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The Auxiliary boundary Stratotype Section and Point (ASSP) of the Jiangshanian Stage (Cambrian: Furongian Series) in the Kyrshabakty section, Kazakhstan

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*The Kyrshabakty section in the Malyi Karatau Range, southern Kazakhstan, has been approved as the Auxiliary boundary Stratotype Section and Point (ASSP) for the base of the Jiangshanian Stage of the Furongian Series (Cambrian System). The first appearance datum (FAD) of the agnostoid trilobite *Agnostotes orientalis* coincides with the horizon marking the base of the Jiangshanian Stage, and the FAD of *A. orientalis* occurs at 259.0 m in the measured section, 61.2 m above the base of Unit 8 in the Zhumabai Formation. The boundary interval in the Kyrshabakty section shows a relatively monotonous succession of carbonate deposits. The section contains an abundance of Cambrian fossils including diverse trilobites, brachiopods, molluscs, bradoriids, protoconodonts and paraconodonts.*

Introduction

At present, the International Subcommittee on Cambrian Stratigraphy (ISCS) is keen to designate not only GSSPs for stage and series boundaries but also ASSPs (Auxiliary boundary Stratotype Sections and Points) in excellent sections and, preferably, in palaeogeographic regions different from those where the GSSPs have been designated. ASSPs will serve not only as important regional standards but at some future time an ASSP may be needed as a functional global standard if a GSSP is later determined to be unusable.

Among horizons having potential as stage boundaries within the Furongian Series discussed by Babcock *et al.* (2005) is the FAD of *Agnostotes orientalis* (Kobayashi, 1935). The species, as revised by Peng and Babcock (2005), has a narrow stratigraphic range and has been documented from the Furongian sections of Canada, Kazakhstan, South China, South Korea, and Siberia. The GSSP at the *A. orientalis* level was recently voted on by the ISCS and ratified by the International Commission on Stratigraphy (ICS) and the International

Union of Geological Sciences (IUGS). The GSSP for the stage, now known as the Jiangshanian (formerly provisional Stage 9) is located in the Duibian B section, Zhejiang, China (Peng *et al.*, 2012).

The Kyrshabakty section in the Karatau Range, Kazakhstan, was proposed as the ASSP section of the Jiangshanian Stage, and in 2012 the ISCS voted overwhelmingly to approve it as such. The ASSP point coincides with the FAD of *Agnostotes orientalis*, which is 259 m above the base of the measured Kyrshabakty section and 61.2 m above the base of Unit 8 of the Zhumabai Formation (also referred to in some literature as Bestogai Formation, Ergaliev *et al.*, 2009).

The Karatau Range in South Kazakhstan exhibits one of the finest Cambrian Series 3 to Furongian Series sequences in the world. The section records an abundance of various groups of fossils including diverse trilobites (Lisogor, 1977; Ergaliev, 1979; 1980; 1981; Ergaliev and Ergaliev, 2001; 2008; Chugaeva and Apollonov, 1982; Apollonov *et al.*, 1988), brachiopods (see Holmer *et al.*, 2001 and references therein), molluscs (Gubanov and Peel, 2001), bradoriids (Melnikova *et al.*, 1997), protoconodonts and paraconodonts (Abaimova 1983; Dubinina 2000 and references therein).

The Kyrshabakty section was for a long time considered as the reference section for all major stratigraphic subdivisions of the traditional Upper Cambrian and for biostratigraphic subdivisions of the traditional Middle and Upper Cambrian in the former USSR. Nowadays the section represents the standard for the Series 3-Furongian Series in Kazakhstan (Ergaliev and Ergaliev, 2008). The section is easily accessible and has been visited by many specialists in Cambrian geology, palaeontology and stratigraphy.

