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# PROBLEM OF THE INTERNATIONAL CHRONOSTRATIGRAPHIC CHART OF LOWER DEVONIAN AND STRATIGRAPHIC BOUNDARIES OF LOWER DEVONIAN STAGES IN SOUTHERN TIAN SHAN

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The boundaries of the International Chronostratigraphic Chart (ICC) are associated with the natural historical stages of the Earth's development, and their boundaries are usually determined by the palaeogeographical or palaeobiological event that is recognized in most regions of the world.

Studies on the standardization of the Lower Devonian ICC stages duration have lasted more than 70 years. The first stages were Gedinnian, Siegenian and Emsian, but their duration was not accurately determined. The article shows the history of the establishment of the currently used Lochkovian, Pragian and Emsian stages.

The key study method of the Lower Devonian stages deposits is biostratigraphic one, based on the use of archistratigraphic pelagic fossils, i.e. revealing of the zonal sequence over the conodonts, dacrioconarids and goniatites fossils and comparing them with the standard sequence adopted by the International Geological Congress (IGC).

The article contains an analysis of the discussed problems related to the determination of the position of the global boundary stratotype section and point (GSSP) of the Lower Devonian stages. The use of the magnetostratigraphic method in comparison of the sections of the Emsian stage in Barrandian and Zarafshan range is also discussed.

The Lower Devonian regional strata of the Zarafshan-Gissar and Turkestan-Altay mountain regions of the Southern Tian Shan are characterized. It is shown that the zonal sequences on conodonts and dacrioconarids presented in these regions almost completely coincide with the standard Lower Devonian sequences in the International Chronostratigraphic Chart. The characteristics of zones and volume of Bursykhirmanian, Sangitovarian, Khukarian, Kunjak, and Kitab horizons are given.

***Key words:*** Lochkovian, Pragian, Emsian stages; Global Boundary Stratotype Section and Point; Sangitovarian, Khukarian, Kunjak, Kitab horizons

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**Introduction.** For the Lower Devonian is currently used a global stratigraphic chart, approved in 1996 by the International Geological Congress and comprising three stages: Lochkovian, Pragian, and Emsian. In the history of this chart the stratotypes positions, volumes and names have changed several times. Although the Devonian system was first determined in England, the biostratigraphic content of the Lower Devonian deposits in this region could not provide detailed interregional correlations, since the strata of England are represented mainly by the red lagoon-continental deposits, usually characterized by the fish remnants.

**History of research.** The first Lower Devonian stages were determined in the Arden-Rhineland region on the basis of regional stratons, which were subsequently used as stages: Gedinnian (with trilobites, fish and lower transgressive boundary), Siegenian (containing fish, bivalves and brachiopods), and Emsian (characterized by tentaculites, goniatites, conodonts and rare brachiopods). Later the first two stages had to be abandoned in connection with the difficulty of applying them as international standards in most regions of the world. The generally accepted correlation requirements were met only by the Emsian stage. That's why it was necessary to look for a replacement for the two lower stages. Well-studied and fairly complete sequences of Lower Devonian normal marine sediments with a diverse pelagic and benthic fauna were known in Barrandian, Czech Republic. These sediments constitute the Lochkovian and Pragian formations. In 1985, the Subcommission on Devonian Stratigraphy (SDS) accepted the typical sections of these formations as stratotypes for the Lower Devonian stages, named Lochkovian and Pragian with global stratigraphic boundaries in Barrandian. The stratotype of the Emsian stage remained in the Rhineland. However, the lower part of this stratotype section was not fully characterized by the pelagic fauna and subsequently, the global stratotype of the Emsian lower boundary (GSSP) was established in the west of the Zarafshan range in the Southern Tian Shan.

As a result of such reconstructions, a «composite» scale was formed for the Lower Devonian. This scale consists of stages, which stratotypes are located in different tectonic blocks of Eurasia. The points of global boundary stratotypes also appeared to be separated into different regions: the global stratotype of the Lochkovian stage base (the base is determined by the zonal graptolite sequence and accepted as

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the base of the *Monograptus uniformis* graptolite zone) is in the section of the Khlong Barrandian structure [18]. The other Lower Devonian stages base determination is founded on the conodonts zonal sequence. The global stratotype of the Pragian stage base is located in the Velká Chuchle quarry in the southwestern part of Barrandian [17, 19] and is originally determined by the bottom of the *Eognathodus sulcatus sulcatus* zone. However, the International Commission on Stratigraphy (ICS) [26] recommended the use of the name *Gondwania juliae* for this level of the conodont sequence. This is caused by taxonomic studies showing that the definition of a species appearing at the base of the Pragian stage as eognathus, is erroneous, and it should be referred to the *Gondwania juliae* [11]. Subsequently, when studying the morphotypes of this species, its relationship with the species of *G. irregularis* was established. At present, the boundary between the Lochkovian and Pragian stages is carried out within the newly determined *Irregularis* zone [14].

The base of the *Eocostapolygnathus kitabicus* conodont zone (the lower part of the Zinsilbans layers) in the Zinsilban sequence in the Kitab State Geological Reserve (KSGR, Uzbekistan) was approved as a stratotype of the Emsian stage base [11]. The *Polygnathus dehiscens* species previously used to define this boundary was recognized as invalid from the taxonomic position [21].

