

Calcareous algae from the Ordovician succession (Thango Formation) of the Spiti Basin, Tethys Himalaya, India

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ABSTRACT. The calcareous algae *Dasyoporella silurica*, *Moniliporella multipora* and *Vermiporella fragilis* are reported for the first time from the Middle Ordovician (Dapingian to Darriwilian) Thango Formation of the Spiti Basin of northern India (Pin Valley, Tethys Himalaya). *Moniliporella multipora* is reported for the first time from the entire Spiti Basin. This algal assemblage is broadly comparable to that of the directly overlying Takche (=Pin) Formation in the Spiti Basin, as well as that reported from the Ordovician succession of the Tarim Basin and from Kazakhstan. The presence of these calcareous algae is of biogeographical and biostratigraphical significance as it indicates a shallow marine depositional environment for the Thango Formation of the Spiti Basin.

KEYWORDS: Algae, depositional environment, biogeography, Middle Ordovician

INTRODUCTION

We report calcareous green algae from the Ordovician succession of Sanugba Group exposed in the Pin Valley (Figs 1, 2). The present work is focused on the Thango Formation (Dapingian to Darriwilian stages of Ordovician), which lies above the Kunzum La Formation in the Pin Valley, Spiti Basin. Calcareous algae are used to reconstruct the ancient sedimentary environment, as they are widespread in various facies of Ordovician carbonate complexes. Calcareous algal remains provide useful information about the palaeoenvironment and were most intense in reef and related shallow-water facies (Riding & Fan 2001). The fossil record of these calcified algae extends back from the Precambrian (600 million years ago).

In the Tethys Himalaya, Reed (1912) reported calcareous algae from the Ordovician succession of the Spiti Basin. He mentioned them as “incertae sedis” and compared them with

Pasceolus and *Apidium*. Pia (1927) interpreted Reed’s *Apidium* as calcareous algae, and *Pasceolus? shianensis* as dasyclad *Coelosphaeridium*. Bhargava and Bassi (1986) reported calcareous algae from the Ordovician succession of the Kinnaur region (Himachal Himalaya), and Kato et al. (1987) reported them from the Spiti Basin. Hubmann and Suttner (2007) described calcareous algae from the Upper Ordovician–Lower Silurian succession (Takche=Pin Formation) of the Pin section. Recently, Sinha and Trampisch (2013) reported calcareous algae from the Lower Palaeozoic of the Shiala Formation (Uttarakhand Garhwal region).

The present study deals with the carbonate beds of the Middle Ordovician succession (Thango Formation) of the Pin Valley in the Spiti Basin, which contains a wide variety of marine calcareous algae along with other microfossil assemblages. Three calcareous algal taxa were identified from the studied section: *Dasyoporella*, *Vermiporella* and *Moniliporella*. The Upper Ordovician age of the lower

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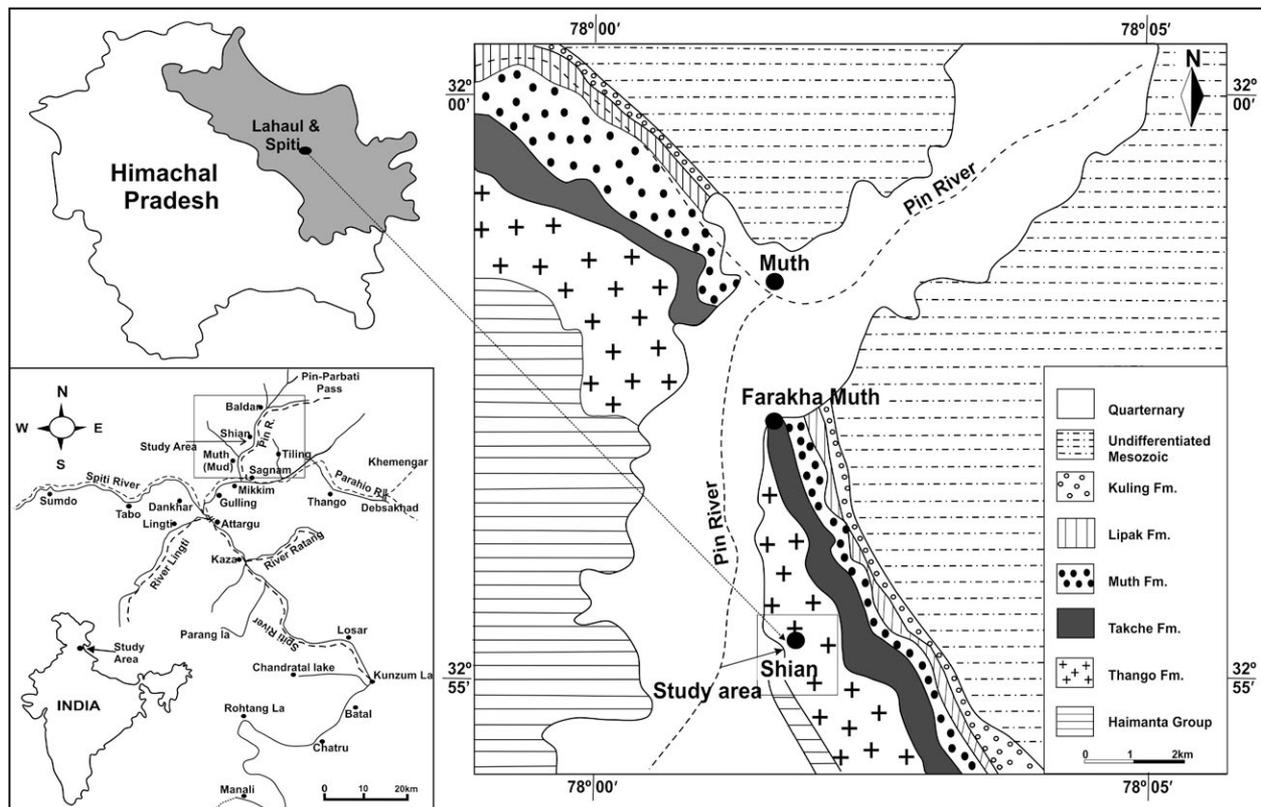


