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Integrated conodont and radiolarian biostratigraphy of the upper Norian in Baoshan Block, Southwestern China

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Two significant stratigraphical microfossils, conodonts and radiolarians, are usually used for the Upper Triassic chronostratigraphy. The Baoshan Block was located in eastern Tethys during the Late Triassic where the biostratigraphical data of Upper Triassic are still poorly known. We collected new samples from the Hongyan section (HY) for biostratigraphical study. This 24-m-thick section in Dabaozi Village, Baoshan City, is mainly composed of thin-layered limestones, sandstone and siltstone. The conodont fauna is referred to Sevatian 1 (late Norian), in which the species *Mockina englandi*, *Mockina carinata and Mockina mosheri* morphotype B are first recognized in the Baoshan Block, and thus eastern Tethys. The Norian radiolarian associations are first reported in the Baoshan Block, which correlate with the biozonation of North America and also that proposed for Central Japan. The radiolarian assemblages found in the analysed samples in HY section can be referred to the Sevatian *Betraccium deweveri* Zone. The Baoshan Block is a key area for conodont and radiolarian-based correlations between the Tethys, Japan and North American domains. □ *Baoshan Block, conodont, integrated biostratigraphy, radiolarian, Upper Triassic.*

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Conodonts and radiolarians are both useful and reliable tools for stratigraphical correlation, especially in Upper Triassic sections (Rigo *et al.* 2018). They are more frequently used as primary biostratigraphical tools for the definition of upper Norian and Rhaetian strata and correlations worldwide (Carter & Orchard 2007; Rigo *et al.* 2007, 2012; Giordano *et al.* 2010; Rigo *et al.* 2016). In North America, the base of the Rhaetian Stage is informally placed at the boundary between the radiolarian *Betraccium deweveri* and *Proparvicingula moniliformis* Zones (Carter 1993) or defined by the first occurrence of the conodont *Mockina mosheri* morphotype A (Carter & Orchard 2007; Orchard *et al.* 2007b). Rigo *et al.* (2016) proposed a GSSP candidate section for the base of the Rhaetian Stage in western Tethys in the Pignola-Abriola section, Italy, based on distinctive and well-preserved cosmopolitan conodont and radiolarian faunas.

In eastern Tethys, Baoshan Block, Yunnan Province, by contrast, the research on Upper Triassic conodont biostratigraphy started late and only a few works have been published. In addition, there have been no previous reports of late Norian radiolarian faunas in this area. The first study of Triassic conodont biostratigraphy in Yunnan Province was initiated by Zhong & Jiang (1979) who established eight conodont zones after studying seven sections from different places; however, no conodont zone was proposed for the Upper Triassic. Dong & Wang (2006) established two different conodont biozonations in eastern and western Yunnan Province, respectively. They proposed six conodont zones for Norian in the western Yunnan, including *Epigondolella abneptis abneptis* Zone, *Epigondolella abneptis spatulata* Zone, *'Epigondolella'* (=*Orchardella*) *multidentata* Zone, *'Epigondolella'* (=*Mockina*) *postera* Zone, *'Epigondolella'* (=*Mockina*) *bidentata* Zone and *Parvigondolella*

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andrusovi - Misikella hernsteini Zone; and four Norian conodont zones in the eastern Yunnan Province, including '*Epigondolella' (=Carnepigondolella) pseudodiebeli-Epigondolella abneptis* Zone, *Epigondolella abneptis* Zone, *'Epigondolella' (=Orchardella) multidentata* Zone and *Misikella hernsteini* Zone. This is the first report of the occurrence of conodonts *Orchardella multidentata*, *Parvigondolella andrusovi* and *Misikella hernsteini* in Yunnan Province. Nevertheless, the classification of *Orchardella multidentata* is controversial and there are no images or descriptions of these latter two species in their study. Wang & Dong (1985) proposed two conodont biozones for the Norian stage in Baoshan Block: the '*Epigondolella*' (=*Mockina*) *postera* and '*Epigondolella*' (=*Mockina*) *bidentata* Zones.

Here, we collected samples from Hongyan (HY) section for new biostratigraphical study in the Baoshan area, and an attempt to propose a more detailed conodont and radiolarian biostratigraphical scheme. Some conodont and radiolarian species are reported for the first time in this area, demonstrating their widespread distribution.

Geological setting

In Yunnan Province, southwest China, four blocks, that is Tengchong, Baoshan, Lanping-Simao and Chuxiong blocks, are separated by several deep fault zones (suture zones). The Baoshan Block is located in southwest China and thought to be located in eastern Tethys Ocean as a part of relatively large Sibumasu Block during the Late Triassic (Wopfner 1996; Ueno 2003). The block is bounded by the Nujiang-Longling-Luxi Fault to the west and the Lancangjiang-Kejie-Nandinghe Fault to the east (Fig. 1; Wang *et al.* 2001). In common with other parts of the Cimmerian continent, it is considered to be a part of the Gondwana Supercontinent before the middle Early Permian (Metcalfe 1996; Jin 2002; Wang & Sugiyama 2002; Sone & Metcalfe 2008; Huang *et al.* 2009) and collided with the Simao-Indochina Block during the Early Mesozoic (Metcalfe 2006). By contrast, Li *et al.* (2005) proposed that the Baoshan Block collided with Simao Block in the Late Permian and then it drifted northward with the Burma-Thailand Block until the Late Triassic. The Late Triassic paleopole suggests a low paleolatitude of ~15°N in the Northern Hemisphere for the Sibumasu Block during the Late Triassic (Zhao *et al.* 2015).

The Triassic System in Baoshan Block is composed of the Middle Triassic Hewanjie Formation, the Upper Triassic Niuhetang Formation, Dashuitang Formation and Nanshuba Formation in stratigraphical order (Wang *et al.* 2001). In the study region, the Niuhetang Formation is mainly composed of volcanics, which are disconformably overlain by the Dashuitang and Nanshuba formations. The Dashuitang Formation, which consists of thick and thin carbonate layers, is nearly 210 m thick in the study area. The Nanshuba Formation is more than 90 m thick and is composed of thin-layered limestones and sandstones (Wang & Dong 1985). There is an apparent lithologic change within Nanshuba Formation, which indicates a change of sedimentary environment. The lower part of this formation is mainly composed of thin-layered limestones and micrites, while the upper part is dominated by sandstones and mudstones with only few micrites and limestone interlayers. Wang & Dong (1985) found conodont species, such as '*Epigondolella*' (=*Mockina*) *postera*, '*Epigondolella*' (=*Orchardella*) *multidentata* and '*Epigondolella' abneptis*, in Dashuitang Formation; conodont '*Epigondolella*' (=*Mockina*) *bidentata* was found in Nanshuba Formation.