The upper boundary of the Emsian stage passes along the base of the *Polygnathus costatus partitus* zone and coincides with the base of the Eifelian stage, which global stratotype point is located in the Wetteldorf section (Eifel mountains, Germany) [34].

Thus, it turned out that the stratotypes of the Lochkovian and Pragian stages were established in the clayey-carbonate facies of Barrandian, of the Emsian stage - in the terrigenous facies of the Rhineland, of the Pragian and Emsian stages boundary - in the carbonate facies of the Zarafshan range, of the Emsian and Eifelian stages boundary - in clayey-carbonate facies of the Eifel mountains (Table 1).

*Table 1*

**Global boundary stratotype section and point (GSSP) of the Lower Devonian**

| Stage | Stratotype locality | Composition of rocks in stratotype | Zonal standard of the lower boundary | Point position of the global stratotype lower boundary (GSSP) | Note |
|---|---|---|---|---|---|
| Eifelian | Ardennes, Eifel mountains (Belgium) | Dolomites | *Polygnathus costatus partitus* | Wetteldorf section, upper part of laminated limestones of Heisdorf layers, 1,9 m below the layer top, Eifel mountains (Germany) | Event at the boundary between Emsian and Eifelian stages (Choteč event, or *Jugleri* event). A second-order event occurs between the bottom of the *Po. costatus partitus* zone and the level of *Pinacites jugleri* appearance |
| Emsian | Arden-Rhineland region (Germany) | Sandstones, clay shales | *Eocostapolygnathus kitabicus* | Zinsilban section laminated limestones, layer 9/5, 58 cm above the Khodzha-Kurgan suite base (West of the Zarafshan Range) | Early Zlíchov event. The third-order global event, recognized in Bohemia on the boundary between Zlíchovian and Pragian suites. The level does not coincide with the Pragian -Emsian boundary, determined by the presence of *Polygnathns kitabicus,* and the beginning of a brief transgression |
| Pragian | Velká Chuchle quarry, near Kosoř, Barrandian (Czech Republic) | Different types of organogenic limestones | *Gondwania juliae* | Base of layer 12 Velká Chuchle quarry | The event on the boundary of Lochkovian and Pragian period. Event of the third order, coinciding with the roof of Lochkovian dark flaglike limestone |
| Lochkovian | Klonk section, near the village of Suchomasty, Barrandian (Czech Republic) | Laminated limestone and clay shales | *Monograptus uniformis* | Base of layer 20, Klonk section | The 5th order event on the Silurian and Devonian border in the roof of the *Neocolo-nograptus transgrediens s. str.* graptolite zone |
| Pridolian | Geopark, Barrandian (Czech Republic) | | *Neocolonograptus parultimus* | Pozhari section, Barrandian (Czech Republic) | |

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**Discussion.** These objective circumstances make it much more difficult to apply the main criterion accepted by the International Commission on Stratigraphy in determining global stratigraphic boundaries: the correlation between natural historical stages of the fauna evolution and sedimentation processes [22]. It is known that the stages and rates of change of the Early Devonian biotas were mainly induced by regional sedimentation events and not always occurred simultaneously in different tectonic blocks. This is particularly true for the Lochkovian and Pragian stages, characterized by active tectonic processes and great endemism of the fauna. To clarify the synchronization of geological processes, it is necessary to use the absolute age of the sequences. However, there is a lack of such information and the existing data is partly contradictory.

Problems of the Lower Devonian stage boundaries are common in establishing standards for most Phanerozoic stages and are caused by objective reasons. On the one hand, it is due to the fact that specific stratotype sequences cannot serve as averaged models by their natural features. On the other hand, it is an obligatory requirement, since the concept of GSSP was accepted by ICS with the aim of stabilizing the position of the stratigraphic boundaries of the main international stratigraphic units.

The requirements (principles) underpinning the determination of stages standard boundaries are also somewhat contradictory. This means the following:

1. According to the rules of the International Commission on Stratigraphy, only the bottom level of their lower boundary is taken as the standard for establishing the stratotype of international units. The upper boundary is considered to be the lower boundary of the overlying stratum. This rule makes it possible to prevent a gap and restore the complete sequence of geological events during the period under review. However, it sometimes leads to misunderstandings in determining the volume of the stratigraphic unit, especially in cases when its lower and upper boundaries are established in sediments of different formations of different regions. Such problems exist with the upper boundaries of Lochkovian [4] and Pragian [31] stages. They are related to the fact that diachronicity of the borders of the Czech formations was not taken into account and the boundaries of the Lochkovian and Pragian stages were not sufficiently studied. In further studies, it was found that the volume of the stratigraphic units changes from facie to facie, and their boundaries are rolling.

2. Phylogenetic lines of used taxons, including pelagic conodonts, are most clearly restored in mono-facial sequences relative to deep-sea sediments. The lithological structure of these deposits not always shows the changes in sedimentation processes. Therefore, the connection of the bio-events with the sedimentation stage is lost.

