-833 section –Syrovaty Formation. Thickness of the Tekhten' Formation in the composite Burovlyanka Section (incomplete) is more than 330 m, Vtorye Utyosy Formation – about 420 m, Syrovaty Formation – more than 100 m.

Vtorye Utyosy Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Rhuddanian, Aeronian.
Regional stratigraphic subdivisions: Vtorye Utyosy and Syrovaty regional stages (horizons).
Local lithostratigraphic subdivisions: Vtorye Utyosy, Syrovaty formations.
Zones: *acuminatus, triangulatus, convolutus-cometa, sedgwicki* graptolite zones.
Fauna: graptolites, chitinozoans.

This is the stratotype section of the Vtorye Utyosy Formation, the lowermost Llandoverian regional stratigraphic unit.

A large fragment of the Llandoverian section crops out in cliff exposures on the left bank of the Inya River, 2.5 km upstream of Chineta Village, in a place called Vtorye Utyosy (Russian for Second Cliff) (Fig. 47). The exposed section begins at the upstream cliff end and includes (Fig. 48):

Fig. 46. Clayey platy limestones from the Ordovician Tekhten' Formation, Burovlyanka section, member 3.

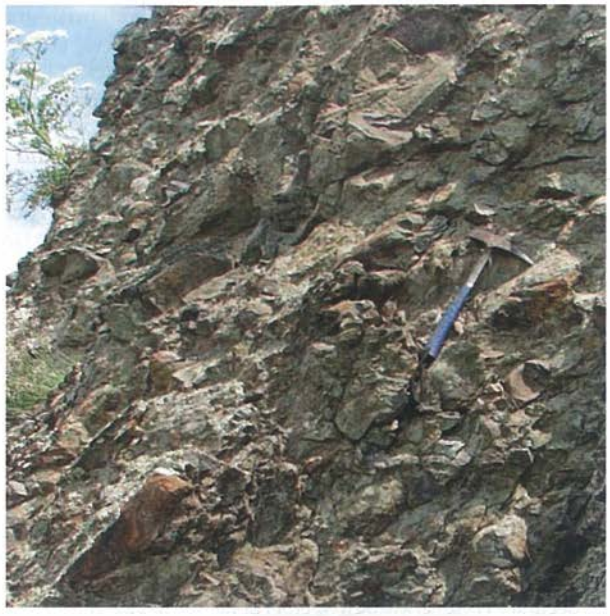


Fig. 50. Underwater-sliding structures (diameter up to 70 cm) in siltstones of the Silurian Syrovaty Formation, Chernaya Mountain section, member 4.

Fig. 47. General view of the exposure on the left bank of Inya River – Ordovician and Silurian Vtorye Utyosy Formation, members 1–5.

Thickness, m

1. Mudstone: black, clayey, very dense, flaggy, with conchoidal fracture, often with mottled textures; frequent pyrite indicates deposition in anxoic conditions; member contains chitinozoans at the very base (loc. S-7343): *Conochitina* aff. *micracantha* Eisenack. In 12 m upward from 10-cm layer (loc. Yo-7129=S-718) graptolites *Persculptograptus* ex gr. *persculptus* (Salter), *Parakidograptus* cf. *acuminatus* (Nicholson), *Dimorphograptus* sp. indet., *Metaclimacograptus hughesi* (Nicholson), *Met. orientalis* Obut et Sob., *Pribylograptus* sp., *Atavograptus* sp., chitinozoans – *Conochitina edjelensis* Taug. et Jekh. were recovered ..... ~50

2. Mudstone: dark gray to black, weathered to greenish, clayey, flaggy, less dense than in member 1, with thin banding; a 50 cm thick layer 20 above member base, near a dike exposure, contains graptolites (loc. Yo-7071=S-7022): *Demirastrites pectinatus pectinatus* (Richter), *Metaclimacograptus hughesi* (Nicholson), *Hedrograptus rectangularis* (McCoy), *Hedrograptus* sp., *Glyptograptus tamariscus* (Nicholson), *Glyptograptus* sp., *Rastrites longispinus* Perner ..... ~40

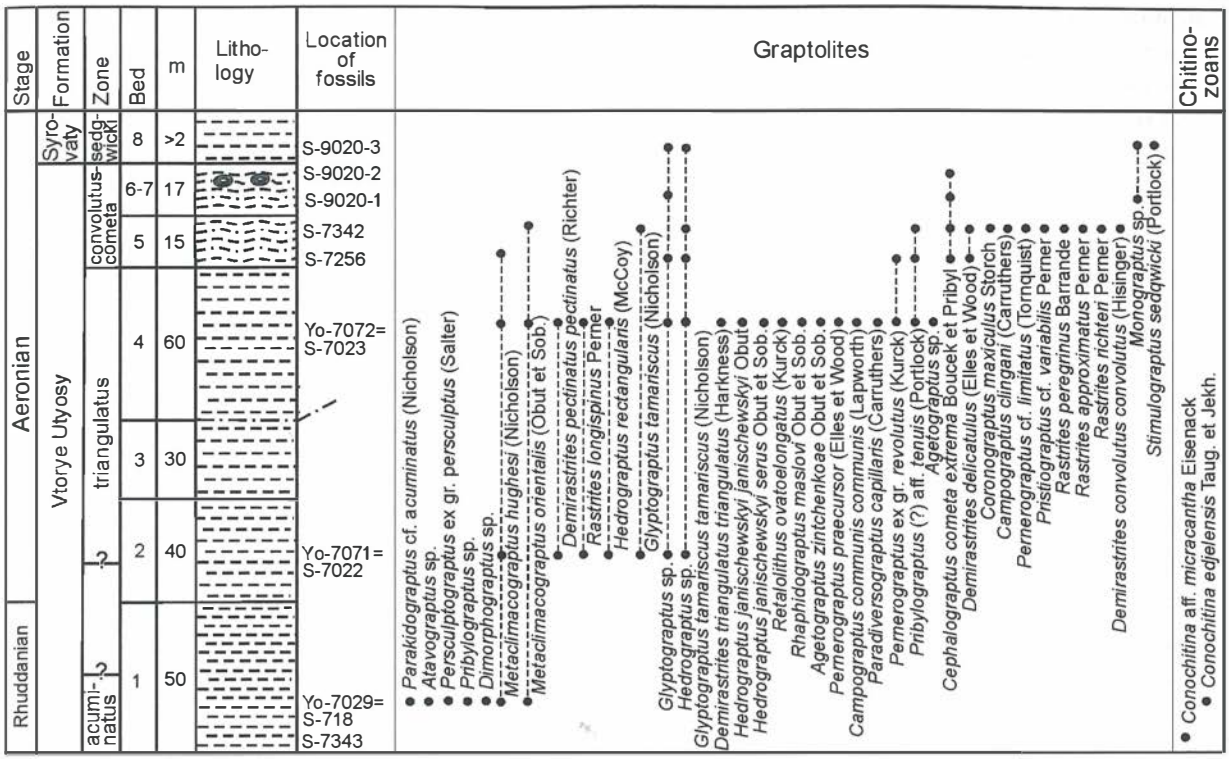


Fig. 48. Ranges of fossil taxa from Vtorye Utyosy section.

3. Mudstone: dark gray to black, clayey, flaggy, less dense than in member 2 ..... ~30

The top of member 3 is truncated by a fault; above the fault there follow:

4. Mudstone, similar to that of member 3; a 1 m thick layer 30 m upsection from the fault contains graptolites (loc. Yo-7072=S-7023): *Demirastrites triangulatus triangulatus* (Harkness), *Dem. pectinatus pectinatus* (Richter), *Metaclimacograptus hughesi* (Nicholson), *Met. orientalis* Obut et Sob., *Hedrograptus janischewskyi janischewskyi* Obut, *Hed. janischewskyi serus* Obut et Sob., *Hed. rectangularis* (McCoy), *Glyptograptus tamariscus tamariscus* (Nicholson), *Glyptograptus* sp., *Petalolithus ovatoelongatus* (Kurck), *Rhaphidograptus maslovi* Obut et Sob., *Agetograptus zintchenkoae* Obut et Sob., *Agetograptus* sp., *Pernerograptus praecursor* (Elles et Wood), *Pernerograptus* ex gr. *revolutus* (Kurck), *Pribylograptus* (?) aff. *tenuis* (Portlock), *Pseudorthograptus* (*Pseudorthograptus*) *insectiformis* (Nicholson), *Campograptus communis communis* (Lapworth), *Rastrites longispinus* Perner, *Paradiversograptus capillaris* (Carruthers) ..... ~ 60

5. Mudstone, clayey, and siltstone, silver-gray, flaggy; peculiar 3–5 cm cavities in middle and upper layers resemble conchoidal cleavage; a 1 m thick layer at the very base of member contains graptolites (loc. S-7256): *Metaclimacograptus hughesi* (Nicholson), *Cephalograptus cometa extrema* Boucek et Pribyl, *Pernerograptus* ex gr. *revolutus* (Kurck), *Pribylograptus* (?) aff. *tenuis* (Portlock), *Demirastrites delicatulus* (Elles et Wood), *Hedrograptus* sp., *Glyptograptus* sp. At the top of the member, from 0,5 m layer (loc. S-7342) the following graptolites were collected: *Metaclimacograptus orientalis* Obut et Sob., *Glyptograptus tamariscus* (Nicholson), *Hedrograptus* sp., *Cephalograptus cometa extrema* Boucek et Pribyl, *Coronograptus maxiculus* Storch, *Campograptus clingani* (Carruthers), *Campograptus* sp., *Pernerograptus* cf. *limitatus* (Tornquist), *Pristiograptus* cf. *variabilis* Perner, *Pribylograptus* (?) aff. *tenuis* (Portlock), *Demirastrites convolutus convolutus* (Hisinger), *Dem. delicatulus* (Elles et Wood), *Dem. pribyli* Boucek, *Rastrites peregrinus* Barrande, *Ras. approximatus* Perner, *Ras. richteri* Perner ..... ~15

6. Mudstone, clayey, and siltstone, dark gray, slightly wavy-bedded; with graptolites (loc. S-9020-1): *Cephalograptus cometa extrema* Boucek et Pribyl, *Glyptograptus* sp., *Monograptus* sp. 13

7. Mudstone: mostly silver-gray, clayey; with graptolites (loc. S-9020-2): *Cephalograptus cometa extrema* Boucek et Pribyl. 4

8. Mudstone: light gray or dark olive-gray, slightly calcareous, thinly banded, platy; with 76. Graptolites *Monograptus* sp., *Glyptograptus* sp., *Hedrograptus* sp., *Stimulograptus sedgwicki* (Portlock) were identified (loc. S-9020-3) ..... over 2

Graptolite assemblage from loc. Yo-7129 (lower member 1) belongs to the *acuminatus* zone; graptolite assemblages from loc. Yo-7071 and Yo-7072 belong to the *triangulatus* zone, those from loc. S-7256, S-7342, S-9020-1, and S-9020-2 are of the *convolutus-cometa* zone, and those from loc. S-9020-3 are of the *sedgwicki* zone. The interval spanning upper half

of member 2, member 3 and, possibly, member 4 corresponds to the *triangulatus* zone, members 5 through 7 belong to the *convolutus-cometa* zone, and member 8 to the *sedgwicki* zone.

Members 1 through 7 make up the stratotype section of the Vtorye Utyosy Formation, and member 8 belongs already to the overlying Syrovaty Formation. Thus, the section displays a normal stratigraphic relationship between two Llandoverian formations as transition from dark clayey mudstone and siltstone to gray flaggy limy mudstone. The incomplete thickness of the Vtorye Utyosy Formation is about 210 m and the Syrovaty Formation is over 2 m thick in the section.

Chernaya Mountain Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Aeronian, Telychian.
Regional stratigraphic subdivisions: Vtorye Utyosy and Syrovaty regional stages (horizons)
Local lithostratigraphic subdivisions: Vtorye Utyosy, Syrovaty formations.
Zones: *convolutus, sedgwicki* graptolite zones.
Fauna: tabulate corals, rugose corals, crinoids, brachiopods, algae, ichnofossils, graptolites, chitinozoans.

The contact between the Vtorye Utyosy and Syrovaty formations and a large lithologically peculiar fragment of the Syrovaty section are exposed on the western slope of Chernaya Mountain (Gora Chernaya). The section starts 300 m far from the Chinetka Brook at the origin of the roadway from Chineta Village to Taly Village where the exposed members (listed up the slope and stratigraphically upwards) are (Fig. 49):

Thickness, m

1. Mudstone: gray, thick- or more rarely medium-bedded, generally well sorted 15

2. Siltstone: silver-gray, clayey, with up to 1 m cavities looking like conchoidal cleavage, and no bedding signature; the fill of cavities occasionally makes separate bodies look like twisted rolls, up to 10 cm in diameter, which easily come out from host siltstone but are compositionally identical to the latter; locally there are traces of traction like small folds at one side of the cavity fill; member contains graptolites in middle layers (loc. Yo-7128=S-717): *Dictyonema delicatulum* Lapworth, *Dict. altayense* Sennikov, *Dictyonema* sp., *Metaclimacograptus hughesi* (Nicholson), *Koremagraptus onniensis* Bulman, *Kor. bulmani* Sennikov, *Hedrograptus rectangularis* (McCoy), *Hed. krivunensis* (Obut), *Orthograptus mutabilis* (Elles et Wood), *Rectograptus* sp., *Glyptograptus* sp., *Campograptus communis communis* (Lapworth), *Demirastrites convolutus convolutus* (Hisinger), chitinozoans *Conoclitina* aff. *oelandica silurica* Taug. et Jekh., crinoids *Pentagonocyclicus* aff. *borealis* Yelt., tabulate corals, rugose corals and brachiopods 15

3. Mudstone, gray and greenish-gray, clayey, massive, well sorted 12

4. Mudstone: gray, clayey, with cavities and rolls; the latter are especially abundant in lower layers making about 90 % of rock volume; they consist of silty-clayey or limy-clayey material like host mudstone and reach a length of 70 cm; rolls in upper layers are fewer and smaller (10–20 cm in diameter) and are compositionally identical to host shale; rolls are randomly oriented throughout the member (Figs 50, 51) 10

5. Mudstone, gray, clayey to limy-clayey with siltstone, gray, clayey, with banding and 20–30 cm flaggyness, and smooth shear surfaces; more calcareous (20-40 cm thick) layers alternate with more silty (50–100 cm thick) ones; a 20-cm thick layer at member top contains graptolites (loc. S-7320): *Stimulograptus sedgwicki* (Portlock), *Pristiograptus* sp., *Campograptus* ex gr. *communis* (Lapworth), *Rastrites* sp., *Paradiversograptus capillaris* (Carruthers) 30

6. Mudstone: gray, with cavities of 30-50 cm in diameter 50

7. Mudstone: gray, with cavities and rolls; rolls reach 90 % vol. as in member 4 near the base and reduce in number up the section; rolls in the lower half have more limy compositions (corresponding to calcareous siltstone) than host mudstone; rolls are mainly isolated from the host and are regularly arranged with their long axes along and short axes across the bedding (all rolls align with the same direction); they reach sizes of 80 x 30 x 10 cm; rolls in upper layers are few, 30–40 cm long, and compositionally identical to host shale 15

8. Mudstone: gray, laminated, with rolls from 5–10 cm to 30–70 cm in diameter (slightly smaller in upper layers), compositionally similar to host mudstone; rolls in lower layers align with bedding, like in member 7, and are more randomly oriented upsection; their number is different in different layers: there are on average as many as 10 small rolls and 4-5 big rolls per square meter of surface area of the bedrock exposure (across the bedding); member contains graptolites *Streptograptus* sp. in the middle layers 15

9. Mudstone: gray, with 3–5 cm (rarely up to 10 cm) cavities in lower layers 30

Members 1 through 4 belong to the Vtorye Utyosy Formation and members 5 through 9 belong to the Syrovaty Formation. The Vtorye Utyosy – Syrovaty transition is marked by change from clayey mudstone to limy-clayey mudstone and siltstone. The two formations have incomplete thicknesses of 52 m and 140 m, respectively.

The graptolite assemblage from member 2 corresponds to the *convolutus-cometa* zone and that from member 5 is of the *sedgwicki* zone. The Llandoverian strata in the immediate vicinity of the section, on the northwestern slope of Chernaya Mt., contain graptolites of the *guerichi* and *turriculatus* zones. The entire section on the western slope of Chernaya Mt. can be assumed to be older than the *guerichi* zone because the intervals corresponding to these graptolite zones are composed of normally bedded rocks without cavities or rolls. Member 1 must be older than the *convolutus-*

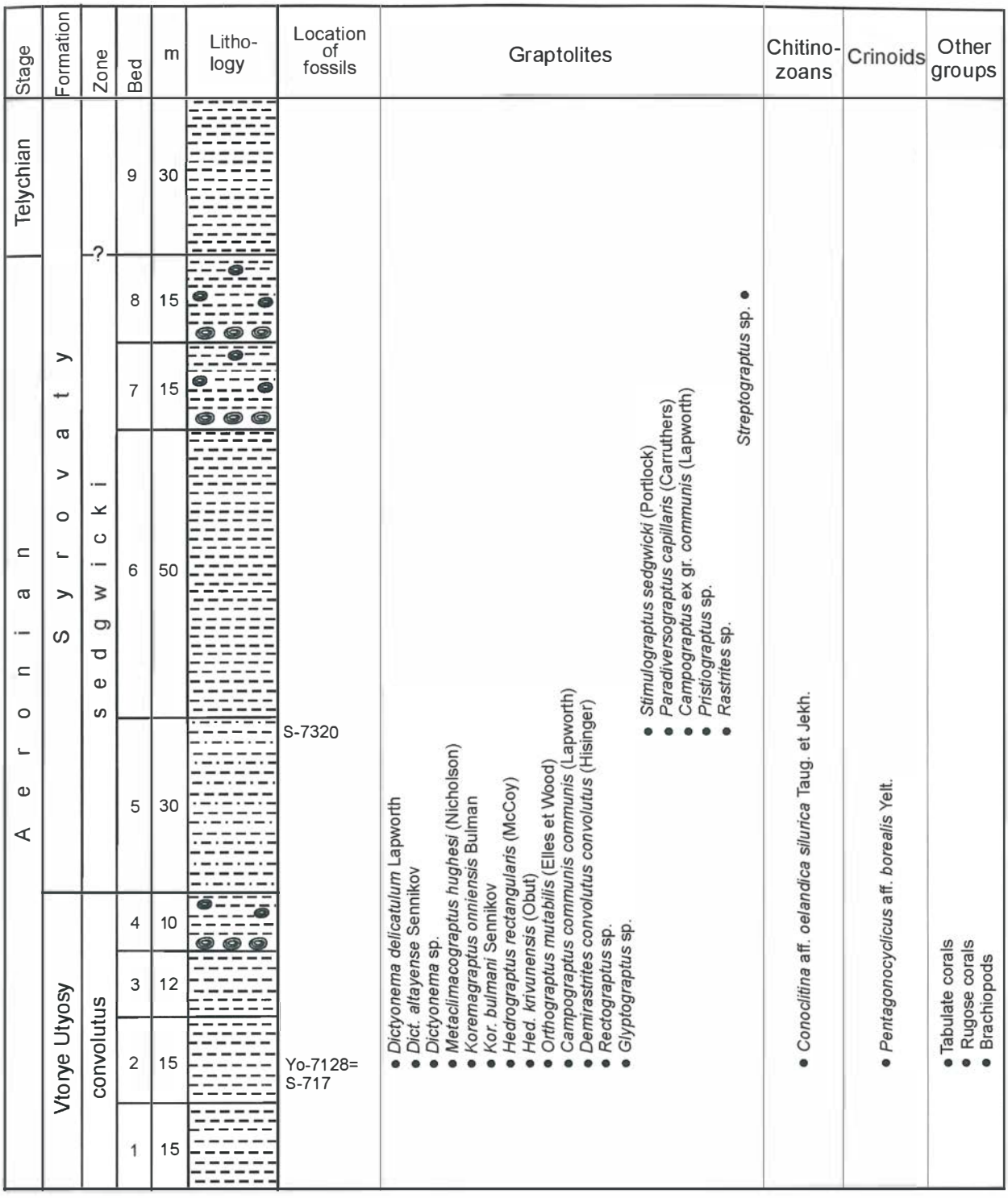


Fig. 49. Ranges of fossil taxa from Chernaya Mountain section.

cometa zone, as cavities appear only above the top of the *triangulatus* zone, which is evident in a continuous succession of graptolite zones from *triangulatus* to *convolutus – cometa* on the left bank of the Inya River. Thus, section on the western slope of Chernaya Mt. (members 2 through at least member 8) by the age is aligned with the *convolutus* and *sedgwicki* graptolite zones. The boundary between the two zones is conventionally defined along the base of member 5.

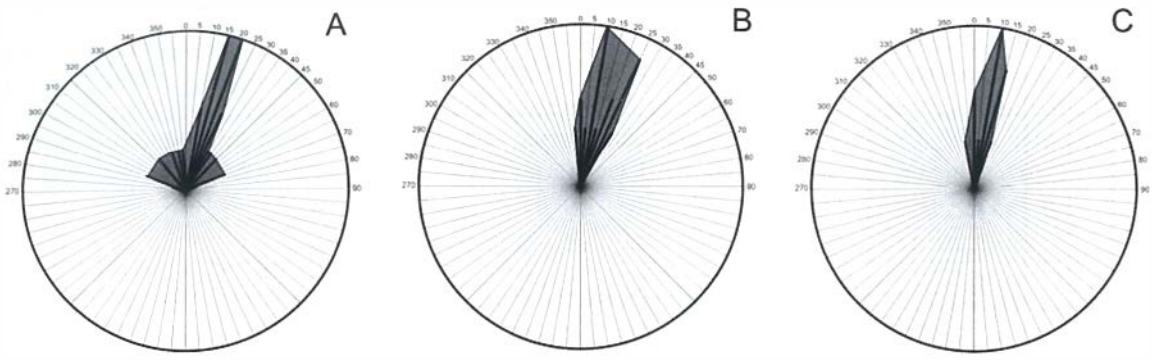


Fig. 51. Diagram (in modern coordinates) for directions of non-lithified deposit-movement during underwater sliding in Chernaya Mountain section (A– member 4, B – member 7, C – member 8).

Rossypnaya Mountain Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Aeronian, Telychian, Sheinwoodian, Homerian.

Regional stratigraphic subdivisions: Vtorye Utyosy, Syrovaty, Polaty, Chesnokovka and Chagyrka regional stages (horizons).

Local lithostratigraphic subdivisions: Vtorye Utyosy, Syrovaty, Polaty, Chesnokovka and Chagyrka formations.

Zones: *triangulatus, spiralis-grandis* graptolite zones, *celloni* conodont zone.

Fauna: stromatoporoids, tabulate corals, rugose corals, crinoids, bryozoans, trilobites, ostracods, brachiopods, graptolites, conodonts, chitinozoans.

The Rossypnaya Mountain Section is a continuous succession of Lower Silurian rocks spanning five local stratigraphic units of the Vtorye Utyosy, Syrovaty, Polaty, Chesnokovka and Chagyrka formations; it is a stratotype section of the Syrovaty and Polaty formations (Fig. 52).

The section in the southwestern part of Rossypnaya Mt., starting from a ford across the Inya River, consists of (Fig. 53):

Thickness, m

1. Mudstone: clayey, and siltstone: gray or silver-gray, weathered to whitish or greenish, dense, flaggy, with thin banding produced by color change; member contains graptolites in middle layers (loc. S-758): *Rastrites longispinus* Perner, *Demirastrites pectinatus* (Richter), *Hedrograptus* sp. At 5 m stratigraphically higher (loc. Yo-7076=S-7026) graptolites *Metaclimacograptus* sp., *Monograptus* (s.l) sp., *Demirastrites* sp., brachiopods *Protatrypa* sp. and indetermined trilobites. In 5 m stratigraphically higher (loc. S-759) graptolites *Hedrograptus* sp. were collected 30

2. Mudstone: greenish-gray, whitish, less often dark to gray, clayey and clayey-carbonate, weathered to coarse (2-4 cm) debris 45

3. Mudstone, clayey and siltstone: dirty green or locally gray, weathered to fine elongate (to 1 cm) debris, with thin banding produced by color change; member contains graptolites found in a trench 20 m above member base (loc. S-7510): *Diplograptus* (s.l) sp., *Rastrites* sp. In 5 m stratigraphically higher, from 2 m layer (loc. Yo-7077) graptolites *Hedrograptus* sp, *Glyptograptus* sp., *Monograptus* sp., *Monoclimacis* sp., *Campograptus* sp. 35

4. Limestone: highly clayey, dirty gray, whitish or greenish on honeycombed weathered surfaces, randomly bedded, lumpy, grading smoothly from underlying shale; clay component is unevenly distributed and gradually decreases upsection; member contains abundant and diverse faunas (loc. Yo-7082), including rugose corals *Pseudophalactis brevtseptatum* Ivnvsk, *Phauluctis notabilis* Zhelt. sp. n., *Tabularia oblonga* Zhelt., brachiopods Pentameridae, tabulate corals and indetermined stromatoporoids, trilobites ans crinoids 20

5. Limestone: dirty gray, clayey, massive, locally crinoidal or detrital, with unevenly distributed clay component; with rugose corals *Phaulactis notabilis* Zhelt. sp. n., *Tabularia oblonga* Zhelt., *Entellophyllum micrommata* Zhelt., *Neopaliphyllum soshkini* Zhelt., brachiopods Plectambonitaceae, *Atrypa* ex gr. *orbicularis* (Sow.), *Carinatina* sp., tabulate corals and indetermined stromatoporoids, trilobites and crinoids (loc. Yo-7083) 10

6. Mudstone: dirty green-gray, clayey and clayey-carbonate, and siltstone, with graptolites (loc. Yo-7083a=S-7033): *Dictyonema graptolithorum* Pocta, *Polygonograptus physophorus* Sennikov, *Stomatograptus* sp., *Monograptus* sp., *Oktavites* sp. and indetermined brachiopods, trilobites, ostracods and crinoids 1.2

7. Limestone: gray, dirty gray, locally dark and brownish-yellow, clayey, massive; clay material is localized in up to 60 cm thick lenses of lumpy limestone with honeycomb weathered surfaces; present are small (1-2 m) algal bioherms; member contains

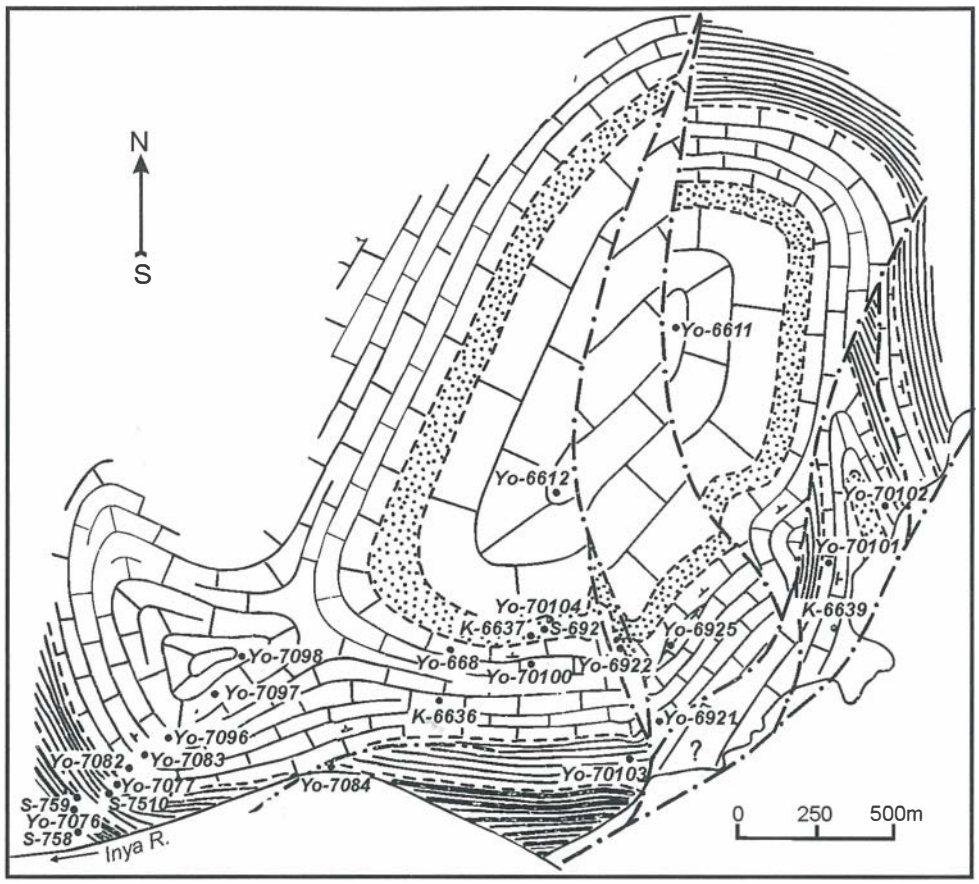


Fig. 52. Sketch map of the location on Rossypnaya Mountain (modified from Yolkin et al., 1974) .

stromatoporoids (loc. Yo-7096): *Clathrodictyon (?)* cf. *avitum* (Nestor), *Stromatopora antiqua* (Nich. et Mur.), rugose corals: *Craterophyllum crassiseptata* Ivnvsk, *Neopaliphyllum soshkini* Zhelt., *Entellophyllum articulatum* (Wahl.), brachiopods *Eostropheodonta* sp. and tabulate corals 50

8. Limestone: light gray, yellowish or cherry-red, locally crinoidal, massive, with large (30 x 20 m) algal bioherms; member contains rugose corals (loc. Yo-7097 and Yo-7098): *Craterophyllum crassiseptata* Ivnvsk., *Neopaliphyllum soshkini* Zhelt., *Holacanthia flexuosa* (Linn.), *Tryplasma rugosum* (M.Edw. et Haime), *Microplasma orientalis* Ivnvsk., brachiopods Pentameridae, *Eospirifer radiatus* (Sow.) and indetermined trilobites ..... ~60

A sharp transition from flaggy clayey mudstone equivalent to rocks of member 1 with *Demirastrites* sp. graptolites to clayey and clayey-carbonate mudstone equivalent to member 2 is exposed farther to the east, on the southeastern slope of Rossypnaya Mt., in a section that starts at the Yarovka Brook mouth. A 50-cm layer in the middle of an equivalent of member 2, on the southeastern slope of Rossypnaya Mt., 25 m far from the Yarovka Brook (loc. Yo-70103) contains graptolites *Hedrograptus* sp. and *Glyptograptus* sp.

Members 3 through 8 crop out uphill, on the southeastern slope of Rossypnaya Mt., where Vorozhbitov (1996) found conodonts in an equivalent of member 7: *Distomodus staurognathoides* (Walliser), *Pterospathodus* sp., and in an equivalent of member 8 – *Pterospathodus celloni* (Walliser), *Apsidognathus tuberculatus* Walliser, *Pseudobelodella silurica* Armstrong, *Pterospathodus* sp.

Equivalents of member 8 on the southeastern slope of Rossypnaya Mt. are overlaid by three more members, along a sharp twisty boundary, with karst cavities:

9. Mudstone: black or locally dark gray, clayey-chlorite; with graptolites found in a 2-m thick layer in the middle of member the (loc. S-692): *Stomatograptus grandis grandis* (Suess), *Retiolites angustidens* (Elles et Wood), *Monoclimacis griestonensis kettneri* (Boucek), *Monograptus priodon* (Bronn), *Oktavites falx* (Suess) and chitinozoans – *Desmochitina* sp. 30

10. Limestone: dark gray, highly clayey, lumpy; clay material is localized along rough bedding surfaces producing a bead-like habit; rocks show gradual transition from underlying clayey-chlorite shale and contain abundant and diverse fossils (loc. Yo-70104): rugose corals *Neobrachielasma variabilis* Zhelt., *Syringaxon* ex gr. *siluriense* McCoy, *Soshkinolites microcorallita* Zhelt., *Kodonophyllum truncatum* (Linn.), *Stereoxylodes pseudodianthus* Weiss., *Neopaliphyllum soshkini* Zhelt., *Cyathactis inensis* Zhelt., *Cyathactis parabreviseptatum* Zhelt., *Calostylus clarae* Zhelt., *Calostylus helminthoides* Zhelt., *Entelophyllum articulatum* (Wahl.),

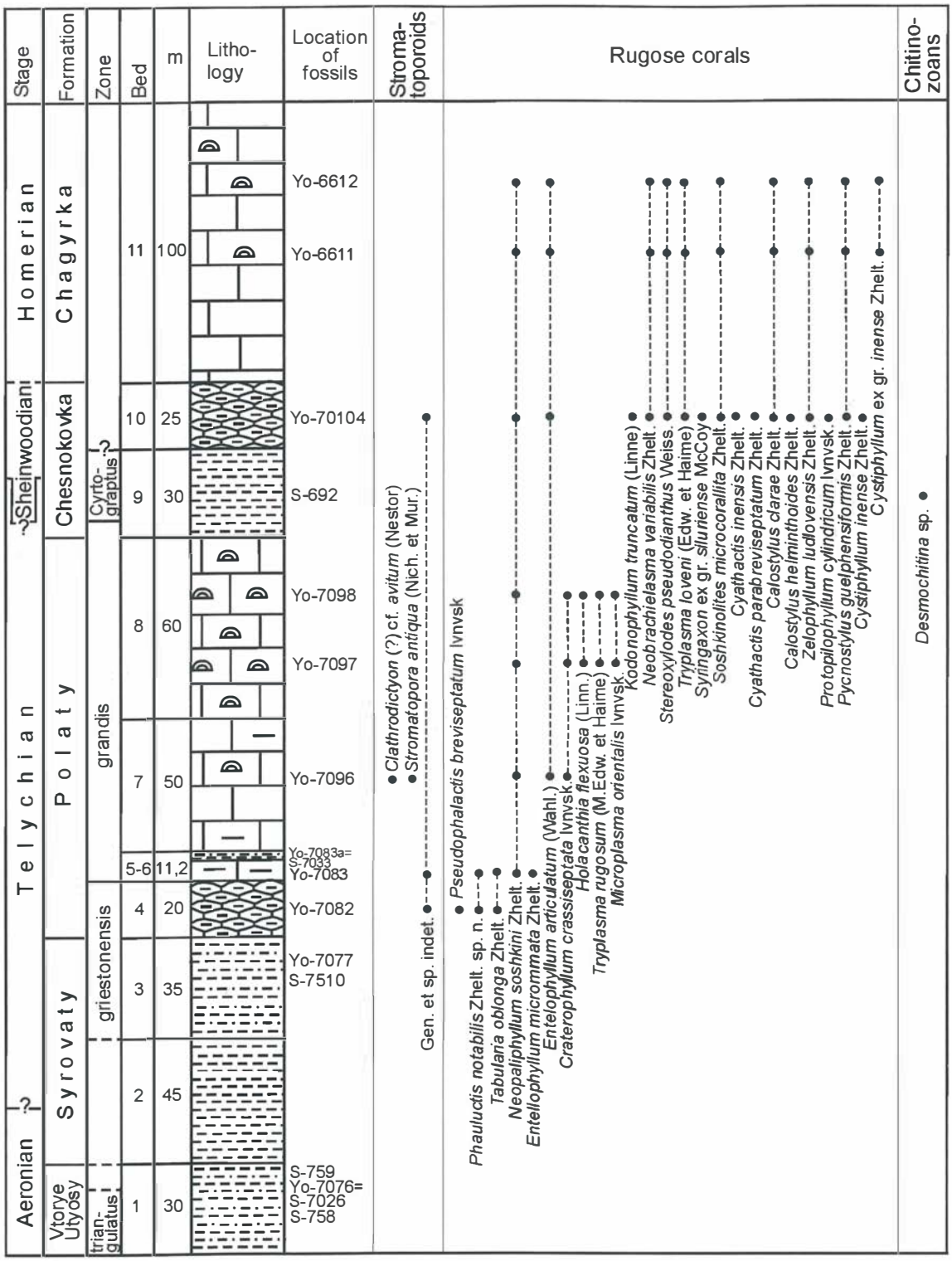
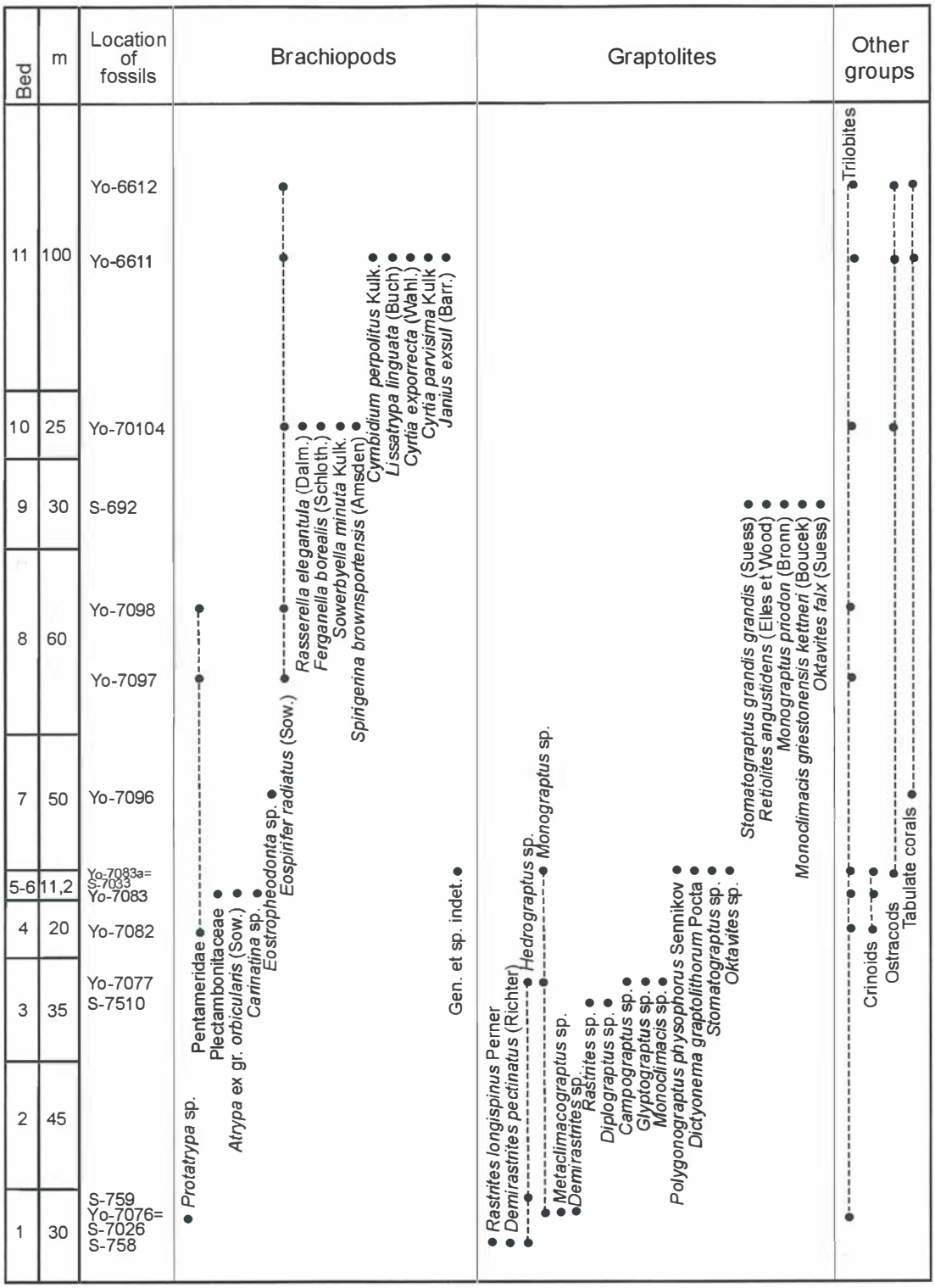


Fig. 53. Ranges of fossil taxa from Rossypnaya Mountain section.

Zelophyllum ludlovensis Zhelt., *Protopilophyllum cylindricum* Ivnvsk, *Pycnostylus guelphensiformis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime), *Cystiphyllum inense* Zhelt., brachiopods *Rasserella elegantula* (Dalm.), *Sowerbyella minuta* Kulk., *Eerganella borealis* (Schloth.), *Spirigerina brownsportensis* (Amsden), *Eospirifer radiatus* (Sow.), tabulate corals and indetermined stromatoporoids, trilobites, ostracods, etc. 25



11. Limestone: light gray or gray, patched yellow and pink, massive, locally of uncertain bedding, often algal, shelly in places; fossils are most often localized in "clusters": The following fauna was obtained (loc. Yo-6611, Yo-6612): rugose corals *Neobrachielasma variabilis* Zhelt., *Soshkinolites microcorallita* Zhelt., *Stereoxylodes pseudodianthus* Weiss., *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelphensiformis* Zhelt., *Neopaliphyllum soshkini* Zhelt., *Calostylus clarae* Zhelt., *Entelophyllum articulatum* (Wahl.), *Tryplasma loveni* (Edw. et Haime), *Cystiphyllum* ex gr. *inense* Zhelt., brachiopods *Cymbidium perpolitus* Kulk., *Lissatrypa linguata* (Buch), *Cyrtia exporrecta* (Wahl.), *Cyrtia parvisima* Kulk., *Eospirifer radiatus* (Sow.), *Janius exsul* (Barr.), *Spirinella striatissima* (Holtedahl), tabulate corals, trilobites, ostracods and others ..... ~100

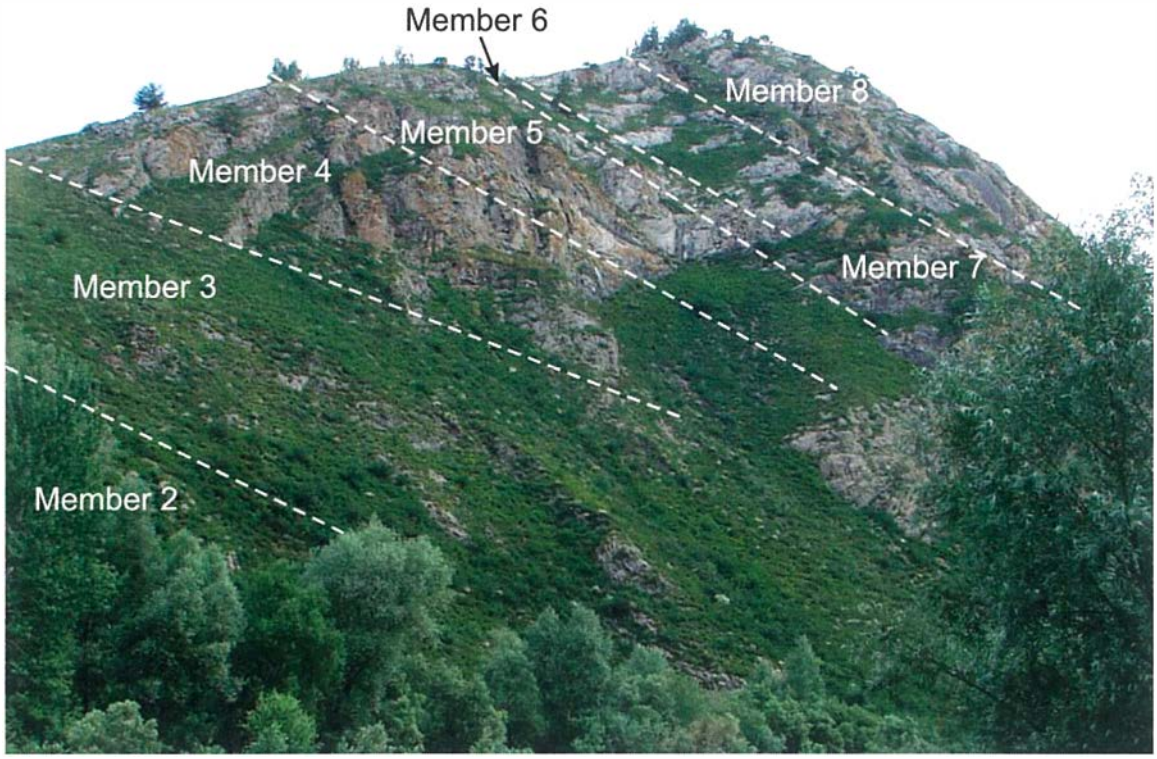


Fig. 54. General view of the outcrop on the Rossypnaya Mountain (Rossypnaya Mountain section, members 2 and 3 - stratotype section of Silurian Syrovaty Formation, members 3-8 - Silurian Polaty Formation). Reef limestones from the Silurian Polaty Formation with large algal bioherms (diameter 30 to 20 m), member 8.

Fig. 55. Erosional structures on the boundary of the reef-carbonate Silurian Polaty Formation (member 9) and black shale Silurian Chesnokovka Formation (member 10) exposed in Rossypnaya Mountain section.

The top of the section is eroded.

Member 1 belongs to the Upper Vtorye Utyosy Formation, members 2 and 3 are designated as the stratotype section of the Syrovaty Formation, members 5 through 8 make up the stratotype section of the Polaty Formation (Fig. 54), members 9 and 10 are compsed of rocks of the Chesnokovka Formation, and member 11 belongs to the Chagyrka Formation (Fig. 55). The transitions between the Vtorye Utyosy and Syrovaty formations and between the Syrovaty and Polaty formations are gradual and marked by regular upsection increase in the carbonate component. The base of the Chesnokovka Formation is sharp, with syndepositional erosion pockets, and coincides with the boundary between the Gromotukha and Tigerek groups.

The incomplete thickness of the Vtorye Utyosy Formation in the section exceeds 30 m, that of the Syrovaty Formation is 80 m, the Polaty Formation is more than 140 m thick, the Chesnokovka Formation is 55 m, and the thickness (incomplete) of the Chagyrka Formation is about 100 m.

Shpil Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Aeronian, Telychian, Sheinwoodian, Homerian.

Regional stratigraphic subdivisions: Chesnokovka and Chagyrka regional stages (horizons).

Local lithostratigraphic subdivisions: Chesnokovka and Chagyrka formations.

Zones: *spiralis-grandis, insectus-centrifugus* graptolite zones.

Fauna: stromatoporoids, tabulate corals, rugose corals, brachiopods, graptolites, chitinozoans.