The ca. 24-m-thick Hongyan (HY) section in Dabaozi Village, Baoshan City (Fig. 1), is mainly composed of limestones and clastic rocks of the Nanshuba Formation. The 13-m-thick lower part of this section mainly consists of thin-layered limestone; the upper part of the section consists of siltstone and limestone with interlayers of sandstones (Fig. 2).

Material

Twelve carbonate rock samples named HY (each sample weighed about 2 kg) were collected for biostratigraphical research from the 24-m-thick HY section (Fig. 2). A total of 156 conodont elements were found, including 133 pectiniform elements and 23 ramiform elements. Conodonts show a Color Alteration Index (CAI) of 3. Abundant radiolarians were found in sample HY-Y6. All the material was picked and examined under a microscope. All the micrographs of conodonts were taken by a scanning electron microscope (Fig. 3). The specimens are deposited in the Department of Geoscience, University of Padova (Italy). Micrographs of the specimens of radiolarians (Figs 4, 5) were also taken by a scanning electron microscope, at the Centre 'Climate Change and Biodiversity in Lakes and Wetlands' of Arpa Umbria, Perugia (Italy), in collaboration with Dr. Rosalba Padula, and they are deposited in the Department of Physics and Geology, University of Perugia (Italy).

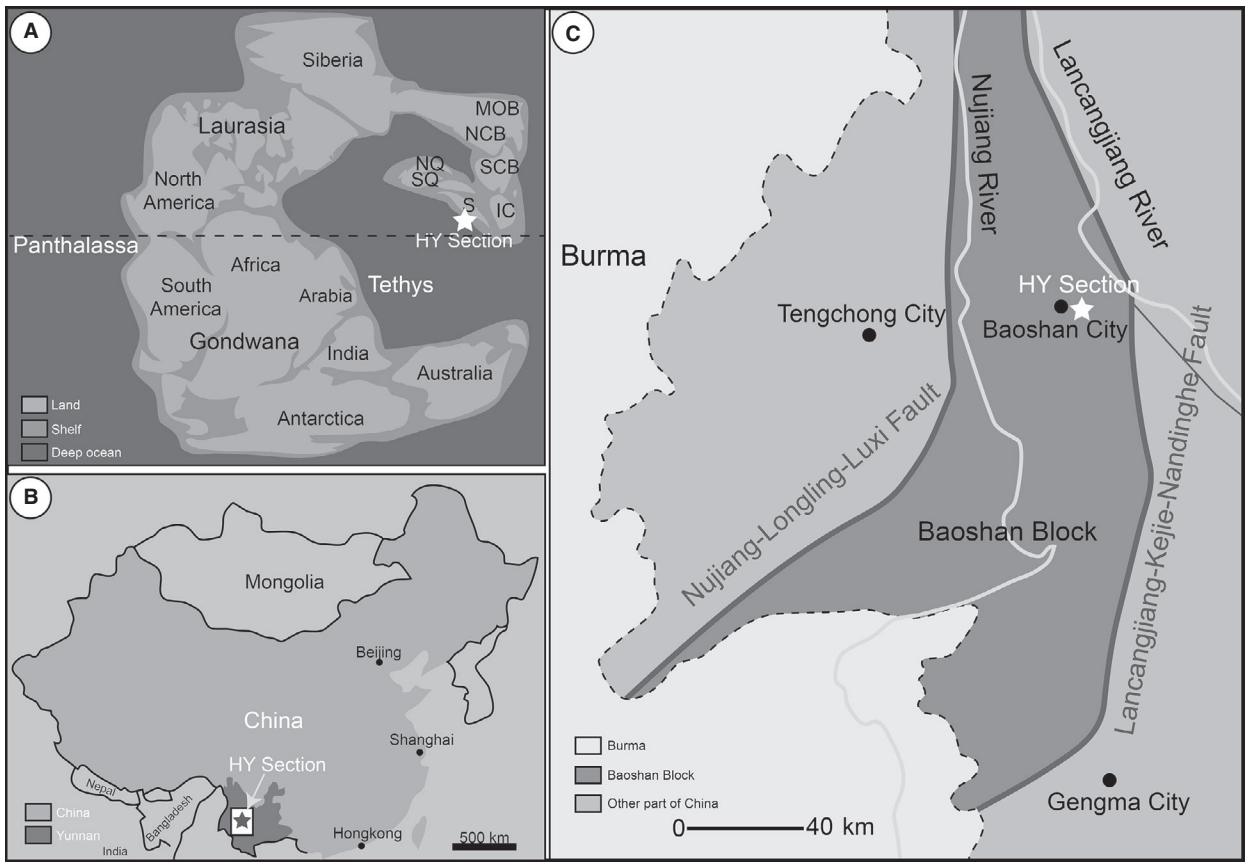

Fig. 1. A, global palaeogeographical map. S: Sibumasu, IC: Indochina, MOB: Mongolian Block, NCB: North China Block, SCB: South China Block, NQ: North Qiangtang, SQ: South Qiangtang; B, location of the Hongyan (HY) section in China; C, detailed map showing the location of the HY section.

Biostratigraphy

Conodont biostratigraphy

All the conodonts were collected from thin-layered limestones in Nanshuba Formation, Hongyan (HY) section. The formation yields numerous well-preserved conodont elements from the samples in ascending order: HY-Y10, HY-Y9, HY-Y8, HY-Y7, HY-Y6, HY-Y5, HY-Y3, HY-Y2, HY-Y0 (Fig. 2).

In the 24-m-thick HY section, the species *Mockina bidentata* occurs at the bottom and ranges into the upper part of the section, about 3 m below the topmost limestone layer. *Mockina bidentata* is a small and slender species with a relatively short platform and two prominent denticles on the anterior margins. Sometimes, an accessory node may be developed on one side (Fig. 3). *Mockina mosheri* morphotype B also present throughout the most part of the section. *M. mosheri* morphotype B has five or more than five carinal denticles and there are several nodes on its one or both lateral margins (Orchard 1994). *Mockina englandi* is characterized by two thick denticles on the anterior part of the element and symmetrically arranged (pairs of) nodes on the platform margins (Fig. 3); *Mockina carinata* is instead short with two large denticles on one anterior margin and one large denticle on the other margin, and several nodes on the posterior margins (Fig. 3). But there are also some atypical *M. carinata* found in HY section (Fig. 3) characterized by one more accessory nodes before the two prominent denticles. The only one *Zieglericonus* sp. is poorly preserved in the HY section; and the *Norigondolella steinbergensis* was broken but is still easily distinguishable (Fig. 3). *Mockina* sp. (Fig. 3) has two large denticles on the anterior margin with a developed accessory denticle, several nodes on the posterior platform margins, the platform is tapered and wedge-shaped and the pit is centrally located.

