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Late Cretaceous (Maastrichtian) non-marine ostracod fauna from Khar, a new intertrappean locality, Khargaon district, Madhya Pradesh, India

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Abstract. The paper records the occurrence of 12 non-marine ostracod species belonging to nine genera from a new intertrappean section located at Khar in Madhya Pradesh, Central India. These are - *Frambocythere tumiensis anjarensis*, *Gomphocythere akalypton*, *G. paucisulcatus*, *G. strangulata*, *Paracyprretta jonesi*, *Stenocypris cylindrica*, *Zonocypris gujaratensis*, *Cypridopsis hyperectyphos*, *Eucypris intervalcanus*, *E. pelasgicos*, *Cyclocypris amphibolos* and *Cypria cyrtonidion*. All these are assigned to previously known species from the Upper Cretaceous Lameta Group and Deccan intertrappean beds of central and western peninsular India. The present ostracod assemblage favours a Late Cretaceous (Maastrichtian) age for the intertrappean beds of Khar and also indicates to the existence of a permanent freshwater, lacustrine body during the deposition of these intertrappean

beds. The lack of marine fossils in the intertrappean beds of the Narmada rift valley do not attest to any marine incursion along the Narmada valley, at least in the latest Cretaceous.

Keywords: Central India, intertrappean, Khar, Maastrichtian, non-marine ostracods

Introduction

The Deccan Traps, covering an area of about 5,00,000 km² in peninsular India, are considered as one of the largest continental flood basalts on the earth's surface. At many places, the Deccan basaltic flows are found occurring in association with fossiliferous sedimentary sequences, either below the volcanic flows or intercalated with them. The sedimentary sequences that occur sandwiched between the volcanic flows are also known as the intertrappean beds. Since the middle of nineteenth century, the intertrappean beds are known to yield non-marine microfossil assemblages especially ostracods and molluscs (Hislop, 1860; Whatley, 2012 and references therein) and vertebrate microfossils (Woodward, 1908; Hora, 1938; Prasad, 2012 and references therein). Until now, there are only two known reports of marine intertrappean sedimentary sequences; one on the east coast of Andhra Pradesh near Rajahmundry yielding abundant foraminifers and marine ostracods (Bhalla, 1965, 1967; Govindan, 1981; Bhandari, 1995; Khosla, 1999; Khosla and Nagori, 2002; Keller *et al.*, 2008 and Malarkodi *et al.*, 2010) and the second one at Jhilmili, in Chhindwara district, Madhya Pradesh yielding Early Danian planktic foraminifers in association with brackish and non-marine ostracod assemblage (Keller *et al.*, 2009a, b; Sharma and Khosla, 2009; Khosla *et al.*, 2009, 2011a). The remaining intertrappean beds of the Deccan volcanic province yielded essentially fluvio-lacustrine biota.

Previous work

Until now, no micropalaeontological studies have been carried out on the intertrappean beds of lower Narmada valley. The earliest work on the ostracod fauna of the Deccan intertrappean beds is by Sowerby (in Malcolmson, 1840), who for the first time described two new species of lacustrine ostracods from the Sichel hills, Andhra Pradesh. Subsequently, Carter (1852) and Jones (1860) reported three and five species of ostracods from the intertrappean beds of Bombay and Nagpur, respectively. Despite these early initiatives, lacustrine ostracods of the intertrappean beds remained neglected for over 125 years until Bhatia and co-workers (Bhatia and Rana, 1984; Bhatia *et al.*, 1990a, b, 1996) described the Upper Cretaceous (Maastrichtian) intertrappean ostracods from a number of localities. These authors suggested that the intertrappean ostracod fauna exhibits Laurasian affinities. Thereafter, Mathur and Verma (1988) described six species of ostracods from the intertrappean beds of Rajasthan. Singh and Sahni (1996) discussed the age and faunal affinities of the Bombay intertrappean beds based on a variety of fossil groups with special emphasis on Ostracoda. Bhandari and Colin (1999) described 11 species of Ostracoda, including a new species and a subspecies from the intertrappean beds near Anjar, Kachchh District, Gujarat. Whatley and his co-workers published a series of papers on ostracods from the lacustrine intertrappean beds of different localities in central and western India. Rich ostracod fauna has been reported by these authors from Lakshmipur, Anjar and Kora intertrappean beds of Kachchh district, Gujarat (Whatley and Bajpai, 2000a, b; Bajpai and Whatley, 2001). Further, Whatley *et al.* (2002a, b, 2002, 2003a-c) described a large number of ostracod species from the intertrappean beds of Chandarki and Yanagundi, Gulbarga district (Karnataka), Mohgaonkalan, Chhindwara district (Madhya Pradesh), Mamoni, Kota district (Rajasthan), and from the intertrappean type collections housed in the Natural History Museum, London. Whatley and Bajpai (2005, 2006) discussed at length the palaeoecological implications of the intertrappean

ostracods and felt that the Indian late Cretaceous ostracod fauna is endemic at species level and does not exhibit any taxonomic affinity to contemporary lacustrine ostracod fauna of Mongolia and China as visualized earlier by Bhatia *et al.* (1990a, b, 1996). Later, Khosla and Nagori (2005, 2007a, b) reported the occurrence of many ostracod species from the intertrappean beds of Anjar, Mohgaon-haveli and Takli. A single report of 14 species of ostracods from the northernmost intertrappean outcrop at Papro near Lalitpur, U.P. was made by Sharma *et al.* (2008). More recently, Khosla *et al.* (2011a) described 20 lacustrine-brackish water ostracod species from the early Danian P1a planktic foraminiferal zone of the Jhilmili intertrappean beds, Chhindwara district, Madhya Pradesh.

Besides from the intertrappean beds, freshwater ostracod fauna has also been documented from the Upper Cretaceous Lameta Group of Jabalpur, Madhya Pradesh (Sahni and Khosla, 1994; Khosla and Sahni, 2000; Khosla *et al.*, 2011b) and Nand-Dongargaon basin (Udhoji and Mohabey, 1996; Khosla *et al.*, 2005, 2010), Chandrapur district, Maharashtra.

