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THE JOURNAL WAS FOUNDED IN 1940

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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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NEW AMMONOID RECORDS AND GAMMA-SPECTROMETRY IN THE STRATOTYPE OF THE BELEUTIAN REGIONAL SUBSTAGE (CENTRAL KAZAKHSTAN)

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Abstract. New ammonoid records from the stratotype of the Beleutian Regional Substage (Ulytau Region, Karsakbay District, Central Kazakhstan) confirm that the basal beds of the Beleutian Regional Substage can be assigned to the upper subzone of the Lower Serpukhovian *Uralopronorites-Cravenoceras* Genozone (E_{1b-c} Zone of the European Carboniferous scale or Nm_1b_2 of the South Urals scale). This study is important for establishing the international GSSP boundary of the Serpukhovian and updating the regional Carboniferous scheme of Kazakhstan. The aim of this study is to resample the marker horizon near the base of the Beleutian Regional Substage containing *Cravenoceras beleutense*, *Cravenoceras ulytauense*, *Neoglyphioceras litvinovichae, Sudeticeras karagandense,* and *Kazakhoceras*

hawkinsi does not correlate with the base of the Serpukhovian of the Global Scale or with the basal Pendleian of the European Scale, as the level of evolutionary development of *Cravenoceras* and *Neoglyphioceras* suggests a younger age. We resampled the marker horizon for ammonoids using a bed-by-bed method together with corals, crinoids and brachiopods. This method of precise sampling in association of spectral gamma ray study showed shallow-water settings with an input of siliciclastics from nearby land. Based on spectral gamma ray readings, the results show that the beds immediately below the marker horizon level could have been deposited in an oxygen-starved environment. Variance of U, Th, and K contents in the ammonoid-bearing beds can be attributed to variable siliciclastic supply in generally oxygenated settings. This study is important for practical substantiation of the base of the Serpukhovian in the Carboniferous regional scheme of Kazakhstan.

Keywords: Carboniferous, Serpukhovian, Beleutian Regional Substage, Central Kazakhstan, ammonoids, gamma-spectrometry

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БЕЛЕУТІ ӨҢІРЛІК ДЕҢГЕЙІНІҢ СТРАТОТИПІНДЕГІ АММОНИТТЕРДІҢ ЖАҢА ОЛЖАЛАРЫ ЖӘНЕ ГАММА-СПЕКТРОМЕТРИЯСЫ (ОРТАЛЫҚ ҚАЗАҚСТАН)

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Аннотация. Қарастырылып отырған жұмыстың көкейкестілігі Белеуті стратотиптік горизонтынан (Ұлытау облысы, Қарсақпай ауданы, Орталық Қазақстан) табылған жаңа аммоноидеялармен айқындалады. Аталған аммоноидеялар Белеуті горизонтының іргелі қабат екендігін нақтылайтын Uralopronorites–Cravenoceras (еуропалық карбон кестесі бойынша E1b–c зона деңгейі немесе оңтүстік Орал кестесі бойынша Nm1b2) генозонасының жоғарғы бөлігіне тиесілі болуы мүмкін. Жұмыстың мақсаты іргелі қабаттардың жасын сипаттау және олардың стратиграфиялық орнын нақтылау болып табылады. Зерттеу нәтижелері көрсеткендей, Белеутин горизонтының төменгі бөлігінен анықталған аммоноидеялар — Cravenoceras beleutense, Cravenoceras ulytauense, Neoglyphioceras litvinovichae, Sudeticeras karagandense және Kazakhoceras hawkinsi — арқылы белгіленген горизонт жаһандық шкаланың серпухов кезеңінің төменгі шекарасымен және еуропалық шкаланың пендлей кезеңінің негізімен сәйкес келмейді. Бұл Cravenoceras және Neoglyphioceras туыстарының эволюциялық даму деңгейінің оның жасын анағұрлым жас көрсететіндігімен түсіндіріледі. Қойылған мақсатқа жету үшін маркерлік қабаттан жаңа үлгілер сериясы іріктеліп алынды. Қабаттық талдау кораллдар, кринойдтар және брахиоподтар деректері негізінде жүргізілді. Сонымен қатар уран (U), торий (Th) және калий (K) мөлшерін бағалау мақсатында гамма-спектрометриялық талдау орындалды, бұл оттектік режим мен терригендік материалдың түсу қарқындылығын бағалауға мүмкіндік берді. Зерттеу нәтижелері бойынша шөгінділер түзілген бассейн салыстырмалы түрде саяз сулы болған және оған жақын орналасқан құрлықтан сынықты тау жыныстары тасымалданғаны анықталды. Радиоактивтік элементтер құрамындағы айырмашылықтар терригендік материалдың түсуі мен оттектік режимнің өзгерістерін айқын көрсетеді. Аталған зерттеу Серпухов кезеңінің төменгі шекарасын дәлірек анықтауға, сондай-ақ Белеутин горизонтының аймақтық стратиграфиясына қатысты практикалық тәсілдерді жетілдіруге мүмкіндік берді. Зерттеудің практикалық маңызы Қазақстан аумағындағы карбон жүйесінің аймақтық стратиграфиялық сызбасында Серпухов жіккабатының төменгі шекарасын нақтылауға бағытталған.

