A proposed crinoid zonation of the Devonian deposits of eastern Transbaikal

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Devonian deposits of eastern Transbaikal, Russia, are widely distributed in the Onon, Argun and Upper Amur terranes, each with a different geological development history. Two lithofacies are represented in the geological section: carbonate-volcanogenic-terrigenous (Onon terrane) and terrigenous-carbonate (Argun and Upper Amur terranes), with strata in the latter characterized by abundant fossil remains, especially numerous crinoids and brachiopods. Brachiopod assemblages are stated for each strata of the Transbaikal Devonian. A crinoid biostratigraphic zonation is proposed within the Mongol-Okhotsk fold belt as follows: *Scyphocrinites mariannae*, *Costatocrinus bicostatus* and *Tastjicrinus paucicostatus* (Lower Lochkovian); *Amazaricrinus ildicanensis* (Pragian); *Paradecacrinus orientalis* (Emsian); *Raricrinus minimus* and *Vasticrinus vastus* (Eifelian); *Ononicrinus gracilis* (Givetian); *Hexacrinites*? *stukalinae* sp. nov. (Frasnian) and *Platycrinites*? *subtuberosus* (Upper Famennian). Local and regional crinoid ages accord well with those of brachiopods. Lateral distribution of faunal assemblages allows regional correlation. • Keywords: Devonian, crinoid biozonation, brachiopods, assemblages, biostratigraphy, Transbaikal.

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Southeastern Transbaikal in far eastern Russia extends from west to east from the middle reaches of the Onon River to the upper reaches of the Amur River. Devonian deposits are widely distributed in the Onon, Argun and Upper Amur terranes, each having a different geological development history (Figs 1, 2).

The Onon terrane formations are dominated by carbonate-volcanogenic-terrigenous deposits of a deep-water backarc basin. The Argun and Upper Amur terranes are composed of limestone, sandstone and aleurolite and were deposited in the shelf zone of a paleobasin. Faunal remains are not numerous in the Onon terrane. In the Argun and Upper Amur terranes all strata are characterized by abundant fossil remains. Crinoids and brachiopods are very numerous.

R.S. Yeltysheva was studying small collections of crinoids from Transbaikal in the 50–60 years of the 20th century (*e.g.*, 1956, 1969). The first taxa were determined from the lower part of Ildikan Suite in the basin of the Gazimur River. Those from the Early Devonian comprise: *Pentagonocyclicus delenificus* Yeltysheva, *Decacrinus orientalis* (Yeltysheva), *Kuzbassocrinus decemlobatus* Yeltysheva, *Cyclocyclicus bohemicus* Yeltysheva and *Cycloellipticus corneus* Yeltysheva. The Middle Devonian assemblage from the upper Ildikan Suite includes: *Pentagonocyclicus vastus* Yeltysheva & J. Dubatolova, *P. arboriformis* Yeltysheva, *P. orientalis* Yeltysheva and *Cyclocyclicus subcrenatus* Yeltysheva (Tichomirov 1960). In addition, Middle Devonian crinoids *Hexacrinites*? ex. gr. *mamillatus* Yeltysheva & J. Dubatolova, *H.*? *biconcavus* Yeltysheva & J. Dubatolova, *Pentagonopentagonalis* ex gr. *floreus* Yeltysheva and *Pentagonocyclicus* cf. *radialis* Yeltysheva were identified by Yeltysheva from the Yakovlev Suite on the left bank of the Onon River and *Pentagonocyclicus* ex gr. *circumvallatus* Yeltysheva and *Platycrinites*? sp. from the Yakovlev Suite on the left bank of the Argun River (in Nalivkin *et al.* 1973). Yeltysheva also studied crinoids from the Bolshoi Never Suite of the Upper Priamur district: *Decacrinus orientalis* (Yeltysheva), *Hexacrinites* cf. *biconcavus* Yeltysheva & J. Dubatolova and *Pentagonopentagonalis radialis* Yeltysheva; from the Oldoy Suite: *Cyatocrinus mamillatus* Yeltysheva and *Entrochus dentatus* Quenstedt, and from the Teplovskii Suite: *Hexacrinites*? sp. and *Pentagonocyclicus* aff. *imatschensis* Yeltysheva & J. Dubatolova, matched by Modzalevskaya.

The first monographic treatments of Devonian crinoids from the Transbaikal was made by Dubatolova and Yeltysheva (Dubatolova *et al.* 1967, Yeltysheva 1969), in

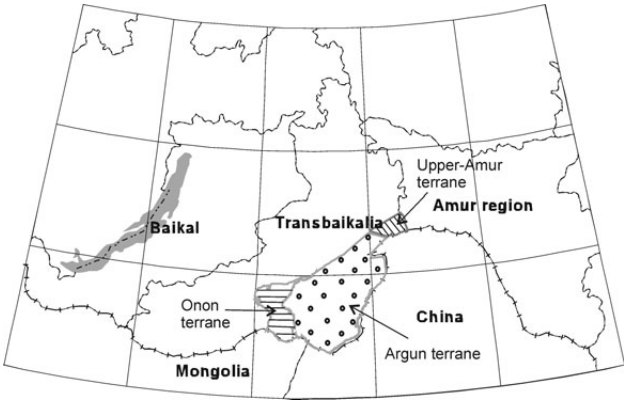


Figure 1. Scheme of terranes in the Transbaikal region.

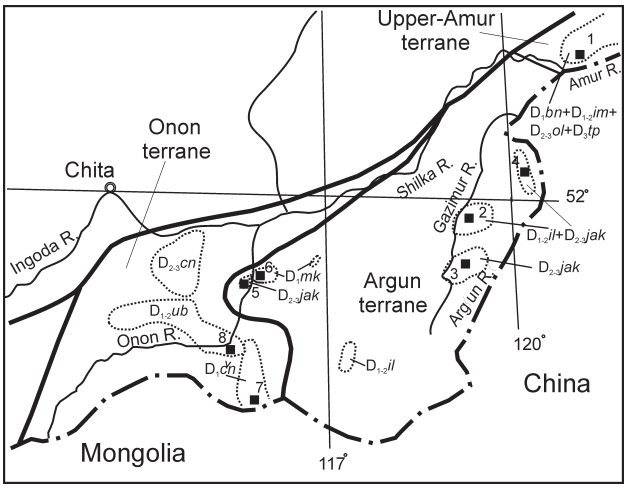


Figure 2. Scheme of Devonian strata in the Transbaikal region. A – position of fauna: 1 – Upper Priamur; 2 – Gazimur River; 3 – Klichka Mountain; 4 –Argun River; 5 – Onon River, the left bank; 6 – Onon River, the right bank; 7 – the railway station Durbachi; 8 – Ust-Borzya village, B – the Devonian section of the Onon terrane: D_1čn – Chindant Suite; D_{2-3}ub – Ustborzya Suite; D_3cn – Tsagan-Nor Suite; the Devonian section of the Argun terrane: D_1mk – Makarov Unit; D_{1-2}il – Ildikan Suite; D_{2-3}jak – Yakovlev Suite; the Devonian section of the Upper-Amur terrane: D_1bn – Bolchoi Never Suite; D_{1-2}im – Imachi Suite; D_{2-3}ol – Oldoy Suite; D_3tp – Teplovskii Suite.

which the following species were described: *Hexacrinites*? *dentatus echinatus* Yeltysheva & J. Dubatolova, *H.*? *biconcavus* Yeltysheva, *H.*? *mamillatus* Yeltysheva & J. Dubatolova, *Entrochus dentatus* Quenstedt, *Decacrinus orientalis* (Yeltysheva), *D.* aff. *pennatus* Yeltysheva, *Kuzbassocrinus decemlobatus* Yeltysheva, *Anthinocrinus floreus* Yeltysheva, *A. raricostatus* Yeltysheva & J. Dubatolova and *Pentagonocyclicus vastus* Yeltysheva & J. Dubatolova.