The Lower Silurian section crops out on the left bank of the Chinetka River (right tributary of the Inya River), on the western slope of Shpil Mt., and comprises (Fig. 56):

Thickness, m

1. Sandstone: light brown, limy-clayey, fine, with a ~10 cm thick bead-like layer of light gray clayey limestone in the middle, and with loaf-shaped bodies up to 50 cm long at necks; no fossils found 3

2. Mudstone: clayey-chlorite, locally with siltstone, with color changing from silver-gray below to dark gray, almost black, upward and greenish hues at the top; a 30-cm thick layer at 11 m above member base (loc. S-729) contains graptolites *Retiolites* sp., *Monograptus priodon* (Bronn), *Oktavites planus* (Barrande), *Callograptus* sp. and chitinozoans *Desmochitina* (?) sp. In 10 m stratigraphically higher – graptolites (loc. S-729a) *Oktavites* sp. In 70 m from the base of the member in 2 m layer (loc. Yo-70106=S-7052) graptolites *Stromatograptus grandis grandis* (Suess), *Retiolites angustissimus* Obut et Sob., *Monograptus priodon* (Bronn), *Monoclimacis griestonensis griestonensis* (Nicol), *Monoclimacis griestonensis kettneri* (Boucek), *Pristiograptus* sp., *Streptograptus* sp., *Campograptus* sp., *Oktavites falx* (Suess), *Oktavites planus* (Barrande), *Diversograptus* sp. were collected, and in 5 m stratigraphically higher (loc. S-7052a) – *Cyrtograptus* aff. *insectus* Boucek, *Cyrtograptus* aff *centrifugus* Boucek 90

3. Mudstone: green or yellowish-green, clayey and clayey-carbonate, with small calcareous concretions and white calcareous efflorescence on weathered surfaces; no fossils found 12

4. Limestone: gray or light gray, locally pinkish, massive algal, locally with highly clayey detrital limestone at member base; limestone grades smoothly from underlying shale; member contains rugose corals *Neobrachielasma variabilis* Zhelt., *Stereoxylodes pseudodianthus* Weiss., *Zelophyllum ludlovensis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime), brachiopods *Carinatina praearimaspus* Nikif., *Spirigenina* cf. *brownsportensis* (Amsden), tabulate corals, stromatoporoids (loc. Yo-70105) 60

Members 1 through 3 belong to the Chesnokovka Formation and member 4 belongs to the Chagyrka Formation. Graptolites are of the *grandis* (loc. Yo-70106=S-7052) and *insectus-centrifugus* (loc. S-7052a) zones. The incomplete thickness of the Chesnokovka Formation in the section exceeds 90 m and that of the Chagyrka Formation is over 60 m.

3.1.6. Area of Tigerek Village

Tigerek Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: ?Telychian, Sheinwoodian, Homerian, Gorstian, Ludfordian.

Regional stratigraphic subdivisions: Chesnokovka, Chagyrka and Kuimov regional stages (horizons).

Local lithostratigraphic subdivisions: Chesnokovka, Chagyrka and Kuimov formations.

Fauna: stromatoporoids, tabulate corals, rugose corals, trilobites, ostracods, brachiopods, crinoids, gastropods, bryozoans, graptolites.

The Tigerek section comprises the Silurian Chesnokovka, Chagyrka, and Kuimov formations. It starts with a natural exposure to the right of the roadway from Tigerek Village to Chineta Village, then proceeds in a trench along the slope and in other natural exposures (Fig. 57). The section comprises (Fig. 58):

Thickness, m

1. Limestone: gray or light gray, massive, locally bioclastic; with stromatoporoids *Stromatopora antique* (Nich. et Mur.), *Stromatopora carteri* Nich., rugose corals *Entelophyllum articulation* (Whalend.), *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelphensiformis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime), *Cysticonophyllum gukovensiformis* Zhelt., brachiopods *Lissatrypa minuta* Kulk., *Spirinella striatissima* (Holtedahl.), *Conchidium* sp., trilobites *Warburgella obscura* Yolk. and tabulate corals (loc. Yo-70114) ..... ~8

2. Limestone: dark, clayey, dense, laminated, grading smoothly but rapidly from underlying limestone; with stromatoporoids *Diplostroma* cf. *validum* Nestor, *Simplexodictyon* sp., rugose corals *Pycnostylus guelphensiformis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime), brachiopods *Rhynchotreta cuneata* (Dalm.), tabulate corals, trilobites and ostracods (loc. Yo-70115) 3

3. Limestone: gray or light gray, dense, algal; with (loc. Yo-70116) rugose corals *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelhensiformis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime) 1.5

4. Mudstone and marl: brownish- and greenish-yellow, clayey, friable, alternating with limestone, dirty gray or dark, clayey, laminated, commonly with knobby bedding planes; clayey mudstone occurs in member lower layers and is interbedded with marl and

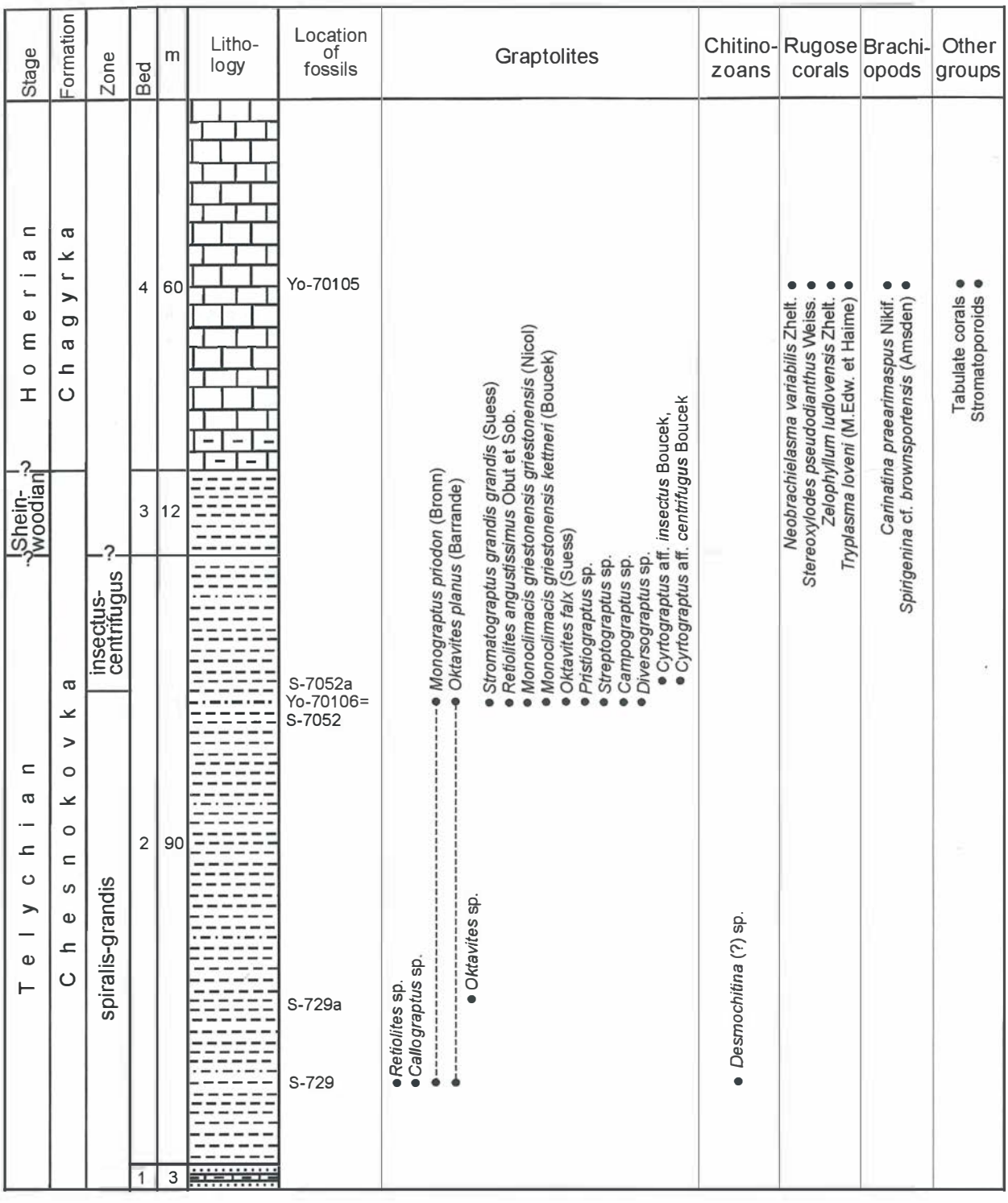


Fig. 56. Ranges of fossil taxa from Shpil Section.

limestone which increase upsection; member contains abundant and diverse fossils, especially in middle layers (loc. Yo-70117 and Yo-70118), including stromatoporoids *Labechia* cf. *conferta* (Lonsd.), *Ecclimadictyon fastigiatum* (Nich.), rugose corals *Neobrachielasma variabilis* Zhelt., *Entelophyllum articulatum* (Wah.), *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelpkensiformis* Zhelt., *Tryplasma loveni* (M.Edw. et Haime), *Chavsakia chavsakiensis* Lavr., *Cystiphyllum siluriense* Lonsd., *Coronoruga delicata* Zhelt. sp. nov., *Ketophyllum subelegantulum* Zhelt., brachiopods *Ferganella borealis* (Schloth.), *Conchidium biloculure* (Linn.),

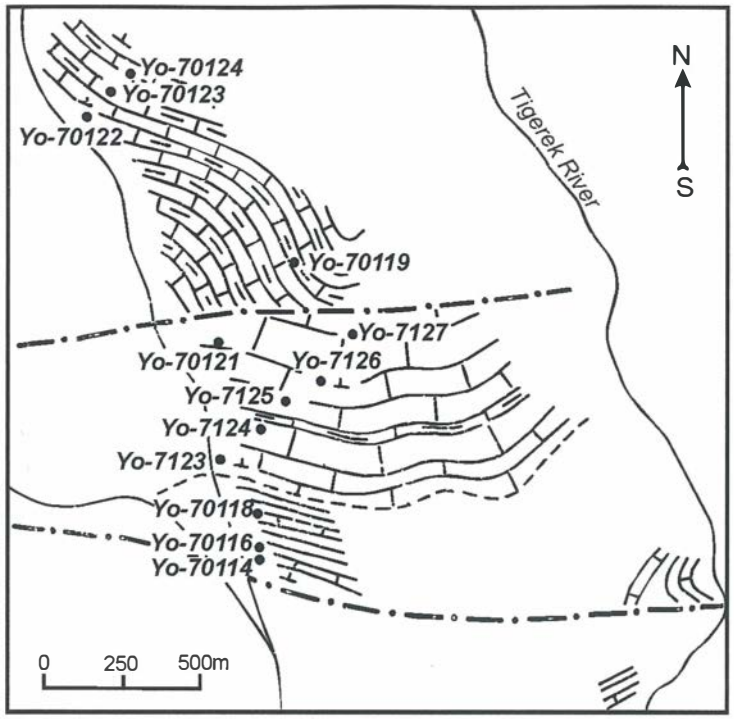


Fig. 57. Sketch map of the left bank of Tigerek River, near Tigerek Village (modified from Yolkin et al., 1974).

Janius exsul (Barr.), *Atrypa reticularis* (Linn.), *Dolerorthis* ex gr. *rustica* (Sow.), trilobites *Warburgella obscura* Yolk., ostracods *Ochescaphella* aff. *aitaica* Pol., *Longiscula silurica* Bazarova, tabulate corals, gastropods, bryozoans, graptolites (loc. S-7056) *Monograptus* sp. ..... ~60

The exposed section is interrupted being buried under a small ravine and continues up along a cape which rises to Mayak Hill. The section from the hill toe includes:

5. Limestone: dirty gray, locally dark or gray, slightly clayey, massive, poor in fauna; with stromatoporoids (loc. Yo-7123): *Actinodictyon* (?) cf. *quebecense* Steam et Hubert, *Parallelostroma tuberculatum* (Yavor.), rugose corals *Neobrachielasma variabilis* Zhelt., *Pycnostylus guelphensiformis* Zhelt., brachiopods *Conchidium biloculare* (Linn.), tabulate corals, trilobites and ostracods. ..... ~15

6. Limestone: similar to that in member 5; fossils are likewise rare, as in member 5, and include (loc. Yo-7124) rugose corals *Pycnostylus quelphensiformis* Zhelt., brachiopods *Conchidium* aff. *biloculare* (Linn.), *Schellwienella* aff. *williamsi* Kulk., ostracods *Ochescaphella* aff. *aitaica* Pol., tabulate corals and stromatoporoids ..... ~55

7. Limestone: dirty gray, unevenly laminated, with thin- to thick-bedded varieties grading into one another along the strike; bedding planes are rough, often bioclastic, with clay material localized along them; abundant fossils include (loc. Yo-7125) stromatoporoids *Diplostroma pseudobilaminatum* (V. Khalf,); rugose corals *Neobrachielasma variabilis* Zhelt., *Ryderophyllum kasandiensis* Tchern., *Zelophyllum ludlovensts* Zhelt., *Pycnostylus guelphensiformis* Zhelt., *Cystiphyllum* ex gr. *inense* Zhelt. sp. n., *Cysticonophyllum gukovensiformis* Zhelt., brachiopods *Ferganella borealis* (Schloth.), *Atrypella operosa* Kulk., *Howellella elegans* (Muir-Wood); trilobites *Warburgella obscura* Yolk., *War. uerecunda* Yolk., ostracods *Ochescaphella* aff. *altaica* Pol., *Microcheilinella rozhdestvenskajae* Neckaja and tabulate corals 40

8. Limestone: dirty gray or gray, massive, medium- and thin-bedded, locally bioclastic; with (loc. Yo-70121 and Yo-7126) stromatoporoids *Pycnodictyon densum* Moris, rugose corals *Zelophyllum ludlovensis* Zhelt.; brachiopods *Janius exsul* (Barr.), ostracods *Ochescaphella* aff. *altaica* Pol., *Libumella accurate.* Bazarova, *Microcheilinella rozdestuenskajae* Neckaja, tabulate corals and bryozoans 35

9. Limestone: gray or light gray, massive, of uncertain or thick bedding, often algal; rare fossils are (loc. Yo-7127) rugose corals *Neobrachielasma variabilis* Zhelt., *Ryderophyllum kasandiensis* Tchern., *Pycnostylus guelphensiformis* Zhelt., *Entelophyllum articulatum* (Wahl.); ostracods *Ochescaphella* aff. *altaica* Pol. and tabulate corals ..... ~ 30

Limestone member 9 builds the top of Mayak Hill and borders, along a fault, a section of mainly dark laminated limestone in the north which includes:

10. Limestone: dark gray or black, clayey, dense, thin- or medium-bedded (5–15 cm), with knobby bedding planes, locally detrital, with dark chert concretions (up to 5 cm); fossils are abundant and often silicified, which is especially well evident on weathered surfaces; faunas include tabulate corals, rugose corals, brachiopods, trilobites *Warburgella stokesii* (Murch.), ostracods etc. (loc. Yo-70119 = Yo-7122) 70

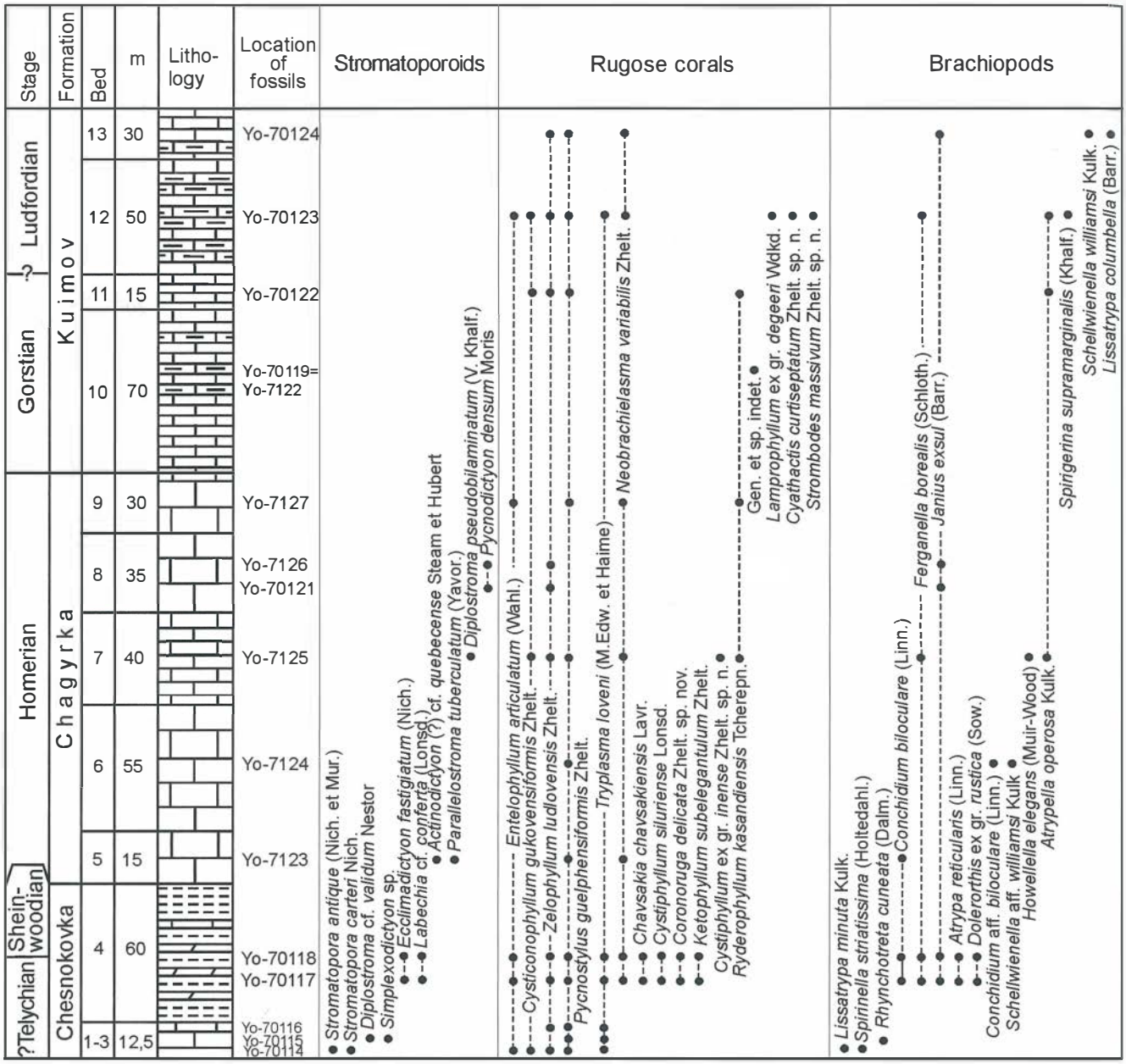
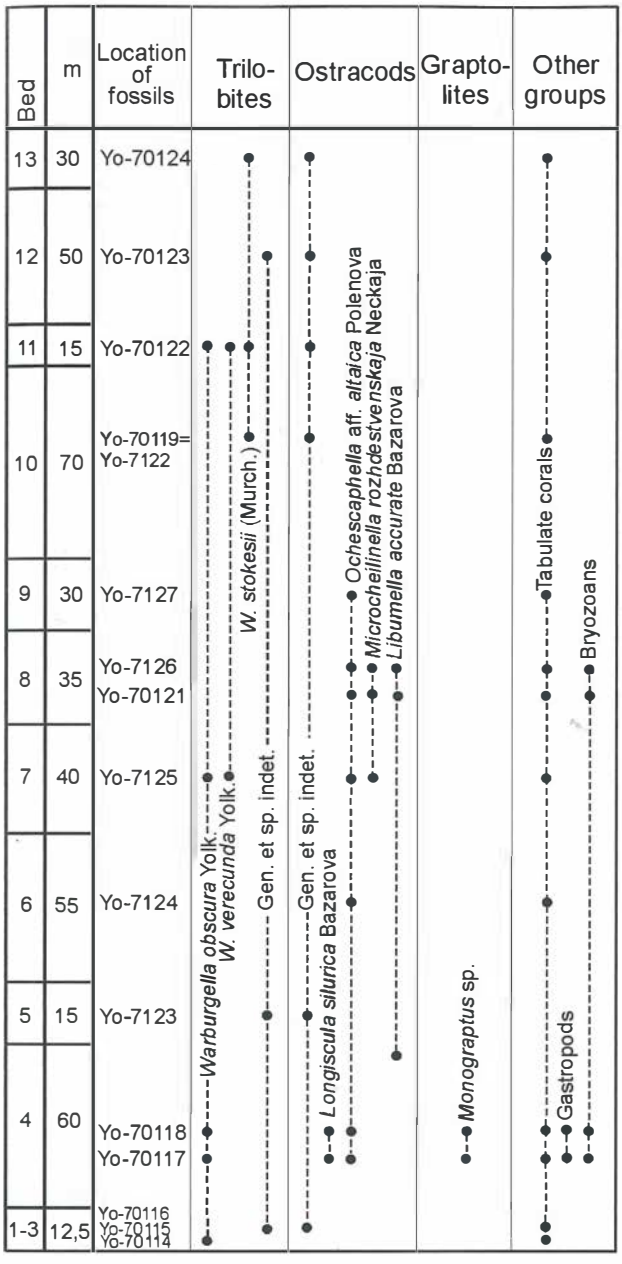


Fig. 58. Ranges of fossil taxa from Tigerek section.

Stratigraphically higher layers of the section are found in bedrock exposures up the valley and comprise:

11. Limestone: dark or dirty gray, slightly clayey, thin- or medium-bedded, deterital or bioclastic; with rugose corals *Ryderophyllum kasandiensis* Tcherepn., *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelphensiformis* Zhelt., *Cystiphyllum gukovensiformis* (Zhelt.); brachiopods *Atrypella operosa* (Kulk.), trilobites *Warburgella obscura* Yolk., *War. verecunda* Yolk., *War. stokesii* (Murch.) and ostracods (loc. Yo-70122) 15

12. Limestone: dirty gray or dark, clayey, alternating with purer detrital limestone, bedded or massive, with unevenly distributed clay component; clay-bearing layers are softer and weathered to yellowish; they commonly occur in topsoiled areas or in niches capped with aprons of massive limestone; massive limestone locally grades on strike into laminated varieties; alternation is rhythmic but the rhythms are not very distinct; member contains rugose corals *Neobrachielasma variabilis* Zhelt., *Lamprophyllum* ex gr. *degeeri* Wdkd., *Cyathactis curtiseptatum* Zhelt. sp. n., *Entelophyllum articulatum* (Wahl.), *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelphensiformis* Zhelt., *Strombodes massivum* Zhelt. sp. n., *Tryplasma loveni* (M.Edw. et Haime), *Cystiphyllum gukovensiformis* (Zhelt.), brachiopods *Ferganella borealis* (Schloth.), *Atrypella operosa* (Kulk.), *Spirigerina supramarginalis* (Khalf.), tabulate corals, trilobites, ostracods etc. (loc. Yo-70123) ..... ~50



13. Limestone: similar to that of member 12 but making three distinct rhythms; first rhythm begins with dark thin-bedded clayey limestone (12 m) which grades into gray and dark gray massive limestone (3 m), locally rich in brownish-yellow clayey material localized in isolated nests; second and third rhythms have a similar structure but different thicknesses of the constituent subrhythms; second rhythm is 7.5 m (6 m clayey and 1.5 m massive limestone) and the third one is 6 m thick (4 m and 2 m, respectively); layers of massive limestone, locally with small algal bioherms separate the valley where the section runs from the Inya River valley; faunas include tabulate corals, rugose corals *Neobrachielasma variabilis* Zhelt., *Zelophyllum ludlovensis* Zhelt., *Pycnostylus guelphensiformis* Zhelt.; brachiopods *Schellwienella williamsi* Kulk., *Lissatrypa columbella* (Barr.), *Janius exsul* (Barr.); trilobites *Warburgella stokesii* (Murch.) and ostracods (loc. Yo-70124) ..... ~30

Members 1 through 4 belong to the Chesnokovka Formation, members 5 through 9 belong to the Chagyrka Formation (Fig. 59), and members 10 through 13 belong to the Kuimov Formation (Fig. 60). The incomplete thickness of the Chesnokovka Formation in the section is more than 70 m, the Chagyrka Formation is 175 m, and the Kuimov Formation is 165 m thick.

3.2. Northwestern Gorny Altai

3.2.1. Area of Ust'-Muta Village

Marchetyonok Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: ?Tremadocian.

Regional stratigraphic subdivisions: Tayanza and Lebed' regional stages (horizons).

Local lithostratigraphic subdivisions: Marcheta Formation.

Marine Ordovician sections in the vicinity of Ust'-Muta Village occur in separate fault blocks on the left bank of the lower Marcheta River (Fig. 61). The section (S-012) of the Marcheta Formation (Zasur'ya Group) is located on the left bank of the Marchetyonok Brook (Marcheta left tributary), 1350 m far from its mouth, and comprises (Fig. 62):

Thickness, m

1. Mudstone: clayey, flaggy (30–40 cm to 2–3 cm), of weakly undulate thin bedding; color of rocks changes within a distance of 50 m along member strike from lilac-red to lilac-brown and yellowish-brown-gray (Fig. 63) 20

2. Mudstone: lilac or lilac-gray, flaggy (1–3 cm), with traces of clay flowage around more solid clay concretions; the latter quite regularly align with bedding and vary in size from 3–5 to 10 cm in length and from 2 to 5–7 cm in width; greenish-gray varieties occur as lenses or concretions 6

3. Mudstone: gray or lilac, lumpy, of uncertain bedding 1.5

4. Mudstone: greenish-gray, siliceous, lumpy; member encloses layers with 50–70 cm long and 15–20 cm thick (up to 1.5–2,0 m × 10–50 cm at the member top) lenses of purple clayey siltstone 2

5. Mudstone: gray, clayey-siliceous, lumpy or flaggy (1–2 cm), with a ~5 m long and 1.5 m thick lens of blue-gray to lilac siliceous mudstone 7

6. Mudstone: sea-green, clayey, unbedded 1

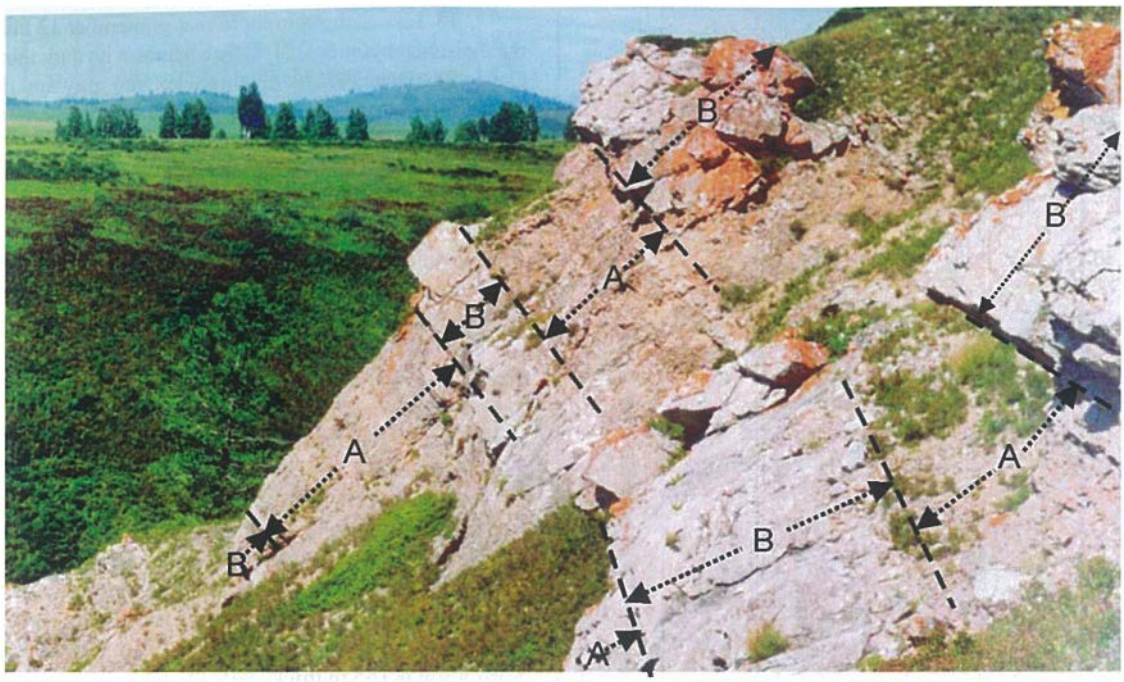


Fig. 59. Rhythmic limestones from the Silurian Kuimov Formation, Tigerek section, member 12.

Fig. 60. General view of the outcropping stratotype section of the Silurian Kuimov Formation on the right bank of Inya River, upstream of Tigerek Village.

7. Mudstone: dirty gray, with lilac hue, clayey, of weak undulate bedding, with concretions (10–15 cm long, 3–5 cm thick) that bear signature of soft sediment slumping in upper layers; rocks are uneven in color and pass on strike into lilac-red or light gray varieties 5

8. Mudstone: dirty olive or gray, of uncertain bedding, locally with lighter-color massive varieties; mudstone in upper layers is flaggy (2–5 cm), with weakly undulate bedding planes 7

All members of the section, with a total thickness of ~50 m, belong to the Marcheta Formation. The Marchetyonok Section is conventionally correlated with the Tremadocian-Dapingian boundary.

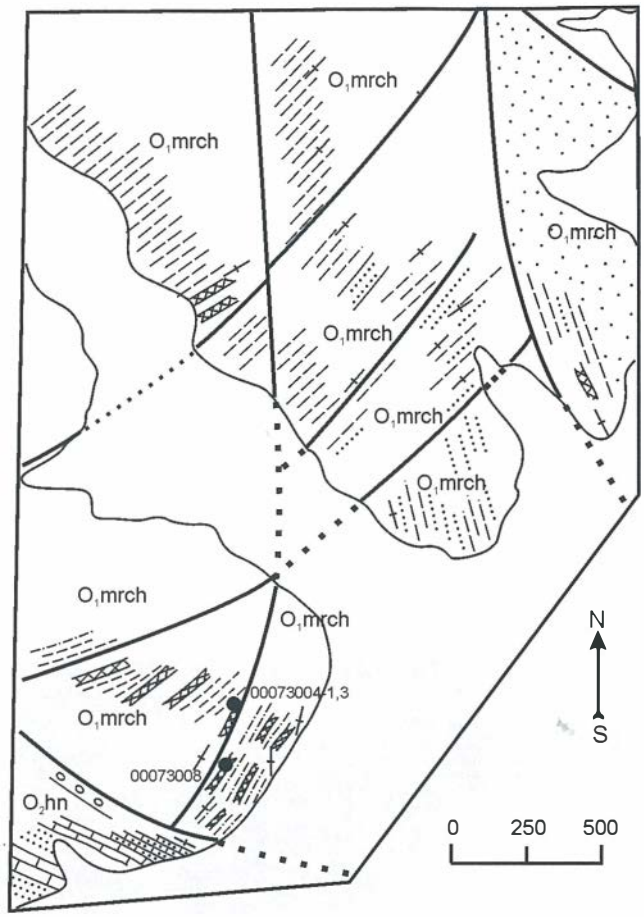


Fig. 61. Sketch map of the location on the right bank of the downstream of Marcheta River (modified from Sennikov et al., 2001b).

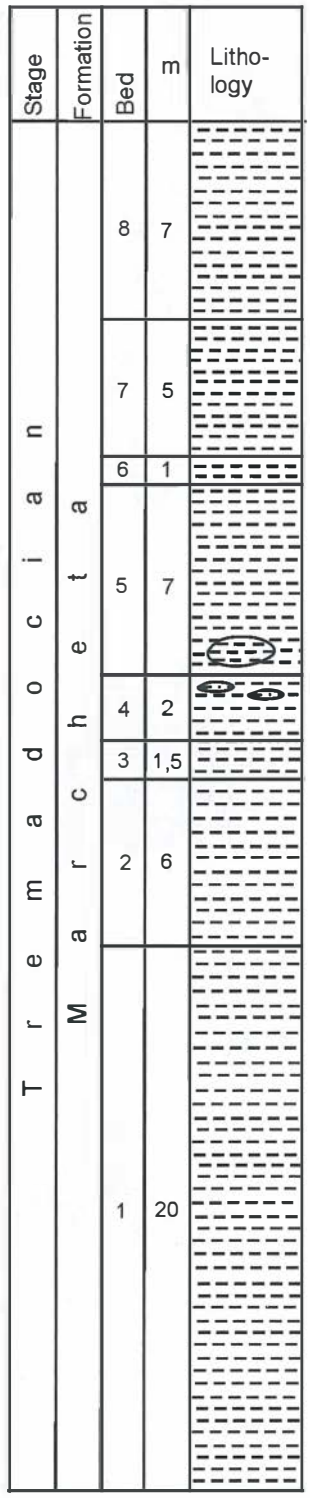


Fig. 62. Marchetyonok section.

Marcheta-1 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Tremadocian, Floian.

Regional stratigraphic subdivisions: Tayanza and Lebed' regional stages (horizons).

Local lithostratigraphic subdivisions: Marcheta Formation.

Zones: *proteus* conodont zone.

Fauna: conodonts, radiolarians, demosponges.

Another section of the Marcheta Formation (S-002) crops out on the left bank of the Marcheta River (left tributary of the Muta River), 900 m far from the Marchetyonok Brook inflow. The section begins at the floodplain terrace, then follows the second ridge from the Marchetyonok value, reaches the Marcheta/Marchetyonok divide, and ends at the top of 1201.0 m mountain. It comprises (Fig. 64):

Thickness, m

1. Mudstone: light green or dark olive, clayey, slightly siliceous, thin-banded, flaggy (1–2 cm) in lower 10 m and massive or lumpy above 70

2. Mudstone: dark olive-gray or light greenish, siliceous-argillaceous, with thin (0.5 cm) banding produced by shade variation and high silica contents 25

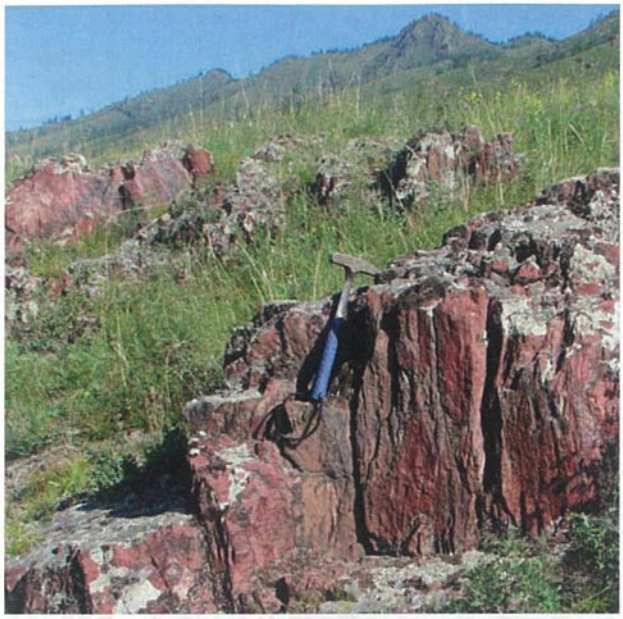


Fig. 63. Violet-reddish mudstones from the Ordovician Marcheta Formation, Marchetyonok section, member 1.

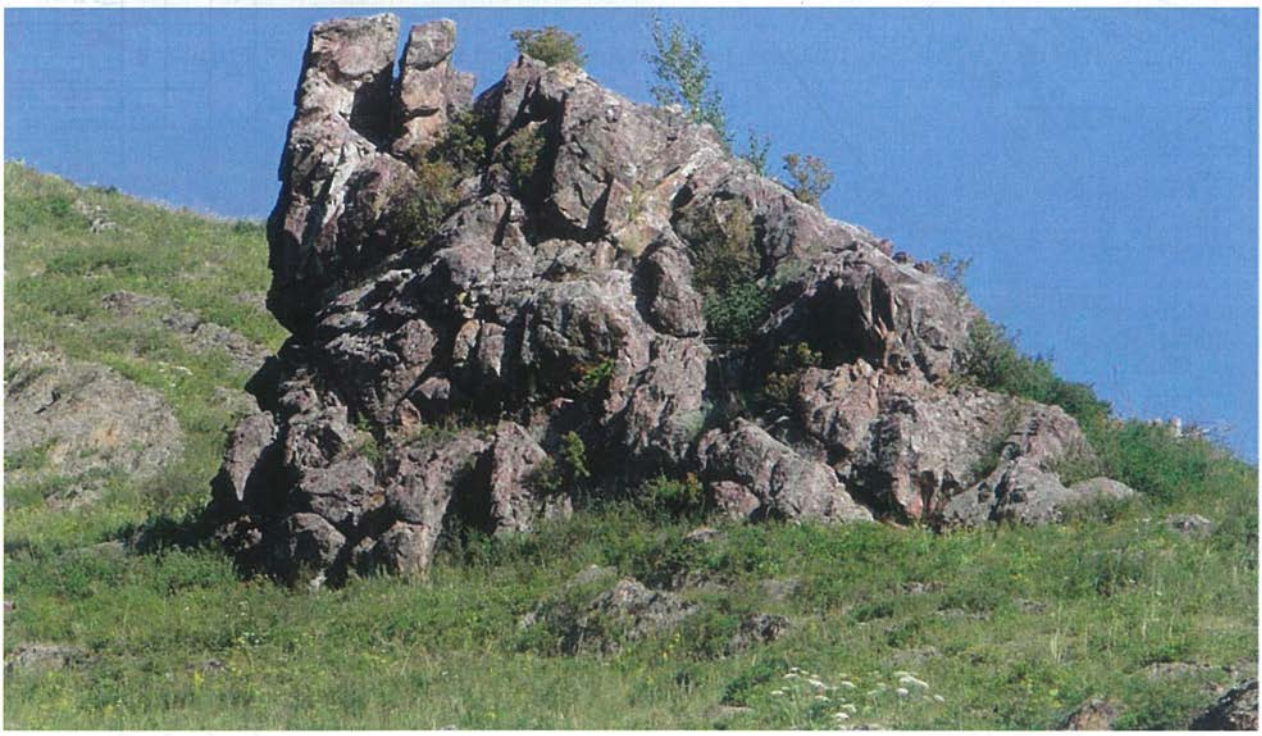


Fig. 65. Massive cherts (hydrothermal quartzites?, jasperoids?) from the Ordovician Marcheta Formation, Marcheta-1 section, member 6.

3. Mudstone: cream-colored or brown, clayey, massive or lumpy, of uncertain bedding 10
4. Rocks similar to those in member 2 but not banded 8
5. Mudstone: sea-green, clayey, uncertainly bedded, massive, containing a 10-15 cm thick layer with 10 × 5 cm lenses or beads of red rocks from overlying member 6 7
6. Chert (hydrothermal jaspellite?) (Fig. 65): red, uncertainly bedded, massive, largely impregnated with ore minerals (hematite); member is lens-shaped: about 40 m long and 0 to 2-6 m thick .....
7. Mudstone: sea-green, uncertainly bedded, massive 23
8. Mudstone: lilac with gray hue 0.3

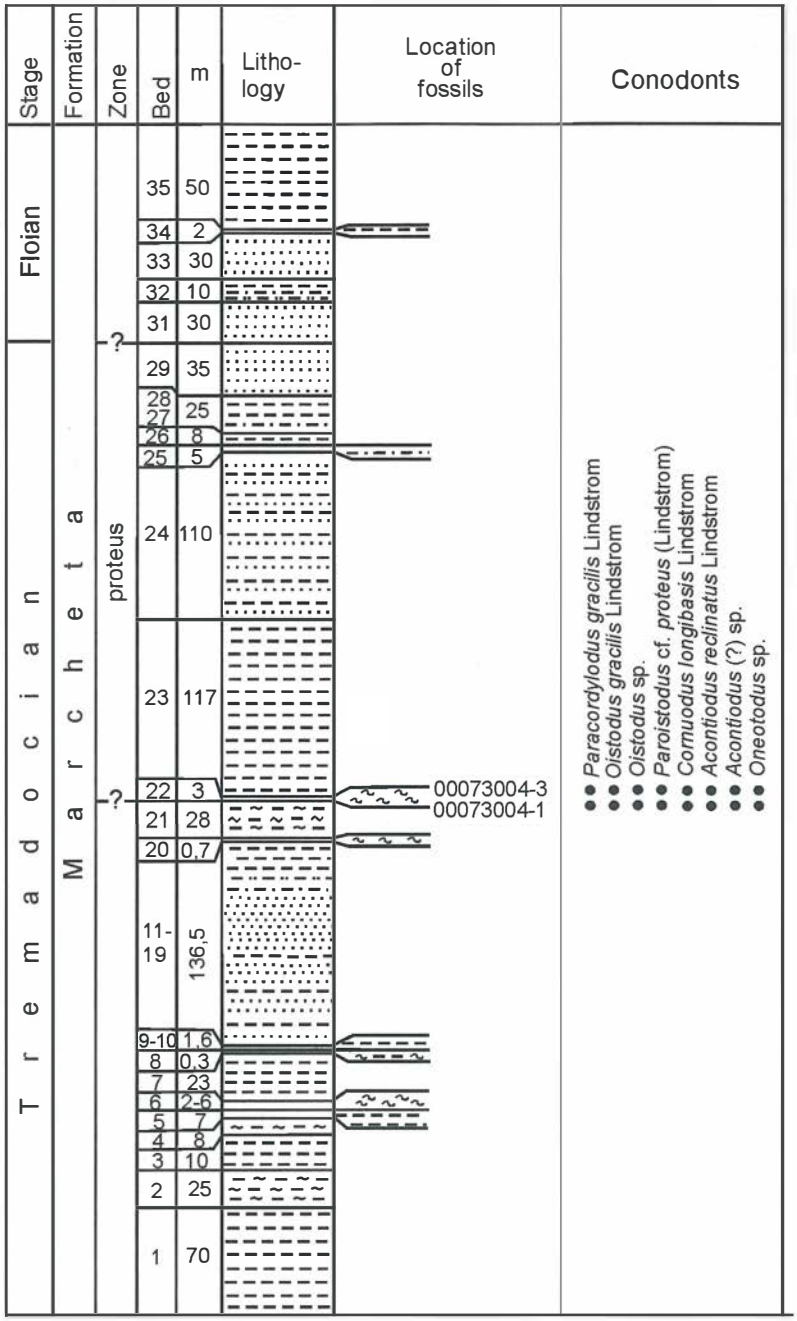


Fig. 64. Ranges of fossil taxa from Marcheta-1 section.

9. Mudstone: lilac with gray hue, clayey, with small lenses of gray chert 0.1
10. Mudstone: lilac, clayey 1.5
11. Sandstone, locally gravelstone: greenish-gray, coarse 0.5
12. Mudstone: dark olive-green, clayey, lumpy, and sandstone, finegrained 2
13. Rocks similar to those in member 11 8
14. Mudstone: dark olive, clayey 4
15. Rocks similar to those in member 11, with sporadic 1–3 cm long lenses of green clayey siltstone 20
16. Mudstone: dark olive-green, clayey 3
17. Rocks similar to those in member 11, with gray-green or sea-green hues in upper layers 60
18. Siltstone or silty sandstone: bright green 5
19. Mudstone: green, clayey 34

20. Chert (possibly, hornfelsed): red or locally yellowish, with radiolarians and siliceous sponge spicules 0.7
21. Mudstone: bright green, siliceous-argillaceous 28
22. Mudstone: dark red, argillaceous and siliceous-argillaceous; with conodonts in lower (loc. 00073004-1) and upper (loc. 00073004-3) layers: of the *proteus* zone – *Paracordylodus gracilis* Lindstrom, *Oistodus gracilis* Lindstrom, *Oistodus* sp., *Paroistodus* cf. *proteus* (Lindstrom), *Cornuodus longibasis* Lindstrom, *Acontiodus reclinatus* Lindstrom, *Acontiodus* (?) sp., *Oneotodus* sp. . 3
23. Mudstone: gray or dark olive-gray, clayey 117
24. Mudstone and fine sandstone: green 110
25. Siltstone: light-green, clayey 5
26. Mudstone: reddish brown, siliceous-argillaceous 8
27. Siltstone: dirty gray, clayey 10
28. Mudstone:dark olive-gray, clayey 15
29. Sandstone: green, poorly sorted, fine 35
30. Siltstone: lilac, clayey 1.5
31. Sandstone: green or dirty gray, poorly sorted, fine massive, of uncertain bedding 30
32. Mudstone: green and dirty gray silty sandstone grading upward into siltstone and then to 10
33. Sandstone: green and dirty gray fine 30
34. Mudstone: reddish-gray siliceous-argillaceous 2
35. Mudstone: dark olive-green clayey ..... ~50

All members, about 730 m of total thickness, belong to the Marcheta Formation.

Section Marcheta-2

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Floian.
Regional stratigraphic subdivisions: Lebed' Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Marcheta Formation.
Zones: *elegans* conodont zone.
Fauna: conodonts, radiolarians, demosponges.

Another section of the Marcheta Formation (S-013) crops out 300 m westward of the Marcheta-1 section, opposite a spring on the left bank of the Marcheta River. The section begins 100 m far from the hill toe. It exposes upper strata of the Marcheta-1 section but with slightly different lithologies and different member thicknesses. The Marcheta-2 section comprises (Fig. 66):

Thickness, m

1. Mudstone: plae dark olive-gray, clayey, massive 150
2. Mudstone: variegated, lumpy; rocks are mainly of dirty gray and dark colors; lilac and dirty lilac rocks occur in bedding-parallel lenses (patches) with either diffuse or sharp boundaries, looking like clasts (up to 20 cm); there are also <3 cm patches (clasts?) of red, bright lilac or green rocks; very thin bedding of 0.5 mm occurs occasionally 17
3. Mudstone: silver-gray, clayey 9
4. Sandstone: greenish-gray (to sea-green), fine 6
5. Syndepositional breccias in a matrix of dark olive-gray mudstone, with 1–3 cm clasts (occasionally 5–7 cm) of lilac, gray, or reddich mudstone more siliceous than the matrix; clasts often consist of thinly (3–5 mm) interbedded lilac and gray rocks. Clasts occasionally occupy up to 50 % of rock volume, but become progressively less abundant up the layer 3
6. Mudstone: lilac or gray, clayey, lumpy; colors are randomly distributed and change rapidly from lilac to gray both laterally and upwards 10
7. Mudstone: red-lilac or red-lilac-gray, clayey, of uncertain bedding, with round nodules of more siliceous rocks; rocks at 8 m above member base show weakly undulate 2 cm banding 12
8. Mudstone: greenish-gray, clayey, massive 5
9. Mudstone: lilac or green-gray, massive, lumpy; rocks change color rapidly both laterally and upwards: within 30 m along strike they pass into lilac-red clayey mudstone with siliceous nodules; a lens of red chert, 2–3 m long and 2–3 m thick (loc. 00073008) contains radiolarians, siliceous sponge spicules, and conodonts of the *elegans* zone – *Juanognathus* (?) sp., *Paroistodus* cf. *paralellus* (Pander), *Paroistodus* sp., *Drepanoistodus* sp. 12
10. Mudstone, massive, and siltstone, greenish-gray or dirty gray, with sporadic nodules of greenish-gray fine sandstone 60
11. Randomly interbedded fine sandstone, siltstone, and mudstone, greenish-gray to dirty dark olive-gray; a 2-m lens of lilac clayey mudstone in upper layers shows 1-3 mm banding and isometric 1–2 cm patches ..... ~70
12. Mudstone: lilac, clayey, wavy-bedded, lumpy 3

All members, about 360 m of total thickness, belong to the Marcheta Formation.

