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REPORTS

Proposal for the Base of the Sakmarian Stage: GSSP in the Kondurovsky Section, Southern Urals, Russia

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Introduction

The Sakmarian is the second stage of the Lower Permian Cisuralian Series and one of the most widely used international standards for Permian stages. The base of the Permian and coincident base of the Asselian Stage was established at the Aidaralash Creek section, Kazakhstan. In the present paper we propose a definition for the base of the Sakmarian Stage and its position in the Kondurovsky section, Orenburg Province, Russia (see Figure 1 for location map). Conodont biostratigraphy combined with de-

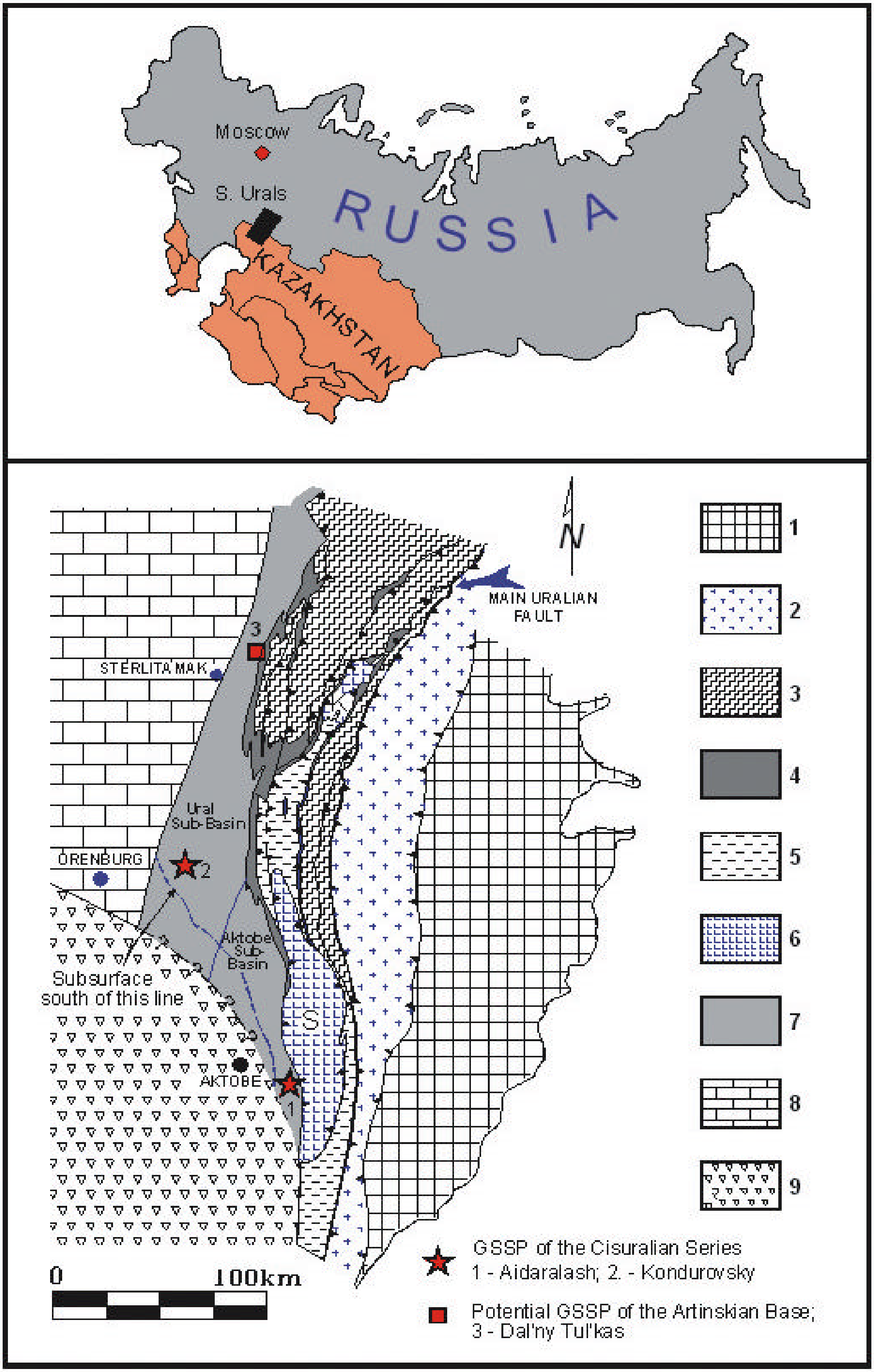

Figure 1. Location map for Cisuralian GSSP's including base of Sakmarian at Kondurovsky.

tailed fusulinacean occurrence data provide excellent bases in support of Kondurovsky as the basal Sakmarian Global Stratotype Section and Point (GSSP). A sweetognathid chronomorphocline exhibiting the evolutionary change from *Sweetognathus expansus* (Pearlmutter) to *Sweetognathus merrilli* Kozur at 115 metres above base (MAB) (uppermost Bed 11 of Chuvashov *et al*., 1993), provides excellent definition for the base of the Sakmarian Stage of the Cisuralian Series. We propose to place the base of the Sakmarian within Bed 11 (115 MAB) based on the first appearance (FAD) of *Sweetognathus merrilli* Kozur. This potential boundary is approximately 14 metres above the originally defined base of Sakmarian of Ruzhencev, 1950 (base of Bed 11, 91 MAB, Fig. 1).