Түйін сөздер: таскөмір жүйесі, серпухов ярусы; белеутин горизонты, Орталық Қазақстан, аммоноидтар; гамма-спектрометрия

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НОВЫЕ НАХОДКИ АММОНОИДЕЙ И ГАММА-СПЕКТРОМЕТРИЯ В СТРАТОТИПЕ БЕЛЕУТИНСКОГО ГОРИЗОНТА (ЦЕНТРАЛЬНЫЙ КАЗАХСТАН)

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Аннотация. Актуальность данного исследования определяется новыми находками аммоноидей из стратотипа белеутинского горизонта (Улытауская область, Карсакпайский район, Центральный Казахстан), которые подтверждают, что базальные слои белеутинского горизонта могут быть отнесены к верхней части генозоны Uralopronorites–Cravenoceras (уровень зоны E1b–c европейской шкалы карбона или Nm1b2 южноуральской шкалы). Цель работы заключается в уточнении возрастных характеристик и стратиграфического положения базальных слоёв. Установлено, что маркирующий горизонт с аммоноидеями у основания белеутинского горизонта (Cravenoceras beleutense, Cravenoceras ulytauense, Neoglyphioceras litvinovichae, Sudeticeras karagandense и Kazakhoceras hawkinsi) не может быть сопоставлен с основанием серпуховского яруса глобальной шкалы и основанием пендлейского яруса европейской шкалы, поскольку уровень эволюционного развития родов Cravenoceras и Neoglyphioceras указывает на более молодой возраст. Для достижения поставленной цели выполнены

отбор новых серий образцов из маркирующего горизонта и послойный анализ с использованием данных по кораллам, криноидеям и брахиоподам. Дополнительно проведён гамма-спектрометрический анализ для оценки содержания U, Th и K, что позволяет судить о кислородном режиме и поступлении терригенного материала. Результаты показывают, что бассейн, в котором формировались отложения, был относительно мелководным и испытывал поступление обломочного материала с близлежащей суши. Различия в содержании радиоактивных элементов отражают изменения терригенного поступления и кислородного режима слоёв. Проведённое исследование позволило более точно уточнить положение нижней границы серпуховского яруса и усовершенствовать практические подходы к региональной стратиграфии белеутинского горизонта. Полученные результаты имеют важное прикладное значение для распознавания нижней границы серпуховского яруса в региональной схеме карбона Казахстана.

Ключевые слова: каменноугольная система, серпуховский ярус; белеутинский горизонт, Центральный Казахстан, аммоноидеи; гамма-спектрометрия

Introduction. Early Carboniferous ammonoids have been known from Central Kazakhstan since the beginning of the 20th century (Krestovnikov, 1940). The best ammonoid occurrences of the *Uralopronorites-Cravenoceras* Genozone are recorded in the sections of the Sholak Syncline in the south of the Ulytau Region, coordinates 47°04'20.9"N 66°41'37.4"E (Fig. 1). Here, during geological surveying and mapping in the 20th century the Beleutian Regional Substage was recognized in the Beleuty (Kalmakkyrgan) River basin and included in the regional stratigraphic schemes (Rezolyutsiya, 1958). Originally, the base of the Beleutian was defined based on the first appearance in this section of the Early Carboniferous ammonoid genus *Cravenoceras* and correlated with the lower boundary of the Namurian Stage in Europe. The entire Beleutian Regional Substage, about 500 m thick, was correlated with the Namurian, and with the interval overlying the Serpukhovian Stage (lower substage of the Bashkirian Stage).

The Beleutian Regional Substage in this section conformably overlies the Dalneian Regional Substage, which has its stratotype in the Akmola Region, on the Ishim River. The Beleutian Regional Substage was subdivided by various authors into three to five major units, while ammonoids were only found in the basal unit (Litvinovich, 1947, 1962; Litvinovich et al., 1985). Vdovenko (1963) suggested, based on foraminifers, that the Beleutian Substage in its lower part might correspond to the Steshevian Regional Substage of the Moscow Basin, while Einor and Vdovenko (1963) assumed that the actual Visean-Namurian (Serpukhovian) boundary in the stratotype could be below the beds with ammonoids. At the same time, the fossil distribution was only published in the most general form, and the question of correlating the lower boundary of the Serpukhovian Stage in the stratotype of the Beleutian Substage remained unresolved.

In 2023-2024 we conducted fieldwork at the type section of the Beleutian Regional Substage and collected many fossils, including ammonoids. The ammonoids come from the basal horizons of the Beleutian Substage from beds of dark, clayey nodular limestones alternating with greenish-gray shales and siltstones (Bed 7 of Litvinovich et al., 1985).