Fig. 1. Geological map, with route map of the Pin Valley area of the Spiti Basin, showing the Paleozoic successions and study area (modified after Parcha & Pandey 2011b)

part of the Pin Valley has been conodont-dated (*Amorphognathus ordovicicus* Zone) and verified by both megafauna and coeval conodonts (Suttner & Ernst 2007). The present reported algal forms indicate Middle Ordovician age, as these algae were reported 72 m below the level where Hubmann & Suttner (2007) reported algae. Here we attempt to interpret the palaeo-environment distribution of the calcareous algae during the Ordovician, and discuss the taxonomic classification of the reported algae.

GEOLOGICAL SETTING

Stoliczkai (1865), Greishbach (1891), Srikantia (1981) and Bhargava et al. (1991) gave detailed geological overviews of the Spiti Basin. Greishbach (1891) and Bhargava & Bassi (1998) recognized the unconformity between the Cambrian and overlying Ordovician rock. Later, Srikantia and Bhargava (1998) grouped the rocks ranging in age from the Neoproterozoic to Cambrian in the Haimanta Group and overlying succession above the unconformity (Ordovician to Silurian) in the Sanugba Group. The present work is focused on the Thango Formation, which lies above the unconformity

in the Pin Valley of the Spiti Basin (Fig. 2). Goel and Nair (1977) used the term “Shian Formation” for the Ordovician rocks and “Pin Formation” for the Silurian rocks exposed in the Pin Valley. Srikantia (1981) used the terms “Thango” and “Takche” for the successions ranging from the Ordovician to Silurian. Bhargava and Bassi (1986, 1998) and Parcha and Pandey (2011a, b) adopted the terminology given by Srikantia (1981), while Ranga Rao et al. (1982), Garzanti et al. (1986), Talent et al. (1988), Bagati (1990) Bagati et al. (1991), Dragnites (2000), Hubmann and Suttner (2007) and Suttner and Ernst (2007) used the terms “Shian” and “Pin” instead of “Thango” and “Takche”. Recently, Bhargava (2008) considered “Thango” and “Takche” to be more suitable, as these formations are best exposed in their type sections. In the present paper we adopt the classification given by Bhargava (2008) (Tab. 1).

The study focuses on the Thango Formation of the Pin Valley, exposed on the left bank of the Pin River facing Babha Joth (Fig. 2). The succession consists mainly of buff-coloured sandstone, shale, siltstone and dolomites with minor grits and occasional intraformational conglomerates. The Thango Formation in the

Table 1. Classification of Lower Palaeozoic rocks of the Spiti Basin given by various workers

Period	Griesbach (1891)	Goel & Nair (1977); Srikantia (1981)	Bagati (1990) and Bagati et al. (1991)	Srikantia & Bhargava (1998) and Bhargava (2008)	Hubmann and Suttner (2007); Suttner and Ernst (2007)	Parcha & Pandey (2011a) and present work			
DEVONIAN	Haimanta System	Muth Fm.	Muth Fm.	Kanwar Group	Muth Fm.	Kanwar Group	Muth Fm.	Kanwar Group	Muth Fm.
SILURIAN		Takche (=Pin) Fm.		Pin Dolomite	Sanugba Group	Takche Fm.	Takche Fm.	Sanugba Group	Takche Fm.
ORDOVICIAN		Haimanta Group	Thango Fm. (=Shian)	Shian Fm.	Sanugba Group	Thango Fm.	Shian Fm.	Sanugba Group	Shian Fm.
			Unconformity	Unconformity		Unconformity	Unconformity		
CAMBRIAN		Kunzum La Fm.	Kunzum La Fm.	Haimanta Group	Kunzum La Fm.	Kunzum La Fm.	Haimanta Group	Kunzum La Fm.	
		Batal Fm.	Batal Fm.	Haimanta Group	Batal Fm.	Batal Fm.	Haimanta Group	Batal Fm.	

