been also observed off the western part of the Seychelles plateau[27]. The Dhosa Oolite represents the detachment of Greater India during a more elaborate second phase (beginning of drift stage). The initial phase of continental stretching is manifested in the coralline Jhurio limestone, a facies which occurs only once throughout the Mesozoic sediment succession. Continental stretching led to the formation of a shallow high energy sediment starved sea which provided an environment conducive to the proliferation of corals (Figure 2).

Ironstones represent events of superplume activity[20]. Superplumes are known to aid and, in some cases, even initiate continent breakup[1]. The Golden oolite and Dhosa oolite show iron sequestration and qualify as ironstones. Iron was derived from element-rich infrequent hydrothermal Event-plumes, a modern example being that of the Juan de Fuca ridge. The ironstones thus document two phases of Event hydrothermal-plume generation related to excessive sea-floor spreading rates. One episode which resulted from the genesis of a mid-oceanic ridge system between Greater India and Africa, took place in the Bathonian, while the final breakup and migration of Greater India took place during the Oxfordian, which is manifested as the Dhosa Oolite.


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# A significant stage of metazoan evolution from the Proterozoic rocks of the Vindhyan Supergroup

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***Skolithos linearis*** **was recently found to occur on the plateau of Chittaurgarh Fort, Rajasthan, in the Morwan Sandstone Formation of the Kaimur Group (Vindhyan Supergroup). The presence of identical burrows from the same stratigraphic horizon at Besla and Rampura in Mandsaur district of Madhya Pradesh has been reported[1,2]. Vertical burrows belonging to *Skolithos* are known to occur in the Proterozoic rocks of Australia, California, southwest Africa, Russian Platform and extra-peninsular India. Vertical burrows provide security against adverse environmental conditions and give protection from predators. Hence, development of capacity to construct vertical burrows must be considered as a significant step in metazoan evolution. Occurrence of *Skolithos* in widely separated Proterozoic basins proves the antiquity of the development of this faculty.**

PRIMITIVE metazoans that thrived during the Proterozoic times did not possess any hard parts. The only clues to their existence and evolution are the lebensspuren