During the last 25 years the senior author has been studying crinoid stem remains, using the systematic method of Stukalina (1964) and Moore *et al.* (1968) revising all material of the abundant stem fragments from the Devonian strata of eastern Transbaikal. The nomenclature and systematic position of 64 species, including those originally identified by Yeltysheva and Dubatolova are here proposed in modern nomenclature. Identification of the assemblages has allowed more refined definition of the age of numerous strata.

Here we present new information from continuing investigations of Devonian stratigraphy and paleontology in the Transbaikal and summarize previous stratigraphic and paleontological data (Luchickiy 1954, Modzalevskaya 1958, Tichomirov 1960, Amantov 1963, Anashkina *et al.* 1997, Popeko 2000).

Results of investigations

Devonian of Onon terrane

Middle Paleozoic deposits of the Onon terrane (Figs 1, 2) are comparatively homogeneous in lithological composition. They are characterized by infrequent fossil-bearing horizons and are divided into blocks with multiple-folded structures. The Devonian Chindant, Ustborzya and Tsagan-Nor suites were recognized (Turbin 1994) in an up-to-date stratigraphic scheme (Table 1) based on the rhythmostratigraphic principle.

These suites make up a continuous series between the underlying Kulinda (O-S?) and Onon (S?) suites and the overlapping Zhun-Shevija (D_3-C_1) Suite. The age of the Chindant Suite is based on rare occurrences of the rugose coral *Embolophyllum mansfieldense* (Duncan), which ranges from the Lochkovian to the beginning of the Pragian in one small tectonic block in the southeastern part of the terrane (Anashkina *et al.* 1997). We date the Ustborzya Suite as Middle to Late Devonian (Early Frasnian) based on the discovery (L. Nebericutina identification) in the upper part of the section of spores of the Late Givetian–Early Frasnian: *Archaeozonotriletes mutatus* Naumova, *A. timanicus* Naumova, *Leiotriletes parvus* Naumova, *Trachytriletes pussilus* Naumova, *Hymenozonotriletes primitivus* Raskazova, *Lophozonotriletes forosus* Raskazova, *Lophotriletes grumosus* Naumova, *L. perpusillus* Naumova, among others; Late Silurian-Devonian coral ?*Alveolites* sp. (B. Sokolov identification); and Middle Devonian-Early Frasnian crinoid ?*Vasticrinus* sp. (R. Yeltysheva identification). The stratigraphic location of the Tsagan-Nor Suite between the Ustborzya and Zhun-Shevija suites defines its age conventionally as Middle Frasnian-Middle Famennian. The lower part of the Zhun-Shevija Suite is characterized by the brachiopod *Cyrtospirifer* ex gr. *verneuili* Murchison, dating from Late Frasnian to Famennian and crinoids *Bicostulatocrinus circumvallatus* (Yeltysheva) and *Pentaridica pulcher* (Yeltysheva), which appear in the Late Famennian (Popeko 2000).

Devonian of Argun and Upper Amur terranes

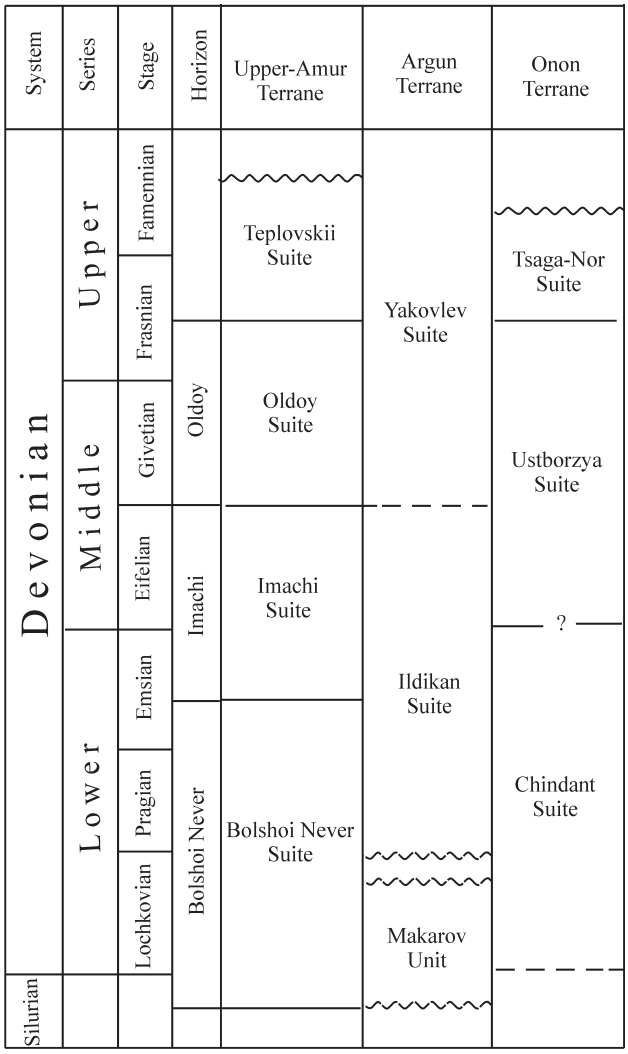
In the Devonian of the Argun terrane, the Lochkovian Makarov Unit, Pragian and Eifelian Ildikan Suite and Givetian-Famennian Yakovlev Suite are present in small grabens that occur from the Onon estuary in the west to the basin of the middle Argun stream in the east (Fig. 2) (Tichomirov 1960, Kurilenko *et al*. 2001, Kurilenko *et al.* 2002). In the Upper Priamur, a complete Devonian section is represented by the Bolshoi Never, Imachi, Oldoy and Teplovskii suites between the subjacent Silurian Omutnaya Suite and superjacent Tournaisian-Lower Visean Tipara Suite (Modzalevskaya 1958, Anashkina *et al*. 1997) (Table 1). All strata contain abundant characteristic paleontological remains. Brachiopods (studied by N.K.) and crinoids (A.K. worked out biostratigraphic ranges), provide age determination of strata within the Argun and Upper Amur terranes (Kurilenko *et al.* 2002) (see Table 2). The lateral distribution of the faunal complexes allows correlation with other regions.