Chuvashov *et al*. (2002) recently provided the review of the base of the Sakmarian, which is paraphrased below. "The Asselian-Sakmarian strata in the Kondurovsky section are represented by the Asselian Kurmaya and Karamurunskaya formations of the Sakmarian Tastubian Horizon. In the upper part of the Kurmaya Formation (Beds 6-10), Davydov found fusulinids *Pseudofusulina* ex. gr. *moelleri* (Schellwein) and Wardlaw and Schiappa discovered the conodont *Streptognathodus* aff. *S. barskovi* Kozur in the same interval (Bed 8). Taking into consideration these finds, our colleagues (Wardlaw *et al*., 1999) proposed to place the base of Sakmarian at the lower level, namely at the base of Bed 8 of the Kurmaya Formation. Chuvashov and Chernykh contend that Beds 6-10 should be united into the *Pseudofusulina* aff. *P. moelleri*-*Streptognathodus* aff. *S. barskovi* zone corresponding to the upper part of the Asselian Stage. In this case, the base of the Sakmarian Stage should be placed near the base of the Karamurunskaya Formation that marks the occurrence level of a substantially different conodont assemblage of *Mesogondolella parafoliosa* Chernykh, *Mesogondolella uralensis* Chernykh, *M. lacerta* Chernykh, *Diplognathodus* aff. *D. stevensi*, *D. stevensi* Clark and Carr, *Sweetognathodus* aff. *S. merrilli* Kozur, and *Stepanovites* sp. This assemblage was found in the first member of laminated marls, argillites, and carbonate mudstones of the Karamurunskaya Formation, which lacks fusulinids. Diverse fusulinids of the *Pseudofusulina moelleri* group and accompanying species from the lower part of the Tastubian Horizon were identified in members II and III. Their assemblage coexists with some conodont species that are present in the lower member of the Karamurunskaya Formation. This allows us to refer the lower part of the Karamurunskaya Formation (members I-III) to the *Pseudofusulina moelleri*-*Sweetognathus* aff. *S. merrilli*-*Diplognathodus stevensi* assemblage zone. The Asselian-Sakmarian boundary is placed at the base of this zone and marks the first appearance of *Sweetognathus* aff. *S. merrilli* in the *D.* aff. *D. stevensi*-*Sw.* aff. *S. merrilli* evolutionary lineage.

The Asselian-Sakmarian boundary is readily detectable based on fusulinids and conodonts in the Usolka section. The upper part of Bed 25 of the Usolka section yields the representative fusulinid assemblage of the upper zone of the Asselian Stage and the conodonts *Mesogondolella* ex. gr. *uralensis* and *M. pseudostriata* characterizing the lower part of the Tastubian Horizon. In materials sampled by Davydov from the same strata, Wardlaw and Schiappa found the conodont *Streptognathodus* aff. *S. barskovi*. In addition, we found the conodonts *S.* aff. *merrilli* and *M. uralensis* 1.5 metres above the base of Bed 26, confirming correctness of their proposed position of the Sakmarian lower boundary in the Kondurovsky section. Thus, the Usolka section can function as a supplementary reference section for the Asselian-Sakmarian boundary.

As a result of the previous studies and substantial new biostratigraphic data, which allows interbasin correlation, the Kondurovsky section can serve effectively as the GSSP of the Sakmarian lower boundary." (Chuvashov *et al*., 2002, p. 325)

History of Asselian/Sakmarian Boundary Definition in Southern Urals

Karpinsky (1874, 1890) was the first to report an ammonoid fauna older than the typical Artinskian in the Sakmara River area, and designated the strata that contained this ammonoid fauna as the "lower belt of the Artinskian Stage". Ruzhencev (1937) described this ammonoid fauna in detail and along with Gerasimov (1937) recognized that it belonged to the Permian System.

Ruzhencev (1951,1954) and Ruzhencev and Bogoslovskaya (1978) established the Sakmarian Stage based on the first appearance of new ammonoid genera (*Synartinskia*, *Propopanoceras*, *Synuraloceras*, *Kargalites*, *Parametalegoceras*, *Thalassoceras*, *Uraloceras*, *Paragastrioceras*, *Metalegoceras*, *Medlicottia*, and *Crimites*). Six of these genera belong to three families that first appeared in Asselian time. *Synartinskia*, *Propopanoceras*, *Synuraloceras* occur in Russia only in the Sakmarian. Subsequently these authors recognized the extinction in the Sakmarian of many ammonoid genera that appeared in Orenburgian – Asselian time. Ruzhencev concluded that the Sakmarian was an important stage in ammonoid evolution, but not as significant as the period of Permian ammonoid evolution during the Asselian.