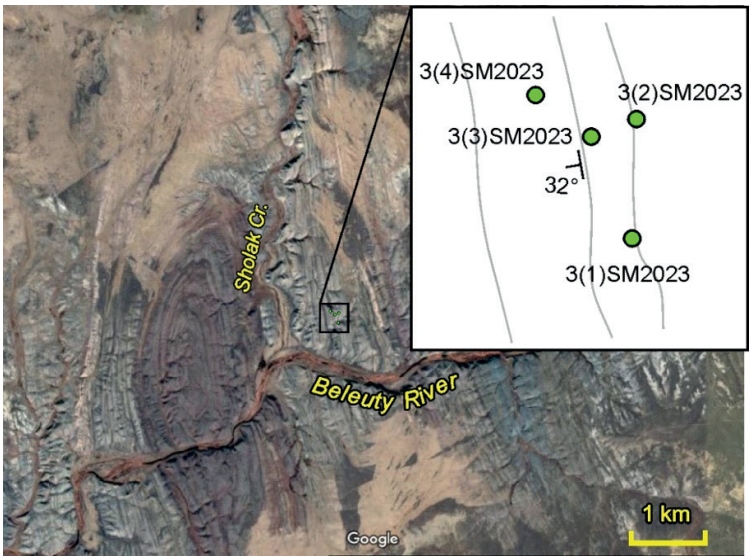

Figure 1 - Beleuty locality and field stations in Central Kazakhstan, Ulytau Region

Materials and methods. The uppermost units of the Dalneian Regional Substage and the lowermost Beleutian Regional Substage were re-examined in this stratotype in 2023 and 2024. The section was remeasured and redescribed (see a new description in stratigraphic order below). The main field stations 3(1)SM2023, 3(2)SM2023, 3(2)SM2023, and 3(4)SM2023 (Table 1) were sampled for macro- and microfossils. Ammonoids were found at locality 3(4)SM2023.

Table 1– Coordinates (degree decimals, NAD83) and bed dip information of measured sections. Azimuth is corrected for magnetic declination.

Beleuty/Sholak (3SM2023)	**Latitude**	**Longitude**	**Bed dip/azimuth**	**Magnetic declination**
3(1)SM2023	47.07188	66.69512		8.62°E
3(2)SM2023	47.073088	66.695173		8.62°E
3(3)SM2024	47.07291	66.694507	32/246	8.62°E
3(4)SM2024	47.073332	66.693672		8.62°E

Figure 2 - Outcrop 3(1)SM2023 (Fig. 2A) and close-ups of the silty shale and the driftwood bed at 0.8 m of the section (Figs. 2B-D). This bed is arrowed in Figure 2B

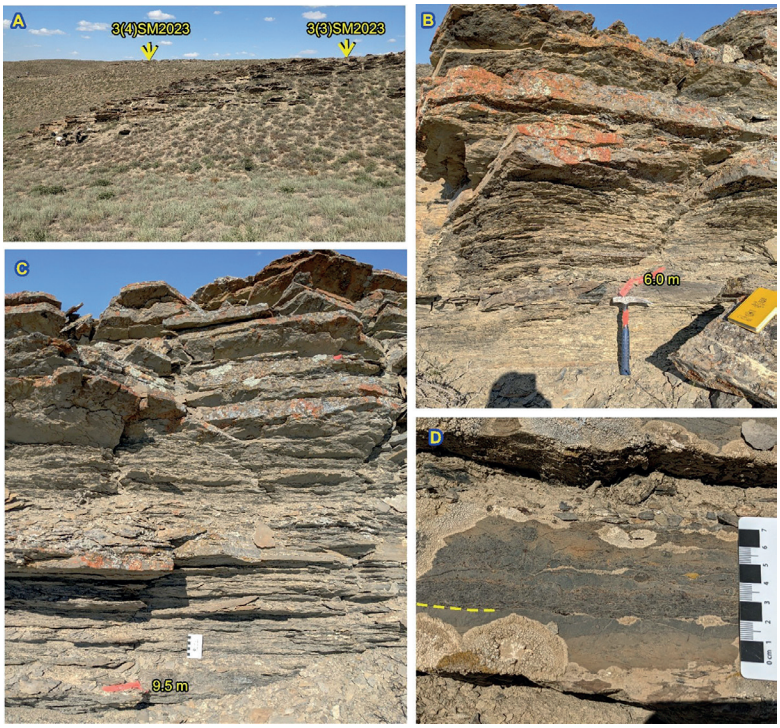

Figure 3 - Outcrop 3(3) SM2023. (A) Westerly view to the outcrop; note the ridge where the Serpukhovian ammonoid horizon (3(4) SM2023) is exposed in the background. (B, C) Two intervals within the outcrop; red tape flags stratigraphic meterage. (D) A normally graded bed on a scour surface (partly traced from the right) with the basal shell coquina composed of imbricated brachiopod valves.