3. Different groups of fauna have different evolution rates, which causes a geochronological divergence in the zones boundaries based on the stages of evolution of different groups caused by the same paleogeographic event. For example, it is known [23] that in the key Lower Devonian Pyrenean sequence the lower layers of the Mariposas formation (layers d4a Alpha) contain the conodonts *Eocostapolygnathus excavatus*, the index of the second zone of the Emsian standard conodont sequence. While the typical German brachiopod complex of Emsian stage occurs in this section above this zone and the lower part of the Mariposas formation (d4a Alpha) is defined as a Siegenian stage [15, 23]. Thus, in a number of cases, for the correlation convenience, the SDS decree on the prioritization of the conodonts sequence before the brachiopod complexes is not taken into account.

The zonal scale based on dacrioconarids and provides the lithostratigraphic breakdown with almost the same detail as the conodonts one. However, the use of dacrioconarids is inhibited by the insufficient study of these fossils.

The Lower Devonian standard stages were identified in 1985, and the decision of the International Subcommission on Devonian Stratigraphy was rendered after a series of discussions in 1989 and ratified in 1996 by the International Union of Geological Sciences (IUGS). However, within 20 years the question about its clarification and partial revision arose. Currently, the main focus is on the lower boundary of the Emsian stage and the position of its stratotype in the Zinsilban sequence of the Zarafshan. It was also proposed to transfer this border to the Czech or Spanish sequences.

This problem has a long history, which began with an unsuccessful attempt to determine this boundary in the Lower Devonian stratotype locality at the Arden-Rhineland region and the Barran-

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dian synform. By this time, the lower part of the Emsian stratotype has been characterized only by the poorly studied and almost endemic species of brachiopods and conodonts. Also, there was no clarity about the Pragian formation and, consequently, no consensus on the position of the Pragian stage upper boundary in Barrandian. In connection with such circumstances, the International Subcommission on Devonian Stratigraphy (SDS), based on the principles of periodicity in the development of the organic world, [22] decided to use as the global stratotype of the Emsian lower boundary a squence outside the stratotype locality, but with a clear major bioevent in the evolution of the conodont genus Polygnathus. It was taken into account that according to the rules for GSSP determination, only the priority name of the stratigraphic unit is retained, but not its original volume. The point for the stratigraphic unit of the Emsian lower boundary was the Zinsilban sequence in the west of the Zarafshan range, where the Pragian-Emsian boundary sediments contained a full standard zonal sequence of conodonts, tentaculites, goniatites, and brachiopods, with a clear boundary of the significant renewal of their generic and species composition [2, 6, 7, 21, 24, 31, 33]. This choice of GSSP outside the Western European stratotype locality was at that time an unprecedented decision of the International Subcommission on Devonian Stratigraphy (SDS), emphasizing the priority of the biota phased development in the determination of stages boundaries.

This boundary was chosen by the presence of the conodont species *Eocostapolygnathus kitabicus*, which indicates the evolution of the Polygnathus. It is located 58 cm above the base of the Zinsilban layers of the Khodzha-Kurgan suite in the base of the interlayer 9/5 in the Zinsilban sequence of the Kitab State Geological Reserve [1, 5, 31,]. In this region, at the same level, among the early Polygnathus conodonts, emerged three branches of *Eocostapolygnathus pireneae* (Boersma) species [11]: 1) *pireneae – kitabicus – excavatus – nothoperbonus – inversus – bultyncki*; 2) *pireneae – sokolovi – hindei – tamara*; 3) *pireneae – pannonicus.* Later the species *Eoc. excavatus* gave rise to two more branches: *– excavatus – mashkovae – totensis – serotinus – foliformis and excavatus – laticostatus*? *Eoc. sp. B – costatus.*

The zonal species of *Eocostapolygnathus kitabicus* has a global spread (Barrandian, Pyrenees, Tian Shan, Ural, Altai-Sayan region, Western Siberia, China, and Australia), but, unfortunately, is absent in the sections of the Rhineland, America and North Africa.

In addition, along with the *Eocostapolygnathus kitabicus*, there is a significant update of the dacrioconarids (tentaculites) generic and species composition, another widespread pelagic and hemipelagic faunal group. Zonal sequences well recognized in different regions of the world are determined for this group [9, 31]. The most prominent representative of dacrioconarids diversification is the *Nowakia* (*Dmitriella*) *praesulcata* species with a narrow shell and a smooth initial cone. The appearance of this species is an important stage in the dacrioconarids evolution. The remains of this species form mass accumulations in the Zinsilban and Norbonak horizons of the Khodzha-Kurgan suite at the level of the *kitabicus – excavatus – nothoperbonus* conodont zones [10, 31, 33]. At the same level, there is a change in the benthic macrofauna composition: corals, stromatoporoidea, brachiopods, trilobites, ostracods, crinoids.

However, with changes in the rocks lithological and genetic composition on the border of the Madmonian and Khodzha-Kurgan suites (Upper Pragian – Lower Emsian), it is difficult to accurately determine the biota taxonomic changes dependence on the evolutionary process of these groups [33].

The widely discussed issue of the Pragian and Emsian stages GSSP revision is caused by the new data obtained from additional studies of the Upper Pragian and Zlíchovian (Lower Emsian) intervals in the Barrandian sections, as well as the desire of Czech stratigraphers to compare the volume of the Pragian stage with the increased volume of the Pragian formation. Thanks to the work of the last decade, it was found [16] that the volume of the Pragian formation in the Czech Republic is larger than the volume of the Pragian stage stratotype in the Prague-Barrandov stratotype section, established by the International Subcommission on Devonian Stratigraphy [20, 28]. At the same time, in the Pyrenees sections, the boundary of the Eoc. kitabicus zone is close to the boundary of the d2c alpha / d2c beta layers of the Mariposas formation, which are traditionally related to Pragian stage [32].