The occurrence of *M. bidentata* and the absence of typical late Norian conodont elements such as

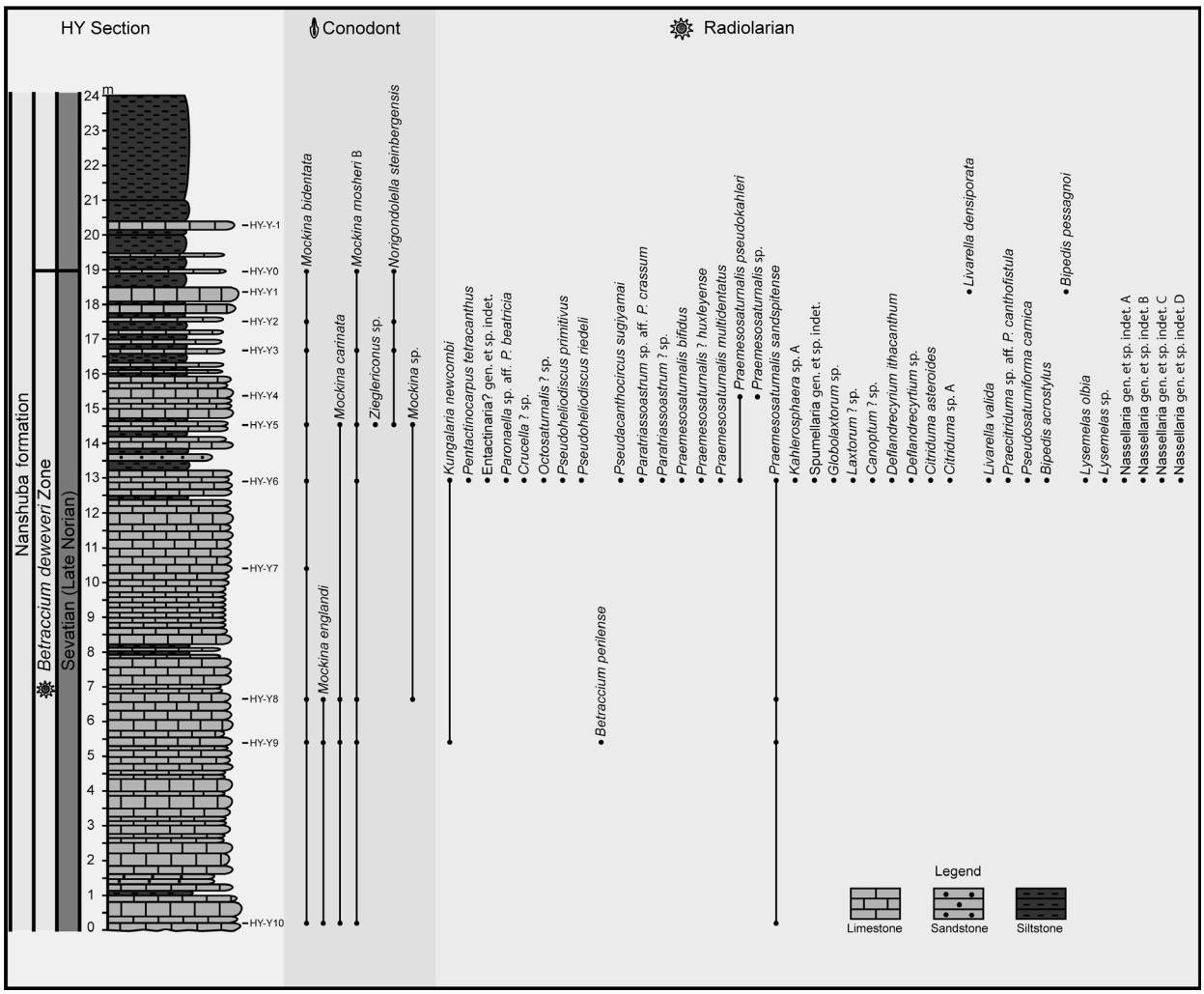

Fig. 2. Stratigraphical log of the Hongyan section, showing lithology and distribution of conodonts and radiolarians; HY-Y10 to HY-Y-1 are sample positions.

Parvigondolella andrusovi and *Misikella hernsteini* indicate an age of Sevatian 1 base on the latest Upper Triassic conodont biozonation of Tethys (Rigo *et al.* 2018). Moreover, according to the conodont biozonation of North America (Moix *et al.* 2007; Orchard *et al.* 2007b; Rigo *et al.* 2018), this conodont association may range from upper Norian to lower Rhaetian, but the absence of *M. mosheri* morphotype A in HY section indicates that the age of this conodont association is still Sevatian.

Radiolarian biostratigraphy

In addition, Radiolarians were found in HY section. Six samples yield very well-preserved radiolarians that are in stratigraphical order: HY-Y10, HY-Y9, HY-Y8, HY-Y6, HY-Y4, HY-Y1 (Fig. 2). The sample HY-Y6 contains a very rich and interesting radiolarian fauna. It contains many species that are already described in the previous literature, but some undescribed species are also present. These taxa are noted under open nomenclature. The range and occurrence chart for radiolarians of HY section are illustrated in Figure 6.

The radiolarian associations conform well with the biozonation proposed by Carter (1993), consisting of radiolarian assemblage zones biochronologically correlated with the North America ammonoid zonation proposed by Tozer (1979), and also closely equivalent to the biozonation proposed by Sugiyama (1997), from Central Japan. According to O'Dogherty *et al.* (2009), however, the ranges of the genera which characterize the HY section assemblages are not in agreement with the coexistence of some taxa; for example, *Lysemelas* Sugiyama (Alaunian-Sevatian) occurs together with *Globolaxtorum* Carter,

