

Subterranean fauna from Siberia and Russian Far East

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Abstract

Description of the main karstic regions of Siberia and Far East, and the most important caves. Survey of the subterranean species collected in caves, springs, hyporheic and MSSh. Relationship with the climate and glacial paleoclimatic periods to explain the paucity of the terrestrial fauna of Siberia. Persistence of some aquatic stygobionts (Crustacea), and richness of the subterranean fauna of the Far East, particularly in the Sikhote-Alin. The Crustaceans of the eastern part of the Ussury basin and Sakhalin Island have relationship with the Japanese and Korean fauna.

Key words: karst, caves, springs, MSS, subterranean fauna, biogeography.

1 Generalities and History

The study of caves in Siberia was begun in the late 17th century (Tsykin *et al.*, 1979), but the first published report were made as early as in the 18th century by swedish geographer **P. von Strahlenberg** who in 1722 visited the cave on the Yenisei river bank above Krasnoyarsk and gave a short description, which is considered the first report of caves in Siberia (Strahlenberg, 1730). Then, in Federation of Russia the subsequent description of karst forms and caves were made by extensive expeditions of St. Petersburg Academy, following the conquest of huge territory of Siberia (Gorbunova, 1987). The first detailed field manual on caves was published by **J. Gmelin** (Gmelin, 1751) as result of the Great North Expedition carried out between 1733 and 1743. The period from 19th century to early 20th century is characterized by increase of data about the karst and caves in the Russian Empire, supported by expeditions in Western, Central and Eastern Asia, and the Far East (Kler, 1938; Gorbunova, 1987; Bersenev, 1989; Kadetskaya, Maximovitch, 2012).

2 Karst, caves, aquifers

The karstic zones covered in the former URSS 14 677 000 km². The karsts are developed in Permian rocks (17 %), Carboniferous (16.3%), Cambrian (14.6 %), Devonian (14.5 %), Cretaceous (13.6 %), old

Proterozoic (7 %), Ordovician (6.6 %), Silurian (3.7 %), Neogene (2.6 %), Triassic (1.8 %), Paleogene (1.5 %) and Jurassic (0.8 %) (Gvozdetski, 1965, 1981).

A continuous permafrost is present in the northern part of the Siberia and often with a thickness of 200 m, whereas a fragmented permafrost characterizes the southern mountainous part, where it disappears in valleys.

The Siberian karsts suffer of hard continental climate, linked to the great Siberian anticyclone centred on the Irkutsk Plateform. The climatic changes of the last decades have induced recession of the permafrost on almost all regions. For instance, it disappeared of the Baikal region and its thickness have strongly decreased in the upper Lena basin. To day, in the Irkutsk region the winter temperatures of -35°C becomes scarce and in summer periods with temperatures over 25°C are more and more lengthy (Salomon & Pulina, 2005).

We distinguish, based on morpho-structural criterions: in eastern Siberia, the Siberian Plateform which covers about 2.9 millions km^2 , with outcrops of limestone and gypsum covering more than 500,000 km^2 . They are located in the permafrost zone or at its nearest periphery; - The regions more southern, were the karst covers about 80,000 km^2 .

The karstic phenomenas were developed in two types of geologic rocks: on the one hand in the old Precambrian rocks of the Baikal orogenesis which consists in marbles and lens of metamorphic rocks, on the other hand in younger rocks (evaporits, Jurassic gypsum) and non-metamorphic limestones.

Caves. The karstic caves were developed in rocks from a wide range of geological age: Archean, Proterozoic, Paleozoic, Triassic, Jurassic, in limestones, dolomites, mixed carbonate rocks, carbonate conglomerates, and gypsum. Pseudokarstic caves are known in sandstones and volcanic lava.

There are more than 1.400 caves in Siberia, widespread along the south of the area: Gornyi Altai, the East Sayan Upland, the Primorsky Range, the Priolkhonskoye Plateau near the Lake Baikal, the southern area of the Central Siberian Upland, and in the Far East the Sikhote-Alin, and the Sakhalin Island.

Paleontological investigations have been carried out for over 150 years in more than 100 caves of southern Siberia and Sakhalin Island. The bones of nine species of bats were found in the caves of the Far East and six species in Transbaikalian and Sakhalin caves (*Myotis*, *Placotus*, *Murina* and *Ambliotus*).

Karstic aquifers. There are extensive karstic aquifers below the permafrost. Cryochemical processes are actif below the permafrost givin, streams and lens of water strongly mineralised, and mineralized spring. We distinguish, several karstic regions: Altai-Kuznetski-Sayan, Baikal, Transbaikalie and northern Siberia, Far East.

Hyporheic (Interstitial) habitat of surface rivers were particularly explored in the Far East region.

2.1 Altai, Baikal and Irkutsk Plateforme, Central Transbaikalia and Northern Siberia

Altai-Kuznetski-Sayan (fig. 1: 4). In the southern mountainous Siberia we can distinguish several karstic regions in Cambrian and Devonian carbonated rocks, and also in Ordovician dolomite, marble, and conglomerate.

On the Altai Mountain and Kuznetski Massif, Eastern Sayan, about 675 caves have been explored (Marinin & Tolmachev, 1981; Tsykin, 1990; Filippov, 2003).

In the Kuznetski Plateau and the Gornaya Shoriya, between Kemerovo and Krasnojarsk, more than 100 caves are know in Cambrian, the longest are the Yashchic Pandory (19,100 m), Fantaziya cave (6.2 km) and Korolëva (5.07 km).

The Gorniy Altai Mountains contains more than 400 caves: the largest are the Altayskaya (4.75 km, 248 m deep), Kekrash (2,300 m), Turkushkaya (1,400 m, 218 m deep).

In the East Sayan Upland, 175 caves are recorded. The Bolshaya Oreshnaya (5,250 m) is the longest caves in the world in carbonated conglomerate. Others caves are known in Ordovician conglomerate: the Badzheiskaya (5.9 km), Temnaya (2,500 m). The Karbonatitovaya cave is the only one in carbonatites known in the world. We have only reduced data about the cave fauna of these regions.

Irkutsk Plateforme and Baikal (fig. 1: 5; fig. 2; fig. 3). The Irkutsk Plateform and the western Baikal region consist of Baikal Mountains which run along the western slope of the Baikal Lake and a large

platform where the Lena rise in. The upper basins of the two large rivers, the Angara and the Lena, cover this region.