Locality details. Field Station 3(3) SM2023. Measurements start from the traceable limestone ridge exposed at 4.0–4.7 m above 3(1) SM2023, while below there is a few meters of scree cover on the bedrock.

4.0–5.0 m. Limestone with marly interbeds: limestone beds are micritic, dark gray on fresh surfaces, with bioclasts; thin receding intercalations of fissile marl.

5.0–6.4 m. Shale and siltstone: dark gray, calcareous, fissile, aphanitic.

6.4–7.1 m. Limestone: dark gray, micritic, with fissile shale interbeds; this resistant limestone protrudes as a low rib.

7.1–8.2. Limestone-marl alternation: limestone is more bioclastic and fossiliferous than stratigraphically below; graded tempestite beds, brachiopod coquinas, and coarse crinoid ossicles occur here at several levels.

8.2–14.0 m. Limestones and marls: low-contrast alternation of more resistant, thin-bedded argillaceous micritic limestone and more recessive, black-colored marl. Spiriferid-dominated brachiopod banks are observed in limestone beds. This interval forms the hill crest. Its western slope parallels the bedding; the bedrocks are very and poorly exposed there.

Field Station 3(4)SM2023. This is a hill with Serpukhovian ammonoid localities to the W of hill 3(3)SM2023. A shallow saddle between two hills is floored with scree.

14.0–24.0 m. Mostly covered, but a few low beds of argillaceous limestone in basal ~ 1 m protrude from soil and are visible. This soil covers recessive shales or siltstones. Above, there is soil with several small patches of soft, buff colored shale disintegrated into small (0.5-2 cm) flakes. These patches do not preserve the original bedding. Poorly preserved bedding elements were observed in only one patch.

The overlying section was measured on the E slope of hill 3(4)SM2023 about 30 m south, where the exposure is slightly better.

24.0 – 27.6 m. Mostly covered. Patchy exposure reveals shale with sandstone seams. Greenish gray, soft, fissile and weathered shale. Bedding is not preserved. A few ribs of greenish gray, fine-grained sandstone (the thickest occurs at 25.0 m). The number of these sandstone beds is unclear, as sandstone blocks on the day surface occur in a displaced position (slumped downslope).

27.6–27.8 m. Sandstone: coarse-grained, bluish gray, non-calcareous, composed mostly of felsic grains (quartz and plagioclase?), with minor mafic grains.

27.6–28.2 m. Sandstone: coarse-grained, massive, fractured, densely penetrated by white hydrothermal veins. The sandstone matrix is calcareous, weathering rusty; grains are prevalently quartz and dark-colored, sometimes black rounded lithic and/or mafic effusive fragments.

28.2–28.6 m. Limestone: dark gray, massive, fractured, fossiliferous, with sand admixture; poorly exposed. This bed is matched to the “bed of fractured finely crystalline limestone in the upper part of unit 6” (Litvinovich et al., 1985).

28.6–32.0 m. Shale: calcareous, dark greenish gray, fissile.

32.0–34.5 m. Limestone: gray, medium to thick bedded; wackestone, locally packstone and floatstone composed of shell hash – mostly cephalopods.

34.5–37.4 m. Limestone: thick (0.2–0.45 m) beds of ammonoid-rich limestone, gray colored, separated by more recessive, thinner intervals of fissile marl. Very gradual transition to overlying limestone.

37.4–43.0 m. Alternation of limestone and marl: gray, nodular, resistant ribs of limestone are interspaced by thicker (20–40 cm), more recessive intervals of fissile marls and siltstone. Crinoid columnals and cephalopod molds were collected at this level.

Results and discussion. The ammonoids come from the base of the Beleuty Formation from beds of dark, clayey nodular limestones alternating with greenish-gray shales and siltstones. Ammonoids from this section were initially identified by L.S. Librovitch, and later by V.E. Ruzhencev and M.F. Bogoslovskaya. A collection of ammonoids from the Beleuty River and several other localities in close vicinity of the mouth of Sholak Creek was previously studied by Ruzhencev and Bogoslovskaya (1971). They identified *Cravenoceras beleutense beleutense* Ruzhencev and Bogoslovskaya, 1971, *C. beleutense evolutum* Ruzhencev and Bogoslovskaya, 1971, *C. beleutense sublatum* Ruzhencev and Bogoslovskaya, 1971, *C. arcticum* Librovitch, 1938, *C. malhamense* Bisat (1924), *Neoglyphioceras litvinovichae* Ruzhencev and Bogoslovskaya, 1971, *Kazakhoceras hawkinsi* (Moore, 1930), *Beleutoceras carinatum* Ruzhencev and Bogoslovskaya, 1971, *Sudeticeras karagandense* Ruzhencev and Bogoslovskaya, 1971, *Girtyoceras* cf. *modestum* Ruzhencev and Bogoslovskaya, 1971. This assemblage corresponds to the *Uralopronorites-Cravenoceras* Genozone, and most likely to its upper part (Nm_1b_2). We re-examined the previously collected ammonoids and our new collections, and we agree that the assemblage does not contain taxa characteristic of the lower part of the *Uralopronorites-Cravenoceras* (Nm1b1) Genozone (for the latter see Ruzhencev and Bogoslovskaya, 1971), while the species of the genera *Cravenoceras* (family Cravenoceratidae) and *Neoglyphioceras* (family Neoglyphioceratidae) in this assemblage have an advanced shell morphology, which is considered to be characteristic of the upper part of the genozone. A new species *Cravenoceras ulytauense* was described from the Beleuty section (Nikolaeva, 2025) (this new species includes specimens previously assigned to *C. malhamense* by Ruzhencev and Bogoslovskaya (1971).

