Palaeogeographic significance of 'Yasin-type' rudist and orbitolinid fauna of the Shyok Suture Zone, Saltoro Hills, northern Ladakh, India

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Along the Shyok Suture Zone in northern India, a ~200 m thick limestone succession within the larger Saltoro Formation has been identified as a carbonate platform margin with build-ups. This limestone succession is overlying volcanic rocks of island arc affinity, most probably a volcanic ridge. The partly recrystallized reefal limestone contains abundant rudists, echinoid spines, gastropods, algae and a rich orbitolinid assemblage. This faunal assemblage reflects a shallow-water tropical environment and also shows a close affinity with that recorded from the Yasin Group sediments exposed along the Northern Suture Zone in Kohistan, northwestern Pakistan. The rudist fauna from both sites resembles the *Horiopleura haydeni*/*Eoradiolites gilgitensis* association from the Yasin Group, and even the very distant classic latest Aptian-Early Albian rudist fauna of the Santander area in NW Spain. The presence of Late Aptian *Horiopleura*, Radiolitidae and different forms of *Orbitolina* and other microfaunal assemblages in the Saltoro reefal limestone dates the underlying volcanic edifice as middle Cretaceous or older. Rudists, nerineids, corals and foraminifers of Early–Middle Cretaceous age are widely distributed as reefal frameworks all along the tropical and subtropical Euro–African–Asiatic regions of the northern and southern margin of the Tethys. However, rudist build-ups may also occur far from the continental margins, associated with volcanic edifices like in the Caribbean, Sicily, and seamounts in the central Pacific region or, in our cases, volcanic arcs within the Tethys.

Keywords: Carbonate platform, limestone succession, orbitolinid assemblage, rudists, volcanic ridge.

Introduction

IN northern India, the Ladakh block lies between the Indian Plate in the south and the Eurasian Plate in the north[1]. To the west, this block is separated from the Kohistan Complex[2] by the Nanga Parbat–Haramosh syntaxis and to the east it is separated from the Lhasa block by the Karakoram Fault (Figure 1). Most workers interpreted the Ladakh block and the Kohistan Complex as a single accreted island arc terrane[3–8]. The Ladakh block is bounded by two suture zones – the Indus Suture in the south and the Shyok Suture in the north. These sutures mark the closing of different branches of the Tethys Ocean with the Indus Suture recording the final collision of India with Asia at 60–50 Ma (refs 3, 9–12). The complex sequence of rocks that occur along the Indus Suture include turbidites, ophiolitic mélanges with basalts interpreted as accreted seamounts[13,14], calc-alkaline volcanics, a granite batholith and the post-orogenic molasse sedimentary deposits[12]. All along its length the Indus Suture is characterized by obducted remnants of Neo-Tethyan oceanic crust. The more northerly Shyok Suture (Figure 1) separates Ladakh from Eurasian continental rocks of the Karakoram mountains to the north and contains ophiolitic mélanges, and thrust units derived from the southern Asian margin that were juxtaposed when Kohistan/Ladakh collided with Asia at 102–85 Ma (ref. 3–5).

The accreted arc units are well exposed along the Indus–Shyok sutures. The occurrence of Aptian–Albian rudists and orbitolinids[15] from the Shyok Suture Zone defines a minimum age for the subduction-related volcanics associated with the Shyok Suture and establishes a firm correlation with the equivalent suture zone in northern Pakistan to the west of the Nanga Parbat–Haramosh syntaxis vis-à-vis their palaeogeographic significance.

The rocks of the Shyok Suture Zone, trending northwest–southeast across the Nubra–Shyok valley, occur within intensely deformed tectonic slices between the Ladakh batholith, to the southwest, and the Karakoram batholith to the northeast (Figure 1). Across a traverse through the Shyok–Nubra river valleys and the adjoining part of the Karakoram block, these tectonic slices comprise a variety of sedimentary, metamorphic and igneous rocks interpreted as an ancient accretionary complex[4,13]. The geological structure of the Shyok Suture Zone has recently been described and discussed elsewhere[4,16–18].

