Neoproterozoic sponge spicules and organic-walled microfossils from the Kangolihat Dolomite, Lesser Himalaya, India

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Isolated hexactinellid and monaxon sponge spicules with cyanobacterial filaments have been discovered in the Kangolihat Dolomite. The microfossils described were recovered in the thin sections of cherty dolomite and phyllite. Comparable sponge spicules are reported so far from lower Vendian sediments; therefore an early Vendian age can be suggested for the Kangolihat Dolomite. The main purpose of this communication is to document the presence of sponge spicules and silica biomineralization during the sedimentation of Kangolihat Dolomite in the Kumaun Lesser Himalaya, India.

SPONGES had a largely undocumented history before their entry into the skeletal fossil record. It is accepted that sponges had achieved skeletal diversity by the latest Proterozoic and that siliceous biomineralization preceded calcareous biomineralization in sponges†. Phylogenetically, they constitute the most original group within the metazoan. Presence of sponge spicules provides an evidence of metazoan silica biomineralization in the Proterozoic fossil record. Late Proterozoic sponge spicules have been documented from Vosgas Mountain, Mongolia, China and Australia1-4. Recently, Neoproterozoic sponge-like fossils have been reported from the Upper Vindhyan in India5. Early Cambrian records of sponge spicules are also documented worldwide (ref. 6 and references therein).

The sponge spicules described in this communication have been recorded from two different localities of the Kangolihat Dolomite, which is extensively developed in the Inner sedimentary belt of the eastern Kumaun Lesser Himalaya (Figure 1). The fossiliferous samples were collected near the village of Uttra, ~ 3.5 km south-west of Kapkot (29°57'N; 79°56'E) in the Bageshwar–Kapkot road and near the village of Chhena in Chandak–Cherra road section in Pithoragarh (29°35'N; 80°15'E) (Figure 1). The discovery of a well-preserved microbiota from the Deoban limestone, Great Limestone, Krol belt of Lesser Himalaya6-13, has given encouragement for further search of palaeobiologic records in the eastern part of Kumaun Lesser Himalaya where no authentic microbiota has been reported so far. Well-preserved sponge spicules and organic-walled microfossils from the Kangolihat Dolomite may certainly provide a nonpareil perception about the early stages of animal evolution and complexity of
Gangolihat Dolomite ecosystem existing at the time of sedimentation.

The stratigraphic succession of the area is shown in Table 1.

The argillo-calcareous sequence of the present area was described as the Calc Zone of Tejam. Valdiya has divided it into two formations, the older Deoban Formation and the younger Mandhari Formation. The carbonate sequence was named the Gangolihat Dolomite. In the Bageshwar–Kapok section, this unit was described as the Kapok Formation. Gangolihat Dolomite constitutes a total thickness of about 700 m in Pithoragarh and consists predominantly of limestone, cherty limestone, stromatolitic dolomite and phyllitic units. It has been divided into four members, Chhera, Hinauni, Chandak and Dhari, respectively, in ascending order. The Gangolihat Dolomite is overlain by the Sor Formation (with Sor slate and Thalkedar limestone Members of Valdiya). In the Chhera village of Pithoragarh, grey and purple coloured phyllite (Chhera Member of Valdiya) is exposed. The phyllite is highly siliceous. In the lower part of the section, thinly-bedded pink limestone alternates with purple calcarceous phyllite sequence (Figure 2a). The stromatolitic dolomite

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**Table 1.** The stratigraphic succession of the Kumaun Leser Himalaya (after Valdiya)

<table>
<thead>
<tr>
<th>Mandhari Formation (Sor Formation)</th>
<th>Thalkedar limestone</th>
<th>Blue–grey banded limestone, often with chert laminae and nodules, and argillaceous limestone alternating with calcareous grey phyllite. Light green and grey–green sandstone.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sor slate</td>
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<tr>
<td>Deoban Formation (Gangolihat, Dolomite, Kapok Formation)</td>
<td>Dhari Member</td>
<td>Blue–grey limestone with calc–slate and marl. Dolomitic limestone characterized by spectacular development of stromatolites. Pockets of flat pebble intraformational conglomerate. Conspicuous chain of lentiform deposits of magnesite.</td>
</tr>
<tr>
<td></td>
<td>Chandak Member</td>
<td>Fine-grained cherty dolomite of pink and white colours alternating with chert laminae. Pink violet and maroon slate-phyllite interbedded with subordinate pink, green and white marble, often sandy.</td>
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<tr>
<td></td>
<td>Hinauni Member</td>
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</tr>
<tr>
<td></td>
<td>Chhera Member</td>
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</tbody>
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**Figure 1.** Geological map of the area showing fossil locality (after Valdiya).