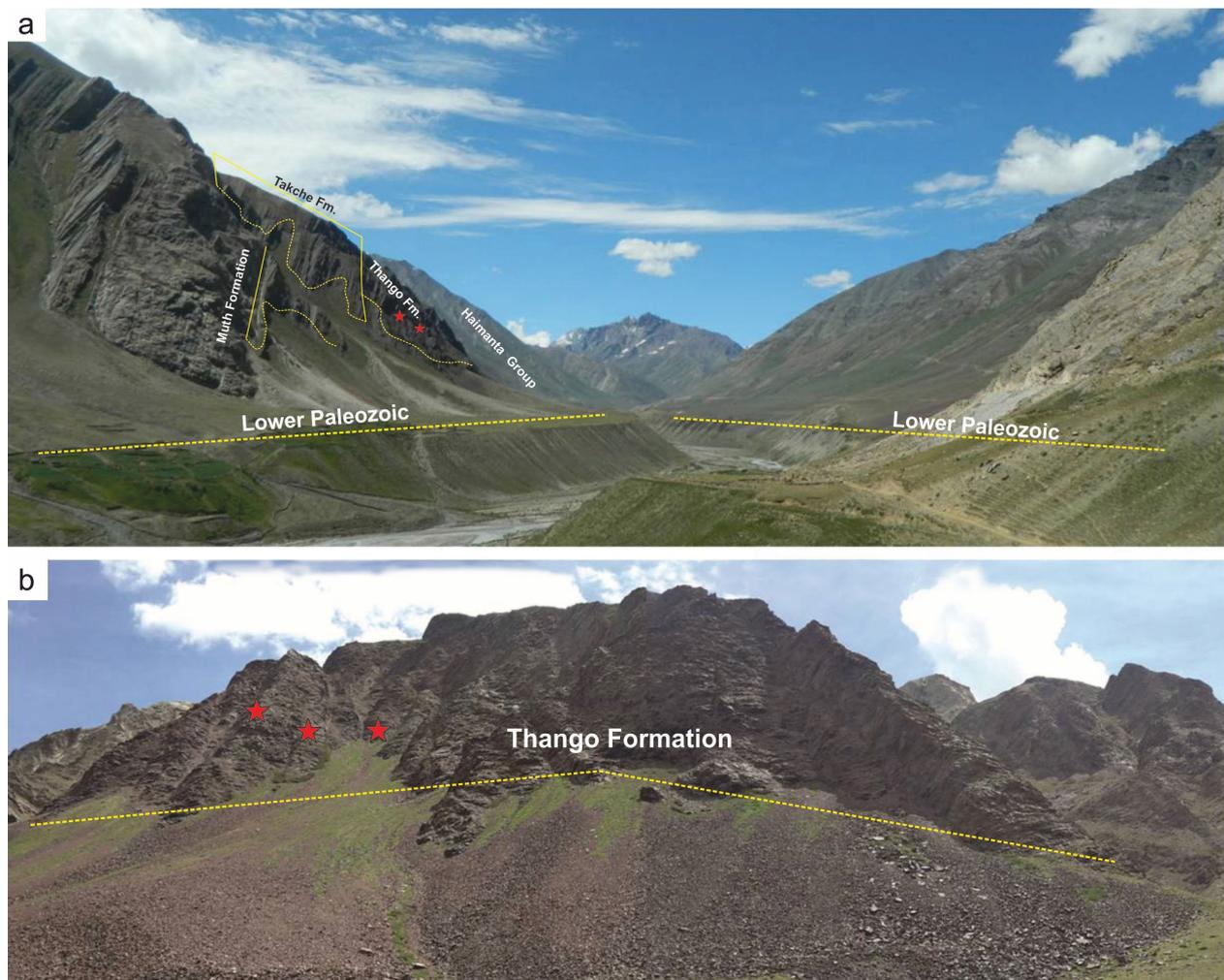


Fig. 2. Panoramic view of the Pin Valley, Spiti Basin. (a) Lower Palaeozoic succession exposed in the Pin Valley (b) Close view of the studied Thango Formation in the Pin Valley

Spiti Basin appears to range from Early Ordovician to early Late Ordovician, as indicated by *Phycodes circinatum* and algae *Prismocorollina* sp. associated with corals, bryozoans and invertebrates, whereas assignments based on coral, conodonts and algal remains place the age of the Takche Formation in the range from Late Ordovician to Middle/early Late Silurian (Bhargava & Bassi 1998, Srikantia & Bhargava 1998, Bhargava 2008). The Thango Formation ranges in age from Lower Ordovician to Middle Ordovician (Floian to Darriwilian), as the basal part of the formation is covered by conglomerates representing an angular unconformity in the entire Spiti Basin. The overlying Takche (= Pin) Formation has gradational to intercalated contact with the Thango Formation.