Lithologies, especially in siliceous members, grade rapidly into one another along the strike in the three Marcheta sections: 6 m of red chert pass into red low-silica mudstone and siltstone within a distance of 30-50 m and then into gray

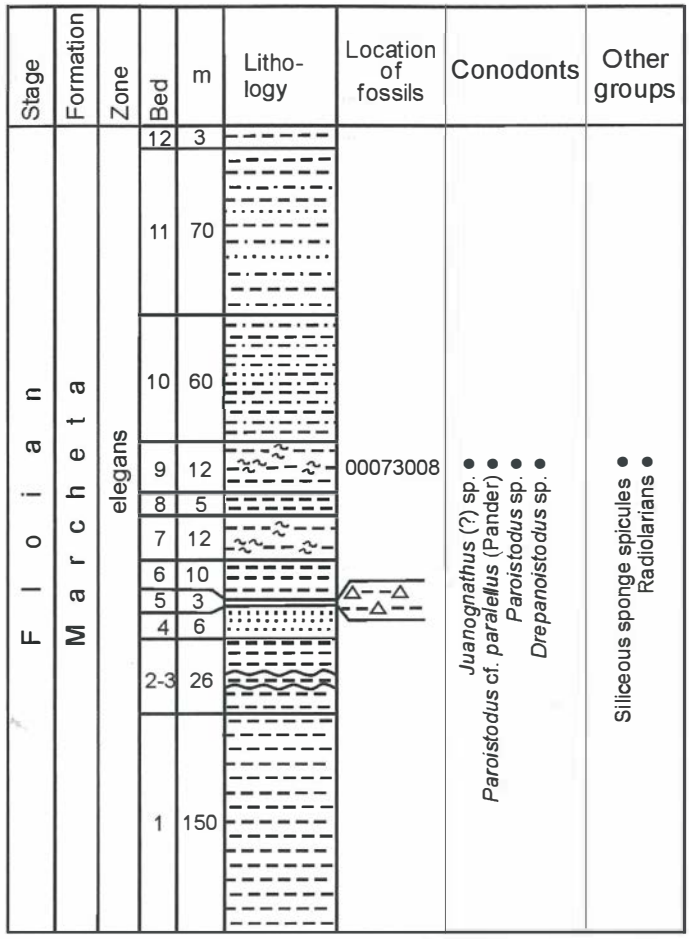


Fig. 66. Ranges of fossil taxa from Marcheta-2 section.

mudstone and siltstone 50–70 m away. Color changes still more rapidly from red or lilac to sea-green, gray, dark olive, etc. Loaf-shaped concretions and traces of clay flowage found in the Marchetyonok Section and a syndepositional breccia in the Marcheta-2 Section are typical of slope facies. Taking into account the marine origin of the Zasur'ya sediments, one may assume that the Marchetyonok Section formed on a seamount slope and the Marcheta-1 and Marcheta-2 sections were deposited on the sea floor in a vicinity of such a slope.

Section Tekhten'

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian, Rhuddanian, Aeronian.

Regional stratigraphic subdivisions: Tekhten', Vtorye Utyosy and Syrovaty regional stages (horizons).

Local lithostratigraphic subdivisions: Tekhten', Vtorye Utyosy, Syrovaty formations.

Fauna: tabulate corals, rugose corals, trilobites, brachiopods, crinoids, graptolites.

The stratotype section of the Upper Ordovician Tekhten' Formation (Tekhten' Regional Stage) and the overlying Lower Silurian Vtorye Utyosy Formation is located on the right bank of the Tekhten' Brook, the right tributary of the Muta River, near Ust'-Muta Village (Fig. 67). The formation, in a much smaller stratigraphic volume, was formerly named the Dietken Formation according to *Dietken*, wrong respelling of an Altai name used in topographic maps. The documented section begins on the right side of a small ravine, 400 m from point 1181.0 m at azimuth 210°. The main section rises from the hill toe to point 1181.0 m and continues to the top at 1451.0 m. Members 1 and 2 and lower member 3 crop out 200 m to the north of the section origin where the section begins with member 3. The section includes (Figs 68, 69):

Thickness, m

1. Interbedded siltstone and silty sandstone, dark olive-gray 15

2. Limestone: black, pelitic ..... ~40

3. Limestone: gray, slightly clayey, massive, containing 0.3 × 1.0 algal-biohermal buildups, with Late Ordovician tabulate corals *Nyctopora dietkensis* Galen. sp (loc. 2018) ..... ~80

4. Limestone: black, flaggy (10-30 cm); with indetermined corals, Late Ordovician rugose corals (loc. 2032) *Parabrachielasma lebediensis* Tcherepn., *Grewingkia altaica* (Tcherepn.), *Ditoecholasma kanica* (Tcherepn.) and Late Ordovician tabulate corals *Catenipora dietkensis* Dziubo in the middle part of the member 30

5. Sodded interval (near point 1181.0 m) 20

6. Siltstone: argillaceous-calcareous, and fine sandstone, gray 20

The top of member 6 is truncated by a fault and then the section is duplicated (members 4 through 6):

4. Limestone: black, eluvial; with Late Ordovician rugose corals (loc. S-77138-16, 2033/1, 2033): *Brachielasma* cf. *altaica* Tcherepn., *Parabrachielasma lebediensis* Tcherepn., *Grewingkia* cf. *altaica* (Tcherepn.), Late Ordovician tabulate corals: *Catenipora dietkensis* Dziubo, *Cyrthophyllum samyshiensis* Dziubo, *C. karasuensis* Dziubo, *C. kanitnsis* Dziubo, *Sibiriolites koldorakensis* Dziubo, *Pragnellia altaica dietkensis* Galen. subsp. n., *Plasmoporella kiaeri* Sok., *Nyctopora elandiensis* Dziubo, *Wormsipora karasuensis* Dziubo ..... at least 30

5–6. Interbedded gray, yellowish-gray or greenish-gray clayey siltstone and fine polymictic limy sandstone, with a 5-m thick layer of black siltstone, and layers of quartz sandstone nearby, at member base; in most of middle layers, polymictic sandstone gives way to quartz sandstone; sandstone layers generally predominate and contain floating pebble and gravel; gravel is locally abundant enough for the rock to be classified as gravelstone 120

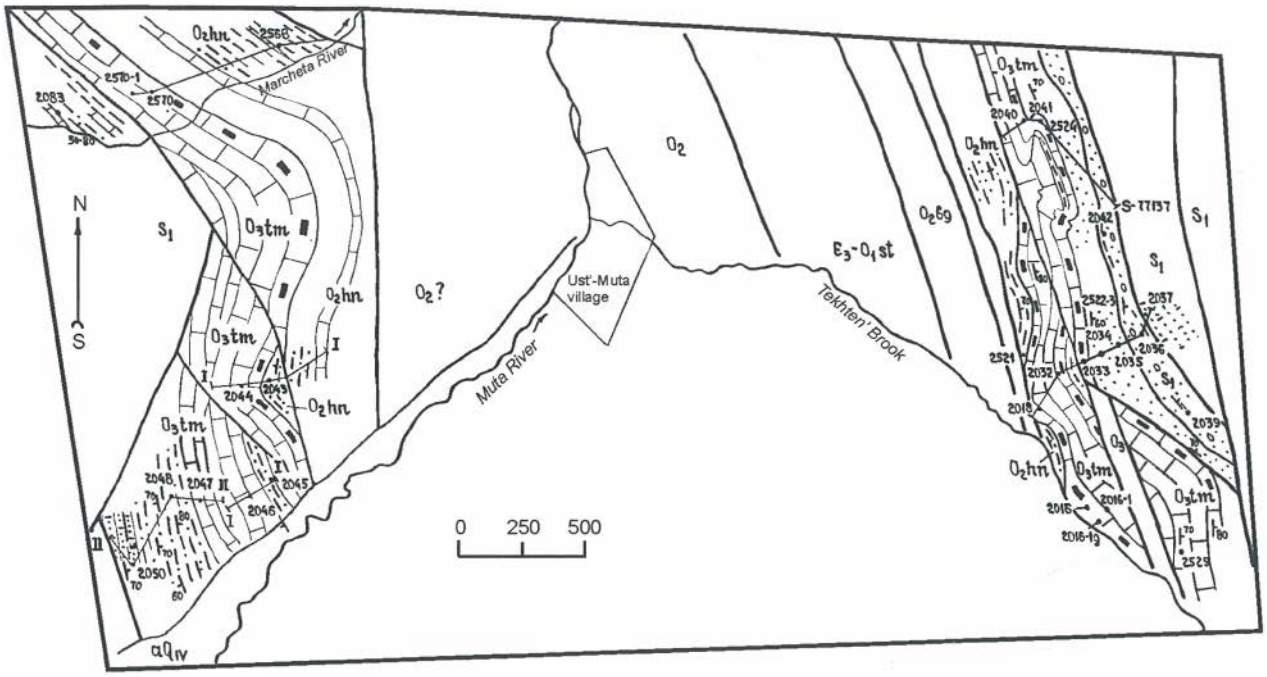


Fig. 67. Sketch map of vicinity of Ust'-Muta Village (modified from Sennikov et al., 2001a).

7. Siltstone: greenish, calcareous; with Late Ordovician tabulate corals (loc. 2034): *Cyrthophyllum* sp. and Ashgillian brachiopods *Catazyga anuensis* Severg., *Rostricellula buriduinica* Rozm. In 5 m from the top of the member (loc. S-77138-18/10) – brachiopods *Salairella anuensis* Severg., *Rostricellula sparsa asiatica* Rozm. *Cyrthophyllum* sp. and Ashgillian brachiopods *Catazyga anuensis* Severg., *Rostricellula buriduinica* Rozm. In 5 m from the top of the member (loc. S-77138-18/10) – brachiopods *Salairella anuensis* Severg., *Rostricellula sparsa asiatica* Rozm. Probably from the same member (loc. 5, year 1988) L.G. Severgina and L.V. Galenko have collected brachiopods *Raphinesquina* cf. *pseudoloricata* (Barr.), Late Ordovician rugose corals *Parabrachielasma* cf. *lebediensis* Tcherepn., *Ditoecholasma kanica* (Tcherepn.), *Grewingkia semilanatum* (Scheff.), Ashgillian tabulate corals *Catenipora dietkensis* Dziubo, *Cyrthophyllum samyshiensis* Dziubo, *C. karasuensis* Dziubo, *Sibiriolites koldorakensis* Dziubo, *Pragnellia altaica dietkensis* Galen. subsp. n., *Plasmoporella vesiculosa* Kiaer, *Paratetradium quadrilobatum* Sok. et Tes., *Tetradium dietkensis* Galen. sp. n., *Wormsipora karasuensis* Dziubo, *W. minuta* Dziubo 15

8. Sandstone: light gray or reddish-brown, quartz, medium and coarse 120

9. Sandstone: dirty yellow, highly calcareous, polymictic, fine, with up to 30 cm thick layers of calcareous siltstone in the middle which locally grades on strike into clayey limestone 30

10. Siltstone: light gray, highly calcareous; with Llandovery (or, possibly Late Ordovician?) corals (loc. 2035): rugose corals *Parabrachielasma* cf. *lebediensis* Tcherepn., *Ditoecholasma* sp., tabulate corals *Plasmoporella convexotabulata* Kiaer, *Wormsipora karasuensis* Dz., Heliolitidae 15

11. Sodded interval 5

12. Coarse clastic rocks, in three units: (i) lower 5 m of reddish-gray fine conglomerate (with quartz, limestone, siltstone, and sandstone pebble), (ii) middle 5 m of gravelstone, and (iii) upper 5 m of coarse polymictic rather quartz sandstone 15

13. Sandstone: dirty yellow or pale lilac, rather quartz, polymictic, fine, occasionally with layers of dirty green clayey siltstone 80

14. Interbedded (0.3–0.5 m) clayey siltstone and fine limy sandstone, greenish-gray; lower half of the member contains (loc. 2036) Early Silurian brachiopods: *Lenatoechia* (?) sp., (loc. 2036/1) Llandoverian brachiopods *Lenatoechia* cf. *elegans* (Nikif.), as well as Late Ordovician-Early Silurian tabulate corals *Taxopora* sp., *Palaeofavosites* sp. Upper half of the member encloses gray limestone layers varying on strike from 5 to 10 m thick. The limestone contains a layer replete with fossils (loc. 2037): numerous Silurian rugose corals *Entelophyllum* cf. *articulatum* Whal., *Microplasma* sp. and rare Llandoverian tabulate corals *Palaeofavosites balticus* (Rukhin), *Subalveolitella repeptina* Sok. ..... over 80

The section continues as far as the Muta/Anui river divide and then along the left side of the Surta Ravine (left bank of the Anui River near Bely Anui Village) as exposed alternating sandy-silty rocks with rare limestone layers containing rather representative Llandoverian corals and brachiopods.

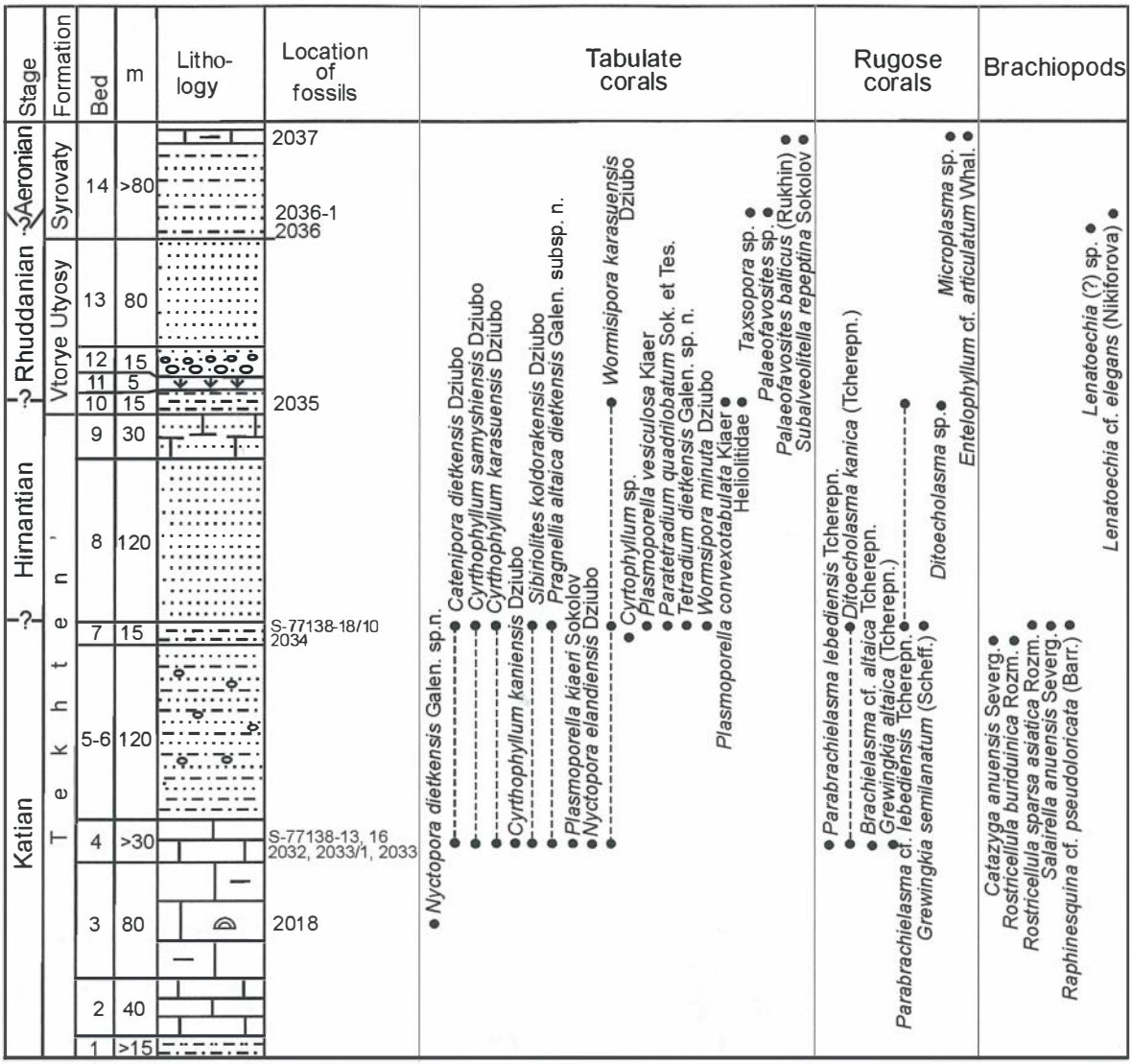


Fig. 68. Ranges of fossil taxa from Tekhten' section.

Some members of the section are clearly traceable southeastwards and northwestwards providing additional faunal evidence. For instance, black flaggy limestone, an equivalent of member 2 on the right side of the upper Shiroky Ravine (a small ravine across the right Tekhten' watershed), 470 m far from point 1251.0 m at azimuth 35° (loc. 2040, 2041) contains Late Ordovician rugose corals: *Grewingkia altaica* (Tcherepn.), *Parabrachielasma lebediensis* Tcherepn., *Ditoecholasma kanica* (Tcherepn.), tabulate corals *Cyrtophyllum kaninensis* Dziubo, *C. samyshiensis* Dziubo. Equivalent of member 10 on the southern slope of point 1402.0 m, (loc. 142) trilobites *Acernaspis (Eskaspis) superciliexcelsis* Howells, *Acer. (Escaspis) becsciensis* Lesp. et Leten., *Podowrinella* cf. *striatonensis* Clarks et all., Warburgenellinae, (loc. 2039) trilobites *Acernaspis (Eskaspis) superciliexcelsis* Howells, *Acer. (Escaspis) xynon* Howells, Warburgenellinae, brachiopods *Isorthis prima* Walm. et Boucot, *Leptaena* cf. *haverfordensis* Bancr., *Atrypa* (?) *lindstromi* Wenjuk., *Eospirigerina* (?) sp., rugose corals *Cyathactis* sp., *Holophragma* sp., as well as dendroid graptolites were collected.

Members 1 through 9 belong to the Tekhten' Formation, members 10 through 13 belong to the Vtorye Utyosy Formation, and member 14 belongs to the Syrovaty Formation. The thickness of the Tekhten' Formation in the section is about 470 m, the Vtorye Utyosy Formation is 115 m thick, and the incomplete thickness of the Syrovaty Formation is over 80 m.

Fig. 69. General view of Tekhten' section (Ordovician Tekhten' Formation, members 2–9).

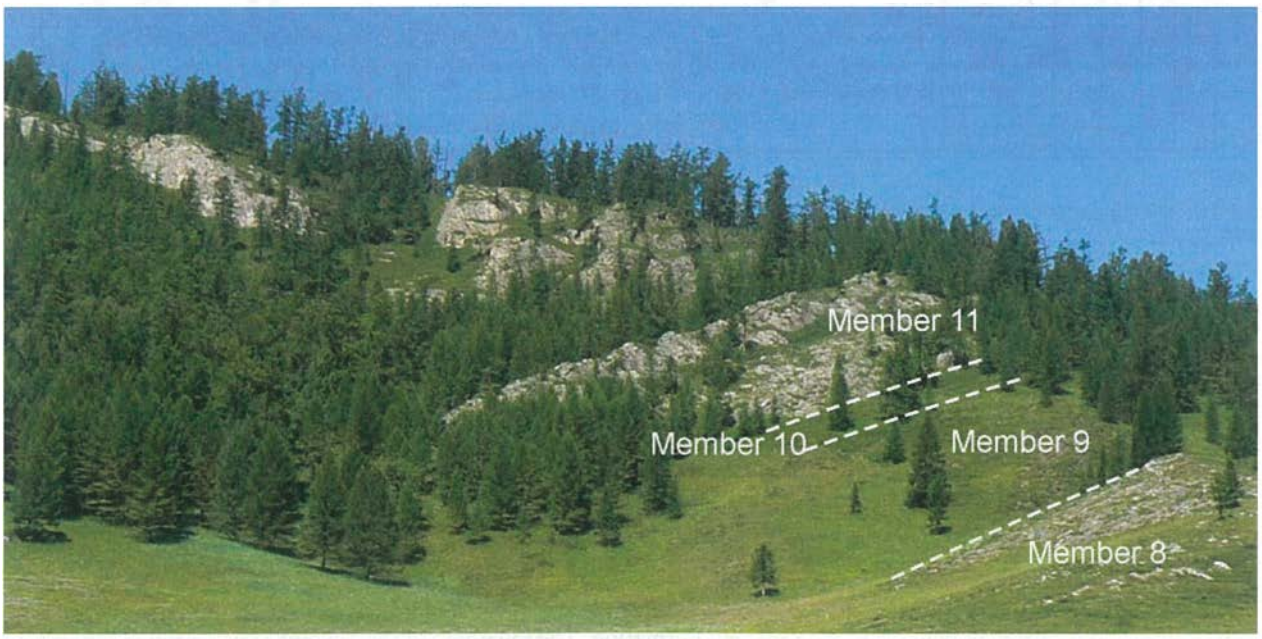


Fig. 71. General view of the exposed upper part of Muta section (Ordovician Tekhten' Formation, members 8–11).

Muta Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, Hirnantian.

Regional stratigraphic subdivisions: Tekhten' Regional Stage (Horizon).

Local lithostratigraphic subdivisions: Tekhten' Formation.

Zones: *supernus* graptolite zone.

Fauna: stromatoporoids, tabulate corals, rugose corals, trilobites, crinoids, graptolites.

A sequence of lithologies different from the Tekhten'-type section but of the same Upper Ordovician age occurs 3 km to the west of the Tekhten' Brook. The section exposed at the Muta site originates 2.5 km uphill from Ust'-Muta Village on the left side of a ravine that crosses the Muta left watershed (Figs. 70, 71). It includes:

Thickness, m

1. Limestone: gray, laminated (5 to 20 cm) ..... ~ 50
2. Sodded interval 30

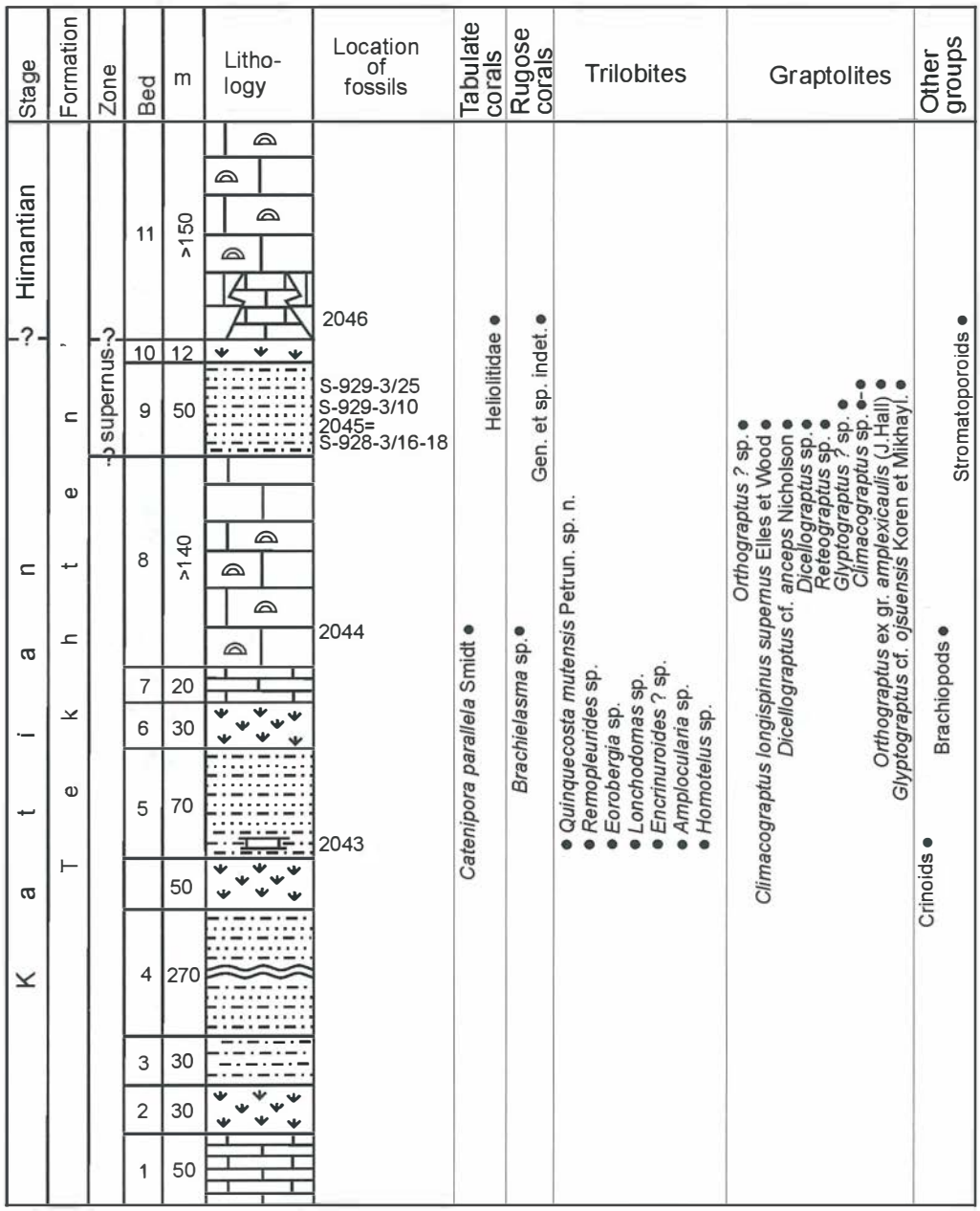


Fig. 70. Ranges of fossil taxa from Muta section.

Fig. 73. General view of Chichka section (members 16-19 - Silurian Polaty Formation, member 20 - Silurian Chesnokovka Formation).

Fig. 76. General view of reef limestones from Silurian Polaty and Chagyrka formations exposed on the right bank of the Anui River, downstream of Cherny Anui Village.

3. Siltstone: greenish-gray, clayey 30
4. Siltstone, thinly (0.1–0.05 m) interbedded with fine micaceous sandstone, gray or greenish-gray 270

Then the section continues after a 50-m sodded interval with siltstone and sandstone debris of member 4 (possibly, a buried fault):

5. Interbedded clayey siltstone and fine polymictic sandstone, dark olive-gray or light gray; at 15–20 m above member base there are scarce 0.2-0.3 m thick layers of gray crystalline limestone; limestone and siltstone nearby (loc. 2043) contain Middle Ordovician (second half of Caradocian) trilobites: *Quinquecosta mutensis* Petrun. sp. n., *Remopleurides* sp., *Eorobergia* sp., *Lonchodomas* sp., *Encrinuroides* ? sp., *Amplocularia* sp., *Homotelus* sp. and crinoids 70
6. Sodded interval 30
7. Limestone: dark gray or black, locally clayey 20
8. Limestone: gray or light gray, massive, with 0.5 × 1.5 m to 3 × 5 m algal-biohermal buildups that occupy up to 80 %

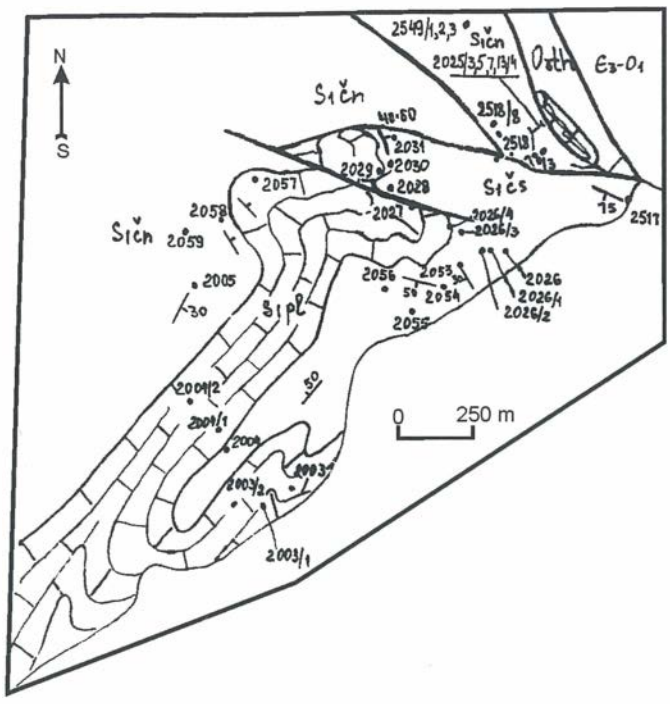


Fig. 72. Sketch map of the left slope of Chichka Ravine.

of rock volume. Limestone is flaggy (5–10 cm) in upper and lower layers; upper 8 m are of uneven bedding; lower 50 m (loc. 2044) contain Late Ordovician tabulate corals: *Catenipora parallela* Schmidt, Late Ordovician-Early Silurian rugose corals *Brachielasma* sp. and indetermined brachiopods ..... over 110

Then the section continues along the left bank of the Muta River toward Verkh-Muta Village, beginning at 2.75 km uphill from Ust'-Muta Village, in a ravine on the southeastern slope of 1132.7 m mountain, 300 m far from the top at azimuth 110°. The extended section includes:

8. Limestone: gray or light gray, massive ..... ~30

9. Interbedded (0.3–0.5–1,0 m) clayey siltstone and fine rather quartz sandstone, rarely with mudstone, gray, dark olive, or black; siltstone dominates over sandstone in lower layers; rocks have unevenly bedded lumpy structure; very thin color banding may be due to submarine roiling of soft sediment; member contains graptolites of the *supernus* zone (20-30 m above member base, loc. 2045 = S-928-3/16-18): *Orthograptus* ? sp., *Climacograptus longispinus supernus* Elles et Wood, *Dicellograptus* cf. *anceps* Nicholson, *Dicellograptus* sp., *Reteograptus* sp. (upper Katian) (Upper Ashgillian). In 100 m northward of the main section line, in 22 m from the base of the member (loc. S-929-3/10) Ordovician graptolites *Glyptograptus* ? sp., *Climacograptus* sp. were collected, and in 37 m from the base of the member (loc. S-929-3/25) – Late Ordovician graptolites *Orthograptus* ex gr. *amplexicaulis* (J.Hall), *Glyptograptus* cf. *ojsuensis* Koren et Mikhayl., *Climacograptus* sp. (upper Katian) ..... ~50

10. Sodded interval, with debris of member 9 and 11 rocks, possibly, a buried fault 12

11. Limestone: gray, massive, with 0.5 × 1.0 m to 2 × 3 m algal-biohermal buildups; limestone is locally black in a few poorly distinct lenses; member occurs along the axis of a synclinal fold; a layer 20 m above member base (loc. 2046) contains tabulate corals Heliolitidae and rugose corals and stromatoporoids ..... no more than 150

All members, about 780 m in total thickness, belong to the Tekhten' Formation.

Chichka Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Rhuddanian, Aeronian, Telychian, ?Sheinwoodian.

Regional stratigraphic subdivisions: Vtorye Utyosy, Syrovaty, Polaty and Chesnokovka regional stages (horizons).

Local lithostratigraphic subdivisions: Vtorye Utyosy, Syrovaty, Polaty and Chesnokovka formations.

Fauna: tabulate corals, rugose corals, trilobites, brachiopods.

The Silurian Chichka Section crops out near Kelei Village, on the left side of the Chichka Ravine (left bank of the lower Saldyk River, the left tributary of the Maly Kelei River) (Fig. 73) and spans the Vtorye Utyosy, Syrovaty, Polaty and Chesnokovka formations, namely (Fig. 74):

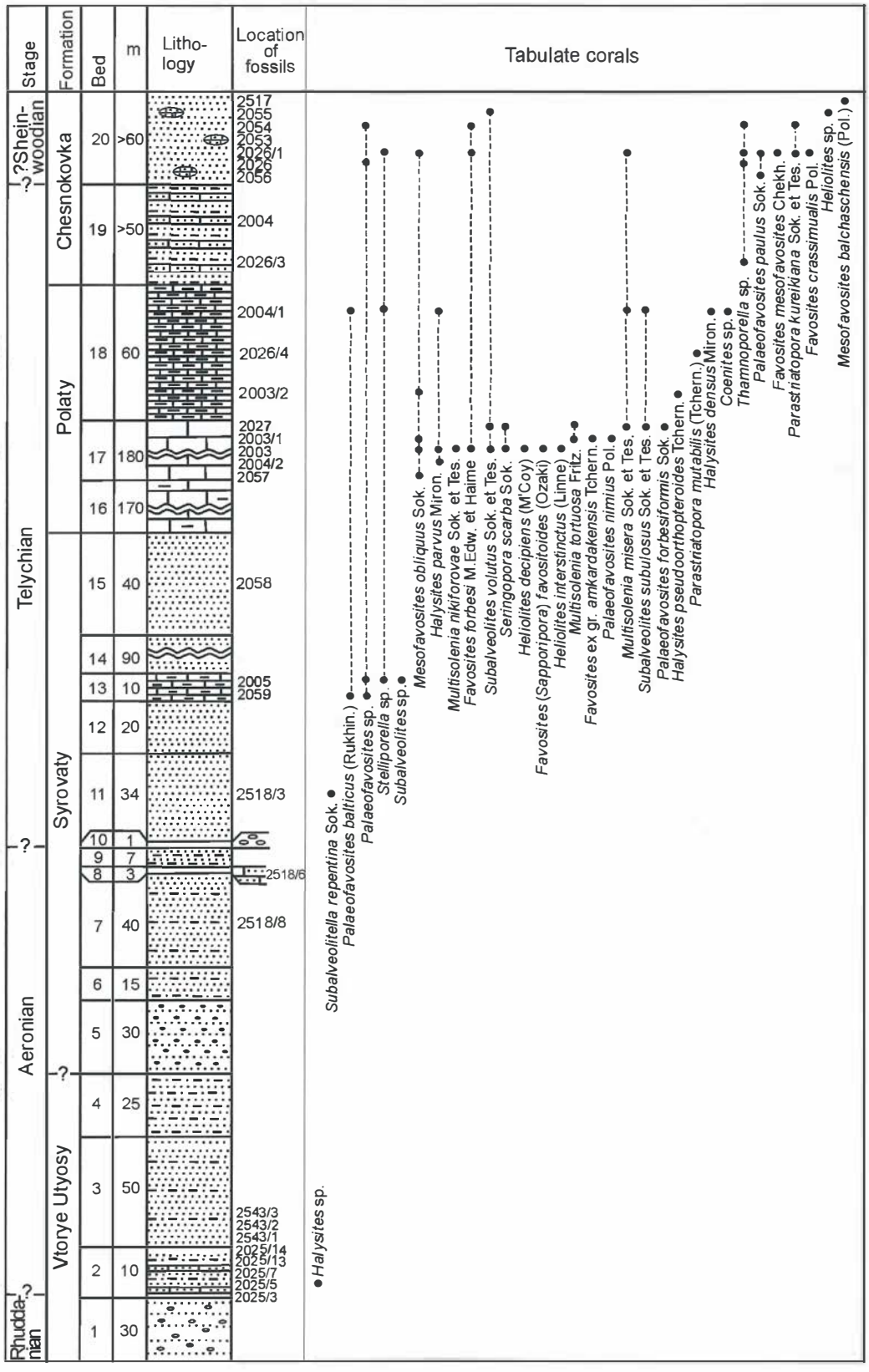
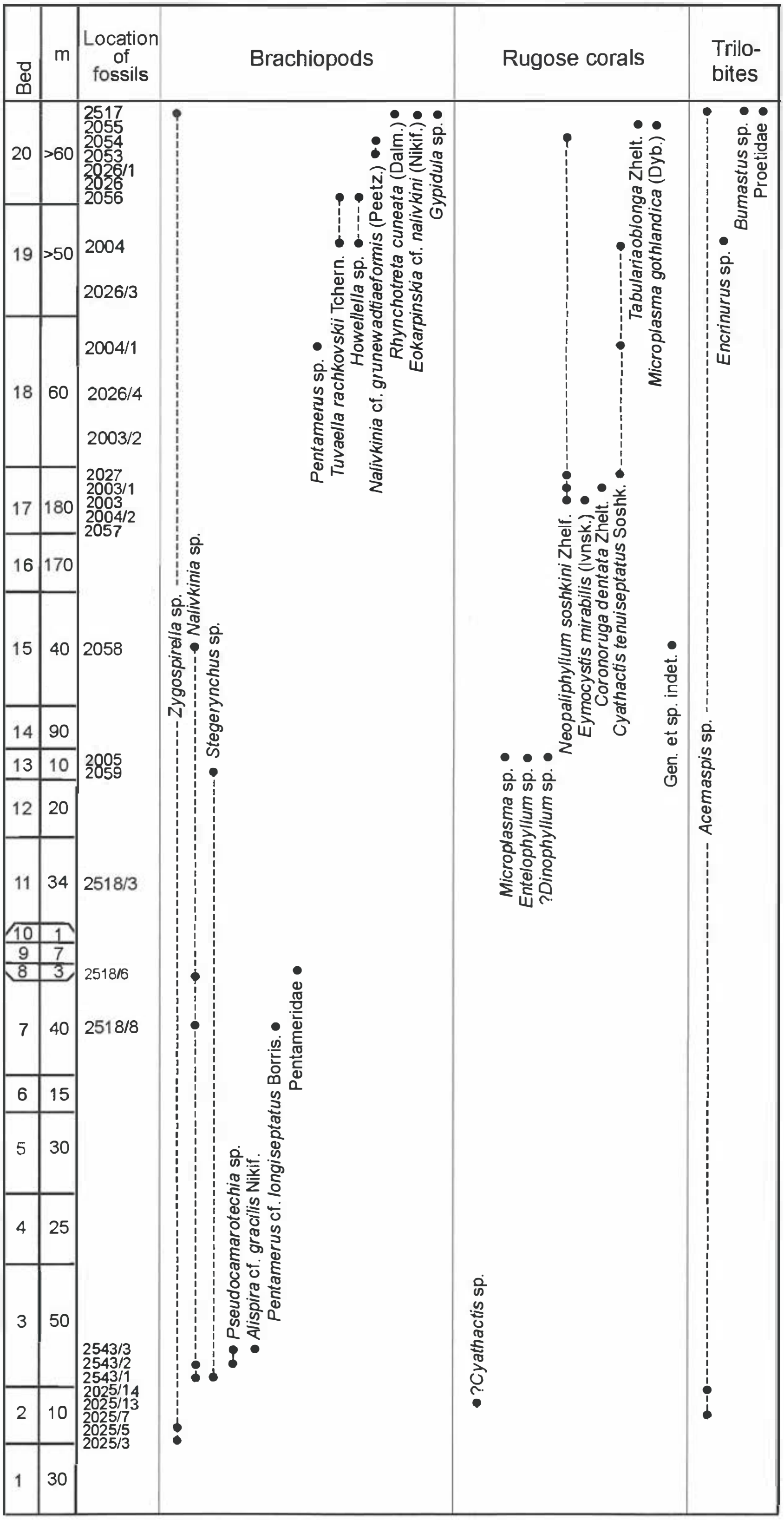


Fig. 74. Ranges of fossil taxa from Chichka section.


Bed
m
Location of fossils
Brachiopods
Rugose corals
Trilobites
Zygospirella sp.
Nalivkinia sp.
Stegerynchus sp.
Pseudocamarotechia sp.
Alispira cf. gracilis Nikif.
Pentamerus cf. longiseptatus Borris.
Pentameridae
Pentamerus sp.
Tuvaella rachkovskii Tchern.
Howellella sp.
Nalivkinia cf. grunewadtiaeformis (Peetz.)
Rhynchotreta cuneata (Dalm.)
Eokarpinskia cf. nalivkini (Nikif.)
Gypidula sp.
?Cyathactis sp.
Microplasma sp.
Entelophyllum sp.
?Dinophyllum sp.
Neopaliphyllum soshkini Zhelt.
Eymocystis mirabilis (Ivnsk.)
Coronoruga dentata Zhelt.
Cyathactis tenuiseptatus Soshk.
Tabularia oblonga Zhelt.
Microplasma gothlandica (Dyb.)
Gen. et sp. indet.
Acemaspis sp.
Encrinurus sp.
Bumastus sp.
Proetidae
20 >60 2517 2055 2054 2053 2026/1 2026 2056
19 >50 2004 2026/3
18 60 2004/1 2026/4 2003/2
17 180 2027 2003/1 2003 2004/2 2057
16 170
15 40 2058
14 90
13 10 2005 2059
12 20
11 34 2518/3
10 1
9 7
8 3 2518/6
7 40 2518/8
6 15
5 30
4 25
3 50 2543/3 2543/2 2543/1
2 10 2025/14 2025/13 2025/7 2025/5 2025/3
1 30

Thickness, m

1. Sandstone: brownish- or greenish-gray, limy, outsized, alternating with outsized gravelly sandstone, with floating quartz-siliceous pebble 30

2. Siltstone: green-gray, limy, thinly interbedded (0.02–0.15 m) with brownish-gray sandstone and sandy limestone; with (loc. 2025/3) brachiopods *Zygospirella* sp., (loc. 2025/5) brachiopods *Zygospirella* sp. and tabulate corals *Halysites* sp., (loc. 2025/7) trilobites *Acernaspis* sp., (loc. 2025/13) rugose corals *Cyathactis* ? sp., (loc. 2025-14) trilobites *Acernaspis* sp. 10

3. Sandstone: green-gray, fine to medium, laminated, with green siltstone interbeds; siltstone in lower layers contains: (loc. 2543/1) brachiopods *Nalivkinia* sp., *Stegerynchus* sp., (loc. 2543/2) brachiopods *Nalivkinia* sp., *Pseudocamarotechia* sp., (loc. 2543/3) brachiopods *Pseudocamarotechia* sp., *Alispira* cf. *gracilis* Nikif. 50

4. Interbedded siltstone and fine sandstone, lilac to gray 25

5. Sandstone: green-gray, thin-bedded, fine, with 0.2–0.4 m layers of greenish-gray fine conglomerate 30

6. Sandstone: purple to gray, limy, fine, with (0.15–0.2 m) layers of lilac-gray or cherry-red siltstone 15

7. Sandstone: green-gray, limy, fine, flaggy, with layers of grass-green siltstone; with (loc. 2518-8) brachiopods *Pentamerus* cf. *longiseptatus* Borris., *Nalivkinia* sp. 40

8. Limestone: green-gray or pinkish, sandy; with (loc. 2518/6) brachiopods *Nalivkinia* sp., Pentameridae 3

9. Siltstone: lilac or lilac-gray, thinly interbedded with purple or cherry-red to gray fine limy sandstone 7

10. Quartz-siliceous conglomerate: purple, fine 1

11. Sandstone: light gray, gravelly, rather quartz with (loc. 2518/3) tabulate corals *Subalveolitella repentina* Sok., Heliolitidae 34

12. Sandstone: gray, dark gray, or pale purple, fine, thickly flaggy 20

13. Limestone: dark gray, clayey with: (loc. 2059) tabulate corals *Palaeofavosites balticus* (Rukhin.), *Palaeofavosites* sp., brachiopods *Stegerhynchus* sp., (loc.2005) tabulate corals *Subalveolites* sp., *Stelliporella* sp., *Palaeofavosites* sp., rugoses *Microplasma* sp., *Entelophyllum* sp., ?*Dinophyllum* sp. 10

14. Sandstone: gray-green, feldspar-quartz, thin-bedded, medium to coarse 90

15. Sandstone: green-gray, fine, limy, with honeycomb weathered surfaces associated with bead-like 2–3 cm layers of dark gray clayey limestone; member c (loc. 2058) contains brachiopods *Nalivkinia* sp. and indetermined rugose corals 40

16. Limestone: dark gray, slightly clayey, massive, fine 70

17. Limestone: gray, massive, pelitic, with 10–20 m x 250 m coral bioherms. Recovered fauna includes (in stratigraphical order): (loc. 2057) tabulate corals *Mesofavosites obliquus* Sok.; (loc. 2004/2) tabulate corals *Halysites parvus* Miron.; (loc. 2003) tabulate corals *Multisolenia nikiforovae* Sok. et Tes., *Favosites forbesi* M.Edw. et Haime, *Mesofavosites obliquus* Sok., *Halysites parvus* Miron., *Subalveolites volutes* Sok. et Tes., *Syringopora scabra* Sok., *Heliolites decipiens* (M'Coy), *Favosites* (*Sapporipora*) *favositoides* (Ozaki), *Heliolites interstinctus* (Linne), rugose coarls *Eymocystis mirabilis* (Ivnsk.), *Neopaliphyllum soshkini* Zhelt.; (loc. 2003/1) tabulate corals *Multisolenia tortuosa* Fritz, *Mesofavosites obliquus* Sok., *Favosites* ex gr. *amkardakensis* Tchern., *Palaeofavosites nimius* Poltaveeva, rugose coarls *Neopaliphyllum soshkini* Zhelt., *Coronoruga dentata* Zhelt.; (loc. 2027, in 150 m southward point 1300,7 m) rugose coarls *Neopaliphyllum soshkini* Zhelf., *Cyathactis tenuiseptatus* Soshk., tabulate coarls *Multisolenia misera* Sok. et Tes., *M. tortuosa* Fritz., *Subalveolites subulosus* Sok. et Tes., *S. volutus* Sok. et Tes., *Seringopora scarba* Sok., *Palaeofavosites forbesiformis* Sok. 180

18. Limestone: black, clayey, laminated; with: (loc. 2003/2) табуляты *Mesofavosites obliquus* Sok., *Halysites pseudoorthopteroides* Tchern., tabulate coarls *Coronoruga dentata* Zhelt.; (loc. 2026/4) tabulate coarls *Parastriatopora mutabilis* (Tchern.); (loc. 2004/1) brachiopods *Pentamerus* sp., tabulate coarls *Multisolenia misera* Sok. et Tes., *Palaeofavosites balticus* (Rukhin), *Halysites parvus* Miron., *Halysites densus* Miron., *Subalveolites subulosus* Sok. et Tes., *Stelliporella* sp., *Coenites* sp., rugose coarls *Cyathactis tenuiseptatus* Soshk. ..... ~60

19. Interbedded fine sandstone, siltstone, and sandy limestone, greenish-gray or gray; with (loc. 2026/3) tabulate corals *Thamnoporella* sp., (loc. 2004) trilobites *Encrinurus* sp., brachiopods *Tuvaella rachkovskii* Tchern., *Howellella* sp., rugose corals *Cyathactis tenuiseptatus* Soshk. ..... >50

20. Sandstone: greenish-grey with grey sandy limestone lenses. Recovered fauna includes (in stratigraphical order): (loc. 2056, in 10 m from base of left slope of the ravine between points 1301,3 m and 1300,7 m) brachiopods *Tuvaella rachkovskii* Tchern., *Howellella* sp., tabulate corals *Palaeofavosites paulus* Sok.; (loc. 2026) tabulate corals *Thamnoporella* sp., *Palaeofavosites* sp.; (loc. 2026/1) tabulate corals *Multisolenia misera* Sok. et Tes., *Palaeofavosites paulus* Sok., *Favosites forbesi* M.Edw. et Haime, *Mesofavosites obliquus* Sok., *Favosites mesofavositoides* Chekh., *Thamnoporella* sp., *Stelliporella* sp., *Favosites crassimualis* Poltaveeva, *Parastritopora kureikiana* Sok. et Tes., rugose corals *Microplasma gothlandica* (Dyb.), ?*Calostylus* sp.; (loc. 2053) brachiopods *Nalivkinia* cf. *grunewadtiaeformis* (Peetz); (loc. 2054) brachiopods *Nalivkinia* cf. *grunewadtiaeformis* (Peetz), *Delthyris* sp., *Ferganella* sp., табуляты *Favosites forbesi* M.Edw. et Haime, *Parastriatopora kureikiana* Sok., *Thamnoporella* sp., *Palaeofavosites* sp., rugose corals *Neopaliphyllum soshkini* Zhelt.; (loc. 2055) tabulate corals *Subalveolites volutes* Sok. et Tes., *Heliolites* sp., rugose corals *Tabulariaoblonga* Zhelt., *Microplasma gothlandica* (Dyb.); (loc. 2517) trilobites *Acernaspis* sp., *Bumastus* sp., Proetidae, брахиоподы *Rhynchotrema cuneata* (Dalman), *Eokarpinskia* cf. *nalivkini* (Nikif.), *Gypidula* sp., *Zygospirella* sp., tabulate corals *Mesofavosites balchaschensis* (Poletaeva) ..... over 60

The total thickness of the Vtorye Utyosy and Syrovaty formations (members 1 through 15) is ~400 m, the Polaty Formation (members 16 through 18) is about 400 m thick, and the Lower Chesnokovka Formation (members 19 and 20) exceeds 120 m.