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Magnetostratigraphic studies of borderline Pragian-Emsian deposits in the Kitab State Geological Reserve and in Barrandian provided conflicting data for comparisons [30]. Comparison of the rocks magnetic susceptibility within the Zinsilban section with the lithologically and stratigraphically closest Czech section Pozar-3 in Barrandian showed that the base of the modern standard of the Emsian lower boundary (the base of the *Eoc.kitabicus* zone) is 88.9 m in the Pozar-3 section. It is the level of the lower part of the Loděnice limestone, which Czech geologists refer to the Pragian formation. In addition, D. Hladil's team determined that the mid-level position for the Czech Middle Emsian anoxic Daleje Event of *gracilis* or *cancellata* (Pozar-3 sequence, 113.2 m) is located at 107 m of the Zinsilban layers, still within the Eoc. kitabicus zone. Moreover, it lays 3 m below the base of the Norbonakian layers in the typical Zinsilban section (however, the Daleje Event in this section is not recognized by most geologists). According to Cowie et. al [30], the volume of the *Eoc. kitabicus* zone (Zinsilban layers in the KSGR) corresponds in the Czech sections of the Zlíchovian and the lower part of the Daleje formation, which, according to the Czech tentaculite sequence, is included in the volume of the *Nowakia zlihovensis – N. cancellata* zones. This contradicts the zonal sequence in real sections of the Southern Tian Shan, where these tentaculite zones correspond to the interval of conodont *Excavatus-serotinus* zones.

According to Western European geologists, the low position of the upper boundary of the modern standard Pragian stage significantly complicated the interregional and intercontinental correlation of the Lower Devonian deposits. At the same time, a significant part of the enlarged Pragian formation, which is associated with the Pragian stage by Western European geologists, formally fell into the lower part of the Emsian stage. At the same time, the lower boundary of the modern Emsian stage (GSSP) could not be associated with the beginning the modern German Emsian stratotype (although we must remember, that the position of this border has been controversial for a long time). In this situation, the International Subcommission on Devonian Stratigraphy (SDS) was forced to change the stratigraphic concept (science policy) of boundaries determination and put the priority on preserving the volumes of the Barrandien and Rhenish Massif regional stratigraphic units [13]. At the SDS workshop it was it was agreed to retain the previous three Lower Devonian stages, but to admit the need for a change in the position of the Emsian lower boundary, moving it higher regarding the modern one and bringing it closer to the base of the Zlíchovian formation. It was also recognized that a new stratotype of the Emsian base should be determined in the same Zinsilban section in the Kitab State Geological Reserve (Uzbekistan), since conodont and tentaculite zonal sequences are most fully represented there. The majority of SDS members supported the transfer of the new Emsian base stratotype to the base of the *Eocostapolygnathus excavatus* conodonts zone, present in the same Zinsilban profile, 114 m along the section line (layer 42) above the currently established GSSP. Studies have shown that there are several subspecies and transitional forms within the *Eoc. excavatus* species, presented by *Eoc. excavatus excavatus, Eoc. excavatus gronbergi, Eoc. excavatus* 114. The new position of GSSP is proposed to be set in the base of the *Eoc. excavatus* 114 morphotype zone, which is consistent with generally accepted selection rules of marker species within a single phylogenetic sequence at the level where the presence of transitional forms allows us to establish its true first appearance.

However, improvement of the morphology phylogenesis of species originating from the *Eocostapolygnathus pireneae* phylogenetic line is hampered by the lack of data required for such a study. In addition, it was found that there are several conodont sequences in the Zinsilban gorge in the interval under study, which are associated with different facies of the Madmon reef mass and differ in species composition from the stratotype section. The obtained material is very important but requires further study.

In parallel, a lot of data about the using of other key fauna groups for regional correlations has appeared. Over the past decade, there are numerous publications detailing and refining the systematic composition of not only Polygnathidae conodonts complexes but also other conodonts families, as well as goniatites, tentaculites, and brachiopods. The stages of their change in the pelagic and shelf sequences of the Lower Devonian deposits in the South-West of Morocco, the Spanish Pyrenees, the Altai-Sayan region, Nevada, and China are revealed. Additional studies in the such Lower Devonian stratotype locali-

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ties as Barrandien and Rhineland allowed finding levels for regional and global correlation of the sequences in these areas [23]. The position of the *Eoc. kitabicus* zone base is correlated in the sequences of the West of the Zarafshan Range, the Urals, Salair, Nevada, the Spanish Pyrenees, Barrandien, and the Rhenish Massif. High correlation potential of the eognathid conodonts group, which sequences are determined in Nevada [25], and the *icriodontid* group from North Africa and Spain, is revealed. The refined zonal tentaculites scale (Table 2) has been developed on the basis of the Kim's et. al., Alberti and Chlupáč materials [31].