Fauna of Devonian deposits of Argun and Upper Amur terranes

In the Makarov Unit of the Argun terrane and the lower part of the Bolshoy Never Suite of the Upper Priamur, the *Scyphocrinites mariannae* Biozone is recognized and overlain by what Biozone with *Costatocrinus bicostatus-Tastjicrinus paucicostatus* (Table 2, Fig. 3). They are components of the lower part of the Bolshoi Never Horizon. The *S. mariannae* Beds correlate with the boundary layers of the Skal and Borschov horizons in the southwestern part of the East-European platform, which are dated by the occurrence of the graptolite *Monograptus uniformis angustidens* Přibyl, known from the Silurian to Devonian boundary layers of northern France, Germany, Poland, Bulgaria, Czech Republic, China and Morocco and the lower part of the *Pennatocrinus subpennatus-Scyphocrinites* zone in the Ainasui Horizon of Kazakhstan. The discovery of *Scyphocrinites* provides the first evidence to determine the Silurian-Devonian boundary interval in Transbaikal (Kurilenko *et al.* 2001).

Beds with *Costatocrinus bicostatus-Tastjicrinus paucicostatus* are coeval with the upper part of the *Pennatocrinus subpennatus-Scyphocrinites* zone and *Decacrinus ovalis-Podoliocrinus nikiforovae* zone (Kokbaital Horizon) of Kazakhstan. The occurrence of *C. bicostatus* (Stukalina) correlates with the Kunzhak and Shishkat horizons of the Zeravshano-Gissarskaya mountainous region of southern Tian-Shan, the *Anthinocrinus radialis* (Stukalina)-bearing Mitkov Beds of the Borschov Horizon of the East-European platform and *Mediocrinus medius* (Yeltysheva), *Gurjevskocrinus impalpabilis* J. Dubatolova and *Costatocrinus bicostatus* (Stukalina)-bearing Tom'chumysh Horizon of the Salair. The beds distinguished in the Transbaikal and Sarajnaya and Sauma horizons in the Urals are also considered coeval because of the occurrence of the genera *Costatocrinus* and *Mediocrinus* (Stukalina 1986, 1991).

Table 1. Correlation of Devonian deposits of the Onon, Argun and Upper Amur terranes



The brachiopods *Dalejina austera* Havlíček, *Plectodonta mimica* (Barrande) and *Lissatrypa* sp. co-occur with crinoids in the lower parts of the Bolshoi Never Suite. *Dalejina austera* and *Plectodonta mimica* are found in the Lochkovian stage of the Barrandian. The latter is characteristic of the coeval level of Podolia and China but in Germany it is also considered to be in the Pragian stage. *Lissatrypa* sp. is close to a species from the Lochkovian of Podolia and Australia. Thus these brachiopods most likely characterize the Lochkovian of the surrounding rocks (Barrande 1879, Boucot *et al.* 1965, Havlíček 1977, Jahnke & Shi Yan 1989).

The lower part of the Ildican Suite of the Argun terrane and the middle part of the Bolshoi Never Suite of the Upper Priamur contain horizons with *Amazaricrinus ildicanensis* (Table 2, Fig. 3). *Amazaricrinus minimus* (Stukalina), *Kuzbassocrinus decemlobatus* Yeltysheva, *Pandocrinus grandis* Kurilenko, *Anthinocrinus primaevus* Sisova, *Urushicrinus ržonsnickae* Kurilenko, rare *Kuzbassocrinus binidigitatus* Yeltysheva, *Tastjicrinus* cf. *tastjiensis* Stukalina, *Paradecacrinus* cf. *decemcrassus* (J. Dubatolova), *Shishkinaecrinus partitus* Kurilenko, *Facetocrinus minusculus* Kurilenko, *Imatschicrinus ivanovi* (Yeltysheva & J. Dubatolova), *Hexacrinites*? *biconcavus* Yeltysheva & J. Dubatolova, *H.*? *mamillatus* Yeltysheva & J. Dubatolova, *Asperocrinus dentatus* (Quenstedt), *Amurocrinus* cf. *imatschensis* (Yeltysheva & J. Dubatolova), and *Graptocrinus incelebratus* (Yeltysheva & J. Dubatolova) are also found in association with the most abundant index-species. *Kuzbassocrinus decemlobatus* and *Amazaricrinus* are extremely characteristic for the Pragian sections of numerous Russian regions. They allow correlation of the strata with the Maly Bachat Horizon of the northeastern Salair, the Yakushinsk Horizon of the Gorny Altai, and the Pandzhrut Horizon of the southern Tian-Shan, Vizhai and Toshemka horizons of the eastern Ural slope (Schewtshenko 1966, Dubatolova *et al.* 1967, Dubatolova 1971, Stukalina 1986).

These same strata contain a rich complex of brachiopods. Typical species of Pragian age in these deposits are: *Prokopia* sp., *Isorthis* cf. *quadrata* Alekseeva, *I. inostranzewi* (Peetz), *Rhytistropia beckii* (Hall), *Areostrophia distorta* (Barrande), *Caplinoplia embyo* (Barrande), *Notanoplia* sp., and *Eucharitina subspeciosa* (Modzalevskaya). *Isorthis inostranzewi* is widely known in the Lochkovian and Pragian deposits of Gorny Altai, Salair and West Siberian plate (Gracianova 1967, Kulkov & Peregoedov 1990); *Rhytistropia beckii* is characteristic of the Pragian stage of North America, Mongolia and Kazakhstan (Johnson 1970, Kaplun 1961, Chernysheva 1937); *Areostrophia distorta* is widespread in the Pragian and lower parts of Emsian stage of the Barrandian, Gorny Altai, and Salair (Havlíček 1967, Gracianova 1967); *Caplinoplia embyo* is distributed in the Pragian stage of the Barrandian, Gorny Altai, West-Siberia plate, and possibly in Germany (Gracianova 1967, Kulkov & Peregoedov 1990); *Notanoplia* occurs in the Pragian stage of Gorny Altai (Gracianova 1967); *Eucharitina subspeciosa* (Modzalevskaya) is known from the Pragian of the Mongolia and Transbaikal (Alekseeva *et al.* 1981, Kulkov *in* Kurilenko *et al.* 2002). Also found in the layers with crinoids and brachiopods are corals *Riphaeolites ramosus* Yanet, *R. virgosus* Yanet, *Favosites porfirievi* Chernyshev var. *oldoica* J. Dubatolova, *Lyrielasma denticulata* Zheltonogova, and the trilobite *Paciphacops* sp. (Kurilenko *et al.* 2002).

Paradecacrinus orientalis, characteristic of the Emsian, has not been found in the Argun terrane but is present in the Upper Amur terrane where it is found in the upper part of the Bolshoy Never and lower part of the Imachi suites (upper Bolshoy Never and lower Imachi horizons) (Figs 2, 3, Table 2). Crinoids are also present in these horizons, as follows: *Paradecacrinus orientalis* (Yeltysheva), *Kuzbassocrinus binidigitatus* Yeltysheva (epibole), *Urushicrinus eugeniae* (Yeltysheva & J. Dubatolova), *U. raricostatus* (Yeltysheva & J. Dubatolova), *Anthinocrinus primaevus* Sisova, *Asperocrinus dentatus* (Quenstedt), *Imatschicrinus ivanovi* (Yeltysheva & J. Dubatolova), *Graptocrinus incelebratus* (Yeltysheva & J. Dubatolova), *Hexacrinites*? *biconcavus* Yeltysheva & J. Dubatolova, *H.*? *torulosus* J. Dubatolova, rare *H.*? *mamillatus* Yeltysheva & J. Dubatolova, *Amurocrinus imatschensis* (Yeltysheva & J. Dubatolova). The occurrence of the same or similar species allows us to correlate these horizons with Emsian deposits of the Gorny Altai: *Paradecacrinus orientalis, Kuzbassocrinus binidigitatus, Urushicrinus raricostatus, Anthinocrinus primaevus, Hexacrinites*? *torulosus*. There are also species in common with the Salairka Horizon of northeastern Salair (*Kuzbassocrinus binidigitatus*, *Anthinocrinus primaevus*) and the Sardzhal and Kazakh horizons of Kazakhstan (*Urushicrinus eugeniae*, *Anthinocrinus primaevus*) (Dubatolova *et al.* 1967; Dubatolova 1971; Stukalina 1986, 1991).