Geological setting and the sample location

The geological succession of the study area comprises Precambrian basement rocks (Bijawar and Mahakoshal groups) covered by marine Cretaceous rocks of the Bagh Group (Bose, 1884; Tripathi, 2006). The Bagh Group comprises three formations namely – Nimar Sandstone, Nodular Limestone and Coralline Limestone in ascending order. The Nimar Sandstone, Nodular Limestone and Coralline Limestone yield marine fossils abundantly and are regarded as Cenomanian, Turonian and Coniacian in age, respectively (Jaitly and Ajane, 2013). These beds are exposed along a narrow stretch of land as detached outcrops along the lower Narmada valley. The Bagh beds in turn are unconformably overlain by the Upper Cretaceous (Maastrichtian)

Lameta Group. Some poorly preserved bones, nests and eggshells of sauropod dinosaurs have been documented from the Lameta Group of this region (Khosla and Sahni, 1995; Fernandez and Khosla, 2015). Following the deposition of Lameta sediments, the eruption of Deccan lava flows, which conceal the underlying sedimentary units to a large extent, took place. At some places, these lava flows are found intercalated with thin sedimentary beds (intertrappean beds).

Several intertrappean localities have been investigated along the Narmada rift valley (Figure 1A) for vertebrate fossils (G V R Prasad personal study). But the present investigation from where the ostracod fauna has been reported and described in this paper are from an intertrappean section exposed near Khar Village (22°18'N, 75°32'E), Khargaon (Khargone) District, Madhya Pradesh (Figure 1B). At this locality, the intertrappean section measures 0.75 m in thickness and extends laterally for about 100 m. It occurs sandwiched between two weathered basaltic flows. The base of the lower basaltic flow is not exposed, whereas the upper flow is 3.65 m thick. This intertrappean section comprises olive green, pebbly mudstone (0.45 m) at the base followed upwards by pale yellow shaly marl (0.30 m) (Figure 2) and the same lithological units continue over the exposed lateral extent of the section. Ostracods have been recovered from both the intertrappean sedimentary units along with gastropods, charophytes, a few fish teeth and scales and carbonaceous plant remains. The molluscan assemblage includes *Physa*, *Paludina*, *Lymnaea* and *Valvata*. This assemblage has been identified based on the study of Deccan intertrappean molluscs by Hartman *et al.* (2008). As far as ostracods are concerned, 12 species have been recovered from this section. All these ostracod species have been previously described from the other intertrappean localities of central and western peninsular India. However, the new finds are important as no such fauna is known from the intertrappean beds of lower Narmada valley.

Age and affinity of the ostracod fauna

The non-marine intertrappean beds have been extensively studied for their biota during the last three decades. These beds have been assigned ages ranging from Late Cretaceous to Early Paleocene or even Eocene (Bhatia and Mannikeri, 1976; Bande *et al.*, 1981; Bande and Prakash, 1982; Bhatia and Rana, 1984; Ghevariya, 1988; Sahni and Bajpai, 1988; Mehrotra, 1989; Srinivasan *et al.*, 1994; Srinivasan, 1996; Kar and Srinivasan, 1998; Bajpai and Prasad, 2000; Singh and Kar, 2002; Keller *et al.*, 2009a, b; Samant and Mohabey, 2009).

The ostracod fauna from the intertrappean beds of Khar shows close affinity with that of the intertrappean beds of Anjar (Bhandari and Colin, 1999; Khosla and Nagori, 2005), Lakshmiपुर (Whatley and Bajpai, 2000a) and Kora (Bajpai and Whatley, 2001) in Kachchh District (Gujarat), Takli in Nagpur District (Maharashtra) (Bhatia and Rana, 1984; Bhatia *et al.*, 1996; Khosla and Nagori, 2007b), Chandarki and Yanagundi in Gulbarga District (Karnataka) (Whatley *et al.*, 2002a), Mamoni in Kota District (Rajasthan) (Whatley *et al.*, 2003a), Phulsagar in Mandla District (Madhya Pradesh) (Bajpai *et al.*, 2004), Mohagaonkalan (Whatley *et al.*, 2002b), Mohgaon-Haveli (Khosla and Nagori, 2007a) and Jhilmili (Khosla *et al.*, 2009, 2011a; Sharma and Khosla, 2009) in Chhindwara District (Madhya Pradesh), Papro in Lalitpur District (Uttar Pradesh) (Sharma *et al.*, 2008), and the Lameta Group of Jabalpur Cantonment (Madhya Pradesh) (Khosla and Sahni, 2000; Khosla *et al.*, 2011b), Pisdura (Khosla *et al.*, 2010) and Nand-Dongargaon Basin (Udhoji and Mohabey, 1996; Khosla *et al.*, 2005) in Chandrapur District (Maharashtra).

All the ostracod species recorded in the present paper have been previously described from the other intertrappean localities (Table 1). A Late Cretaceous (Maastrichtian) age is assigned to the intertrappean beds of Khar in view of the close resemblance of its ostracod fauna to that of

Upper Cretaceous intertrappean sections dated as Late Cretaceous in age based on radiometric ages of the underlying or overlying basaltic flows and associated fish fauna and palynofossils.

Palaeoecology of the ostracod fauna

The ostracod fauna of the Khar intertrappean beds occur in the following order of predominance - *Paracyprretta* (55%), *Gomphocythere* (9.8%), *Frambocythere* (9.2%), *Stenocypris* (8.4%), *Eucypris* (8.0%), *Cypridopsis* (3.4%), *Cyclocypris* (3.0%), *Cypria* (2.3%) and *Zonocypris* (0.8%). Whatley and Bajpai (2005) discussed at length the palaeoecological implications of the non-marine Ostracoda from the Upper Cretaceous intertrappean beds and the Lameta Group of the Peninsular India and the same criteria are utilized here in our interpretations also. Accordingly, the above reported ostracod genera can be divided into two groups: (i) non-swimmers, endobenthonic or epibenthonic walkers / crawlers (*Frambocythere* and *Gomphocythere*) and (ii) swimmers, varying from moderate to very active (*Paracyprretta*, *Stenocypris*, *Zonocypris*, *Cypridopsis*, *Eucypris*, *Cyclocypris* and *Cypria*).