MATERIAL AND METHODS

Fourteen thin sections of carbonate rocks were prepared from samples collected from the Ordovician section of the Thango Formation, which lies in Shian Kogma village opposite Mud village (type locality of Muth Formation) in the Pin Valley. The thin sections, bearing algae and other microfossils, were prepared and examined with a Nikon Eclipse E600Pol microscope. The reported material is housed in the Repository of the Wadia Institute of the Himalayan Geology Museum, Dehradun, India (Repository numbers WIMF/A/4668 to WIMF/A/4680).

SYSTEMATIC PALAEOONTOLOGY

Order: DASYCLADALES Pascher 1931

Family: SELETONELLACEAE (Korde 1950)
Bassoullet et al. 1975

Tribe: DASYPORELLEAE (Pia 1920)
Bassoullet et al. 1979

Genus: *Dasyoporella* Stolley 1893

Dasyoporella silurica Stolley 1893

Plate 1, figs 2–4; Plate 2, fig. 3; Plate 3, figs 1–3

Type species: *Dasyoporella silurica*
Stolley 1893

Description. Well-preserved thallus with broad central cavity. Cylindrical to sub-cylindrical

calculated tube, moderately thick wall pierced at right angles by narrow, closely spaced tubular pores, slightly enlarged at distal end. Overall external thallus size 1000–5500 µm. Internal diameter (d) 800–2700 µm, external diameter (D) 1000–3200 µm. Pore diameter 50–70 µm, pore length 60–85 µm, pore interspace 30–45 µm.

Remarks. The classification of the Dasyoporelleae was reviewed by Berger and Kaever (1992). The basic character of *Dasyoporella* is its simple form, broad central cavity, unbranched thallus and comparatively thick wall (Stolley 1893). The presently described specimen shows resemblance to the genus *Dasyoporella* (Pia 1920) in the nature of the thick wall and broad central cavity. The described genus shows morphological dimensions mostly similar to the form defined by Riding and Fan (2001) and Sinha and Trampisch (2013). The specimen resembles *Dasyoporella silurica* described by Riding and Fan (2001) from the Ordovician of the Tarim Basin and by Sinha and Trampisch (2013) from the Ordovician succession of the Shiala Formation in the Garhwal region due to its broad central cavity, thick wall and closely spaced pores. Bhargava and Bassi (1986) described *Dasyoporella* from the Kinnaur Basin but did not give a morphological description; Hubmann and Suttner (2007) gave external thallus size and wall thickness. The reported form differs from *Dasyoporella* sp. described by Hubmann and Suttner (2007) from the Ordovician of Spiti and by Bhargava and Bassi (1986) from the Silurian of the Kinnaur Basin in its sub-cylindrical thallus and in the nature of the central cavity.

Family: **Moniliporellaceae**
Gnilovskaya 1972

Genus: ***Moniliporella*** Gnilovskaya 1972

Moniliporella multipora Riding & Fan 2001

Plate 1, fig. 1; Plate 3, fig. 4

Type species: *Moniliporella multipora*
(Stolley) Riding & Fan 2001

Description. Sub-cylindrical tube-like structure with broad central cavity with filled pores. Longitudinal section shows constriction, with regular arrangement of branches around

