RESEARCH COMMUNICATIONS

important role in the degradation of organic matter, thus making the Lonar ecosystem a live one. Isolation of aerobic bacteria from Lonar lake sediment has already been reported by Kanekar et al.20 This signifies the biodiversity of Lonar lake with respect to microbial life.

In conclusion, strain LN 1 isolated from the sediment of Lonar crater is an alkalophilic, halotolerant methanogenic archaean that can grow at pH 9.0, which differs from the known species of the Methanosarcina.


Acknowledgements. We thank the Director, Agharkar Research Institute for help and facilities provided. C.D.T. thanks the Ministry of Environment and Forest, Govt. of India, for providing research fellowship.

Received 3 September 2001; revised accepted 16 November 2001

Microfauna and age of the Sangcha Malla Formation of Garhwal Tethys Himalaya, India

K. P. Juyal1, S. K. Parcha2,*, N. S. Mathur† and Jagmohan Singh*†

1Wadia Institute of Himalayan Geology, Dehradun 248 001, India
*Oil and Natural Gas Corporation, KDMIPE, Dehradun 248 001, India
*Present address: Western Onland Basin, RGL, Oil and Natural Gas Corporation Ltd., Vadodara 390 009, India

Biostatigraphic investigations of the Sangcha Malla Formation in the type area of the Garhwal Tethys Himalaya were carried out during an expedition. Systematic investigations of samples from this unit led to the recovery of several well-preserved species of Archaeoglobigerina, Rosita, Globotruncanites, Globo- truncanita, Heterohelix and Pseudotextularia. The faunal assemblage is indicative of deposition under a deep marine condition. The foraminiferal taxa are recorded from the upper part of the Sangcha Malla Formation, which is the youngest marine litho-unit deposited in the Garhwal Tethys Himalaya. Stratigraphic distribution of the taxa indicates that this part of the Sangcha Malla Formation was deposited during the Campanian times. The fauna recovered herein from the Garhwal Tethys Himalaya shows a close affinity with that of the Zanskar region of Ladakh Himalaya and the Spiti region of Himachal Pradesh, suggesting thereby that during the Late Cretaceous times there were marine connections in these regions and the Upper Cretaceous sediments were deposited under similar (deep marine) palaeoenvironment.

The fossiliferous sedimentary succession of the remote Malla Jorah area in the Kiogad sector of the Garhwal Tethys Himalaya has been studied since early times. Heim and Gansser1 gave a detailed geological account of the area and differentiated various litho-units. Several other geologists contributed to the geology of the area2–6. The present contribution is based on the field-work carried out by two of the authors (K.P.J. and S.K.P.) in an expedition in the Garhwal Tethys Himalaya organized by the Wadia Institute of Himalayan Geology, Dehra Dun in 1998.

A perusal of the literature reveals that age of the Sangcha Malla Formation of the Garhwal Tethys Himalaya was established mainly on the basis of planktonic foraminifera2–5 studied in thin sections of rocks. Planktonic foraminiferal studies based on thin sections without their morphotypes have been questioned by several workers, as the latter provide additional characters such as peripheral keels, ventral and dorsal suture lines, etc. for specific determination. For precise identifica-

*For correspondence. (e-mail: bswihg@nede.vsnl.net.in)
Table 1. Lithostratigraphic framework of the Malla Johar area

<table>
<thead>
<tr>
<th>Litho-unit</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sangcha Malla Formation (&gt;1000 m) (Turonian–Campanian)</td>
<td>Grey shale often gritty</td>
</tr>
<tr>
<td></td>
<td>Variegated shale</td>
</tr>
<tr>
<td></td>
<td>Marl with sandstone and red shale</td>
</tr>
<tr>
<td></td>
<td>Variegated shale</td>
</tr>
<tr>
<td></td>
<td>Green shale with greywacke</td>
</tr>
<tr>
<td>Giumal Sandstone (Late Neocomian–Cenomanian)</td>
<td>Greenish-grey sandstone and sandy shale with thick bands of massive radiolarian chert. Thick-bedded glauconitic sandy shale and sandstone</td>
</tr>
<tr>
<td>Spiti Shale (Late Jurassic – Early Neocomian)</td>
<td>Black shale with phosphatic, ferruginous and calcareous concretions (fossiliferous)</td>
</tr>
<tr>
<td>Laphthal Formation (Lias)</td>
<td>Dark blue to grey limestone with bands of coquina</td>
</tr>
<tr>
<td>Koto Limestone (Late Triassic)</td>
<td>Grey limestone with <em>Megalodon</em></td>
</tr>
</tbody>
</table>

The Sangcha Malla area, lying in the northern part of Chamoli District of Garhwal region, falls in the Tethyan Himalayan zone. The lithostratigraphy of the area is shown in Table 1. Several workers in the past had investigated fauna of the various litho-units exposed in the area. The present paper deals with biostratigraphy of the Sangcha Malla Formation, which is exposed between Sangcha Malla and Belcha Dhura localities (Figures 1 and 2).