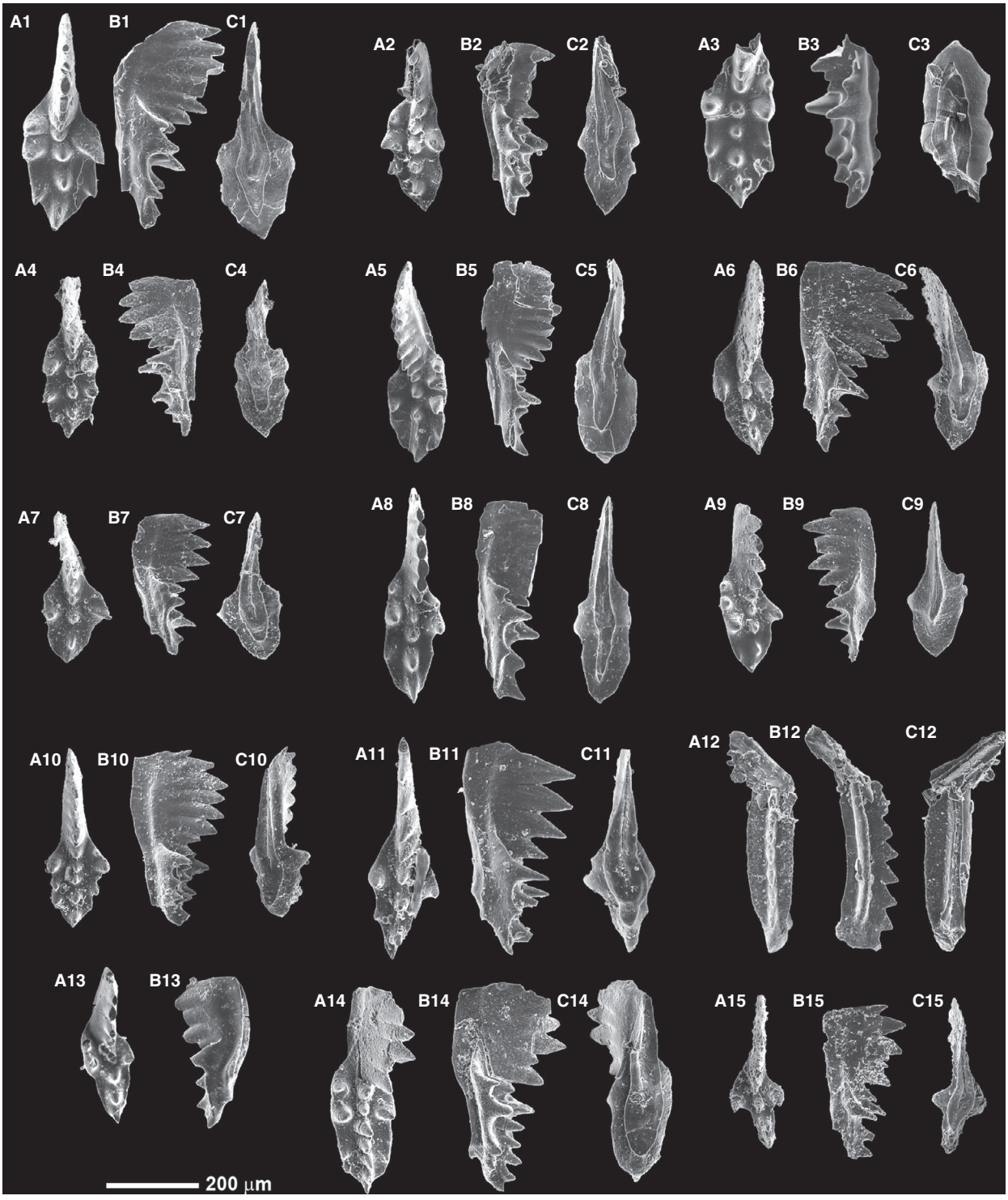

Fig. 3. Conodont species from Hongyan (HY) section; A, upper view; B, lateral view; C, lower view. 1, 2, *Mockina carinata*, HY-Y10; 3, *Mockina mosheri* morphotype B, HY-Y10; 4, *Mockina englandi*, HY-Y10; 5, *Mockina carinata*?, HY-Y10; 6, *Mockina bidentata*, HY-Y9; 7, *Mockina* (juvenile), HY-Y9; 8, *Mockina mosheri* morphotype B, HY-Y8; 9, *Mockina carinata*?, HY-Y8; 10, 11, *Mockina* sp., HY-Y6; 12, *Norigondolella steinbergensis*, HY-Y5; 13, *Mockina bidentata*, HY-Y0; 14, *Mockina mosheri* morphotype B, HY-Y5; 15, *Mockina bidentata*, HY-Y9.

Kungalaria Dumitrica & Carter, *Paronaella* Blome, *Praecitriduma* Kozur, *Pseudacanthocircus* Kozur & Mostler, which are referred by O'Dogherty *et al.* (2009) only to the Rhaetian. In ascending stratigraphical order, the recovered radiolarian assemblages are as follows.

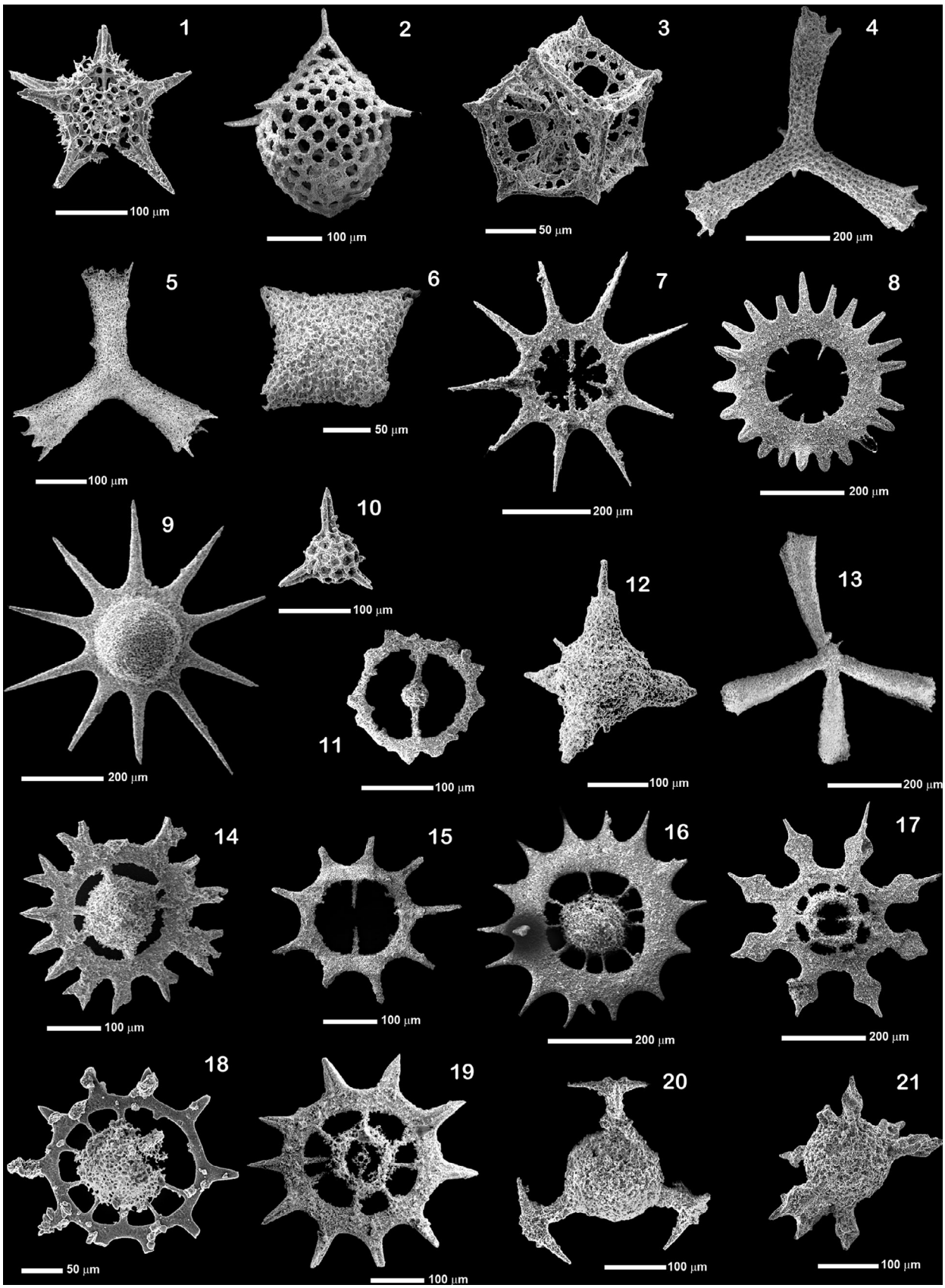
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Fig. 4. Scanning electron micrographs of radiolarians (entactinarians and spumellarians) from HY-Y9 and HY-Y6. Taxa are figured with family order. 1, *Kungalaria newcombi* Dumitrica & Carter, HY-Y9; 2, *Pentactinocarpus tetracanthus* Dumitrica, HY-Y6; 3, *Entactinaria*? gen. et sp. indet., HY-Y6; 4. *Paronaella* sp. aff. *P. beatricia* Carter, HY-Y6; 5, *Paronaella* sp. aff. *P. beatricia* Carter, HY-Y6; 6, *Crucella*? sp., HY-Y6; 7, *Octosaturnalis*? sp., HY-Y6; 8, *Pseudoheliodiscus primitivus* (Kozur & Mostler), HY-Y6; 9, *Pseudoheliodiscus riedeli* Kozur & Mostler, HY-Y6; 10, *Betraccium perilense* Carter, HY-Y9; 11, *Pseudacanthocircus sugiyamai* Tekin, HY-Y6; 12, *Paratriassoastrum*sp. aff. *P. crassum* sensu Carter 1993, HY-Y6; 13, *Paratriassoastrum*? sp., HY-Y6; 14, *Praemesosaturnalis bifidus* (Kozur & Mostler), HY-Y6; 15, *Praemesosaturnalis*? *huxleyense* Carter, HY-Y6; 16, *Praemesosaturnalis multidentatus* (Kozur & Mostler), HY-Y6; 17, *Praemesosaturnalis pseudokahleri* Sugiyama, HY-Y6; 18, *Praemesosaturnalis sandspitense* (Blome), HY-Y9; 19, *Praemesosaturnalis sandspitense* (Blome), HY-Y6; 20.*Kahlerosphaera* sp. A *sensu* Carter 1993, HY-Y6; 21, *Spumellaria* gen. et sp. indet., HY-Y6.