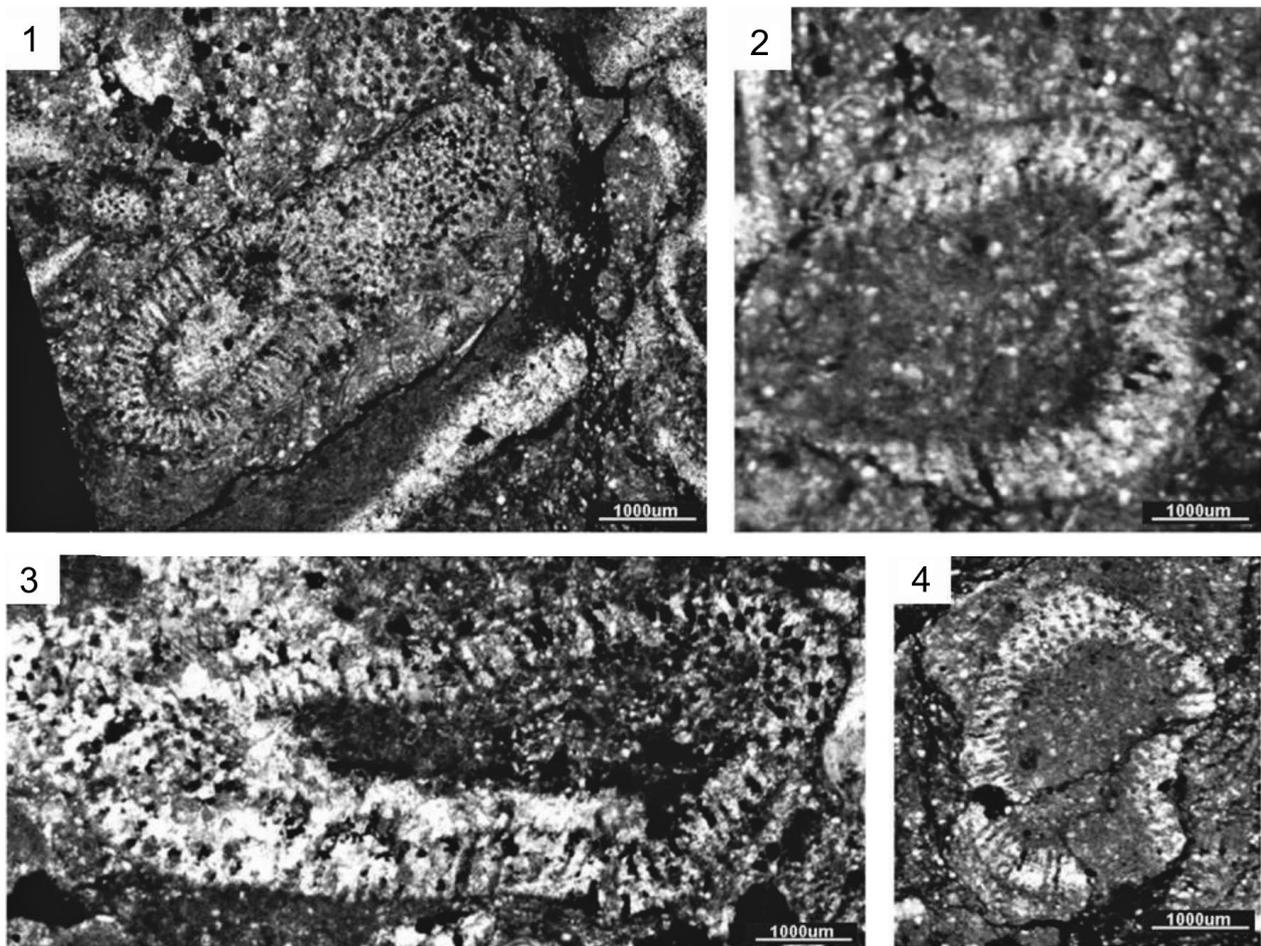


Plate 1. Fig. 1. *Moniliporella multipora* Gnilovskaya, calcareous alga from the Ordovician succession of the Thango Formation in the Pin valley, Spiti Basin. 1, WIMF/A/4673; **Figs 2–4.** *Dasyoporella silurica* Stolley. 2 – WIMF/A/4670; 3 – WIMF/A/4676; 4 – WIMF/A/4672

central cavity and pores between branches. Surface mostly covered with densely distributed, rounded pores at right angles to central cavity, tube-like thick wall with closely spaced pores. Total length of thallus 3200–4800 µm, internal diameter (d) 400–600 µm, external diameter (D) 1600–2000 µm. Pore interspace 50–63 µm, pore diameter 32–48 µm.

Remarks. The specimens resemble the genus *Moniliporella* in its sub-cylindrical thallus and also its tube-like structure with a broad central cavity with filled pores. Based on its irregular form and comparatively thinner wall, Stolley (1893) differentiated *Dasyoporella multipora* (*Moniliporella multipora*) from *Dasyoporella silurica* and other species of *Dasyoporella*. The more complex thallus shape of *Dasyoporella multipora*, with well-defined constrictions, appears to be identical to *Moniliporella camerata*. The described specimens differ from *Dasyoporella silurica* and other forms of *Dasyoporella* in having a sub-cylindrical thallus with a long calcified tube, which is the most significant

feature of *Moniliporella*. The present specimens show similarity in the nature of the sub-cylindrical thallus, calcified tube, thick wall and broad central cavity with *Moniliporella multipora* described by Riding and Fan (2001) from the Ordovician of the Tarim Basin and by Sinha and Trampisch (2013) from the Ordovician of the Shiala Formation of the Garhwal region, India.