*Table 2*

**Comparison of conodont, tentaculite and goniatite zones of the Lower Devonian sections of the west of the Zarafshan Range and Barrandien [after A.I. Kim et al. 2012, oral report]**

| Series | Stage | Suite | Barrandien [I. Chlupac, 1998] | | | Stage | Suite | Beds | Zinsilban and Khodzha-Kurgan [Kim et al., 2012] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Conodont zones | Tentaculite zones | Graptolite and goniatites zones | | | | Conodont zones | Tentaculite zones | Graptolite and goniatites zones |
| Middle Devonian | Givetian | Serbian | ? | ? | *C. crispiforme* | Givetian | | | ? | *N. otomari* | |
| | | | | *N. otomari* | | | | | | | |
| | Eifelian | Choteč | *T. kock. kockel*<br>*T.kock.australis*<br>*Po. cost. costatus*<br>*Po. cost. partitus* | *N. chlupaciana*<br>*N. pumilio*<br>*N. sulcata* | *Pin. jungleri* | Eifelian | Khodzha-Kurgan | Novobak | *T. kock. kockel*<br>*T.kock.australis*<br>*Po. costatus costatus*<br>*Po. costatus partitus* | *N. sulcata* | |
| Lower Devonian | Dalejan | Dalejan - Trebova | *Po. costatus patulus* | *N. holynensis*<br>*N. richteri*<br>*N. cancellata* | *Anarcestes* | Emsian | | Obisaft | *Po. costatus patulus*<br>*Po. kimi*<br>*Po. serotinus* | *N. holynensis*<br>*N. richteri*<br>*N. cancellata* | *Wernerocerasc f. crispiforme* |
| | | | *Po. serotinus* | | | | | | | | |
| | | | *Po. laticostatus* | | | | | Dzhaus | | | |
| | Zlicovian | Zlicovian | | *N. elegans*<br>*N. barrandei*<br>*N. praecursor* | *Anetoceras* | | | Norbonak | *Po. invercus*<br>*Po. nothoperbonus*<br>*Po. excavatus excavatus* | *N. elegans*<br>*N. barrandei*<br>*N. praecursor*<br>*N. zlichovensis* | *Erbenoceras kimi*<br>*Gyroceratites laevis*<br>*M. yukonensis* |
| | | | *Po. grodbergi* | | | | | | | | |
| | | | *Po. dehiscens* | *N. zlichovensis* | | | | Zinzilban | *Po. kitabicus* | *N. (Dmitriella) praesulcata* | |
| | Pragian | Pragian | *I. curvicauda*<br>*E. sulcata* | *G. striangulata*<br>*N. acuaria* | *M. yukonensis*<br>*M. atopus* | Pragian | Madmon | Khukar | *Po. pireneae*<br>*E. kindlei*<br>*E. sulcatus* | *N. acuaria* | |
| | Lochkovian | Lochkovian | *Ped.pesavis*<br>*A. delta*<br>*A. omus*<br>*I. postwoshmidti*<br>*I. w. hesporis*<br>*I.w.woshmidti* | | *M. hercynicus*<br>*M. praehercy-nicus*<br>*M. uniformis* | Lochkovian | | Sangitovarian | *Anac. omus*<br>*Oz.pandora* | *P. intermedia*<br>*H. cf. bohemica* | |
| | | | | | | | | Bursykhirmanian | *Oz. rem. remsh.*<br>*Oz. rem. repetitor* | | |

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Further improvement of the Lower Devonian International Chronostratigraphic Chart is associated with the identification of event levels and biostratigraphic markers, providing more reliable stages correlation and their division into substages. The draft of such a chart is published in the last special issue of the Geological Society of London [14]. However, in order to recognize these boundaries, the International Subcommission on Devonian Stratigraphy (SDS) should adopt such criteria for the volumes of the Pragian and Emsian stages that would be convenient to use in all regions of the world. It is planned to divide Pragian and Emsian stages into two substages since in many regions two sedimentation cycles are determined in these intervals. The Lochkovian stage is going to be divided into three substages. The lower substage in the volume of its modern standard is considered for the Pragian stage. An assumed name of the upper substage is Zinsilban. Its borders are going to be determined by the interval of the *Eoc. kitabicus* zone. For the Emsian stage, the boundary of the lower and upper substages should approach the boundary between the Czech Zlíchovian and Daleje formation, characterized in Barrandien by the transgressive Daleje Event [12]. However, this complex event cannot be determined in all regions, since it was found out that the Daleje slates in the stratotype locality have a diachronic lower boundary and a significant endemity of conodonts.

The use of the Southern Tian Shan sequences, which are well-studied and contain rich fauna, formed in the central part of Prototetis, one of the largest Phanerozoic oceans, contributes to the expansion of intercontinental correlations of the Lower Devonian deposits and the possibility of identifying stable features of standard boundaries for their stage and substage division. The sequences of this region can solve the Lower Devonian stratigraphy problems and provide the possibilities of global use of stages, accepted on the basis of Western European stratotypes.