Brachiopods occurring with crinoids in the lower part of the Imachi Suite mentioned above are identified as: *Reeftonia borealis* (Hamada), *Schizophoria* cf. *kobajashii* (Hamada), *Leptaenopyxis* cf. *bouei* (Barrande), *Leptostrophia* cf. *kharkraica* N. Chernysheva, *Xystostrophia* sp., *Douvillina* cf. *nalivkini* (Khalfin), *Chonetes* sp., *Wilsoniella* cf. *prima* (Khalfin), *Acrospirifer* cf. *korovini* (Khalfin), *Leptodontella zmeigorskiana* (Peetz), *Rotundostrophia* cf. *rotundata* (Khalfin), *Maoristrophia kailensis* Schischkina, *Leptogonia zlichovensis* (Havlíček) and *Paraspirifer urcanensis* Modzalevskaya. The largest number of species are in common between this horizon and the Emsian of Gorny Altai (*Leptaenopyxis bouei, Xystostrophia* sp., *Douvillina* cf. *nalivkini, Wilsoniella* cf. *prima, Acrospirifer* cf. *korovini, Rotundostrophia* cf. *rotundata, Leptogonia zlichovensis* among others) and Salair (*Leptaenopyxis bouei, Leptodontella zmeigorskiana, Leptogonia zlichovensis*). Also, there are species in common with the Emsian strata of the West-Siberia plate (*Xystostrophia* sp.), Kazakhstan (*Leptaenopyxis bouei*); Rudny Altai (*Leptodontella zmeigorskiana*); and the Far East (*Leptodontella zmeigorskiana, Rotundostrophia* cf. *rotundata*). In addition, *Reeftonia borealis* and *Schizophoria kobajashii* are identified from the Khulanmen Formation of Maly Khingan; *Leptogonia zlichovensis* was reported by Havlíček (1977) from the base of the lower Emsian Zlikhov limestones of the Barrandian; and *Leptostrophia kharkraica* and *Wilsoniella prima* are

Table 2. The distribution of crinoids and brachiopods associations in Devonian deposits of Transbaikal. Abbreviations: AT – Argun terrane, UAT – Upper Amur terrane, *C.-T. – Costatocrinus bicostatus-Tastjicrinus paucicostatus*

Stage	Horizon	Suite, unit		Biozone	Association of crinoids	Association of brachiopods
		AT	UAT			
Famennian	Kotikha	Yakovlev	Teplovskii	*P.? subtuberosus*	*Platycrinites*? *donicus*, *Pl.*? *gazimuricus*, *Bicostulatocrinus circumvallatus*, *Pentaridica pulcher*, *Florycyclus* sp., *Ungulicrinus* sp., *Anthinocrinus* sp. (s. l.), *Asperocrinus* sp., *Amurocrinus* sp.	*Cyrtospirifer ivanovae*, *Tenticospirifer dobroljubovae*, *Sphenospira julii*
					Amurocrinus ex gr. *imatschensis, Bicostulatocrinus* ex gr. *circumvallatus*	*Streptorhynchus* sp., *Athyris bajeti*, *Syringothyris* sp., *Cyrtospirifer verneuili*
Frasnian	Oldoy		Oldoy	*Hexacrinites? stukalinae*	*Amurocrinus imatschensis*, *A. conserratus*, *Urushicrinus parvulus*, *U. digitatus*, *Schyschcatocrinus tatyanae*, *Ononicrinus delicatus*, *Asperocrinus paucus*, *Anthinocrinus* sp., *Platystela* sp., *Facetocrinus* sp.	*Schizopheria striatula*, *Carihiferella carinata*, *Productella subaculeata*, *Mucrospirifer mucronatus*, *Cyrtospiriter achmet*, *Quadrithyrina petita*, *Elytha* sp.
Givetian				*Ononicrinus gracilis*	*Pentapterocrinites brevijugatus*, *Amurocrinus imatschensis, A. conserratus*, *Hexacrinites? biconcavus*, *H.*? *mamillatus*, *Oldojicrinus oldoicus*, *Schyschcatocrinus tatyanae*, *Vasticrinus vastus*, *Peribolocrinus aequiplicatus, Platystela*? sp., *Anthinocrinus* sp.	*Aulacella eifeliensis*, *Eoschuchertella arctostriata*, *Devonochonetes coronata*, *Devonoproductus*? *halli*, *Uncinulis*? *concentricus*, *Hadrorhynchia* sp., *Spinatrypa spinosa*, *Rhynchospirina ussiensis*, *Rh. lopatini*, *Meristina* sp., *Athyris concentrica*, *Nucleospira* sp., *Ambocoelia umbonata*, *Emanuella subumbona*, *Euryspirifer pseudocheehiel*, *Mucrospirifer mucronatus*, *Spinocyrtia martianovi*, *Cranaena* sp.
Eifelian	Imachi	Ildikan	Imachi	*Raricrinus minimus-Vasticrinus vastus*	*Hexacrinites*? *biconcavus*, *H.*? *mamillatus*, *H.*? *carinatus*, *Asperocrinus giganteus*, *A. dentatus*, *Amurocrinus conserratus*, *A. imatschensis*, *Shishkinaecrinus petalatus*, *Imatschicrinus ivanovi*, *Graptocrinus incelebratus*, *Schyschcatocrinus consuetus*, *Pandocrinus grandis*	*Cyrtinopsis nalivkini*
Emsian				*Paradecacrinus orientalis*	*Kuzbassocrinus binidigitatus*, *Urushicrinus eugeniae*, *U. raricostatus, Anthinocrinus primaevus*, *Asperocrinus dentatus*, *Imatschicrinus ivanovi*, *Graptocrinus incelebratus*, *Hexacrinites*? *biconcavus*, *H.*? *torulosus*, *H.*? *mamillatus*, *Amurocrinus imatschensis*	*Reeftonia borealis*, *Discomyorthis kinsuiensis*, *Schizophoria* cf. *kobajashii*, *Leptoenopyxis* cf. *bouei*, *Leptoshophia* cf. *kharkraica*, *Gladiostrophia kondoi*, *Xystostrophia* sp., *Douvillina* cf. *nalivkini*, *Chonetes* sp., *Chonostrophia*? aff. *comlanata*, *Notoconchidium*? sp., *Protochonetes*? sp., *Uncinulus* sp., *Wilsoniella* cf. *prima*, *Spinatrypa* sp., *Plectospira* sp., *Acrospirifer* cf. *korovini*, *Leptodontella zmeigorskiana*, *Rotundostrophia* cf. *rotundata*, *Maoristrophia kailensis*, *Leptogonia zlichovensis*, *Paraspirifer urcanensis*, *Deltospirifer*? *amurensis*
Pragian	Bolshoi Never		Bolshoi Never	*Amazaricrinus ildicanensis*	*Amazaricrinus minimus*, *Kuzbassocrinus decemlobatus*, *K. binidigitatus*, *Kuzbassocrinus* sp., *Pandocrinus grandis*, *Anthinocrinus primaevus*, *Urushicrinus* ržonsnickae, *Tastjicrinus* cf. *tastjiensis*, *Paradecacrinus* cf. *decemcrassus*, *Shishkinaecrinus partitus*, *Facetocrinus minusculus*, *Imatschicrinus ivanovi, Hexacrinites*? *biconcavus, H.*? *mamillatus*, *Asperocrinus dentatus*, *Amurocrinus* cf. *imatschensis*	*Dalejina austera, Discomyorthis kinsuiensis*, *Prokopia* sp., *Isorthis inostranzewi*, *I.* cf. *quadrata*, *Molongella* cf. *lineata*, *Plectodonta mimica*, *Leptostrophia* sp., *Gladiostrophia kondoi*, *Rhytistrophia beckii*, *Douvillina cf. orientalis*, *Areostrophia distorta*, *Caplinoplia embryo*, *Notanoplia* sp., *Chonostrophia*? aff. *complanata*, *Ch. sinuata*, *Eodevonaria* sp., *Trigonirhynchia* sp., *Uncinulis* sp., *Eucharitina subspeciosa*, *Coelospira burabaensis*, *Lepticoelia* sp., *Deltospirifer*? *amurensis*
Lochkovian						
		Makarov		*C.-T.*	*Mediocrinus medius*, *Tolenicrinus lenticularis*, *Tolenicrinus* sp., *Anthinocrinus radialis*, *Asperocrinus echinatus*, *Gurjevskocrinus impalpabilis, Gregariocrinus forus*, *Facetocrinus stellatus*, *Scyphocrinites mariannae*, Tetraptocrinidae	*Dalejina austera*, *Plectodonta mimica*, *Lissatrypa* sp.
Silurian				*Scyphocrinites mariannae*	*Mediocrinus* aff. *medius*	