The Sakmarian Stage was proposed by Ruzhencev in 1936. However, at first the Sakmarian included everything between the top of the Orenburgian (latest Carboniferous) to approximately mid-Artinskian (Ruzhencev, 1936, 1938). Later, the Sakmarian was divided into two substages: the Asselian and Sakmarian (Ruzhencev, 1950) and subsequently both units became independent stages (Ruzhencev, 1954). Both ammonoids and fusulinids have served to make the Sakmarian well known and widely utilized in world stratigraphy (Ruzhencev, 1938, 1951; Rauser-Chernousova, 1940, 1949, 1965).

Although Ruzhencev did not share the concept of a stratotype, he described the Kondurovsky section as a type section for the Sakmarian Stage (Ruzhencev, 1950). His definition of Sakmarian was based on the evolution of ammonoids and fusulinids and related lithologic characteristics. He established the Asselian/Sakmarian boundary at the base of Karamurunskaya Formation because of the correlation of latest Asselian ammonoids occuring in the Shikhanian Horizon (Gerasimov, 1937) in the Shikhans (eastern margin of Russian Platform) to the underlying Uskalikskaya and Kurmainskaya Formations of the southern Urals (Ruzhencev, 1951). Typical Sakmarian ammonoids were found in the Sarabilskaya Formation. No ammonoids (except long-ranging *Agathiceras uralicum*) were described by Ruzhencev from the Karamurunskaya Formation. However, the Karamurunskaya Formation was included in the Sakmarian because of significant changes in lithofacies and fusulinid faunas.

Indeed, over most of the Russian Platform Asselian marine carbonates are replaced by sabkha evaporites of the Sakmarian. In the southern Urals (particularly in the Ural subbasin) predominately carbonate sedimentation is replaced by predominantly siliciclastic sedimentation (Ruzhencev, 1936, 1950; Snyder *et al*., 1996).

The *Schwagerina* Horizon (in the sense of a stage) has been used in the Russian literature since the last century (Nikitin, 1886). The top of this "stage" is marked by the extinction of "*Schwagerina*" (= *Sphaeroschwagerina* in the modern sense). In the southern Urals it was believed that the *Sphaeroschwagerina* extinction occurred at the top of the Kurmainskaya Formation (Rauser-Chernousova, 1940, 1949, 1965). "*Pseudofusulina*" *moelleri* (= *Schwagerina moelleri* in the modern sense) was chosen as the index for the base of Sakmarian (Rauser-Chernousova, 1940, 1949, 1965). Therefore, the disappearance of *Sphaeroschwagerina* and appearance of *Schwagerina moelleri* at the base of the predominantly siliciclastic Karamurunskaya Formation marked the Asselian/Sakmarian boundary. This definition is widely accepted by most stratigraphers and geologists. However, our data show that the first appearance of the *Schwagerina moelleri* group actually occurs in the uppermost part of the Kurmainskaya Formation (see fusulinid section).

New ammonoids recovered from Bed 12 (172.5 MAB) in the Karamurunskaya Formation contain typical Sakmarian species including *Artinskia nalivkini*, *Propopanoceras postsimense*, *Sakmarites postcarbonarius*, *Neopronorites tenuis*, and *Paragastrioceras sintasense* (Schiappa, 1999).

Stratigraphy and Sedimentology of the Asselian-Sakmarian Boundary Units at Kondurovsky, Russia

The Kondurovsky section was originally described by Murchison *et al*. (1845), and Karpinsky (1874), with subsequent descriptions by Ruzhencev (1950; 1951), Rauser-Chernousova (1965) and Chuvasov *et al*. (1993). Ruzhencev and Rauser-Chernousova subdivided the section into several units: the Asselian Kurmainskaya Formation, the Sakmarian (Tastubian) Karamurunskaya and Sarabilskaya formations and the Sakmarian (Sterlitamakian) Maloikskaya and Kondurovskaya formations. Lowermost Artinskian strata are represented in this section.

Sedimentary Facies Description

The Cisuralian strata at Kondurovsky are divided into several major lithofacies, modified from Schiappa and Snyder, 1998 to reflect the mixed siliciclastic-carbonate nature of each lithofacies (Table 1). Sedimentologic, stratigraphic, and petrographic information indicates that the lithofacies reflect a mixed siliciclastic-carbonate, middle and outer ramp depositional environment consisting of fine to coarse silty to sandy limestones, occasional rudstones and floatstones, and very fine to coarse allochemic sandstones (Table 1).

