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Foraminiferal biostratigraphy of the Early Cretaceous Hundiri Formation, lower Shyok area, eastern Karakoram, India

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The arc sequence in the lower Shyok area comprises volcanics (Shyok Volcanics) and intra-arc basin sediments (Hundiri, Saltoro Flysch and Saltoro Molasse formations). Biostratigraphic investigations on the Hundiri Formation indicate that this lithounit contains several Aptian–early Albian orbitolinids comprising *Mesorbitolina*, *Orbitolina*, *Praeorbitolina*, *Palorbitolinoides*, *Palorbitolina*, *?Neorbitolinopsis* and *Paracoskinolina*. The orbitolinid taxa from the Shyok tectonic belt are comparable with those known to occur in Ladakh, Chitral, Burzil Pass (Indo-Pak region), Afghanistan, South Tibet and Myanmar. Fossil data suggest the existence of transgressive Neo-Tethys sea during Early Cretaceous, north of the Indian Plate.

Keywords: Aptian–Albian, orbitolinids, biostratigraphy, eastern Karakoram.

THE Shyok tectonic belt, which lies in the northwestern part of Ladakh, is a geologically poorly known terrain (Figure 1 *a*, *b*). In this belt several igneous, sedimentary and metamorphic rock types occur and are sandwiched between the Ladakh Batholith to the south and the Karakoram Batholith to the north (Table 1). The marine sedimentary succession in the lower Shyok area is represented by the Hundiri and Saltoro Flysch formations. The latter lithounit is overlain unconformably by the Saltoro Molasse Formation. The Shyok tectonic belt attracted the attention of several pioneering geologists[1,2]. This region is of great geological interest as it is related to subduction of the Indian Plate below the southern margin of Asia and was studied by several researchers in the recent past[3–9]. The Hundiri and Saltoro Flysch formations (=Saltoro Formation of Upadhyay[8]) (Figure 2) are well exposed at several localities in the Saltoro Hills and are also exposed along the right bank of Shyok river (Figure 1 *b*). Sections of the Hundiri Formation from east to west were observed along the Dosam–Biagdong route at several localities, namely Dosam (a camp site east of Hundiri village), Hundiri, Hora Sostan villages and Sukur Nala. The outcrop of this formation extends up to Biagdong and further west.

Orbitolinids are larger foraminifera that are helpful for stratigraphic calibration. They belong to the family Orbitolinidae – an important fossil group, known to occur in the pelagic carbonate platform facies – and range from Barremian to Cenomanian (middle part of the Cretaceous, i.e. approx. 125–93.5 m.y.). Thus, orbitolinids are restricted to a short stratigraphic range and have a wide geographical distribution. They are helpful in palaeogeographic reconstruction and in interpreting environment of deposition. They are well developed in carbonate build-ups, volcanic seamounts in the Shyok Suture, Ladakh, India and are excellent markers in correlation on a global scale[10]. Along this suture, the Ladakh arc sediments containing orbitolinids indicate transgression of sea during Aptian–Albian. Appearance of orbitolinid taxa in Shyok suture zone indicates that the sea transgressed in this zone during early Cretaceous time. In the Indian subcontinent, coeval orbitolinid taxa occur in the Lhasa–Shyok–Kohistan block as well as in the Indus suture zone of Ladakh, indicating the presence of transgressive sea in these areas during Aptian–Albian.