Among the first group, ostracod genera *Frambocythere* and *Gomphocythere* belonging to the family Limnocytheridae are clearly epibenthonic walkers/crawlers and live in permanent water bodies, mainly in ponds and lakes. In the second group, the genus *Paracyprretta* is well known as a good swimmer at present. The genus *Stenocypris* is characteristic of shallow, warm, freshwater environments. The genus *Zonocypris* with its heavy ornament is probably a rather sluggish swimmer. *Cypridopsis* is mainly found in permanent lakes and ponds, and rarely in rivers and streams. The genus *Eucypris* mostly lives in temporary water bodies that dry out in summer months. Whatley and Bajpai (2005) suggested that it is probable that *Eucypris* and other taxa that prefer temporary waters lived around the margins of the lakes and ponds that dried out in the dry

season, while those preferring permanent waters would then retreat to the deeper parts of the water body. Modern species of *Cycloocypris* are very active swimmers. Although some of them occur in temporary ponds and others in only shallow permanent waters, many live in water bodies ranging from small ponds to large lakes. Recent species of *Cypria* are probably even better swimmers and *Cypria ophthalmica* (Jurine), which is an almost universally distributed freshwater and oligohaline species in the Northern Hemisphere, is an excellent example of the genus requiring permanent waters. It is clear from the above discussion that except for the genus *Eucypris* which is indicative of temporary pool environment, all other genera suggests the existence of permanent waters (pond / lake) during the deposition of the mudstone and shaly marl of the intertrappean beds of Khar.

Palaeobiogeographic implications

The recent discovery of planktic foraminifera in association with lacustrine to brackish-marine ostracod assemblage from the intertrappean beds of Jhilmili, Central India (Keller *et al.*, 2009a, b) was interpreted in terms of a marine incursion taking place from the western margin of India along the east-west trending Narmada rift valley close to the Cretaceous-Palaeogene boundary. Khosla *et al.* (2011a), on the other hand, based on the occurrence of brackish-water ostracod *Neocyprideis raoi* in great profusion from the intertrappean beds of Jhilmili in Central India and Rajahmundry along the southeastern coast of India suggested that the planktic foraminifers and brackish-water ostracods might have been brought to Central India by a marine incursion from the east coast along the northwest-southeast trending Godavari graben. These palaeogeographic models can be tested only with the discovery of marine fossils from the latest Cretaceous/early Palaeocene rocks exposed along the Narmada and Godavari rift valleys. The Upper Cretaceous (Maastrichtian) Lameta Group of Pisdura (Jain and Sahni, 1983) and

Marepalli (Prasad and Singh, 1991) and the Upper Cretaceous (Maastrichtian) intertrappean beds of Asifabad (Prasad and Sahni, 1987; Prasad and Cappetta, 1993), Nagpur (Rana, 1984), and Piplanarayanwar (Lourembam *et al.*, in press) located along the Godavari rift valley yielded an admixture of freshwater, brackish water, and marine faunal elements favoring the existence of a marine sea way along the Godavari rift valley, at least in the latest Cretaceous (Sahni, 1983; Prasad and Singh, 1991).

Besides Khar, five other intertrappean localities viz. Banjari, Bhagwaniya, Gandhwani, Kakarda and Gujri Gate in and around the Narmada valley have been studied in detail (ongoing work in our lab) for their fossil content and all of them have revealed the presence of predominantly freshwater ostracods, molluscs, charophytes and vertebrates. The molluscan fauna from the present study area is represented by *Physa*, *Paludina*, *Lymnaea* and *Valvata* which are typical freshwater forms. The associated freshwater fishes *Lepisosteus indicus* and Osteoglossidae gen. et sp. indet. further support a freshwater depositional environment for the Khar intertrappean beds. Despite of intensive search, none of these six studied intertrappean sections yielded brackish water or marine taxa.

Marine to brackish water batoid fishes characteristic of the vertebrate fauna of the Lameta Group and the intertrappean beds exposed along the Godavari rift valley are absent in the intertrappean fauna of the Narmada rift valley. Therefore, the existing fossil data from the latest Cretaceous deposits of Godavari and Narmada rift valleys favor a possible marine incursion along the Godavari rift valley, at least at the end of Cretaceous. This needs to be definitively confirmed by further extensive studies on the intertrappean sections all along the Narmada valley. However, it does not rule out an Early Palaeocene (Danian) marine transgression from the

western margin of India as proposed by Keller *et al.* (2009a, b) as no Early Palaeocene intertrappean beds are known from the Narmada valley.

Systematic Palaeontology

In this paper, the authors have adopted the classification of ostracods as given by Moore and Pitrat (1961) or have followed the works of Whatley and Bajpai (2000a, b); Bajpai and Whatley (2001) and Whatley *et al.* (2002a, b, c, 2003a, b, c). All the illustrated ostracod specimens in this paper are deposited in the Department of Geology, University of Delhi, India and are catalogued as DUGF (Delhi University Geology Fossils) numbers.

Subclass Ostracoda Latreille, 1806

Order Podocopida Muller, 1894

Suborder Podocopina Sars 1866

Superfamily Cypridoidea Baird, 1845

Family Cyprididae Baird, 1845

Genus *Paracyprretta* Sars, 1924

Paracyprretta jonesi Bhatia and Rana, 1984

Figures 3.1-3.3

Paracyprretta jonesi Bhatia and Rana, 1984, p. 30-33, pl. 2, figs. 1-3.

Material.— 426 carapaces.

Remarks.—This species was reported for the first time from the intertrappean beds of Gitti Khadan, Nagpur by Bhatia and Rana (1984). It was subsequently recorded from the intertrappean beds of Kora, Kachchh district (Bajpai and Whatley, 2001); Chandarki, Gulbarga district (Whatley *et al.*, 2002a); Mohgaon-Haveli and Jhilmili, Chhindwara district (Khosla and Nagori, 2007a; Khosla *et al.*, 2009a, 2011a; Sharma and Khosla, 2009); Takli, Nagpur (Khosla and Nagori, 2007b). Besides, the species has also been recorded from the Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b), Pisdura hill section (Khosla *et al.*, 2010, 2011b), Nand-Dongargaon basin; and Chui hill and Bara Simla hill sections, Jabalpur (Khosla *et al.*, 2011b).