Class ULVOPHYCEAE
Mattox and Stewart 1984

Genus: *Vermiporella* Stolley 1893

Vermiporella fragilis Stolley 1893

Plate 2, figs. 1, 2, 4, 5, 6

Type species: *Vermiporella fragilis* Stolley 1893

Description. Cylindrical thallus, irregularly ramified with numerous straight cylindrical branches. Surface of tubes covered with

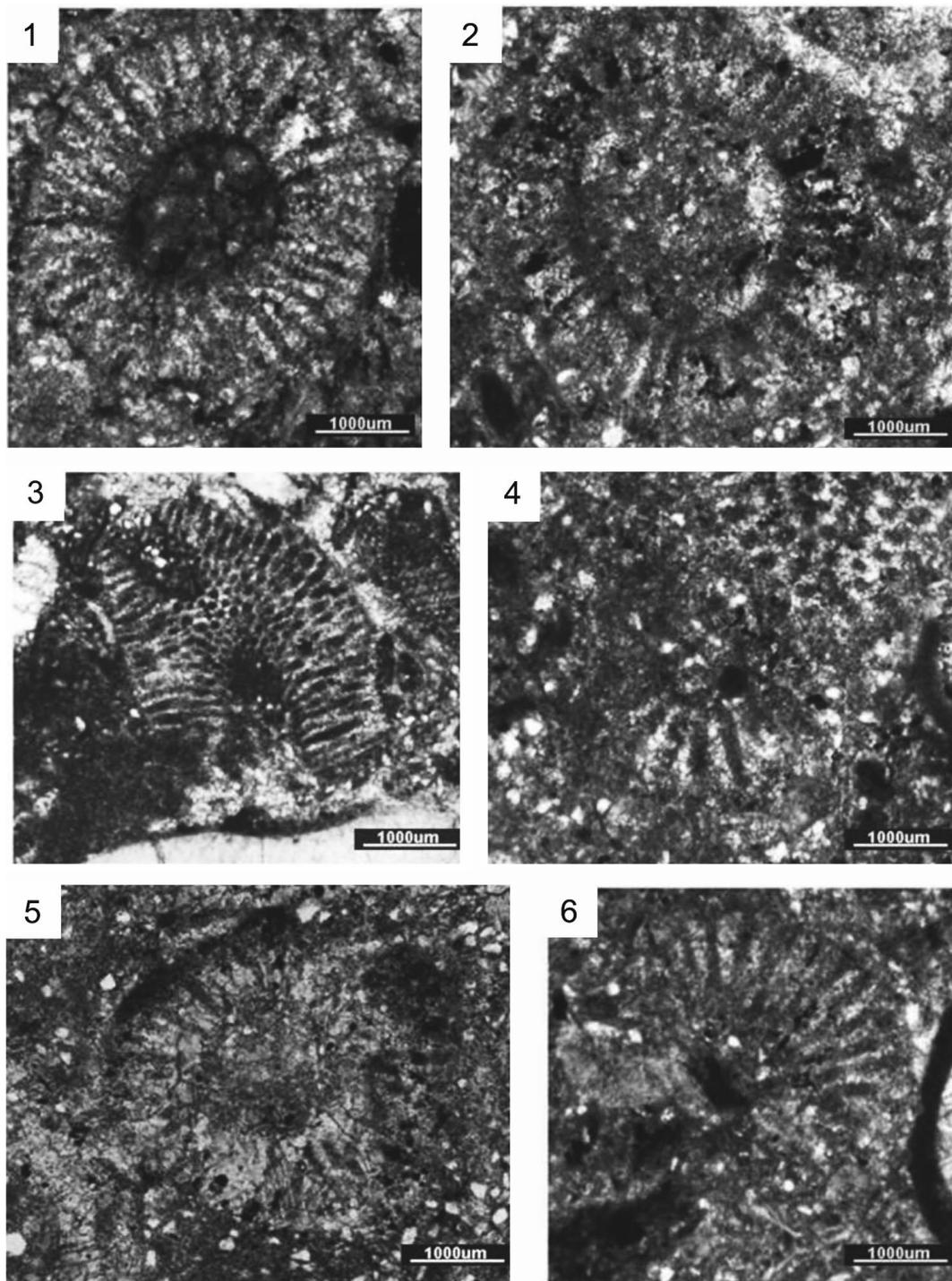


Plate 2. Figs 1, 2, 4, 5, 6. *Vermiporella fragilis* Stolley, calcareous algae from the Ordovician succession of the Thango Formation in the Pin valley, Spiti Basin. **1** – WIMF/A/4674; **2** – WIMF/A/4675; **4** – WIMF/A/4670; **5** – WIMF/A/4668; **6** – WIMF/A/4669; **Fig. 3.** *Dasyoporella silurica* Stolley, WIMF/A/4679

densely distributed rounded pores. Overall external thallus length 900–3100 µm. Internal diameter (d) 140–300 µm, external diameter (D) 240–460 µm, wall thickness 55–65 µm, pore diameter 30–45 µm.