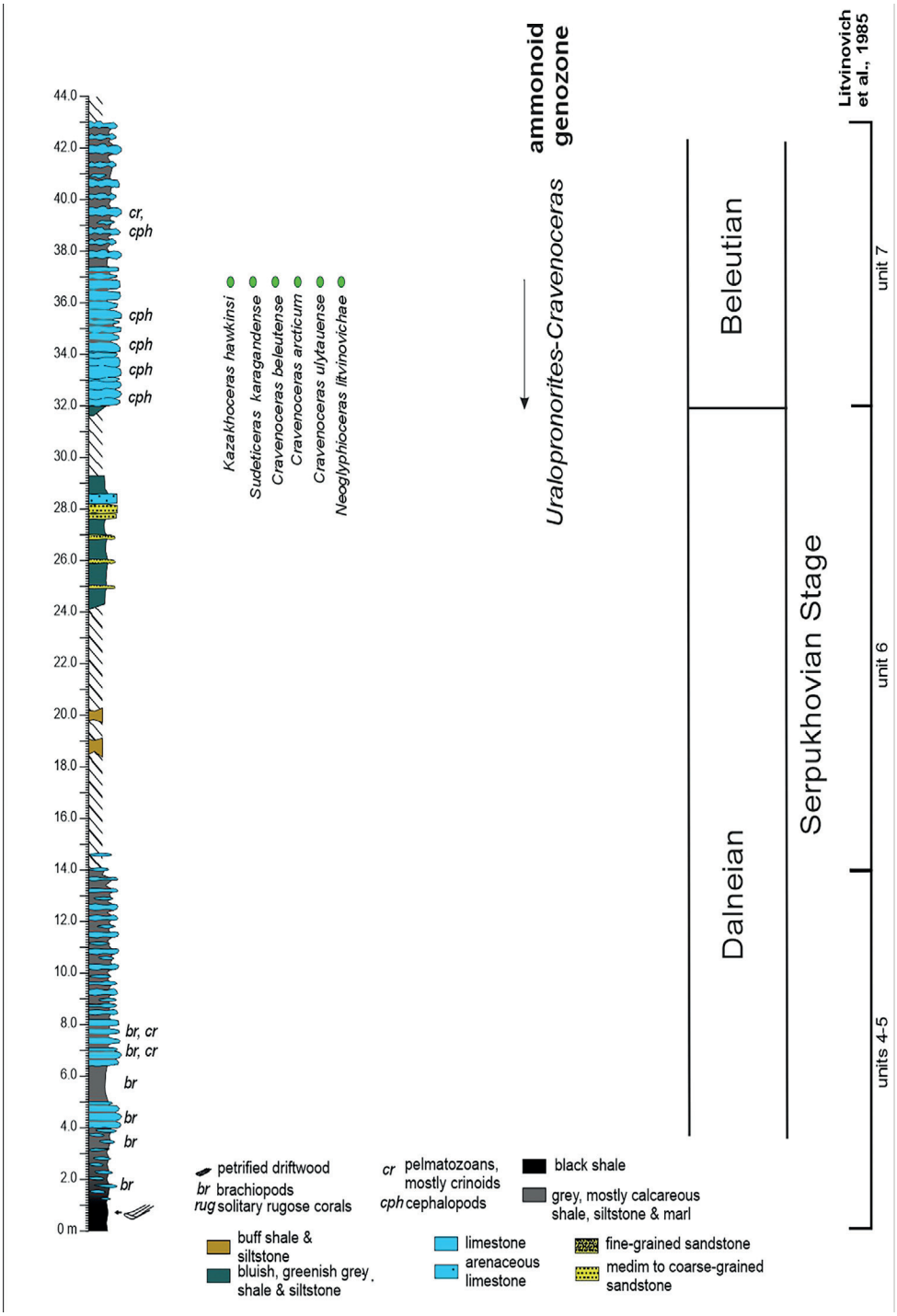

Figure 4 - Ammonoid occurrences in Outcrop 3(4)SM2023 (stratotype of the Beleuty Formation and Beleutian Regional Substage) studied in 2023