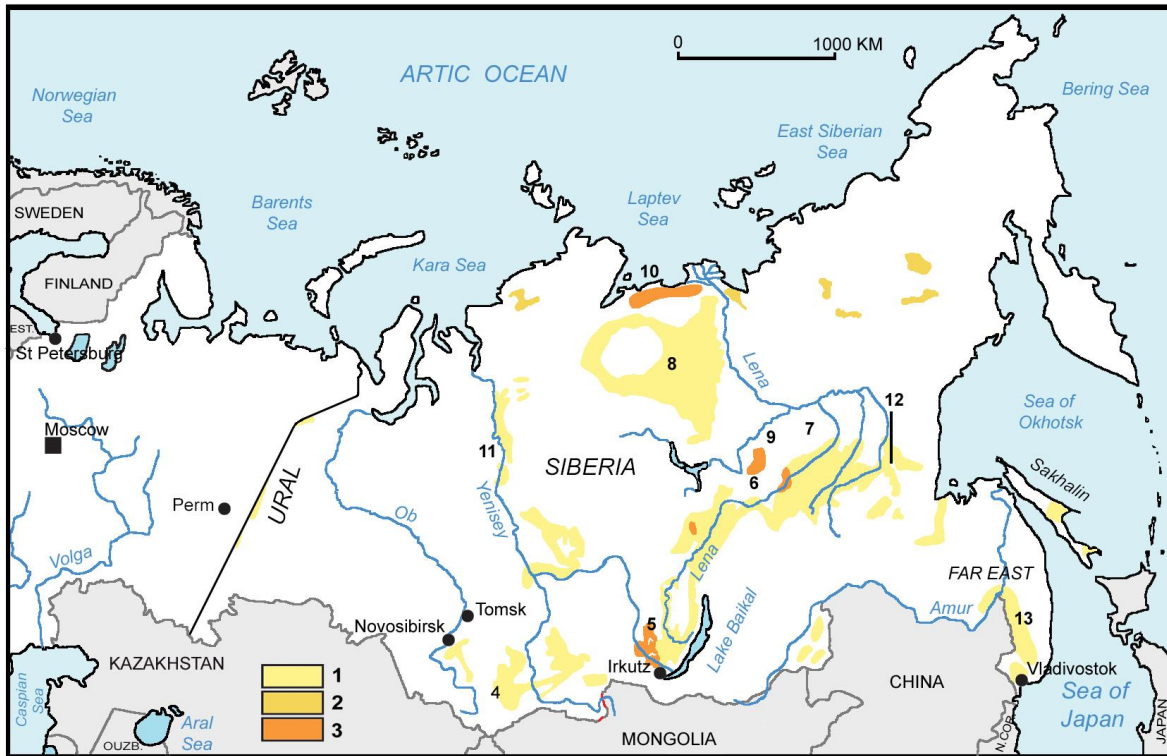


Figure 1. Karst of Siberia and Russian Far East. – 1. Carbonated rocks and locally sulfated (studied and recorded). – 2. Carbonated rocks and locally sulfated (estimated). – 3. Sulfated rocks (salt). – Numbers: 4 – Altai, Kuznetski, Saianski. – 5. Irkutsk Plateau. – 6. Patomskoye Mountains. – 7. Middle Lena valley. – 8. Anabar region. – 9. Anhydrite karst of Kempendal. – 10. Anhydrite karst of Norwinski. – 11. Gypsum and Anhydrite karst of the Poutoran Plateau. – 12. Karst of the Uchur and Maia rivers and valleys. – 13. Amur, Khor valleys and Sikhote-Alin Mountain ridge (after Pulina, 2005; modified; map Bernard Juberthie).

The region is limited to the south by the eastern Sayan Mountains. The karst covers 350,000 km². It consists of Cambrian limestones and dolomites, and in addition Cambrian gypsum and anhydrite karsts.

The karstification was developed in Cambrian gypso-carbonated series which lie upon the Precambrian base, and in the complex of interstratified of carbonated rocks with gypsum 200 to 400 m thick.

On the top of gypsum, mainly in the southern region, Ordovician and Jurassic carbonated beds lie which contain coal, and also Tertiary and Quaternary deposits.

The “*sukhodoly*” are karstic forms characteristic of the Siberian karst. They are elongated depressions in bottom of dry valleys from several hundred metres to some kilometres in length. Entrances of subterranean passages and large caves can be present (Pulina, 1992, 2005).

The karstic aquifers of the Plateau receive high quantity of waters from rivers, however the plateau is located in center of the Siberian anticyclone characterized by a low level of annual rains (403 mm at Irkutsk, 378 mm at Bataganska).

Numerous caves are located on slopes of valleys (fig. 3). The largest are: the Batovskaya cave (40 km) the longest maze cave in Russia, Argaracanskaya cave (8.3 km), Balaganskaya cave (1.6 km), Grebnevskaya (1 km), and the Kundugunskaya (1 km). At least 13 caves have more than 500 m in length, the deepest is the Kuturyanskaya (-144 m) (Filippov, 1993, 2003; Pulina, 2005).

Usually they consist of horizontal passages in zones of subterranean waters running. They present several levels of passages consequently to changes of the basic level (Trzcinski *et al.*, 1977; Trzcinski, 1996; Vologodsky, 1975; Pulina, 2005). In 1988, V. Kniss explored the subterranean fauna of 12 caves in the Baikal National Park (Kniss, 1991).

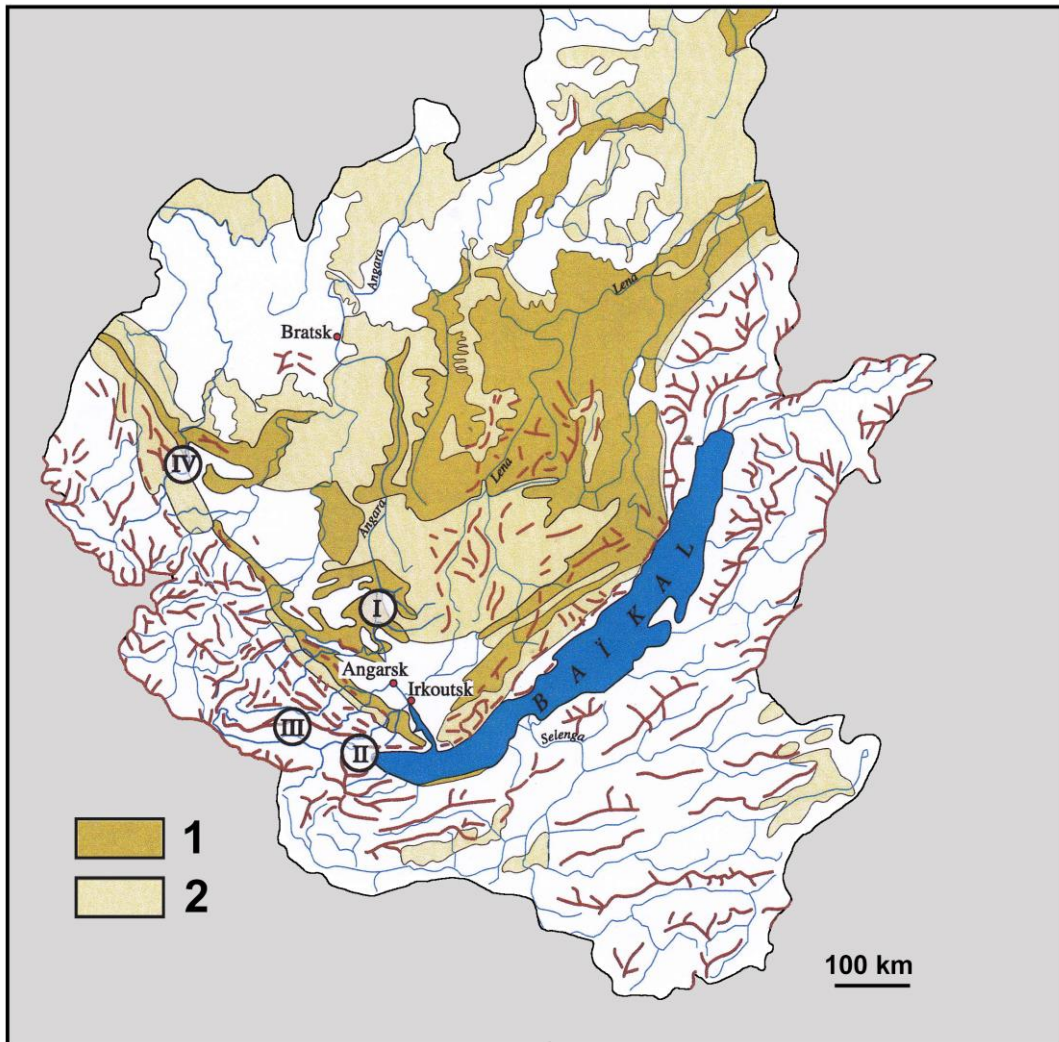


Figure 2. Karts of the Irkutsk plateau. 1. Karstic regions with limestone, dolomite, gypsum and anhydrite. 2. Potential karstic regions. I. Southern part of the Irkutsk plateau. II. Western region of the Khamar-Daban Mts. III. Tounginsk Alps. IV. Around Niznieudinsk (after Marian Pulina, *Karstologia*, 2005).

Transbaikalia central and northern Siberia (fig. 1: 6, 7, 8, 9, 10, 11). Several karstic zones are distinguished: Patomskoye Mts, Stanovoye Mts, Anabar, mainly in Cambrian and Ordovician marbles, dolomites, gypsum and anhydrite.

Stanovoye Mountains to the north-east of the Baikal Lake, contain 35 caves in Cambrian limestone, among themj the Dolganskaya cave (5,120 m).