The species has following characters: subtriangular in lateral outline and very arcuate to subumbonate dorsally, anterior 1/6 of length conspicuously compressed and lip-like; greatest height and width nearly equal; left valve larger than right valve; dorsal margin symmetrically convex, subangulate in the middle; ventral margin straight; surface of each valve ornamented with minute, very dense puncta, arranged in longitudinal striations parallel to the ventral margin in lower half.

Genus *Stenocypris* Sars, 1889

Stenocypris cylindrica (Sowerby, in Malcolmson, 1840)

Figures 3.4-3.6

Cypris cylindrica Sowerby, in Malcolmson, 1840, pl. 67, fig. 2.

Mongolianella cylindrica (Sowerby). Whatley and Bajpai, 2000a, p. 403, 404, pl. 6, figs. 1-8.

Stenocypris cylindrica (Sowerby). Khosla *et al.*, 2009b, p. 580-583, pl. 1, figs. 1-7, 3A.

Material.— 65 carapaces.

Remarks.—The species was initially described as *Cypris cylindrica* by Sowerby (in Malcolmson, 1840) from the intertrappean beds of Sichel Hills, Andhra Pradesh. Whatley and Bajpai (2000a) recorded the species from the Intertrappean beds of Lakshmipur, Kachchh district, and on the basis of a thorough study of the collections and registers of the Natural History Museum (NHM), London stated that the Kachchh specimens are identical with the types of *Cypris cylindrica* housed there. They recorded the species as *Mongolianella cylindrica* and erected a lectotype and a number of paralectotypes out of Sowerby's syntypes in the NHM. Apart from Lakshmipur, the species has also been recorded from the intertrappean beds of Kora (Bajpai and Whatley, 2001) and Anjar (Khosla and Nagori, 2005), Kachchh district; Chandarki and Yanagundi, Gulbarga district (Whatley *et al.*, 2002a); Mamoni, Kota district (Whatley *et al.*, 2003a); Takli, Nagpur (Khosla and Nagori, 2007b); Phulsagar, Mandla district (Bajpai *et al.*, 2004); Papro, Lalitpur (Sharma *et al.*, 2008); Jhilmili, Chhindwara district (Khosla *et al.*, 2009a, 2011a; Sharma and Khosla, 2009); from the Lameta Group of Pisdura hill section, Nand-Dongargaon basin (Khosla *et al.*, 2010, 2011b); and Chui hill and Bara Simla hill sections (Khosla *et al.*, 2011b), Jabalpur basin.

Recently Khosla *et al.* (2009b) restudied the species from the intertrappean beds of Lakshmipur, Kachchh district and based on the outline shape of the carapace and some internal characters transferred the species to *Stenocypris* Sars, 1889.

The species is elongate, subcylindrical in lateral outline and fusiform in dorsal; left valve larger than the right overlapping it prominently along the posterior and ventral margins; dorsal

margin arched, ventral margin slightly concave; anterior margin rounded, posterior somewhat pointed; valve surface smooth.

Genus *Zonocypris* Muller, 1898

Zonocypris gujaratensis Bhandari and Colin, 1999

Figures 3.7-3.8

Zonocypris gujaratensis Bhandari and Colin, 1999, p. 17, pl. 2, figs. 1-4.

Material.— Six carapaces.

Remarks.—This species has been so far described from the intertrappean beds of Anjar, Kachchh district (Bhandari and Colin, 1999; Khosla and Nagori, 2005); Mohgaon-Haveli, Chhindwara district (Khosla and Nagori, 2007a); Takli, Nagpur (Khosla and Nagori, 2007b); and the Lameta Group of Bara Simla hill section (Khosla *et al.*, 2011b), Jabalpur basin.

The species is characterized by its small carapace, subovate to subtriangular lateral outline globular, regularly rounded in the dorsal; valve surface ornamented by spiral ribs extending over number of whorls and at times bifurcating giving rise to secondary ribs.

Subfamily Cypridopsinae Kaufmann, 1900

Genus *Cypridopsis* Brady, 1868

Cypridopsis hyperectyphos Whatley and Bajpai, 2000a

Figures 3.9-3.11

Cypridopsis hyperectyphos Whatley and Bajpai, 2000a, p. 397, 398, pl. 4, figs. 4-10.

Material.— 26 carapaces.

Remarks.—The species has been widely recorded from the intertrappean beds of Lakshmiपुर (Whatley and Bajpai, 2000a), Kora (Bajpai and Whatley, 2001) and Anjar (Khosla and Nagori, 2005), Kachchh district; Yanagundi, Gulbarga district (Whatley *et al.*, 2002a); Mamoni, Kota district (Whatley *et al.*, 2003a); Takli, Nagpur (Khosla and Nagori, 2007b); Papro, Lalitpur (Sharma *et al.*, 2008); Jhilmili, Chhindwara district (Khosla *et al.*, 2009a, 2011a; Sharma and Khosla, 2009); and the Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b), Pisdura hill section (Khosla *et al.*, 2010, 2011b), Nand-Dongargaon basin; and Chui hill section (Khosla *et al.*, 2011b), Jabalpur basin.

The species is triangularly subovate in lateral outline and very strongly inflated, almost circular in dorsal outline; length sometimes equal to width; left valve slightly overlapping the right valve along the dorsal and posterior margins; dorsal margin strongly convex, ventral margin with slight concavity; valve surface punctated.

Subfamily Eucypridinae Bronsthein, 1947

Genus *Eucypris* Vávra, 1891

Eucypris intervalcanus Whatley and Bajpai, 2000a

Figures 3.12-3.14

Eucypris intervalcanus Whatley and Bajpai, 2000a, p. 402, pl. 5, figs. 16-19.

Material.— 23 carapaces.

Remarks.—The species has been previously described from the intertrappean beds of Lakshmipur (Whatley and Bajpai, 2000a), Kora (Bajpai and Whatley, 2001) and Anjar (Khosla and Nagori, 2005), Kachchh district; Mohgaonkala (Mohgaon-Kalan), Chhindwara district (Whatley *et al.*, 2002b); and Yanagundi, Gulbarga district (Whatley *et al.*, 2002a). This species is similar to *Eucypris pelasgicos* Whatley and Bajpai, 2000a, in overall shape but the latter differs in being larger in size and having pronounced anteroventral angulation.