Remarks. The genus *Vermiporella* shows some similarity to the genus *Dasycladus* and so is regarded as dasycladalean (Tappan

1980, Berger & Kaever 1992). Kozłowski and Kazmierczak (1968) described internal microscopic details of *Vermiporella fragilis* that suggest a comparison with ulotrichalean green algae. Riding and Fan (2001), Lewis and McCourt (2004) and Feng et al. (2010) placed *Vermiporella* in the Ulyophyceae, which includes Dasycladales and Ulotrichales. *Vermiporella* is a widely reported genus, characterized by

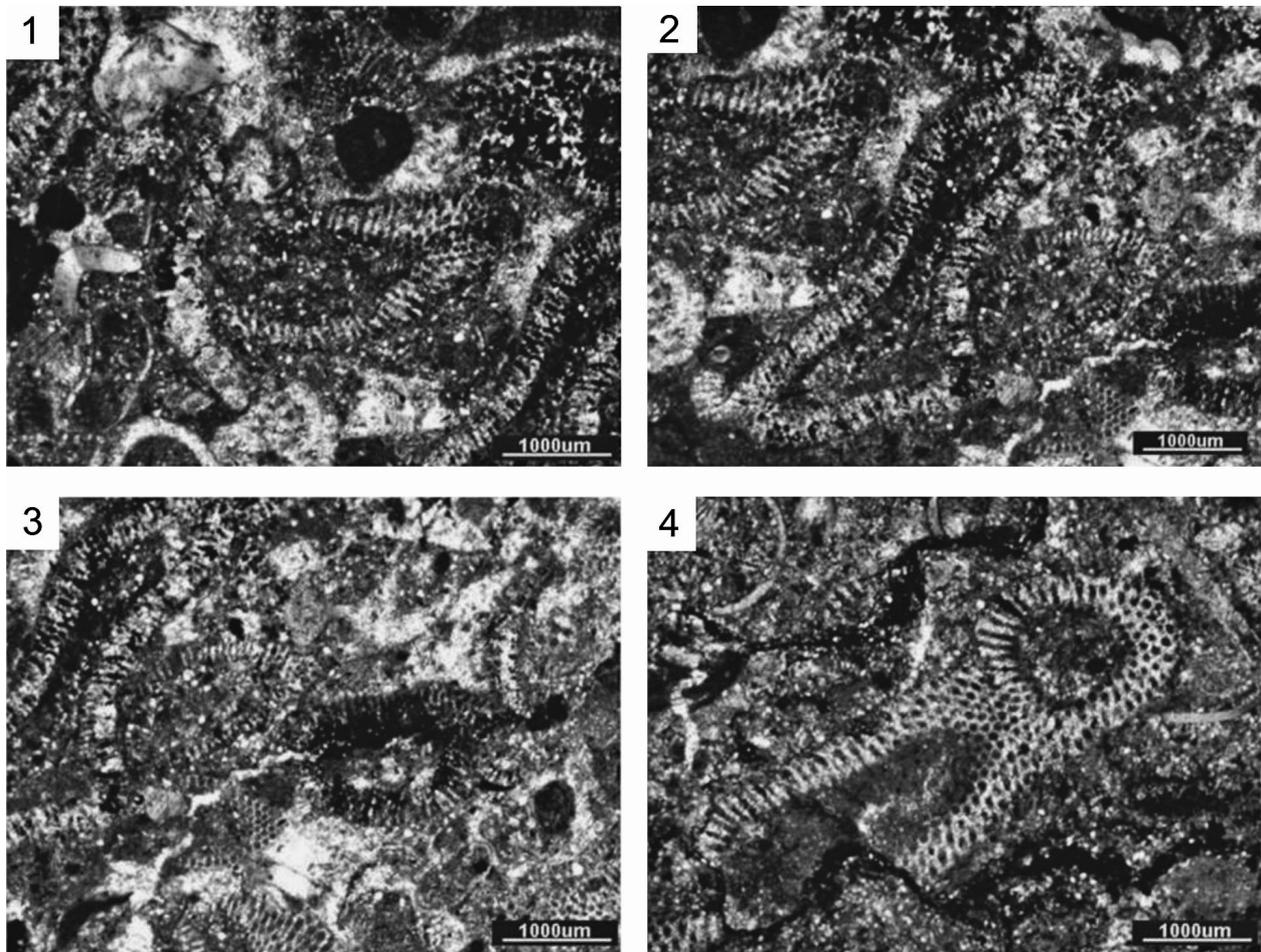


Plate 3. Figs 1–3. *Dasyoporella silurica* Stolley, calcareous algae from the Ordovician succession of the Thango Formation in the Pin valley, Spiti Basin. **1** – WIMF/A/4679; **2** – WIMF/A/4680; **3** – WIMF/A/4678; **Fig. 4.** *Moniliporella multipora* Gnilovskaya, WIMF/A/4677