3.2.2. Area of Cherny Anui Village

Mayak Section

Chronostratigraphic subdivisions of the International Sratigraphic Scale: Telychian, Sheinwoodian, Homerian.
Regional stratigraphic subdivisions: Polaty, Chesnokovka and Chagyrka regional stages (horizons).
Local lithostratigraphic subdivisions: Polaty, Chesnokovka and Chagyrka formations.
Zones: *spiralis* graptolite zone.
Fauna: tabulate corals, rugose corals, trilobites, brachiopods, crinoids, bryozoans, graptolites.

A large fragment of the Silurian section occurs on the western slope of Mayak Mt. in the Karakol – Shinok interfluve (both are left tributaries of the Anui River). The succession uphill from the toe includes (Fig. 75):

Thickness, m

1. Limestone: dark gray or light gray, slightly clayey, fine to coarse crystalline, dense, detrital, laminated (20–30 cm), with (loc. Yo-6624) tabulate corals ..... ~ 80

Other members are separated from member 1 by a fault and are exposed east of member 1 on the other side of a small ravine:

2. Limestone: highly clayey, fine crystalline, lumpy, locally beaded, with abundant tabulate corals and scarce rugose corals and brachiopods (loc. Yo-6625) ..... ~ 25

3. Limestone: dark or dark gray, highly clayey, containing layers of purer limestone and clayey-carbonate shale; with abundant corals (loc. Yo-6626) ..... ~ 70

4. Mudstone: gray, clayey and clayey-carbonate, with limestone inclusions represented by colonies of tabulate corals; mudstone of member 4 grades smoothly from clayey limestone of member 3 and to pure limestone of member 5... ..... ~ 20

5. Limestone: dark, dirty gray, or gray, fine, locally medium or coarse crystalline, detrital; clay material is localized in thin (0.5-1.5 cm) lenses; limestone at loc. Yo-6627 contains abundant corals and sporadic trilobites: ..... ~ 12

6. Mudstone: dirty green, clayey, locally grading into clayey siltstone, with tabulate corals (loc. Yo-6627a); fossils occur in up to 3 m thick layers of gray clayey limestone; member base is distinct and quite sharp and the top is more diffuse ..... at least 100

7. Interbedded clayey mudstone, clayey siltstone and fine sandstone, dirty green, locally with banding produced by light-to-dark color change; no fauna found. Member 7 grades smoothly into overlying mudrocks of member 8. ..... ~ 100

8. Mudstone: clayey, dark gray to black, locally with greenish hue; with graptolites found in a 50-cm thick layer in themiddle of the member (loc. S-7312): *Callograptus* sp., *Retiolites angustidens* Elles et Wood, *Monoclimacis* sp., *Monograptus* sp., *Oktavites spiralis* (Geinitz) ..... ~30

The eight exposed members are followed up the hill by a buried interval with two more members exposed at its end:

9. Limestone: dark and gray, clayey, dense, fine crystalline, massive, with uneven bedding planes; fossils are scarce, mainly crinoids ..... ~ 14

10. Limestone: gray or light gray, dense, massive; fossils are scarce and include (loc. Yo-6628a) algae, stromatoporoids, tabulate corals, crinoids, and bryozoans. Member 10 grades smoothly from the underlying clayey limestone of member 9. ..... > 80

According to their lithologies and faunas, members 1 through 5 belong to the Polaty Formation, members 6–9 belong to the Chesnokovka Formation, and member 10 belongs to the Chagyrka Formation. The incomplete thickness of the Syrovaty Formation in the section is about 200 m, the Chesnokovka Formation is 245 m thick, and the incomplete thickness of the Chagyrka Formation exceeds 80 m.

Turata Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Telychian, Sheinwoodian, Homerian.
Regional stratigraphic subdivisions: Syrovaty, Polaty, Chesnokovka and Chagyrka regional stages (horizons).
Local lithostratigraphic subdivisions: Syrovaty, Polaty, Chesnokovka and Chagyrka formations.
Fauna: tabulate corals, rugose corals, brachiopods, crinoids.

Another large fragment of the Silurian section in the area of Cherny Anui Village crops out on the right bank of the Anui River at the Muta River mouth near Turata Village where the uphill succession is (Figs 76 –78):

Thickness, m

1. Siltstone, clayey and fine sandstone, black ..... > 5

2. Limestone: gray, thick-bedded. In the interval 5–10 m from the base of the bed (loc. S-929-1/5-10=2070) were collected: tabulate corals *Favosites gothlandicus* (Lamark), *Multisolenia nikiforavae* Sok. et Tes., *Mesofavosites obliquus* Sok., *Halysites pseudoorthopteroides* Tchern., *Mesofavosites fleximurinus* Sok., *Syringopora novella* Klaaman, rugose corals *Crassilasma* sp., *Cyatactis typus* Soshk., brachiopods *Eospirifer chingizicus* Boris., *Stegerhynchella angachiensis* Tchern., *Howelella* sp., Stropheodontidae 15

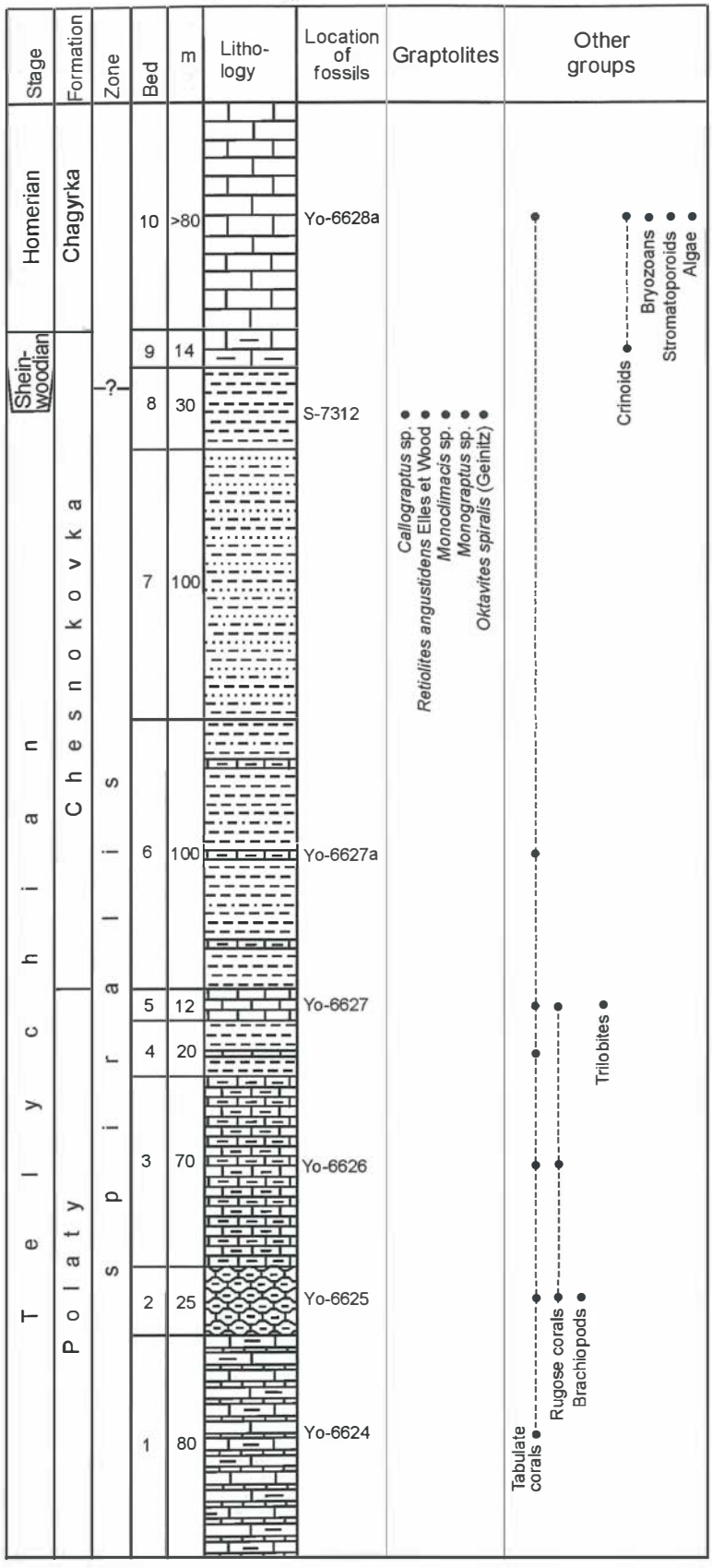


Fig. 75. Ranges of fossil taxa from Mayak section.

3. Siltstone: light greenish-gray, limy-clayey, banded; with brachiopods found in lower 20 m (loc. S-929-2/0-20) and at 35–40 m above member base (loc. S-929-2/35-40=2070/1): *Eospirifer chingizicus* Borris., Septatrypa sp., *Brachyprion* sp., tabulate corals *Holophragma mitrata* Schloth., *Multisolenia nikiforovae* Sok. et Tes., *Mesofavosites obliquus* Sok., *Mes. fleximurinus* Sok., *Halysites pseudoorthopteroides* Tchern., *Seringopora novella* Klaaman. 50

4. Limestone: gray, clayey, flaggy (1 – 3 cm), grading on strike into calcareous siltstone 5

5. Limestone: gray or black, slightly clayey; with tabulate corals in upper layers (loc. S-929-4/15-20 = 2070/2): *Multisolenia tortuosa* Fritz, *Palaeofavosites alveolaris* (Goldfus) 20

The section continues after a small sodded interval:

6. Siltstone: light gray and greenish-gray, calcareous, with fine sandstone in upper layers; member contains brachiopods in its lower half (loc. S-929-6/0-5=2071): *Eospirifer chingizicus* Borris., *Meristella* cf. *parva* Nikif. 8

7. Limestone: clayey, of uncertain bedding with mud patches, containing brachiopods (loc. S-929-7/1=2071/1) *Eospirifer chingizicus* Borris., *Meristella* cf. *parva* Nikif., tabulate corals *Tecipora* sp. 2

8. Sandstone: silty greenish-gray, slightly calcareous, and fine polymictic sandstone 10

9. Limestone: gray, as concretions (up to 50 vol.%) in a matrix of calcareous siltstone 1

10. Siltstone: light greenish-gray, calcareous, of uncertain bedding 5

11. Limestone: clayey, with clay interbeds, crinoidal; crinoids (1–3 mm in diameter) occupy up to 50–70 % of rock volume 2

12. Sandstone: silty, dark green, clayey 10

13. Limestone: gray cavern with 0.5 m interbeds of massive limestone, without clay component, with (upper layers, loc. S-929-13/10=2072) rugose corals *Altaja gracilis* (Billings) 10

14. Limestone: light gray or white, massive 8

15. Limestone: dirty yellow-gray, clayey, lumpy 15

16. Limestone: black or dark gray, thick-bedded (3–5 m), with (upper layers, loc. S-929-16/10-15=2072/1) tabulate corals *Mesofavosites insuetus* Smirn., rugose corals *Holophragma* sp. 18

17. Sodded interval 10

18. Limestone: gray or yellow-gray, with minor sand and clay 10

19. Siltstone: greenish-gray, calcareous, of uncertain bedding; with brachiopods (lower layers loc. S-929-19/2 = 2073): *Protatrypa* cf. *lepidota* Nikif. et Modzal., *Eospirifer* sp. 8

20. Sandstone: green-gray, fine 12

21. Limestone: gray, with dark olive mud patches; with tabulate corals (lower layers, loc. S-929-21/3=2073/1): *Mesofavosites fleximurinus* Sok., *Paleofavosites* ex gr. *paulus* Sok., *Heliolites* sp. 10

22. Limestone: clayey, honecomb (1–3 cm), with mud patches (small lenses, 1–5 cm) with tabulate corals *Favosites forbesi* (M. Edw. et Haime), *F. gothlandicus* Lamark and crinoid fragments 7

23. Siltstone: green-gray, clayey, slightly calcareous 15

24. Limestone: gray, clayey, lumpy ..... over 7

Siltstone of member 23 and limestone of member 24 contain brachiopods: *Schizonema* sp., *Mendacella* sp., corals *Cystiphyllum siluriense* Lonsdale, *Entelophyllum articulatum* (Wahl), *Tryplasma aequabile* (Lonsdale), *Ptychophyllum tenuiseptatus* Ivnvs., *Zelophyllum intermedium* Wedekind, *Phaulactis cyathophylloides* Ryder, *Cyathactis tenuiseptatus* Soshk., *Multisolenia tortuosa* Fritz, *Propora salairica* Miron.

25. Sodded interval 40

26. Siltstone: green-gray, clayey ..... >5

27. Sodded interval 50

28. Sandstone: green-gray, fine, of 0.2–0.5 m banding produced by lighter-color layers with carbonates; grain sizes fine up the section and sandstone grades into silty sandstone; member contains tabulate corals (lower layers, loc. S-929-28/5-15=2074/1): *Crassielasma curtiseptatum* Ivnvsk., *Multisolenia misera* Sok. et Tes., *Multisolenia* sp., *Favosites gothlandicus* Lamark, *Favosites* sp., *Palaeofavosites balticus* Rukhin, *Stelliporella* sp. Sandstone grades along strike into silty sandstone and into calcareous siltstone with limestone nodules, with corals. Thickness 25 m.

29. Sodded interval 5

30. Interbedded (0.1–0.15 m) fine sandstone and clayey siltstone, green-gray, with (lower layers, loc. S-929-30/0-5=2075) tabulate corals *Barrandeolites bowerbankii* (M.Edw. et Haim) and sporadic pieces of crinoid stems (1-3 mm in diameter) 18

31. Siltstone: greenish-gray, calcareous, weathered to honecomb structure produced by carbonate-rich bead-like layers; member contains tabulate corals (lower half, loc. S-929-31/0-5=2075/1): *Barrandeolites bowerbankii* (M.Edw. et Haim.), *Mesofavosites obliquus* Sok., *Heliolites* sp., rugose corals *Holophragma mitrata* (Schloth) 10

32. Siltstone (debris): dark olive or silver-gray, clayey and slightly calcareous 30

33. Siltstone: similar to that in member 32, with tabulate corals (loc. S-929-33/0-3=2075/2): *Favosites forbesi* (M.Edw. et Haime), *Halysites opimus* Koval., *Stelliporella* sp., *Heliolites* sp., rugose corals *Holophragma mitrata* (Schloth), *Pseudophaulactis glevensiformis* Zhelt. 3

34. Siltstone: greenish-gray or gray, clayey, with (loc. S-929-34/10= 2075/3) brachiopods *Leptaena* cf. *depressa* (Sow.), *Strophonella* cf. *euglypha* (Dalm.), *Eospirifer* sp., *Prtotatrypa* sp. 35

35. Limestone: gray or light gray, massive, locally crystalline; with tabulate corals (lower layers, loc. S-929-35/1-10=2076): *Multisolenia tortuosa* Frits, *Mesofavosites obliquus* Sok., *Taxopora* sp., rugose corals *Pseudophaulactis glevensiformis* Zhelt. sp. n.,

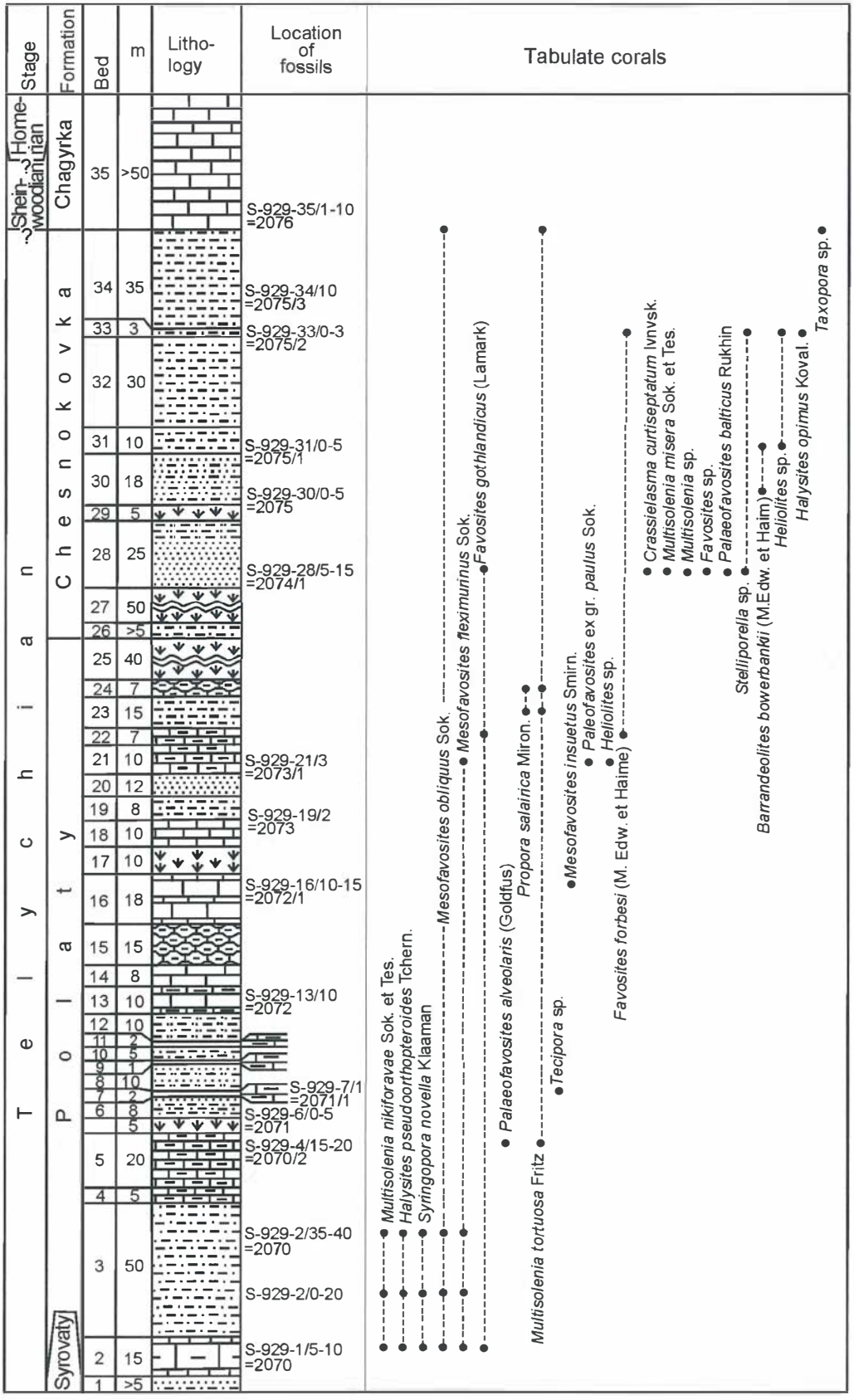
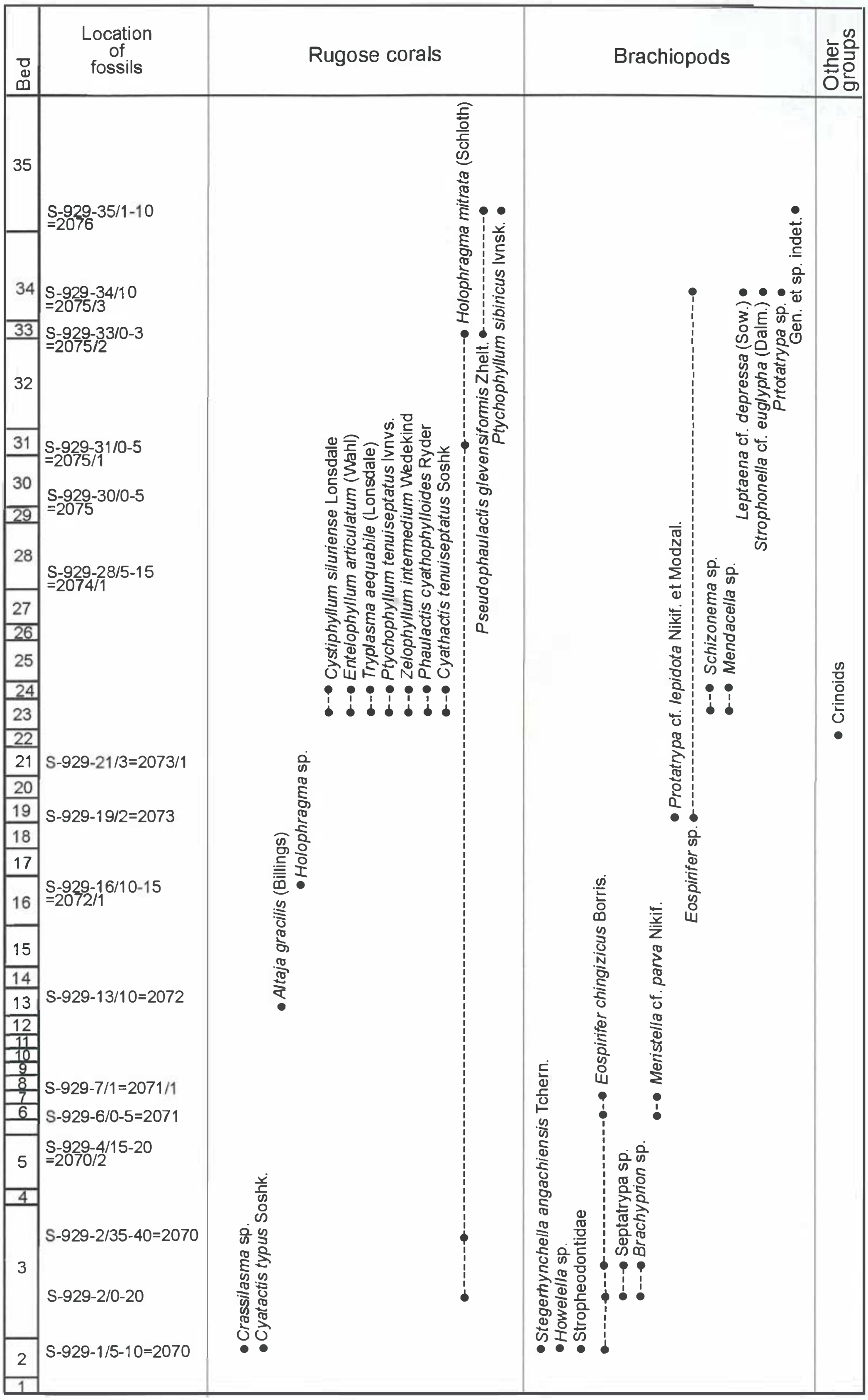


Fig. 78. Ranges of fossil taxa from Turata section.


Bed
Location of fossils
Rugose corals
Brachiopods
Other groups
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
S-929-35/1-10 =2076
S-929-34/10 =2075/3
S-929-33/0-3 =2075/2
S-929-31/0-5 =2075/1
S-929-30/0-5 =2075
S-929-28/5-15 =2074/1
S-929-21/3=2073/1
S-929-19/2=2073
S-929-16/10-15 =2072/1
S-929-13/10=2072
S-929-7/1=2071/1
S-929-6/0-5=2071
S-929-4/15-20 =2070/2
S-929-2/35-40=2070
S-929-2/0-20
S-929-1/5-10=2070
Crassilasma sp.
Cyatactis typus Soshk.
Altaja gracilis (Billings)
Holophragma sp.
Cystiphyllum siluriense Lonsdale
Entelophyllum articulatum (Wahl)
Tryplasma aequabile (Lonsdale)
Ptychophyllum tenuiseptatus Ivnvs.
Zelophyllum intermedium Wedekind
Phaulactis cyathophylloides Ryder
Cyathactis tenuiseptatus Soshk
Holophragma mitrata (Schloth)
Pseudophaulactis glevensiformis Zhelt.
Ptychophyllum sibiricus Ivnsk.
Stegerhynchella angachiensis Tchern.
Howelella sp.
Stropheodontidae
Eospirifer chingizicus Borris.
Septatrypa sp.
Brachyprion sp.
Meristella cf. parva Nikif.
Eospirifer sp.
Protatrypa cf. lepidota Nikif. et Modzal.
Schizonema sp.
Mendacella sp.
Leptaena cf. depressa (Sow.)
Strophonella cf. euglypha (Dalm.)
Prtotatrypa sp.
Gen. et sp. indet.
Crinoids

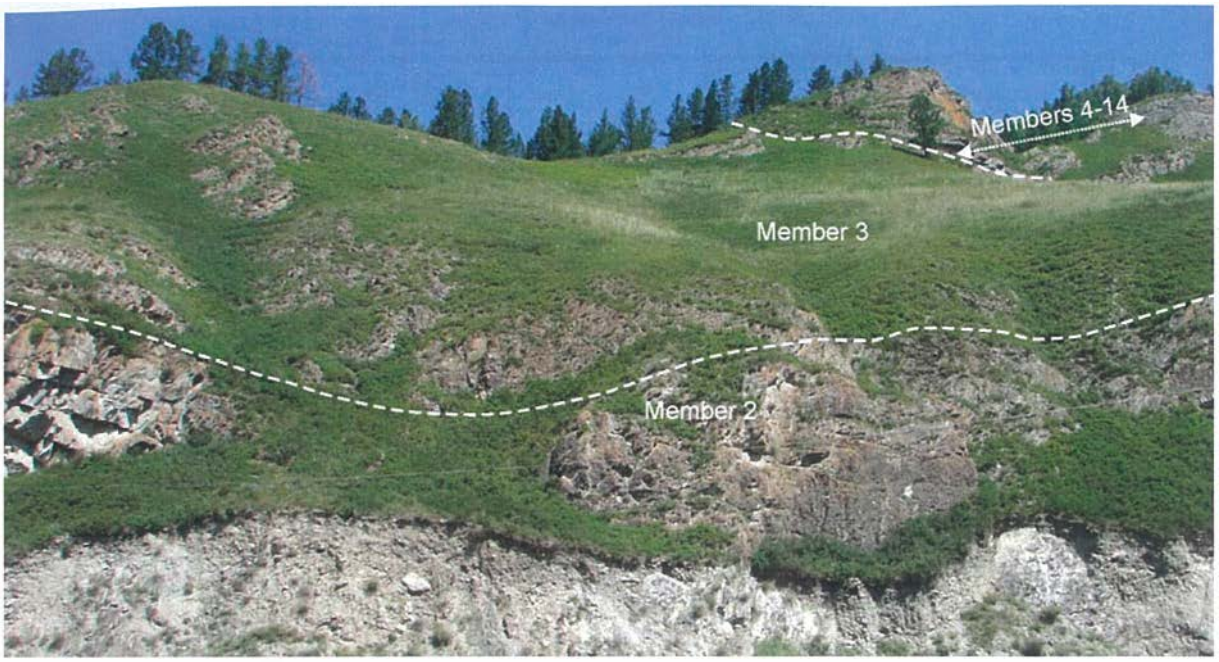


Fig. 77. General view of the Turata section (Silurian Polaty Formation, members 2–11).

Fig. 82. Red fine-grained sandstones from the Silurian Cherny Anui Formation, Cherga section, member 5.

Ptychophyllum sibiricus Ivnsk, brachiopods ..... >50

The thicknesses of the formations are more than 5 m for the Upper Syrovaty Formation (member 1), 400 m for the Polaty Formation (members 2 through 25), 210 m for the Chesnokovka Formation (members 26 through 34), and over 50 m for the Chagyrka Formation (member 35).

Cherny Anui Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Ludfordian, Pridoli.

Regional stratigraphic subdivisions: Kuimov and Cherny Anui regional stages (horizons).

Local lithostratigraphic subdivisions: Kuimov and Cherny Anui formations.

A small fragment of the Upper Silurian section is known at the eastern end of Cherny Anui Village, on the right bank of a ravine which opens into the village central part, 300–400 m far from the place where the ravine enters the Anui River terrace. The stratigraphic succession along the divide between the ravine and the Cherga Brook is (Fig. 79):

Thickness, m

1. Limestone: dark, reef (up to 4 m thick layers), alternating with highly clayey bioclastic limestone (10–20 m thick layers), locally grading into clayey-carbonate mudstone; clayey limestone is often thinly banded according to clay contents; reef limestone contains tabulate and rugose corals, clayey limestone (loc. Yo-6617) contains brachiopods *Protathyris* sp., *Lyssatripa* sp., *Conchidium* sp., tabulate corals, rugose corals, ostracods ..... ~180
2. Mudstone: gray, clayey and clayey-carbonate ..... ~120
3. Mudstone: gray, clayey-carbonate, with abundant bryozoans which impart a limestone: habit to the rock ..... ~2
4. Mudstone and clayey siltstone, cherry-red 2

The lower three members belong to the Kuimov Formation and member 4 belongs to the Cherny Anui Formation. Incomplete thickness of the Kuimov Formation is 300 m and that of the Cherny Anui Formation is more than 2 m.

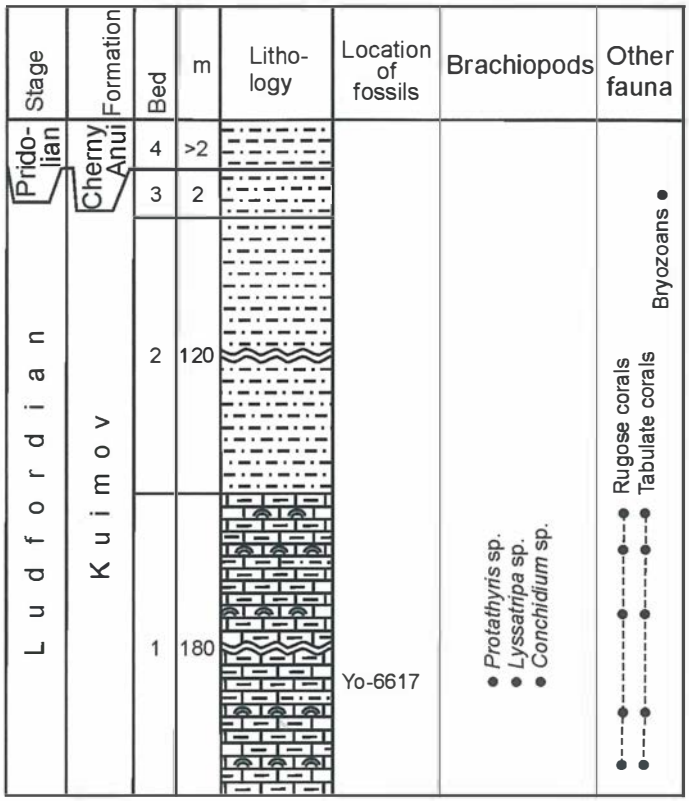


Fig. 79. Ranges of fossil taxa from Cherny Anui section.

Cherga Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Ludfordian, Pridoli.
Regional stratigraphic subdivisions: Kuimov and Cherny Anui regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Kuimov and Cherny Anui formations.
Fauna: stromatoporoids, rugose corals, trilobites, brachiopods, ostracods.

The stratotype section of the Cherny Anui Formation occurs in the western limb of a box syncline on the left bank of the Cherga Brook, the Anui right tributary (Fig. 80). Rocks of the Kuimov and Cherny Anui formations form the core of a small anticlinal fold in two fault blocks on the right side of an unnamed ravine which descends left of the Cherga Brook about 3 km far from its mouth. The section includes (Fig. 81):

Thickness, m

1. Limestone: dirty gray, highly clayey, lumpy, bioclastic, with rare thin interbeds of clayey-carbonate shale; limestone contains (loc. Yo-6630) brachiopods *Atrypella operosa* (Kulk.), *Janius exsul* (Barr.) and trilobites *Warburgella obscura* Yolkin~20
2. Sandstone: red, fine to outsized, locally grading into gravelstone 15
3. Sodded interval. 30
4. Sandstone: gray or reddish-gray, limy, quartz, dense, fine and coarse, commonly of uncertain bedding or massive, locally with scattered fine quartz pebble ..... ~45
5. Sandstone: gray-pinkish, quartz, fine; less often some layers may be pale cherry-red; locally limy sandstone, with dispersed fine quartz pebble, of thick or uncertain bedding, commonly massive; distinct thin banding on weathered surfaces may be produced either by grain size change or by distribution of carbonate material (Fig. 82). ..... ~60
6. Sandstone: similar to that in member 4 but with more frequent cherry-red layers and wavy bedding 18
7. Limestone: greenish-gray, clayey, dense; clay is more or less evenly spread and imparts greenish hue to limestone; member contains trilobites: *Warburgella waigatschensis* (Tschern. et Yak.) 1.5
8. Limestone: dark, dirty gray or gray, clayey, dense, locally detrital or oolitic; limestone is in places silty or less often sandy with evenly spread sand and silt components which is especially evident on weathered surfaces; member contains abundant but poorly diverse fossils (loc. Yo-6619), including stromatoporoids *Plexodictyon* ex gr. *katriense* Nestor, *Densastroma* ex gr. *podolicum* (Yavor.), *Parallelostroma typicum* (Rosen), rugose corals *Phaulactis* sp., *Spongophylloides nikiforovae* (Bulv.), *Stereoxylodes gracilis*

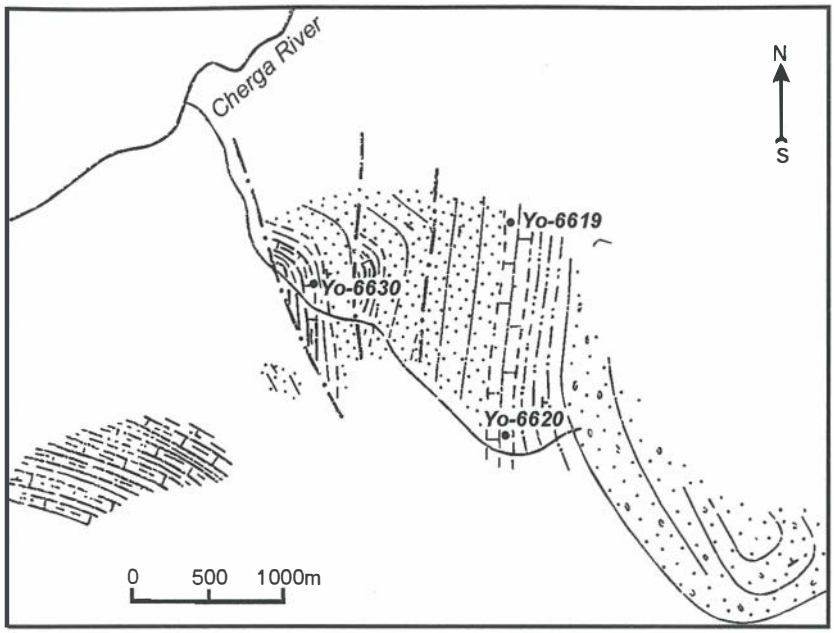


Fig. 80. Sketch map of the location on the left bank of the Cherga River mid-stream (left tributary of the Anui River) (modified from Yolkin et al., 1974).

Zhelt. sp. n., *Mucophyllum* sp., trilobites *Warburgella waigatschensis* (Tschern. et Yak.), ostracods *Neobeyrichiina anuica* Pol., (loc. Yo-6620) rugose corals *Phaulactis* sp., trilobites *Warburgella waigatschensis* (Tschern. et Yak.), ostracods *Neobeyrichiina anuica* Pol., *Ochescaphella altaica* Pol. ..... ~ 35

9. Limestone: gray or dirty gray, highly sandy, dense, thick-bedded; sand is mainly of coarse grain size and quartz composition, evenly spread 20

10. Limestone: up to 2 m thick layers, dirty gray, clayey-sandy (more clayey than sandy), detrital, alternating with 5-8 m thick layers of sandstone, yellowish-gray, quartz, dense, fine; member upper layers consist mainly of sandstone and the lower layers are mostly of limestone with fragments of brachiopods and tabulate corals ..... ~ 60

11. Sandstone: yellowish-gray, quartz and quartz-feldspar, thick-bedded, dense, fin 80

12. Sandstone: reddish-gray or pale cherry-red, with abundant angular clasts (up to 3–4 cm but most often 0.5–1.5 cm); they are more or less evenly spread but locally accumulated in layers or lenses of gravelstone or fine conglomerate breccias; pebbles and debris are composed of quartz, jade, chert, or less often sandy limestone and limy sandstone 25

Rocks of member 12 build the top of a hill but are not the section top. Stratigraphically higher layers crop out further to the southeast in the core of a synclinal fold on the divide between the Cherga Brook and a broad ravine which rises up the Anui River and descends to Turata Village. The section includes easily recognizable rocks of members 9, 10, and 11, and member 12 is followed upsection by

13. Conglomerate: cherry-red or reddish-gray, fine or coarse, less often boulder, with 10–20 cm pebbles and cobbles of quartz, chert, cherry-red or gray jade, gray or red limestone, and gray or red siltstone; cement is mostly carbonate, locally up to 50 % vol.; cement at 1 km far from Maragda Mt. (1218.2 m) at azimuth 20° (loc. S-77131) contains indefinable possibly allochthonous species of trilobites, brachiopods, and rugose corals ..... over 30

Member 1 belongs to the Kuimov Formation and members 2 through 12 belong to the Cherny Anui Formation making its stratotype section; member 13 at the section top is most likely Lower Devonian. The incomplete thickness of the Kuimov Formation in the section is about 20 m and the Cherny Anui Formation is 390 m.

The Cherga Section displays a three-stage sedimentary cycle, with terrigenous rocks below, mainly limestone in the middle, and again terrigenous sediments above. The three units show regular transitions: upsection fining of rocks which overlaid by limestone, then again overlaid by fine terrigenous rocks, and, finally – by mostly coarse material on the top. Taken together, the rocks make up a classic sedimentary sequence. The boundary between the lower and middle units is rather sharp being marked by rapid change from variegated terrigenous rocks (member 6) to carbonates (member 7). The middle and upper units are divided by a smoother boundary (interbedded carbonate and terrigenous sediments) which is defined by disappearance of limestone at the base of member 11.

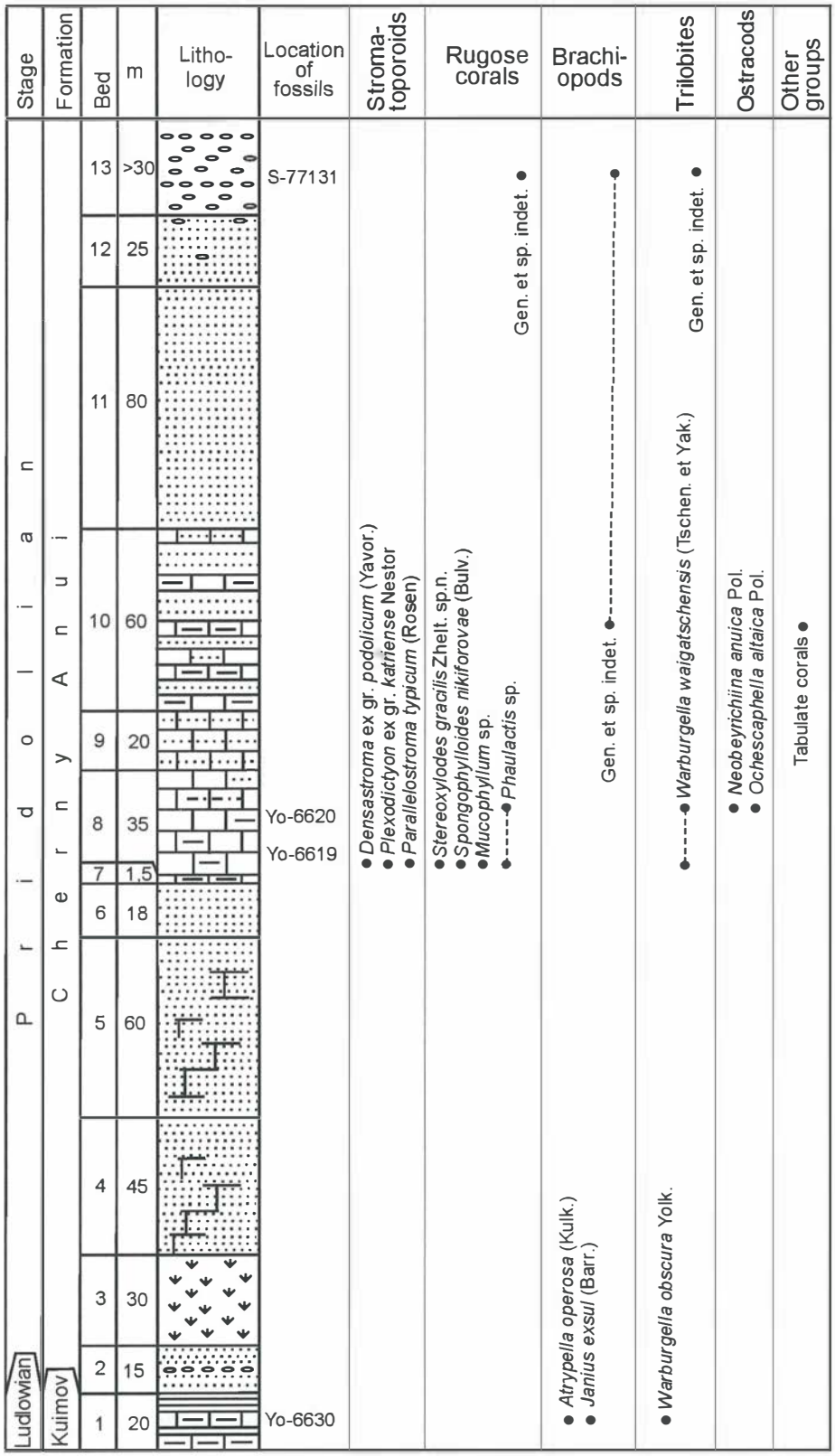


Fig. 81. Ranges of fossil taxa from Cherga section.

3.3. CENTRAL GORNY ALTAI

3.3.1. Area of Inya Village

Verkhnyaya Karasu Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Sandbian, Katian, Hirnantian, Rhuddanian, Aeronian, Telychian, Sheinwoodian.

Regional stratigraphic subdivisions: Bugryshikha, Khankhara, Tekhten', Vtorye Utyosy, Syrovaty, Polaty and Chesnokovka regional stages (horizons).

Local lithostratigraphic subdivisions: Bugryshikha, Khankhara, Tekhten', Vtorye Utyosy, Syrovaty, Polaty and Chesnokovka formations.

Zones: *exiguus, tuvaensis, linnaei, spiralis* graptolite zones.

Fauna: tabulate corals, rugose corals, bryozoans, crinoids, trilobites, brachiopods, ostracods, gastropods, graptolites, ichnofossils.

Ordovician and Silurian strata including the Ordovician Bugryshikha, Khankhara, and Tekhten' formations and the Silurian Vtorye Utyosy, Syrovaty, Polaty, Chesnokovka, and Chagyrka formations crop out in a section along the Verkhnyaya Karasu River (right tributary of the Inya River) (Fig. 83).

The section begins on the right bank of the Inya River 200 m downstream of the Verkhnyaya Karasu inflow and continues uphill along the Verkhnyaya Karasu right bank (section S-8413) (Figs 84, 85):

Thickness, m

1. Siltstone: greenish-gray or gray, clayey, and silty sandstone, with signature of wave activity and syndepositional slumping of soft sediment; rocks contain worm holes, trilobites (loc. S-0715) and crinoids 150

There are two fauna localities in interbedded clayey mudstone and siltstone, equivalent to member 1 or possibly slightly (300 m) stratigraphically lower, found at 1.5 km down the Inya River from the Verkhnyaya Karasu inflow: loc. 5050 with trilobites *Jaboganellus perrectilimbus* Petrun. sp. n. and loc. 5050/1 with brachiopods and trilobites.