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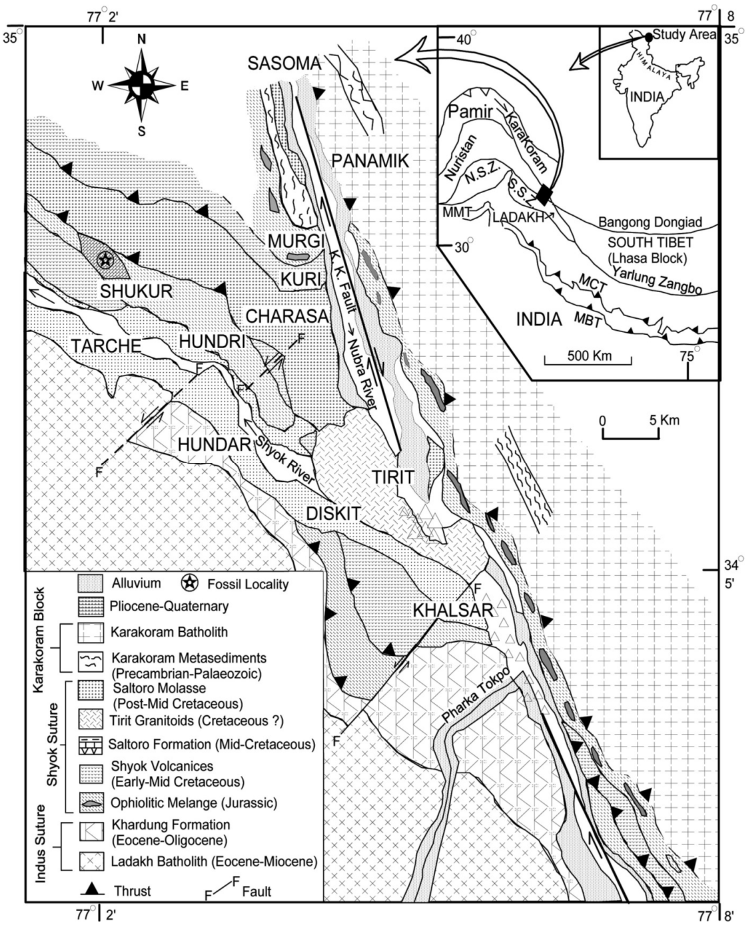

Figure 1. Geological map of the Shyok Suture Zone in the Nubra–Shyok valley, northern Ladakh. The fossil-bearing locality within the Saltoro Formation is near the village of Shukur. K.K. Fault, Karakoram Fault (modified after Upadhyay *et al.*[4]).

Figure 2. ***a***, Shyok volcanics overlain by fossiliferous Saltoro limestone near Shukur. The contact between the volcanics and the limestone is a local thrust. The original stratigraphic superposition of the limestone on the volcanics is testified by the occurrence of volcanic clast in the basal limestone. ***b***, Close-up of the fossiliferous Saltoro limestone. ***c***, Outcrop view of limestone with rudists and other mollusk shells, Saltoro Formation, Aptian–Albian, near Shukur.

The occurrence of a ~200 m thick, highly folded and partly recrystallized limestone sequence within the marine Saltoro Formation of the Shyok Suture Zone (Figures 1 and 2) has yielded abundant late Aptian rudists (Figures 2 *c* and 3), Aptian–Albian foraminifera (Figure 4 *a–f*) and other faunal elements (Figures 3 and 4). The Saltoro Formation is a 1000–1500 m thick complex consisting of thinly and mostly even-bedded, highly fissile and cleaved slate, siltstone, turbiditic sandstone and limestone (Figure 1). The rocks yielding the Aptian–Albian fossils are dark grey to light grey limestone and tectonically overlie volcanic rocks of island arc affinity[4,17,18] (Figures 1 and 2). The contact between the volcanics and Saltoro limestone could be a non-conformity that might have been tectonically overprinted during collisional and post-collisional tectonic episodes. The upper part of the Saltoro Formation comprises sandstone turbidites interbedded with thinly to medium-bedded, black, pyritic shales, grey to green fissile slate, siltstone and dark grey-black coloured chert.