Karsts in the Patomskoye Mountains (fig. 1: 6), located in central part of the Lena River they are characterized by the paucity of vegetation, with ridges 1100-1800 m in elevation, under hard climate, with permafrost 200 m in thickness between rivers, and 100 m deep in valleys, locally absent in sunny slopes of valleys. Karstic phenomenas are developed in dolomite, marbles, interstratified with metamorphic schists and Proterozoic gneiss. Caves are numerous.

Karst of the middle valley of the Lena (fig. 1: 7). The Lena central plateau consists of sedimentary Cambrian rocks: limestone, dolomite, marl, sandstone, gypsum and evaporite. The surface of the karst is estimated to 160,000 km² with 15,000 km² of gypsum and salt (Cykin, 1990). Permafrost 300 m thick, temperatures – 50° to – 60 °C in winter. An important paleokarst is present (Korzuyev, 1961) and also recent karstic morphology related to warmer periods of Pleistocene, with numerous dolines connected to karstic aquifers. Several important karstic aquifers and karstic springs are present. Numerous small caves inside the Cambrian limestone-gypsous rocks are recorded.

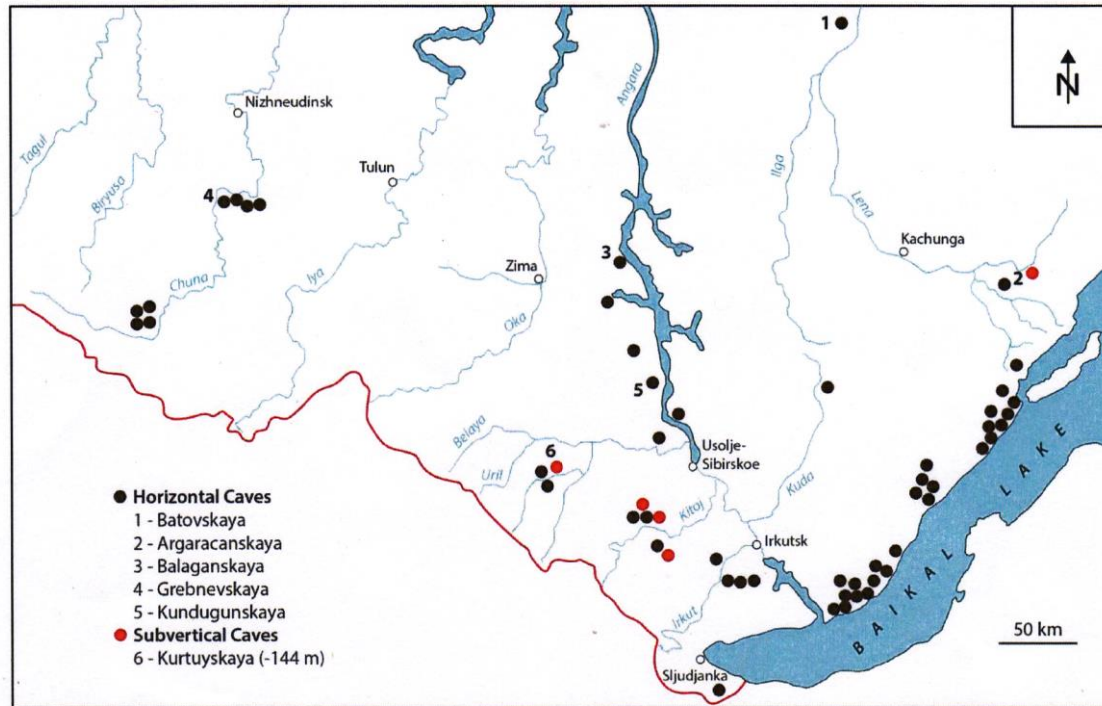


Figure 3. Main caves on the Irkutsk Plateform (after Trofimova, 1996, and Pulina, 2005; drawing Bernard Juberthie and George Nazareanu).

The Anabar Paleokarst (fig. 1: 8), an immense karstic region to the north of the Siberian Plateform between the Olenok and Kotuy rivers, which consists of Cambrian limestones and dolomites. Several cycles of karstification are recorded from the Carboniferous, the Jurassic and Cretaceous to the Paleozoic.

Anhydrite karsts in the northern part of the Lena basin: anhydrite karst of Kempendal (fig. 1: 9), anhydrite karst of Norwinsk (fig. 1:10), area estimated several 10 000 of km². In spite of the presence of an important permafrost, the karstification was developed in a great scale.

Gypsum and Anhydrite karsts of the northern Yenisey River (fig. 11). The Poutoran Plateau, Norillk region, presents many dolines up to 200 m in diameter and 60 m depth. An originality is the hydrohalite deposits in front of the salt karstic springs, named “Naled salinsi” or above the salt spring “Naled bougres salinsi”.

2.2 Far East: Primorye, Priamurye, Sakhalin island

The territory is divided in several regions.

The Sikhote-Alin Mountain ridge (fig. 1: 13; fig. 4: E), it extends 1000 km from the north to the south, and 200-250 km broad, running along the Japan Sea, its northern part in front of the Sakhalin Island. Cambrian, Carboniferous, Permian and Triassic limestones are widespread in the Sikhote-Alin. In the Sikhote-Alin about 215 karstic caves, 4 volcanic caves, numerous springs and also a MSS site were explored, and the subterranean fauna sampled. The largest caves are: the Proshchal'naya (3.200 m of passages) and Spasskaya (2,220 m long) (Dyomin, 1980, 1981; Dyomin *et al.*, 1980; Bersenev, 1989; Filippov, 2003; Salomon & Pulina, 2005).

M.S.S. (fig. 6) and Seep habitat. *D. Sidorov* found a shallow subterranean habitat at the spring of the Solontsovy brook on the eastern slope of the Sikhote-Alin Mountain ridge. The biotope is mixed: a terrestrial part corresponding to the MSS which consists of coarse limestone, coarse-grained sand, detritus, depth 5-10 cm, with slight soil horizon, where a diplopod species was collected, and an aquatic part, similar to the seep described by *D. Culver* (2010).

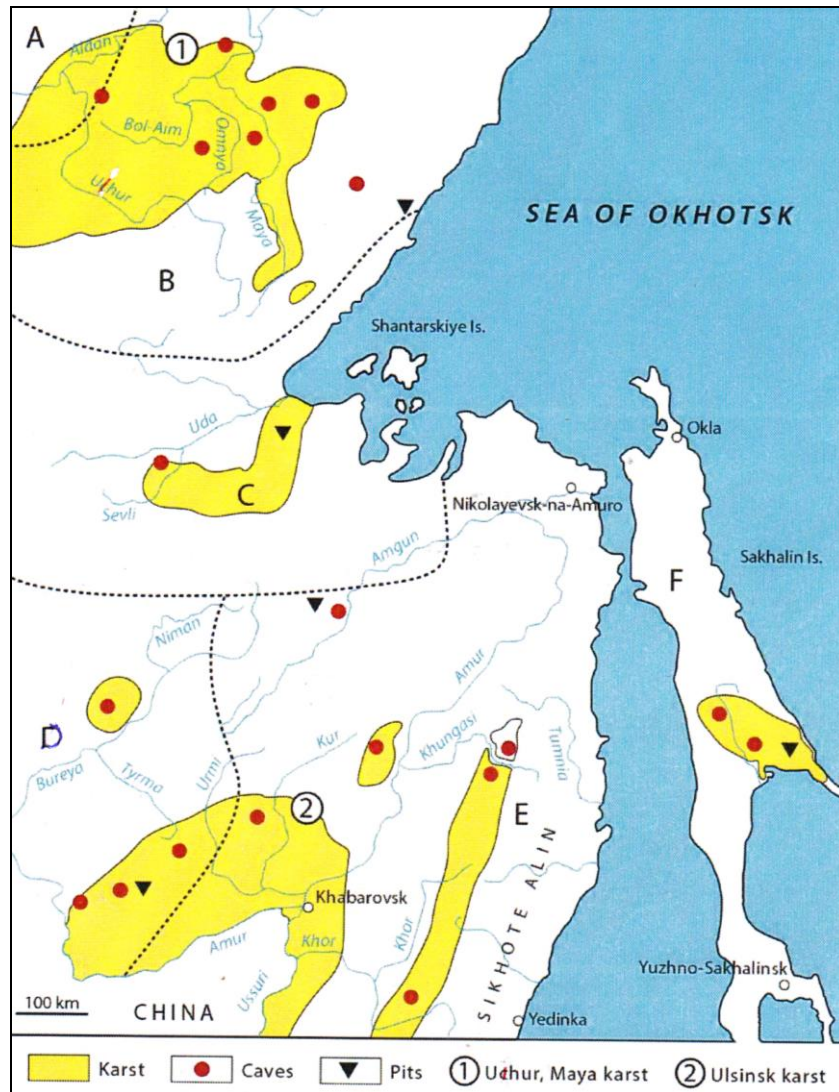


Figure 4. Regions with main caves in the Far East. – 1. Uchur-Maya karst. – 2. Ulsinsk karst. - A. Leno-Aldanskyi. B. Aldano-Stanovoyi. C. Amuro-Ochotskyi. D. Buryenskyi. E. Shikote-Alin Mountain ridge. F. Sakhalin Island (after Bersenev, 1989 and Pulina, 2005; drawing Bernard Juberthie and George Nasareanu).