Asselian-Sakmarian Facies Sequence
Asselian – Shikhanian Substage

Shikhanian strata are exposed from the base of the section to 115 MAB at Kondurovsky section II and III; this corresponds to Beds 1 through the lowermost part of Bed 11. This interval is dominated by sM lithofacies interbedded with several 30 centimetres to 1 metre thick s/ssWPe and ssGe and 1.5 m RFL of Bed 8 and several metres thick RFL of Bed 10. The RFL lithofacies of Bed 10 vary in thickness from one to several metres and contain large carbonate mud clasts, ranging from centimetres to metres in size (Fig. 2). This is probably related to lateral variation within the sediment gravity flow or perhaps this interval represents a succession of gravity flow deposits. A shallowing upward, outer ramp deposition is interpreted for this stratigraphic interval with the influx of event deposits possibly initiated by storms.

GSSP Boundary Interval

The boundary interval is characterized by a nearly continuous 7.5 metre monofacial succession of silty micrite (sM) from 114 – 121.5 MAB (Fig. 2).

Sakmarian - Lower Tastubian Substage

The basal units of the Sakmarian Stage (early Tastubian) are exposed from 115 to 220 MAB in sections II and III, Kondurovsky and are grouped into four lithofacies, sM, s/ssWPe, and ssGe. The sM facies dominates this interval, interbedded with numerous 30 centimetres to 1 metre thick s/ssWPe and ssGe units (Fig. 2). Outer to middle ramp deposition is interpreted for this stratigraphic interval with the incursion of event deposition, possibly driven by storms.

Depositional Environment

The Kondurovsky Asselian-Sakmarian succession reflects mixed siliciclastic-carbonate deposition on a storm-dominated, open, outer to middle ramp. The stratigraphic record does not contain any time-significant stratigraphic discontinuities, however a sea level lowstand may be represented by the RFL unit of Bed 10 (Fig. 2).

The lithofacies recognized at Kondurovsky reflect normal background, hemipelagic to pelagic sedimentation and episodic event deposition (see Table 1 for details). The sM and mS successions are interpreted as background deposition on the mid-outer ramp. The sM and mS lithofacies record continuous deposition with no evidence of subaerial exposure even during periods of relative sea level lowstands. This suggests that subsidence was uninterrupted, keeping up with eustasy, or that relative sea level changes were only a few tens of metres in magnitude. Ramps react differently to changes in relative sea level than rimmed platforms. A minor sea level fall will result in a basinward shift of depositional facies, leaving only the old inner ramp exposed, whereas on a flat-topped rimmed shelf, the whole platform interior will be exposed (Burchette and Wright, 1992).

The silty-sandy wackestone/packstone (s/ssWPe) and sandy grainstone (ssGe) lithofacies appear abruptly throughout the section. The clastic components (bioclasts and siliciclastic intraclasts) were derived from the inner to middle ramp and accumulated during event deposition. Systematic study of sedimentary structures was not conducted, but the majority of these event beds appear to lack sedimentary structures such as sole marks, hummocky cross stratification and wave ripples. This lack of sedimentary structures has made reconstruction of sedimentary dynamics difficult. However, the most plausible interpretation is that these event beds were storm-induced, accumulating below storm wave base. The offshore-directed bottom currents reflect contemporaneous trans-

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DESCRIPTION

Carbonate-dominated	**Siliciclastic-dominated**
sM	mS
Light brown to brown silty micrite with pellets, sponge spicules, minor amounts of organic detritus; silt content up to approximately 25%	Micritic siltstone with sponge spicules and minor amounts of organic debris, carbonate mud content up to approximately 30%
s/ssWP	aSS1
Fossiliferous silty to sandy wackestone - packstone, fine to medium grained, with variable amounts of silt and fine sands, fusulinaceans, small foraminifera, bryozoans, pelmatozoan fragments, pelloids, and carbonate mud intraclasts. Bed thickness varies from a few centimetres to several metres.	Very fine, structureless allochemic sandstone, interbedded with siltstone-mudstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix
ssG1	aSS2
Fossiliferous sandy grainstone, fine to coarse grained, with fusulinaceans, small foraminifera, bryozoan, pelmatozoan, brachiopod and cephalopod fragments (allochems), pelloids, carbonate mud intraclasts, and variable amounts of extraclasts. Alignment of grains is visible in some samples. Laminar beds with lateral dimensions of a few centimetres to 0.75 metre in thickness.	Fine allochemic sandstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, grading apparent in some beds; parallel laminations common in most beds, thickness of a few centimetres, typically 15 to 30 cm, and up to 1.5 metres in amalgamated beds.
ssWPGe	aSS3
Wackestone-packstone-grainstone event beds (“e”); medium to coarse grained, locally graded and scoured bases with rare flute casts and load structure and rippled tops. Constituents same as s/ssWP and ssG1. Beds vary from a few centimetres to several metres thick.	Medium (coarse to fine) allochemic sandstone with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, typically graded and parallel laminations; rippled tops common, but not ubiquitous; some exhibit erosive bases with flutes, tool marks, load structures and local hummocky cross stratification.
RFL	aSS4
Grey black and brown limestone pebble rudstone and floatstone, with minor fossiliferous debris (fusulinacean, pelmatozoan and bryozoan fragments) and carbonate mud clasts. Fine-grained micrite matrix. Carbonate mud clasts vary in size from 1 mm to several tens of cm, tend to be well rounded and oblate. Minor component of wackestone clasts with fusulinacean, small foraminifera and pelmatozoan fragments. Bed varies in thickness from 30 centimetres to several metres.	Coarse grained allochemic sandstones to very fine pebble conglomerates with up to approximately 30% fossiliferous debris and a silty carbonate mud matrix, thickness of several centimetres to 1 metre.
	Modifiers: m = micritic; applied to siliciclastics with < 50% carbonate, s/ss = silty/sandy; applied to carbonates with < 50% sand/silt, a = allochemic; carbonate bioclasts and lime clasts (Schiappa, 1999)