The species has large subovate carapace in lateral outline and fusiform in the dorsal; left valve overlapping right valve all along the free margins; dorsal margin posteriorly inclined and ventral slightly concave; anterior margin narrowly rounded, apex below mid-height; posterior margin broadly rounded, apex at mid-height; greatest length, height and width medianly; valve surface smooth.

***Eucypris pelasgicos* Whatley and Bajpai, 2000a**

Figures 3.15-3.17

Eucypris pelasgicos Whatley and Bajpai, 2000a, p. 400-402, pl. 5, figs. 7-15.

Material.— 39 carapaces.

Remarks.—This species has been recorded earlier from the intertrappean beds of Lakshmipur (Whatley and Bajpai, 2000a), Kora (Bajpai and Whatley, 2001) and Anjar (Khosla and Nagori, 2005), Kachchh district; Mohgaonkala (Mohgaon-Kalan) (Whatley *et al.*, 2002b) and Jhilmili (Khosla *et al.*, 2009a, 2011a), Chhindwara district; Takli, Nagpur (Khosla and Nagori, 2007b); and Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b), Pisdura hill section (Khosla *et*

al., 2010, 2011b), Nand-Dongargaon basin; and Chui hill and Bara Simla hill sections (Khosla *et al.*, 2011b), Jabalpur basin.

Carapace large, elongate to subovate in lateral outline and fusiform in dorsal, anterior half slightly more compressed than posterior half; dorsal margin distinctly umbonate at mid-length, ventral margin nearly straight; anteroventral angulation in the left valve where it pronouncedly overreaches the right valve; valve surface very smooth.

Family Cyclocyprididae Kaufmann, 1900

Genus *Cyclocypris* Brady and Norman, 1889

Cyclocypris amphibolos Whatley, Bajpai and Srinivasan, 2002a

Figures 4.1-4.3

Cyclocypris amphibolos Whatley *et al.*, 2002a, p. 182-184, pl. 6, figs. 6-18.

Material.— 23 specimen.

Remarks.—The species was first reported from the intertrappean beds of Yanagundi, Gulbarga district (Whatley *et al.*, 2002a); Kora, Kachchh district (Whatley *et al.*, 2002c); Mamoni, Kota district (Whatley *et al.*, 2003a); Mohgaon-Haveli (Khosla and Nagori, 2007a) and Jhilmili (Khosla *et al.*, 2009a, 2011a), Chhindwara district; Takli, Nagpur (Khosla and Nagori, 2007b); and from the Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b); Pisdura (Khosla *et al.*, 2010, 2011b), Nand-Dongargaon basin; and Jabalpur (Khosla *et al.*, 2011b), Jabalpur basin.

The species is irregularly subovate in lateral outline and regularly fusiform in the dorsal; left valve larger than the right valve overlapping all along the entire margin except posteriorly where right valve overreaches the left; dorsal margin convex anterodorsally but straight, sloping posteriorly; ventral margin overhung by valve timidity and with shallow oral concavity; surface ornamented with numerous minute papillae.

Genus *Cypria* Zenker, 1854

Cypria cyrtonidion Whatley and Bajpai, 2000a

Figures 4.4-4.6

Cypria cyrtonidion Whatley and Bajpai, 2000a, p. 404, pl. 6, figs. 9-14.

Material.— 18 carapaces.

Remarks.—This species has been widely recorded from the intertrappean beds of Lakshmipur (Whatley and Bajpai, 2000a), Kora (Bajpai and Whatley, 2001) and Anjar (Khosla and Nagori, 2005), all in Kachchh district; Yanagundi and Chandarki, Gulbarga district (Whatley *et al.*, 2002a); Mohgaonkala (Whatley *et al.*, 2002b), Mohgaon-Haveli (Khosla and Nagori, 2007a) and Jhilmili (Sharma and Khosla, 2009; Khosla *et al.*, 2009a, 2011a), all in Chhindwara district; Papro, Lalitpur district (Sharma *et al.*, 2008); and the Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b) and Pisdura hill section (Khosla *et al.*, 2010, 2011b), Nand-Dongargaon basin. Also, Whatley *et al.* (2002a, b) assigned *Cyprois* sp. recorded from the Intertrappean beds of Nagpur by Bhatia and Rana (1984) and Kota by Mathur and Verma (1988) to this species.

The species is subquadrate to subcircular in lateral outline and fusiform in the dorsal, left valve larger than right valve overlapping all around the periphery except dorsally where right valve overreaches the left valve; surface smooth.

Superfamily Cytheroidea Baird, 1850

Family Limnocytheridae Klie, 1938

Subfamily Timiriaseviinae Mandelshtam, 1960

Genus *Frambocythere* Colin, (in Colin and Danielopol, 1980)

Frambocythere tumiensis anjarensis Bhandari and Colin, 1999

Figures 4.7-4.10

Frambocythere tumiensis anjarensis Bhandari and Colin, 1999, p. 12, 13, pl. 1, figs. 1-10.

Material.— 71 carapaces.

Remarks.—The subspecies was initially described from the intertrappean beds of Anjar, Kachchh district by Bhandari and Colin (1999). Apart from this, it has been also recorded from the intertrappean beds of Chandarki and Yanagundi, Gulbarga district (Whatley *et al.*, 2002a); Mamoni, Kota district (Whatley *et al.*, 2003a); Mohgaon-Haveli, Chhindwara district (Khosla and Nagori, 2007a); Takli, Nagpur (Khosla and Nagori, 2007b); Jhilmili, Chhindwara district (Khosla *et al.*, 2009a, 2011a); and the Lameta Group of Dongargaon (2005, 2011b) and Pisdura hill section (Khosla *et al.*, 2010, 2011b), Nand-Dongargaon basin.

It is a strongly dimorphic subspecies of *Frambocythere tumiensis* with normal overlap i.e. left valve larger than the right valve; females strongly inflated posteriorly whereas males much

narrower, with maximum width near middle; surface ornamented by dense concentrically disposed papillate tubercles, tubercles somewhat coarser in anterodorsal region.

Genus *Gomphocythere* Sars, 1924

Gomphocythere akalypton Whatley, Bajpai and Srinivasan, 2002a

Figures 4.11, 4.12

Gomphocythere akalypton Whatley *et al.*, 2002a, p. 170-172, pl. 1, figs. 12-23, pl. 2, figs. 1-5.