Geographic and geologic settings

The Karatau Range represents a north-western extension of the Tien Shan Mountains. It is a system of parallel ridges 50 to 200 km wide trending north-west over a distance of 400 km. Elevation in the Karatau Range averages 1000 m, and rarely extends above 1500 m; the maximum elevation is 2000 m. Ridges normally extend 50 to 250 m above the floors of adjacent valleys. The Karatau Range is crossed by a system of parallel river valleys extending trending to the

north-east and crossing the main geologic structures. This creates excellent conditions for geologic studies, as Proterozoic through Phanerozoic strata are well exposed. Major geologic features, including stratigraphic sequences, can be traced over large distances through the region (Zhemchuzhnikov and Ergaliev, 2010).

The section, which is free from significant unconformities, is a natural exposure situated about 28 km north-east of the town of Zhanatas along in the middle course of the Kyrshabakty River (Figures 1 and 4). Geographic coordinates for the base of the section are: 43°32'02" N and 69°51'28" E, altitude 527 m. Geographic coordinates of the top of the section are: 43°32'27.8" N and 69°57'24.8" E, altitude 557 m. The section is within a steep monocline dipping 80° to 90° north-east, and not interrupted by major faults.

Conodont alteration indices are low and do not exceed CAI-2.

Cambrian carbonate sediments (Figure 2) exposed in the Kyrshabakty section were deposited along the margin of a carbonate platform situated on an isolated aggrading seamount (Aisha-Bibi seamount; Cook *et al.*, 1991; Zhemchuzhnikov and Ergaliev 2010). The platform, which was situated on the passive margin of an early Palaeozoic plate (Kazakstania), prograded seaward slightly. Faunal affinities suggest that it was situated in relative proximity to South China and the Australasian segment of East Gondwana (Holmer *et al.*, 2001; Popov *et al.*, 2009).

The central part of the Aisha-Bibi seamount had a flat top that was covered by sea water, and was partly lagoonal, in which shallow marine carbonates accumulated and sedimentation consisted largely of peloidal, algal/cyanobacterial and rare oolitic grainy carbonate material (Zhemchuzhnikov, 1989). The flanks were steep carbonate slopes where accumulated gravity flow deposits (Zhemchuzhnikov, 1986).

The Malyi Karatau exhibits a large variety of carbonate lithofacies including those of a basin plain, carbonate slope, platform margin,

and platform interior with a transition to intertidal settings. Early Palaeozoic sedimentation mainly of dark carbonates, shales and black cherts characteristic of the deep basin plain or some continent-margin to slope environments (Babcock *et al.*, 2012). Similar deposits are well documented in surrounding areas, particularly in Bolshoi Karatau and north-east of Malyi Karatau towards the Shu-Sarysu Basin (Zhemchuzhnikov and Ergaliev, 2010). Characters of carbonate sedimentation across the region in the mid-Cambrian to Ordovician show no evidence of any significant influence of local tectonics (Allen *et al.*, 2001; Popov *et al.*, 2009). In spite of subsequent tectonic deformation, the ancient relief of the carbonate seamount is mainly preserved and lithofacies zonation can be reconstructed with certainty.

The Kyrshabakty section is more than 600 m thick. It includes up to 100 m of basin plain lithofacies, succeeded by 465 m of carbonate slope deposits with easily recognizable lithofacies of the outer-fan fringe (50 m), outer-fan lobe (175 m), mid-fan distributary channels (105 m) and inner-fan feeder channels (135 m). There are some slides and thick (>10 m) debris flow breccia beds with clasts of shallow water carbonates transported down-slope. Deposits of the upper slope and platform margin have in situ *Girvanella* and *Epiphyton* bioherms preserved in the uppermost 60 m of the measured section (Cook *et al.*, 1991).

Cambrian Series 3 and Furongian rocks are exposed continuously in the area along a distance more than 5 km to either side of the measured section.

Location of ASSP level and stratigraphic completeness

The ASSP for the base of the Jiangshanian Stage is located at 259.0 m above the base of the Kyrshabakty section and 61.2 m above the base of Unit 8 of the Zhumabai (also known as Bestogai, Ergaliev

Figure 1. Geographic location of the Kyrshabakty section in relation to major settlements and transport routes. Topographic map of part of the area east of Zhanatas in the Malyi Karatau Range showing boundaries of the Aksai State Geological Natural Reserve and location of the Kyrshabakty section. Inset, Kyrshabakty section within territory of the Republic of Kazakhstan.