known from the Lower Devonian of Mongolia (Khalfin 1939, 1948; Chernysheva 1937; Gracianova 1975; Kulkov & Pergoedov 1990; Kurilenko *et al.* 2002). The age of deposits with *Paradecacrinus orientalis,* according to brachiopods is undoubtedly Emsian.

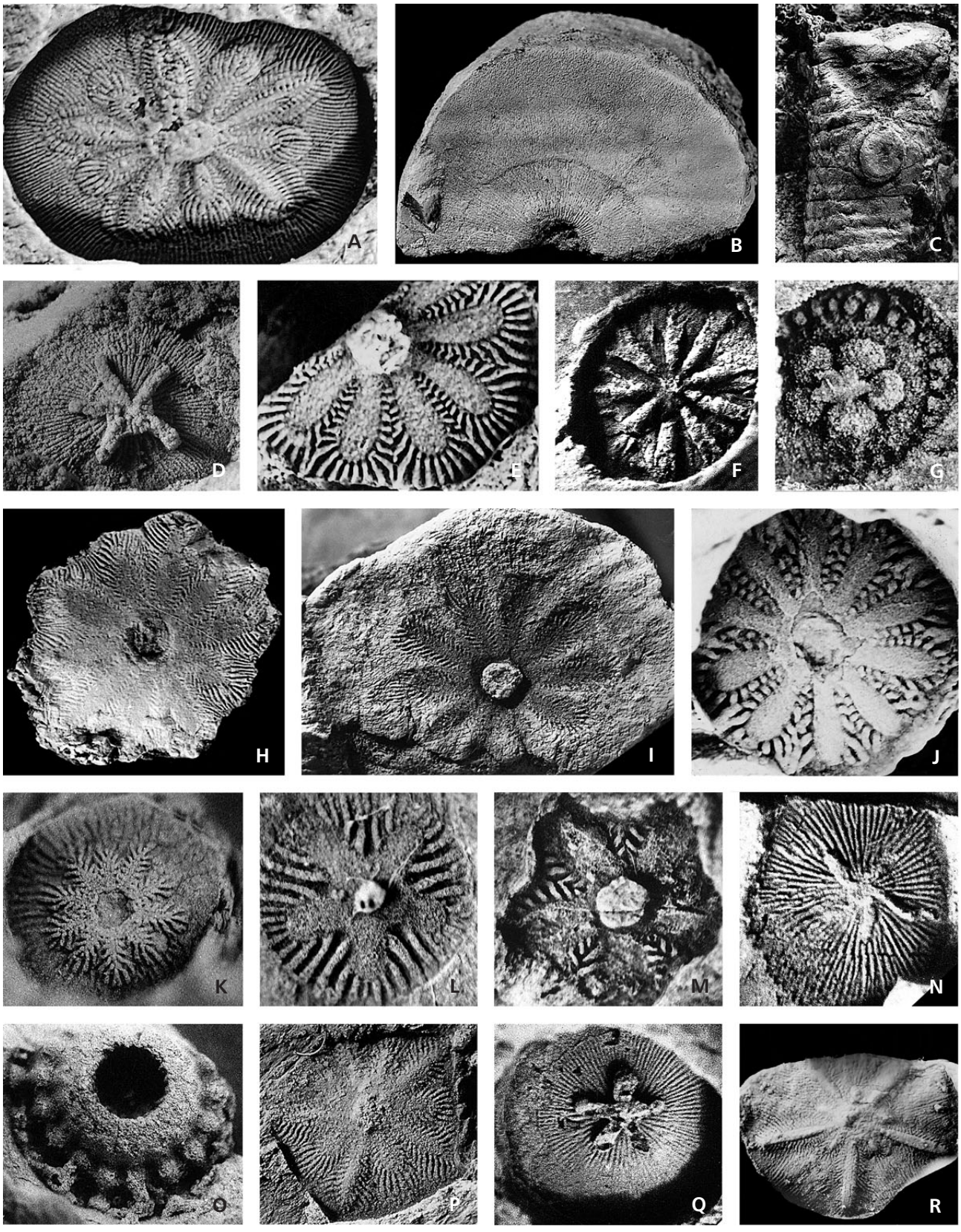
The *Raricrinus minimus-Vasticrinus vastus* Biozone corresponds to the upper parts of the Ildikan and Imachi suites (upper Imachi Horizon) (Figs 2, 3, Table 2). The typical assemblage comprises *Raricrinus minimus* (Yeltysheva & J. Dubatolova), *Vasticrinus vastus* (Yeltysheva & J. Dubatolova), *Hexacrinites*? *biconcavus* Yeltysheva & J. Dubatolova, *H.*? *mamillatus* Yeltysheva & J. Dubatolova, *H.*? *carinatus* Yeltysheva & J. Dubatolova, *H.*? *humilicarinatus* Yeltysheva, *Asperocrinus giganteus* Stukalina, *A. dentatus* (Quenstedt), *Amurocrinus conserratus* (Yeltysheva & J. Dubatolova), *A. imatschensis* (Yeltysheva & J. Dubatolova), *Shishkinaecrinus petalatus* (Yeltysheva & J. Dubatolova), *Imatschicrinus ivanovi* (Yeltysheva & J. Dubatolova), *Graptocrinus incelebratus* (Yeltysheva & J. Dubatolova), *Schyschcatocrinus consuetus* J. Dubatolova, *Pandocrinus grandis* Kurilenko, and *Pestericrinus* sp. In this stratigraphic interval there are no members of the families Paradecacrinidae, Kuzbassocrinidae, Anthinocrinidae, which are characteristic of the Pragian and Emsian stages in Transbaikal and the Far East. *Raricrinus minimus* and *Shishkinaecrinus petalatus* are known from the Eifelian of the Far East. *Hexacrinites*? *carinatus*, occurring in this assemblage, is the key for correlating these deposits with the Upperlosishino Subsuite of the Rudny Altai and the Mamontovo Horizon of Salair. Representatives of the genus *Pestericrinus* are characteristic of the Eifelian of the Rein region as well as the Emsian-Eifelian of regions of the Arctic, the eastern slope of the Urals, Salair and southern Tian-Shan (Dubatolova *et al.* 1967, Yeltysheva 1969, Dubatolova 1971, Stukalina 1986).