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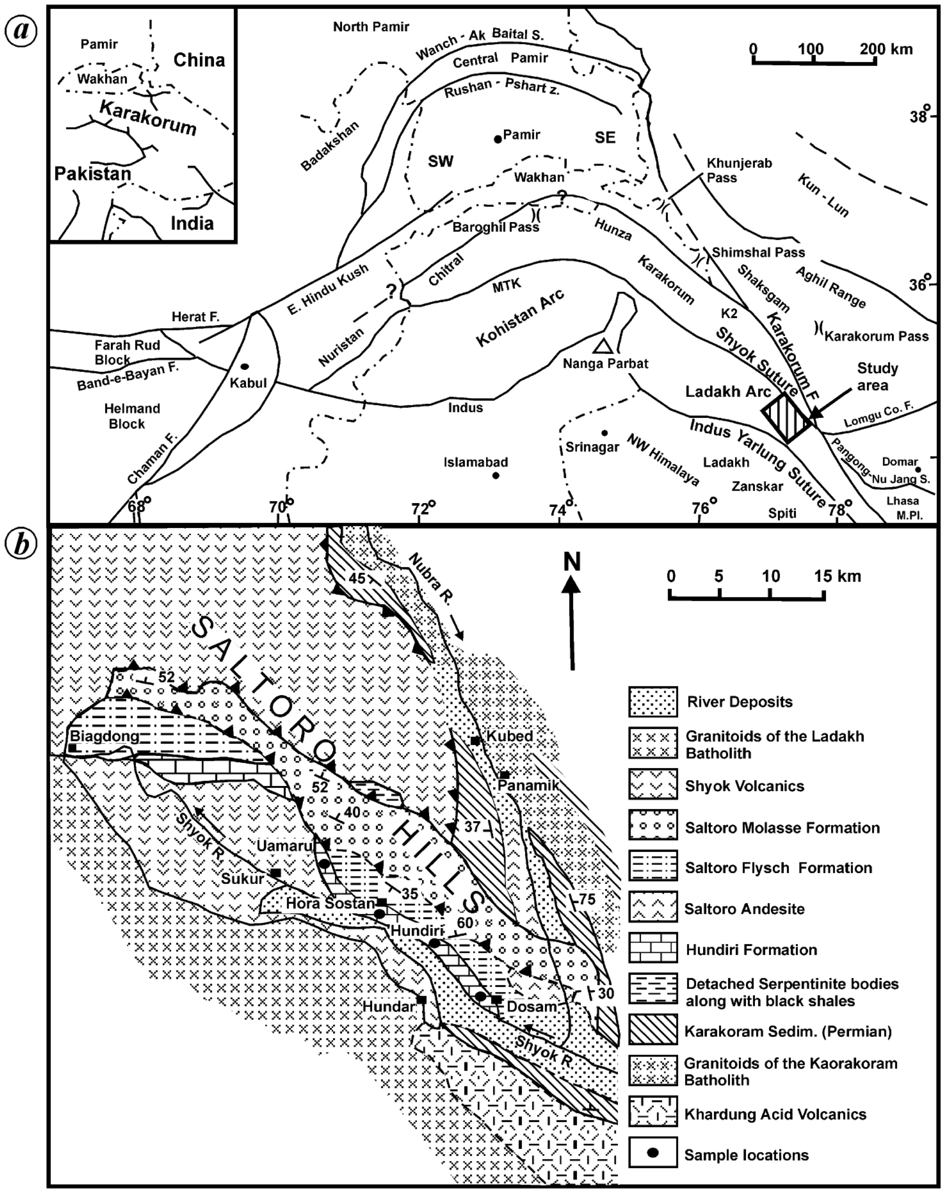

Figure 1. ***a***, Major tectonostratigraphic blocks and sutures with index map (inset) of the Pamir–Karakoram knot (adapted from Gaetani[9]). The study area is shown in box. ***b***, Geological map of the lower Shyok area (modified)[4,5].

Comprehensive biostratigraphic studies have not so far been carried out by palaeontologists in the Shyok suture zone. Bhandari *et al.*[3] recorded the presence of orbitolinids from the Hundiri Formation and assigned Cretaceous age to it. This age assignment was supported with illustration of orbitolinid fauna from this lithounit[7] (=Saltoro Formation[8]). Sporadic finds of *Nummulites* and bryozoans from this formation are given by a few workers[4,6]. However, they have neither illustrated/described these taxa nor have they given repository numbers. Thus their material is not available for further studies. In this communication, all illustrated material has been deposited at the Wadia Institute of Himalayan Geology Museum, Dehra Dun, India under Cat. nos. WIMF/A 551–564. Age diagnostic orbitolinid fauna was recovered from different horizons from the bottom to top of the Hundiri Formation (Figure 2). Therefore, the reported occurrence of nummulitids from the Hundiri Formation is untenable.