2. Limestone: white, locally oolitic, with conchoidal fracture, enclosing sporadic 0.5 m thick and 1 m long lenses of gray clayey siltstone 2

3. Rocks as in member 1 40

4. Limestone: gray, clayey, laminated, locally oolitic 3

5. Sodded interval 125

6. Siltstone: greenish-gray, limy-clayey, and silty sandstone, with scarce interbeds of green fine polymictic sandstone; the number of sandstone layers increases in the member second half and then decreases again toward the top; member contains tabulate corals Proporidae and rugose corals at 40 m and rugose corals at 60 m from its base 120

7. Mudstone: dark-silver-gray, limy 50

8. Limestone: 1-3 m thick layers, mostly gray, crystalline, flaggy, alternating with 3-5 m layers of clayey siltstone, silty sandstone, and fine sandstone (Fig. 86). At 10 m above the member base were found: tabulate corals *Plasmoporella vesiculosa* Kiaer, *Plasmoporella convexotabulata* Kiaer, *Plasmoporella kiaeri* Sok., *Plasmoporella bugryshichiensis* Dziubo, *Wormsipora karasuensis* Dziubo, *Pragnellia* sp., *Propora* cf. *parvotabulata* (Kiaer), *Pragnellia altaica* Dziubo, brachiopods *Strophomena* cf. *lebediensis* Severg., *Severginella altaica* (Severg.), in 20th m – brachiopods *Cataziga* sp., rugose corals, tabulate corals *Cyrtophyllum karasuensis* Dziubo, *Wormsipora karasuensis* Dziubo, bryozoans *Phaenoporella* sp. 80

9. Limestone: gray, clayey, flaggy, thick-bedded (0.2-1.0 m) in upper layers, with thin (2–3 to 5 cm) interbeds of gray limy-clayey siltstone (Fig. 87). At 5 m above the member base trilobites, brachiopods *Severginella altaica* (Severg.), pelecypods, tabulate corals *Wormsipora karasuensis* Dziubo, *Plasmoporella kiaeri* Sok., *Plasmoporella convexotabulata* Kiaer, *Plasmoporella vesiculosa* Kiaer, *Plasmoporella bugryshichiensis* Dziubo, rugose corals *Parabrachielasma* sp., crinoids, bryozoans *Phaenopora* sp., and in 25th m – trilobites have been colleceted 30

10. Limestone: gray, massive 15

11. Siltstone: gray or yellowish-gray, limy-clayey; less often flaggy silty sandstone, with brachiopods found at 3 m above member base 15

12. Limestone: gray, slightly to highly clayey, thin-bedded in lower layers (5–10 cm) and thick-bedded (to 1 m) in upper layers 3

13a. Siltstone, calcareous, thinly (1–3 cm) interbedded with dirty yellow clayey limestone; with tabulate corals *Pragnellia altaica* Dziubo, at 20 m above member base, and at 40th m – tabulate corals, rugose corals, crinoids, bryozoans *Oanduella* sp. ... 70

13b. Interbedded highly calcareous siltstone, silty sandstone, and fine sandstone, dark olive-gray or greenish-gray; with brachiopods near the top: *Severginella* cf. *altaica* (Severg.), *Hesperorthis* cf. *lebediensis* Severg., *Strophomena* sp., tabulate corals 150

14. Limestone: gray, clayey, thin-bedded (5–10 cm) in upper layers and thick-bedded (1–2 m) in lower layers, with thin interbeds of sericitized calcareous siltstone; member contains faunas at 20 m from its base: rugose corals *Ditoecholasma canica* (Tcherepn.), tabulate corals, brachiopods 35

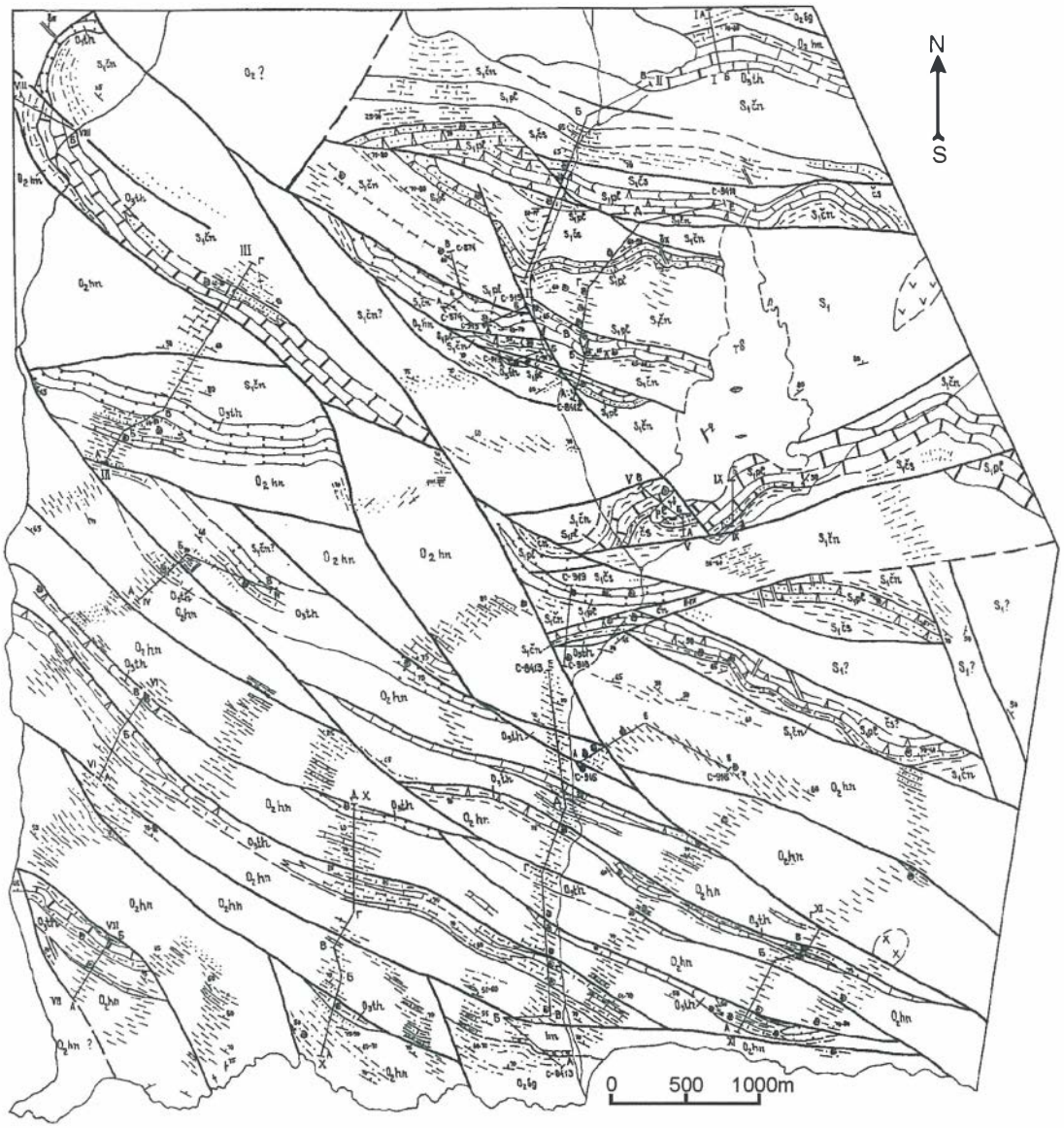


Fig. 83. Sketch map of the Verkhnyaya and Nizhnyaya Karasu Rivers interfluve (right tributaries of the Inya River).

15. Limestone: clayey, flaggy (5–15 cm), with tabulate corals at 10 m above member base: *Lyopora altaica* Dziubo, *Paleofavosites* sp., *Mesofavosites* sp. 30

16. Siltstone, greenish-gray or gray, clayey, with silty sandstone and fine polymictic sandstone in upper layers; with tabulate corals at 10 m above member base: *Cyrtophyllum kaniensis* Dziubo *Cyr. karasuensis* Dziubo, gastropods 140

17. Limestone: gray or light gray, flaggy (5-10 cm) 12

18. Interbedded lumpy clayey siltstone and silty sandstone 135

19. Interbedded yellowish- or greenish-gray clayey siltstone (over 70 % vol.) and laminated clayey limestone; with tabulate corals *Cyrtophyllum samyshiensis* Dziubo 18

20. Limestone: gray, massive, in a 20 m long lens; with brachiopods *Strophomena* aff. *lebediensis* Severg ..... from 1 to 7

21. Alternating fine polymictic sandstone, silty sandstone, and clayey or less often highly calcareous siltstone; with tabulate corals at 10 m above member base: *Propora parvotabulata* (Kiaer), *Khangailites* sp., *Eofletcheria* (?) sp. 35

22. Limestone: gray or dark gray, clayey 25

23. Interbedded (5–20 cm) clayey siltstone, silty sandstone, and fine polymictic sandstone, greenish-gray 250

24. Limestone: gray, with faunas at 5 m above member base: brachiopods, gastropods, tabulate corals *Mesofavosites subfallax* Dziubo, *Paleofavosites alveolaris* (Goldfuss), *Cyrtophyllum* sp., *Aulopora* sp., *Favosites* sp., *Lyopora minima* Dziubo, *Baikitolites karasuensis* Dziubo, *Baikitolites* sp. 35

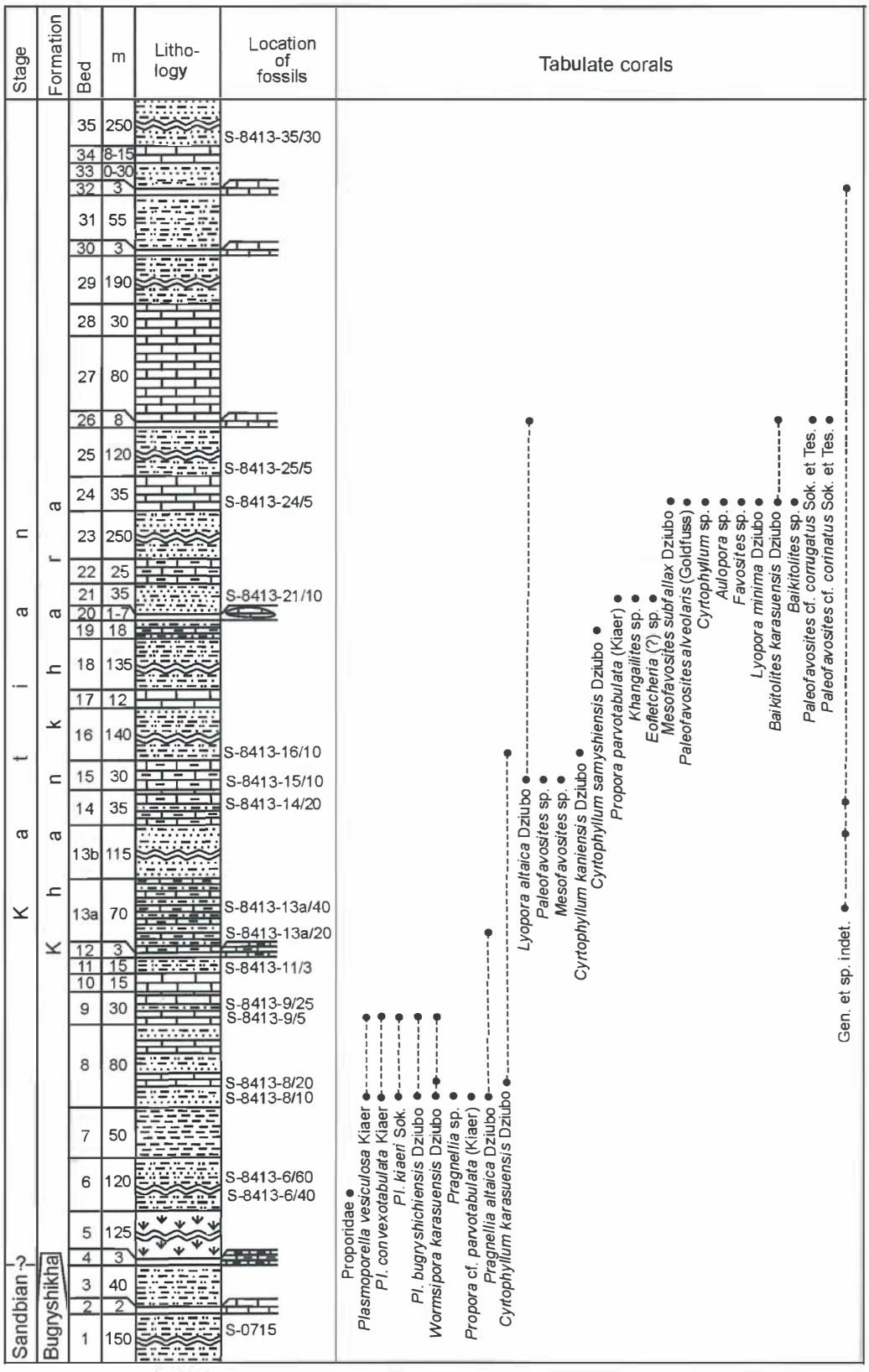
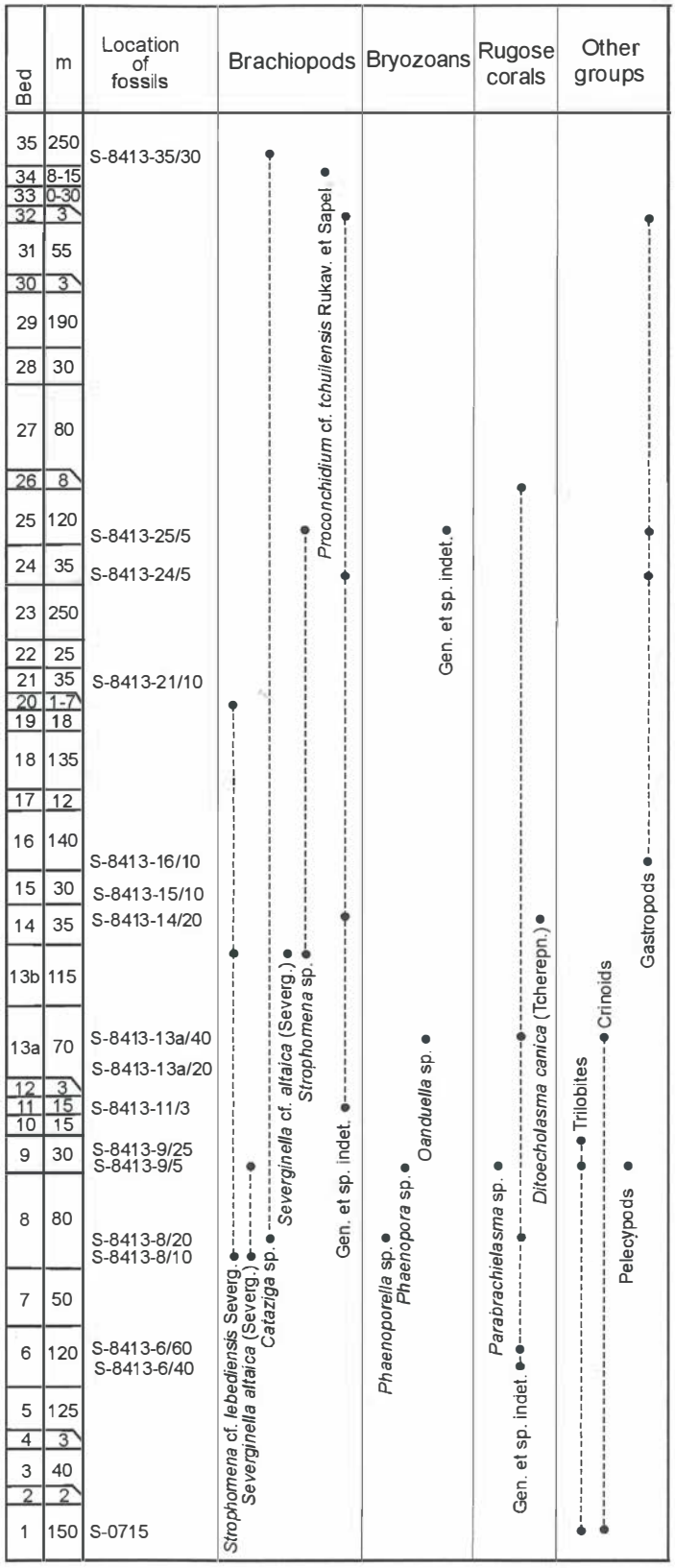


Fig. 84. Ranges of fossil taxa from Verkhnyaya Karasu section.


Bed
m
Location of fossils
Brachiopods
Bryozoans
Rugose corals
Other groups
35 250 S-8413-35/30
34 8-15
33 0-30
32 3
31 55
30 3
29 190
28 30
27 80
26 8
25 120 S-8413-25/5
24 35 S-8413-24/5
23 250
22 25
21 35 S-8413-21/10
20 1-7
19 18
18 135
17 12
16 140 S-8413-16/10
15 30 S-8413-15/10
14 35 S-8413-14/20
13b 115
13a 70 S-8413-13a/40
S-8413-13a/20
12 3
11 15 S-8413-11/3
10 15
9 30 S-8413-9/25
S-8413-9/5
8 80 S-8413-8/20
S-8413-8/10
7 50
6 120 S-8413-6/60
S-8413-6/40
5 125
4 3
3 40
2 2
1 150 S-0715
Strophomena cf. lebediensis Severg.
Severginella altaica (Severg.)
Cataziga sp.
Severginella cf. altaica (Severg.)
Strophomena sp.
Proconchidium cf. tchuilensis Rukav. et Sapel
Gen. et sp. indet.
Phaenoporella sp.
Phaenopora sp.
Oanduella sp.
Gen. et sp. indet.
Parabrachielasma sp.
Gen. et sp. indet.
Ditoecholasma canica (Tcherepn.)
Trilobites
Crinoids
Pelecypods
Gastropods

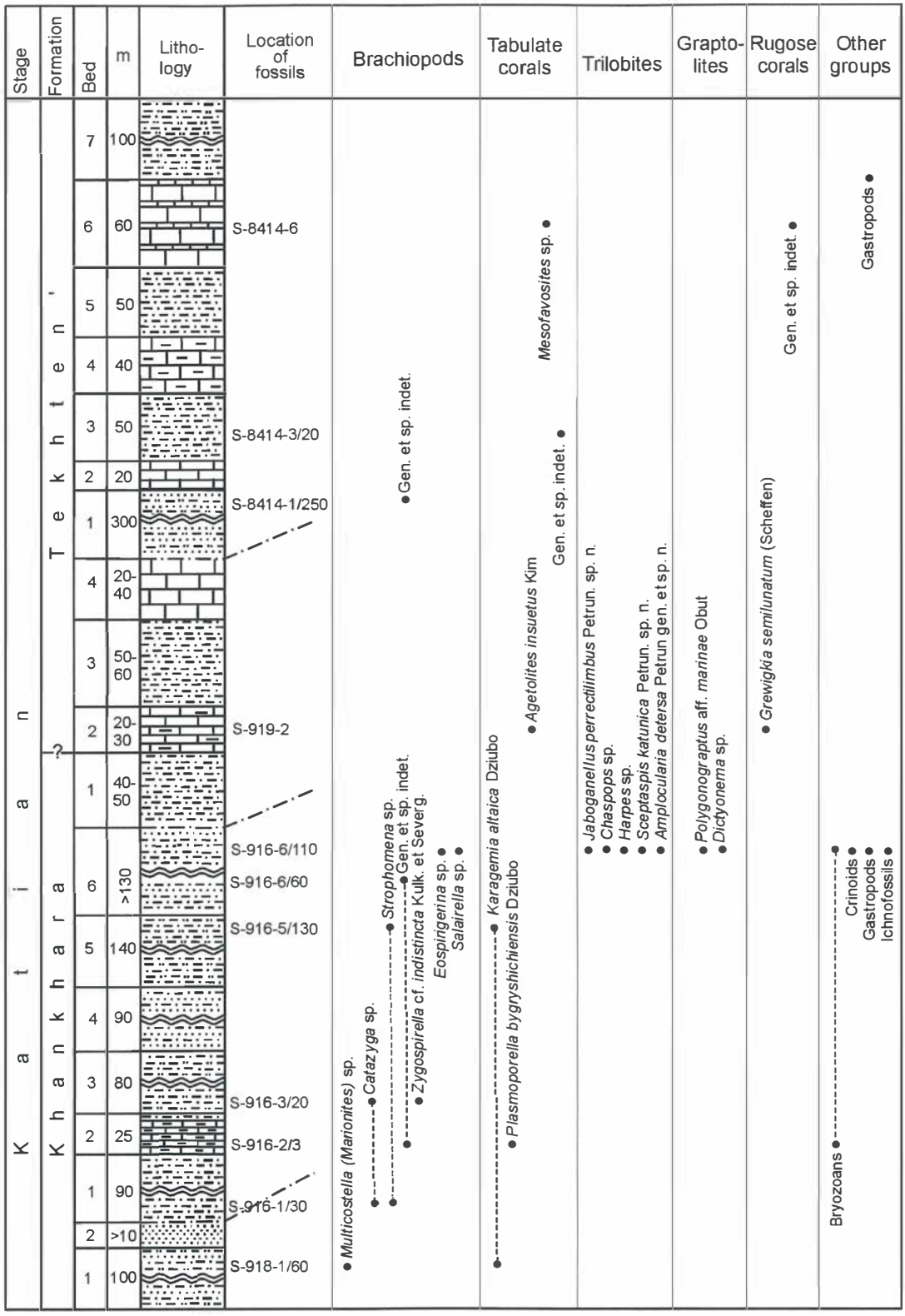
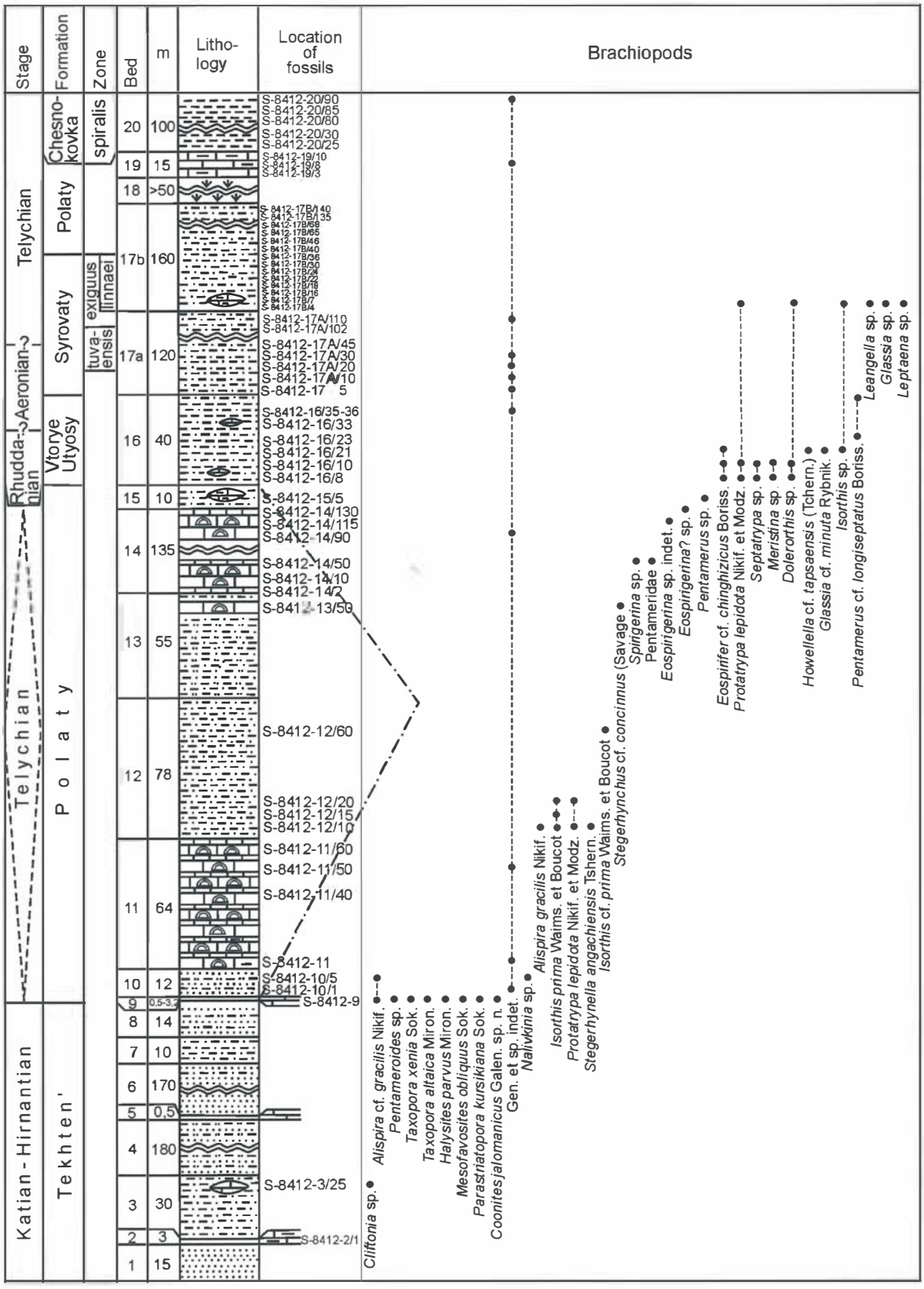


Fig. 84. Continued.


Stage
Formation
Zone
Bed
m
Litho-logy
Location of fossils
Brachiopods
Katian-Hirnantian
Aeronian-Telychian
Rhudda-nian
Telychian
Tekhten'
Polaty
Vtorye Utyosy
Syrovaty
Polaty
Chesno-kovka
tuva-ensis
exiguus linnaei
spiralis
Cliftonia sp.
Alispira cf. gracilis Nikif.
Pentameroides sp.
Taxopora xenia Sok.
Taxopora altaica Miron.
Halysites parvus Miron.
Mesofavosites obliquus Sok.
Parastriatopora kursikiana Sok.
Coonites jalomanicus Galen. sp. n.
Gen. et sp. indet.
Nalivkinia sp.
Alispira gracilis Nikif.
Isorthis prima Waims. et Boucot
Protatrypa lepidota Nikif. et Modz.
Stegerhynella angachiensis Tshern.
Isorthis cf. prima Waims. et Boucot
Stegerhynchus cf. concinnus (Savage
Spirigerina sp.
Pentameridae
Eospirigerina sp. indet.
Eospirigerina? sp.
Pentamerus sp.
Eospirifer cf. chinghizicus Boriss.
Protatrypa lepidota Nikif. et Modz.
Septatrypa sp.
Meristina sp.
Dolerorthis sp.
Howellella cf. tapsaensis (Tchern.)
Glassia cf. minuta Rybnik.
Isorthis sp.
Pentamerus cf. longiseptatus Boriss.
Leangella sp.
Glassia sp.
Leptaena sp.

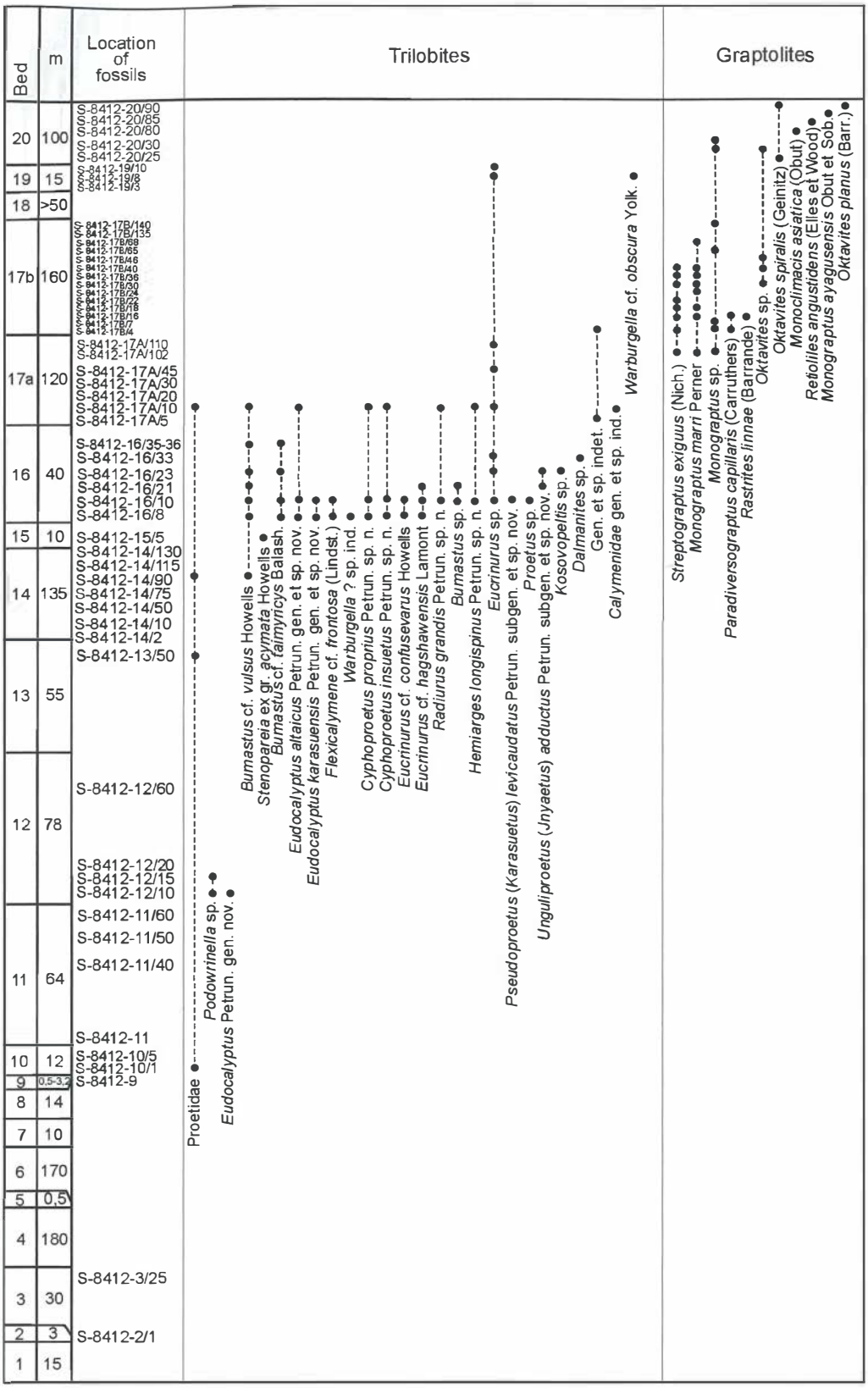
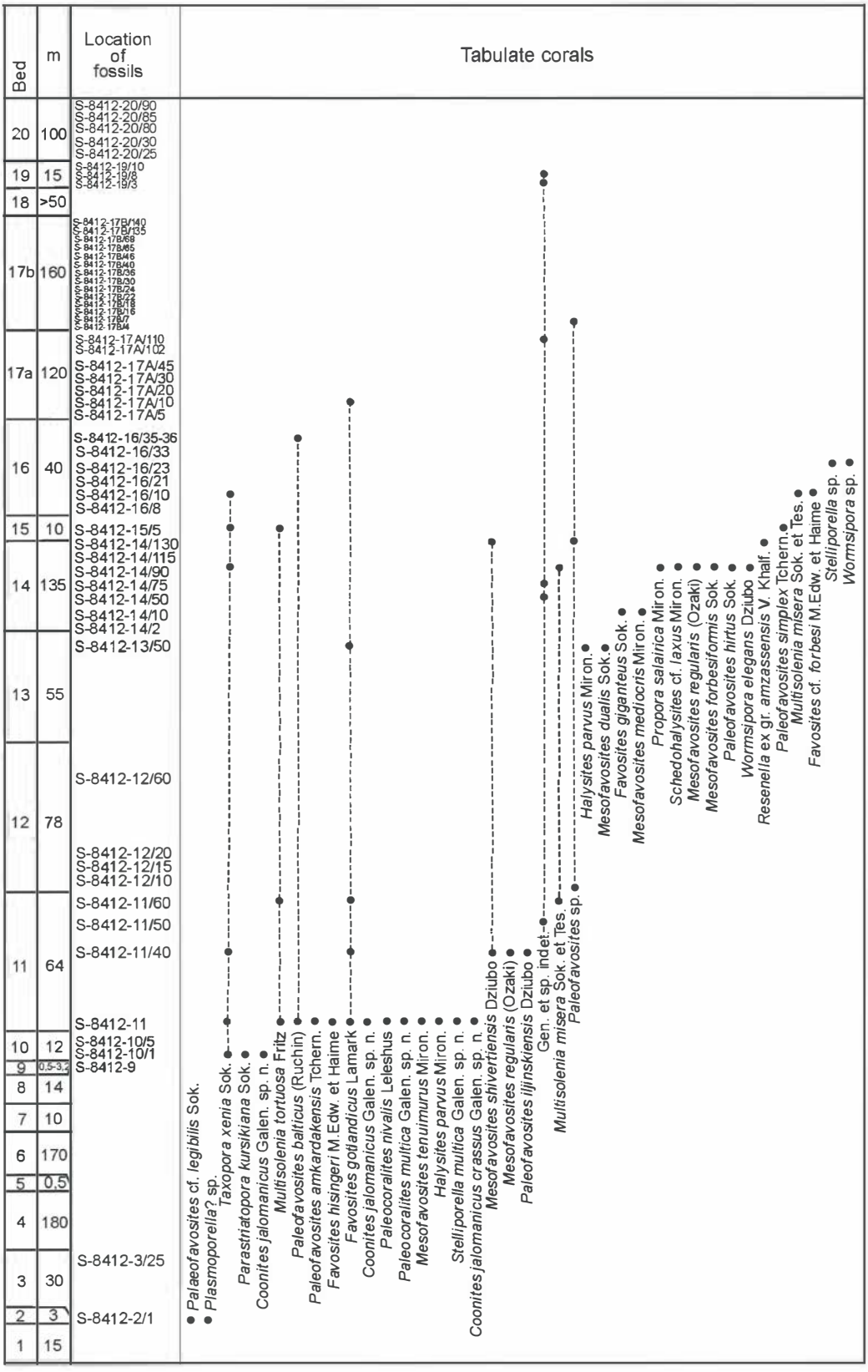


Fig. 84. Continued.


Bed
m
Location of fossils
Tabulate corals
20
100
19
15
18
>50
17b
160
17a
120
16
40
15
10
14
135
13
55
12
78
11
64
10
12
9
0.5-3.2
8
14
7
10
6
170
5
0.5
4
180
3
30
2
3
1
15
S-8412-20/90
S-8412-20/85
S-8412-20/80
S-8412-20/30
S-8412-20/25
S-8412-19/10
S-8412-19/8
S-8412-19/3
S-8412-17B/140
S-8412-17B/135
S-8412-17B/68
S-8412-17B/65
S-8412-17B/46
S-8412-17B/40
S-8412-17B/36
S-8412-17B/30
S-8412-17B/24
S-8412-17B/22
S-8412-17B/18
S-8412-17B/16
S-8412-17B/7
S-8412-17B/4
S-8412-17A/110
S-8412-17A/102
S-8412-17A/45
S-8412-17A/30
S-8412-17A/20
S-8412-17A/10
S-8412-17A/5
S-8412-16/35-36
S-8412-16/33
S-8412-16/23
S-8412-16/21
S-8412-16/10
S-8412-16/8
S-8412-15/5
S-8412-14/130
S-8412-14/115
S-8412-14/90
S-8412-14/75
S-8412-14/50
S-8412-14/10
S-8412-14/2
S-8412-13/50
S-8412-12/60
S-8412-12/20
S-8412-12/15
S-8412-12/10
S-8412-11/60
S-8412-11/50
S-8412-11/40
S-8412-11
S-8412-10/5
S-8412-10/1
S-8412-9
S-8412-3/25
S-8412-2/1
Palaeofavosites cf. legibilis Sok.
Plasmoporella? sp.
Taxopora xenia Sok.
Parastriatopora kursikiana Sok.
Coonites jalomanicus Galen. sp. n.
Multisolenia tortuosa Fritz
Paleofavosites balticus (Ruchin)
Paleofavosites amkardakensis Tchern.
Favosites hisingeri M.Edw. et Haime
Favosites gotlandicus Lamark
Coonites jalomanicus Galen. sp. n.
Paleocoralites nivalis Leleshus
Paleocoralites multica Galen. sp. n.
Mesofavosites tenuimurus Miron.
Halysites parvus Miron.
Stelliporella multica Galen. sp. n.
Coonites jalomanicus crassus Galen. sp. n.
Dziubo
Mesofavosites shivertiensis
Mesofavosites regularis (Ozaki)
Paleofavosites iljinskiensis Dziubo
Gen. et sp. indet.
Multisolenia misera Sok. et Tes.
Paleofavosites sp.
Halysites parvus Miron.
Mesofavosites dualis Sok.
Favosites giganteus Sok.
Mesofavosites mediocris Miron.
Propora salairica Miron.
Schedohalysites cf. laxus Miron.
Mesofavosites regularis (Ozaki)
Mesofavosites forbesiformis Sok.
Paleofavosites hirtus Sok.
Wormsipora elegans Dziubo
Resenella ex gr. amzassensis V. Khalf.
Paleofavosites simplex Tchern.
Multisolenia misera Sok. et Tes.
Favosites cf. forbesi M.Edw. et Haime
Stelliporella sp.
Wormsipora sp.

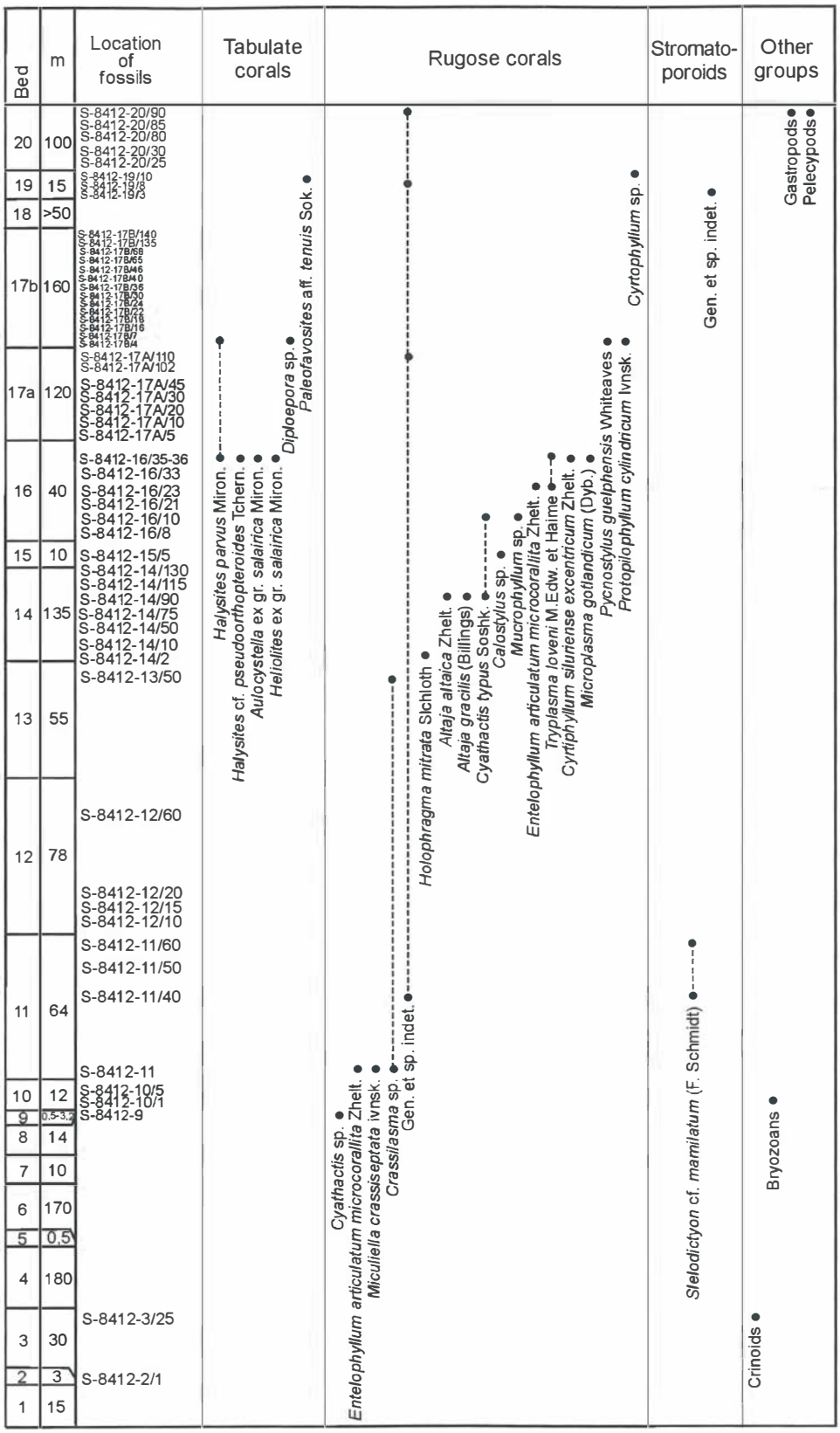

Bed
m
Location of fossils
Tabulate corals
Rugose corals
Stromato-poroids
Other groups
20
100
19
15
18
>50
17b
160
17a
120
16
40
15
10
14
135
13
55
12
78
11
64
10
12
9
0,5-3,2
8
14
7
10
6
170
5
0,5
4
180
3
30
2
3
1
15
S-8412-20/90
S-8412-20/85
S-8412-20/80
S-8412-20/30
S-8412-20/25
S-8412-19/10
S-8412-19/8
S-8412-19/3
S-8412-17B/140
S-8412-17B/135
S-8412-17B/66
S-8412-17B/65
S-8412-17B/46
S-8412-17B/40
S-8412-17B/36
S-8412-17B/30
S-8412-17B/24
S-8412-17B/22
S-8412-17B/16
S-8412-17B/8
S-8412-17B/7
S-8412-17B/4
S-8412-17A/110
S-8412-17A/102
S-8412-17A/45
S-8412-17A/30
S-8412-17A/20
S-8412-17A/10
S-8412-17A/5
S-8412-16/35-36
S-8412-16/33
S-8412-16/23
S-8412-16/21
S-8412-16/10
S-8412-16/8
S-8412-15/5
S-8412-14/130
S-8412-14/115
S-8412-14/90
S-8412-14/75
S-8412-14/50
S-8412-14/10
S-8412-14/2
S-8412-13/50
S-8412-12/60
S-8412-12/20
S-8412-12/15
S-8412-12/10
S-8412-11/60
S-8412-11/50
S-8412-11/40
S-8412-11
S-8412-10/5
S-8412-10/1
S-8412-9
S-8412-3/25
S-8412-2/1
Halysites parvus Miron.
Halysites cf. pseudoorthopteroides Tchern.
Aulocystella ex gr. salairica Miron.
Heliolites ex gr. salairica Miron.
Diploepora sp.
Paleofavosites aff. tenuis Sok.
Cyathactis sp.
Entelophyllum articulatum microcorallita Zhelt.
Microlella crassiseptata Ivnsk.
Crassilasma sp.
Gen. et sp. indet.
Holophragma mitrata Slchloth
Altaja altaica Zhelt.
Altaja gracilis (Billings)
Cyathactis typus Soshk.
Calostylus sp.
Mucrophyllum sp.
Entelophyllum articulatum microcoralita Zhelt.
Tryplasma loveni M.Edw. et Haime
Cyrtiphyllum siluriense excentricum Zhelt.
Microplasma gotlandicum (Dyb.)
Pycnostylus guelphensis Whiteaves
Protopiliophyllum cylindricum Ivnsk.
Cyrtophyllum sp.
Stelodictyon cf. mamilatum (F. Schmidt)
Gen. et sp. indet.
Crinoids
Bryozoans
Gastropods
Pelecypods

Fig. 84. End.

25. Alternating clayey siltstone and silty sandstone, dark olive and greenish-gray, with rare thin (1–3 cm) gray limestone interbeds in lower layers; with tabulate corals found at 5 m above member base: *Mesofavosites subfallax* Dziubo, *Paleofavosites alveolaris* (Goldfuss), *Cyrtophyllum* sp., *Ailopora* sp., *Favosites* sp., brachiopods *Strophomena* sp., gastropods, bryozoans .. 120

26. Limestone: gray or dark gray, with tabulate corals *Baikitolites karasuensis* Dziubo, *Lyopora altaica* Dziubo, *Paleofavosites* cf. *corrugatus* Sok. et Tes., *Paleofavosites* cf. *corinatus* Sok. et Tes., rugose corals 8

27. Rocks as in member 26. 80

28. Limestone: gray or dark gray 30

29. Rocks as in member 25, with mostly black clayey siltstone in upper third 190

30. Limestone: gray, crystalline 3

31. Rocks as in member 29, with mostly black clayey siltstone in upper third 55

32. Limestone: gray or dark gray; with tabulate corals at 2 m above member base 3

33. Siltstone, clayey, with silty sandstone, and fine sandstone, greenish-gray, in a ~200 m long lens ..... from 0 to 30

34. Limestone: gray or dark gray; with brachiopods in upper layers: *Proconchidium* cf. *tchuilensis* Rukav. et Sapel. 8–15

35. Alternating limy-clayey siltstone and fine polymictic sandstone, greenish-gray; at 30–35 m above member base there is a lens (10 m long and up to 5 m thick) of gray limestone; at 120 m above member base there are a few 10 cm thick layers of light gray sandy limestone; sandstone become lightr colored in upper layers; siltstone at 30 m above member base contains brachiopods *Catazyga* sp. 250

The top of member 35 is truncated by a fault. Then the section continues as S-918 on the right bank of the Verkhnyaya Karasu River, along a ravine with its head 900 m downstream of the confluence of the left and right Verkhnyaya Karasu; the section begins 100 m far from the ravine head, on its left side, and includes:

1. Alternating clayey flaggy (3–5 cm) siltstone, silty sandstone, and fine sandstone, greenish-gray, light gray or cream-colored; with brachiopods at 60 m above member base: *Multicostella (Marionites)* sp., tabulate corals *Karagemia altaica* Dziubo. ..... ~ 100

2. Sandstone: highly calcareous, fine and medium ..... over 10

Members 1 and 2 of S-918 are equivalent to member 35 of S-8413.