The brachiopods *Cyrtinopsis nalivkini* Rzhonsnitskaya (E. Modzalevskaya identification) are found in limestones of the upper part of the Ildikan Suite. They are characteristic for Emsian deposits of numerous regions of Russia (Rzhonsnitskaya 1952, Zanina & Likharev 1975).

The *Ononicrinus gracilis* Biozone within the lower part of the Oldoy Horizon is also the lower part of the Yakovlev and the Oldoy suites (Figs 2, 4, Table 2), beds dated as Givetian. In addition to the index-species *Pentapterocrinites brevijugatus* J. Dubatolova, *Amurocrinus imatschensis* (Yeltysheva & J. Dubatolova), *A. conserratus* (Yeltysheva & J. Dubatolova), *Hexacrinites*? *biconcavus* Yeltysheva & J. Dubatolova, *H.*? *mamillatus* Yeltysheva & J. Dubatolova, *Oldojicrinus oldoicus* (Yeltysheva & J. Dubatolova), *Schyschcatocrinus tatyanae* Kurilenko, *Vasticrinus vastus* (Yeltysheva & J. Dubatolova), *Peribolocrinus aequiplicatus* (Yeltysheva & J. Dubatolova) and *Platystela*? sp. are present at this level. The index-species itself is widespread in Givetian strata of the Upper Priamur, the Zeisko-Depsky district (lower Oldoy Suite), Gorny Altai (Belgebasch Suite), the Urals (Vysotino Horizon), Mongolia, and Poland. Similar forms have been described from coeval deposits in North America (Dubatolova *et al.* 1967; Yeltysheva 1969; Dubatolova 1971, 1982; Stukalina 1986; Kurilenko *et al.* 2002).

The brachiopods *Devonoproductus*? *halli* (Modzalevskaya), ?*Athyris concentrica* (Buch), *Euryspirifer pseudo-*

Figure 3. A, H, P – *Amazaricrinus ildicanensis* Kurilenko, 2001. A – exemplar 12/10900, × 5; P – exemplar 25/13038, × 7; articular facets of a proximal columnals. Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* H – exemplar 2/12704, × 4; articular facet of a proximal columnal. Transbaikal, Gazimur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • B – *Pandocrinus grandis* Kurilenko, 2001. Holotype 4/12704, × 2; articular facet of a distal columnal. Transbaikal, Gazimur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • C – *Vasticrinus vastus* (Yeltysheva & J. Dubatolova, 1960). Exemplar 122/13038, × 1.2; lateral view of a pluricolumnal. Transbaikal, Gazimur River. Middle Devonian, Beds with *Raricrinus minimus-Vasticrinus vastus.* • D, N, Q – *Scyphocrinites mariannae* Yakovlev, 1953. D – exemplar 88/13038, × 4.5; articular facet of a columnal. Transbaikal, Onon River. Lower Devonian, Beds with *Costatocrinus bicostatus-Tastjicrinus paucicostatus.* N – exemplar 90/13038, × 6; Q – exemplar 91/13038, × 5; articular facets of the columnals. Transbaikal, Onon River. Lower Devonian, Beds with *Scyphocrinites mariannae.* • E, J – *Kuzbassocrinus binidigitatus* Yeltysheva, 1957. E – exemplar 61/9597, × 7; J – exemplar from collection 9597, × 11; articular facets of the proximal columnals. Far East, Amur River. Lower Devonian, Beds with *Paradecacrinus orientalis.* • F – *Costatocrinus bicostatus* (Stukalina, 1961). Exemplar 18/13038, × 4; articular facet of a columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Costatocrinus bicostatus-Tastjicrinus paucicostatus.* • G – *Raricrinus minimus* (Yeltysheva & J. Dubatolova 1967). Exemplar 138/13038, × 15; articular facet of a proximal columnal. Transbaikal, Amur River. Middle Devonian, Beds with *Raricrinus minimus-Vasticrinus vastus.* • I – *Kuzbassocrinus decemlobatus* Yeltysheva, 1957. Exemplar 8/12704, × 4.5; articular facet of a proximal columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • K – *Amazaricrinus minimus* (Stukalina, 1977). Exemplar 42 /13038, × 10; articular facet of a proximal columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • L – *Urushicrinus ržonsnickae* Kurilenko, 2002. Not the actual specimen. Holotype 49/13038, × 9.5; articular facet of a proximal columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • M – *Shishkinaecrinus partitus* Kurilenko, 2002. Not the actual specimen. Holotype 61/13038, × 7; articular facet of a proximal columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • O – *Hexacrinites*? *mamillatus* Yeltysheva & J. Dubatolova, 1960. Exemplar 74/13038, × 5; articular facet of a proximal columnal. Transbaikal, Amur River. Lower Devonian, Beds with *Amazaricrinus ildicanensis.* • R – *Paradecacrinus orientalis* (Yeltysheva, 1957). Exemplar 15/10900, × 3.5; articular facet of a proximal columnal. Far East, Amur River. Lower Devonian, Beds with *Paradecacrinus orientalis.* Type species stored in the Central Science-Research Geological Exploration Museum named after Academician F.N. Chernyshev (CNIGR Museum), St. Petersburg.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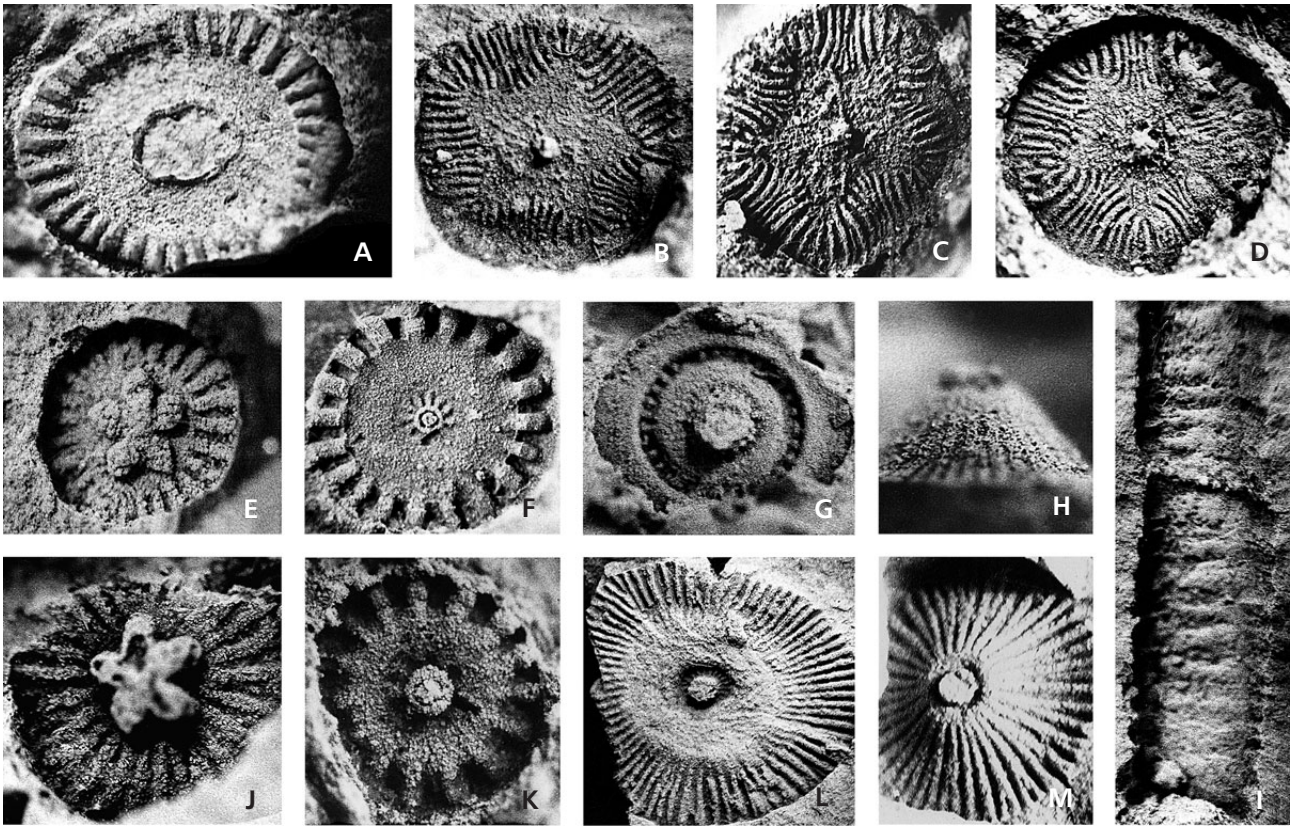