Biostratigraphic investigations on the Hundiri Formation revealed that the limestone succession occurring at Hora Sostan locality is highly fossiliferous, which has yielded age diagnostic orbitolinid taxa[7].

A detailed laboratory work revealed the occurrence of *Praeorbitolina cormyi* Schroeder, *Palorbitolinoides hedini* Cherchi and Schroeder, *Mesorbitolina*? *drasensis* (Mamgain and Jagannatha Rao), *M. parva* (Douglass)-*texana* (Reo-

Table 1. Tectonostratigraphic set-up along the Shyok tectonic belt, India (modified)[5]

NORTH Karakoram Batholith (Neogene)	
------------ Intrusive contact/thrust ------------	
	Northern mélange: red and light brown shale, black shale, pebbles and boulder of chromite rich serpentinite
Ophiolitic mélange (Cretaceous)	Dongpolas mélange: mainly black shale, serpentinite and basic volcanics
	Southern mélange: mainly phyllite with limestone, quartzite and serpentinite
------------ Thrust ------------	
Saltoro Molasse Formation (?post Cretaceous)	Variegated shale, sandstone in the upper part, conglomerates in lower part, porphyritic andesite, dolerite and apatite dykes with pockets of iron ore
------------ Unconformity ------------	
Saltoro Flysch Formation (post early Albian)	Micaceous phyllite, limestone and quartzite intruded by basic dykes
Hundiri Formation (Aptian–early Albian)	Fossiliferous limestone, black carbonaceous shale, phyllite, quartzite and chert intruded by highly altered porphyritic dykes
------------ Thrust ------------	
Shyok Volcanics (Early Cretaceous)	Basic lava flows intruded by gabbro, hornblendite, pyroxenite and granite
------------ Thrust ------------	
Khardung Volcanics (Oligocene)	
------------ Intrusive contact ------------	
Ladakh Batholith (Cretaceous–early Eocene) SOUTH	

mer), *Orbitolina discoidea* Gras, *Mesorbitolina* sp., *Palorbitolina* sp., ?*Neorbitolinopsis* sp. and *Paracoskinolina* sp. (Figure 3). This fossil assemblage indicates an Aptian – early Albian age to the Hundiri Formation.

The author has recognized the following assemblages (in ascending order) in the limestone succession of the Hundiri Formation at Hora Sostan:

Praeorbitolina cormyi-rudist assemblage: This assemblage contains ill-preserved orbitolinids and rudists, in addition to *P. cormyi* – an index early Aptian orbitolinid.

Palorbitolinoides hedini – Orbitolina discoidea assemblage: In addition to these age diagnostic orbitolinids, this assemblage contains *Palorbitolina* sp., ill-preserved corals and algae. This assemblage indicates a late Aptian age.

Mesorbitolina ?drasensis – M. parva-texana assemblage: Besides these age diagnostic orbitolinids, *Mesorbitolina* sp., *Orbitolina* sp., ?*Neorbitolinopsis* sp., ill-preserved rudists and algae were encountered in this assemblage. The faunal assemblage indicates an early Albian age.

As given above, the other section, namely Sukur *Nala* section, has yielded *Salpingoporella* sp., ?*Salenopora* sp., *Cayeuxia piae* and *Cayeuxia* sp. (algae). Among these, *Salpingoporella* sp. and *Cayeuxia* sp., which occur in association with orbitolinids in Hora Sostan section, are found in the Lower Cretaceous sediments elsewhere.

The Hundiri Formation of the lower Shyok area has yielded a number of orbitolinid taxa, including *Praeorbitolina cormyi*, *Mesorbitolina ?drasensis*, *M. parva-texana*, *Orbitolina discoidea* (= *O. tibetica*), *Palorbitolinoides hedini* in addition to ?*Neorbitolinopsis* sp. and *Palorbitolina* sp. *P. cormyi* has been recorded from the lower Aptian sediments of Ladakh (India), Gangdise–Nyainquentanglha and Ngari regions (Tibet) and Yasin (Pakistan); *Mesorbitolina ?drasensis* has so far been described from the lower Cretaceous rocks of Ladakh; *Orbitolina discoidea* has been recorded from the lower Cretaceous sediments of Ladakh (India) and Gangdise–Nyainquentanglha and Ngari regions (Tibet); *Palorbitolinoides hedini* has been reported from the lower Cretaceous rocks of Shigatse (South Tibet), Ladakh (India) and Afghanistan; *Palorbitolina* sp. has been recorded from the lower Cretaceous rocks of Ladakh (India) and Yasin (Pakistan); and *Mesorbitolina parva-texana* has been described from the upper Aptian to lower Albian sediments of Khalsi (India), Gangdise–Nyainquentanglha and Ngari regions (Tibet), Yasin area (Pakistan).