The stratified Lower Devonian deposits are the most widespread in the Southern Tian Shan. These deposits are studied in the Zarafshan-Gissar and Turkestan-Altay mountain regions and are represented by thick sequences of predominantly shelf carbonate and terrigenous-carbonate sediments. The sequences contain diverse groups of marine benthic and pelagic fauna, including zonal species of conodonts, tentaculites, graptolites and goniatites, which allow us to establish the intervals of the Lochkovian, Pragian, and Emsian stages. The sediments originate from a variety of shelf and, to a lesser extent, slope facies. The Devonian regional stratigraphic units used in the Southern Tian Shan are based on a biostratigraphic principle, i.e. on the presence of the global zonal sequences of conodonts, dacrioconarids, and graptolites in this region. This made it possible to identify regional stratigraphic units (superhorizons and horizons) comparable to the International Chronostratigraphic Chart (Table 3).

The most significant sequences of Zarafshan-Gissar mountain region are located in the western part of the Zaravshan range: Zinsilban and Khodzha-Kurgan (Kitab Reserve) and Shishkat (the northern slope of the Zaravshan Range, the right bank of the Kshtut River). These sections contain standard sequences of conodonts polygnathus (icriodus) and dacrioconarids (nowakia), described in various articles [1-3]. These groups formed the basis of the modern conodont scale for the Pragian and Emsian stages. In the Zinsilban section, as stated earlier, a stratotype for these stages boundaries was established. Moreover, a zonal tentaculites chart was created for this region [31]. This chart has been developed on the basis of sequences determined by Alberti et. al. [8, 10]. The abundant complexes of various benthic fauna are also given in numerous works [1, 2, 5, 7, 8, 27, 33].

In this territory, the Lower Devonian deposits are represented by the Bursykhirmanian, Sangitovarian and Khukarian horizons of the Madmon superhorizon and the Kitab horizon belonging to the Lower Devonian part of the Shirdagian superhorizon (table 3). The Bursykhirmanian horizon includes sediments in the volume of the regional *remscheidensis* conodont zone, which corresponds to the standard *woschmidti-postwoschmidti* conodont zone from the lower part of the Lochkovian stage. The Sangitovarian horizon includes sediments in the volume of regional *omus* and *pandora* conodont zones, corresponding to the standard *delta* and *pesavis* conodont zones of from the upper part of the Lochkovian stage. At a higher stratigraphic inter-

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val, the regional conodont zones correspond to the standard ones. The Khukar horizon includes sediments of the standard *sulcatus*, *kindlei,* and *pireneae* conodont zones, which corresponds to the modern standard volume of the Pragian stage. In the Lochkovian and Pragian interval of the Shishkat section, *Monograptus hercynicus, M. angustidens, M. falcarius, M. fanicus,* and *Dictyonema torschini* graptolites were found.

*Table 3*

**Regional stratigraphic scheme of the Southern Tian Shan Lower Devonian deposits**

| ICC | | Conodonts biozonal standard [Becker et al., 2012] | Subregional chronostratigraphic chart [Kim A., Erina M., Kim I., Ivanova O., 2007] | | | | | Turkestan-Altay mountain region | Zarafshan-Gissar mountain region |
|---|---|---|---|---|---|---|---|---|---|
| | | | Superhorizons | Biostratigraphic zones | | | | | |
| Series | Stage | | | Conodonts | Dacrioconarids | | Graptolites | Horizons | Horizons |
| Lower Devonian | Emsian | Polygnathus patulus | Shirdagian s | Patulus | Nowakia holynensis | | | Kitab | Kitab |
| | | Linguipolygnathus serotinus | | Serotinus | Nowakia richteri | | | | |
| | | | | | Nowakia cancellata | | | | |
| | | Polygnathus inversus | | Inversus | Nowakia elegans | | | | |
| | | Eo. nothoperbonus | | Nothoperbonus | Nowakia barrandei | | | | |
| | | Eo. gronbergi | | Excavatus | | | | | |
| | | Eo. excavatus | | | Nowakia praecursor – Nowakia chovensis | | | | |
| | | Eocostapolygnathus kitabicus | | Kitabicus | Nowakia praesulcata | | | | |
| | Pragian | Eocostapolygnathus pireneae | Madmon | Pireneae | N.(Turkestanella) acuaria | Guerichina strangulata | M.yukonensis | Khukarian | Khukarian |
| | | Gondwania kindlei | | Kindlei | | | M. thomasi | | |
| | | Gondwania irregularis | | Sulcatus | | G.bavarianus | M. fanicus | | |
| | Lochkovian | Pedavis gilberti | | Pesavis-pandora | | N.sororcula | M. falcarius | Kunjak | Sangitovarian |
| | | Masaraella pandora morph. beta | | | | | M. hercynicus | | |
| | | Ancyrodelloides trigonicus | | Delta – omus | | Paranowakia intermedia | | | |
| | | L. transitans | | Remscheidensis – postwoschmidti | | | M. prehercynicu | | Bursykhirmanian |
| | | L.eleanorae | | | | | | | |
| | | Lanea omoalpha | | | | | Monograptus niformis | | |
| | | C. postwoschmidti | | | | P. bohemica | | | |
| | | Candicriodus hesperius | | | | | | | |

The standard boundary of the Pragian and the Emsian stages determined by SDS is at the base of the Shirdagian superhorizon coinciding with the base of the Kitab horizon. Kitab horizon includes sediments corresponding to the volume of standard *kitabicus*, *excavatus*, *nothop-*

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*erbonus*, *inversus*, *serotinus*, and *patulus* conodont zones. In the Kitab sections within the KSGR territory, there are Early Devonian *Monograptus craigensis, M. aequabilis notoaequabilis,* and *M. thomasi* graptolites, and also the tentaculites of the regional zones from *Nowakia* (*Dmitriella*) *praesulcata* to *N. holynensis*.