It has been suggested based on the material from the Urals, Western Europe and North America (Korn, 1988; Korn and Tilsley, 2002) that in the time interval of the *Uralopronorites-Cravenoceras* Genozone, the relative width of the umbilicus changed in ontogeny. In the early species of *Cravenoceras* from the basal Serpukhovian and its equivalents (e.g., *C. leion* Bisat, 1930 from the basal E_{1a} Zone of UK and Ireland), the relative umbilical width changes in ontogeny showing first a decrease in pre-adults and a slight increase in adults. In later species of this group, the relative width of the umbilicus seems to have increased more consistently, and in some species the shell becomes wide and cadiconic at adult stages. The species of the genus *Cravenoceras* (*C. beleutense beleutense*, *C. beleutense evolutum, C. beleutense sublatum*) from the Beleutian Regional Substage, are distinguished by a wider umbilicus than the known representatives of the genus from the basal Serpukhovian and its equivalents (e.g. *C. leion* Bisat, 1930), and the assemblage does indeed contain many representatives with a wide shell identified as *C. arcticum* and *C. ulytauense*. Morphologically similar species of the genus are known from deposits of the E_{1c} zone in Great Britain (Bisat, 1952), from the upper part of the Pendleian Stage, correlated with the upper half of the lower Serpukhovian of the Moscow Basin and the Urals. The assemblage also contains a derived species of *Neoglyphioceras*, in which the shell is compressed, and the umbilicus is very narrow, features usually associated with phylogenetically younger members of the genus. With its intricately curved constrictions and growth lines, *Neoglyphioceras litvinovichae* from the Beleutian Regional Substage is interpreted as one of the latest representatives of the genus. Such a biconvex transverse ornamentation is observed only at the end of the phylogeny of this genus (Ruzhencev and Bogoslovskaya, 1971).

The *Uralopronorites–Cravenoceras* Genozone is defined by the time of existence of the genera *Eumorphoceras, Cravenoceras, Tumulites, Dombarites* (species of the genus without falcatoid ornamentation), and some others. *Uralopronorites* is a very characteristic genus, but it is not very common, e.g., it is not found in Central Kazakhstan, so it is not suitable for global correlations. The lower boundary of the genozone was traditionally drawn at the base of the beds with the first representatives of the genus *Cravenoceras* (the species *C. leion* in the sections of Great Britain and Ireland), and in geological practice the genozone was identified with the time of existence of the species of the genera *Cravenoceras* and *Eumorphoceras*. The base of the Pendleian Stage in the UK and Ireland contains three interbeds with *Cravenoceras leion*, and one of these beds contains a girtyoceratid *Edmooroceras pseudocoronula*, which is also used for the boundary definition in Western Europe (Korn, 1996; Korn and Tilsley, 2002). At present, species of the genus *Cravenoceras* are better suited for the correlation of the European Lower Serpukhovian successions with those on Novaya Zemlya, the South Urals and Kazakhstan (Nikolaeva and Kullmann, 2003; Nikolaeva, 2022). The assemblages in the Urals, Western Kazakhstan (Mugodzhary) and Central Asia are

dominated by various species of Dombaritinae (primarily the genus *Dombarites*), while the abundance of cravenoceratids (*Cravenoceras, Verancoceras*), Pronoritids (*Uralopronorites*), girtyoceratids (*Eumorphoceras, Tumulites*), and prolecanitids (*Dombarocanites, Epicanites*) is significantly less (Ruzhencev and Bogoslovskaya, 1971; Nikolaeva et al., 2009). The Beleutian fauna is very different from those of Mugodzhary (Dombar Hills) and the South Urals, in that cravenoceratids predominate in it, while there are no Dombaritinae. The generic composition of the ammonoid fauna resembles that of Novaya Zemlya (Berkha Island, Maly Zayachy Island) (Librovitch, 1938; Kusina and Yatskov, 1999) and to some extent North America (see Saunders and Work, 1999). The genozone is subdivided into two zones, which Ruzhencev and Bogoslovskaya named Nm_1b_1 and Nm_1b_2. Coeval faunas are found in $E_{1b\text{-}c}$ of Great Britain and possibly in the "*Tumulites varians–Cravenoceras fayettevillae*" Zone and in the Barnett Shale in Texas, USA (Titus et al., 2015).