Bhandari *et al.*[3] recorded orbitolinid foraminiferal fauna from the Hundiri Formation and assigned a Cretaceous age to this formation. From hard, grey limestone which occurs in this lithounit in Sukur *Nala* section, Rai[4] recorded a few foraminiferal and algal taxa, and assigned a Maastrichtian to Eocene age to it. Later, Srimal[6] revised the age and assigned a Jurassic to Eocene age to the Hundiri Formation.

From the lower part of the Hundiri Formation, *P. cormyi* and rudists have been recovered by the author. The former taxon is restricted to early Aptian[11], indicating that lower part of the Hundiri Formation was deposited during this time. In the middle part of this formation two taxa, namely *Palorbitolinoides hedini* (late Aptian–Albian?)[12] and *Orbitolina discoidea* (Aptian–early Cenomanian)[13] are found. The latter taxon has maximum development in Aptian time. Therefore, the middle part of the Hundiri Formation may provisionally be assigned a late Aptian age on stratigraphic grounds. In the upper part of this lithounit, *Orbitolina ?drasensis* (Barremian–Cenomanian)[13] and *Mesorbitolina parva-texana* (late Aptian–Albian) are found. Therefore, this part may be assigned an early Albian age. Thus the faunal assemblages in the Hundiri Formation are indicative of Aptian–early Albian age. The Hundiri Formation is followed upwards by the marine Saltoro Flysch Formation (? late Albian). The Saltoro Molasse Formation was deposited unconformably over the Saltoro Flysch Formation.

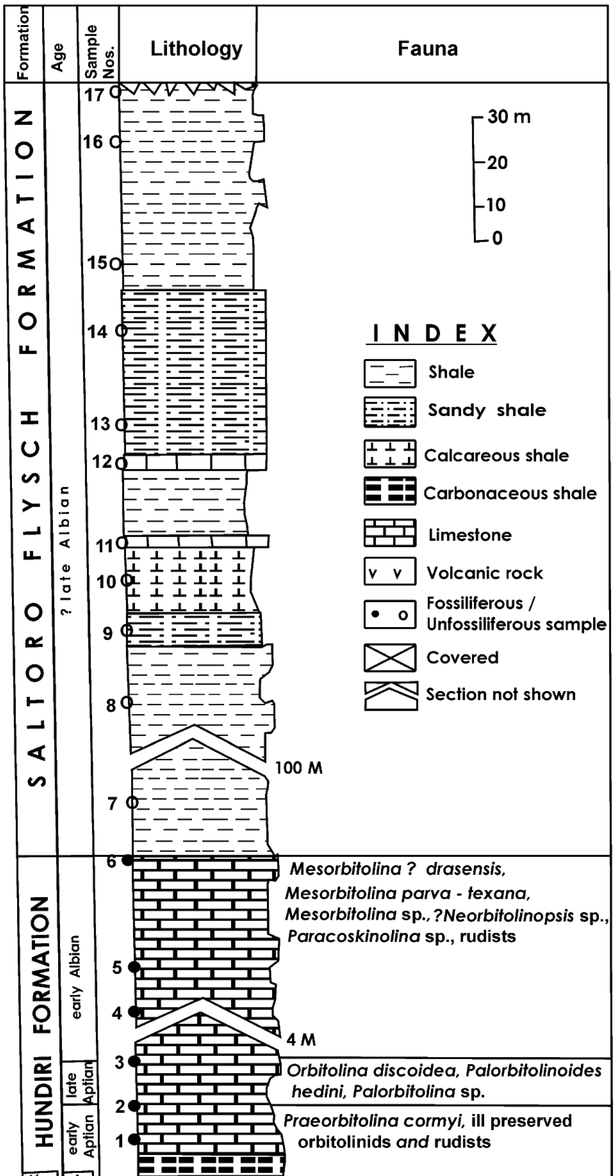

Figure 2. Biostratigraphic section at Hora Sostan.