The section continuation (S-916) is exposed on the left side of the Verkhnyaya Karasu valley, along the right side of a ravine that descends from 1575.0 m mountain and then runs between 1129.4 m and 1092.1 m hills; the members from the ravine head toward point 1575.0 m are:

1. Siltstone: greenish-gray, calcareous, with 5 ×3 cm concretions of gray silty sandstone; member contains brachiopods at 30 m from its base: *Catazyga* sp., *Strophomena* sp. 90

2. Limestone: gray or yellowish-gray, clayey, locally flaggy (2–7 cm), crinoidal, with thin (1–3 cm) calcareous siltstone interbeds which become more frequent in upper layers; member contains tabulate corals at 3 m from its base: *Plasmoporella bygryshichiensis* Dziubo, brachiopods, bryozoans 25

3. Siltstone, limy-clayey, flaggy (5–40 cm), and silty sandstone, yellowish-dirty gray, with 10 × 3 cm concretions of gray limestone; with brachiopods at 20 m above member base: *Zygospirella* cf. *indistincta* Kulk. et Severg., *Catazyga* sp. 80

4. Interbedded siltstone (5 m) and fine sandstone (3–5 cm), greenish-gray bluish 90

5. Siltstone, calcareous, and silty sandstone, light gray or yellowish; with brachiopods at 130 m above member base: *Strophomena* sp., tabulate corals *Karagemia altaica* Dziubo. 140

6. Siltstone: clayey, flaggy (3–15 cm), with scarce 5–15 cm layers of fine sandstone; member contains brachiopods at 60 m and at 110 m from its base; the latter locality (loc. 1471=S-916-6/110) is 300 m below point 1575.0 m: *Eospirigerina* sp., *Salairella* sp., trilobites *Jaboganellus perrectilimbus* Petrun. sp. n., *Chaspops* sp., *Harpes* sp., *Sceptaspis katunica* Petrun. sp. n., *Amplocularia detersa* Petrun gen et sp. n., graptolites *Polygonograptus* aff. *marinae* Obut, *Dictyonema* sp., bryozoans, crinoids, gastropods, ichnofossils ..... over 130

There are several other sections on the right bank of the Verkhnyaya Karasu River besides S-918 which is truncated by a fault. The strata above the fault (section S-919 on the right side of a ravine, 180 m far from its head located 820 m downstream of the confluence of the left and right Verkhnyaya Karasu) include:

I. Siltstone: greenish-gray, limy-clayey 40–50

2. Limestone: gray or dark gray (weathered to reddish), slightly clayey, flaggy (0.2–0.3 m), with rugose corals *Grewigkia semilunatum* (Scheffen), tabulate corals *Agetolites insuetus* Kim 20–30

3. Siltstone: greenish-gray, clayey 50–60

4. Limestone: gray, massive 20–40

Member 1 of S-919 is equivalent of member 35 of S-8413, and member 4 of S-919 is equvalent of member 4 (or 6) of S-8414 (see below).

The S-919 section is truncated by a fault upstream the Verkhnyaya Karasu River and is followed by S-8414 including 7 members listed geographically upstream:

I. Sandstone: fine, and silty sandstone, greenish-gray; with brachiopods found at 250 m above member base 300

2. Limestone: gray, in a lens ..... >20

3. Siltstone: greenish-gray, clayey and calcareous; with tabulate corals found at 20 m above member base 50

4. Limestone: gray, clayey, massive, in a lens ..... >40

Fig. 85. Fine-bedded, platy siltstones from the Ordovician Bugryshikha Formation, Verkhnyaya Karasu section, member 1 (S-8413-1).

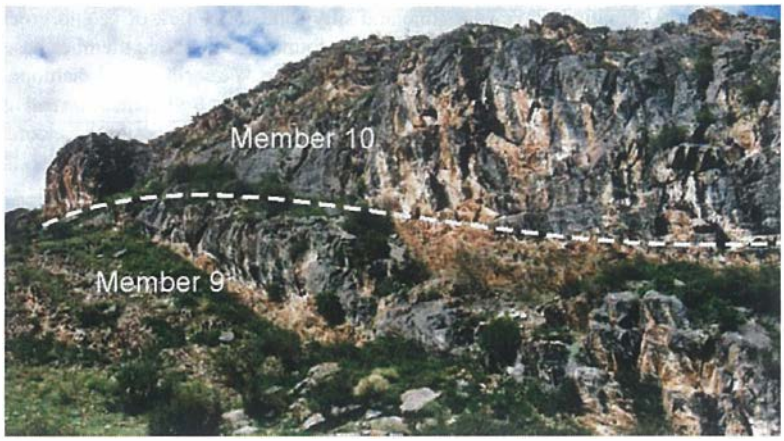


Fig. 86. Relation of fine-bedded clayey limestones with intercalated siltstones and massive limestones from the Ordovician Khankhara Formation, Verkhnyaya Karasu section (members 9 and 10 of section S-8413).

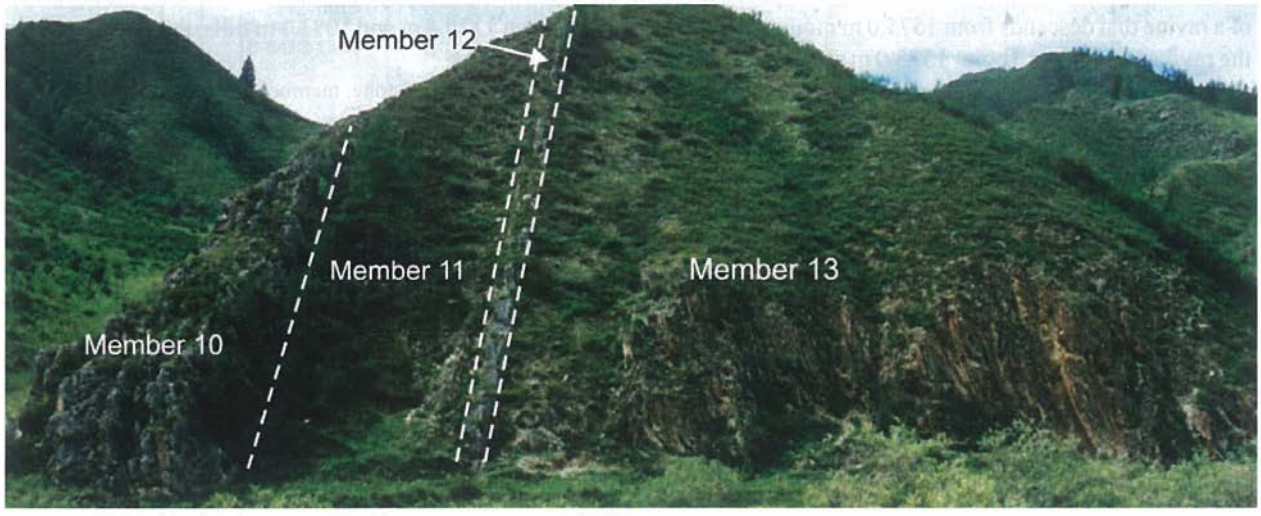


Fig. 87. General view of the middle and lower parts of Verkhnyaya Karasu section (Ordovician Khankhara Formation, members 10–13, section S-8413).

5. Siltstone: gray, limy and clayey 50

6. Limestone: thick-bedded (massive), with tabulate corals *Mesofavosites* sp., rugose corals, and gastropods; the member occurs slightly downstream of the left and right Verkhnyaya Karasu confluence 60

7. Siltstone: limy-clayey and silty sandstone, greenish-gray; member occurs at the confluence of the left and right Verkhnyaya Karasu and extends upstream the right arm ..... ~ 100

S-8414 is likewise truncated by a fault and then the exposed strata continue as section S-8412 located 350 m north of the confluence on the left side of the right stream of Verkhnyaya Karasu R. toward point 1575.2 m (Fig. 88):

1. Sandstone: green-gray, limy, polymictic, fine 15

2. Limestone: gray, clayey, lumpy, with tabulate corals *Palaeofavosites* cf. *legibilis* Sok., *Plasmoporella*? sp. at 1st m above the member base 3

3. Siltstone: yellow, limy-clayey, cross-bedded; with brachiopods *Cliftonia* sp. and crinoids found at 25 m above member base in a lens of dark gray limestone 30

4. Silty sandstone and fine sandstone, green-gray, thick-bedded (0.5–1.0 m) medium-grained and polymictic in upper layers 180

The top of member 4 is constrained by a small fault.

5. Limestone: white, detrital; member top may be cut by a fault 0.5

6. Sandstone: green-gray, quartz, fine, thick-bedded (0.2–0.5 m) and containing scarce (1–2 m) clayey siltstone interbeds in upper layers 170

7. Siltstone: gray, clayey, foliated 10

8. Silty sandstone and sandstone, limy, fine, polymictic, gray 14

9. Limestone: light gray, with brachiopods in middle layers: *Alispira* cf. *gracilis* Nikif., *Pentameroides* sp., *Taxopora xenia* Sok., *Taxopora altaica* Miron., *Halysites parvus* Miron., *Mesofavosites obliquus* Sok., *Parastriatopora kursikiana* Sok., *Coonites jalomanicus* Galen. sp. n., rugose corals *Cyathactis* sp. 0.6–3.2

10. Silty sandstone and fine quartz sandstone, locally limy, light gray, with trilobites Proetidae, brachiopods, and tabulate corals found at 1st m above member base: *Taxopora xenia* Sok., *Parastriatopora kursikiana* Sok., *Coonites jalomanicus* Galen. sp. n., at 5th m – brachiopods *Alispira* cf. *gracilis* Nikif., *Nalivkinia* sp. 12

11. Limestone: mostly gray or silver-gray, algal-biohermal, (2 × 3 m) in a matrix of laminated clayey limestone; with brachiopods in basal layer of black slightly clayey limestone, rugose corals *Entelophyllum articulatum microcorallita* Zhelt., *Miculiella crassiseptata* Ivnsk., *Crassilasma* sp., tabulate corals *Multisolenia tortuosa* Fritz, *Paleofavosites balticus* (Ruchin), *Paleofavosites amkardakensis* Tchern., *Favosites hisingeri* M.Edw. et Haime, *Favosites gotlandicus* Lamark, *Coonites jalomanicus* Galen. sp. n., *Paleocoralites nivalis* Leleshus, *Paleocoralites multica* Galen. sp. n., *Mesofavosites tenuimurus* Miron., *Taxopora xenia* Sok., *Halysites parvus* Miron., *Stelliporella multica* Galen. sp. n., *Coonites jalomanicus crassus* Galen. sp. et subsp. n. At the top of the member in 40 m from the member base stromatoporoids *Slelodictyon* cf. *mamilatum* (F. Sch.), tabulate corals *Mesofavosites shivertiensis* Dziubo, *Mesofavosites regularis* (Ozaki), *Taxopora xenia* Sok., *Paleofavosites iljinskiensis* Dziubo, *Favosites gotlandicus* Lamark, rugose corals, at 50 m – brachiopods и tabulate corals, and at 60 m – tabulate corals *Multisolenia tortuosa* Fritz, *Multisolenia misera* Sok. et Tes., *Favosites gotlandicus* Lamark, stromatoporoids *Stelodictyon* cf. *mamillatum* (F.Schmidt) were collected 64

12. Siltstone: green-gray, limy-clayey; with tabulate corals *Paleofavosites* sp. near member base and trilobites at 10 m above member base: *Podowrinella* sp., *Eudocalyptus* Petrun. gen. nov., brachiopods *Alispira gracilis* Nikif., *Isorthis prima* Waims. et Boucot, *Protatrypa lepidota* Nikif. et Modz., *Stegerhynella angachiensis* Tshern., rugose corals, bryozoans, at 15th m – brachiopods *Isorthis prima* Waims. et Boucot, trilobites *Podowrinella* sp., at 20th m brachiopods *Isorthis prima* Waims. et Boucot, *Protatrypa lepidota* Nikif. et Modz., at 60 m – brachiopods *Isorthis* cf. *prima* Waims. et Boucot. 78

13. Silty sandstone and limy-clayey siltstone, yellow-, or less often green-gray, containing scarce bioherms (2 × 3 m) of gray algal limestone; with trilobites Proetidae in limestone at 50 m above member base, tabulate corals *Halysites parvus* Miron., *Favosites gotlandicus* Lamark, *Mesofavosites dualis* Sok., rugose corals *Crassilasma* sp., brachiopods *Stegerhynchus* cf. *concinnus* (Savage) 55

14. Limestone: gray, with algal bioherms (from 3 × 5 to 10 × 30 m in exposed plan view) occupying up to 80 % vol., in a matrix of thick-bedded limestone; member contains rugose corals found at 2nd m from its base: *Holophragma mitrata* Slchloth, at 10th m – tabulate corals *Favosites giganteus* Sok., *Mesofavosites mediocris* Miron., at 50th m – brachiopods *Spirigerina* sp., Pentameridae, tabulate corals, at 75th m – tabulate corals, at 90th m – trilobites *Bumastus* cf. *vulsus* Howells, Proetidae, brachiopods, tabulate corals *Taxopora xenia* Sok., *Propora salairica* Miron., *Schedohalysites* cf. *laxus* Miron., *Mesofavosites regularis* (Ozaki), *Multisolenia misera* Sok. et Tes., *Paleofavosites hirtus* Sok., *Mesofavosites forbesiformis* Sok., *Wormsipora elegans* Dziubo, rugose corals *Altaja altaica* Zhelt., *Altaja gracilis* (Billings), *Cyathactis typus* Soshk. At 115th m brachiopods *Eospirigerina* sp. indet., at 130th m brachiopods *Eospirigerina*? sp., tabulate corals *Palaeofavosites* sp., *Mesofavosites shivertiensis* Dziubo, *Resenella* ex gr. *amzassensis* V. Khalf. have been found 135

15. Siltstone: yellow-gray, calcareous, with lenses (0.5–1.0 m) of gray clayey limestone, containing fragments of corals and crinoids; limestone at 5m above member base contains trilobites: *Stenopareia* ex gr. *acymata* Howells, brachiopods *Pentamerus* sp., tabulate corals *Taxopora xenia* Sok., *Multisolenia tortuosa* Fritz, *Paleofavosites simplex* Tchern., rugose corals *Calostylus* sp. ... 10

16. Mudstone, limy-clayey, and siltstone: gray and brownish-gray, with layers and lenses (from 3–5 to 10–20 cm thick) of gray crystalline limestone; member contains trilobites at 8 m above its base: *Bumastus* cf. *vulsus* Howells, *Bum.* cf. *taimyricys* Balash., *Eudocalyptus altaicus* Petrun. gen. et sp. nov., *Eudocalyptus karasuensis* Petrun. gen. et sp. nov., *Flexicalymene* cf. *frontosa* (Lindst.), *Warburgella* ? sp. ind., *Cyphoproetus proprius* Petrun., sp. n., *Cyphoproetus insuetus* Petrun., sp. n., *Eucrinurus* cf. *confusevarus* Howells, *Eucrinurus* cf. *hagshawensis* Lamont, brachiopods *Eospirifer* cf. *chinghizicus* Boriss., *Protatrypa lepidota* Nikif. et Modz., *Septatrypa* sp., *Meristina* sp., *Dolerorthis* sp., at 10 m – trilobites *Radiurus grandis* Petrun. sp. n., *Bumastus* cf. *vulsus* Howells, *Bumastus* cf. *taimyricus* Balash., *Bumastus* sp., *Hemiarges longispinus* Petrun. sp. n., *Flexicalymene* cf. *frontosa* (Lindst.), *Eucrinurus* cf. *confusevarus* Howells, *Eucrinurus* cf. *hagshawensis* Lamont., *Eucrinurus* sp., *Eudocalyptus altaicus* Petrun. gen. et sp. nov., *Eudocalyptus karasuensis* Petrun. gen. et sp. nov., *Pseudoproetus* (*Karasuetus*) *levicaudatus* Petrun. subgen. et sp. nov., *Proetus* sp., *Cyphoproetus proprius* Petrun. sp. n., *Cyphoproetus insuetus* Petrun. sp. n., brachiopods *Eospirifer* cf. *chinghizicus* Boriss., *Protatrypa lepidota* Nikif. et Modz., *Septatrypa* sp., *Meristina* sp., *Dolerorthis* sp., tabulate corals *Taxopora xenia* Sok., *Multisolenia misera* Sok. et Tes., *Favosites* cf. *forbesi* M.Edw. et Haime, rugose corals *Cyathactis typus* Soshk., *Mucrophyllum* sp. At 21st m from the member base trilobites *Bumastus* cf. *vulsus* Howells, *Bumastus* sp., *Encrinurus* cf. *hagshawensis* Lamont,

Fig. 88. General view of the upper part of Verkhnyaya Karasu section (members 1–8, section S-8412 – Ordovician Tekhten' Formation, members 9–14, section S-8412 –Silurian Polaty Formation).

Fig. 92. General view of massive reef limestones from the Silurian Polaty Formation, near the mouth of the Chuya River.

Unguliproetus (*Jnyaetus*) *adductus* Petrun. subgen. et sp. nov., brachiopods *Howellella* cf. *tapsaensis* (Tchern.), *Eospirifer* cf. *chinghizicus* Boriss., *Glassia* cf. *minuta* Rybnik., *Isorthis* sp. were obtained. At 23rd m – trilobites *Bumastus* cf. *vulsus* Howells, *Bumastus* cf. *taimyricus* Balash., *Kosovopeltis* sp., *Encrinurus* sp., *Unguliproetus (Jnyaetus) adductus* Petrun. subgen. et sp. nov., brachiopods *Pentamerus* cf. *longiseptatus* Boriss., tabulate corals *Stelliporella* sp., *Wormsipora* sp., rugose corals *Entelophyllum articulatum microcorallita* Zhelt., *Tryplasma loveni* M.Edw. et Haime, *Crassilasma* sp. have been collected. At 33 m from the member base trilobites *Dalmanites* sp., *Ecrinurus* sp. were found. At 35th and 36th m – trilobites *Bumastus* cf. *vulsus* Howells, *Bumastus* cf. *taimyricus* Balash., brachiopods, tabulate corals *Halysites parvus* Miron., *Halysites* cf. *pseudoorthopteroides* Tchern., *Paleofavosites balticus* (Rukhin), *Aulocystella* ex gr. *salairica* Miron., *Heliolites* ex gr. *salairica* Miron., rugose corals *Tryplasma loweni* M.Wdw. et Haime, *Cyrtiphyllum siluriense excentricum* Zhelt., *Microplasma gotlandicum* (Dyb.). From the top of the member brachiopods *Pentamerus* cf. *longiseptatus* Boriss. were recovered 40

17a. Siltstone: gray or dark-silver-gray, clayey, foliated, with fragments of brachiopods at 1 m, brachiopods and trilobites at 5 m, and trilobites at 10 m above member base: *Hemiarges longispinus* Petrun. sp. ind., *Calymenidae* gen. et sp. ind., *Radiurus grandis* Petrun. sp. n., *Bumastus* cf. *vulsus* Howells, *Eudocalyptus altaicus* Petrun gen. et sp. nov., *Eucrinurus* sp., *Proetidae* gen. et sp. ind., *Cyphoproetus proprius* Petrun. sp. n., *Cyphoproetus insuetus* Petrun. sp. n., brachiopods, tabulate corals *Favosites gotlandicus* Lamark, at 20th m – brachiopods, at 30th m – brachiopods, at 45th m – trilobites *Eucrinurus* sp., brachiopods *Pentlandella* cf. *marrasma* Havl., *Leptaena* sp., at 110 m – trilobites *Eucrinurus* sp., brachiopods, tabulate corals, rugose corals. At 102nd m graptolites *Streptograptus exiguus* (Nich.), *Monograptus marri* Perner, *Monograptus* sp. were identified ..... ~ 120

17b. Siltstone: gray or dark-silver-gray, clayey, less often limy, with lenses (3–5 m long and up to 1–2 m thick) of gray slightly clayey limestone; member contains trilobites in one such lens at 4 m above member base, brachiopods *Protatrypa lepidota* Nikif. et Modz., *Isorthis* sp., *Leangella* sp., *Dolerorthis* sp., *Glassia* sp., *Leptaena* sp., rugose corals *Pycnostylus guelphensis* Whiteaves, *Protopilophyllum cylindricum* Ivnsk., tabulate corals *Halysites parvus* Miron., *Palaeofavosites* sp., *Diploepora* sp. at 16 and 135 m. Graptolites were recovered: at 4th m – *Streptograptus exiguus* (Nich.), *Paradiversograptus capillaris* (Carruthers), *Monograptus* sp., at 7th m – *Monograptus* sp., at 16th m – *Streptograptus exiguus* (Nich.), *Monograptus marri* Perner, *Rastrites linnae* (Barrande), *Paradiversograptus capillaris* (Carruthers), at 18th m – *Streptograptus exiguus* (Nich.), *Monograptus marri* Perner, at 22nd m – *Streptograptus exiguus* (Nich.), at 24th m – *Monograptus marri* Perner, at 30th m – *Streptograptus exiguus* (Nich.), *Monograptus marri* Perner, *Oktavites* sp., at 36th m – *Streptograptus exiguus* (Nich.), *Monograptus marri* Perner, at 40th m – *Monograptus marri* Perner, *Streptograptus exiguus* (Nich.), *Oktavites* sp., at 46th m – *Oktavites* sp., at 65th m – *Monograptus* sp., at 68th m – *Monograptus marri* Perner, at 140 m – *Monograptus* sp. ..... ~ 160

More graptolites (*Monograptus tuvaensis* Obut) occur at two localities (loc. S-8410-11/10 and S-8410-11/19) in equivalents of member 17 located 300–350 m to the north, on the same ridge but in the other limb of the synclinal fold.

18. Sodded interval, with siltstone debris ..... over 50

19. Limestone: gray, with mud patches; the clay component increases (to 5–10 %) in upper 5 m to produce a 3–5 x 1–3 cm honecomb structure; member contains stromatoporoids and tabulate corals at 3 m and trilobites at 8 m from its base: *Eucrinurus* sp., *Warburgella* cf. *obscura* Yolk., brachiopods, ostracods, rugose corals, tabulate corals, at 10 m – trilobites *Encrinurus* sp., tabulate corals *Paleofavosites* aff. *tenuis* Sok., rugose corals *Cyrtophyllum* sp. This member westward along the right bank of the right stream of Verkhnyaya Karasu River and eastward along the opposite ridge increase in thickness from 15 to 30–50 m. From different locations tabulate corals *Multisolenia tortuosa* Fritz, *Favosites gotlandicus* Lamark, *Fav. kennihoensis* Ozaki, *Fav. forbesi* Edw. et Haime, *Palaeocoralites multica* Galen., *Cyathactis tenuiseptatus* Soshk., *Propora salairica* Miron., *Halysites* cf. *parvus* Miron., Heliolitidae, rugose corals *Zolophyllum compactum* Zhelt. sp. n., *Neopaliphyllum socialis* Zhelt., brachiopods *Pentamerus* ex. gr. *oblongus* (Sow.), *Howelelia* sp., *Eospirifer* sp., *Carinatina* cf. *duanae* Kulk., trilobites *Encrinurus* cf. *confusevatus* Howells, *Warburgella* cf. *obscura* Yolk. were collected 15

20. Mudstone: dark gray, clayey; with graptolites: at 25th m – *Oktavites spiralis* (Geinitz), at 30th m – *Monograptus* sp., *Oktavites* sp., at 35th m – *Monograptus* sp., at 45th m – *Monoclimacis asiatica* (Obut), at 80th m – *Retioliles angustidens* (Elles et Wood), at 85th m – *Monograptus ayagusensis* Obut et Sob., at 90th m – *Oktavites spiralis* (Geinitz), *Oktavites planus* (Barr.). member encloses slightly calcareous interbeds containing minor suppressed fauna groups: brachiopods, pelecypods, gastropods, rugose corals, etc. ..... at least 100

The top and bottom of the Verkhnyaya Karasu section are constrained by faults; faults also divide the parts of the composite section but they do not disturb the stratigraphic succession. Member 1 of S-8413 belongs to the Bugryshikha Formation and members 2 through 35 of S-8413 belong to the Khankhara Formation; members 1 through 7 of S-8414 and members 1 through 8 of S-8412 are assigned to the Tekhten' Formation; members 9 through 15 occur in a large tectonic lens and belong to the Polaty Formation; member 16 of S-8412 belongs to the Vtorye Utyosy Formation, member 17a and lower member 17b of S-8412 belong to the Syrovaty Formation, upper member 17b and members 18 and 19 of S-8412 belong to the Polaty Formation, and member 20 of S-8412 belongs to the Chesnokovka Formation.

The following graptolite zone could be distinguished in the section S-8412: *exiguus* (middle 17a and lower 17b), *tuvaensis* (middle 17a), *linnaei* (lower 17b), and *spiralis* (member 20).

In the year 2007 P. Mannik collected limestone samples from the Verkhnyaya Karasu section. Chemical proceeding revealed conodonts (provisional identification): from the lower part of the section (member 10, loc. S-8413), sample N 5 – *Panderodus* sp.; from the middle part of the section (member 6, loc S-8414), sample N 6 - *Panderodus* sp., *Oulodus*? cf. *panuarensis* Bischoff; from the upper part of the section (member 14, loc. 8412), sample N 7 –*Panderodus* sp.

The thicknesses of the Ordovician formations in the composite Verkhnyaya Karasu section are at least 150 m for the Bugryshikha Formation, up to 2000 m for the Khankhara Formation, and about 650 m for the Tekhten' Formation.

The thicknesses of the Silurian formations are about 160 m for the Vtorye Utyosy Formation, 250 m for the total of the Syrovaty Formation, from 80 m to 220 m for the Polaty Formation, and over 100 m for the Chesnokovka Formation.

Inya Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Telychian.
Regional stratigraphic subdivisions: Syrovaty and Polaty regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Khankhara, Tekhten', Syrovaty and Polaty formations.
Fauna: algae, tabulate corals, rugose corals, crinoids, ostracods, brachiopods, gastropods.

A Lower Silurian section crops out on the left bank of the Katun' River opposite Inya Village on the Chuya Roadway (Fig. 89). The section (S-9041) includes (Fig. 90):

Thickness , m

1. Siltstone: hornfelsed ..... over 50
2. Sandstone: slightly calcareous, fine; member contains indefinable rugose corals, tabulate corals, and brachiopods *Strophomena* cf. *lebediensis* Severg. In lower (loc. 1367/1) and upper (loc. 1367/3) layers, indetermined rugose and tabulate corals ..... ~50
3. Interbedded (10–20 m) fine sandstone and siltstone ..... ~100
4. Interbedded (0.1--0.2 m) bioclastic sandy limestone and calcareous siltstone, with (loc. 1366) ostracods, tabulate corals *Paleofavosites* sp., indetermined rugose corals, and indetermined brachiopods 30
5. Siltstone: thin-bedded 50
6. Interbedded (1–3 m) grayish brown limy sandstone and white marbled limestone 80

Further tectonic dislocation is observed. The terrigenous part (Rhuddanian, Aeronian and Lower Telychian) belonge to the Vtorye Utyosy and Syrovaty formations dropped out of the section. The Syrovaty Formation section could be observed in 500 north-east, opposite old Katun' bridge, in 600 m from the the slope toe.

7. Limestone: gray or grayish brown, marbled, with sporadic algal caliptrae (small bioherms from 10–15 cm to 1 m in diameter) with a length/width ratio of 3/1; member contains indetermined rugose corals, tabulate corals, brachiopods (loc. 1364, 500 m upstream of the old bridge across the Katun' River, 80 m far from the slope toe). Fauna collected throughout the member thickness (loc. 9153): rugose corals *Altaja kasandiensis* Zhelt. sp. n., *Cyathactis tenuiseptatum* Soshk., *Miculiella crassiseptata* Ivnvs., *Tryplasma loweni* (M.Edw. et Haime), *Strombodes socialis* (Soshk.), *Diplophyllum* (?) *microcorallites* Zhelt. sp. n., tabulate corals *Multisolenia nikiforovae* Sok. et Tes., *Helioplasmolites* sp., *Halysites parvus* Miron., *Paleofavosites paulus* Sok., *Taxopora xenia* Sok., Favositidae, (loc. 9155) tabulate corals *Paleofavosites balticus* (Rukhin), indetermined gastropods ..... over 200

Members 1–3 belong to the Khankhara Formation, members 4 through 6 – to the Tekhten' Formation, members 7 to 9 – to the Syrovaty Formation and member 10 – to the Polaty Formation. Thus, the thicknesses of the Khankhara Formation in the section is over 150 m, Tekhten' Fm. – exceeds 160 m, Syrovaty Fm. – over 160 m, and Polaty Fm. - over 200 m.

Chuya Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Telychian.
Regional stratigraphic subdivisions: Syrovaty and Polaty regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Syrovaty and Polaty formations.
Fauna: tabulate corals, rugose corals, bryozoans, crinoids, trilobites.

The documented Lower Silurian section along the Chuya Roadway near the Chuya River mouth exposed in bedrock outcrops and roadway excavations (S-9052) includes (Figs 91–93):

Thickness, m

1. Siltstone: clayey, thin-bedded, green-gray ..... >50
2. Siltstone and sandy-siltstone: hornfelsed, gray, dark gray and brownish-gray ..... >450
3. Siltstone, calcareous, banded, thinly interbedded (0.2--0.3 m) with limy mudstone and clayey limestone, green-gray or light gray; limestone layers are lens-shaped and occur in lower member half; with (loc. 1242) tabulate corals *Palaeofavosites* sp., *Coenites* sp., (loc. S-9052-2 = 1374) trilobites *Podowrinella straitonensis* Clarkson, *Podowrinella* sp., *Warburgella insperata* Yolk., Illaenacea, brachiopods *Stegerhynchella* (?) *angaciensis* (Tchern.), *Isorthis angaciensis* Vlad., *Amphistrophia striata* (Hall.), *Molearnites* cf. *prosperus* Kulk., indetermined rugose corals, bryozoans, crinoids 10
4. Limestone: dark gray, clayey, flaggy (0.2--0.3 m), with scarce thin layers and patches of gray mudstone contain (loc. S-9052-7 = 1374/1) tabulate corals *Favosites* ex gr. *forbesi* M.Edw. et Haime. Thin beds and patches of gray mudstones 5

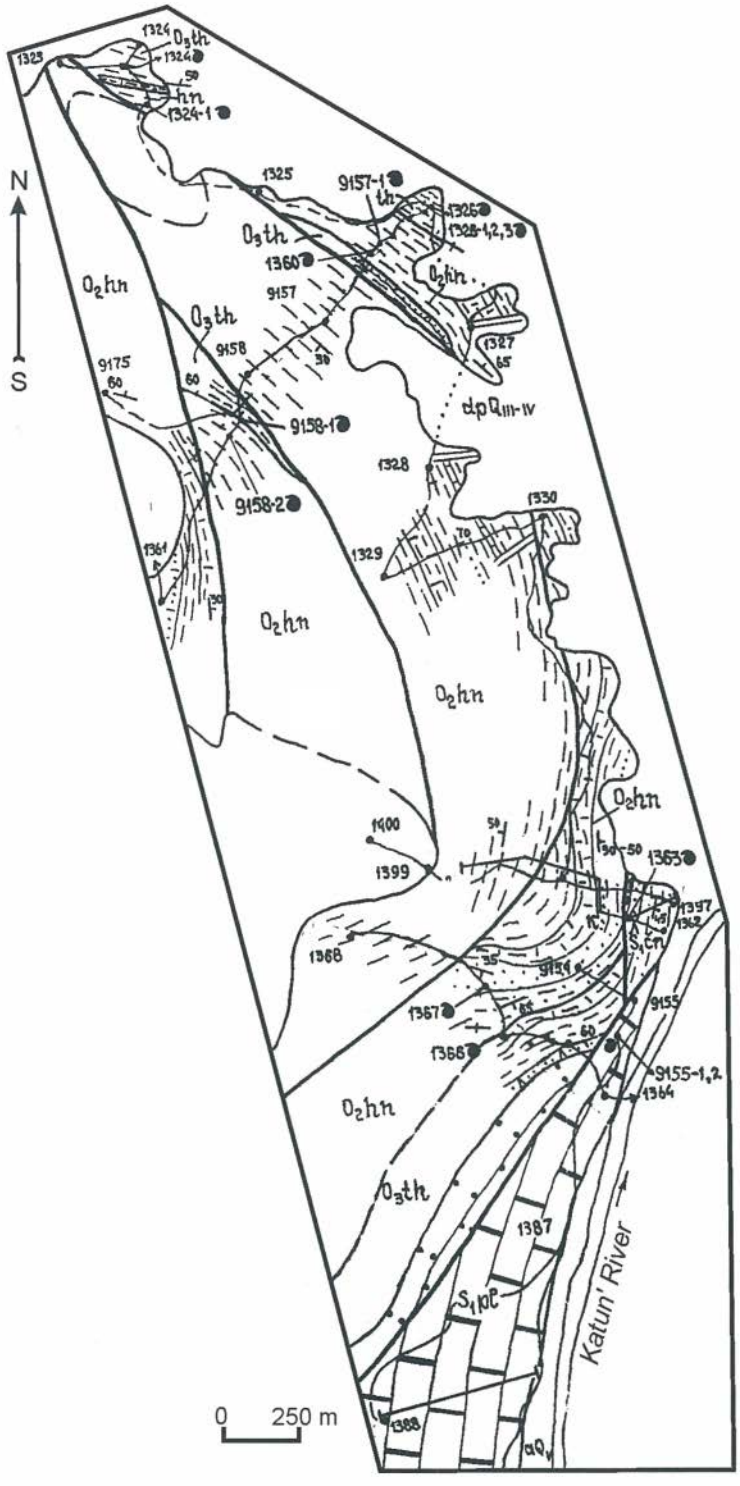


Fig. 89. Sketch map of the left bank of the Katun' River, vicinity of the Inya Village.

5. Limestone: dark gray, (0.5–1 m) laminated, locally with a honecomb structure produced by thin (2–5 cm) layers of gray wavy-bedded bioclastic limestone inside light gray thinly banded slightly clayey limestone 10

6. Limestone: dark gray, clayey ..... >5

7. Limestone: light gray, clayey, flaggy (0.2–0.3 m) ..... ~ 3

8. Limestone: light gray, thick-bedded (5 m), bioclastic, with tabulate corals (loc. S-9052-7 = 1374/2) *Multisolenia misera* Sok. et Tes., *Mesofavosites mediocrinus* Miron., *Mes. olbiquus* Sok., *Mes. dualis* Sok., *Halysites densus* Miron. ..... ~ 20

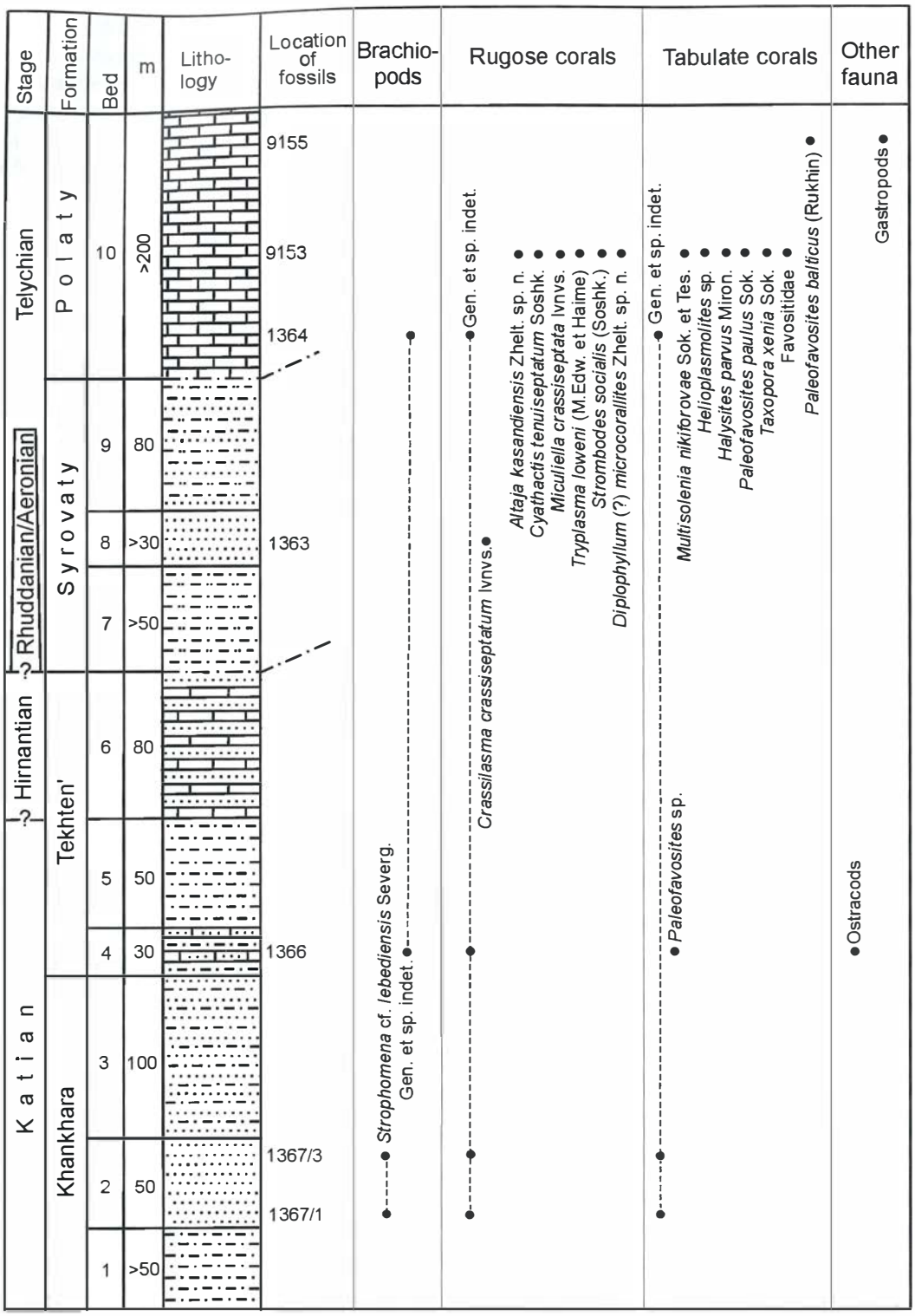
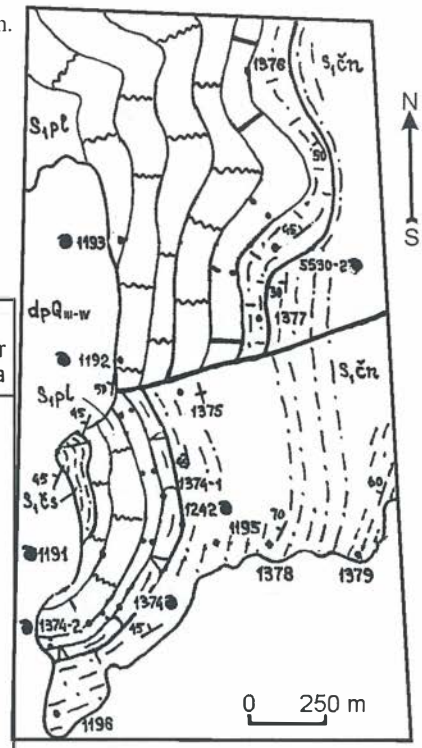


Fig. 90. Ranges of fossil taxa from Inya section.

Fig. 91. Sketch map of the right bank of Chuya River mouth.



Stage	Formation	Bed	m	Litho-logy	Location of fossils	Tabulate corals	Trilobites	Brachiopods	Other fauna
Aeronian ?	Syrovaty	1	>50						
		2	>450						
		3	10		S-9052-2 =1374 1242	*Palaeofavosites* sp. ● *Coenites* sp. ● *Favosites* ex gr. *forbesi* M.Edw. et Haime ●	*Podowrinella straitonensis* Clarkson ● *Podowrinella* sp. ● *Warburgella insperata* Yolk. ● Illaenacea ●	●*Stegerhynchella* (?) *angaciensis* (Tchern.) ●*Isorthis angaciensis* Vlad. ●*Amphistrophia striata* (Hall.) ●*Moleamites* cf. *prosperus* Kulk.	● Rugose corals ● Bryozoans ● Crinoids
		4	5		S-9052-7 =1374/1				
		5	10						
		6	>5						
		7	3						
	Polaata	8	20		S-9052-7 =1374/2	*Multisolenia misera* Sok. et Tes. ● *Mesofavosites mediocrinus* Miron. ● *Mesofavosites albiquus* Sok. ● *Halysites densus* Miron. ● *Mesofavosites dualis* Sok. ● *Halysites* sp. ●			
		9	2						
		10	>10		1191				
		11	>5						
		12	>200						

Fig. 93. Ranges of fossil taxa from Chuya section.

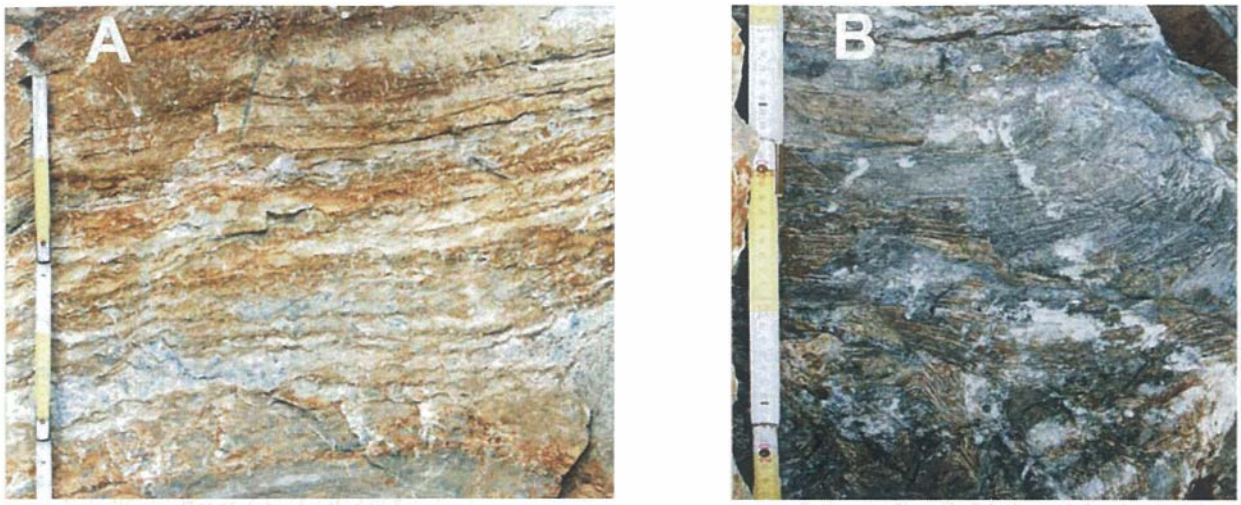


Fig. 94. Stratal (A) and bunchy (B) stromatolites from limestones from the Silurian Polaty Formation, upper part of Chuya section.

Fig. 95. Syngenetic slips healed with clayey material within massive limestones of the Silurian Polaty Formation, upper part of Chuya section.

Fig. 96. Rhythmical structure of the bedded limestones from the Silurian Polaty Formation in the middle part of Chuya section.

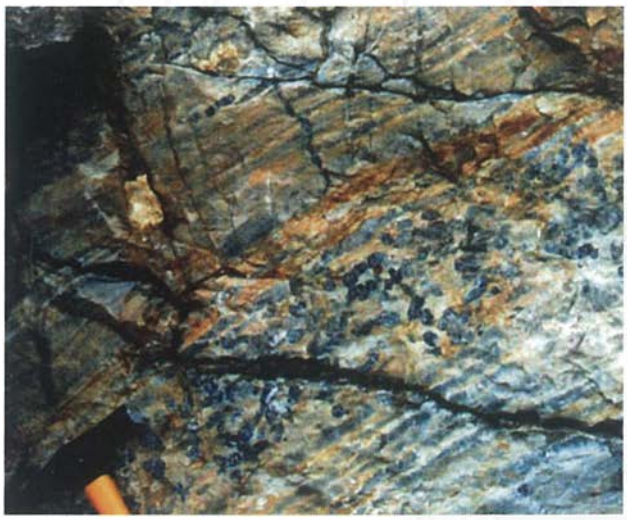


Fig. 97. Detrital beds in massive limestones from the Silurian Polaty Formation, middle part of Chuya section.

Fig. 98. Fine chert micro-beds in massive bedded limestones from the Silurian Polaty Formation in the middle part of Chuya section.

Fig. 99. Syngenetic strike-slip folds in non-lithified limestones from the Silurian Polaty Formation in the middle part of Chuya section.

9. Limestone: light gray, gray or silver-gray, massive, with thin (3–5 mm) layers of black chert at every 2–7 cm, each of thin banding (0.5–1 mm); this chert may have been produced by silicification of algal films ..... ~2

10. Limestone: dark gray, bioclastic, massive; with tabulate corals (loc. S-9052-7 = 1374/1) *Mesofavosites dualis* Sok., *Halysites* sp. ..... >10

11. Limestone: gray and light gray, massive, with 0.2–1.0 m layers containing tabulate or less often columnar (up to 0.1–0.15 m high) stromatolites 5

12. Limestone: gray or dark gray, massive ..... >200

In the year 2007 P. Mannik collected limestone sample (N 4) from the Chuya section. Chemical proceeding revealed conodonts (provisional identification): *Panderodus* ex gr. *greenladensis* Armstrong, *Aspelundia*? cf. *expansa* Armstrong, *Ozarkodina* sp.

Members 1-3 belong to the Syrovaty Formation and members 3 through 12 belong to the Polaty Formation. The Polaty section is of a carbonate coral- and stromatolite-biohermal type (Figs 94–99).

3.3.2. Area of Bely Bom Village

Bely Bom Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Katian, ?Hirnantian.

Regional stratigraphic subdivisions: Tekhten' Regional Stage (Horizon).

***Local lithostratigraphic subdivisions*:** Tekhten' Formation.

Fauna: tabulate corals, brachiopods.

Upper Ordovician strata crop out in the vicinity of Bely Bom Village on the right bank of the Chuya River; they are poorly characterized by faunas but contain one of region's largest reefal buildup of that age (Figs 100, 101).

Upper Ordovician rocks are exposed in sections S-9117 and S-9045 upstream of Bely Bom along an old roadway right near the contact with massive limestone and on toward the Satakular Brook mouth (Fig. 102):

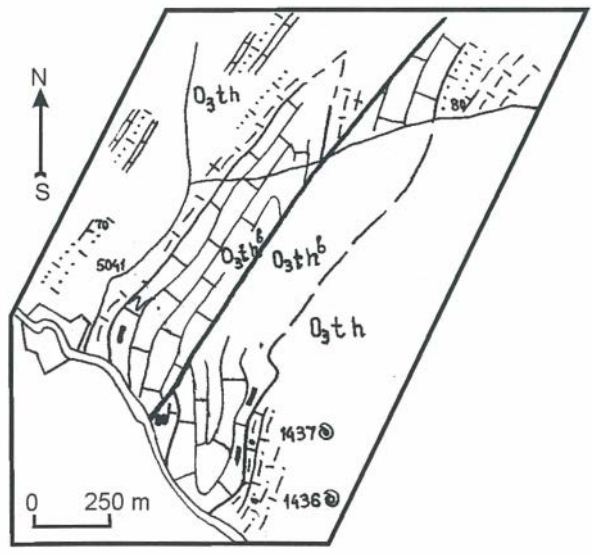


Fig. 100. Sketch map of location of Bely Bom.