For the Turkestan-Altai mountain region, the most complete sections of the Devonian deposits are located in southern Fergana on the right bank of the Isfara River near the village of Matchay, as well as in the Igarold valleys and the Kuralimtau Mountains [27]. Here the Madmon and Shirdagian superhorizons are used by analogy with the Zarafshan-Gissar mountain region. The Madmon superhorizon includes the Kunjak and Khukarian horizons, and the lower part of the Shirdagian superhorizon includes the Kitab horizon. The Kunjak horizon corresponds to the interval of the *remscheidensis-pandora* conodont zones. In its sediments, there is a sequence of *uniformis – falcarius* monograptus. The Khukarian horizon includes sediments corresponding to the volume of conodont zones from *sulcatus* to *pireneae* and the tentaculite zones of *baravianus* and *strangulata*, which corresponds to the upper part of the *acuaria* zone. The faunistic characteristic of the Kitab horizon corresponds to the given above for the Zarafshan-Gissar mountain region.

## Conclusions

1. The standard boundary between the Pragian and the Emsian stages is based on a significant event of bioevent recognized in many regions of the world.

2. The current discussion on the transfer of this boundary in the Kitab Reserve has arisen because the Barrandien, Arden-Rhineland, and Spanish sections have no clear correlation by archistratigraphic groups of fauna (goniatites, tentaculites, and conodonts). The proposal to transfer the boundary is based not on the determined evolutionary event, but on the principles of its usability for the correlation of the Western European sections.

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### REFERENCES

1. Izokh N.G., Elkin E.A. The conodonts biodiversity of in the Lower Devonian section of the Tian Shan (Zinsilban, Uzbekistan). *Materialy LVI sessii Paleontologicheskogo obshchestva*. 2010, p. 51-52 (in Russian).

2. Kim A.I. Tentakulity. Tentaculites. Biostratigraphy of Devonian Zarafshan-Gissar Mountain Region. FAN. Tashkent, 1984. p. 65-73 (in Russian).

3. Kim A.I. The Devonian Tentaculites of the Kitab State Geological Reserve (Zarafshan-Gissar Mountain Region, Uzbekistan). *Novosti paleontologii i stratigrafii*. 2011. Iss. 15, p. 65-81 (Prilozhenie k zhurnalu «Geologiya i geofizika». Vol. 52) (in Russian).

4. Kul'kov N.P. Lochkovian stage of the Lower Devonian (volume and correlation by brachiopods). *Regional'naya geologiya*. 2010. N 4, p. 48-51 (in Russian).

5. Elkin E.A., Bakharev N.K., Yazikov A.Yu., Izokh N.G., Sennikov N.V., Kim A.I., Erina M.V., Rakhmonov U.D. Lithostratigraphy of the stratotype section of the Emsian Stage lower boundary (GSSP), Lower Devonian (Zinsilban, Zarafshan-Gissar Mountain Region, Uzbekistan). *Novosti paleontologii i stratigrafii*. 2011. Iss. 15, p. 7-24. (Prilozhenie k zhurnalu «Geologiya i geofizika». Vol. 52) (in Russian).

6. Kim A.I., Elkin E.A., Erina M.V., Gratsianova R.T. Field session of the International Subcommission on Devonian Stratigraphy. Tipovye razrezy pogranichnykh sloev nizhnego i srednego devona Srednei Azii: Putevoditel' ekskursii. Tashkent: Izd-vo «Tashkent-geologiya», 1978, p.54 (in Russian).

7. Sapel'nikov V.P., Mizens L.I., Kim A.I. Brachiopods and stratigraphy of the Devonian deposits of the typical region of the Pragian-Emsian stages border (Zaravshan Range, Southern Tian Shan). UrO RAN. Ekaterinburg, 2004, p. 248 (in Russian).

8. Alberti G.K.B. Paläontologische Daten zum Grenzbereich Pragium/Zlichovium (Unter Devon) auf Grund der Tentaculites (Dacryoconarida). *Newsl. Stratigr*. 1982. Vol. 11. N 1, p. 22-31.

9. Alberti G.K.B. Dacryoconaride und Homoctenide Tentaculiten des Unter und Mittel-Devons. *Tail I. Cour. Forsch.-Inst. Senckenberg*. Frankfurt am Main, 1993. Vol. 158, p. 229.

10. Alberti G.K.B. Planktonische Tentakuliten des Devon. III. Dacryoconarida Fisher 1962 aus dem Unter-Devon und oberen Mitteldevon. *Palaeontogr*. 1998. Abt. A 250 (1/3), p. 1-46.

11. Bardashev I., Weddige K., Ziegler W. The phylomorphogenesis of some Early Devonian Platform Conodonts. *Senck. leth*. 2002. N 82(2), p. 375-451.

12. Becker R.T. Emsian substages and the Daleje Event – a consideration of conodont, dacryoconarid, ammonoid and sealevel data. *SDS Newsletter*. 2007. N 22, p. 29-32.