Figure 2. Schematic geologic map of the Malyi Karatau Mountains (modified after Ergaliev and Zhemchuzhnikov, 2011). Legend: 1 - Precambrian undifferentiated shales, limestones and siliciclastics; 2 - Cambrian-Lower Ordovician cherts, shales, limestones and siliciclastics; 3 - Cambrian-Lower Ordovician limestones and dolostones; 4 - Middle Ordovician siliciclastics siltstones, sandstone, units of conglomerates; 5 - Middle Devonian red beds siltstones, sandstones, conglomerate; 6 - Upper Devonian limestone and dolomites; 7 - Lower Carboniferous limestones; 8 - Lower Permian red beds, siltstones and sandstones; 9 - Middle to Upper Ordovician granites; 10 - Cenozoic undifferentiated sand, clay and boulders; 11 - Faults; 12 - Studied sections with Cambrian and Lower Ordovician successions; 13 - Regional geological subdivisions.

Italic numerals in black circles denote large regional faults: I – Bolshekaroi fault, II – Malokaroi fault, III – Aksai fault, IV – Ushbulak fault.

Capital letters in black circles denote tectonic blocks and/or facies areas: A – Bolshekaroi block, B – Malokaroi block, C – Aksai block, D – Zhanatas block, E – Ushbulak block, F – Kokzhot zone, G – Baizhansai area.

Numerals denote sections where studied Cambrian and Ordovician sequences: 1-Kyrshabakty section; 2-Shabakty section, 3 – Batyrbai section, 4 – Batyrbai-bulak section, 5 – Dongulek section, 6 – Ushbas section, 7 – Koksui section, 8 – Berkuty section, 9 – Ausokkan section, 10 – Aktugai section, 11 – Zhyrukauz section.

et al., 2009) Formation. It is identified by the first appearance of the agnostoid trilobite *Agnostotes orientalis* (Figure 3).

The boundary interval (Figure 3) is a relatively monotonous succession of amalgamated centimetre-scale turbidites showing Ta, Tab and Tbc Bouma divisions with rare metre-scale mass-flow deposits containing carbonate breccia derived from the adjacent carbonate platform. A laterally discontinuous lens of debris flow breccia immediately below the boundary can be used as a local marker for the boundary. Major lithologies are mudstones and wackestones with some oolitic and peloidal packstones. Sedimentation patterns represented in Series 3 to Furongian Series strata of the Kyrshabakty section indicate a fairly stable carbonate-dominated environment evolving from an outer-fan lobe of the slope to the lower slope of a tropical carbonate platform on an isolated carbonate seamount (Cook *et al.*, 1991).

Deposition occurred well below wave base and was not affected by any significant lithofacies shifts, submarine erosion or non-

deposition caused by sea level fluctuations of eustatic or tectonic nature. A few debris flow breccia beds in the boundary interval represent lens-like bodies not more than 2 m thick, and there is no evidence of significant erosion of underlying sediments at the time of deposition. Detailed biostratigraphic (Ergaliev, 1980; Ergaliev and Ergaliev, 2008; Holmer *et al.*, 2001), lithostratigraphic (Zhemchuzhnikov 1989; Ergaliev and Zhemchuzhnikov, 2011), sedimentologic (Cook *et al.*, 1991) and carbon-isotope chemostratigraphic studies (Saltzman *et al.*, 2000) confirm uninterrupted sedimentation of deep water carbonates through the upper half of the Cambrian.