Table 1. Lithofacies description for the type Sakmarian Region, southern Ural Mountains, Russia (Schiappa, 1999).

port of pelmatozoan ossicles, bryozoan fragments, fusulinaceans, carbonate mud clasts and siliciclastics from near shore to deposition as event beds. There is no significant time reworking of the bioclastic debris. The unique occurrences of the rudstone/floatstone (RFL) units suggest that some major event triggered their deposition and that the mixed siliciclastic-carbonate ramp may have been steepened distally. A series of RFL beds occur at the same stratigraphic position in the Karamuruntau Range along the edge of the Sakmara River Valley (minimum of 10-30 km long along strike). Unlike the event beds, the RFL units are oligomictic. These units are laterally extensive, typically 0.5 to a few metres thick and are characterized by well rounded, oblate carbonate mud clasts varying in size from 1 mm to several tens of cm (long dimension) and minor fossiliferous debris (fusulinacean, pelmatozoan and bryozoan fragments) in a carbonate mud matrix. Storm deposition of these units is unlikely because they lack sedimentary structures and are oligomictic as opposed to the polymictic nature typical of storm-induced strata. Storm induced strata are typically matrix-poor and better sorted than the mud-rich and poorly sorted RFL lithofacies. Therefore, two other possible interpretations for the origin of this lithofacies are suggested:

1). The RFL units were the result of slope collapse. During sea level lowstands, the exposed or shallower portion of the ramp is weakened by physical and chemical processes, and collapse of the distally steepened ramp results in limestone conglomerate accumulations (Burchette and Wright, 1992; Coniglio and Dix, 1992).