its external lobed form and thin wall which distinguish it from *Dasyoporella*. The presently described specimens are grouped under *Vermiporella fragilis* due to their cylindrical thallus, irregular ramified thallus and numerous straight branches, described by Riding and Fan (2001) and Feng et al. (2010).

STRATIGRAPHIC AND PALAEOENVIRONMENTAL SIGNIFICANCE

The presence of calcareous algae in the Ordovician succession reveals that these successions developed within a shallow sea. Extensive deposition of carbonates and other environmental conditions fostered the development of algae (Maithy et al. 1999). These calcareous algae are major sources of primary production during their life and contribute to the buildup of carbonate sediments in marine environments after their decay (Hillis-Collinvaux 1980, Drew 1983,

Multer 1988, Payri 1988). The described calcareous algae provide useful information about the palaeoenvironmental setting and also complement interpretations based on other biota and on the depositional features observed during studies of the region. The presence of calcified green algae in the studied section indicates shallow marine to near-shore environmental conditions followed by different stages of regression and transgression.

Vermiporella has been considered an important genus as it is the major contributor to the backreef (Opalinski & Harland 1981, Webby 2002) and is among the oldest calcified fossils, which appears in the Middle Cambrian and became extinct in the Permian (Herak et al. 1977, Riding & Fan 2001). Gnilovskaya (1965) reported *V. fragilis*, *V. wesenbergensis*, *V. acerosa* and *V. diffluens* from the Ordovician of the Tarbagatay Range (Kazakhstan). Stolley (1893) described *V. fragilis* from the Upper Ordovician of northern Germany. The genus is also reported from the Upper Ordovician of Poland

(Kozłowski & Kazmierczak 1968), Upper Ordovician of Scotland (Elliott 1972) Lower Ordovician of eastern North America (Roux 1991) and Upper Ordovician of the Lianglitage Formation in the Tarim Basin (Liu et al. 2012).

The genus *Dasyoporella* ranges in age from Middle Ordovician to Permian. Apart from the Spiti Basin, the genus is reported from Middle to Upper Ordovician successions of the Tarim Basin in China, eastern Kazakhstan, Utah and Nevada in the USA, and Norway, and from Silurian successions of northern California. Here we report *Moniliporella* for the first time from the Middle Ordovician succession of the Pin Valley in the Spiti Basin. The occurrence of *Moniliporella* in the Pin Valley of India as well as from the Tarim Basin and Kazakhstan suggests a regional link between these three regions.

The distribution of these algae in the Ordovician, particularly in India, the Tarim Basin, Kazakhstan, Baltica and North America indicates that all these areas were on the 0–30° latitudinal belt during the Ordovician, reflecting continental reconstruction. It has also been observed that the latitudinal positions of India and the Tarim Basin were adjacent to each other, possibly due to plate reconstruction during Ordovician-Silurian times (Smith 2001, Sinha & Trampisch 2013). The floristic similarities between these widely separated regions indicates that these algal structures developed through the Ordovician and further to the end of the Permian, and were cosmopolitan. In the light of these studies, we are presently attempting to determine the palaeoenvironmental conditions of these calcareous algae and to correlate them at genus level with comparable successions of Kazakhstan, the Tarim Basin and Kinnaur Basin.

CONCLUSION

The Ordovician succession of the Pin Valley of Spiti Basin is composed of mixed carbonate and siliciclastic sedimentary rocks. The described calcareous algae from this section have a relatively wide stratigraphic distribution during the Ordovician and thus are not of biostratigraphic relevance, but can be used as indicators, particularly for identifying shallow marine, warm, well-oxygenated and relatively high-energy environments. The presence of calcified green algae in the carbonate beds of the

Ordovician succession indicates shallow marine to near-shore environmental conditions followed by different stages of regression and transgression. The distribution of calcareous algae in the Tarim Basin, Kazakhstan, Baltica, North America, Scotland and India indicates that all these areas were along the 0–30° latitudinal belt during the Ordovician period. It further suggests a regional link between India, the Tarim Basin and Kazakhstan. The floristic similarities between widely separated areas suggests these calcareous algae to be cosmopolitan.

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