Figure 4. A – *Amurocrinus imatschensis* (Yeltysheva & J. Dubatolova, 1961). Not the actual specimen. Exemplar 198/13038, × 7; articular facet of a proximal columnal. Transbaikal, Onon River. Upper Devonian, Beds with *Hexacrinites*? *stukalinae.* • B, C, D, I – *Ononicrinus gracilis* (Yeltysheva & J. Dubatolova, 1961). B – exemplar 161/13038, × 8; C – exemplar 158/13038, × 7; D – exemplar 160/13038, × 7; articular facets of the proximal columnals. I – exemplar 163/13038, × 4; side view of a stem fragment. Transbaikal, Onon River. Middle Devonian, Beds with *Ononicrinus gracilis.* • E – *Schyschkatocrinus tatyanae* Kurilenko, 2002. Not the actual specimen. Holotype 201/13038, × 10; articular facet of a columnal. Transbaikal, Onon River. Upper Devonian, Beds with *Hexacrinites*? *stukalinae.* • F, K – *Hexacrinites*? *stukalinae* Kurilenko sp. nov. F – holotype 208/13038, × 9; K – paratype 211/13038, × 16; articular facets of the columnals. Transbaikal, Onon River. Upper Devonian, Beds with *Hexacrinites*? *stukalinae.* • G – *Amurocrinus conserratus* (Yeltysheva & J. Dubatolova, 1967). Exemplar 216/13038, × 4; articular facets of the proximal columnals. Transbaikal, Onon River. Upper Devonian, Beds with *Hexacrinites*? *stukalinae.* • H, M – *Asperocrinus paucus* Kurilenko, 2000. H – exemplar 222/13038, × 8; M – holotype 3/13037, × 7; articular surfaces of the columnals. Transbaikal, Gazimur River. Upper Devonian, Beds with *Hexacrinites*? *stukalinae.* • J – *Floricyclus* sp. Not the actual specimen. Exemplar 239/13038, × 8; articular facet of a columnal. Transbaikal, Klichka Mountains. Upper Devonian, Beds with *Platycrinites*? *subtuberosus.* • L – *Hexacrinites*? *biconcavus* Yeltysheva & J. Dubatolova, 1960. Exemplar 169/13038, × 4; articular facet of a proximal columnal. Transbaikal, Onon River. Middle Devonian, Beds with *Ononicrinus gracilis.* Type species stored in the Academician F.N. Chernyshev Central Science-Research Geological Exploration Museum (CNIGR Museum), St. Petersburg.

cheehiel (Hou), *Mucrospirifer mucronatus* (Conrad) and *Spinocyrtia martianovi* (Stuckenberg), among others, are found in the same layers with the crinoids in Transbaikal. The brachiopod assemblage is composed of taxa typical for the upper parts of the Givetian of the Minusinsk depression, Mongolia, Gorny Altai and the Kuznets Basin. Some species in common, *i.e.*, *Eoschuchertella arctostriata* (Hall), *Devonochonetes coronata* (Conrad), *Ambocoelia subumbonata* (Hall), *Mucrospirifer mucronatus* (Conrad), are known from the Givetian Hamilton Formation of North America (Hall 1867, Stuckenberg 1886, Hall & Clarke 1892–1894, Khalfin 1937, Chou 1959, Modzalevskaya 1969, Gratsianova *at al.* 1987, Goldman & Mitchell 1990, Kurilenko *et al.* 2002).

The crinoids of the Upper Devonian of the Russian territory are still poorly known. The Frasnian sequence of the *Hexacrinites*? *stukalinae* Biozone in Transbaikal is represented by numerous remains, but some species (*Urushicrinus parvulus* Kurilenko, *U. digitatus* Kurilenko, *Asperocrinus paucus* Kurilenko, *Schyschcatocrinus tatyanae* Kurilenko) are not known beyond the region (Figs 2, 4, Table 2). The age of the strata is determined by the brachiopods *Schizophoria striatula* (Schlotheim), *Cariniferella carinata* (Hall), *Productella subaculeata* (Murchison), *Mucrospirifer mucronatus* (Conrad), *Cyrtospirifer achmet* Nalivkin and *Elytha* sp. found in these deposits. *Schizophoria striatula* occurs in the Givetian and Frasnian stages of many regions;

Cariniferella carinata was reported by Hall & Clarke (1892–1894) in the Frasnian (Chemungian) deposits of North America; *Mucrospirifer mucronatus* is most frequently encountered in the Givetian but also occurs in the Frasnian in many regions including eastern Transbaikal; *Cyrtospirifer achmet* is characteristic for Frasnian deposits of numerous regions. Our stratigraphic analysis of the brachiopod species distribution leads us to conclude that these deposits are of Frasnian age.

Initially the stratum was dated as based on *Amurocrinus imatschensis* and *Hexacrinites*? *mamillatus* (Kurilenko *et al.* 2002). However, our research has now shown that the first species has a longer range although generally it is very abundant in Frasnian deposits. Regarding the second species, the senior author, as previous researchers, mistakenly identified a specimen, which differs greatly from the holotype and so here, below, we propose a new species of *Hexacrinites*? *stukalinae*, which is characteristic for Frasnian deposits.