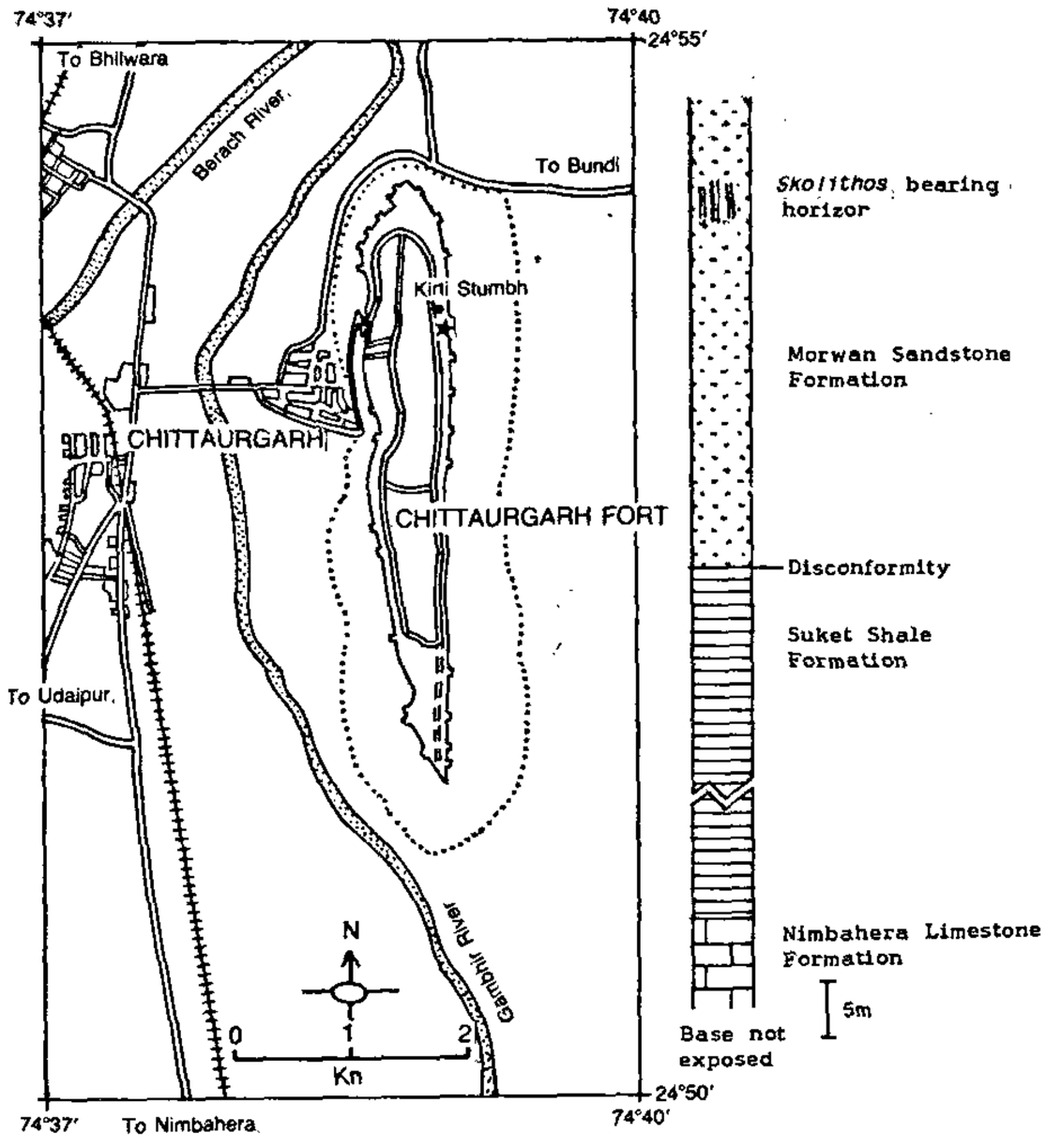


**Figure 1.** Fossil locality on Chittaurgarh Fort, indicated by * along with litholog.

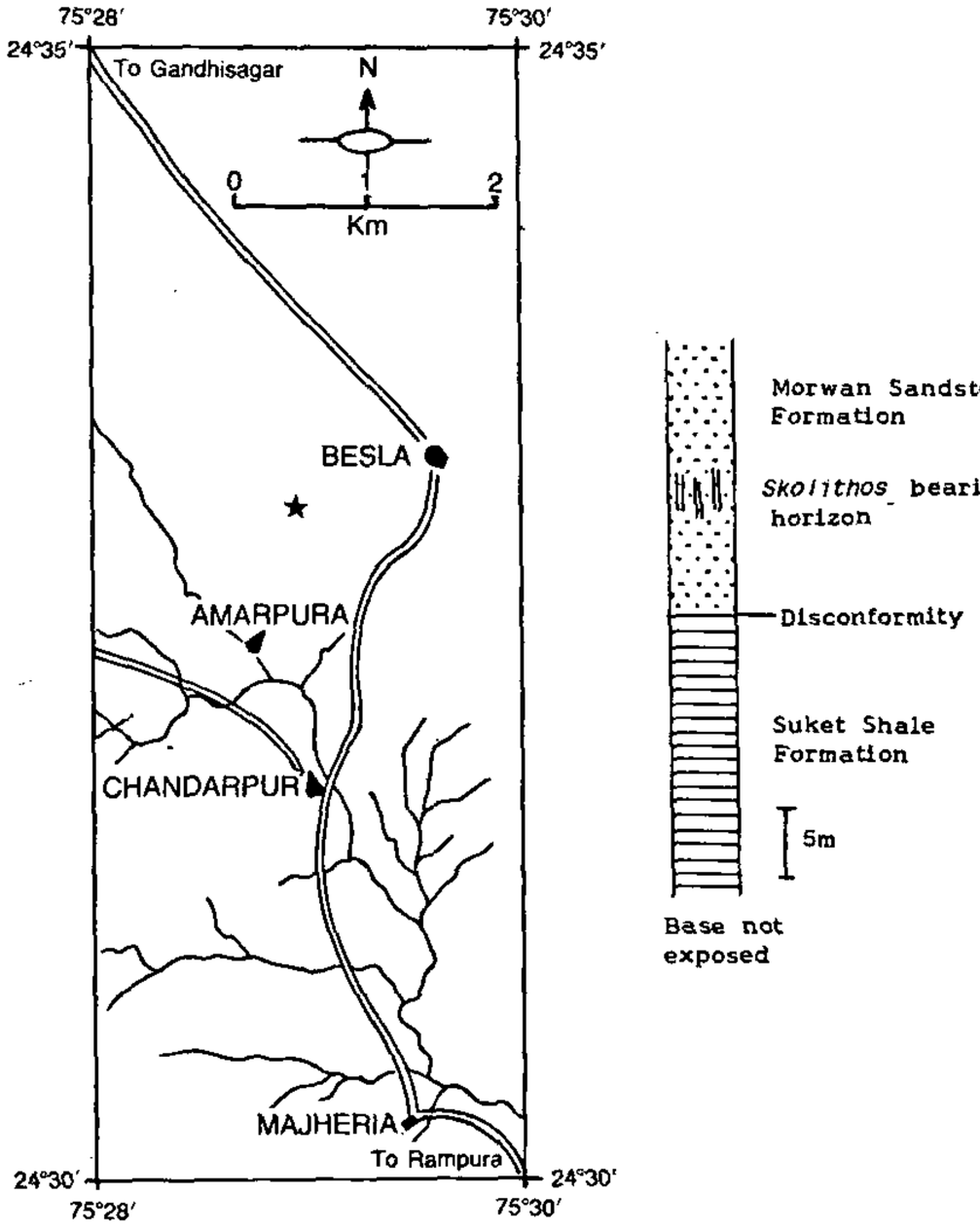


**Figure 2.** Fossil locality near Besla, indicated by * along with litholog.

produced by them. In this context, a recently discovered occurrence of certain vertical burrows in the Morwan Sandstone Formation (homotaxial with the Lower Kaimur Quartzite) of the Kaimur Group, is significant. The burrows were collected from the plateau of Chittaurgarh Fort, near the Kirti Stumbh (24°53'48":74°38'54"), Rajasthan (Figure 1). These burrows belong to the ichnospecies *Skolithos linearis* Haldemann, 1840. Similar burrows occurring in the same formation were also collected by us from village Besla (24°33'12":75°29'40"), Mandsaur district, Madhya Pradesh (Figure 2).

Straight, vertical to steeply inclined, unbranched, cylindrical burrows (Figures 3 and 4), ranging in diameter from 3 mm to 7 mm, occur in endorelief (Figure 5). The diameter may occasionally reach up to 12 mm, while the maximum measured length extends up to 120 mm. The fill is structureless (Figure 6) and resembles host rock material. The burrows occur in medium-grained, well-sorted, ripple laminated, grey quartz arenite of the Morwan Sandstone Formation. Though burrows in Besla (Figures 4 and 7) are better preserved than the ones at Chittaurgarh (Figure 3), the latter are more closely spaced.

In his review of the ichnogenus *Skolithos*, Alpert[3,4] identified straight nature, vertical disposition, distinct to indistinct burrow wall, diameter ranging from 3 mm to 7 mm often reaching up to 12 mm as the diagnostic characters of *Skolithos linearis* Haldemann, the type ichnospecies of the ichnogenus. The specimens from the Morwan Sandstone exhibit these essential, diagnostic characters and compare well with *S. linearis* from Bell Island and Wabana Groups of eastern Newfoundland, Canada[5] and hence are identified as *S. linearis*.