Material.— 12 carapaces.

Remarks.—The species has been originally described from the intertrappean beds Chandarki, Gulbarga district, Karnataka (Whatley *et al.*, 2002a). It was subsequently recorded from the intertrappean beds of Phulsagar, Mandla district, Madhya Pradesh (Bajpai *et al.*, 2004); and Papro, Lalitpur district, Uttar Pradesh (Sharma *et al.*, 2008).

This species is subrectangular in lateral outline and subhastate in the dorsal; dorsal margin nearly straight with anterior cardinal angle; ventral margin obscured by surface ornamentation; valve surface marked by a short anterodorsal sulcus and a prominent median sulcus; a row of 8-10 spinose tubercles ventro-laterally overhanging the margin and other tubercles posteriorly, rest of the area smooth or punctated.

Gomphocythere paucisulcatus Whatley, Bajpai and Srinivasan, 2002b

Figures 4.13-4.15

Gomphocythere paucisulcatus Whatley *et al.*, 2002b, p. 107-109, pl. 1, figs. 1-6.

Material.— 21 carapaces.

Remarks.—This species has been described from the intertrappean beds of Mohgaonkalan, Chhindwara district (Whatley *et al.*, 2002b); Anjar, Kachchh district (Bhandari and Colin, 1999; Khosla and Nagori, 2005); Takli, Nagpur (Khosla and Nagpur, 2007b); Papro, Lalitpur (Sharma *et al.*, 2008); Jhilmili, Chhindwara district (Khosla *et al.*, 2009a, 2011a); and the Lameta Group of Dongargaon (Khosla *et al.*, 2005, 2011b) and Pisdura hill section (Khosla *et al.*, 2010), Nand-Dongargaon basin.

It is a medium-sized species of *Gomphocythere* having subovate to subrectangular outline in lateral view, subfusiform in the dorsal; almost equally acuminate at both ends and with a very slight median sulcus; valve surface comprises large reticulae having 1 to 4 secondary puncta within fossae. Sexual dimorphism indistinct.

***Gomphocythere strangulata* (Jones, 1860)**

Figures 4.16-4.20

Cypris strangulata Jones, 1860, p. 187, pl. X, figs. 73a-d.

Gomphocythere strangulata (Jones). Whatley *et al.*, 2002a, p. 169, pl. 1, figs. 10, 11.

Material.— 43 carapaces.

Remarks.—This species has been widely described from the intertrappean beds of Nagpur and Asifabad (Bhatia and Rana, 1984; Bhatia *et al.*, 1990a, 1996; Khosla and Nagori, 2007b); Mamoni, Kota district (Bhatia *et al.*, 1990b); Yanagundi, Gulbarga district (Whatley *et al.*, 2002a); Lakshmipur and Anjar, Kachchh district (Whatley and Bajpai, 2000a; Khosla and Nagori, 2005); Jhilmili, Chhindwara district (Khosla *et al.*, 2009a, 2011a); and the Lameta Group

of Dongargaon, Nand-Dongargaon Basin (Udhoji and Mohabey, 1996; Khosla *et al.*, 2005, 2011b).

It is a strongly dimorphic form, females being much inflated posteriorly, males lensoid in dorsal outline with maximum width near middle; valve surface marked by a deep median sulcus, a smaller anterior sulcus, ornamentation comprises polygonal and hexagonal reticulations and each reticulæ contain 4-5 puncta, and a narrow ventrolateral rib. In some specimens, the external layer of the outer lamella is well preserved and comprises dense papillate tubercles on the surface whereas it is absent in those specimens where the outer layer is not preserved.

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Accepted manuscript

Figure Captions

Figure 1. Map showing different intertrappean sections around Narmada rift valley (A) and the location of Khar intertrappean section (B), Khargaon district, Madhya Pradesh, India.

Figure 2. Litholog of the studied intertrappean section at Khar, Madhya Pradesh, India.

Figure 3. SEM photomicrographs of ostracods recovered from the Khar intertrappean section.