The lower Paleozoic karstic territories of Ulsinsk (fig. 1: 13; fig. 4: 2), along the Amur River and its tributary the Kour is constellated of dolines whose some give subterranean passages. The complex of the Quadrat and Stregouchtcheye Kopye caves is the best known, its upper and middle levels are in large part with ice and ice concretions. In summer the temperature in the upper level oscillating between $-0.6\text{ }^{\circ}\text{C}$ and $-2.2\text{ }^{\circ}\text{C}$.

The karst of the Uchur and Maya basins (fig. 1: 12; fig. 4: 1). The Cambrian dolomitic and limestone, in front of the Okhotsk Sea, is a region of uplands, 1000 m in elevation, cuted by deep valleys. On the Mar-Kyouzl plateau the Aardach River disappears into deep ponors giving a subterranean stream flowing 18 km until the Selidinsk springs (Bersenev, 1989). Among the caves, the well known is the complex Abagy-Dze caves, 1400 m of passages, the bottom flooded by waters of the Maia river, with lakes, surface with ice in winter.

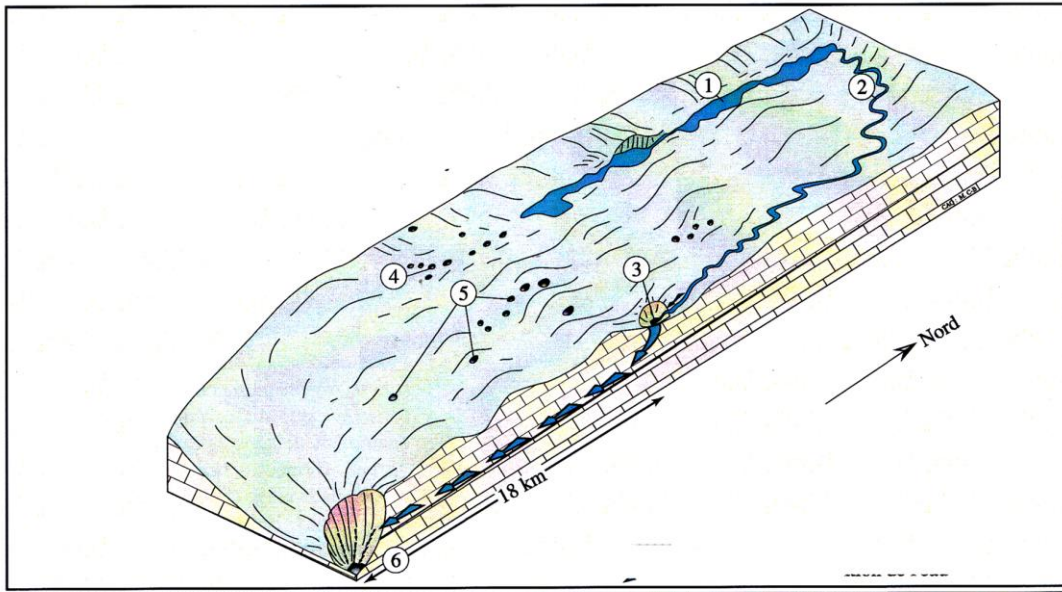


Figure 5. Ulsinsk karstic region, Mar-Kyouzl Plateau. Karstic lake (1), The Aardach River (2), Ponor (3), Subterranean stream of the Aardach River and Selendinskye karstic spring (6), Dolines (4-5) (after Bersenev 1989; Pulina 2005).

Sakhalin Island (fig. 4: F). The karstic caves in the Eastern Mountains of the Sakhakin Island are dug in Upper Jurassic reef limestones. 56 caves are known. Among the most known, 5 % present more than 500 m of passages. The Spasskaja cave, 2.2 km in length, is estimated the longest.

Kamchatka Peninsula (fig. 1). Around 30 volcanic caves have been described in the Kamchatka Peninsula and Kuril Islands (Slezin *et al.*, 1981; Filippov, 2003).



Figure 6. MSS on the eastern slope of the Sikhote-Alin Mountain ridge, Primory, Far East.

3 Subterranean fauna

Birstein and Ljovuschkin (1950) divided Russia in two major biospeological zones:

1 – A northern zone covering the major part of the Russian territory (Russian plain, northern Ural, northern and central Siberia) characterized by a very poor terrestrial subterranean fauna, with some stygobionts belonging to copepods, syncarids *Bathynella* and amphipods, corresponding to old groups widespread.

2 – A southern zone (Ciscaucasia, western Transcaucasia and southern Far East) characterized by numerous endemic stygobionts and troglobionts.

Based on actual knowledge, this paper consists in an overview of the subterranean fauna of the two Asian zones: Siberia and Far East. The majority of subterranean species inhabits the southern Far East (59 spp), only 10 stygobionts are recorded from Siberia and anyone troglobiont.

3.1 Siberia

Data on the subterranean fauna of Siberia were published by: (Martynov, 1930; Birstein & Borutzky, 1950; Livanov & Zabusova, 1940; Maximovitch, 1963; Chikishev, 1978; Holsinger, 1987; Sidorov *et al.*, 2010).

The cave fauna studies in this wide region are fragmentary (Martynov, 1930; Ljovuschkin, 1966). However more detailed studies have been performed in the National Parc National of the Irkutsk (Kniss, 1991, 2001).

The hypogean fauna of micro-arthropods consists mainly in troglophile species as in Ural, in consequence of the direct impact of glacial periods. In contrast the subterranean aquatic fauna consists of 8 stygobionts:

COPEPODA

Cyclopidae

From the Baikal Lake, *Acanthocyclops profundus* was sampled from the depth of 325 m in muddy bottom, and *A. notabilis* from the depth of 1.5 m in the sandbank.

Harpacticoidea

- *Attheyella glatkovi sibirica*, from the Karaulinsk cave located on the bank of the Ienissei River near Krasnojarsk.

ISOPODA

Asellidae

- *Asellus birsteini* sampled near the thermal springs Chaplinsky, eastern Siberia.

Note: From the Baikal Lake 4 species eyed of *Baicalasellus* were collected, and also *Asellus (Mesoasellus) dybowskii* from the bottom of the lake (Birstein, 1951; Henry & Magniez, 1993).

AMPHIPODA

Crangonyctidae

- *Stygobromus pusillus* described by Martynov (1930) from Telestskoye lake and source of the Biya River in the Altai Mountains of south central Siberia, and collected in several springs near Kokaika, Yajelu, Karba falls and Kokshi; estimated relict species,

- *Stygobromus mikhaili* from a small spring on the right bank of the Chuya River, in Altai,

- *Stygobromus anastasiae* from a spring in the Irkutsk University and the Olkhinsky spring in the Shelekhov territory. The genus *Stygobromus* is mainly North American (around 134 subterranean species).

- *Synurella*, two stygophiles species were found: *Synurella jakutana* and *S. levanidovae*. *Stygobromus* and *Synurella* occur in Eurasia and North America.

SYNCARIDA

Bathynellidae

Two stygobionts were described from sediments of Baikal Lake: - *Baicalobathynella magna* and

Bathynella baicalensis. Another undetermined Bathynellidae was found in the hyporheic of a small stream near the road to the Irkusk Museum by **Claude Bou** and **Jeanine Gibert**.