Since the morphology of the shell of cravenoceratids and neoglyphioceratids of the Beleutian assemblage suggests horizons higher than the basal Nm_1b_1 Zone, but more likely Nm_1b_2 Zone, the lower boundary of the Beleutian Regional Substage in the stratotype cannot be correlated with the base of the Serpukhovian Stage, which is defined by the first appearance of *Cravenoceras leion* and morphologically similar cravenoceratids of the Nm_1b_1 Zone and its equivalents. Therefore, the boundary of the Visean and Serpukhovian in the stratotype of the Beleutian Regional Substage in the regional scheme of Kazakhstan has to be transferred to a lower stratigraphic level, below the ammonoid-bearing horizon, to the beds previously assigned to the underlying Dalneian Regional Substage (Bed 6 of Litvinovich et al., 1985 or possibly even lower). These conclusions are confirmed by recent finds of the foraminifers *Neoarchaediscus postrugosus* and *Monotaxinoides subplanus* in the stratotype of the Beleuty Formation, in beds below the level with *Cravenoceras beleutense* (Nikolaeva et al., 2025) and agree with the scheme of Zholtayev et al. (2021).

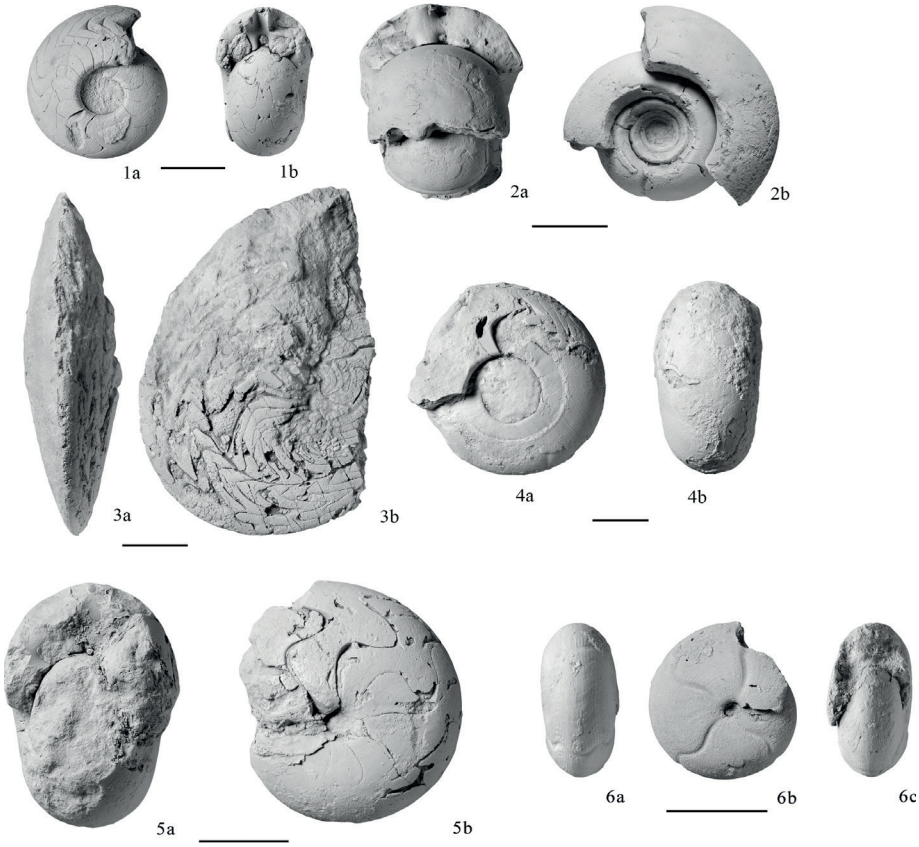

Figure 5 - Ammonoids from the stratotype section of the Beleutian Regional Substage: 1, 4 – *Cravenoceras beleutense beleutense* Ruzhencev et Bogoslovskaya, 1971

1 – specimen PIN, no. 5900/1; 4 – specimen PIN, no. 5900/23; 2 – *Cravenoceras ulytauense*, holotype PIN, no. 2493/158; *Kazakhoceras hawkinsi* (Moore, 1930), specimen PIN, no. 5900/10; 5 – *Sudeticeras karagandense* Ruzhencev et Bogoslovskaya, 1971, specimen PIN, no. 5900/2; 6 – *Neoglyphioceras litvinovichae* Ruzhencev et Bogoslovskaya, 1971, specimen PIN, no. 5900/18; Serpukhovian, *Uralopronorites-Cravenoceras* Genozone, upper part; Kazakhstan, Ulytau Region, Beleuty River; scale bars 10 mm.

Gamma spectrometry. The continuous stratigraphic intervals in the stratotype Beleuty section (Figs. 1 and 2) were surveyed with the RS-230 BGO scintillometer of Radiation Solutions Inc. Signal acquisition time was set to 120 seconds. Tabulated tool output data and the collection of spectra are available in the supplementary MS Excel file for this report.

Decomposition of gamma radiation into U, Th and K spectra is widely used to interpret lithology and deposition metals are widely used as elemental proxies to interpret the degree of oxygen starvation of the depositional environment (*e.g.,* Tribovillard et al., 2006). On Figure 3, we use the U_{aut}, or authigenic uranium – a popular proxy to the excess of uranium (Myers and Wignall, 1987):

$$U_{aut} = U[\text{ppm}] - Th[\text{ppm}]/3$$

Shales with $U_{aut} >> 0$ can in many cases be interpreted as those with the authigenic enrichment above the U content in detrital minerals (Myers and Wignall, 1987).