Sample HY-Y10. – Yields some specimens of *Praemesosaturnalis sandspitense* (Blome) and spumellarian gen. et sp. indet. It also contains siliceous sponge spicules and fish teeth.

Sample HY-Y9. – Yields *Betraccium perilense* Carter, *Praemesosaturnalis sandspitense* (Blome), *Kungalaria newcombi* Dumitrica & Carter, spumellarian gen. et sp. indet. It contains siliceous sponge spicules, different in shape from the previous sample, and holothurian sclerites.

Sample HY-Y8. – Yields only *Praemesosaturnalis sandspitense* (Blome) and Spumellarian gen. et sp. indet.

Sample HY-Y6. – Yields a very rich assemblage with many different taxa: *Kungalaria newcombi* Dumitrica & Carter, *Pseudacanthocircus sugiyamai* Tekin, *Praemesosaturnalis bifidus* (Kozur & Mostler), *Praemesosaturnalis huxleyense* Carter, *Praemesosaturnalis multidentatus* (Kozur & Mostler), *Praemesosaturnalis pseudokahleri* Sugiyama, *Praemesosaturnalis sandspitense* (Blome), *Kahlerosphaera* sp. A *sensu* Carter (1993), *Pseudoheliodiscus primitivus* (Kozur & Mostler), *Pseudoheliodiscus riedeli* Kozur & Mostler, *Pseudosaturniforma carnica* Kozur & Mostler, *Paratriassoastrum* sp. aff. *P. crassum sensu* Carter (1993), *Deflandrecyrtium ithacanthum* (Sugiyama), *Praecitriduma* sp. aff. *P. canthofistula* Carter, *Citriduma asteroides* Carter, *Citriduma* sp. A *sensu* Carter (1993), *Livarella valida* Yoshida, *Lysemelas olbia* Sugiyama, *Pentactinocarpus tetracanthus* Dumitrica, *Bipedis acrostylus* Bragin, *Bipedis* sp., *Globolaxtorum* sp. Four uncertain nassellarian taxa are indicated with open nomenclature: Nassellarian gen. et sp. indet. A, B, C, D.

Sample HY-Y4. – Yields fragments of *Praemesosaturnalis pseudokahleri* Sugiyama and *Praemesosaturnalis* sp.

Sample HY-Y1. – Yields *Bipedis pessagnoi* (Yeh & Cheng), *Livarella densiporata* Kozur & Mostler and fish teeth.

The radiolarian assemblages in all of the analysed samples can be referred to the Sevatian *Betraccium deweveri* Zone, U.A. 1, according to Carter (1993) and to the upper part of TR8A *Praemesosaturnalis multidentatus* group Lowest occurrence Zone, TR8B *Praemesosaturnalis pseudokhaleri* group Lowest Occurrence Zone and lower part of TR8C Skirt F Lowest Occurrence Zone, according to Sugiyama (1997). All of these biozones are referred to the upper Norian (Carter 1993; Sugiyama 1997) and lower Rhaetian only for TR8C (Sugiyama 1997). The section lacks the most representative form *Betraccium deweveri* Pessagno & Blome.

Discussion

Conodonts

The first occurrence of *Mockina bidentata* marks the beginning of Sevatian 1 in Tethys region (Rigo *et al.* 2018). In Pizzo Mondello section, Italy, it occurs within Sevatian and ranges into the *Misikella hernsteini* Zone (Mazza *et al.* 2012; Onoue *et al.* 2018), a similar distribution to that at Silická Brezová (Slovakia; Channell *et al.* 2003). However, *M. bidentata* extends into the *Misikella posthernsteini* Zone in Steinbergkogel, Austria (Krystyn & Kuerschner 2005), and in Pignola-Abriola Section, Lagonegro Basin, Southern Italy (Bazzucchi *et al.* 2005; Rigo *et al.* 2005, 2016; Karádi *et al.* 2019). In Baja, North America, *M. bidentata* ranges upwards into the upper part of *M. mosheri* Zone (early Rhaetian) and it is associated with *Proparvicingula moniliformis* radiolarian Zone of Assemblage 2c (Orchard *et al.* 2007b).