HYDRACHNIDIA

Thermacaridae

- *Thermacarus thermobius*, thermal springs near Baikal Lake, Buryatia, and also known in Kashmir (India) (Sokolow, 1940; Vitzthum, 1940-1943).

Wandesiidae

- *Wandesia paralia*, fine sand at 1 m depth, coast of Arctic Ocean, Sakha Republic. It is the only record of the freshwater mite genus *Wandesia* from the sea coast. The site where it was collected is influenced by the freshwater flow from Kolyma River (Abe, 2010).

COLLEMBOLA

The springtails were exclusively collected in 12 caves of the National Park of Baikal by **V. Kniss** in 1991. 8 troglophile species were recorded (Table 1), two troglaxene, *Folsomia tajmirica* and *Desoria hiemalis*, and undetermined species presumably troglaxene of the genera *Anurida*, *Entomobrya*, *Mucrella*, *Sminthurinus* and *Xenylla*.

Table 1. List stygobionts*/ stygophiles, troglaphiles and ^{lx}troglaxenes from Siberia.

Planariidae
<i>Polycelis receptaculosa</i> (Livanov & Zabusova, 1940)
COPEPODA
Canthocamptidae
* <i>Attheyella gladkovi sibirica</i> Borutzky, 1969
ISOPODA
Asellidae
* <i>Asellus birsteini</i> Levanidov, 1976
AMPHIPODA
Crangonyctidae
* <i>Stygobromus pusillus</i> (Martynov, 1930)
* <i>Stygobromus mikhaili</i> Sidorov, Holsinger & Takhteev, 2010
* <i>Stygobromus anastasiae</i> Sidorov, Holsinger & Takhteev, 2010
<i>Synurella jakutana</i> (Martynov, 1930)
<i>Synurella levanidovae</i> Karaman, 1990
SYNCARIDA
Bathynellidae
* <i>Baicalobathynella magna</i> (Bazikalova, 1954)
* <i>Bathynella baicalensis</i> Bazikalova, 1954
ARANEAE
Linyphiidae
<i>Lepthyphantes</i> sp.

..continued on the next page

Table 1. (Continued)

HYDRACHNIDIA

Thermacaridae

* *Thermacarus thermobius* Sokolow, 1927

Wandesiidae

* *Wandesia paralia* Abe, 2010

COLLEMBOLA

Hypogastruridae

Ceratophysella armata (Nicolet, 1841)

Ceratophysella denticulata Bagnall, 1941

Bonetogastrura cavicola Börner, 1901

Isotomidae

^{tx} *Desoria hiemalis* (Schött, 1893)

Desoria violacea (Tullberg, 1876)

^{tx} *Folsomia tajmirica* Martynova, 1973

Neanuridae

Anurida granaria (Nicolet, 1947)

Onychiuridae

Onychiurus schoetti Lie-Pettersen, 1896

Protaphorura armata (Tullberg, 1869)

Paronychiurus cf. *ramosus* Folsom, 1917

Tomoceridae

Pogonognathellus flavescens (Tullberg, 1871)

Tomocerus minutus (Tullberg, 1876)

Tomocerus sibiricus Reuter, 1891

COLEOPTERA

Cholevidae

Catops carinatus Jeannel, 1936

Conclusion. Actually the terrestrial subterranean fauna of Siberia is rare, only locally prospected, and composed of some troglophile without endemic and relict species (Table 1). In contrast, the aquatic subterranean fauna consists of 9 stygobitic species.

3.2 Russian Far East

Data on the subterranean fauna of Far East were published by: (Derzhavin, 1927, 1930; Birstein, 1955; Birstein & Levadinov, 1952; Birstein & Ljovuschkin, 1965, 1967 a, b, 1968; Borutzky, 1966; Chevrison, 1978, 1986; Tuzovskij, 1982, 1987, 1988, 1990, 2010; Henry & Magniez, 1993; Mikhaljova, 1997, 1998, 2004; Labay, 2001; Ljovuschkin, 1971; Pan'kov & Pan'kova, 2004; Holsinger & Sidorov, 2006; Sidorov &

Holsinger, 2007 a, b, 2008; Sidorov, 2009, 2010 a, b, 2011; Sidorov & Gontcharov, 2013; Sidorov *et al.*, 2010; Semenchenko, 2008, 2010 a, b, 2016; Tuzoskij & Semenchenko, 2009 a,b; Semenchenko & Tuzovskij, 2011; Pešić, Semenchenko & Lee, 2013; Zabusova, 1929, 1936; Karanovic *et al.*, 2015.

The hypogean fauna of Russian Far East is various, with many endemics. It consists of about 60 stygobionts and 11 troglobionts.

TRICLADIDA

Planariidae

- *Phagocata coarctata* stygobiont known from the Makrushinskaya cave, Olga Bay district.

Stygophile species from the Kamchatka Peninsula:

- *Polycelis (Polycelis) elongata*, *P. (P.) eurantron*, *P. (P.) polyopis*, *P. (Sorocelides) eudendrocoeloides*, *P. (Seidlia) relictata*, from groundwaters of Kamchatka.

Stygophile species from the Sakhalin Island:

- *Polycelis (P.) karafto* from Sakhalin Island.

COPEPODA

Canthocamptidae

- *Bryocamptus zschokkei caucasicus* from Nikolaevskaya cave.

- *Epactophanoides udegeicus*, described from the subterranean lake in the Makrushinskaya and Nikolaevskaya caves, near the littoral of the Far East (Borutzky, 1966).

OSTRACODA

Candonidae

- *Nannocandona schornikovi* Karanovic, Sidorov & Marmonier, 2015, *Schellencandona cf. tea* Karanovic & Lee, 2012 from groundwaters of the southern part of Primory Krai.

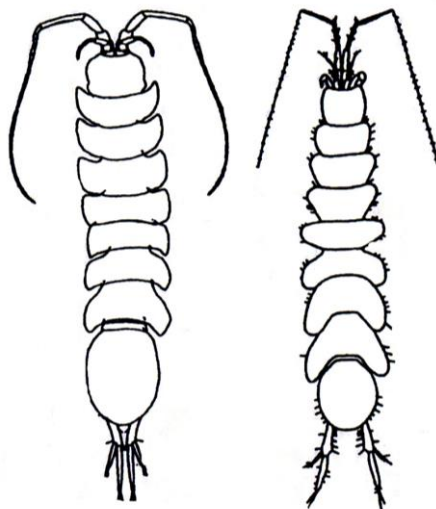


Figure 7. On the left: - Isopoda Janiridae *Mackinia continentalis* Birstein & Ljovuschkin, 1965, from a small cave near Boetc-Kuznetcovo, Far East. On the right: - Isopoda Asellidae *Sibirasellus purpurae* Henry & Magniez, 1993, from a pit-hole, Primory, Far East.

ISOPODA

(Birstein & Ljovuschkin, 1970; Botosaneanu, 1986, 1998; Henry & Magniez, 1993)

Asellidae

The Asellidae are represented by 4 subterranean asellids:

- *Asellus hilgendorffii* polymorph complex of subspecies widespread in epigeal freshwater in Far East and Eastern Asiatic region, pigmented and eyed, with subterranean stygobitic populations ± unpigmented in the Far East, in Korea and Japan.

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The territories around the Japan Sea (Korea, Russian Far East, Sakhalin Island, Japan archipelago) were connected during several Quaternary marine regressions. The existence of common hydrographic systems explains the presence of the same dulcaquicole fauna of *Asellus* which put in the place of the widespread *Asellus aquaticus* in Far East,

- *Asellus primoryensis*, stygobiont, anophthalme and unpigmented from interstitial of the Imbishi, Bikin, Perekatnaya, Toukhe rivers and in springs Sukhoy, Blisky and Bolotny.
- *Sibirasellus dentifer*, microphthalme species from a spring, Ussury basin, Khor region,
- *Sibirasellus parpurae*, anophthalme and unpigmented, from a pit-hole (4 m depth), Yedinka river District, NW of Sikhote-Alin Mountain ridge (fig. 7), related to *Asellus hilgendorffii*.