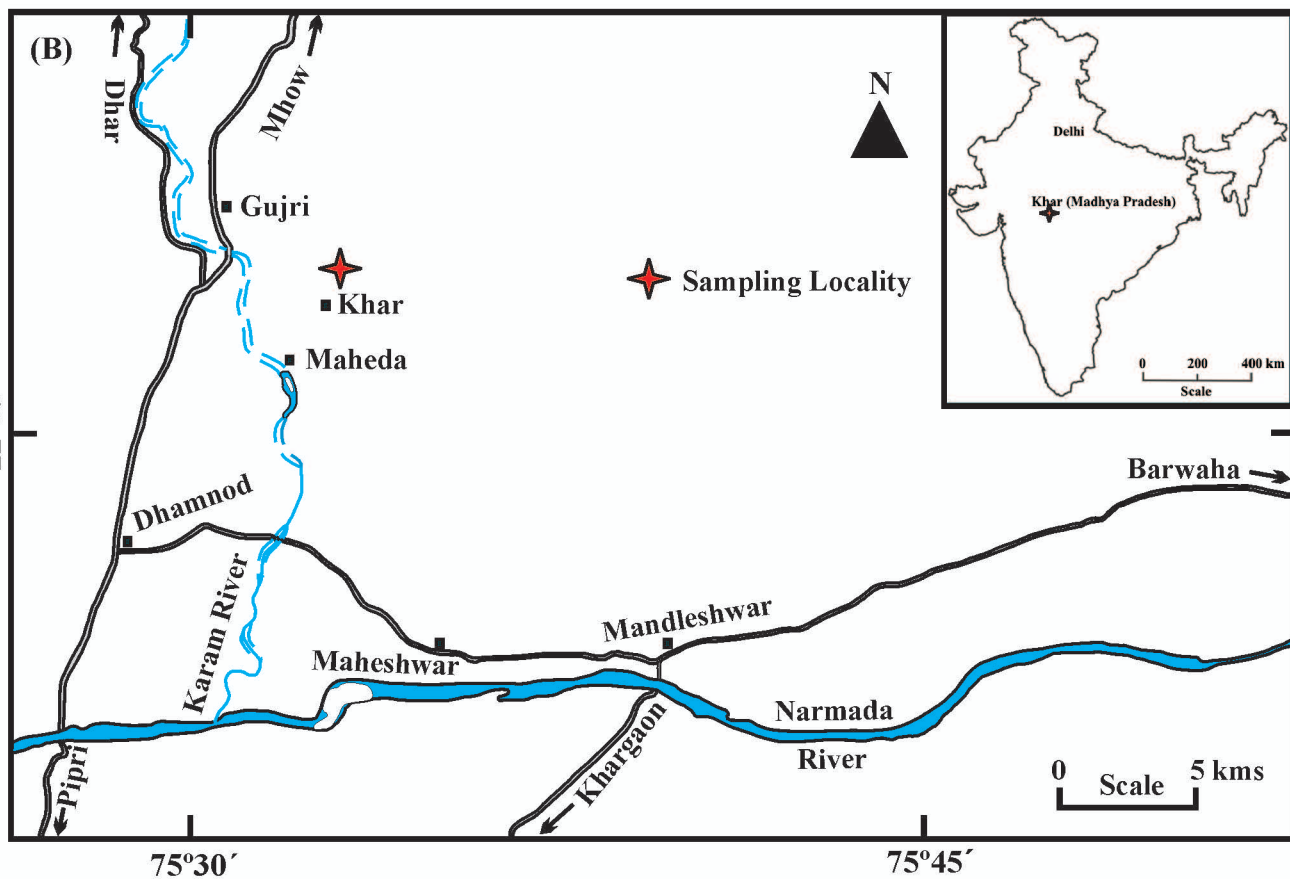
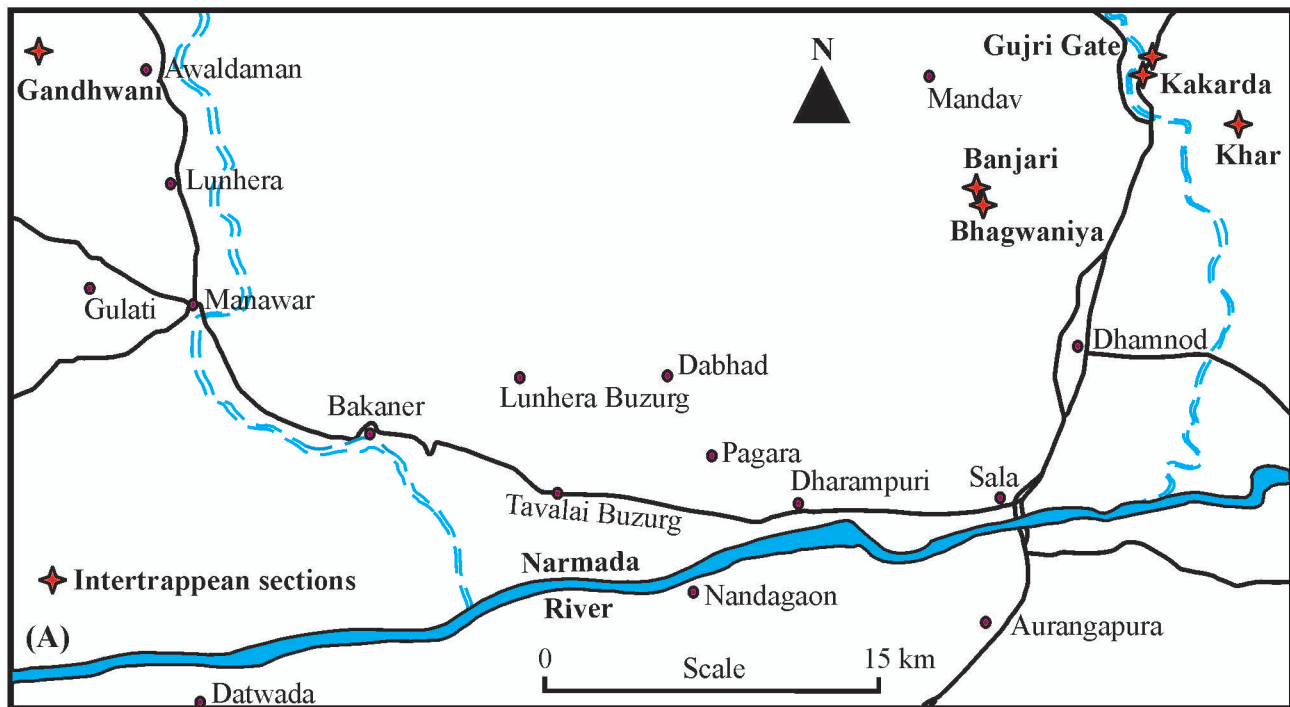
1-3, *Paracyprretta jonesi* Bhatia and Rana, 1984; 1, carapace (DUGF/301), right valve view; 2, carapace (DUGF/302), dorsal view; 3, carapace (DUGF/303), left valve view; **4-6**, *Stenocypris cylindrica* (Sowerby in Malcolmson, 1840); 4, carapace (DUGF/304), right valve view; 5, carapace (DUGF/305), dorsal view; 6, carapace (DUGF/306), left valve view; **7, 8**, *Zonocypris gujaratensis* Bhandari and Colin, 1999; 7, carapace (DUGF/307), left valve view; 8, carapace (DUGF/308), dorsal view; **9-11**, *Cypridopsis hyperectyphos* Whatley and Bajpai, 2000a; 9, carapace (DUGF/309), right valve view; 10, carapace (DUGF/310), dorsal view; 11, carapace (DUGF/311), left valve view; **12-14**, *Eucypris intervalcanus* Whatley and Bajpai, 2000a; 12, carapace (DUGF/312), right valve view; 13, carapace (DUGF/313), dorsal view; 14, carapace (DUGF/314), left valve view; **15-17**, *Eucypris pelagicos* Whatley and Bajpai, 2000a; 15, carapace (DUGF/315), right valve view; 16, carapace (DUGF/316), dorsal view; 17, carapace (DUGF/317), left valve view; scale bar for 1-6 and 12-17 = 200 μm , for 7-11 = 100 μm .