Mockina mosheri morphotype A was reported by Orchard (1991) as being typical species from the *Cassianella* beds of Tyaughton Creek in south-central British Columbia (Umhoefer & Tipper 1998), the type section for the *Cochloceras amoenum* Zone (Tozer 1994; Orchard *et al.* 2007a). *Mockina mosheri* morphotype B was defined by Orchard (1994), and it differs from the *M. mosheri* morphotype A in bearing several nodes on one or both posterior part of lateral

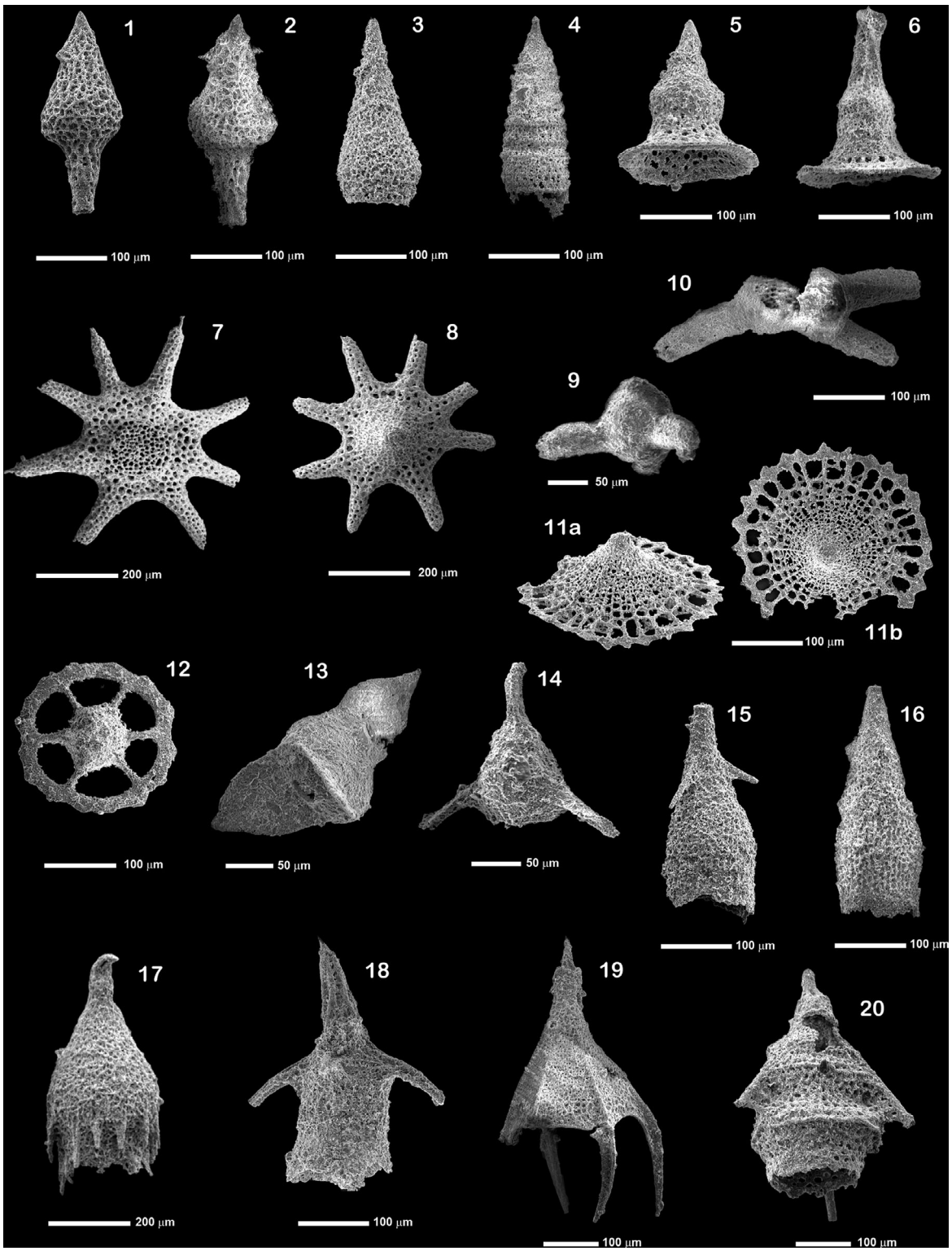

Fig. 5. Scanning electron micrographs of upper Norian (Sevatian) radiolarians (nassellarians) from samples HY-Y6 and HY-Y1. Taxa are figured with family order. 1, *Globolaxtorum* sp., sample HY-Y6; 2, *Globolaxtorum* sp., HY-Y6; 3, *Laxtorum*? sp., HY-Y6; 4, *Canoptum*? sp., HY-Y6; 5, *Deflandrecyrtium ithacanthum* (Sugiyama), HY-Y6; 6, *Deflandrecyrtium* sp., HY-Y6; 7, *Citriduma asteroides* Carter, HY-Y6; 8, *Citriduma* sp. A *sensu* Carter 1993, HY-Y6; 9, *Livarella densiporata* Kozur & Mostler, HY-Y1; 10, *Livarella valida* Yoshida, HY-Y6; 11a, b, *Praecitriduma* sp. aff. *P. canthofistula* Carter, HY-Y6; 12, *Pseudosaturniforma carnica* Kozur & Mostler, HY-Y6; 13, *Bipedis acrostylus* Bragin, HY-Y6; 14, *Bipedis pessagnoi* (Yeh & Cheng), HY-Y1; 15, *Lysemelas olbia* Sugiyama, HY-Y6; 16, *Lysemelas* sp., HY-Y6; 17, Nassellarian gen. et sp. indet. A, HY-Y6; 18, Nassellarian gen. et sp. indet. B, HY-Y6; 19, Nassellarian gen. et sp. indet. C, HY-Y6; 20, Nassellarian gen. et sp. indet. D, HY-Y6.