Lozo[14] considered that the orbitolinids occur in shallow warm waters of normal salinity. Orbitolinids are generally found in close association with biohermal or biostromal deposits and are most common in the lime-rich shales and calcarenites of the fore-reef deposits; they are common but not abundant in the reef limestone[15]. Members of the family Orbitolinidae occur in open reef shoals[16]. According to Bergquist and Cobban[17], orbitolinids developed in warm, clear shallow waters of normal salinity and are commonly associated with rudists. According to Arnaud Vanneau and Premoli Silva[18], *Orbitolina* is found either with wave resistant species in coarse sand or during rises in sea level in the lagoons and their diversity in sediments is poor, except during periods of rising sea. It is interpreted that the orbitolinid and rudist limestone of the Hundiri Formation represents platformal sediments.

An analysis of the early Cretaceous orbitolinid assemblages recorded from the Hundiri Formation points to biotic dispersal in the regions north of the Indian Plate. These regions include Ladakh (India), Kohistan (Pakistan), Afghanistan and western Tibet, and probably shared a single faunal province which was occupied by a wide shallow sea. The vast extent of the *Orbitolina* sea extending from Afghanistan to Myanmar through Chitral Ladakh and Tibet was postulated by Sahni and Sastri[19]. The present study from lower Shyok area shows that this part lying in the northern margin of the sea was well connected with the other regions.

Palaeomagnetic data from the Tibetan Plateau suggest that during middle Cretaceous times, the Neo-Tethys was at least 6000 km wide[20]. Matte *et al.*[21] have shown that the Albian *Orbitolina* Flysch and Cretaceous Volcanics of the Jaggang–Shiquanhe mélange zone extend 1000 km to the east near Nam Co, and to the north of Kohistan, and further north up to Kabul. Gaetani[9] postulated marine connections of Pangong–Nujang backarc basin with the Shyok backarc, Kohistan and Ladakh–Gangdise regions.

The transgressive phase in the lower Shyok area continued till ?late Albian, during which the Hundiri and Saltoro Flysch formations were deposited. There was a regression of the sea after deposition of these lithounits and due to tectonic activities, the area uplifted and continental condition developed. The occurrence of orbitolinid limestone pebbles in the conglomerate of the succeeding freshwater Saltoro Molasse Formation suggests uplift of the region due to first collision after ?Albian time along the Shyok Suture zone.