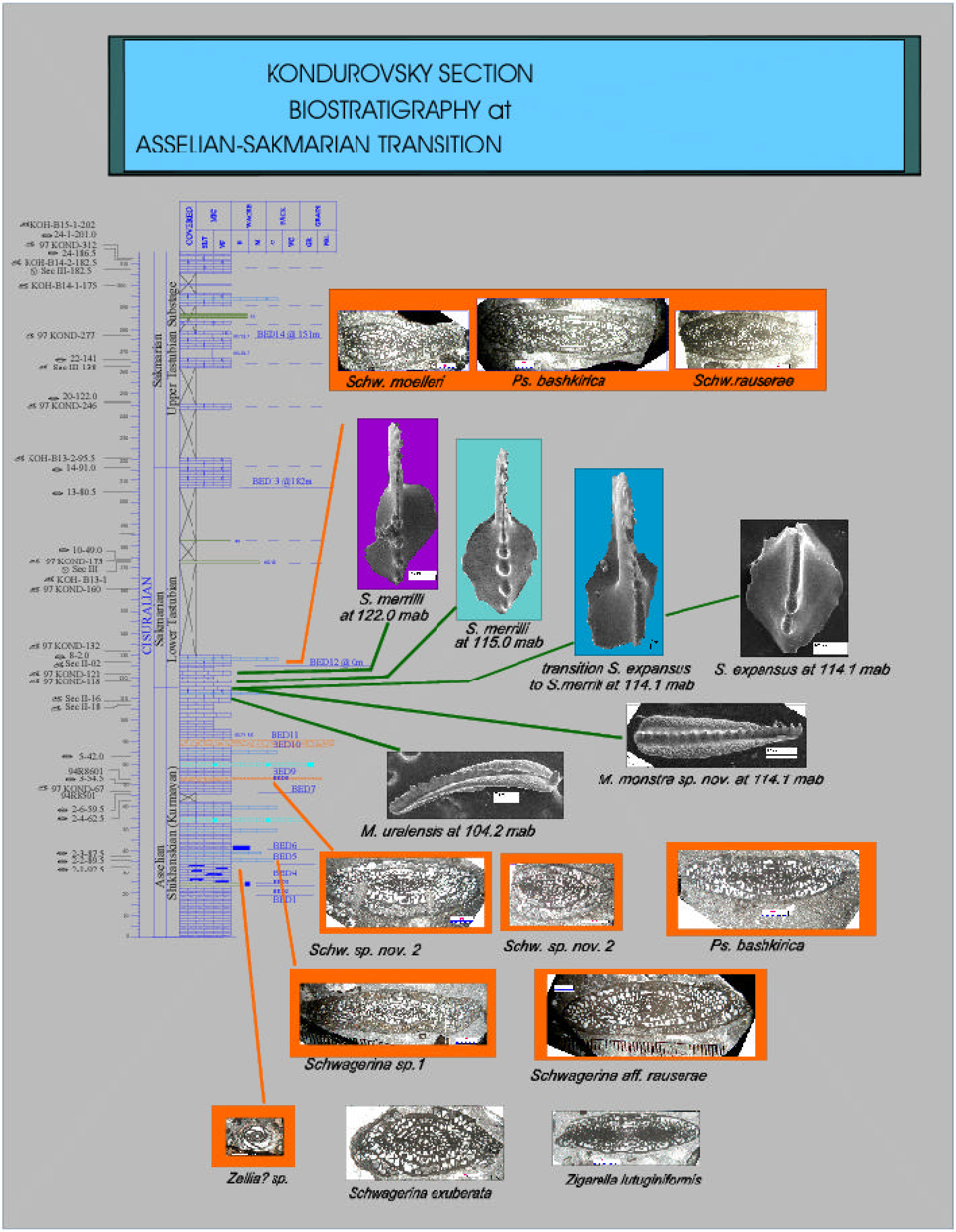

Figure 2. Detailed stratigraphic log and fossils for the Kondurovsky section, which is herein proposed as the base Sakmarian GSSP at 115 m above base.