The Sangcha Malla Formation is the youngest litho-unit exposed in the Kiogad segment of the Garhwal Tethys Himalaya. This unit lies conformably over the Giumal Sandstone and the contact between the two units is marked by a variegated red shale horizon. Lithologically, the Sangcha Malla Formation comprises
sandstone and chocolate reddish shale with intercalated chert bands, greenish-grey shale, marl, greywacke and black silty shale. This unit was named as ‘Upper Flysch’ by Heim and Gansser and was subsequently named as ‘Sangcha Malla Formation’ by Shah and Sinha.

Figure 2. Biostratigraphic column of the Sangcha Malla Formation.

Figure 3. Age of the Sangcha Malla Formation and the earlier age assignments by different workers.

Figure 4. Globotruncanita arca. a. Ventral view; b, c. Dorsal view; d–f. Globotruncanita linneiana, dorsal view; g. Rosita fomicata, dorsal view; h. Archaeoglobobergerina blowi, ventral view; and i. A. cretacea, ventral view (bar size = 0.1 mm).

Figure 5. a. Heterohelix sp. I. front view; b, c. H. striata, front view; d, e. Pseudotextularia elegans, front view; f, g. Globotruncanita calcarata, dorsal view (f), ventral view (g) (bar size = 0.1 mm).
Heim and Gansser\textsuperscript{1} recorded small globular radiolarians and Nasellarians and assigned a Late Cretaceous age to this formation. This age assignment was supported by Kalia (\textit{fide} Shah and Sinha\textsuperscript{3}, p. 19) who recorded \textit{Globotruncanita}, \textit{Heterohelix}, \textit{Plummerita}, \textit{Shackoinea} and \textit{Eouvigerina} from purple shale occurring in the upper part of this unit. Mamgain and Sastry\textsuperscript{4} carried out palaeontological studies in the Jhangu Gad (a tributary of Kigod) section of the Sangcha Malla area, and reported twenty-one taxa of planktonic foraminifera from the upper part of the unit and assigned it an early Maastrichtian age. They also reported five taxa from this section, one metre above the base of their ‘Upper Flysch’ unit and assigned a Late Cenomanian age to the lower part of the unit. During biostratigraphic studies in this area, Sastry and Mamgain\textsuperscript{5} assigned a Late Creta-

\textbf{Figure 6.} a–d, \textit{Globotruncanita calcarata}; e, k, \textit{Rosita fornicata}; f, \textit{Praeglobotruncana} sp.; g, h, \textit{Globotruncanita stuartiformis}; i, \textit{G. elevata}; j, \textit{Globotruncana ventricosa}; l, \textit{Heterohelix} sp. II (bar size = 0.1 mm).
ceous age to this unit based on the occurrence of *Glo-
botrunca*na spp. and *Heterohelix* spp. Later on, Mehro-
tra and Sinha¹ and Sinha² recorded several taxa of
palynomorphs from the Sangcha Malla Formation and
assigned it a Late Cretaceous to Middle Eocene age. How-
ever, Jain and Garg¹⁰ questioned their identifica-
tions. The age assigned by different workers is shown in
Figure 3. Recently, Juyal and Parcha¹¹ illustrated the
morphotypes of foraminifera from this unit.

In this communication, we place on record the pres-
ence of several morphotype planktonic foraminiferal
taxa from the Sangcha Malla Formation of the Garhwal
Tethys Himalaya. The present identifications are based
on well-preserved complete specimens from this unit,
which give additional features for their comparison and
detailed studies for a precise age assignment.

Thin sections of rocks from lower and middle parts of
the Sangcha Malla Formation have revealed the pres-
ence of radiolarians. Due to their poor preservation, no
precise age could be assigned to these parts of the unit.
However, lower age limit of this unit may be assigned
on stratigraphic grounds, as it overlies the Giumal
Sandstone without any apparent sedimentological gap.
The Giumal Sandstone has been assigned a late Neoco-
mian–Cenomanian age. Therefore lower and middle
parts of the Sangcha Malla Formation are considered to
have been deposited during Turonian–Santonian inter-
val. Samples from the upper part (Figure 2) yielded pro-
lific foraminiferal fauna, indicative of Late Cretaceous
age. Well-preserved material enabled us to identify
eleven foraminiferal species, namely *Archaeoglobig-
erina* blowi Pessagno, *A. cretacea* (d’Orbigny), *Rosita*
*ornicata* (Plummer), *Globotruncana arca* (Cushman),
*G. linneiana* (d’Orbigny), *G. ventricosa* White, *Glo-
botrunca*na *calcarata* (Cushman), *G. elevata* (Brotzen), *G. stuartiformis* (Delbeiz), *Heterohelix stri-
ata* ( Ehrenberg), and *Pseudotextularia elegans* (Rzehak)
(Figures 4–6).