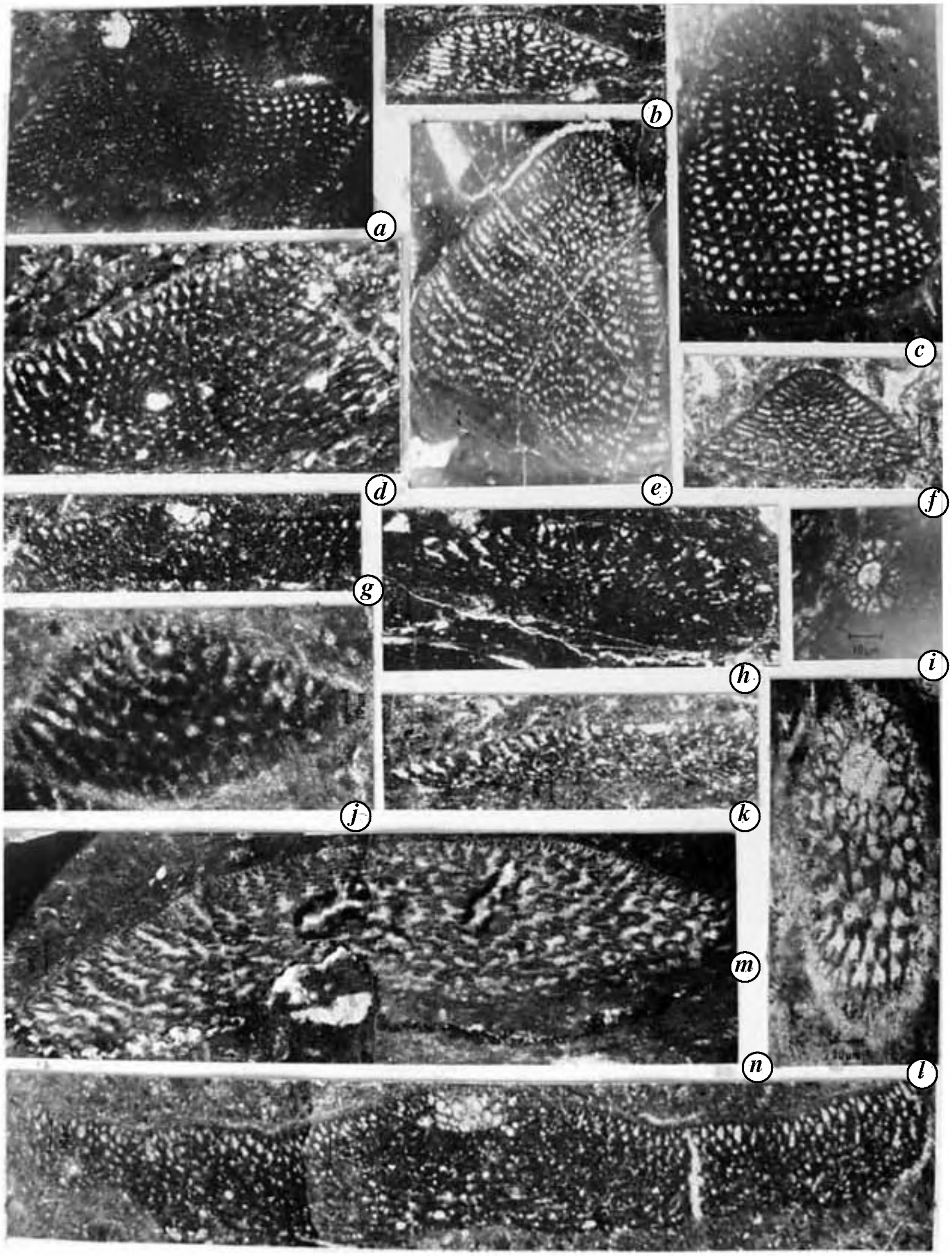

Figure 3. ***a***, ***d***, *Praeorbitolina cormyi* Schroeder, tangential section passing through proloculus (WIMF/A551, 552). ***b***, *Mesorbitolina* sp., oblique section (WIMF/A553). ***c***, *?Neorbitolinopsis* sp., tangential section passing obliquely through proloculus (WIMF/A559). ***e***, *Paracoskinolina* sp., tangential section (WIMF/A560). ***f***, *Mesorbitolina ?drasensis* (Mamgain and Jagannatha Rao), subaxial section (WIMF/A557). ***g***, ***h***, ***k***, *Mesorbitolina parva* (Douglass)-*texana* (Roemer), axial sections of meglospheric form (WIMF/A562,554,563). ***i***, Proloculus of *Orbitolina*, enlarged view (WIMF/A555). ***j***, *Palorbitolina* sp., oblique section through meglospheric apparatus (WIMF/A561). ***l***, Orbitolinid, oblique section passing through the center (WIMF/A556). ***m***, *Orbitolina discoidea* Gras, subaxial section of discoid form (WIMF/A558). ***n***, *Palorbitolinoides hedini* Cherchi and Schroeder, axial section passing through a relatively small embryonic apparatus (WIMF/A564).

The fauna from the marine Hundiri Formation, lower Shyok area points to an Aptian to early Albian (early Cretaceous) age. During the above time oceanic areas of the Shyok and Indus tectonic belts of Ladakh, Kohistan, and western Tibet were connected, and were parts of the wide shallow Neo-Tethys. The transgressive sea during early Cretaceous existed south of Karakoram microplate and North Tibet (i.e. Qiangtang microplate).

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