13. Becker R.T. International Commission on Stratigraphy – Subcommission on Devonian Stratigraphy Annual Report 2009. *SDS Newsletter*. 2010. N 25, p. 7-12.

14. Becker R.T., Königshov P., Brett C.E. Devonian climate, sea level and evolutionary events: an introduction Geological Society, London, Special Publications, 2016, p. 423.

15. Carls P., Valenzuela-Ríos J.I. Early Emsian Conodonts and associated shelly faunas of the Mariposas Fm (Iberian Chains, Aragón, Spain). *Cuad. Museo Geomin*. 2002. N 1, p. 315-333.

16. Carls P., Slavik L., Valenzuela-Ríos J.I. Comments on the GSSP for the basal Emsian stage boundary: the need for its redefinition. *Bull. Geosci*., 2008. N 83(4), p. 383-390.

17. Chlupáč I. Cyclicity and duration of Lower Devonian stages: Observations from the Barrandian area, Czech Republic. *Neu. Jb. Geol. Paläont*. 2000. Abh. 215 (1), p. 97-124.

18. Chlupáč I., Hladil J. The global stratotype section and point of the Silurian-Devonian boundary. Cour. *Forsch.-Inst. Senckenberg*. 2000. N 225, p. 1-7.

19. Chlupáč I., Oliver W.A. Decision on the Lochkovian – Pragian boundary stratotype (Lower Devonian). Episodes. 1989. N 12 (2), p.109-113.

20. Chlupáč I., Lukes P. Pragian. Zlicovian and Zlicovian/Dalejan boundary sections in the Lover Devonian of the Barrandian area, Czech Republic. *Newsl. Strat*. 1999. N 37 (1/2), p. 75-100.

21. Yolkin E.A., Izokh N.G., Weddige K., Erina V., Valenzuela-Rios J.I., Apekina L.S. Eognathodid and polygnathid lineages from the Kitab State Geological Reserve sections (Zeravshan-Gissar mountainous area, Uzbekistan) as the bases for improvements of the Pragian-Emsian standard conodont zonation. News on Paleontology and Stratigraphy, Supplement to Geologiya and Geofizika. 2011. Vol. 52. N 15, p. 37-47.

22. Cowie J.W., Zigler W.H., Boucot A., Bassett M.G., Remane J. Guidelines and statutes of the International Commissionon Stratigraphy (ICS). *CourierI otschl-in&sinst. Senckenberg*. 1986. Vol. 83, p. 1-14.

23. Jansen U. Siegenien-Emsian brachiopod stratigraphy, Germany. *SDS Newsletter*. 2012. N 27, p. 21-27

24. Kim A.I. Dacryoconaride biostratigrahpy of the Devonian Deposits of South Tien Shan. International conference «Global Alignments of Lower Devonian carbonate and clastic sequences» Contributions. Kitab State Geological Reserve, Uzbekistan, 25 August – 3 September. 2008. Tashkent, p. 51-55.

25. Murphy M.A. Conodonts first occurrences in Nevada. Devonian Correlation Table. *Senckenbergiana Lethaea*. 2000. Vol. 80, p.695

26. Chlupáč I., Havlíček V., Kříž J., Kukal Z., Štorch P. Palaeozoic of the Barrandian (Cambrian to Devonian). Prague: CGS, 1998, p. 101-133.

27. Kim A.I., Erina M.V., Yolkin E.A., Sennikov N.V. Subdivision and correlation of the Devonian of South Fergana (Turkestan-Alai- Mountain Area, USSR). *Can. Soc. Petrol. Geol., Mem*. 1988. N 14 (3), p. 703-714.

28. Slavick L. The Pragian-Emsian conodont successions of the Barrandian area: search of an alternative to the GSSP polygnathid-based correlation concept. *Geobios*. 2004. N 37, p. 454-470.

29. Becker R.T., Gradstein F.M., Ogg J.G., Schmitz M.D., Ogg G.M. The Devonian Period. *The Geologic Time Scale*. 2012, p. 559-601.

30. Hladil J., Vondta M., Slavik L., Koptikova L., Cejehan P., Vich R. The Pragian-Emsian strata of Kitab Reserve and Barrandian area: The 2008 SDS research task on magnetic susceptibility logs and their stratigraphic correlation by means of the dynamic time warping technoques. *SDS Newsletter*. 2011. N 26, p. 54-56.

31. Kim A.I., Erina M.V., Kim I.A., Salimova F.A., Meshchankina N.A., Rakhmonov U.D. The Pragian-Emsian event and subdivision of the emsian in the Zinzilban and Khodzha-Kurgan sections. *SDS Newsletter*. 2012. N 27, p. 38-41.

32. Valenzuela-Rios J.I., Carls P. Brief comments on the Future Pragian Subdivision and Revision of the Emsian base. *SDS Newsletter*. 2010. N 26, p. 19.

33. Volkin E.A., Kim A.I., Talent J.A. Devonian Sequences of the Kitab Reserve area. Field Excursion Guidebook. International Conference «Global Alingments of Lower Devonian Carbonate and clastic sequences». Novosibirsk, Publishing House SB RAS. 2008, p. 245.

34. Ziegler W., Klapper G. Stages of the Devonian System. *Episodes*. 1985. Vol. 8. N 2, p.104-109.

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