The occurrence of vertical burrows from the Morwan Sandstone Formation was noticed earlier[1,2]. Ghare and Badve[1] had collected it from village Rampura (22°17'30":74°46'52"), Mandsaur district, Madhya Pradesh. They had designated their specimens as *Palaeocuniculites osangustus*, erecting new ichnogenus and new ichnospecies. A comparison of type specimens of *P. osangustus*[1] with specimens from Chittaurgarh and Besla reveals that these two forms exhibit identical morphology. It transpires that designating the specimens from Rampura under a new name[1] was unwarranted and hence they are included here under *S. linearis* Haldemann, 1840.

Sisodiya and Jain[2] reported occurrence of identical burrows from village Besla, without any taxonomic identification. However, from the description and illustration given by them, the burrows from Besla show all the essential diagnostic features of *S. linearis*. The same is true of the specimens collected by us from Besla.

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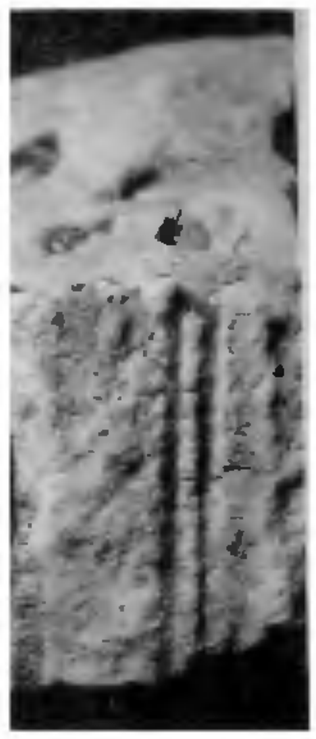

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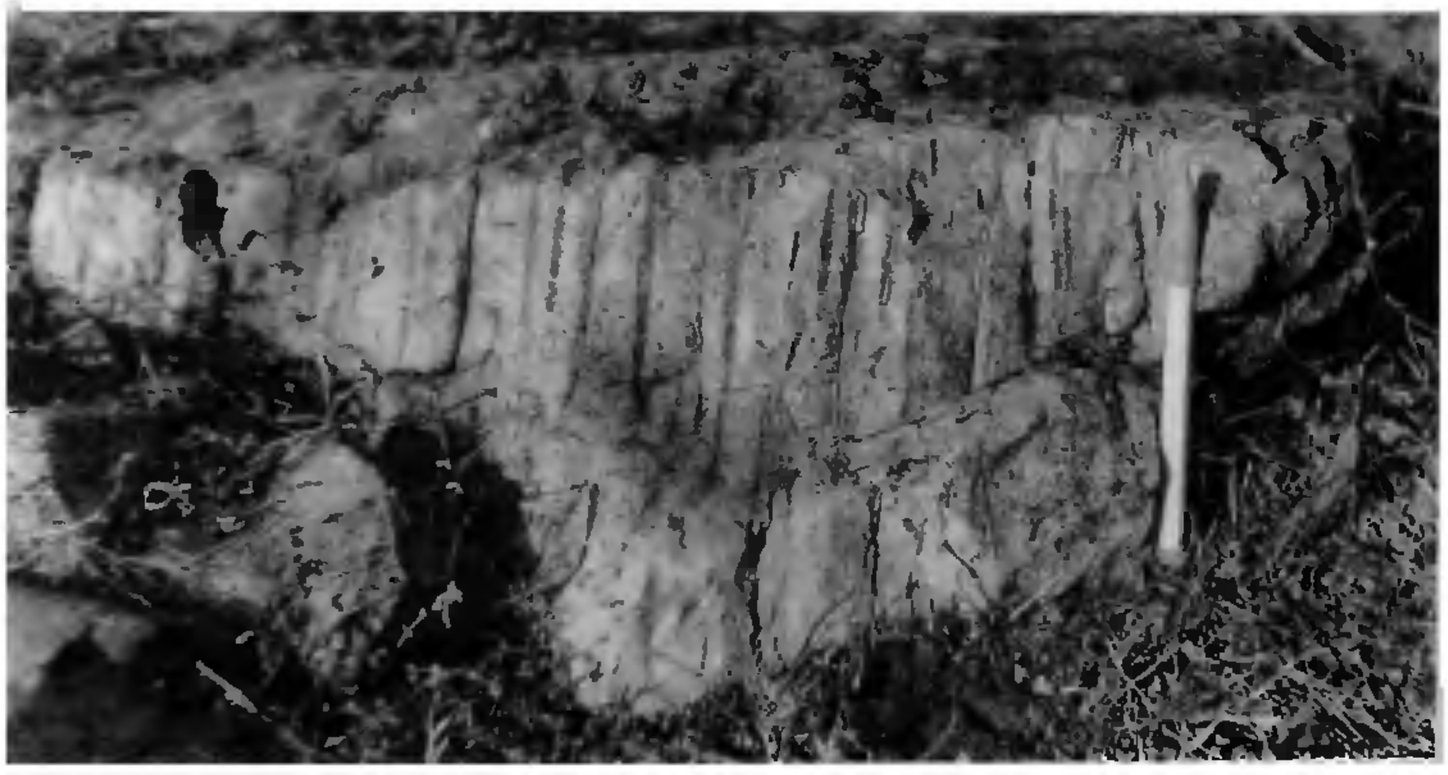