Janiridae

- *Mackinia continentalis* sampled in the Kuznetcovskaya cave, right bank of the Suchan River, near Boetc-Kuznetcovo (fig. 7).

AMPHIPODA

(Birstein & Borutzky, 1950; Derzhavin, 1927; Holsinger, 1989; Holsinger, & Sidorov, 2006; Sidorov & Holsinger, 2007a, b; Sidorov, 2009, 2010, 2011)

Crangonyctidae

Despite the widespread occurrence of the family Crangonyctidae in the Holarctic region, the majority of species are found in North America, and only a few are known from Eurasia. Just two species from the Far East:

- *Amurocrangonyx arsenjevi* slightly troglomorphic, found again in the type locality, the spring Orekhovy in Khor river basin, tributary of the Ussury, in front of the Okhotsk Sea, and in several springs of the same river basin. The specimens of moderate stygobiomorphic facies, are light reddish in color and eyeless with yellowish pigment in their place.
- *Synurella stadukhini*, collected in a spring of the Inya River, near the northern littoral of the Okhotsk Sea.

Pseudocrangonyctidae

The stygobiont genus *Pseudocrangonyx* inhabits exclusively subterranean freshwater in the Asian-Pacific region: Russian Far East, Korea, northern China and Japan. They are adapted for life in groundwater conditions: body narrow, appendages relatively elongated, eyes and pigmentation lost, sterna respiratory organs presented by humps.

Nine species of *Pseudocrangonyx* inhabits the subterranean waters of the Amur basin (Ussury District), the eastern Manchuria, the Sikhote-Alin Mountain ridge, the Kamchatka Peninsula and the Sakhalin Island.

Genus *Pseudocrangonyx*.

- *Pseudocrangonyx bohaensis* from spring near Fadeevka, Manchuria Mts,
- *P. elenae*, described in 2011 by **D. Sidorov** from a shallow subterranean habitat at the spring of the Solontsovy brook near Shanduy cordon, in the Serebryanka river basin, 44 km north Terney, eastern slope of the Sikhote-Alin Mountain ridge. The biotope consists of coarse limestone, coarse-grained sand, detritus, depth 5-10 cm, temperature 3.0 °C, with slight soil horizon. The biotope is mixed: an aquatic part, similar to the seep described by **D. Culver** (2010) and a terrestrial part corresponding to the MSS where the diplopod Mongoliulidae *Skleroprotopus coreanus* was collected.
- *P. febras* (fig. 8), from a pit-hole, Primory,
- *P. korkishkoorum* hyporheic of the Kedrovaya River in the eastern Manchuria Mts,
- *P. levanidovi* from several springs near Georgievskaya town on the Khor River, and spring of the Arsenyevka river, near Vinogradovka, SW Sikhote-Alin Mountain ridge,
- *P. camtschaticus* from a spring of the Bolsaya River in the Kamchatka Peninsula,
- *P. birsteini* from a spring near Yuzhno-Sakhalinsk, Sakhalin Island, S region,
- *P. relicta* from springs SW Waida Mountain Ridge, Sakhalin Island, middle region,
- *P. susunaensis* from springs on the Susunaisky Mountain ridge, southern region of the Sakhalin Island.

Three new stygobitic *Pseudocrangonyx* were described in 2013 found in springs and related ground water habitats of several river systems, in the southern part of Primorye, belonging to the Japan Sea.

- *P. holsingeri* pumped in hyporheic of the Steklajnuha River,

- *P. sympatricus* pumped in hyporheic of the Kievka River,
- *P. tiunovi* collected from a spring in the Vladivostok suburb.

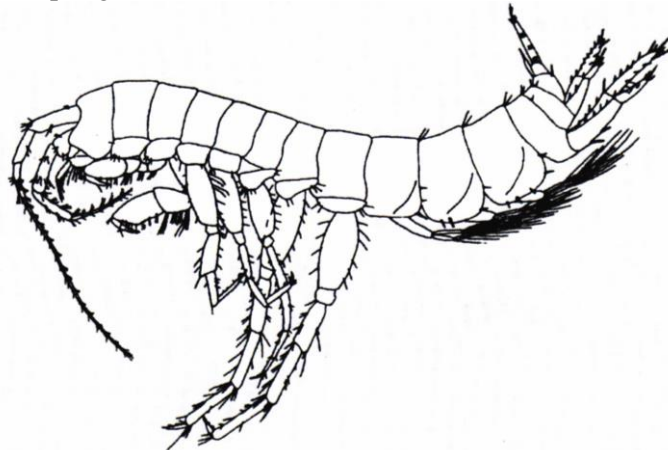


Figure 8. Amphipoda Pseudocrangonyctidae *Pseudocrangonyx febras* Sidorov, 2009, from a pit-hole, Primory, Far East.

Genus *Procrangonyx*.

- *P. primoryensis*, described from a subterranean spring in the cellar of house of Igor Z. Parpura some 200 m from the Yedinka river, and found again in wells in the Yedinka and Samarga river basins, NW of the Sikhote-Alin Mountain ridge (fig. 9).

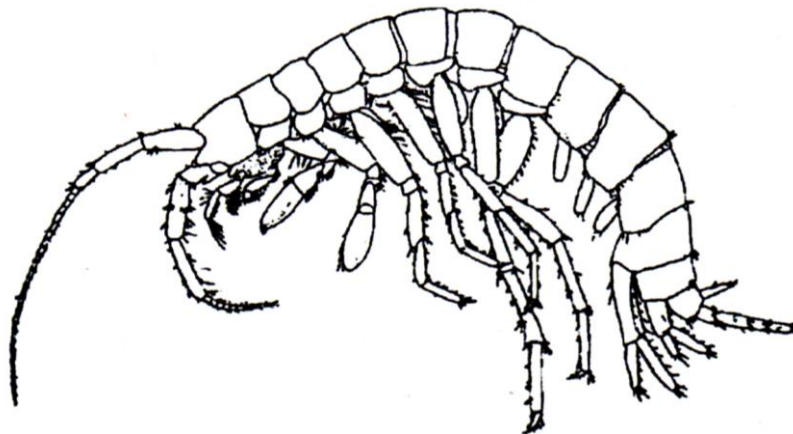


Figure 9. Amphipoda Pseudocrangonyctidae *Procrangonyx primoryensis* Stock & Young Won Jo, 1990, from a pit-hole, Primory, Far East.

Two other *Procrangonyx* inhabit subterranean waters in Japan (*P. japonicus*) and in north of China (*P. limpidus*) (Stock & Jo, 1990; Sidorov, 2010).

Note: - *Procrangonyx stygoedincus* described from a well in the Yedinka River basin is a junior synonym of *P. primoryensis* (Sidorov & Barabanshchikov, 2010).

Eusiridae

Family mainly marine, known in the Palaearctic and in the Australian regions. Two stygomorphic species of the endemic sub-genus *Ganigamoera* were described from subterranean waters of the southeastern part of the Sikhote-Alin Mountain ridge:

- *Paramoera (Ganigamoera) myslenkovi*, wells and hyporheic in the Kievka River basin,
- *P. (G.) tiunovi*, from a spring in the Solontsovaya River basin.

SYNCARIDA

Bathynellidae

Three species of *Bathynella* were found (Birstein & Ljovuchkin, 1967):

- *B. arsenjevi* from Primorsky-Velikan cave, right bank of the Malaza River, tributary of the Suchan, near Vladivostok,
- *B. glacialis* from the Ledjanaka ice-cave, Samara basin, Khabarovsk district,
- *B. gregaria* from Makrushinska cave, near Olga Bay and Vesely Yar.

HYDRACHNIDIA

Twenty two species of interstitial Hydrachnidia and one species from the phalanx Stygothrombidia are known from the Far East. Most of them distributed on the south of the region, three *Wandesia* species are found only in Magadan or Chukchi Autonomous area.

Aturidae

- *Albaxona lunata*, *Aturus insolitus*, *A. similis* from groundwaters of Primory Krai.

Chappuisididae

- *Chappuisides orientalis*, *Uchidastygacarus primoryensis* from groundwaters of Primory Krai.