Although stratigraphic changes in siliciclastic richness and degree of U_{aut} buildup cannot be asserted with so many covered intervals (Fig. 6), our gamma spectrometry data suggest that the 9.0-32.0 m interval of the section could have deposited in an oxygen-starved environment (U_{aut} ~2-6). The dark-colored shale at the base of our measured section (0.0-1.2 m) does not exhibit this U_{aut} enrichment. The overall height of SGR at 28.0-33.0 m is due to high siliciclastic content (elevated Th and K spectra readings), whereas uranium stays close to the background level.

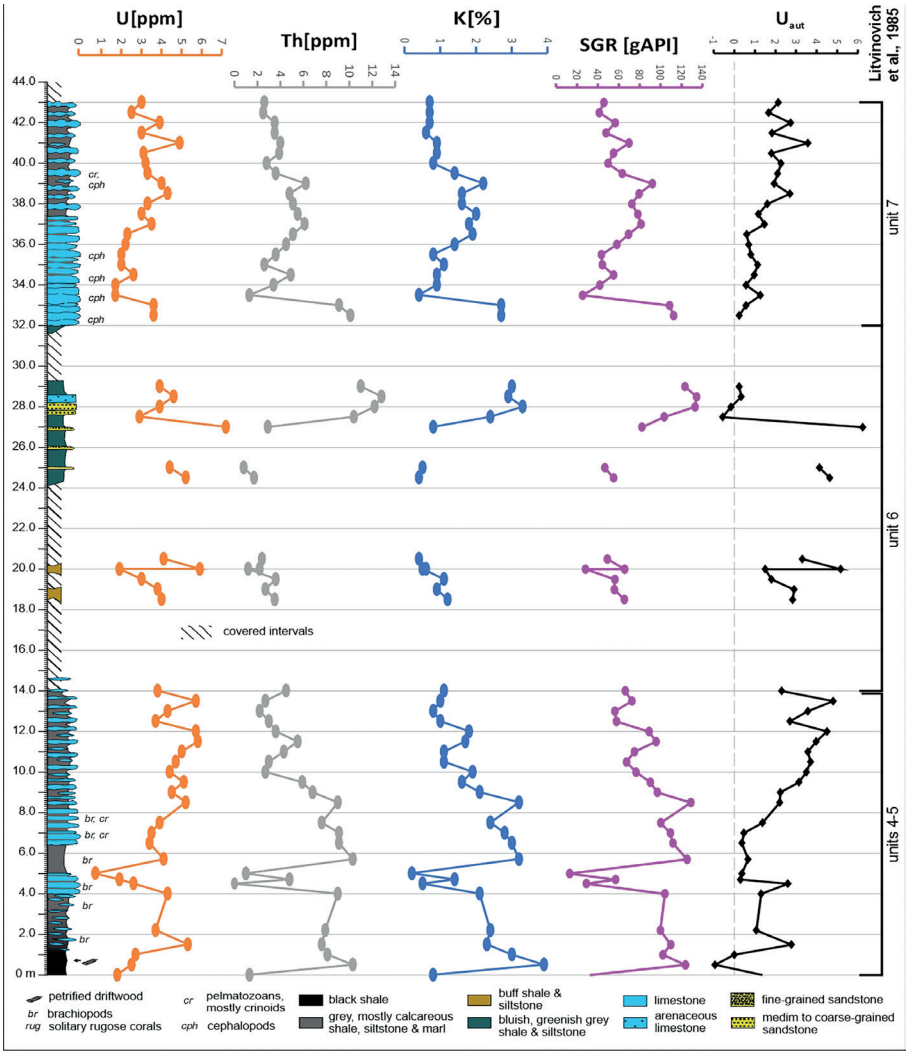

Figure 6 - Measured section at Beleuty with gamma-spectrometry logs

Conclusions. The basal beds of the Beleutian Regional Substage in the stratotype section are characterized by ammonoids found in association with foraminifers, gastropods, crinoids, corals and brachiopods. These faunas suggest a reasonably shallow-water basin with an input of siliciclastics from nearby land. The original base of the Beleutian as suggested by ammonoids does not correlate with the base of the Serpukhovian, or with the basal Pendleian.

Based on spectral gamma ray readings, we hypothesize that the "siliciclastic gap" at 9.0–28.0 m, largely overlapping with Unit 6 of Litvinovich et al. (1985), could have been deposited in an oxygen-starved environment. Variance of U, Th, and K contents on other stratigraphic intervals, including the ammonoid beds at 32.0-43.0 m, can be attributed to variable siliciclastic contribution in an overall oxic depositional environment.

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