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**Figures 3–7.** *Skolithos linearis* Haldemann. **3**, Plesiotype (specimen no. MACS G 4333) from Chittaurgarh Fort, Rajasthan; **4**, A specimen (no. MACS G 4334) from Besla, showing cross-section of the burrow as viewed from above; **5**, Another specimen from Besla (no. MACS G 4335), showing distinct burrow lining; **6**, Structureless burrow fill in longitudinal section (specimen no. MACS G 4336). All photographs are of natural size; **7**, Field photograph from Besla. Length of pen is 14.3 cm.

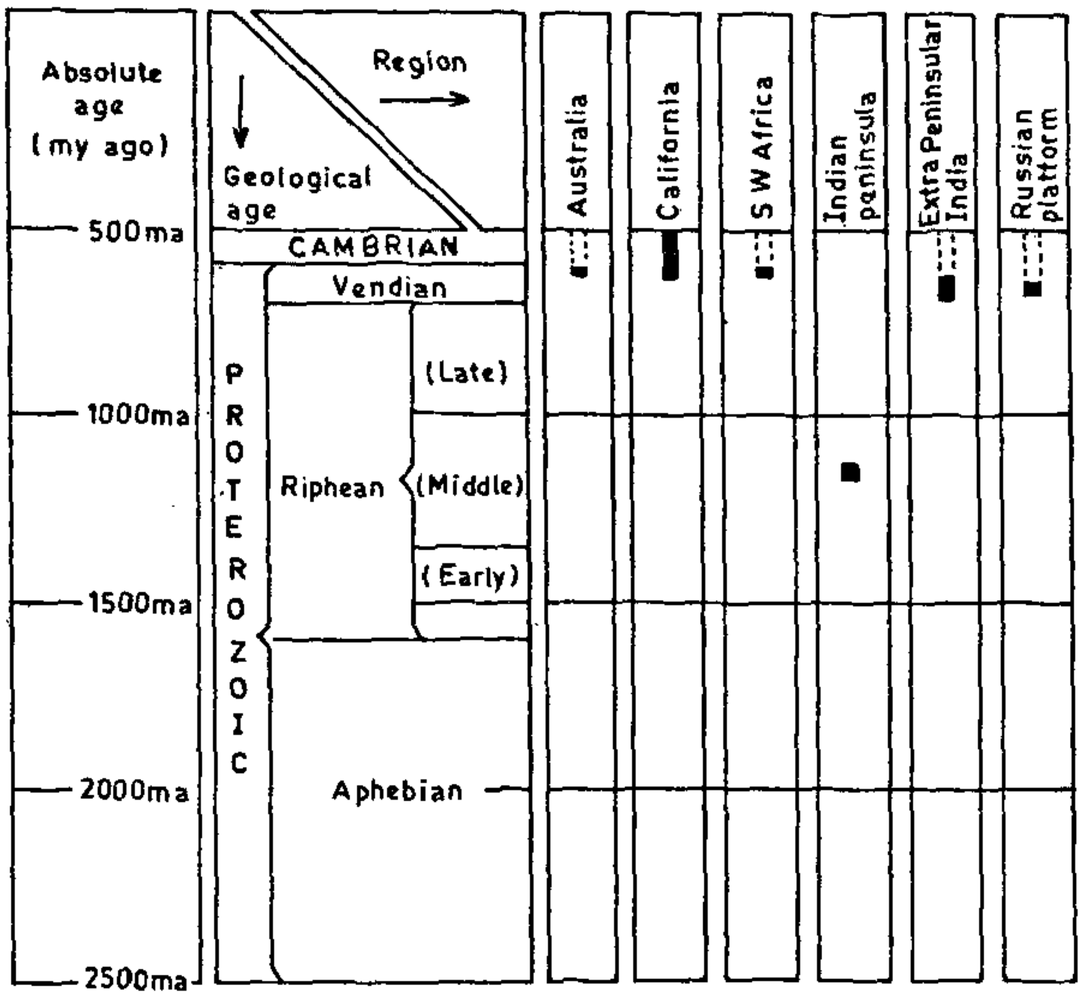


**Figure 8.** Distribution of *Skolithos* in Proterozoic basins.

Hence the burrows reported from Besla[2] are being assigned to *S. linearis*.

Though *Skolithos* is known to occur in a range of environments varying from deep water submarine channels and canyons to flood–plain and dune environments, it is usually associated with high energy marine conditions, particularly in nearshore shallow waters[5]. The primary sedimentary structures and the petrography of the rocks in which *Skolithos* occurs at Chittaurgarh, Besla and Rampura point to shallow water, nearshore, high energy conditions.

It is a well-accepted fact that the burrows assigned to *Skolithos* are constructed by annelids or phoronids[3–5]. It can, therefore, be inferred that the *Skolithos* from Chittaurgarh, Besla and Rampura were constructed by primitive worm-like metazoans resembling annelids or phoronids.

The extensive proliferation of metazoa at the base of Cambrian must not have been as abrupt as actual palaeonotological record suggests[6]. Existence of predecessors is documented in Proterozoic rocks as trace fossils. There is a unanimity in accepting that early life