Stratigraphic distribution of the planktonic foraminif-
eral taxa occurring in the Sangcha Malla area is arranged ac-
cording to their stratigraphic ranges based on the work of
Caron¹² (Figure 7). As seen in Figure 7, most of the taxa in the upper part of the Sangcha Malla Formation
range in age from Campanian to Maastrichtian. How-
ever, *G. calcitara* is a zonal planktonic foraminiferal
species, which is restricted to upper Campanian sedi-
timents elsewhere. It is, therefore, interpreted that the
sediments in the upper part of this unit were deposited
during the Campanian times supporting thereby the age
assigned to this unit by Mamgain and Sastry⁴.

The planktonic foraminiferal taxa recovered during the
present biostratigraphic investigations from the Garhwal
region are also recorded by earlier workers from the Zanskar and Spiti regions. Nine taxa recorded
from the Zanskar region¹³,¹⁴ have also been recovered
herein from the Garhwal region, which include *A. cre-
tacea, R. fornicata, G. arca, G. linneiana, G. ven-
tricosa, G. calcarata, G. stuartiformis, H. striata,* and
*P. elegans.* Four species, namely *G. linneiana, G. cal-
carata, G. stuartiformis* and *P. elegans,* recorded from
the Chikkim Formation of the Spiti region by Mamgain
and Sastry⁵, are also common to the Sangcha Malla
Formation of the Garhwal Tethys Himalaya. Thus the
fauna shows close similarity in these regions.

Palaeontological data from the Sangcha Malla Forma-
tion of Garhwal Tethys Himalaya are of great import-
ance, as this region lies at the northern margin of the
Indian plate. Foraminiferal taxa recorded herein from
the Sangcha Malla area and those recorded by earlier
workers from Spiti and Zanskar, which lie adjacent to
the Sangcha Malla area, are comparable. Most of these
taxa are common to these regions. This shows that dur-
ing the Late Cretaceous times, all these regions were
well connected under sea waters of atleast 80–120 m
paleobathymetry or more.

   1–246.
   India,* 1972, 15, 88–98.
   1975, XLIII, 1–33.  
   219.
   1–219.
   1001–1004.
12. Caron, M., in *Plankton Stratigraphy* (eds. Bolli, H. M., Sau-
    nders, J. B. and Perch-Nielsen, K.), Cambridge Earth Science
On the origin of the artesian groundwater and escaping gas at Narveri after the 2001 Bhuj earthquake

S. K. Gupta*,†, N. Bhandari†, P. S. Thakkar# and R. Rengarajan†

†Physical Research Laboratory, Navrangpura, Ahmedabad 380 009, India
‡Space Applications Centre, Ahmedabad 380 053, India
§Wadia Institute of Himalayan Geology, Dehradun, India

At Narveri, north of Khavada in the Great Rann of Kachchh, an outflow of groundwater continued even more than four months after the Bhuj earthquake of 26 January 2001, although at a considerably reduced rate compared to that immediately following the earthquake. Air or gas bubbling through the freshly oozing water has also been observed. We had collected a large number of samples from different parts of Gujarat, where post-earthquake groundwater outpourings were reported. Narveri, however, was the only site where the samples showed dissolved helium concentrations, significantly above the air equilibrium value. Based on measurements of helium, radon, chloride, sulphate and sodium concentrations and temperature, we suggest that the flowing water and escaping gases at Narveri have a deep confined source with a reservoir age in excess of \(10^4\) years.

ACKNOWLEDGEMENTS. We are thankful to Dr N. S. Virdi, Director, Wadia Institute of Himalayan Geology, Dehradun for providing necessary facilities and for encouragement. K.P.J. and S.K.P. thank Mr T. P. Semwal, then Dy. Commandant of ITBP at Sangacha Malla for his help. All the materials are housed in the Repository Section of the Wadia Institute of Himalaya Geology Museum, Dehra Dun and are numbered from WIMF/A/528 to WIMF/A/550.

Received 30 May 2001; revised accepted 15 November 2001

*For correspondence. (e-mail: skgupta@prl.ernet.in)