Feltridae

- *F. aculeata*, *F. cornuta rossica*, *F. japonica* from groundwaters of Primory Krai.

Frontipodopsidae

- *Frontipodopsis cuspidata*, interstitial, the Tigrovaya River, the Partizanskay River basin, Primory Krai.

Hygrobatidae

- *Atractides kotoensis*, interstitial, Primory Krai.

Momoniidae

- *Stygomomonium manchurica*, interstitial, Primory Krai.

Stygothrombiidae

- *Stygothrombium orientalis*, interstitial, the Komarovka River, Ussuri National Park, Primory Krai.

Thyadidae

- *Amerothyasella tiunovae*, interstitial of a small brook, near the Tartar Strait coast, Khabarovsk Krai.

Torrenticolidae

- *Monatractides abei*, *Torrenticola kimichungi*, *T. nipponica*, from groundwaters of Primory Krai.

Wandesiidae

- *Wandesia arctica*, interstitial, Primory Krai, Khabarovsk Krai, Amurskaya Area, Magadan area, Chukchi Autonomous area,
- *W. morozovensis*, interstitial, Morosov brook, tributary of the Kontactovy brook, Magadan area,
- *W. multiseta*, interstitial, the Kulu river, Magadan area,
- *W. polyseta*, interstitial, the Anadyr river, Chukchi Autonomous area,
- *W. rara*, interstitial, Primory Krai,
- *W. reducta*, interstitial, Primory Krai, Jewish Autonomous area, Amurskaya area, Magadan area,
- *W. sokolowi*, interstitial, Primory Krai.

OPILIONES

Sabaconidae

- *Taracus birsteini*, from the Bely Dvorec cave near Suchan, troglobiont. The genus *Taracus* is North American.

DIPLOPODA

Previously the review of cavernicolous diplopods of the Far East by *Elena Mikhailjova* (1997) only two millipede species, troglophile or troglaxene, were known from the Maritime Province (=Primory Krai): the Polydesmidae *Epanerchodus polymorphus* from Yuzhnaya cave, Dalnegorsk District (Mikhailjova, 1993), and the Xystodesmidae *Levizonus thaumasius* from the Khrebtovyi grotto, Partizansk District (Lokshina & Golovatch, 1977).

According to *Mikhailjova* (1997, 2004) ten strictly determined millipede species have been encountered in the karstic caves of the Russian Far East, lying within the Sikhote-Alin Karstic Region. All species are

troglophile at best. No troglobiont have been recorded.

Diplomaragnidae

- *Diplomaragnidae* gen. sp., only larvae and females have been collected in the Barbarisovaya cave, Kedrovaya Pad Reserve, the Bogataya Fanza cave, Khasan District, and in the Sadovaya cave, Dalnegorsk District. Based on these specimens, it appears impossible to attribute this material not only to a definite species but even to a genus, because the erstwhile *Diplomaragna* has just been split into several genera. They do not represent true cave-dwellers.

Polyzoniidae

- *Angarozonium bonum* from the Kolonok cave, Ussuriyskii Reserve; first time found in a cave, this species is common in forests of the Maritime Province.

Julidae

- *Anaulaciulus golovatchi*, from Bogataya Fanza cave, Khasan District; Skazka cave, Kedrovaya Pad Reserve; Drakon and Fakel Entuziastov caves, Shkotovo District; Kolonok cave, Ussuriyskii Reserve. This species is distributed in various types of forest in the central and southern Maritime Province and in North Korea.

- *Pacifiulus amurensis* found in a cave near Izvestkovyi spring, Kedrovaya Pad Reserve, Lisyaya cave, Partizansk District, Spyashchaya Krasavitsa cave, Ussuriyskii Reserve. This species inhabits forest biotopes in the Southern Siberia and in the southern Far East; it has also been recorded in Northeast China.

Mongoliulidae

- *Kopidoiulus continentalis* Golovatch, troglophile species known from ten caves in Maritime Province: Bliznets, Dalnaya, Kuznetsovskaya, Lisyaya, Malenkaya, Skvoznaya caves, Partizansk district; Drakon and Fakel Entuziastov caves, Shkotovo District; Kolonok cave, Ussuriyskii Reserve; Medvezhya cave, Anuchino District. Widespread in the southern part of the Maritime Province in litter and the uppermost soil strata of various forest types; juveniles can occur to 50 cm soil depth. Recorded also in north-eastern China (Murakami, 1990). In Japan the genus *Kopidoiulus* has true troglobionts.

- *Kopidoiulus khasanicus*, described from Bogataya Fanza cave, Khasan District, Gryaznaya cave, Kedrovaya Pad Reserve, and from litter of *Abies holophylla* forest. Eyes absent, body beige, antennae and legs pale.

- *Skleroprotopus coreanus*, one of the most common and abundant species in forests of the southern Russian Far East. The species is widespread all over Korea. Known from 10 caves in the Maritime Province: Priiskovaya cave, Anuchino District; Belyi Parus cave, Dalnegorsk District; Krabbe cave, Khasan District; Mecha Speleologa, Bliznets, Kabarga, Skvoznaya, Malenkaya caves, Partizansk District; Drakon, Fakel Entuziastov cave, Shkotovo District; Spyashchaya Krasavitsa cave, Ussuriyskii Reserve. Colouration of cave-dwelling specimens is dark brown to pale beige.

Xystodesmidae

- *Levizonus thaumasius* (Attems), from Khrebtovyi grotto, Partizansk District. This species is common and abundant in the southern part of Maritime Province.

- *Levizonus* sp. The only female found in the Barbarisovaya cave, Khasan District, cannot be determined to species, although it seems to actually belong to *L. thaumasius*.

Paradoxosomatidae

- *Sichotanus eurygaster*, first record in caves: Bliznets, Dalnaya, Mechta Speleologa, Skvoznaya caves, Partizansk District; Izvestkovaya cave, Khasan District; Kolonok cave, Ussuriyskii Reserve; and Serebryanaya cave, Shkotovo District. Mostly epigeal, common throughout the south of Russian Far East, North Korea and Northeast China.

Polydesmidae

- *Epanerchodus koreanus*, found in the Bogataya Fanza and Skazka caves, Khasan District; Serebryanaya cave, Shkotovo District. The species is widespread outside of caves in southern Maritime Province, southern Japan, Korea, and known from some Korean caves.

- *E. polymorphus*, widespread in southern part of the Maritime Province; it has also been recorded in North Korea. Found in the Barbarisovaya, Gryaznaya, Izvestkovaya caves, Kedrovaya Pad Reserve; Belyi Parus and Yuzhnaya caves, Dalnegorsk District; Dalnaya and Mechta Speleologa caves, Partizansk District; Kolonok cave, Ussuriyskii Reserve; Medvezhya cave, Anuchino District; Tirol cave, Khasan District.

Table 2. Liste of stygobionts* and troglobionts*, stygophiles/troglophiles of the Russian Far East

TRICLADIDA

Planariidae

- **Phagocata coarctata* Arndt, 1922
- Polycelis (Polycelis) elongata* (Zabusova, 1929)
- Polycelis (P.) eurantron* Zabusova, 1936
- Polycelis (P.) karafto* Ijima & Kaburaki, 1916
- Polycelis (P.) polyopsis* Zabusova, 1936
- Polycelis (Seidlia) relictata* (Zabusova, 1929)
- Polycelis (Sorocelides) eudendrocoeloides* Zabusova, 1936

GASTROPODA

Amnicolidae

- **Saganoa* sp.

Hydrobiidae

- **Moria* sp.