Stratigraphy

Biostratigraphic subdivision of the Kyrshabakty section is based on characteristic agnostoid trilobites (Figure 3). Guide species for the Cambrian Series 3 are assigned to the family Ptychagnostidae

Figure 3. Stratigraphic succession of Cambrian deposits in the Kyrshabakty section, showing revised biostratigraphic units, ranges of selected trilobite taxa (modified from Ergaliev et al., 2008; Ergaliev and Ergaliev, 2008) and sequence stratigraphic interpretation. Plots of $\delta^{33}\text{C}$ (‰ PDB) are after Saltzman et al. (2000, Table 1). Lithologic legend: 1 – thin parallel-laminated lime mudstone; 2 – carbonate turbidites of varied grain size; 3 – undifferentiated carbonate wackestone; 4 – bioturbated carbonate (lime wackestone and packstone); 5 – imbricated pebble flat carbonate breccia; 6 – debris flow breccia with mixed fragments. SB1 and SB2 – sequence boundaries.

and the subfamily Glyptagnostinae, whereas species of the subfamilies Agnostinae and Ptychagnostinae have been used as guide taxa in the Furongian Series. In the Kyrshabakty section, trilobites are moderately common in Series 3; undergo extinction (which is most obvious among

polymerid trilobites) at the beginning of the Paibian Age, and then show increasing diversity as a recovery fauna evolves. Other animal groups, brachiopods in particular, have diversity patterns mimicking that of the trilobites across the Series 3-Furongian interval.

Figure 4. Easterly view of the Kyrshabakty section showing measured intervals in meters, the FAD of trilobite species diagnostic of the Stage boundaries, and position of potential GSSP levels within the section.

Figure 5. 1-6. *Agnostotes orientalis* (Kobayashi) from *Pseudagnostus* (P.) *vastulus*-*Irvingella tropica* Assemblage-zone; 1-4, 6, Kyrshabakty section; 5, Bатырбай Section; 14, Acc. IGNA 1950/8051, latex cast of exoskeleton, $\times 3.5$, sample 2004; 2, IGNA 1950/7030, latex cast of exoskeleton, $\times 5.5$, sample 2004; 3, IGNA 1950/3225, cephalon, $\times 12$; sample 1357-3; 4, IGNA 1950/3256, pygidium, $\times 5$, sample 1357-3, 5, 1950/8051, exoskeleton, $\times 7.5$, sample 1466-2; 6, IGNA 1950/3344a, pygidium, $\times 9.5$, sample 1357-2. 7-10, *Irvingella tropica* Öpik from *Pseudagnostus* (P.) *vastulus*-*Irvingella tropica* Assemblage-zone; 7, IGNA 1950/7060, latex cast of pygidium with attached thorax, $\times 4.3$, sample 2004; 8, 1950/2061, incomplete cranidium, $\times 6$, sample 2004; 9, Acc. IGNA 1950/197, cranidium, $\times 6$, sample 1357-1; 10, IGNA 1950/198, cranidium, $\times 6$, sample 1357-1. Specimens are repositied in the K.I.Satpaev Institute of Geological Sciences, Almaty, Kazakhstan (IGNA).

Agnostotes orientalis (Figure 5, 1-6) is an easily recognisable agnostoid taxon with a wide geographic distribution (see Babcock *et al.*, 2005; Peng and Babcock, 2005). Its first appearance in sections is usually slightly above the first appearance of the polymerid trilobite *Irvingella* (Babcock *et al.*, 2005, Peng and Babcock, 2005). In the Kyrshabakty section *Irvingella tropica* Öpik (Figure 5, 7-10) makes its first appearance just 2.0 m below the ASSP level, where it occurs with another biostratigraphically informative agnostoid, *Pseudagnostus* (*Pseudagnostus*) *vastulus* (Whithouse). In some earlier publications (e.g., Ergaliev, 1980) this species was listed as '*Pseudagnostus curtare*'. Most of the other trilobite taxa that occur within the boundary interval are transitional, which confirms relative stability of the environment.