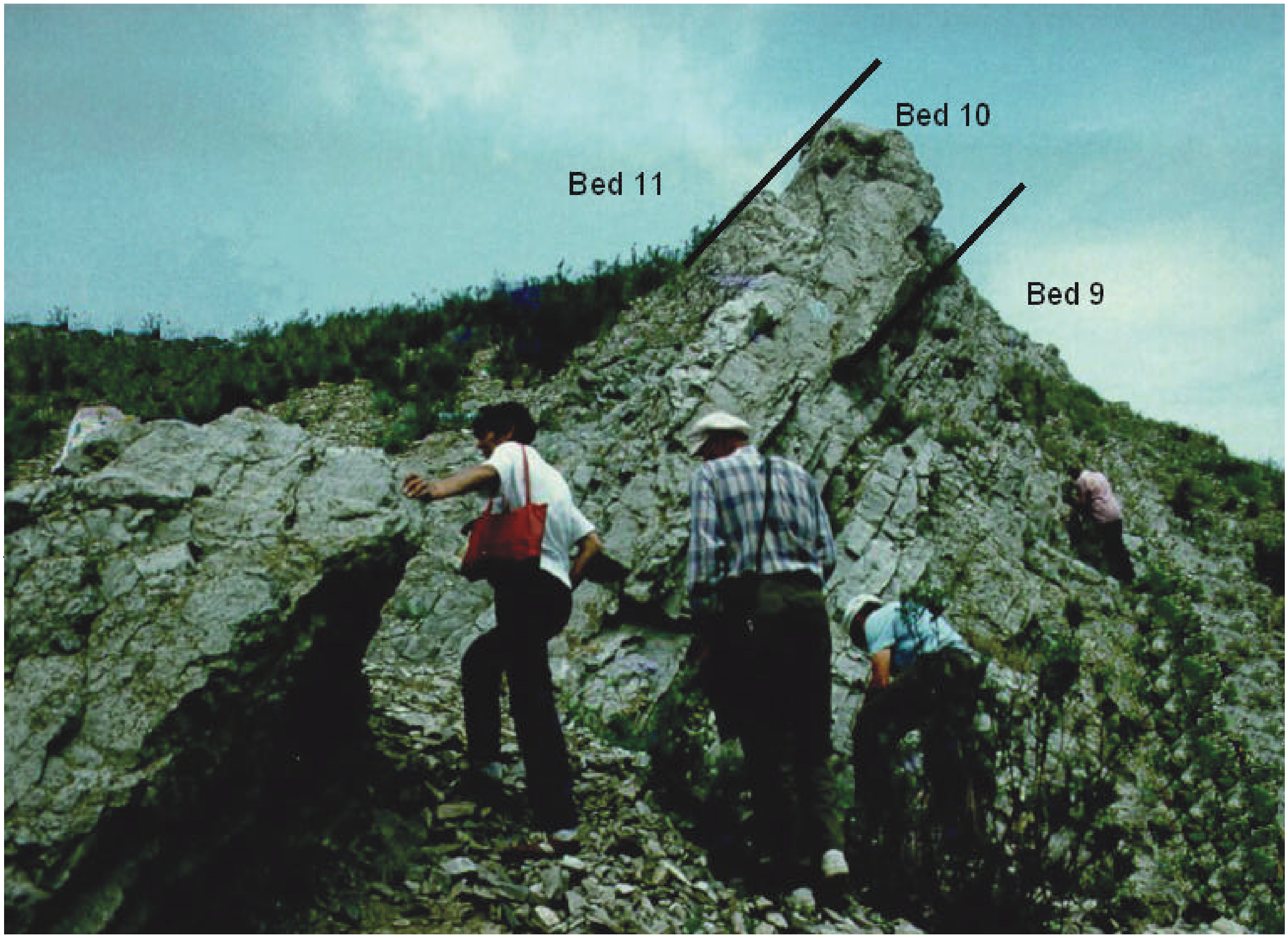

Figure 3. Photograph of Kondurosky section; the base of bed 11 is the traditional boundary and the proposed GSSP is within bed 11 at 115 mab.

Accumulation of coarse limestone sediments is enhanced on distally steepened ramps. This interpretation for the mechanism of deposition would indicate that the Pre-Uralian ramp was distally steepened and not a homoclinal feature.

2). Another plausible scenario for production of these units is slope failure due to tectonism. Seismic activity may induce a slide and the carbonate mud blocks and clasts are rafted along in a mud slurry down a very low angle slope (Burchette and Wright, 1992; Coniglio and Dix, 1992). Because the entire southern Uralian region was tectonically active from Upper Carboniferous through late Cisuralian, it is possible that these units were seismically induced.

Fusulinid Biostratigraphy at the Asselian-Sakmarian Boundary in Kondurovsky Section

Fusulinids are important and most widely used as biostratigraphic tools for defining the base of the Sakmarian in the Russian Platform and Urals. Rauser-Chernousova in the Preurals (Rauser-Chernousova, 1940) and Shamov *et al*. (1936) in the subsurface of Russian Platform margin (Ishimbay oil-field area) proposed fusulinid biostratigraphic succession of the Asselian and Sakmarian. The boundary between these stages was placed at the base of the horizon characterized by *"Pseudofusulina" moelleri* [= *Schwagerina moelleri* (Schellwien) in terms of modern taxonomy]. In the Preurals this boundary was defined between the Kuraminskaya Formation with advanced *Sphaeroschwagerina*, *Pseudofusulina* (*Ps. sulcata, Ps. declinata*), and *Schwagerina* (*S. idelbajevica, S. parajaponica, S. sphaerica* and *S. firma*) and the Karamurunskaya Formation with "*Pseudofusulina*" *moelleri* and related species. *Sphaeroschwagerina* is believed to have become extinct by the end of Asselian (Rauser-Chernousova, 1940, 1949, 1965). Ruzhencev (1951) and Rosovskaya (1952) listed the occurrence of "*Pseudofusulina moelleri*" in the Kurmainskaya Formation, suggesting that the unit should be included within the Sakmarian. However, these data have never been included in definition of the base of the Sakmarian.

Fusulinid studies during the last decade (Davydov *et al*., 1995, 1997, 1998) have recognized several new aspects of fusulinid biostratigraphy at the Asselian-Sakmarian transition in the Kondurovsky section. In Beds 5-7, the assemblage is represented by typical late Asselian fusulinids including *Schwagerina firma* (Shamov), *S idelbajevica* (Shamov), *S. parva* (Belyaev), *S. exuberata* (Shamov), *Schwagerina? declinata* (Korzhinskyi), *Schwagerina? composita* (Korzhinskyi), *Pseudofusulina sulcatiformis* Leven and Scherbovich, *Schwagerina? gareckyi*

(Scherbovich), *Zigarella lutuginiformis* (Rauser), and numerous and diverse *Rugosofusulina*. Two poorly preserved specimens of the Tethyan fusulinid ?*Zellia* sp. were also identified.

Within Bed 6 two specimens of *Schwagerina* sp. 1 which is related to the fusulinids of the *Schwagerina moelleri* (Schellwien) group were identified. At four and a half volutions, the test is relatively small (5 mm and 8.5 mm in length), and coiled smoothly throughout its growth. Irregular septal fluting is significant only in the inner volutions, and in the outer two volutions fluting is intense mostly in the polar regions. Only rare (one or two) phrenotheca were recognized in the outermost volution of these specimens.

In Bed 8 the fusulinid assemblage is generally the same as in the underlying beds. However, two specimens of *Schwagerina* sp. 2 (which will be described as a new species) were found. They are very similar and certainly very closely related to *Schwagerina moelleri* (Schellwien), resembling that species in shape of the test of all volutions: similar non-regular coiling – compact in the first three-four volution and high in the fourth-fifth and following volutions. However these specimens differ from true *Schwagerina moelleri* in smaller size of their corresponding volutions and less developed septal fluting, particularly around the tunnel area. These forms also have phrenotheca, but they are rare. Other specimens of this species were found near the base of Kurmainskaya Formation at the Novogafarovo section.