comprised prokaryotes like bacteria and cyanophyta[7–9]. The early prokaryotes inevitably evolved into small, poorly defined, primitive metazoans devoid of hard parts. According to Valentine[6], high mutation rates, broad environmental opportunities and rise of complexity in body plans together gave rise to complicated ecosystems. The changes that took place in the earth's crust during the Proterozoic era also played an important and decisive role.

In the sequel, certain organisms developed the faculty to build vertical burrows for dwelling, which endowed them with two major advantages: (i) safety against vagaries of the ecosystems, (ii) protection from predators[10]. In addition, procuring food perhaps became more convenient. Therefore, capacity to create vertical burrows is a significant step in the steady progress of metazoans[11].

Genus *Skolithos* occurs in widely separated Proterozoic basins, viz. Australia[12], California[4], southwest Africa[13], Russian Platform[14], extra-peninsular India[15] and central India (present report). In these basins, *Skolithos* is variously associated in field with simple traces like *Archaeichnium, Buchhlozbrunnichnus, Bunyerichnus, Cochlichnus, Harlaniella, Planolites* and *Torrowangea*. Some of these genera are known to be restricted to Proterozoic rock formations. It can safely be concluded that capacity to create vertical burrows was successfully achieved well before the end of Proterozoic era as seen in Figure 8. Also, that the earliest record of *Skolithos* is from the Vindhyan Supergroup is clearly evident from this figure. This conclusion reveals the antiquity of the metazoans acquiring the ability to construct vertical burrows.

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