Linguloid brachiopods were strongly affected by the extinction at the beginning of the Paibian Age, and distinctive components of the micromorphic lingulate associations like *Linnarssonina*, *Neotreta*, *Picnotreta*, *Rhondellina*, *Stilpnotreta* and some others vanished completely before the Paibian. In the Kyrshabakty section most of the Paibian is poor in brachiopods (Holmer *et al.*, 2001). The first

signs of recovery appear in the upper part of the *Acutagnostus acutatus*-*Erixanium* Assemblage-zone. The appearance of *Quadrisonia minor* Rowell and Henderson 6.5 m below the base of the FAD of *Agnostotes orientalis* is important because it is a relatively widespread taxon that is also known from Laurentia, the Australian sector of Gondwana and the Argentinian Precordillera (Holmer *et al.*, 2001). *Aboriginella denudata* Koneva, an endemic member of the family Lingulotretidae, is traceable from the early part of the Cambrian to the Tremadocian. It appears 5m below the FAD of *Agnostotes orientalis*. *Notiobolus indefinites* Holmer *et al.*, 2001 is another endemic form that appears 7.5 m below FAD of *Agnostotes orientalis*.

Some regional biostratigraphic subdivisions based on protoconodonts and paraconodonts have been established (An, 1982) they are of limited long-range use because of long stratigraphic ranges of most of the taxa. Only after the appearance of euconodonts a satisfactory conodont-based biostratigraphic subdivision achieved. In the Malyi Karatau a low diversity protoconodont and paraconodont fauna occurs in the boundary interval. Most of the taxa cannot be used for precise correlation (Abaimova, 1983).

Cambrian lithostratigraphy developed for Malyi Karatau comprises two sets of the units. One set is applied to shallow water carbonates deposited on the top of the seamount, and the other set is applied to deposits formed on the slopes of the seamount. The slope units tend to be diachronous (Zhemchuzhnikov 1989; Ergaliev and Zhemchuzhnikov, 2011) because the Aisha-Bibi carbonate seamount prograded a little seaward as parasequence sets aggraded upwards (Zhemchuzhnikov, 1989).

The SPICE excursion (Saltzman *et al.*, 2000) in the lower Furongian is one of the most recognisable global oceanographic events of the Cambrian. It is documented from sections in Laurentia, Kazakhstan, South China, Australia, Baltica and Gondwana. The base of the Jiangshanian Stage in Kyrshabakty is 16 m above the level that corresponds to the point of maximum positive deflection (+4.82‰ $\delta^{13}\text{C}$ at 243 m in the measured section) of the SPICE excursion. Its position correspond to the onset of the negative shift of $\delta^{13}\text{C}$ (+3.18‰ at 260 m, about 1 m above the ASSP level; Figure 3).

Two major sedimentary cycles, probably second-order sedimentary cycles, are recognised in the Cambrian sequence of Kyrshabakty (Figure 3). They are separated by a Type 1 Sequence Boundary (SB1) about 350 m above the base of the measured section, in the mid part of the *Pseudagnostus pseudagnostilobus-Acrocephalina* Zone. Several sequences, third-order and lower, separated by Type 2 Sequence Boundaries (SB2) are recognisable within each major sedimentary cycle.

In Kyrshabakty, the base of the Jiangshanian Stage is located within an inferred second-order cycle and at the end of a third-order cycle. Sea level did not fall below the edge of the carbonate platform margin, and the depositional environment through the interval was characterized by relative stability. This is supported by the occurrence of non-eroded, concentrically zoned, redeposited oolitic grains in gravity flow carbonates and by the presence of small imbricate breccias.

Provisions for conservation, protection, and accessibility

The Kyrshabakty section (Figure 1) is located on public land, and is easily accessible for research without restriction. It is relatively close (less than 30km from) the town of Zhanatas, which is the main urban settlement of the region. Zhantas has good transport connections to Taraz and Almaty. The significance of the Kyrshabakty section is recognised by the government of the Republic of Kazakhstan and has been included into the protected area of the Aksai State Natural Reserve since 1985. Any building, landscaping or other activities related to landscape alteration or destruction are strictly prohibited, whereas access to the area for research purposes is unrestricted.

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