One additional specimen of *Schwagerina* sp. 2 was found in Bed 30 at the Aidaralash section. In 1986 this bed was correlated with the Sakmarian (Davydov & Popov, 1986, Davydov, 1986) because of the occurrence of this new species and particularly because of the occurrence of many taxa (first primitive *Darvasites*, and numerous new species of *Pseudofusulina* and *Rugosofusulina*) described from Sakmarian beds in the Darvaz region (Leven & Scherbovich, 1980). However, the base of Sakmarian at Aidaralash was later tentatively placed at the base of Bed 34.

In Bed 12 at Kondurovsky, the fusulinid assemblage includes some species that appear in older strata, but most of the Asselian *Schwagerina* species disappeared and *Schwagerina* sp. 2 becomes numerous in this bed. Typical *Schwagerina moelleri* (Schellwien) first appeared in Bed 12 of the Karamurunskaya Formation.

Based on these new data, we suggest that the nearest fusulinid evolutionary event to the base of the Sakmarian is the first appearance of *Schwagerina* sp. 2. So this would place the fusulinid biozonal boundary at 72 MAB, 42 metres below the Sakmarian GSSP at the Kondurovsky section. This fusulinid biozonal boundary can also be recognized at the base of Bed 30 in the Aidaralash Creek section and at 551 MAB in the Novogafarovo section and at the base of Bed 26 at Usolka.

Conodont Definition

It is proposed that the base of the Sakmarian Stage be defined by the first appearance of *Sweetognathus merrilli* Kozur in the evolutionary chronomorphocline of *Sweetognathus expansus* to *Sweetognathus merrilli*. *Sweetognathus expansus* evolved into *Sweetognathus merrilli* through short-lived transitional morphotypes that are best displayed in the Pa element showing the progressive development of clearly defined nodes along the carina, starting at both the posterior and anterior ends of the carina and developing toward the middle through time. *Sweetognathus merrilli* is recognized as the first form that displays clearly defined nodes along the entire carina of the Pa element. This chronomorphocline is displayed in both the Kondurovka (ramp) and Usolka (basin) sections in the PreUralian Foredeep and the Eiss Limestone of the Bader Limestone in Kansas, Midcontinent, USA (Wardlaw *et al*., 2003). The chronomorphocline is well displayed in Bed 11 of the Karamurunskaya Formation of the Kondurovka section, and the base of the Sakmarian is defined by the first appearance (FAD) of *Sweetognathus merrilli* at 115 m above the base of the section, just below the acme of the fusulinid *Schwagerina* sp. 2. The taxonomy and distributional controls of *Sweetognathus* species was recently summarized by Mei *et al*. (2002).

Numerical Age

The poor temporal resolution of the Late Pennsylvanian through Early Permian geologic time scale limits substantially our ability to clarify and correlate many aspects of late Paleozoic geologic history. Commonly cited time scales differ by as much as 14 Ma in the estimated age of the Pennsylvanian-Permian boundary, and vary by 500% in the inferred duration of various stages. Significant uncertainties in this part of the time scale arise because the numerical ages assigned to period and stage boundaries are based on linear interpolation between relatively sparse control points. Moreover, the existing control points were obtained from stratigraphic sections in different parts of the world, assigned positions in the time scale using several different taxa, and dated by several different radiometric techniques. Because many fundamental aspects of geologic research depend directly on the accuracy and precision of the geologic time scale, improving its age calibration is critical and requires a robust, well constrained, and internally consistent framework of biostratigraphic and geochronologic data for the Late Carboniferous through Early Permian. Numerous volcanic ash layers occur within the Upper Pennsylvanian and Cisuralian successions in Usolka and the Dal'ny Tulkas sections where most of these ash layers contain abundant, well-preserved conodonts and less well preserved radiolaria. The conodont-radiolaria-zircon bearing ashes in the Pennsylvanian and Cisuralian sections of the southern Urals provide an exceptional opportunity to develop a well constrained numerical time scale and Graphic Correlation Composite Standard Section for the Pennsylvanian-Cisuralian geological time period, and to examine rates of ecological processes in the late Paleozoic. Further, the Usolka section provides a significant reference section, not only for the base of the Sakmarian, but also for the Carboniferous/Permian boundary. It contains numerous ash layers that can be used to constrain both boundaries.

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Potential base-Artinskian GSSP

Introduction

The following is paraphrased from Chuvashov *et al*. (2002). “A potential stratotype for the Artinskian lower boundary is located in the Kondurovsky section. The Artinskian Stage corresponds here to the Kondurovka Formation, which is about 100 metres thick and composed of alternating thick units (30-40 m) of sandy-clayey rocks and thin (1-9 m) limestone and limestone breccia units. Earlier, Chuvashov *et al*., (1991) substantiated the position of the Artinskian lower boundary based on the first occurrence of the fusulinid *Pseudofusulina pedissequa* Viss. group in