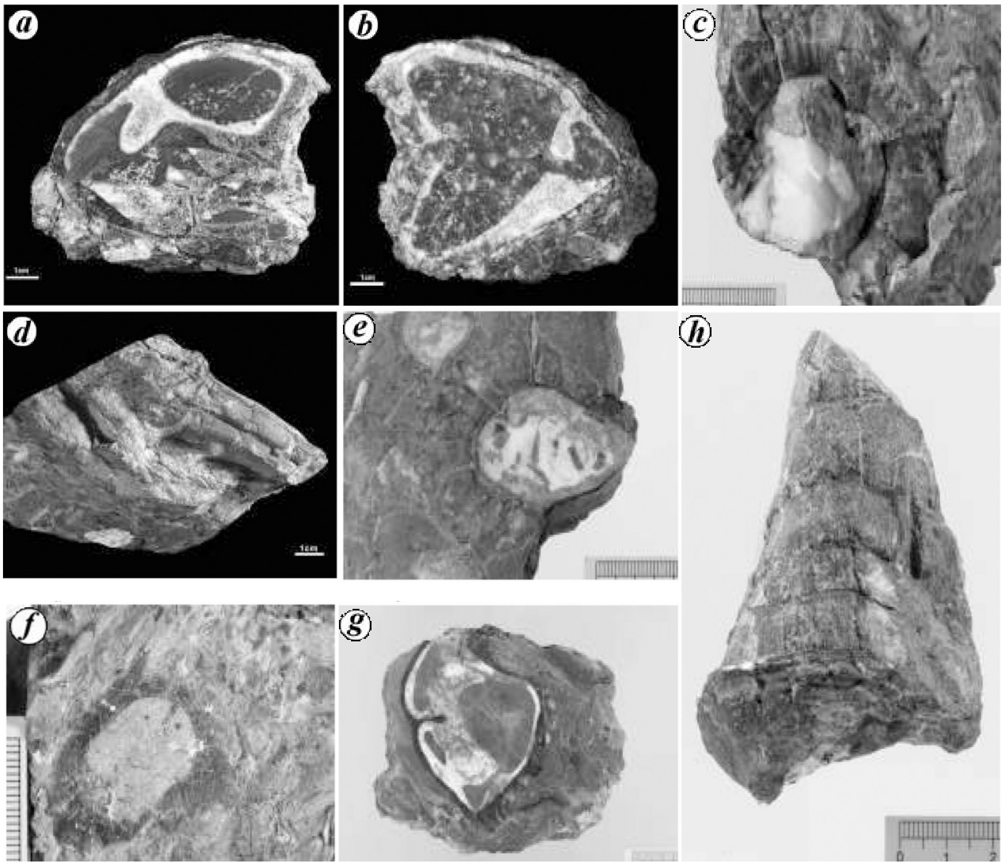

Figure 3. ***a***, ***b***, *Horiopleura* sp. similar to *Horiopleura haydeni* Douvillé of late Aptian age. ***c–f***, Radiolitids (*Eoradiolites gilgitensis* Douvillé) of latest Aptian–Early Albian age[15].

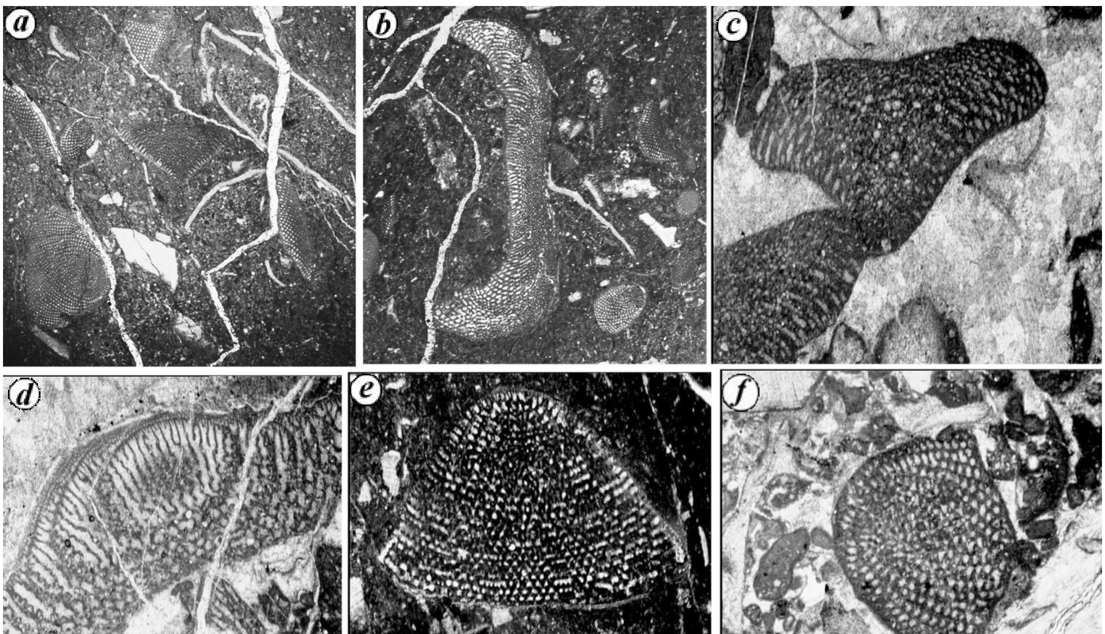

Figure 4 *a–f*. *Orbitolina*-bearing limestone. *Orbitolina* are similar to *Orbitolina discoidea-concoidea*, *Orbitolina lenticularis* of Aptian/Albian age.