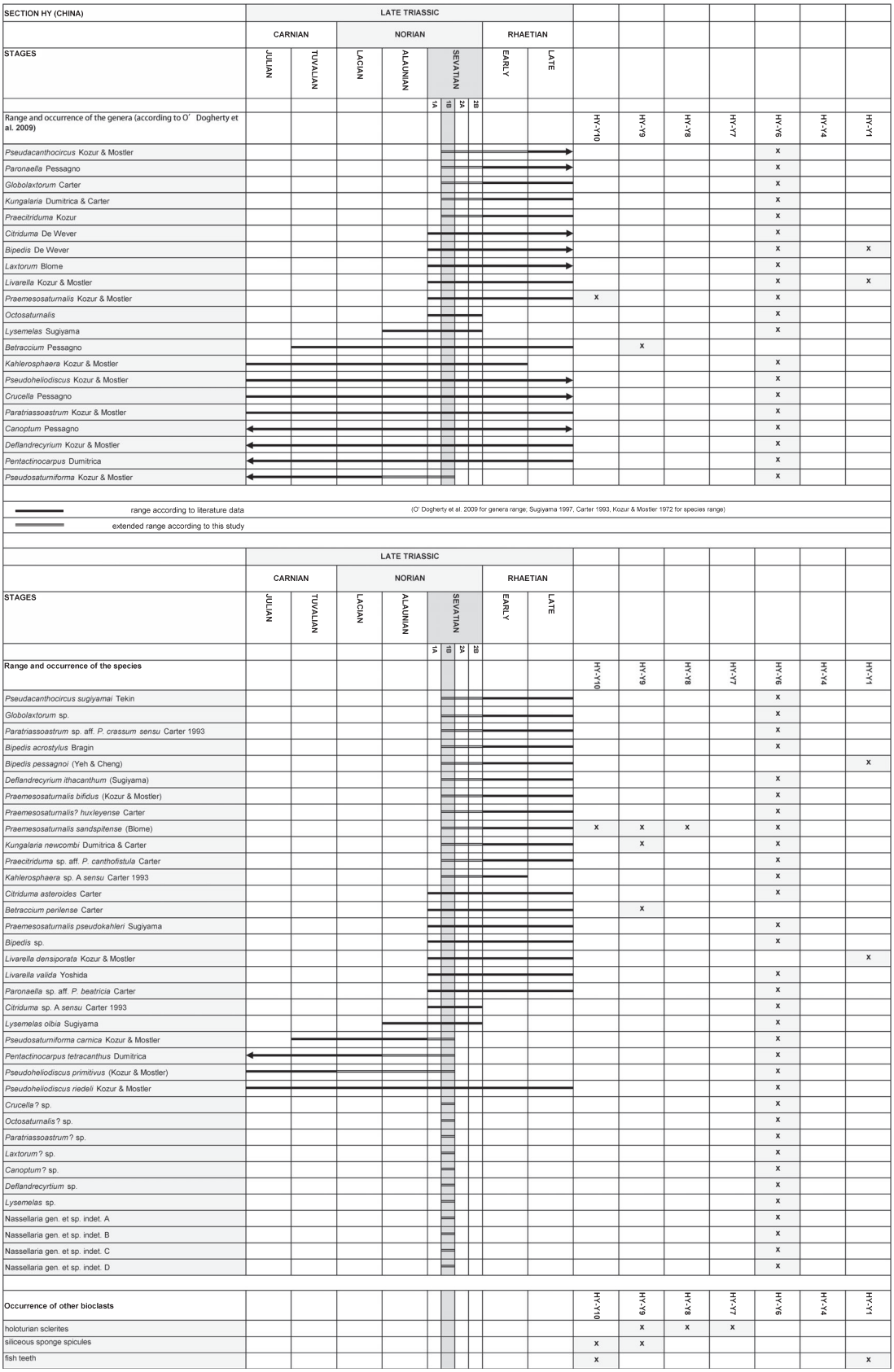

Fig. 6. The range and occurrence of Late Triassic radiolarians in HY section. Stratigraphical ranges of radiolarians are after O'Dogherty et al. (2009) for genera range; Sugiyama (1997), Carter (1993), Kozur & Mostler (1972) for species range.

margins. Later, Orchard *et al.* (2007a) described a new strongly elongate morphotype of *M. mosheri* (i.e. morphotype C) that is characterized by 7–9 carinal denticles. The Rhaetian age of *M. mosheri* Zone is well established in North America. However, the occurrence of *M. mosheri* morphotype B is earlier than the *Mockina mosheri* Zone in Kennecott Point, Haida Gwaii and it appeared in the upper part of *Betraccium deweveri* Zone (Carter & Orchard 2007). *Mockina mosheri* morphotype B is also common in Pucara Group, Peru; Sandilands Formation, Tyaughton Group, Lewes River Group and Bocock Limestone in Canada and Gabbs Formation in USA (Orchard 1994). In Tethys, *M. mosheri* morphotype B has been documented in Austria in older strata than in North America (Krystyn *et al.* 2007).

Mockina englandi was defined by Orchard (1991) at Lewes River, Yukon Territory. It ranges into the upper part of *Proparvicingula moniliformis* Zone in Baja (Orchard *et al.* 2007b), North America, but it occurs more earlier in late Norian in Steinbergkogel, western Tethys (Krystyn *et al.* 2007). *Mockina carinata* is common in North America, and it occurs from Norian to Rhaetian (Carter & Orchard 2007; Orchard *et al.* 2007b). In western Tethys (Europe), *Mockina carinata* was also reported from the Seefeld Formation in Tirol (Western Northern Calcareous Alps) (Donofrio *et al.* 2003). These two species also occur in the HY section and documented for the first time in eastern Tethys (Baoshan Block).

The cosmopolitan element *Norigondolella steinbergensis* is a long-ranged species, from middle Norian to late Rhaetian, which have been recorded in different places. In Pizzo Mondello section, Italy, *N. steinbergensis* ranges from middle Norian to upper Norian but it occurs in *Misikella ultima* Zone in Hungary (Pálfy *et al.* 2007). Similarly, in Haida Gwaii, North America, *N. steinbergensis* extends to the Triassic–Jurassic boundary transition, above the last appearance of *M. posthernsteini* (Tipper *et al.* 1994). In HY section, the first occurrence of *N. steinbergensis* is at the position of sample HY-Y5 within the Sevatian. However, *N. steinbergensis* seems to be influenced by temperatures, preferring cooler and/or deeper water, and its distributions might be thus affected by its lifestyle (Trotter *et al.* 2015).

The conodont assemblage, including *M. bidentata*, *M. mosheri* morphotype B, *M. englandi* and *M. carinata*, from HY section in eastern Tethys region also has been reported in western Tethys, but it is more common in North America. The conodont fauna in HY section (Baoshan Block) indicates that the distribution of *M. mosheri* morphotype B, *M. englandi* and *M. carinata* is worldwide, instead of endemic and thus they can be useful index-species for biozones with global extent.

Radiolarians

Comparison with upper Sevatian Radiolarian biozonation of Carter (1993) from Queen Charlotte Islands, British Columbia (North America). – According to the radiolarian biozonation of Carter (1993) for the upper Norian-Rhaetian, the *Betraccium deweveri* Zone (U.A. 1 – upper Sevatian) is characterized by the presence of *Betraccium deweveri* Pessagno & Blome and *Betraccium maclearni* Pessagno & Blome, exclusively restricted to this radiolarian zone. In Carter's radiolarian biozonation, some taxa range from the *Betraccium deweveri* Zone crossing the Norian-Rhaetian Boundary (NRB), such as *Praemesosaturnalis gracilis* (Kozur & Mostler), *Pantanellium fosteri* Pessagno & Blome, *Praemesosaturnalis sandspitense* (Blome), *Betraccium inornatum* Blome, *Bipedis acrostylus* Bragin, *Livarella densiporata* Kozur & Mostler.