Famennian crinoids rarely occur in Transbaikal. They are found only in the Teplovskii Suite of the Upper Priamur. *Amurocrinus* ex gr. *imatschensis* (Yeltysheva & J. Dubatolova) is widely distributed in the Devonian sections of Transbaikal. This is the first report of species similar to *Bicostulatocrinus circumvallatus* (Yeltysheva), which is most abundant in the Upper Famennian and Lower Carboniferous of Transbaikal. Occurring with the crinoids from the Teplovskii Suite listed above, the brachiopods *Athyris bajeti* Rigaux and *Cyrtospirifer verneuili* (Murchison) provide evidence of the Famennian age by comparison with Kazakhstan, Kuznetsk Basin (Nalivkin 1930; Khalfin 1932, 1933; Rzhonsnitskaya 1952).

The *Platycrinites*? *subtuberosus* Biozone spins the transition from the Devonian to the Carboniferous and yield massive collections in the Transbaikal (Figs 2, 4, Table 2). The fauna of this interval occurs in the sections of the upper part of the Yakovlev Suite (Kotikha Horizon). The crinoid assemblage has a mixed composition and is represented by the co-occurrence of Devonian and Carboniferous species. The representatives of the family Platycrinidae are characteristic for Carboniferous deposits of many Russian regions: *Platycrinites*? *subtuberosus* Stukalina, *Pl*? *donicus* Kurilenko, *Pl*? *gazimuricus* Kurilenko, among others, are most widespread. Besides the Platycrinidae, the typical assemblage is composed of Carboniferous species: *Bicostulatocrinus circumvallatus* (Yeltysheva), *Pentaridica pulcher* (Yeltysheva), *Florycyclus* sp. and *Ungulicrinus* sp. Devonian crinoids are represented by *Anthinocrinus* sp. (*sensu lato*), *Asperocrinus* sp. and *Amurocrinus* sp. Representatives of these genera are widespread in Devonian sections of the eastern Urals, Kazakhstan, southern Tian-Shan, Gorny Altai, Salair, and the Far East. A sharp renewal of the taxonomic composition of the crinoid faunas is associated with this biostratigraphic subdivision. Most of the typical Devonian genera disappeared. Genera widely distributed in the Lower Carboniferous occur for the first time.

Sections containing the *Platycrinites*? *subtuberosus* Biozone are characterized by the Upper Famennian bryozoan fauna *Cyclotrypa arboracea* Nekhoroshev, "*Stictoporina" bifurcata* Nekhoroshev, *Monotrypa carbonica* Nekhoroshev, *Pseudobatostomella longipora* (Nekhoroshev), *Ipmorella irregularis* (Nekhoroshev), *Nikiforovella bytchokensis* Trizna, *Fenestella quadrulla* Nekhoroshev and *Laxifenestella juxtaserratula* Trizna as well as brachiopods *Cyrtospirifer ivanovae* Beznosova, *Tenticospirifer dobroljubovae* Beznosova and *Sphenospira julii* (Dehee). These assemblages allow correlation of deposits with the Abyshevo Horizon (Topkin Unit) of the Kuzbass and the middle subsuite of the Tarkhanskaya Suite of the Rudny Altai (Popeko 2000).

Systematic palaeontology

Class Crinoidea Miller, 1821
Subclass Camerata Wachsmuth & Springer, 1885
Order Monobathrida Moore & Laudon, 1943
Family Hexacrinitidae Wachsmuth & Springer, 1885

Genus *Hexacrinites* Austin & Austin, 1843 (*sensu lato*)

***Hexacrinites*? *stukalinae* Kurilenko sp. nov.**
Figure 4F, K

Holotype. – No. 208/13038 (Fig. 4F) is deposited in the CNIGR Museum, St. Petersburg, Russia.

Paratypes. – Nos 211/13038 (Fig. 4K), 205/13038, 209/13038 are deposited in the CNIGR Museum, St. Petersburg, Russia.

Type horizon and locality. – Eastern Transbaikal, Onon River; Upper Devonian, Lower Frasnian, upper part of the Oldoy Horizon, Beds with *Hexacrinites*? *stukalinae*.

Material. – Several hundreds of isolated columnals and pluricolumnals.

Etymology. – The name of the species is given in recognition of the many contributions of the paleontologist G. Stukalina.

Diagnosis. – Stem slender homeomorphic, characterized by low, circular holomeric columnals and facet with concave areola; short, wide crenulae; small, pentalobate axial canal, high and wide perilumen.

Description. – The stem is composed of small (D = 2–3 mm) monolithic circular columnals, which are homeomorphic (h = 0.5–1.0 mm). The areola is central, concave, and smooth. The width of the areola changes depending on the position of the columnal in the stem. Distal columnals have areolae with a width less than one-half the diameter of the columnal; proximal columnals have very wide areolae. All facets bear a narrow crenularium containing numerous short, straight, wide, high, radial crenulae. Costae enlarge greatly to the peripheral edge of the columnal. The length of the costae also depends on the position of the columnal in the stem and changes in proportion to the dimension of the areola. The axial canal is very small (less than 1 mm), and pentalobate. A high and rather wide perilumen is situated around the axial canal. The perilumen has minute, radially-disposed denticles.

Remarks. – R. Yeltysheva and G. Stukalina (in manuscripts) and A. Kurilenko (Kurilenko *et al.* 2002) described the same columnals in the composition of the species *Hexacrinites*? *mamillatus* Yeltysheva & J. Dubatolova. They defined their taxon in open nomenclature (cf., ex gr., aff.). Numerous specimens discovered in the sections of Transbaikal allow recognition of *Hexacrinites*? *stukalinae* sp. nov. It is distinguished from *H*? *mamillatus* by the following characters: smaller size of the columnals (D = 2–3 mm – y *Hexacrinites*? *stukalinae*, 5–9 mm – y *H.*? *mamillatus*); less prominent areola; homeomorphic columnals.

Occurrence. – Eastern Transbaikal, Far East Russia; Upper Devonian, Frasnian, upper part of the Oldoy Horizon, Beds with *Hexacrinites*? *stukalinae*.

Summary

The Devonian deposits of Eastern Transbaikal are represented by two lithofacies within the geological section: carbonate-volcanogenic-terrigenous (Onon terrane) and terrigenous- carbonate (Argun and Upper Amur terranes). In the latter terranes strata are characterized by abundant crinoids and brachiopods. A crinoid biostratigraphic zonation is proposed within the Mongol-Okhotsk fold belt as follows: *Scyphocrinites mariannae*, *Costatocrinus bicostatus* and *Tastjicrinus paucicostatus* (Lower Lochkovian); *Amazaricrinus ildicanensis* (Pragian); *Paradecacrinus orientalis* (Emsian); *Raricrinus minimus* and *Vasticrinus vastus* (Eifelian); *Ononicrinus gracilis* (Givetian); *Hexacrinites*? *stukalinae* (Frasnian) and *Platycrinites*? *subtuberosus* (Upper Famennian). Local and regional crinoid ages accord well with those of brachiopods and lateral distribution of faunal assemblages allows correlation across regions.

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