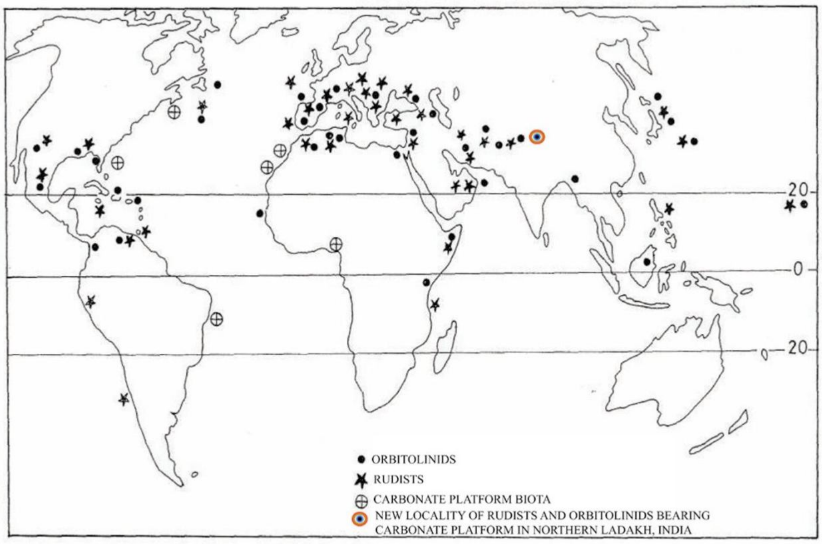

Figure 5. Geographic distribution of Early Cretaceous rudists, orbitolinids and other carbonate-platform biota (larger foraminifera, dasyclad algae; modified after Masse[48]). Note the addition of new locality of rudists and orbitolinids bearing carbonate platform as recorded from the Shyok Suture Zone in northen Ladakh, India.

Facies

The fossiliferous limestone is rich in thick-shelled bivalves, gastropods and other mollusks, echinoids and corals. Bivalves, limited to the Aptian, are mostly rudists – *Horiopleura* and Radiolitids (Figures 2 *c* and 3). *Horiopleura* has a well-defined and restricted geographical distribution and Albian stages[19]. The presently recorded Caprotinid genus *Horiopleura* from the Shyok Suture Zone is similar to *Horiopleura hydeni* Douvillé[20] of Aptian age. The large size of the present specimens (Figure 3) suggests a latest Aptian–Early Albian age. Similarly, the relatively massive size of the radiolitids suggests *Eoradiolites gilgitensis* (Douvillé; Figure 3). Similarly, the occurrence of late Aptian *H. hydeni*, *E. gilgitensis*, corals, nerineids and other mollusks from a dark limestone sequence resting above equivalent volcanic rocks has been mentioned and described from the Yasin group sediments exposed along the Northern Suture in northern Pakistan[20–24].

In the thin section different limestone microfacies are observed, including floatstones, grainstones, boundstones and packstones, in part with well-preserved geopetal fabrics. The overall microfacies association is rich in fragments of rudists, gastropods, crinoids, corals, bryozoans, hydrozoans, foraminifers, algae and oncoids (Figure 4). Floatstones are rich in *Lithocodium*/*Bacinella*, encrusting foraminifera of *Placopsilina*-type, indeterminable rudist fragments, echinoid spines, dasycladacean algae and orbitolinids ex group *Orbitolina lenticularis* (Figure 4 *b*) of probable Aptian–Albian age. Other thin sections also yielded a rich foraminiferal assemblage, including *Orbitolina concoidea-discoidea*, *Palorbitolina* and *Texularia* of Aptian–Albian age besides the volcanic rock fragments (Figure 4).

This limestone microfacies association and faunal assemblage thus document the presence of shallow-marine, open shelf/platform margin reefal build-ups which grew on a volcanic seamount or ridge (Figure 2 *a*). Presence of *Lithocodium*/*Bacinella* algae suggests that these might have acted as binding organisms, while the volcanic edifice was a submarine high on which the build-ups grew.