COPEPODA

Cyclopidae

- Acanthocyclops bisetosus* (Rehberg, 1880)
- Acanthocyclops vernalis* (Fischer, 1853)
- **Acanthocyclops orientalis* Borutzky, 1966
- Eucyclops serrulatus* (Fischer 1851)

Canthocamptidae

- Bryocamptus zschokkei caucasicus* Borutzky, 1960
- **Epactophanoides udegeicus* Borutzky, 1966

OSTRACODA

- **Nannocandona schornikovi* Karanovic, Sidorov & Marmonier, 2015
- Schellencandona cf. tea* Karanovic & Lee, 2012

SYNCARIDA

Bathynellidae

- **Bathynella arsenjevi* Birstein & Ljovuschkin, 1967
- **Bathynella glacialis* Birstein & Ljovuschkin, 1967
- **Bathynella gregaria* Birstein & Ljovuschkin, 1967

ISOPODA

Asellidae

- Asellus hilgendorffi* Bovallius, 1886
- **Asellus primoryensis* Birstein & Levanidov, 1952
- **Sibirasellus dentifer* (Birstein & Levanidov, 1952)

Janiridae

- **Mackinia continentalis* Birstein & Ljovuschkin, 1965

AMPHIPODA

Crangonyctidae

- **Amurocrangonyx arsenjevi* (Derzhavin, 1927)
- **Stygobromus mikhaili* Sidorov *et al.*, 2010
- **Synurella stadukhini* Derzhavin, 1927

Pseudocrangonyctidae

- **Procrangonyx primoryensis* Stock & Young Won Jo, 1990
- **Pseudocrangonyx birsteini* Labay, 1999
- **Pseudocrangonyx bohaensis* (Derzhavin, 1927)

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Table 2. (Continued)

* <i>Pseudocrangonyx camtschaticus</i> Birstein, 1955
* <i>Pseudocrangonyx elenae</i> Sidorov, 2011
* <i>Pseudocrangonyx febras</i> Sidorov, 2009
* <i>Pseudocrangonyx holsingeri</i> Sidorov & Gontcharov, 2013
* <i>Pseudocrangonyx korkishkorum</i> Sidorov, 2006
* <i>Pseudocrangonyx levanidovi</i> Birstein, 1955
* <i>Pseudocrangonyx relictata</i> Labay, 1999
* <i>Pseudocrangonyx susunaensis</i> Labay, 1999
* <i>Pseudocrangonyx sympatricus</i> Sidorov & Gontcharov, 2013
* <i>Pseudocrangonyx tiunovi</i> Sidorov & Gontcharov, 2013
Eusiridae
* <i>Paramoera</i> (G.) <i>myslenkovi</i> Sidorov, 2010
* <i>Paramoera</i> (G.) <i>tiunovi</i> Sidorov, 2010
HYDRACHNIDIA
Aturidae
<i>Albaxona lunata</i> Kim & Chung, 1996
* <i>Aturus insolitus</i> Semenchenko & Tuzovskij, 2011
Chappuisiidae
* <i>Chappuisides orientalis</i> Semenchenko, 2016
* <i>Uchidastygacarus primoryensis</i> Semenchenko, 2010
Feltriidae
* <i>Feltria aculeata</i> Tuzovskij & Semenchenko, 2009
<i>Feltria cornuta rossica</i> Tuzovskij & Semenchenko, 2009
* <i>Feltria japonica</i> Imamura, 1954
Frontipodopsidae
* <i>Frontipodopsis cuspidata</i> Semenchenko, 2016
Hygrobatidae
* <i>Atractides kotoensis</i> Imamura, 1983
Momoniidae
* <i>Stygomomonium manchurica</i> Semenchenko, 2008
Stygothrombiidae
* <i>Stygothrombium orientalis</i> Tuzovskij, 2010
Thyadidae
* <i>Amerothyasella tiunovae</i> Semenchenko, 2010
Torrenticolidae
<i>Monatractides abei</i> Pešić, Semenchenko & Lee, 2013
<i>Torrenticola kimichungi</i> Pešić, Semenchenko & Lee, 2013
<i>Torrenticola nipponica</i> (Enami, 1940)
Wandesiidae
* <i>Wandesia arctica</i> Tuzovskij, 1988
* <i>Wandesia morozovensis</i> Tuzovskij, 1987
* <i>Wandesia multiseta</i> Tuzovskij, 1987
* <i>Wandesia polyseta</i> Tuzovskij, 1982
* <i>Wandesia rara</i> Tuzovskij, 1990
* <i>Wandesia reducta</i> Tuzovskij, 1987

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Table 2. (Continued)

**Wandesia sokolowi* Semenchenko, 2016

OPILIONES

Sabaconidae

**Taracus birsteini* Ljovuschkin, 1971

DIPLOPODA

Diplomaragnidae

Diplomaragnidae gen. sp.

Julidae

Anaulaciulus golovatchi Mikhaljova, 1982

Pacifiulus amurensis (Gerstfeldt, 1859)

Mongoliulidae

Kopidoiulus continentalis Golovatch, 1979

Kopidoiulus khasanicus Mikhaljova, 1996

Skleroprotopus coreanus Pockock, 1909

Paradoxosomatidae

Sichotanus eurygaster Attems, 1898

Polydesmidae

Epanerchodus polymorphus Mikhaljova & Golovatch, 1981

Epanerchodus koreanus Verhoeff, 1937

Polyzoniidae

Angarozonium bonum (Mikhaljova, 1979)

Xystodesmidae

Levizonus sp.

COLLEMBOLA

Hypogastruridae

**Typhlogastrura korenevskyi* Babenko, 1987

**Typhlogastrura thibaudi* Babenko, 1994

DIPLURA

Campodeidae

**Pacificampa birsteini* Chevrison, 1978

**Pacificampa caesa* Chevrison, 1978

**Plutocampa amurensis* Chevrison, 1978

**Plutocampa methoria* Chevrison, 1978

**Plutocampa mica* Chevrison, 1978

**Plutocampa paurochaeta* Chevrison, 1978

**Plutocampa speophila* Chevrison, 1978

**Stilicampa tiunovi* Chevrison, 1986

COLEOPTERA

Leiodidae

**Fusi nyujwa* Perkovsky, 1989

ORTHOPTERA

Raphidophoridae

Distrammema japonica Blatchley, 1969

Distrammema unicolour Brunner-Wattenwyl, 1888

Tachycines (T.) boldyrevi Uvarov, 1938

PSOCOPTERA

Psyllipsocidae

Psyllipsocus ramburii Selys-Longchamps, 1872

The cave millipede fauna of Siberia is hitherto practically unknown. Only a single specimen of *Diplomaragna* from Irkutsk Area was published by **Kniss** (1991). However, this publication contains a taxonomic error. In addition, the record requires confirmation in the light of new taxonomic knowledge.

COLLEMBOLA

Hypogastruridae

Two troglobitic species, *Typhlogastrura korenevskyi* and *T. thibaudi*, were described of the Far East.

DIPLURA

Campodeidae

Several troglobionts were described by **Chevrisov** (1978, 1986): two *Pacificampa*, five *Plutocampa* and one *Stilicampa* (see Table 2).

COLEOPTERA

Leiodidae

The troglobiont Cholevini *Fusi nyujwa* was described by **Perkovsky** (1989), known from the Bely Dvorec cave of Primory Krai (Fresneda *et al.*, 2011) (see Table 2).

CHIROPTERA

Nine species of bats are found in the caves of the Far East and six in the Sakhalin Island caves.

4 Conclusions

The Russian subterranean fauna of Siberia and Far East distributes amongst 3 zoogeographic groups:

- Centre-Asiatic taxa (Japanese): Asellidae and Janiridae, anophthalmes and unpigmented, recorded from the subterranean waters of the eastern part of the Ussury basin; *Sibirasellus dentifer* and *S. parpurae*, relationship with the *Nipponasellus* from Japan; *Asellus primoriensis*, strong related to the epigeal *A. hilgendorffii*; and *Mackinia continentalis*. Among the terrestrial taxa, *Diestrammena unicolor* and *D. japonica* (Orthoptera, Rhabdophoridae). This group of troglobionts and troglaphiles inhabite the Japanese caves.

- Autochtonous and endemic Far East taxa: *Epactophanoides udegeicus* (Copepoda, Harpacticoida), *Pacificampa birsteini* and *P. caesa* (Diplura, Campodeidae), *Amurocrangonyx arsenjevi* (Amphipoda).

- Widespread old taxa: the troglobiont *Taracus birsteini* (Opiliones), the troglaphile *Psyllipsocus ramburii* (Psocoptera), and the stygobionts *Bathynella gregaria*, *B. arsenjevi* (Syncarida), *Synurella stadukhini*, *Pseudocrangonyx* and *Procrangonyx primoryensis* (Amphipoda).

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