**Figure 2.** Stratigraphic column of a, Chhera section and b, Utrora section, showing the position of fossiliferous samples. a, limestone; b, phyllite; c, dolomite; d, cherty dolomite; e, cryptagal laminates; f, stromatolitic dolomite; *, fossiliferous samples.
exposed in the Bageshwar–Kapkot section is siliceous dolomite which often contains chert nodules and chert bands (Figure 2.b). The chert nodules range from 1 to 12 cm in diameter. The cherty bed is approximately 10 m thick. Dolomite units become thicker upward in the sequence, and are oolitic at places.

The age of the Gangolihat Dolomite was mainly deduced on the basis of stromatolites in the absence of radiometric dates. The carbonate belt shows characteristic forms of Lower Riphean stromatolites (Kussiella kussensis, Conophyton gargaricus, Conophyton cylindricus, Colonella columnaris, and Plicatina antiqua) at the base, Middle Riphean stromatolites (Baicalia bacalica) in the Middle and Upper Riphean stromatolites (Minjaria uralic, Masloviella columnaris) in the upper part. The biozation based on stromatolites established that the Deoban, Shali and Jammu (Great) Limestone belts are correlatable and homotaxial with the Gangolihat Dolomite and indicate an Early to Middle Riphean age. The microfossil assemblage comprising cyanobacteria, algae, fungi, acritarchs and possible nematodes, suggests an Early Vendian age for the Deoban Formation. The micobial fossils, including cyanobacteria, sphaeromorphic and acanthomorphic acritarchs and vase-shaped microfossils.
reported from the Great Limestone suggest a Late Riphean to Vendian age. Besides, in the eastern extension of these carbonate rocks in Nepal, Neoproterozoic to Cambrian Palaeobasidiospores have been recorded.

Neoproterozoic monaxial siliceous sponge spicules have been earlier reported from quartz phyllite of the Ville Series from the Vosges Mountain. Some disk-like bodies of hexaxellidid sponge spicules have been reported from the Neoproterozoic Ediacara fauna of South Australia. Further, Ediacaran (~543 Ma) hexaxellidid sponge spicules have been reported from the southwestern Mongolia. Late Proterozoic sponges have been documented with soft tissue from phosphorite of Doushantuo, South China. These sponges are older than the Ediacara and are reported to be of Early Vendian age, ca. 580 Ma and they contained only monaxon spicules. Early Cambrian sponge spicules were mainly hexaxellidids and were documented worldwide (ref. 6 and references therein). It is concluded on the basis of the worldwide presence of these spicules, that silica biomineralization started during Early Vendian. Therefore, a comparison of the recorded Neoproterozoic sponge spicules, especially from Mongolia and China to those present in the Gangolihat Dolomite suggests an Early Vendian age for the Gangolihat Dolomite. The present communication mainly deals with the discovery of well-preserved sponge spicules and cyanobacterial filament from the Gangolihat Dolomite. A detailed study of this microbial assemblage will provide new information on early stages of metazoan evolution during Neoproterozoic (Gangolihat) sedimentation. A large number of thin sections were examined and unquestioned simple small monaxial oxeas and hexaxellidin sponge spicules occur abundantly in the collection. Long and thin monaxons are straight or sometimes bent a little, spicules are equidimensional and smooth, ranging in diameter from 0.5 to 1 μm and 20 to 70 μm long (Figure 3b). The presence of monaxon ray is confirmed by the tapering of the ray in both directions. Hexaxellid spicules are 1 to 5 μm in diameter and 10 to 300 μm in length (Figure 3a, c, d–f). In a thin section, there is cross-section of a vertical ray near the intersection of other rays (Figure 3a). Some thicker, short spicules with diameters ranging from 5 to 7 μm are also seen embedded in the matrix. Long and unbranched chain-like aggregates with the length up to 600 μm are seen in thin section of chert nodule-bearing dolomite (Figure 3g). A chain of 8 to 10 μm diameter spheres occurs as a single filament. Such structures are known to be remains of filamentous microorganisms whose organic matter has been completely replaced by diagenesis of iron minerals, and are classed under Nostocospumma Sin and Liu. No organic matter is visible in these fossils. Comparable structures were also reported from various Proterozoic successions.

20. Pers. commun. with Dr Rigby to Meera Tiwari. Rigby regarded these forms as unquestioned hexaxellidin sponge spicules.

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