The taxa common with HY section are mainly of the genus *Praemesosaturnalis* Kozur & Mostler, but also *Betraccium perilense* Carter, *Citriduma asteroides* Carter, *Citriduma* sp. A *sensu* Carter, *Praecitriduma* sp. aff. *P. canthofistula* Carter, *Bipedis acrostylus* Bragin, *Livarella densiporata* Kozur & Mostler and *Kungalaria newcombi* Dumitrica & Carter are present.

Comparison with upper Sevatian Radiolarian biozonation of Sugiyama (1997) from southwestern Mino Terrane (Central Japan). – The radiolarian biozonation of Sugiyama (1997) established 20 zones, ranging from the Permian to Jurassic, using primary marker taxa. For the upper Norian, the Sevatian zones are TR8A, TR8B and the lower part of TR8C.

TR8A: *Praemesosaturnalis multidentatus* group Lowest occurrence Zone is characterized by the following taxa: *Praemesosaturnalis multidentatus* (Kozur & Mostler), *Praemesosaturnalis bifidus* (Kozur & Mostler), *Praemesosaturnalis decilobum* (Carter), *Praemesosaturnalis gracilis* (Kozur & Mostler), *Ayrtonius elizabethae* Sugiyama, *Bipedis acrostylus* Bragin, *Blomella megasphaera* Sugiyama, *Braginella rudis* (Bragin), *Sarla vetusta* Pessagno and *Capnuchosphaera neosagaris* Sugiyama. In the upper part of the zone, there is the first occurrence of *Betraccium deweveri* Pessagno & Blome and *Dreyericyrtium ithacanthum* Sugiyama, now *Deflandrecyrtium ithacanthum* (Sugiyama).

TR8B: *Praemesosaturnalis pseudokhaleri* group Lowest occurrence Zone is characterized by the following taxa: *Praemesosaturnalis pseudokhaleri*

Sugiyama, *Citriduma asteroides* Carter, *Haekelicyrtium takemurai* Yeh & Cheng, *Globolaxtorum hullae* (Yeh & Cheng). Different species of *Praemesosaturnalis* are abundant in the entire interval, and species of *Betraccium* and *Livarella* gradually increase in abundance upward.

TR8C: Skirt F Lowest Occurrence Zone is characterized in its lower part (Norian) by the first appearance of *Canoptum rhaeticum* Kozur & Mostler and the acme of *Betraccium deweveri* Pessagno & Blome, *Bipedis acrostylus* Bragin, *Hagiastrum* (?) *pacificum* Sugiyama and *Dreyericyrtium* (?) *carterae* (Yeh & Cheng). The upper part of the zone is characterized by exclusively Rhaetian taxa as *Dreyericyrtium trispinosum* (Carter), *Haeckelicyrtium karcharos* Carter, *Paronaella pacofiensis* Carter and *Risella tledoensis* Carter. The species of *Praemesosaturnalis* rapidly decrease in abundance in the upper part of the zone.

HY: section yields some common taxa with TR8A, TR8B and TR8C zones. *Praemesosaturnalis bifidus* (Kozur & Mostler), *Praemesosaturnalis multidentatus* (Kozur & Mostler), *Praemesosaturnalis pseudokhaleri* Sugiyama, *Deflandrecyrtium ithacanthum* Sugiyama, *Citriduma asteroides* Carter, *Bipedis acrostylus* Bragin and *Lysemelas olbia* Sugiyama are the common marker.

The first appearance of *Lysemelas olbia* Sugiyama is in TR7 *Lysemelas olbia* Lowest occurrence Zone, but its range is from TR7 to TR8C.

Comparison with The GSSP candidate Pignola-Abriola section, Southern Apennines (Italy). – The Pignola-Abriola section (Southern Apennines, Italy), a GSSP candidate section for the base of the Rhaetian Stage, is characterized by similar assemblages in the part of the section around the proposed NRB – Norian/Rhaetian Boundary (Rigo *et al.* 2016; Bertinelli *et al.* 2016). The radiolarian assemblage in the samples just below the NRB is represented by *Betraccium deweveri* Pessagno & Blome, *Praemesotaturnalis gracilis* Kozur & Mostler, *Tetraporobrachia* sp. aff. *T. composita* Carter, *Ayrtonius elizabethae* Sugiyama, *Citriduma* sp. A *sensu* Carter (1993), *Globolaxtorum* sp. cf. *G. hullae* (Yeh & Cheng), *Lysemelas* sp. cf. *L. olbia* Sugiyama, *Livarella valida* Yoshida and *Livarella* sp. *sensu* Carter (1993) (Giordano *et al.* 2010). The presence of *Globolaxtorum* sp. cf. *G. hullae* Yeh & Cheng in this assemblage is atypical, because the genus *Globolaxtorum* is usually referred only to the *Proparvicingula moniliformis* and *Globolaxtorum tozeri* zones (O'Dogherty *et al.* 2009). A different radiolarian assemblage, just above the proposed NRB, is referable to the *Proparvicingula moniliformis* Zone, Assemblage 1 and 2, Subassemblage 2a (U.A. 2-8, Carter 1993), for the presence of *Fontinella primitiva* Carter, *Praemesosaturnalis* sp. cf. *P. sandspitense* (Blome), *Globolaxtorum* sp. cf. *G. hullae* Yeh & Cheng and *Livarella densiporata* Kozur & Mostler (Bazzucchi *et al.* 2005; Giordano *et al.* 2010, 2011).

Some taxa of the HY section are common to both the assemblages, but as for the Pignola-Abriola section, the integrated biostratigraphy with conodonts can refer the radiolarian assemblage to the *Betraccium deweveri* Zone (U.A. 1, Carter 1993).

Conclusions

New, integrated, conodont and radiolarian data from HY section (Baoshan Block) indicate as follows: (1) the conodont faunas are referred to Sevatian 1 (late Norian); (2) the species *Mockina englandi*, *Mockina carinata* and *Mockina mosheri* morphotype B are first recognized in the Baoshan Block, Eastern Tethys, indicating their worldwide distribution; and, moreover; (3) this is the first report of a Norian radiolarian fauna in Baoshan area and it is referred to the *Betraccium deweveri* Zone (*sensu* Carter 1993). The integrated conodont-radiolarian biostratigraphy poses questions about the distributions of some radiolarian genera (e.g. *Globolaxtorum, Kungalaria, Paronaella, Praecitriduma* and *Pseudacanthocircus*).

Furthermore, the Baoshan Block is a key area for the equivalences of not only between conodonts and radiolarians zones, but also correlation between the western to eastern Tethys, Japan and the North American domains.

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