Fig. 101. General view of Bely Bom section.

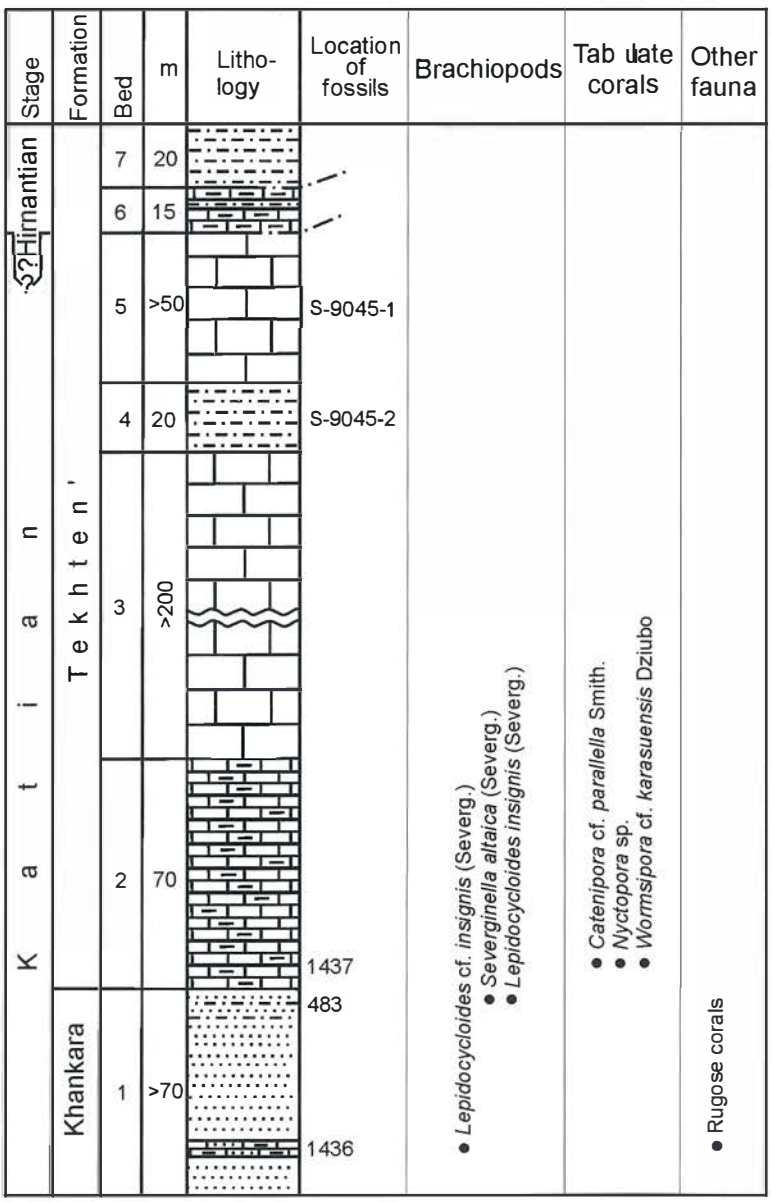


Fig. 102. Ranges of fossil taxa from Bely Bom section.

Thickness, m

1. Sandstone: brown or pale yellow, rather quartz, fine, with calcareous cement; two 15–20 cm thick layers of gray and dirty gray sandy-clayey limestone spaced at 4 m, at 50 m from member top, contain brachiopods *Lepidocycloides* cf. *insignis* (Severg.) and rugose corals (loc. 1436, 50 m far from the old roadway and 1.5 km far from the Satakular Brook mouth); fine sandstone in upper layers coexists with calcareous siltstone 400 m far from the old roadway toward 1283.3 m mountain; it may be the member containing an earlier brachiopod locality (483): *Severginella altaica* (Severg.), *Lepidocycloides insignis* (Severg.) ..... >70

2. Limestone: gray or dark gray, slightly clayey, thin-bedded (3–5 cm); member contains tabulate corals (400m from loc. 1437) ..... >70

3. Limestone: gray or light gray, massive ..... > 200

4. Siltstone: gray or yellowish-gray, clayey; (loc. S-9045-2, on a low hill right above the Satakular Brook mouth on its left bank) 20

5. Limestone: gray or light gray; massive; (loc. S-9045-1) ..... >50

There the member was probably truncated by a fault and the following section includes:

6. Limestone: gray or silver-gray, clayey, flaggy (from 1–3 cm to 1 m), with 1 to 20 cm thick interbeds of clayey siltstone; member crops out on the left bank of the Satakular Brook at its mouth in Bely Bom Village ..... ~15

Then, possibly above a fault, there follow:

7. Siltstone: silver-gray, with pieces of algae ..... ~20

The member boundaries are marked by faults, and some parts of the section may repeat. Member 1 belongs to the Upper Khankhara Formation or to the Lower Tekhten' Formation; the other members rather belong to the Tekhten' Formation; the top member may already belong to the Lower Silurian Vtorye Utyosy Formation. Thus, the thickness of the Tekhten' Formation in the section may exceed 700 m.

3.3.3. Area of Bolshoi Yaloman Village

Yaloman-1 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Rhuddanian, Aeronian, Telychian.
Regional stratigraphic subdivisions: Vtorye Utyosy, Syrovaty and Polaty regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Vtorye Utyosy, Syrovaty and Polaty formations.
Fauna: tabulate corals, rugose corals, graptolites.

Lower Silurian strata crop out upstream of Bolshoi Yaloman Village along the Yaloman River, in a section (S-894) on the river right bank, 3.1 km upstream of the mouth, on the right side of a ravine, opposite a bridge across the Yaloman R. (Fig. 103). It includes (Fig. 104):

Thickness , m

1. Mudstone and siltstone: silver to dark gray, clayey, with 0.2--0.3 m thick interbeds of gray fine polymictic sandstone in lower 25 m; rocks in lower 90–100 m are more massive than rocks above; member contains graptolites: at 45th m – *Pseudoclimacograptus* sp., *Glyptograptus* sp., *Diplograptus* (s.l.) sp., at 90th m – *Monograptus* sp., *Glyptograptus* sp., *Diplograptus* sp., *Demirastrites* sp., at 135th m – *Pseudoclimacograptus* sp., *Diplograptus* (s.l.) sp. indet., *Monograptus* sp., *Pribylograptus* sp., *Petalolithus* ex gr. *ovatoelongatus* (Kurck), at 142nd m – *Monograptus* sp., at 150th m – *Diplograptus* (s.l.) sp. indet., at 155th m – *Glyptograptus tamariscus* (Nicholson), *Campograptus* ex gr. *communis* (Lapworth), *Streptograptus* sp. ..... ~190

2. Mudstone and siltstone (70% vol.): dirty yellow-gray, laminated (0.1-0.3 m), with interbeds (up to 30 % vol.) of dark gray detrital clayey limestone, locally oolitic, and lenses of purer massive limestone; member contains tabulate corals at 3 and 5 m from its base. At 3rd m of the member (loc. S-894-2/3) indetermined tabulate corals and (loc. S-894-4/3) rugose corals *Altaja minima* Zelt., at 5th m (loc. S-894-2/5, loc. S-894-4/5) tabulate corals *Mesofavosites dualis* Sok., *Paleofavosites* sp. (varying along strike) ..... from 2 m to 16

3. Siltstone: light gray, clayey ..... ~10 m

4. Limestone: dark gray, highly clayey, flaggy, with tabulate corals at 5 m and brachiopods at 35 m above member base. . 55

5. Limestone: slightly clayey, of uncertain bedding ..... ~10

6. Limestone: massive, often algal ..... >150

In the year 2007 P. Mannik collected 3 limestone samples from the member 4 (loc. S-894-4) of the Yaloman-1 section. Chemical proceeding revealed conodonts (provisional identification): sample N 1– *Panderodus* sp., sample N 2 – *Panderodus* sp., *Aspidognatus* sp. *Oulodus?* sp., *Ozarkodina* sp., *Aspelundia* sp., *Belodella* sp., sample N 3 – *Panderodus* sp.

The lower part of member 1 belongs to the Vtorye Utyosy Formation, and the upper part – to Syrovaty Formation. Members 2–6 are aligned with the Polaty Formation. Thickness of the Vtorye Utyosy Formation may exceed 100 m, Syrovaty Formation – about 90 m, Polaty Formation – 250 m.

Fig. 103. Sketch map of Yaloman River, mid-stream.

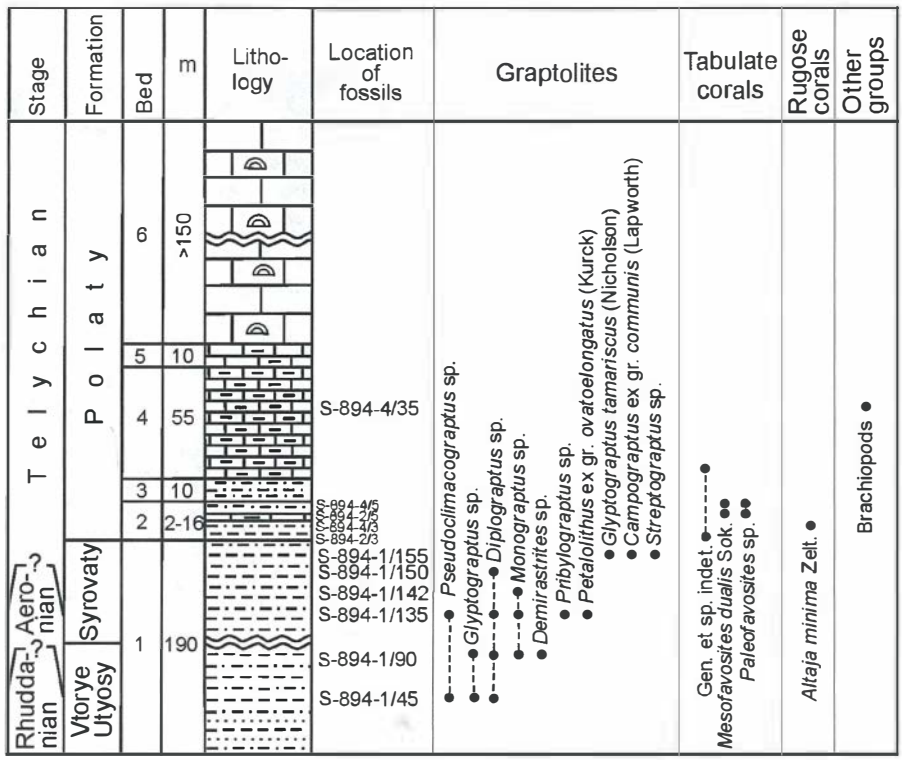


Fig. 104. Ranges of fossil taxa from Yaloman-1 section.

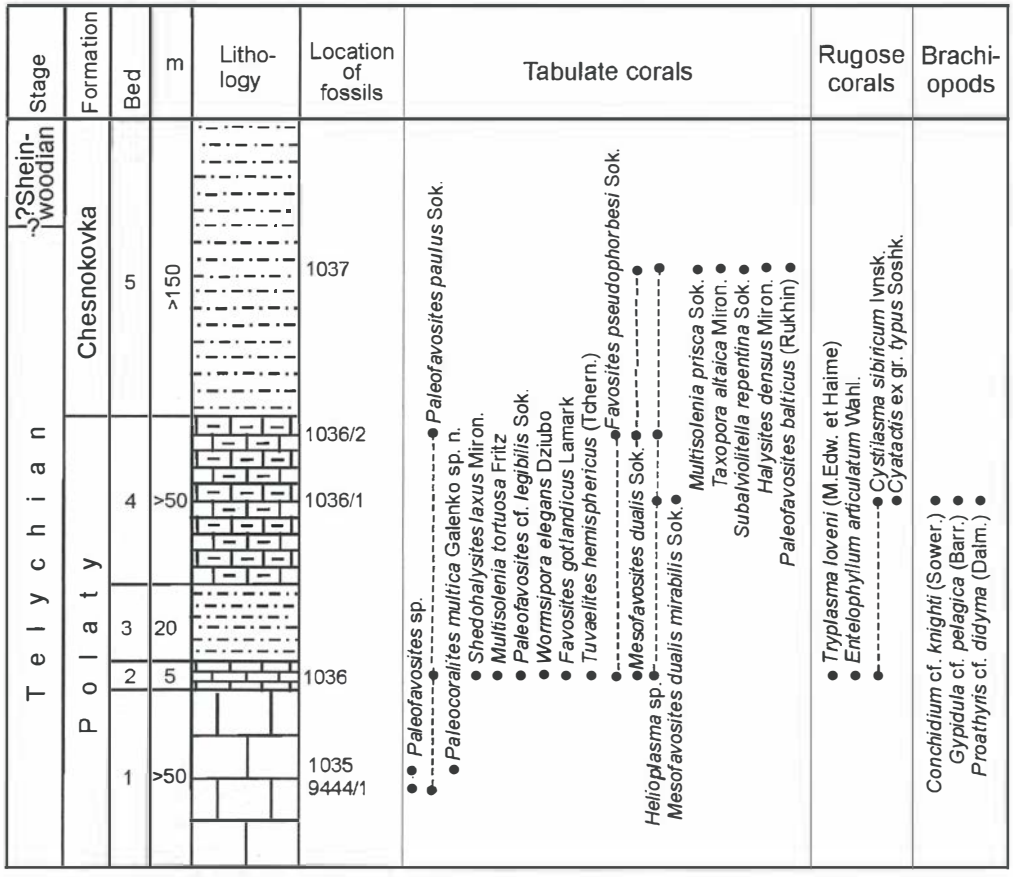


Fig. 105. Ranges of fossil taxa from Yaloman-2 section.

Fig. 106. Fine rhythmical intercalation of calcareous mudstones and clayey limestones from the Silurian Polaty Formation, Yaloman-1 section, member 2.

Fig. 107. Fine-platy clayey limestones from the Silurian Polaty Formation, Yaloman-1 section, member 4.

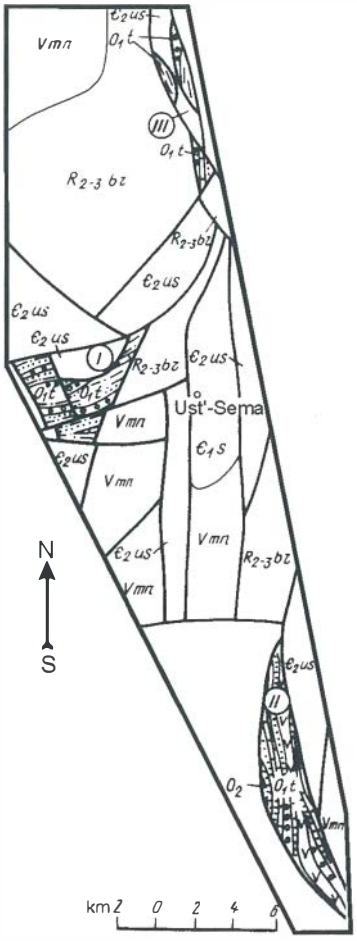


Fig. 108. Sketch map of the Katun' riverside, northern Gorny Altai (modified from Ermikov et al., 1979).

Yaloman-2 Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Telychian, ?Sheinwoodian.

Regional stratigraphic subdivisions: Polaty and Chesnokovka regional stages (horizons).

***Local lithostratigraphic subdivisions*:** Syrovaty and Polaty formations.

Fauna: tabulate corals, rugose corals, brachiopods, crustaceans.

The Yaloman-2 section continues upstream Yaloman R. right bank, in 150 m far from the Ak-Kaya Ravine head, on the ravine's right side (S-895, S-896) (Figs 105–107):

Thickness , m

1. Limestone: gray, massive, with tabulate corals (loc. 9444/1) *Paleofavosites paulus* Sok., *Paleofavosites* sp., (loc. 1035) *Paleocoralites multica* Galenko sp. n., *Paleofavosites* sp. ..... >50

2. Limestone: gray, laminated, with (loc. 1036) rugose corals *Tryplasma loveni* (M.Edw. et Haime), *Entelophyllum articulatum* Wahl., *Cystilasma sibiricum* Ivnsk, tabulate corals *Mesofavosites dualis* Sok., *Shedohalysites laxus* Miron., *Favosites pseudophorbesi* Sok., *Helioplasma* sp., *Multisolenia tortuosa* Fritz, *Paleofavosites paulus* Sok., *Paleofavosites* cf. *legibilis* Sok., *Wormsipora elegans* Dziubo, *Favosites gotlandicus* Lamark, *Tuvaelites hemisphericus* (Tchern.) 5

3. Siltstone: gray or greenish-bluish-gray, calcareous 20

4. Limestone: gray clayey, with patches of calcareous siltstone. From the middle part of the member were recovered: tabulate corals *Mesofavosites dualis mirabilis* Sok., *Helioplasma* sp., rugose corals *Cystilasma sibiricum* Ivnsk, *Cyatactis* ex gr. *typus* Soshk., brachiopods *Conchidium* cf. *knighti* (Sower.), *Gypidula* cf. *pelagica* (Barr.), *Protathyris* cf. *didyma* (Dalm.),

crustaceans. At the upper part of the member (loc. 1036/2) tabulate corals *Paleofavosites paulus* Sok., *Mesofavosites dualis* Sok., *Favosites pseudophorbesi* Sok., *Helioplasma* sp. have been collected .....>50

5. Siltstone: clayey, rarely calcareous, dark-grey and grey, with (loc. 1037) tabulate corals *Multisolenia prisca* Sok., *Taxopora altaica* Miron., *Subalviolitella repentina* Sok., *Halysites densus* Miron., *Mesofavosites dualis* Sok., *Paleofavosites balticus* (Rukhin), *Helioplasma* sp. .....>150

Members 1 to 4 belong to the Polaty Formation; and members 5 – to the Chesnokovka Formation. Thickness of the Polaty Formation is more than 130 m, and the incomplete thickness of the Chesnokovka Formation exceeds 150 m.

3.4. NORTHERN GORNY ALTAI

3.4.1. Area of Kamlak Village

Kamlak Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Upper Cambrian, Tremadocian.
Regional stratigraphic subdivisions: Dobry and Tayanza regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Kamlak Formation (Lower, Middle and Upper Subformations).
Zones: *Cordylodus lindströmi – Iapetognathus fluctivagus* conodont zones, *osloensis – ramosus* graptolite zone.
Fauna: trilobites, brachiopods, conodonts, graptolites, chitinozoans.

Tremadocian strata are most completely represented and best constrained by faunas near Kamlak Village thus making a tie for Tremadocian correlations throughout the Gorny Altai. A small (6 × 7 km) Kamlak graben is filled with terrigenous-carbonate sediments folded in an asymmetric fold cut by faults. According to lithology and fauna patterns, the stratotype section includes three units of unequal thicknesses: the Lower, Middle, and Upper Kamlak Subformations (Figs 109, 110).

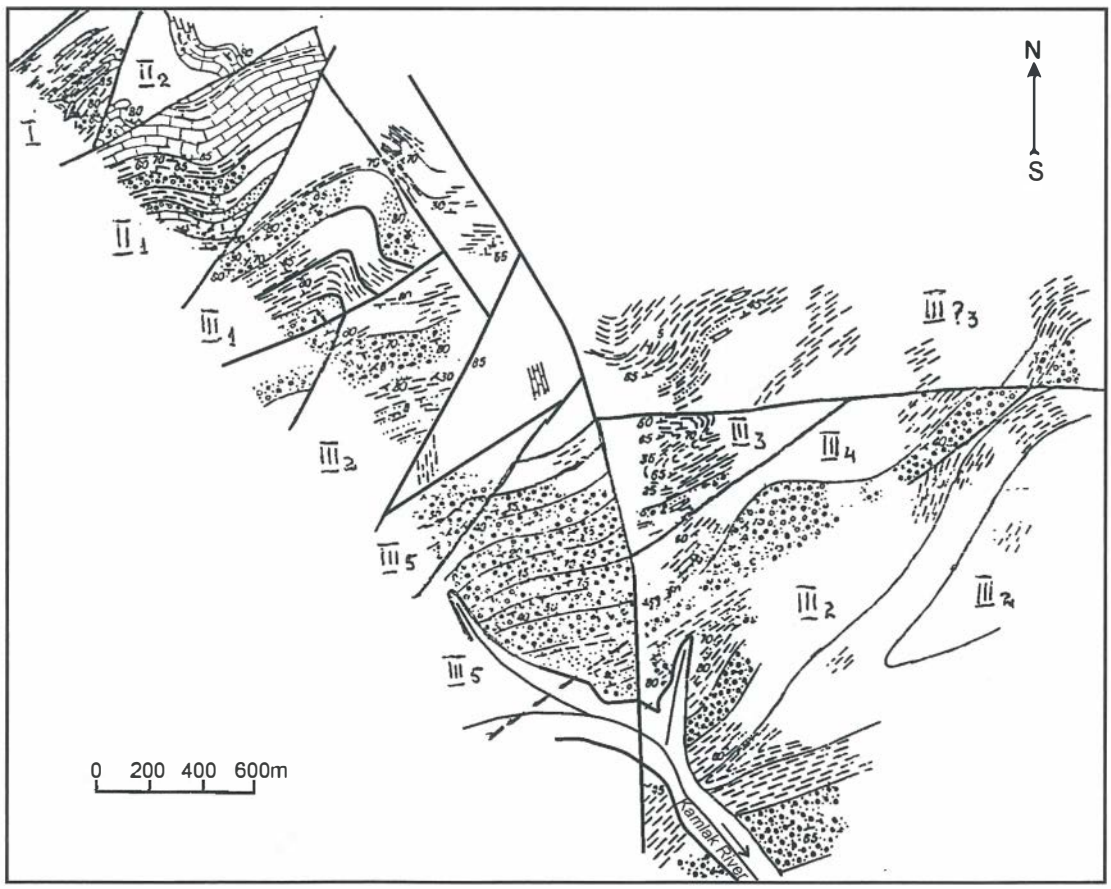


Fig. 109. Sketch map of the Maly Kamlak River, lower stream (modified from Ermikov et al., 1979).

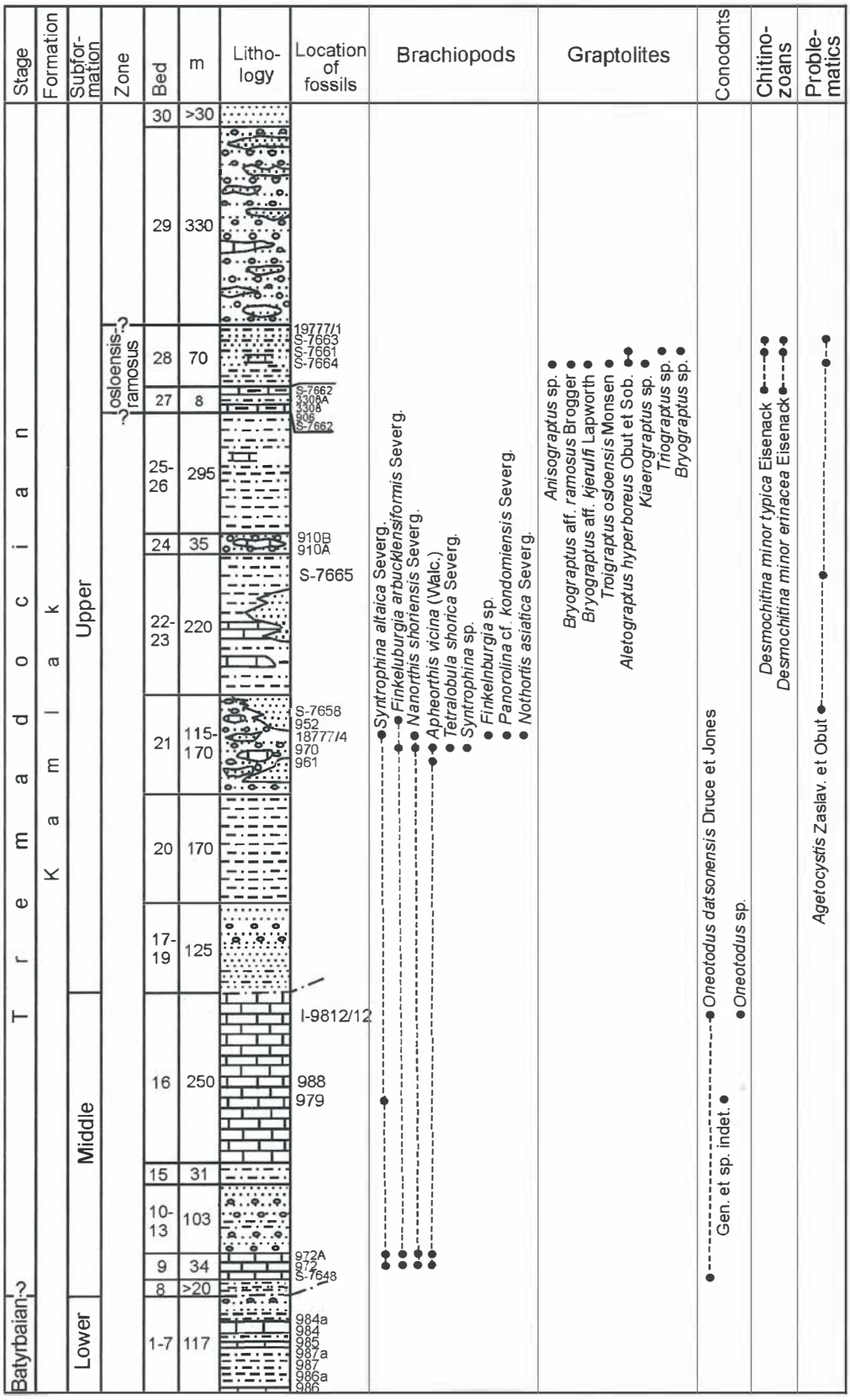


Fig. 110. Ranges of fossil taxa from Kamlak section.

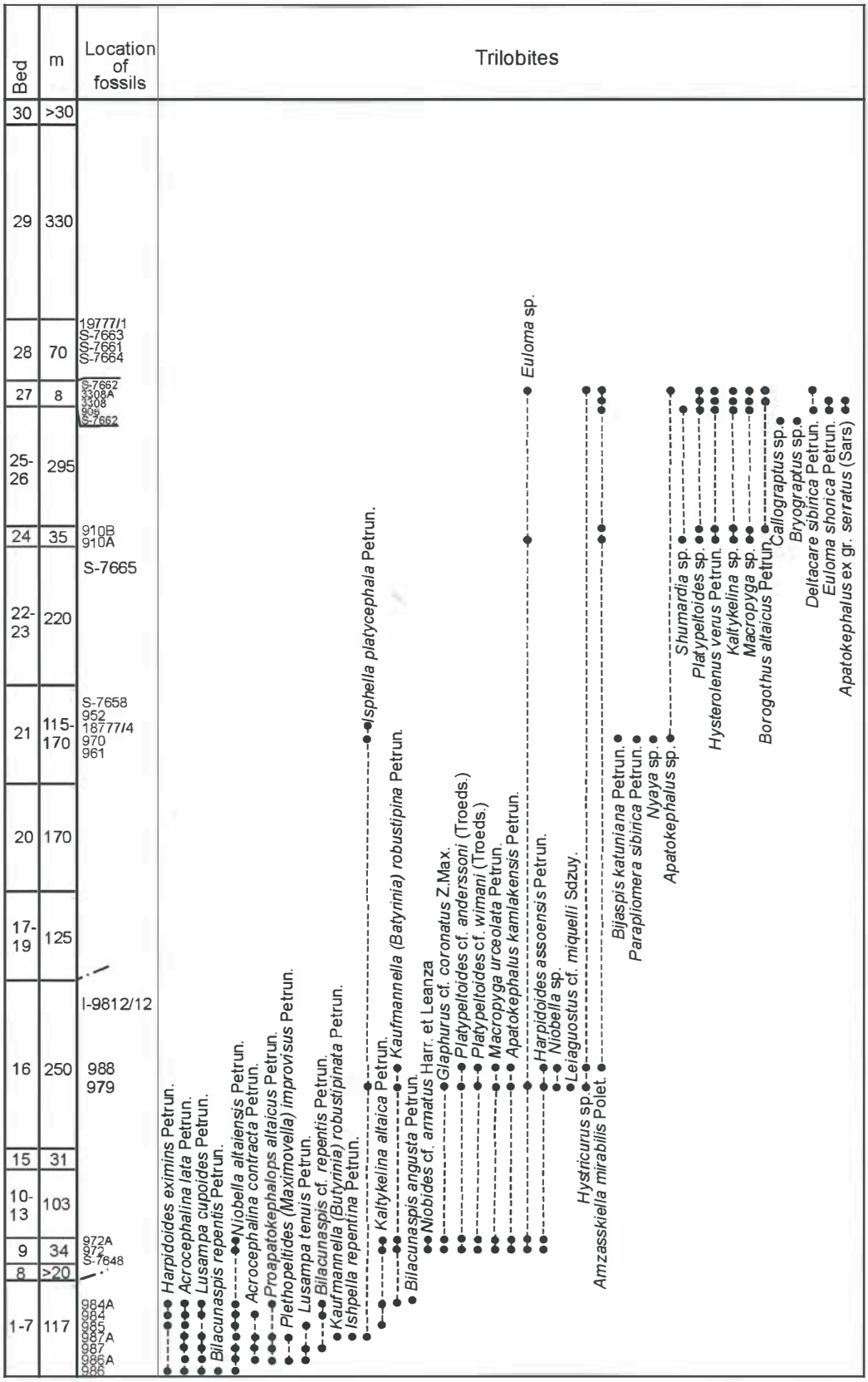

Bed
m
Location of fossils
Trilobites
30
>30
29
330
28
70
19777/1
S-7663
S-7661
S-7664
27
8
S-7662
3308A
3308
909
S-7662
25-26
295
24
35
910B
910A
S-7665
22-23
220
21
115-170
S-7658
952
18777/4
970
961
20
170
17-19
125
I-9812/12
16
250
988
979
15
31
10-13
103
9
34
972A
972
S-7648
8
>20
1-7
117
984A
984
985
987A
987
986A
986
Harpidoides eximins Petrun.
Acrocephalina lata Petrun.
Lusampa cupoides Petrun.
Bilacunaspis repentis Petrun.
Niobella altaiensis Petrun.
Acrocephalina contracta Petrun.
Proapatokephalops altaicus Petrun.
Plethopeltides (Maximovella) improvisus Petrun.
Lusampa tenuis Petrun.
Bilacunaspis cf. repentis Petrun.
Kaufmannella (Butyrinia) robustipinata Petrun.
Ishpella repentina Petrun.
Isphella platycephala Petrun.
Kaltykelina altaica Petrun.
Kaufmannella (Batyrinia) robustipina Petrun.
Bilacunaspis angusta Petrun.
Niobides cf. armatus Harr. et Leanza
Glaphurus cf. coronatus Z.Max.
Platypeltoides cf. anderssoni (Troeds.)
Platypeltoides cf. wimani (Troeds.)
Macropyga urceolata Petrun.
Apatokephalus kamlakensis Petrun.
Euloma sp.
Harpidoides assoensis Petrun.
Niobella sp.
Leiaguostus cf. miquelli Sdzuy.
Hystricurus sp.
Amzasskiella mirabilis Polet.
Bijaspis katuniana Petrun.
Parapliomera sibirica Petrun.
Nyaya sp.
Apatokephalus sp.
Shumardia sp.
Platypeltoides sp.
Hysterolenus verus Petrun.
Kaltykelina sp.
Macropyga sp.
Borogothus altaicus Petrun.
Callograptus sp.
Bryograptus sp.
Deltacare sibirica Petrun.
Euloma shorica Petrun.
Apatokephalus ex gr. serratus (Sars)

Fig. 111. Massive limestones from the Ordovician Middle Kamlak Subformation, Kamlak section, member 16.

Fig. 112. Rhythmical intercalation of siltstones and mudstones from the middle part of the Ordovician Upper Kamlak Subformation, Kamlak section.

Fig. 113. Massive conglomerates from the Ordovician Lower Kamlak Subformation, Kamlak section, member 24.

Fig. 114. Clayey massive bedded limestones from the Ordovician Upper Kamlak Subformation, Kamlak section, member 27.

The Lower Kamlak Subformation crops out in the middle reaches of the Maly Kamlak River where the base of the Kamlak Formation conacts, along a fault, with the volcanic rocks of the Middle Cambrian Ust'-Sema Formation. The Lower Kamlak Subformation section includes:

Thickness, m

1. Limestone: light gray, locally pinkish- or brownish-gray, thick-bedded, with trilobites in 1-m thick layers (loc. 986): *Harpidoides eximins* Petrun., *Acrocephalina lata* Petrun., *Lusampa cupoides* Petrun., *Bilacunaspis repentis* Petrun., *Niobella altaiensis* Petrun., (loc. 986a) trilobites *Proapatokephalops altaicus* Petrun., *Plethopeltides* (*Maximovella*) *improvisus* Petrun., *Lusampa tenuis* Petrun., *Lusampa cupoides* Petrun., *Niobella altaiensis* Petrun., *Acrocephalina lata* Petrun., *Acrocephalina contracta* Petrun., (loc. 987) trilobites *Niobella altaiensis* Petrun., *Bilacunaspis* cf. *repentis* Petrun., *Acrocephalina lata* Petrun., *Acrocephalina contracta* Petrun., *Proapatokephalops altaicus* Petrun., *Lusampa cupoides* Petrun., *Lusampa tenuis* Petrun., (loc. 987a) trilobites *Niobella altaiensis* Petrun., *Proapatokephalops altaicus* Petrun., *Plethopeltides* (*Maximovella*) *improvisus* Petrun., *Ishpella platycephala* Petrun., *Ishpella repentina* Petrun., *Kaufmannella* (*Butyrinia*) *robustipinata* Petrun., *Lusampa cupoides* Petrun., *Acrocephalina lata* Petrun., *Acrocephalina contracta* Petrun 6

2. Siltstone and mudstone: purple-gray and brown-red, with 3–4 cm pebble of dark gray limestone and black quartzite .. 17

3. Limestone: lilac- or pinkish-gray, of uncertain banding, crinoidal; a 50-cm thick layer (loc. 985) contains trilobites *Lusampa tenuis* Petrun., *Niobella altaiensis* Petrun., *Harpidoides eximins* Petrun., *Acrocephalina lata* Petrun., *Kaltykelina altaica* Petrun. etc. 6–8

4. Siltstone: lilac-gray, calcareous, of uncertain bedding 18

5. Limestone: pinkish-gray, massive, locally thin-bedded; a 50-cm thick layer (loc. 984) contains trilobites *Niobella altaiensis* Petrun., *Bilacunaspis* cf. *repentis* Petrun., *Acrocephalina lata* Petrun., *Acrocephalina contracta* Petrun., *Harpidoides eximius* Petrun., *Lusampa cupoides* Petrun., (loc. 984a) trilobites *Kaufmannella (Batyrinia) robustispina* Petrun., *Niobella altaiensis* Petrun., *Bilacunaspis* cf. *repentis* Petrun., *Bilacunaspis angusta* Petrun., *Proapatokephalops altaicus* Petrun., *Kaltykelina altaica* Petrun., *Acrocephalina lata* Petrun., *Harpidoides eximius* Petrun., *Lusampa cupoides* Petrun. etc. 6

6. Siltstone and slightly calcareous mudstone: lilac or brown-red, with layers of gray fine massive rather quartz-feldspar sandstone 60

7. Conglomerate: fine, with well- and rather well-rounded pebble of black and red quartzite and granite in a sandy-clayey-limy cement ..... >2

The total thickness of the Lower Kamlak Subformation is about 120 m.

The Lower and Middle Kamlak subformations are divided by a fault. The Middle Kamlak Subformation comprises:

8. Siltstone: gray or purple-gray, with 1–3 cm thick silty sandstone interbeds ..... >20

9. Limestone: light gray, massive, crystalline, with 2-4 m thick layers and lenses of purple-red limestone at member base; a 50-cm thick limestone layer (loc. 972, 972a) contains trilobites *Kaufmannella (Batyrinia) robustispina* Petrun., *Niobides* cf. *armatus* Harr. et Leanza, *Niobella altaiensis* Petrun., *Kaltykelina altaica* Petrun., *Platypeltoides* cf. *anderssoni* (Troeds.), *Platypeltoides* cf. *wimani* (Troeds.), *Macropyga urceolata* Petrun., *Apatokephalus kamlakensis* Petrun., *Euloma* sp., *Harpidoides assoensis* Petrun., *Glaphurus* cf. *coronatus* Z.Max., brachiopods *Finkelnburgia arbucklensiformis* Severg., *Syntrophina altaica* Severg., *Nanorthis shoriensis* Severg., *Apheorthis vicina* (Walc.). Chemical proceeding of rock samples revealed (loc. S-7648) conodonts *Oneotodus datsonensis* Druce et Jones from the member base 34

10. Conglomerate: fine to medium, with well rounded but poorly sorted pebbles of diverse quartzite, porphyry, less often schists, gneisses, and limestone in a limy-sandy cement 30

11. Siltstone: lilac-gray, brownish-gray or greenish-gray 22

12. Conglomerate: fine to medium, compositionally similar to that in member 10 31

13. Sandstone: variegated, rather quartz-feldspar, outsized, with minor amounts of disseminated "jasperiods" 12

14. Conglomerate: fine to medium 8

15. Siltstone: lilac or brown-red 31

16. Limestone: light gray, massive, crystalline, with lenses and layers (1-3 m) of reddish and grayish-brown limestone in lower layers (Fig. 111); member contains trilobites (loc. 979): *Kaufmannella (Batyrinia) robustispina* Petrun., *Glaphurus* cf. *coronatus* Z.Max., *Niobella* sp., *Ishpella platycephala* Petrun., *Macropyga urceolata* Petrun., *Apatokephalus kamlakensis* Petrun., *Leiagnostus* cf. *miquelli* Sdzuy., *Harpidoides assoensis* Petrun., *Glaphurus* cf. *coronatus* Z.Max., *Platypeltoides* cf. *anderssoni* (Troeds.), *Platypeltoides* cf. *wimani* (Troeds.), *Hystricurus* sp., *Euloma* sp., brachiopods *Syntrophina altaica* Severg., conodonts, (loc. 988) trilobites *Kaufmannella (Batyrinia) robustispina* Petrun., *Platypeltoides* cf. *anderssoni* (Troeds.), *Platypeltoides* cf. *wimani* (Troeds.), *Macropyga urceolata* Petrun., *Apatokephalus kamlakensis* Petrun., *Niobella* sp., *Hystricurus* sp., *Harpidoides assoensis* Petrun., *Amzasskiella mirabilis* Polet., (loc. I-9812/12) conodonts *Oneotodus datsonensis* Druce et Jones, *Oneotodus* sp. 250

The total thickness of the Middle Kamlak Subformation is about 440 m.

The Middle and Upper Kamlak Subformations are divided by a fault. The Upper Kamlak Subformation comprises:

17. Sandstone: gray or reddish-gray, fine to coarse, with siltstone interbeds 59

18. Conglomerate: fine, grading on strike into sandstone 35

19. Sandstone: gray or reddish-gray, fine to coarse, with angular clasts of brown-red siltstone in detrital material 29

20. Siltstone and mudstone, brown-red (Fig. 112) 170

21. Conglomerate: fine and medium, with poorly sorted quartzite, quartz, granite, volcanic, and limestone pebbles of high or

medium roundness, grading on strike into gravelstone and sandstone; conglomerate encloses scarce lenses of reddish-gray sandy limestone with brachiopods (loc. 961) *Apheorthis vicina* (Walc.), (loc. 970) trilobites *Ishpella platycephala* Petrun., *Bijaspis katuniana* Petrun., *Parapliomera sibirica* Petrun., *Nyaya* sp., *Apatokephalus* sp., brachiopods *Apheorthis vicina* (Walc.), *Nanorthis shoriensis* Severg., *Finkelnburgia arbucklensiformis* Severg., *Syntrophina* sp., *Tetralobula shorica* Severg., (loc. 18777/4) trilobites *Ishpella platycephala* Petrun., brachiopods *Finkelnburgia* sp., *Syntrophina altaica* Severg., *Nanorthis shoriensis* Severg., *Panorolina* cf. *kondomiensis* Severg., *Nothortis asiatica* Severg., (loc. 952) brachiopods *Finkelnburgia arbucklensiformis* Severg. Chemical proceedings of rocks from loc. S-7658 revealed problematic *Agetocystis* Zaslav. et Obut 115–170

22. Siltstone: and mudstone, brown-red, with fine sandstone interbeds and limestone lenses ..... >200

23. Siltstone: gray or greenish-gray; dissolution of rocks from loc. S-7665 revealed problematic *Agetocystis* Zaslav. et Obut. ..... >20

24. Fine and medium conglomerate (Fig. 113), with trilobites found in a limestone layer in the middle of the member (loc. 910a): *Amzasskiella mirabilis* Polet., *Platypeltoides* sp., *Hysterolenus verus* Petrun., *Kaltykelina* sp., *Macropyga* sp., *Shumardia* sp., *Eulonia* sp., (loc. 9106) trilobites *Borogothus altaicus* Petrun., *Amzasskiella mirabilis* Polet., *Platypeltoides* sp., *Hysterolenus verus* Petrun., *Kaltykelina* sp., *Macropyga* sp. 35

25. Siltstone and mudstone: brown-red 165

26. Siltstone: brown-red, with lenses and layers of red nodular limestone 130

27. Limestone: black and gray, clayey, with black, gray, and yellowish-gray siltstone interbeds; limestone and less often siltstone (Fig. 114) (loc. S-7662) contains graptolites: *Callograptus* sp., *Bryograptus* sp., (loc. 906) trilobites *Deltacare sibirica* Petrun., *Euloma shorica* Petrun., *Apatokephalus* ex gr. *serratus* (Sars), *Platypeltoides* sp., *Hysterolenus verus* Petrun., *Kaltykelina* sp., *Amzasskiella mirabilis* Polet., *Shumardia* sp., *Macropyga* sp., (loc. 3308) trilobites *Platypeltoides* sp., *Hysterolenus verus* Petrun., *Amzasskiella mirabilis* Polet., *Macropyga* sp., *Eulonia shorica* Petrun., *Apatokephalus* ex gr. *serratus* (Sars), *Kaltykelina* sp., *Borogothus altaicus* Petrun., (loc. 3308a) trilobites *Borogothus altaicus* Petrun., *Platypeltoides* sp., *Macropyga* sp., *Amzasskiella mirabilis* Polet., *Hystricurus* sp., *Apatokephalus* sp., *Hysterolenus verus* Petrun., *Kaltykelina* sp., *Eulonia* sp., *Deltacare sibirica* Petrun. dissolution of rocks from loc. S-7662 revealed chitinozoans *Desmochitina minor* Eisenack 8

28. Siltstone: brown-red, grading toward member top into gray and greenish-gray siltstone, with fine sandstone layers and limestone lenses in member upper part; sandstone contains graptolites (loc. S-7664): *Anisograptus* sp., *Bryograptus* aff. *ramosus* Brogger, *Bryograptus* aff. *kjerulfi* Lapworth, *Troigraptus osloensis* Monsen, *Aletograptus hyperboreus* Obut et Sob., *Kiaerograptus* sp., (loc. S-7661) graptolites *Bryograptus* sp., *Aletograptus hyperboreus* Obut et Sob., *Triograptus* sp. Chemical proceeding of silstones (loc. S-7661) revealed chitinozoans *Desmochitina minor erinacea* Eisenack and problematics, (loc. S-7663) chitinozoans *Desmochitina minor* Eisenack and (loc. S-7663 and S-7664) – problematics *Agetocystis* Zaslav. et Obut 70

According to B.D. Erdtmann who looked through the data, some graptolite forms found in member 28 and identified as *Triograptus osloensis* Monsen and *Aletograptus hyperboreus* Obut et Sob. may belong to genus *Psigraptus* Jackson. These forms are rhabdosomes buried in sandstone, and their preservation leaves unknown the intravital direction (upward or horizontal?) of branches off the sicula. On the other hand, the Altai morphs lack occluded autothecas typical of *Psigraptus* and thus may be transitional from the *Triograptus* Monsen and *Aletograptus* genera to *Psigraptus* Jackson. The graptolite assemblage from locs S-7662, S-7664, and S-7661 generally corresponds to the *osloensis – ramosus* zone.

Locality 19777/1, which occurs 1 km to the northwest of the Takoshkin Brook mouth and possibly belongs to the same member 28, contains trilobites *Platypeltoides* sp., *Hysterolenus verus* Petrun., *Kaltykelina* sp., *Macropyga* sp., *Borogothus altaicus* Petrun.

29. Conglomerate: fine and medium, with poorly sorted quartzite, quartz, granite, volcanic, sandstone, and limestone pebbles of high to medium roundness 330

30. Sandstone: gray, dark gray, or greenish-gray, outsized, polymictic ..... > 30

In the year 2007 P. Mannik collected limestone samples from the Kamlak section. Chemical proceeding revealed conodonts (provisional identification): from the lower part of the Middle Kamlak Formation, member 9, sample N 10 and from the upper part of the Middle Kamlak Formation, member 16, sample N 9 - *Variobiliconus* sp.

The Upper Kamlak Subformation has a total thickness of about 1400 m and is of a Late Tremadocian age according to the faunas.

The subdivision of the Kamlak Section into subformations is based on lithology and faunal control, mainly from trilobites. Members are aligned according to lithology and trilobite, graptolite, and brachiopod assemblages.

The composite section of the Kamlak Formation can be correlated with the International Stratigraphic Chart on the basis of few species of conodonts and graptolites. The conodont species *Oneotodus datsonensis* Druce et Jones found in members 9 and 12 in the lower half of the Middle Kamlak Subformation is known in the Datsonian and lowermost Warendian groups of Australia that span a stratigraphic interval of the *Cordylodus proavus, Hirsutodontus simplex, Cordylodus prolindstromi* and *Cordylodus lindstromi* zones (Dubinina, 2000). One may expect to find a transitional assemblage between the *Cordylodus lindströmi* and *Iapetognathus fluctivagus* zones in the Lower Middle Kamlak Subformation. The graptolite assemblage found in member 28 of the Upper Kamlak Subformation corresponds to the

osloensis – ramosus zone. Earlier data on trilobites from the Lower Kamlak Subformation defined its Early Tremadocian age (Ermikov et al., 1979; Petrunina et al., 1984). The present view is that the Lower Kamlak Subformation must rather correlate with the uppermost Cambrian, proceeding from the revised conodont-based age and stratigraphy of the Ordovician-Silurian boundary strata (Webby et al., 2004) and from the correlation of the Mansian and Loparian regional stages of the Siberian Platform with the Late Cambrian (Kanygin et al, 2007). The trilobite and graptolite data suggest a Late Tremadocian age of the Upper Kamlak Subformation. Thus, the Middle Kamlak Subformation may correlate with the Lower Tremadocian. The trilobite assemblage from the Middle Kamlak Subformation differs from those in both the Lower and Upper Kamlak subformations.