Regional correlation

The rudist fauna and the microfaunal assemblage of the Saltoro Formation of northern Ladakh suggest that it is an equivalent of the Aptian–Albian Yasin group of northern Kohistan, west of the Nanga Parbat–Haramosh syntaxis, deposited ~ 700 km further west[24]. Furthermore, it can be correlated with a volcano-sedimentary succession yielding Aptian–Albian *Orbitolinae* reported along the Shyok Suture exposed farther southeast near Pangong Tso Lake in northeastern Ladakh (~ 150 km southeast of the present locality)[25,26]. Razdan and Raina[27] have also reported *Orbitolina* sp. in limestone bands forming part of their Cretaceous Diskit Formation. Recently, Juyal[28] has recorded middle Cretaceous foraminifera from the Shyok Suture Zone. Although the presence of *Orbitolina*-bearing sediments was known earlier, the rudist-bearing sediments in the Shyok Suture Zone of northern Ladakh have been recorded by the present author during his 1996 and 2002

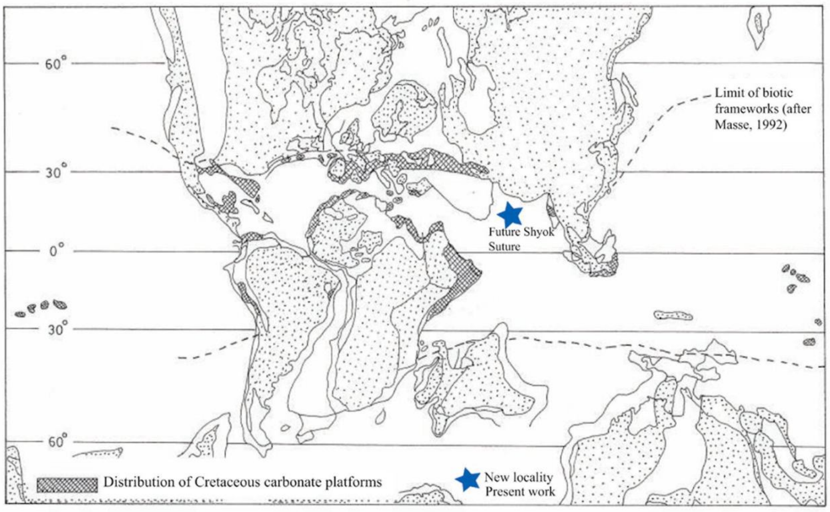

Figure 6. Distribution of Cretaceous carbonate platforms having rudist-dominated framework (modified after Simo[29]). The present work adds the new locality of the Cretaceous carbonate platform as recorded from the Shyok Suture Zone in northern Ladakh, India.

field work in the Saltoro Hills of the Nubra–Shyok valley region[15].

Palaeogeographic implications

Rudists, nerineids, corals and foraminifers of Early Cretaceous are widely distributed as reefal frameworks all along the tropical and subtropical Euro–African–Asiatic regions of the northern and southern margins of Tethys[29] (Figures 5 and 6). The places of their greatest development are along the northern margin of the Pyrenean-Cantabrian region, other parts of Spain, Portugal and the Urgonian facies of southern France[30], along the Adriatic margin of the peri-Adriatic carbonate platforms of the Apennines[31], the Dinarides[32], the Hellenides, the Taurides and the southern margin between north Africa, Israel[33] and Oman[34,35], continental fragments and islands arcs within Tethys, including areas in northern Pakistan[22,24], and Nagri in western Tibet[36]. Cretaceous rudist-dominated reefal frameworks have also been reported[37] from the western Tethyan region of Texas[38,39], Arizona[40] and Mexico[41]. Recently, Skelton *et al.*[42] have reported similar rudist-bearing sedimentary records from Ghomenjan (Qumenjan) area of Iran. Beside these occurrences that are widespread along the passive continental margins of Tethys, rudist-bearing shallow-water limestone is known to cap isolated volcanic edifices and seamounts throughout the Tethys (Sicily[43]; the Caribbean[44,45]) and the tropical central Pacific[46,47]. These isolated occurrences allow to map the Cretaceous tropical belt in more detail[15,48] (Figures 5 and 6), whilst the examples from Yasin group in Pakistan and Nubra–Shyok valley in northern Ladakh, India allow to place an upper time-bracket for the subduction-related volcanics of the Shyok Suture Zone.

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ACKNOWLEDGEMENTS. I thank late Prof. Erik Flügel, Profs. Daniel Bernoulli, P. W. Skelton and Richard Hoefling for help in various stages of the present work. I also thank Prof. P. Balaram (former Editor, *Current Science*) for encouragement. I also thank the Head, Centre of Advanced Study in Geology, Kumaun University, Nainital for providing the necessary facilities for research within the framework of UGC-CAS and DST-FIST programmes and the anonymous reviewers for their suggestions that helped improve the manuscript.