3.5. NORTHESTERN GORNY ALTAI

3.5.1. Area of Verkh-Biysk Village

Pereval Section
Chronostratigraphic subdivisions of the International Stratigraphic Scale: Tremadocian.
Regional stratigraphic subdivisions: Tayanza Regional Stage (Horizon).
Local lithostratigraphic subdivisions: Ishpa Formation.
Zones: *tenellus – kiaeri* graptolite zone.
Fauna: trilobites, graptolites.

A small fragment of the Ishpa Formation (S-0726) is exposed in a quarry on a pass along the left side of the roadway from Gorno-Altaisk to Verkh-Biysk Village (distance mark 105/9) (Figs 115–117):

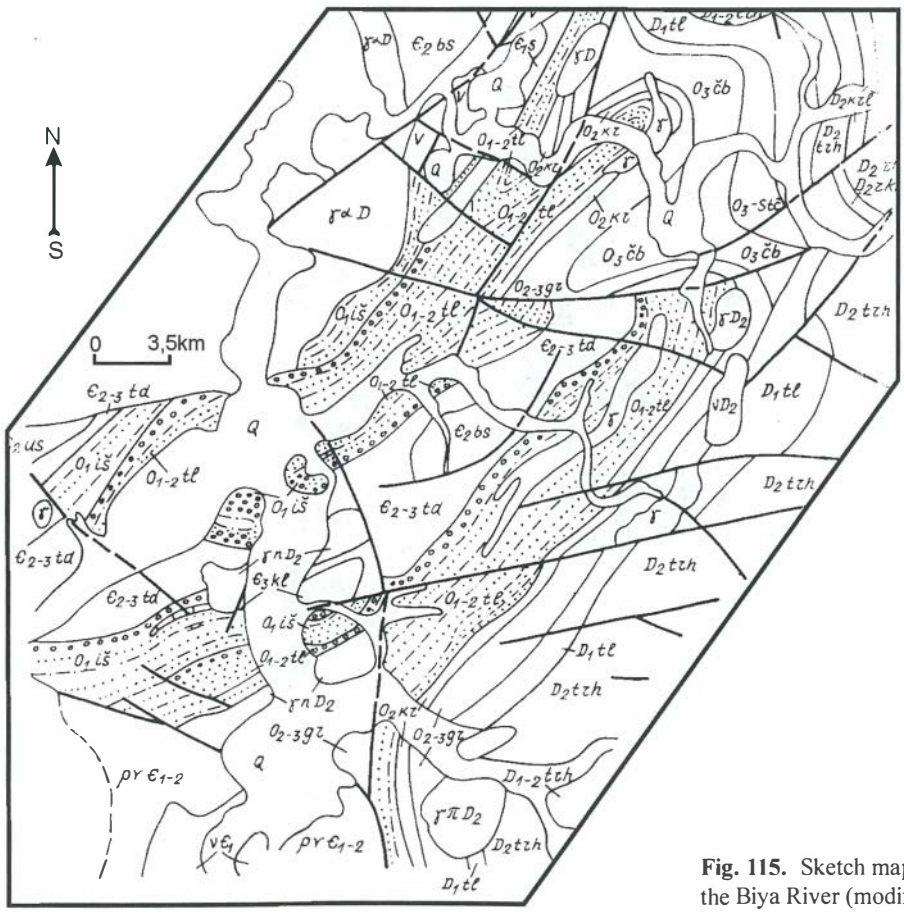


Fig. 115. Sketch map of the lower and middle stream of the Biya River (modified from Petrunina et al., 1984).

Fig. 116. General view of Pereval section (upper part of the Ordovician Ishpa Formation, member 1, section S-0727).

Fig. 120. General view of Tuloi section (upper part of the Ordovician Tuloi Formation, members 15 and 16).

Thickness, m

1. Sandstone: dark olive, rather quartz, fine to coarse, polymictic, alternating with dark olive clayey siltstone, often with conchoidal cleavage; both sandstone and siltstone layers are 1 m thick; sandstone is of high and medium roundness and shows good 1-2 cm sorting from fine to medium and on to coarse grain sizes; locally there are syndepositional lenses (from 1–3 cm to 5–7 cm long and 1–3 cm thick) and patches of siltstone in sandstone ..... ~15

Another fragment of the Ishpa Formation (S-0727) is exposed 2 km to the east in a quarry on the left side of the roadway from Gorno-Altaisk to Verkh-Biysk Village, 100 m far from distancemark 107/7:

1. Sandstone: greenish-gray, fine to medium, well sorted, and tuffaceous sandstone, with scarce thin (to 10 cm) layers of greenish-gray clayey siltstone; sandstone shows 1.5 m cleavage and 20-30 cm flaggyness; thin (1-3 cm) layers of fine sandstone are of cross bedding; fine sandstone encloses lens-shaped (10–15 cm long and 0.5–1 cm thick) medium to coarse sandstone and scarce floating siltstone pebble of 3–10 cm in diameter; there are large (to 15 cm) "tongues" of slumping soft sediment ..... > 25

Green sandstone is thrust on yellow siltstone in the eastern end of the quarry (S-0727).

Dark olive-gray siltstone in bedrock exposures along the right side of the roadway between the two quarries (S-0726 and S-0727) contains graptolites (loc. S-78146) *Adelograptus* aff. *tenellus* (Linnarsson), *Kiaerograptus kiaeri* (Monsen), and sanstone (loc. 205) contains trilobites *Symphysurus* sp., *Geragnostus* sp., Raphiophoridae; graptolites *Anisograptus* sp. are found at loc. 4062a/1668 in the same area. According to rock lithology and faunas (trilobite and graptolite assemblages), the section fragment belongs to the Ishpa Formation. Graptolites correspond to the Tremadocian *Adelograptus tenellus* and *Kiaerograptus kiaeri* zones.

The total thickness of the Ishpa composite section (S-0726, S-0727, S-78146) may reach no less than 100 m.

Mengalevsky Section

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Tremadocian.
Regional stratigraphic subdivisions: Tayanza Regional Stage (Horizon).
***Local lithostratigraphic subdivisions*:** Ishpa Formation .
Fauna: trilobites, brachiopods.

At the top of the Ishpa section there is a 100-m thick member of yellow, dark olive-gray, and grayish-brown siltstone with thin layers of gray limestone. The member crops out near Verkh-Biysk Village along the Mengalevsky Brook and contains rich trilobite assemblages in 5-cm layers spaced at 10 m *Apatokephalus* ex. gr. *serratus* (Sars), *Symphysurus* sp., *Ceratopyge mengalensis* Petrun. sp. n., *Shumardia optima* Petrun., *Glaphurus* cf. *coronatus* Z. Max., *Amzasskiella mirabilis* Polet., *Am. obliqua* Petrun., *Hystricurus* sp., *Pseudagnostus* sp., *Euloma* cf. *shorica* Petrun. sp. n., *Hospes* sp., *Miraspis* sp., *Illaenus* sp., *Geragnostus* sp., *Nyaya* sp. etc. Among brachiopods are: *Finkelnburgia* aff. *delicatula* Cooper, *Fin. arbucklensiformis* Severg., *Nanorthis shoriensis* Severg. (locs 160, 160a, 162, 163). The member is conformably overlain by the Tuloi Formation. Trilobites found at the Mengalevsky Brook define a Late Tremadocian age of the sediments.

3.5.2. Area of Tuloi Village

Section Tuloi

Chronostratigraphic subdivisions of the International Stratigraphic Scale: Floian, Dapingian, Darriwilian, Sandbian.
Regional stratigraphic subdivisions: Lebed', Kostinsky and Khankhara regional stages (horizons).
***Local lithostratigraphic subdivisions*:** Tuloi, Karasa and Gur'yanovka formations.
Zones: *approximatus, densus, angustifolius elongatus, gibberulus, hirundo, dentatus* graptolite zones, *Cyathochitina parvicolla, Cyath. calix* chitinozoan biozones.
Fauna: trilobites, brachiopods, ostracods, orthoceratids, crinoids, gastropods, hyolites, graptolites, ostracods, chitinozoans.

The stratotype section of the Tuloi Formation extends along the right bank of the Biya River downstream of the Tuloi inflow and then upstream the Tuloi on its right bank (Fig. 118). According to graptolites, trilobites, and brachiopods, the Tuloi Formation spans the Floian, Dapingian, and lower Darriwilian. The formation overlaid conformably the Ishpa Formation and is underlain by the Karasa Formation.

The section includes (Fig. 119):

Thickness, m

1. Conglomerate, variegated, coarse, or less often conglomerated sandstone, with pebbles of granite, microgranite, porphyry granite, pegmatite granite, intermediate and basic porphyry, tuff, quartz, siltstone, sandstone, clayey and siliceous shale. Member

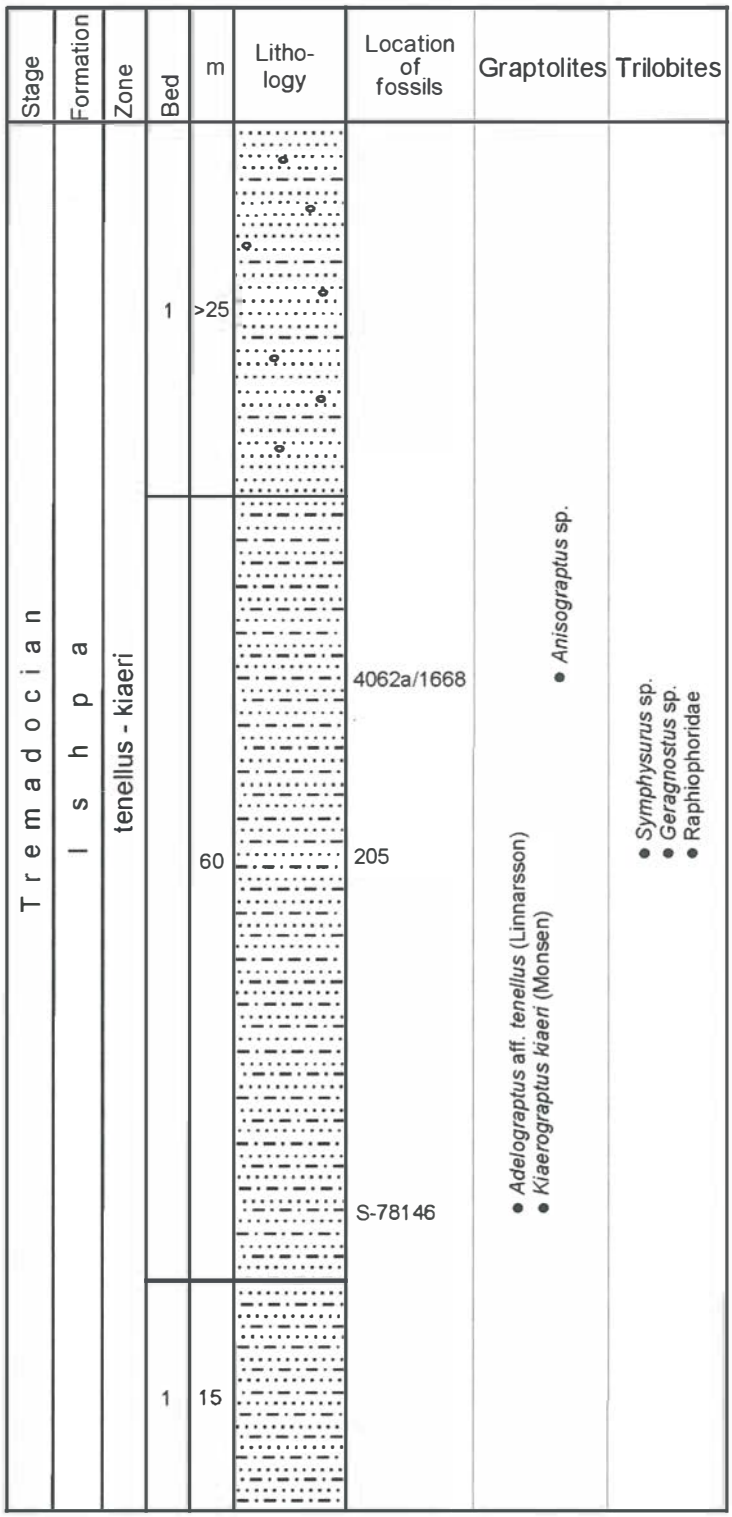


Fig. 117. Ranges of fossil taxa from Pereval section.

occurs on the right bank of the Mengalevsky Brook near Verkh-Biysk Village and on a pass along the roadway from Turochak Village to Artybash Village. The section exposed in a quarry on the pass (distance mark 194/43) consists of brownish-dirty gray massive medium to coarse and boulder conglomerate with unsorted well rounded round pebbles from 1 cm to 10 cm in diameter, rarely up to 20 cm, occupying up to 80-95 % of rock volume in a fine-medium sandstone matrix; there are lenses of reddish brownish-gray medium to coarse sandstone 130

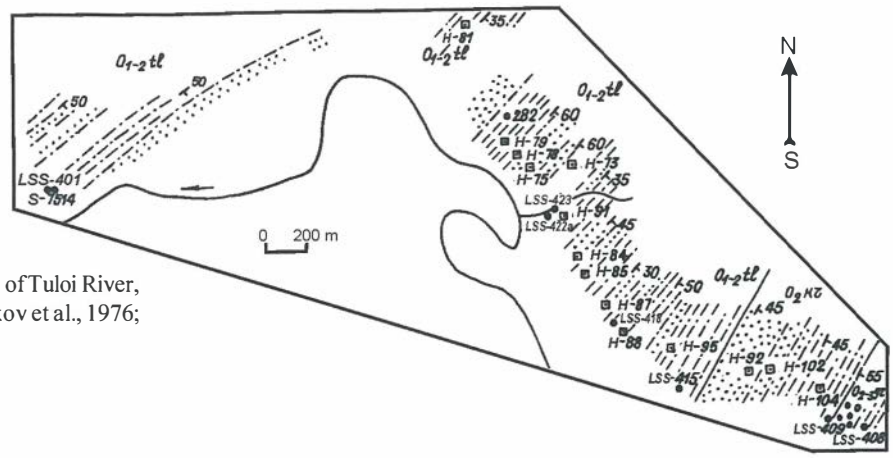


Fig. 118. Sketch map of the right bank of Tuloi River, lower stream (modified from Krivchikov et al., 1976; Petrunina et al., 1984).

2. Sandstone: variegated, polymictic, fine to medium 70
3. Siltstone: greenish-gray, more rarely gray to dark gray, rarely purple 150
4. Sandstone: greenish-gray, polymictic, fine to medium 175
5. Interbedded siltstone, silty sandstone, and fine polymictic sandstone, greenish-gray, dark olive-gray, locally dark gray ... . ~ 700

A section exposed in a quarry on the pass (roadway from Turochak Village to Artybash Village, distance mark 195/42) consists of well washed and well sorted laminated (0.5–1.0 m) siltstone of thin (1 mm) banding; rocks show graded bedding from fine sandstone, with a straight distinct lower boundary, to siltstone and mudstone, in 15–20 cm rhythms; sandstone has thin cross bedding; some sandstone layers occasionally enclose flat (10–15–20 cm in diameter and 2–3–5 cm thick) "rolls" of silver-gray siltstone occupying 5–10 % vol.; there are divergent ripple marks (0.1–0.3 cm wide ripples spaced at 0.5–1 cm).

Dark gray siltstone in member upper third on the right bank near the Tuloi River mouth contains graptolites (loc. LSS-401): *Paratetragraptus approximatus* (Nicholson), (loc. S-7514) – *Dichograptus* sp., *Tetragraptus* sp., *Paratetragraptus approximatus* (Nicholson), *Eotetragraptus* aff. *headi* (Hall) .

6. Interbedded greenish-gray siltstone and silty sandstone, less often fine sandstone; with graptolites in lower layers (loc. H-81 = S-7516): *Expansograptus suecicus* (Tullberg), *Pendeograptus* aff. *pendens* Elles 230
7. Sandstone: greenish-gray, polymictic, fine to medium 150
8. Siltstone: greenish-gray, less often silty sandstone (to fine polymictic sandstone), with indefinable graptolites of an Ordovician habit in member lower third (loc. 282) and graptolites *Acrograptus* sp. found in middle layers (loc. H-79) 155
9. Siltstone: gray or dark gray, occasionally silty sandstone, with chitinozoans (loc. H-78 = S-7517) *Desmochitina minor* Eisenack, *Hercochitina* sp., *Rhabdochitina* sp. and graptolites *Isograptus gibberulus* (Nicholson), *Expansograptus hirundo* (Salter), *Isograptus* sp., *Expansograptus* sp. 20
10. Sandstone: greenish-gray or dark olive-gray, fine, polymictic, alternating with silty sandstone, or less often siltstone, with graptolites in member lower third (loc. H-75 = S-7518): *Isograptus gibberulus* (Nicholson), *Tetragraptus* sp., *Tetragraptus bigsbyi bigsbyi* (Hall), *Tristichograptus ensiformis* (Hall), *Expansograptus* sp., *Isograptus* sp., *Expansograptus extensus* (Hall). From the upper part of the member graptolites (loc. LSS-422a) *Expansograptus* sp., (loc. LSS-423 = S-7512) - *Isograptus gibberulus* (Nicholson), *Isograptus* sp., *Expansograptus extensus* (Hall), *Expansograptus* sp., *Tristichograptus ensiformis* (Hall), *Tristichograptus* sp., *Cryptograptus* sp., together with chitinozoans *Conochitina* aff. *parvicolla* Tougourdeau, (loc. H-91 = S-7513) *Isograptus gibberulus* (Nicholson), *Isograptus* sp., *Expansograptus taimyrensis* Obut et Sob., *Expansograptus* sp., *Corymbograptus* sp., *Phyllograptus* sp., *Acrograptus* sp. have been found. 230
11. Interbedded siltstone, silty sandstone, and rarely fine sandstone, greenish-gray, occasionally with thin layers of gray to dark gray siltstone 55
12. Interbedded fine polymictic sandstone and silty sandstone, greenish-gray and gray, with scarce thin (to 2 cm) layers of dark gray calcareous siltstone; member contain graptolites in lower layers (loc. H-84 = S-7522): *Isograptus gibberulus* (Nicholson), *Expansograptus extensus* (Hall), *Expansograptus* sp., *Tristichograptus ensiformis* (Hall), *Pseudophyllograptus* ex gr. *angustifolius* Hall. 65
13. Silty sandstone: greenish-gray, more rarely fine polymictic sandstone, and greenish-gray, gray to dark gray siltstone; silty sandstone in lower layers (loc. H-85 = S-7521) contains graptolites *Isograptus gibberulus* (Nicholson), *Is. schrenki* Obut et Sob., *Is. hemicyclus* (Harris), *Isograptus* sp., *Expansograptus extensus* (Hall), *Eotetragraptus harti* (Hall), *Phyllograptus* sp. 45
14. Silty sandstone: greenish-gray, less often greenish-gray fine polymictic sandstone, and dark gray siltstone (Fig. 120). Member contains graptolites in middle layers (loc. H-87 = S-7520): *Isograptus gibberulus* (Nicholson), *Corymbograptus holubi* Kraft, *Corym. deflexus* (Elles et Wood), *Expansograptus* sp., *Tristichograptus* sp., *Cryptograptus* sp.

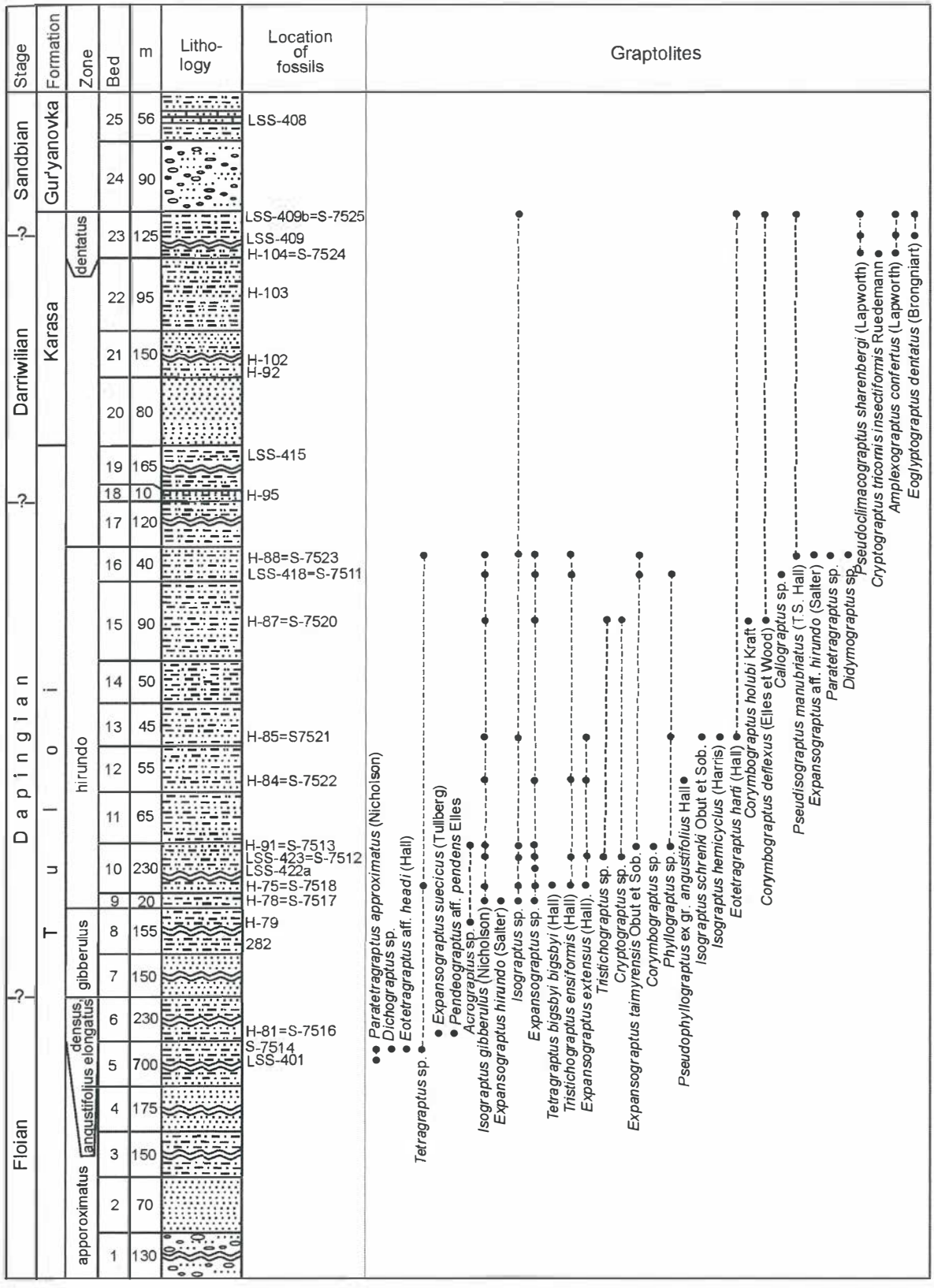
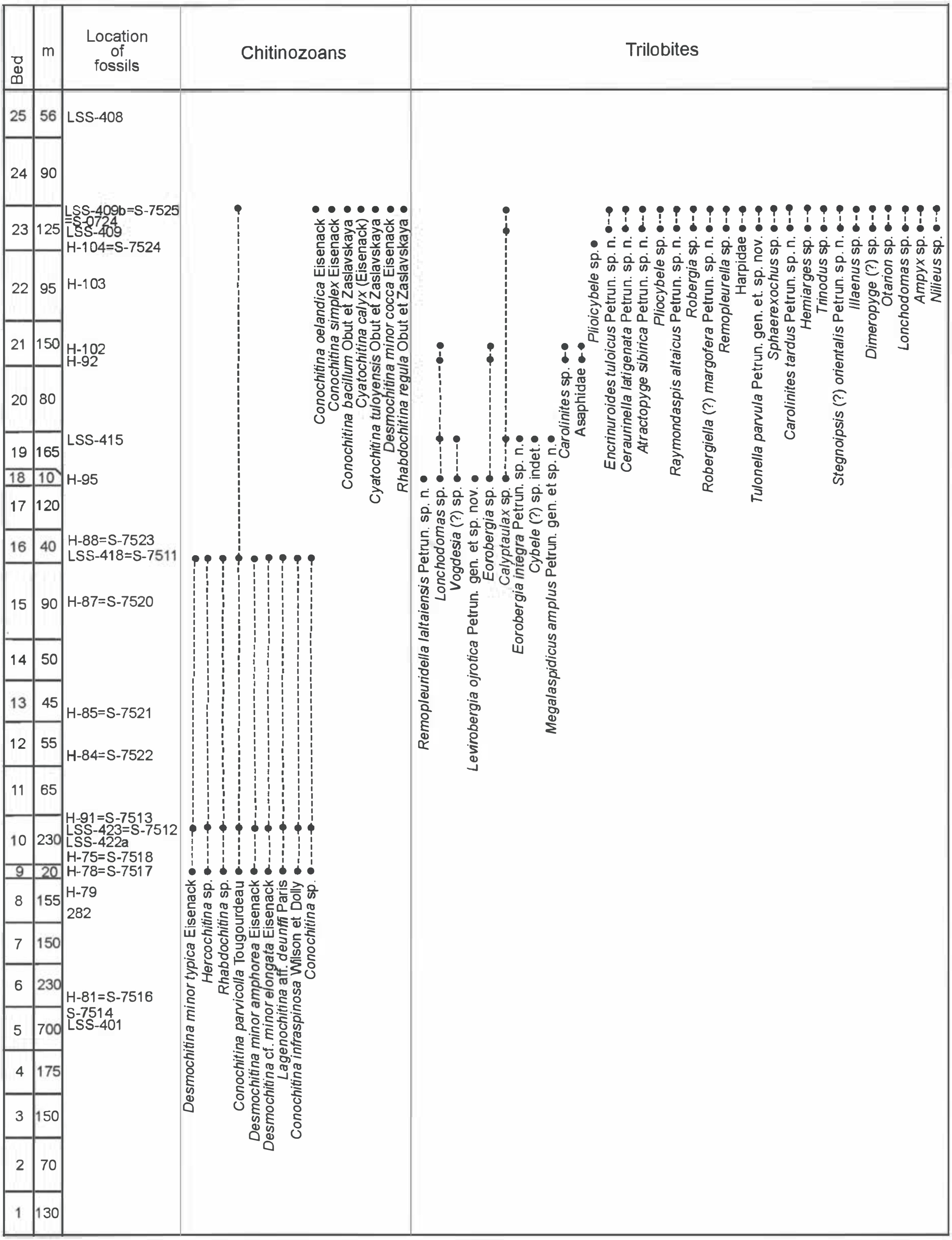


Fig. 119 A. Ranges of fossil taxa from Tuloi section.


Bed
m
Location of fossils
Chitinozoans
Trilobites
25 56 LSS-408
24 90
23 125 LSS-409b=S-7525 =S-0724 LSS-409 H-104=S-7524
22 95 H-103
21 150 H-102 H-92
20 80
19 165 LSS-415
18 10 H-95
17 120
16 40 H-88=S-7523 LSS-418=S-7511
15 90 H-87=S-7520
14 50
13 45 H-85=S-7521
12 55 H-84=S-7522
11 65
10 230 H-91=S-7513 LSS-423=S-7512 LSS-422a H-75=S-7518
9 20 H-78=S-7517
8 155 H-79 282
7 150
6 230 H-81=S-7516
5 700 S-7514 LSS-401
4 175
3 150
2 70
1 130
Desmochitina minor typica Eisenack
Hercochitina sp.
Rhabdochitina sp.
Conochitina parvicolla Tougourdeau
Desmochitina minor amphorea Eisenack
Desmochitina cf. minor elongata Eisenack
Lagenochitina aff. deunffi Paris
Conochitina infraspinosa Wilson et Dolly
Conochitina sp.
Conochitina oelandica Eisenack
Conochitina simplex Eisenack
Conochitina bacillum Obut et Zaslavskaya
Cyatochitina calyx (Eisenack)
Cyatochitina tuloyensis Obut et Zaslavskaya
Desmochitina minor cocca Eisenack
Rhabdochitina regula Obut et Zaslavskaya
Remopleuridella laltaiensis Petrun. sp. n.
Lonchodomas sp.
Vogdesia (?) sp.
Levirobergia ojrotica Petrun. gen. et sp. nov.
Eorobergia sp.
Calyptaulax sp.
Eorobergia integra Petrun. sp. n.
Cybele (?) sp. indet.
Megalaspidicus amplus Petrun. gen. et sp. n.
Carolinites sp.
Asaphidae
Plioicybele sp.
Encrinuroides tuloicus Petrun. sp. n.
Ceraurinella latigenata Petrun. sp. n.
Atractopyge sibirica Petrun. sp. n.
Pliocybele sp.
Raymondaspis altaicus Petrun. sp. n.
Robergia sp.
Robergiella (?) margofera Petrun. sp. n.
Remopleurella sp.
Harpidae
Tulonella parvula Petrun. gen. et. sp. nov.
Sphaerexochus sp.
Carolinites tardus Petrun. sp. n.
Hemiarges sp.
Trinodus sp.
Stegnoipsis (?) orientalis Petrun. sp. n.
Illaenus sp.
Dimeropyge (?) sp.
Otarion sp.
Lonchodomas sp.
Ampyx sp.
Nileus sp.

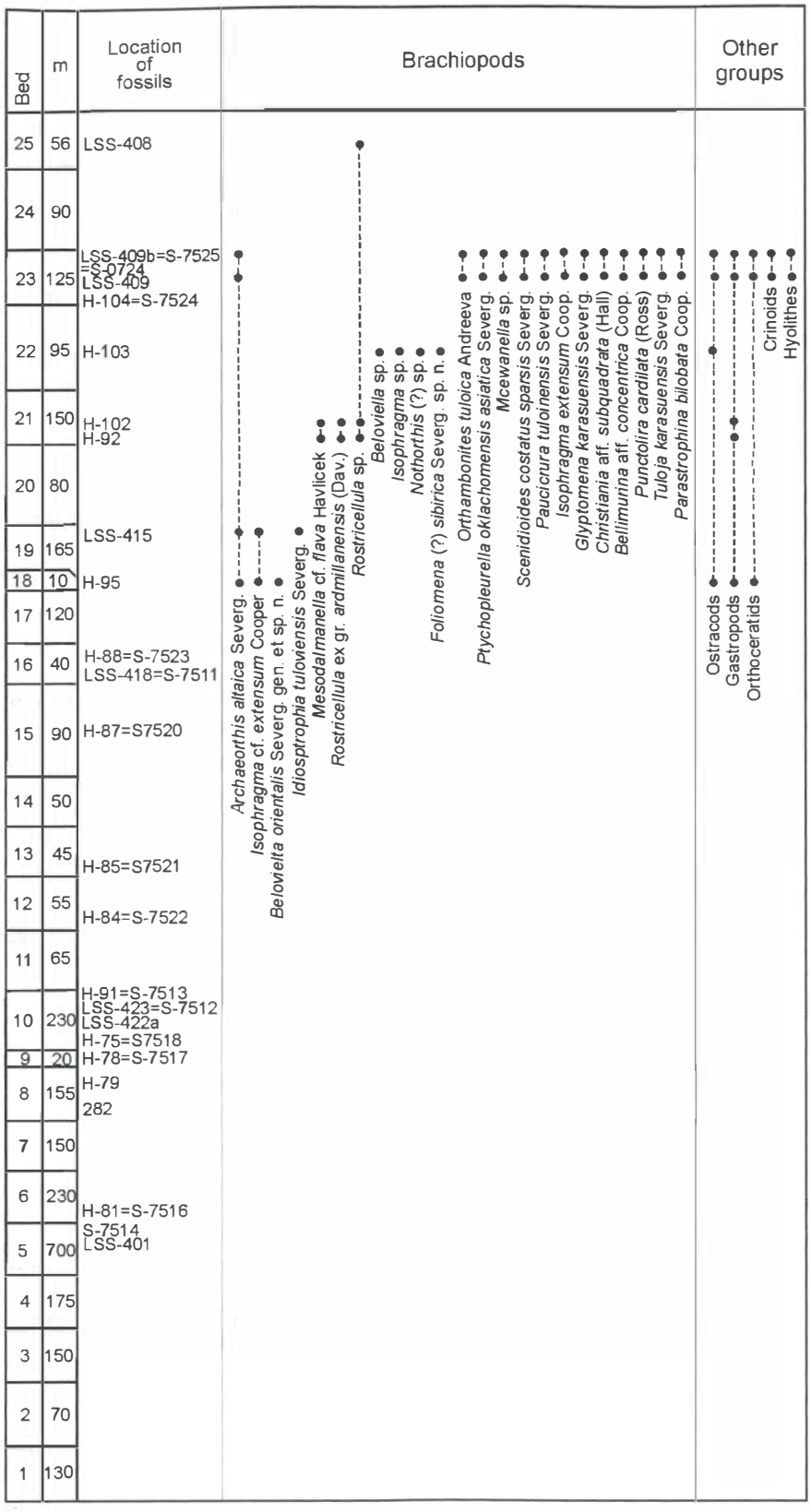

Bed
m
Location of fossils
Brachiopods
Other groups
25 56 LSS-408
24 90
23 125 LSS-409b=S-7525 =S-0724 LSS-409 H-104=S-7524
22 95 H-103
21 150 H-102 H-92
20 80
19 165 LSS-415
18 10 H-95
17 120
16 40 H-88=S-7523 LSS-418=S-7511
15 90 H-87=S7520
14 50
13 45 H-85=S7521
12 55 H-84=S-7522
11 65
10 230 H-91=S-7513 LSS-423=S-7512 LSS-422a H-75=S7518
9 20 H-78=S-7517
8 155 H-79 282
7 150
6 230 H-81=S-7516
5 700 S-7514 LSS-401
4 175
3 150
2 70
1 130
Archaeorthis altaica Severg.
Isophragma cf. extensum Cooper
Belovieita orientalis Severg. gen. et sp. n.
Idiosptrophia tuloviensis Severg.
Mesodalmanella cf. flava Havlicek
Rostricellula ex gr. ardmillanensis (Dav.)
Rostricellula sp.
Belovieila sp.
Isophragma sp.
Nothorthis (?) sp.
Foliomena (?) sibirica Severg. sp. n.
Orthambonites tuloica Andreeva
Ptychopleurella oklachomensis asiatica Severg.
Mcewanella sp.
Scenidioides costatus sparsis Severg.
Paucicrura tuloinensis Severg.
Isophragma extensum Coop.
Glyptomena karasuensis Severg.
Christiania aff. subquadrata (Hall)
Bellimurina aff. concentrica Coop.
Punctolira cardilata (Ross)
Tuloja karasuensis Severg.
Parastrophina bilobata Coop.
Ostracods
Gastropods
Orthoceratids
Crinoids
Hyolithes

Fig. 119 A. End.

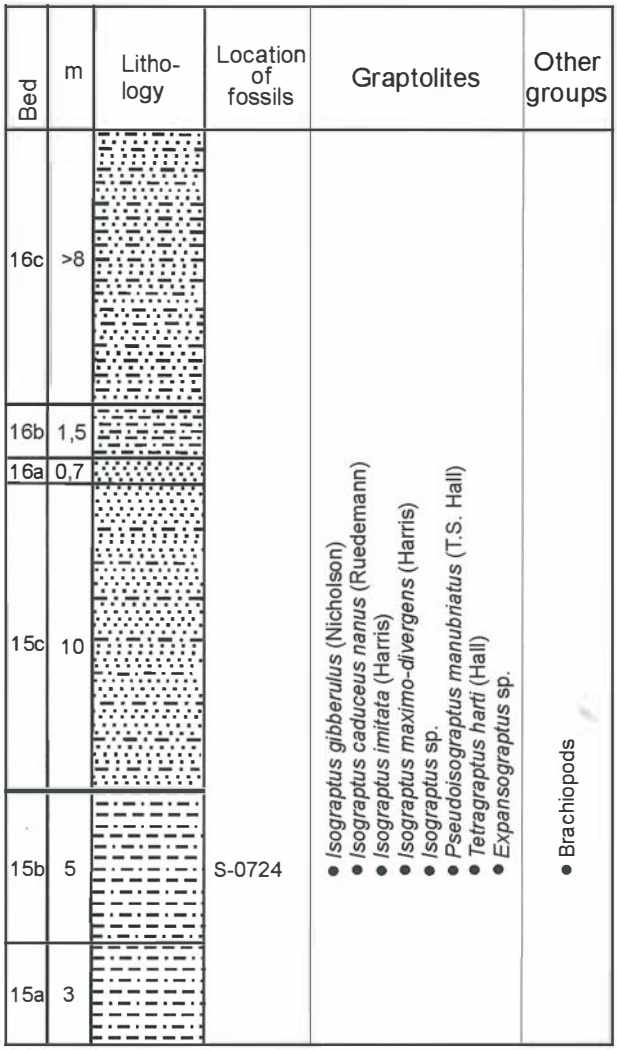


Fig. 119 B. Ranges of fossil taxa from Tuloi microsection (members 15–16).

The boundary between members 15 and 16 marked by a fault is exposed in a quarry (loc. S-0724) where the section includes:

15a. Mudstone and clayey siltstone, dark silver-gray or black ..... ~ 3

15b. Mudstone and siltstone, dirty olive, of thin 1–3 cm banding produced by more silty layers in mudstone, with graptolites (loc. S-0724) *Isograptus gibberulus* (Nicholson), *Isograptus caduceus nanus* (Ruedemann), *Isograptus imitata* (Harris), *Isograptus maximo-divergens* (Harris), *Isograptus* sp., *Pseudisograptus manubriatus* (T.S. Hall), *Tetragraptus harti* (Hall), *Expansograptus* sp. and brachiopods ..... ~ 5

15c. Thinly (1–3 cm) interbedded siltstone and fine sandstone; sandstone layers are slightly thicker than those of siltstone; sandstone shows cross bedding; the section is cut by a fault apparent in the middle of the quarry ..... ~ 10

16a. Sandstone: olive, slightly calcareous, fine to medium, well rounded and well sorted 0.7

16b. Siltstone: gray 1.5

16c. Interbedded (at 0.3–0.5 m in lower layers and at 0.1-0.3 m in upper layers), silver-gray well rounded and well sorted fine polymictic sandstone and dark gray clayey siltstone ... > 8

16. Interbedded greenish-gray fine sandstone and silty sandstone, with scarce thin (to 1 cm) layers of gray and dark gray siltstone; sandstone at member base (loc. LSS-418 = S-7511) contains graptolites *Expansograptus taimyrensis* Obut et Sob., *Expansograptus extensus* (Hall), *Expansograptus* sp., *Isograptus gibberulus* (Nicholson), *Tristichograptus ensiformis* (Hall), *Phyllograptus* sp., *Callograptus* sp. and chitinozoans *Desmochitina minor amphorea* Eisenack. Among graptolites, collected at the upper part of the member (loc. H-88 = S-7523) the following taxa were identified: *Isograptus gibberulus* (Nicholson), *Isograptus* sp., *Pseudisograptus manubriatus* (T.S. Hall), *Expansograptus* aff. *hirundo* (Salter), *Expansograptus taimyrensis* Obut et Sob., *Expansograptus* sp., *Tetragraptus* sp., *Paratetragraptus* sp., *Tristichograptus ensiformis* (Hall), *Didymograptus* sp. 40

17. Interbedded greenish-gray silty sandstone and siltstone, with scarce layers of fine sandstone 120

18. Sandstone: greenish-gray and brownish-gray polymictic, fine; rarely siltstone; sandstone (loc. H-95) contains abundant trilobites and brachiopods and sporadic orthoceratites, ostracods, and gastropods. Trilobites are *Remopleuridella altaiensis* Petrun. sp. n., *Lonchodomas* sp., *Vogdesia* (?) sp., *Levirobergia ojrotica* Petrun. gen. et sp. nov., *Eorobergia* sp., *Calyptaulax* sp., etc., brachiopods - *Archaeorthis altaica* Severg., *Isophragma* cf. *extensum* Cooper, *Belovielta orientalis* Severg. gen. et sp. n. 10

19. Interbedded greenish-gray siltstone, mudstone, and silty sandstone, with trilobites in upper layers (loc. LSS-415): *Vogdesia* (?) sp., *Eorobergia integra* Petrun. sp. n., *Calyptaulax* sp. indet., *Lonchodomas* sp., *Cybele* (?) sp. indet., *Megalaspidicus amplus* Petrun. gen. et sp. n., etc., brachiopods *Isophragma extensum* Cooper, *Archaeoorthis altaica* Severg., *Idiosptrophia tuloviensis* Severg., *Beloviella orientalis* Severg. gen. et sp. n. and indetermined graptolites 165

20. Sandstone: gray or light gray, quartz, medium to coarse 80

21. Sandstone: gray, greenish-gray to green, polymictic, fine, occasionally siltstone and silty sandstone, locally limy sandstone, in member lower half (loc. H-92, H-102), with gastropods, brachiopods *Mesodalmanella* cf. *flava* Havlicek, *Rostricellula* ex gr. *ardmillanensis* (Dav.), *Rostricellula* sp., trilobites *Eorobergia* sp., *Lonchodomas* sp., Asaphidae, *Carolinites* sp. 150

22. Silty sandstone: greenish-gray, less often fine polymictic sandstone and siltstone, with (loc. H-103) ostracods and brachiopods *Beloviella* sp., *Isophragma* sp., *Nothorthis* (?) sp., *Foliomena* (?) *sibirica* Severg. sp. n. 95

23. Siltstone: greenish-gray, more rarely silty sandstone, with graptolites at member base (loc. H-104 = S-7524): *Pseudoclimacograptus sharenbergi* (Lapworth), *Cryptograptus tricornis insectiformis* Ruedemann, *Amplexograptus confertus* (Lapworth) and trilobites *Plioicybele* sp. A 10–15 cm thick siltstone layer in member upper part abounds in diverse well preserved fossils (loc. LSS-409, LSS-409b = S-7525); the rock can be classified as trilobite-brachiopod coquina; it contains graptolites *Eoglyptograptus dentatus* (Brongniart), *Pseudoclimacograptus sharenbergi* (Lapworth), *Amplexograptus confertus* (Lapworth), trilobites *Encrinuroides tuloicus* Petrun. sp. n., *Ceraurinella latigenata* Petrun. sp. n., *Atractopyge sibirica* Petrun. sp. n., *Pliocybele*

sp., *Raymondaspis altaicus* Petrun. sp. n., *Robergia* sp., *Robergiella* (?) *margofera* Petrun. sp. n., *Remopleurella* sp., Harpidae, *Tulonella parvula* Petrun. gen. et. sp. nov., *Sphaerexochus* sp., *Carolinites tardus* Petrun. sp. n., *Hemiarges* sp., *Trinodus* sp., *Calyptaulax* sp., *Stegnoipsis* (?) *orientalis* Petrun. sp. n., *Illaenus* sp., *Dimeropyge* (?) sp., *Otarion* sp., *Lonchodomas* sp., *Ampyx* sp., *Nilieus* sp., etc., brachiopods *Archaeorthis altaica* Severg., *Orthambonites tuloica* Andreeva, *Ptychopleurella oklachomensis asiatica* Severg., *Mcewanella* sp., *Scenidioides costatus sparsis* Severg., *Paucicrura tuloinensis* Severg., *Isophragma extensum* Coop., *Glyptomena karasuensis* Severg., *Christiania* aff. *subquadrata* (Hall), *Bellimurina* aff. *concentrica* Coop., *Punctolira cardilata* (Ross), *Tuloja karasuensis* Severg., *Parastrophina bilobata* Coop. Also present ostracods, orthoceratids, crinoids, chiolites, and gastropods 125

24. Conglomerate: greenish-gray or purple-gray, fine, with pebbles of granite, sandstone, siltstone, siliceous rocks, quartz, etc., conglomerated sandstone, and medium to coarse sandstone 90

25. Siltstone, greenish-gray, calcareous, with silty fine sandstone and sandy limestone; with brachiopods (loc. LSS-408) *Rostricellula* sp. 56

Members 1 through 19 belong to the Tuloi Formation, members 20 through 23 belong to the Karasa Formation, and members 24 and 25 - to the Gur'yanovka Formation. The total thickness of the Tuloi Formation in the section exceeds 2500 m, the Karasa Formation is 450 m thick, and the Gur'yanovka Formation is more than 150 m thick.

The graptolite zonation of the section is as follows: members 1 through 5 belong to the *apporoximatus* zone (loc. LSS-401a, S-75141); member 6 may conventionally correspond to the *densus* and *angustifolius elongatus* zones (loc. H-81), and members 7 and 8 are conventionally aligned with the *gubberulus* zone (loc. 282, H-79); the base of member 9 correlates with the *gibberulus—hirundo* boundary, and members 9 through 16 belong to the *hirundo* zone (loc. H-78, H-75, H-73, LSS-422a, LSS-423, H-91, H-84, H-85, H-87, LSS-418, H-88); members 17 through 22 contain no graptolites; members 18 through 22 correlate with the Darriwilian according to trilobites and brachiopods (loc. H-95, LSS-415, H-92, H-102, H-103); graptolites from member 23 (loc. H-104, LSS-409) correspond to the *dentatus* zone.

CONCLUSIONS

The abundant faunal assemblages in the Ordovician-Silurian reference sections from the Gorny Altai provide reliable ties for dating the sedimentary strata, for constraining the age and stratigraphic position of boundaries between regional units (stages), and for correlating the latter with stages (or often also substages) of the International Stratigraphic Chart. With this solid biostratigraphic background, global biologic and deposition events can be distinguished in the Ordovician-Silurian Altai-Salair basin.

The bed-by-bed descriptions of the reference sections include mostly the faunal groups that we collected and studied. However, it is almost impossible to tie the lengthy lists of fossils dispersed in numerous publications to specific stratigraphic layers in the sections.

Revision of earlier data and investigation into recent data on the Ordovician and Silurian stratigraphy of the Gorny Altai, including the reported reference sections, will provide the basis for a new regional stratigraphic chart.

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