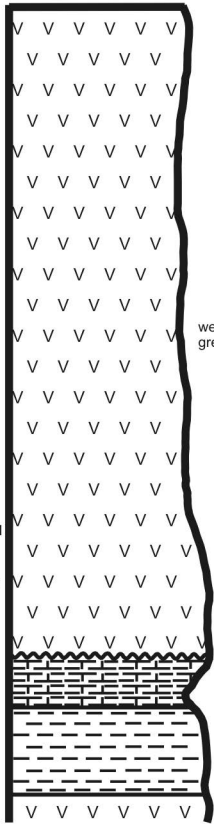
Figure 4. SEM photomicrographs of ostracods recovered from the Khar intertrappean section.

1-3, *Cyclocypris amphibolos* Whatley *et al.*, 2002a; 1, carapace (DUGF/318), right valve view; 2, carapace (DUGF/319), dorsal view; 3, carapace (DUGF/320), left valve view; **4-6**, *Cypria cyrtonidion* Whatley and Bajpai, 2000a; 4, carapace (DUGF/321), right valve view; 5, carapace (DUGF/322), dorsal view; 6, carapace (DUGF/323), left valve view; **7-10**, *Frambocythere*

tumiensis anjarensis Bhandari and Colin, 1999; 7, female carapace (DUGF/324), right valve view; 8, female carapace (DUGF/325), ventral view; 9, male carapace (DUGF/326), dorsal view; 10, female carapace (DUGF/327), left valve view; **11, 12**, *Gomphocythere akalypton* Whatley *et al.*, 2002a; 11, carapace (DUGF/328), right valve view; 12, carapace (DUGF/329), ventral view; **13-15**, *Gomphocythere paucisulcatus* Whatley *et al.*, 2002b; 13, carapace (DUGF/330), right valve view; 14, carapace (DUGF/331), dorsal view; 15, carapace (DUGF/332), left valve view; **16-20**, *Gomphocythere strangulata* (Jones, 1860); 16, male carapace (DUGF/333), dorsal view; 17, female carapace (DUGF/334), left valve view; 18, male carapace (DUGF/335), right valve view; 19, female carapace (DUGF/336), dorsal view; 20, female carapace (DUGF/337), left valve view; scale bar for 1-6, 11, 12, 15, 16 = 200 μ m, for 7-10, 13, 14 and 17-20 = 100 μ m.

Table 1. Distribution of ostracod species in the Lameta Group and intertrappean beds of Peninsular India.





weathered spheroidal basalt
greenish black in colour

Pale yellow shaly marl rich
in ostracods and gastropods

Olive green pebbly mudstone
rich in ostracods and gastropods

Index



Shaly marl



Mudstone



Basalt

Scale



40 cm

20

0



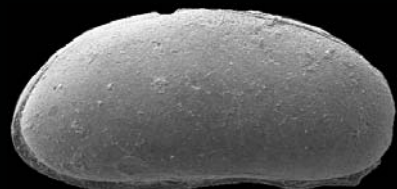
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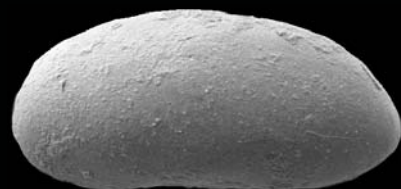
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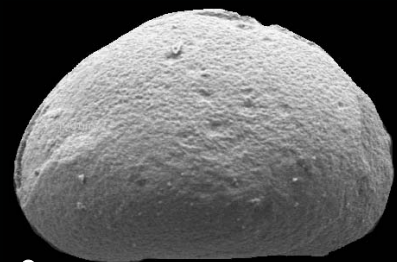
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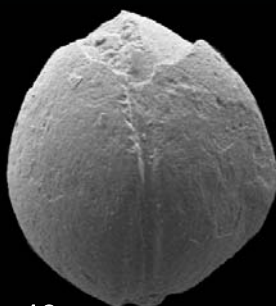
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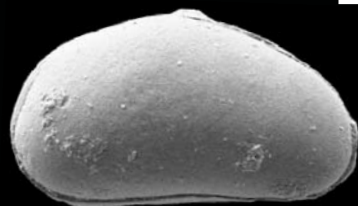
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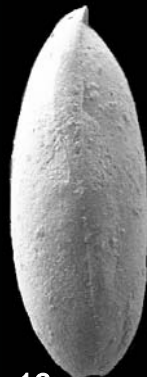
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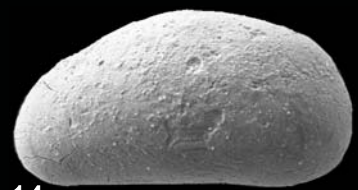
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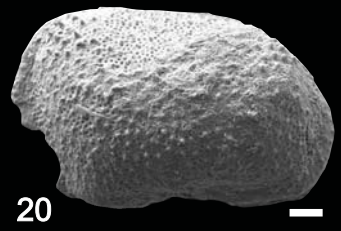
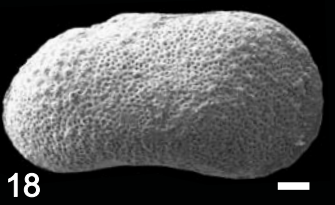
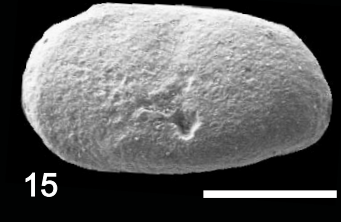
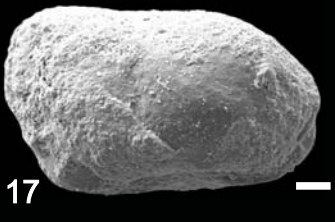
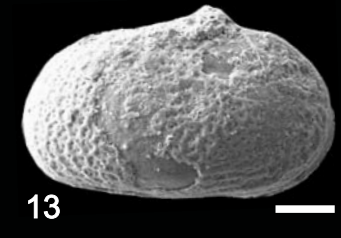
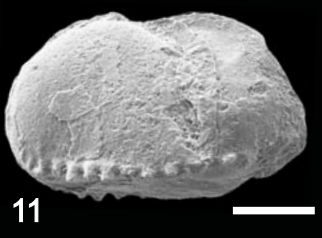
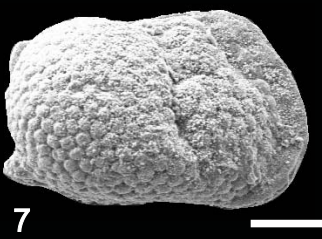
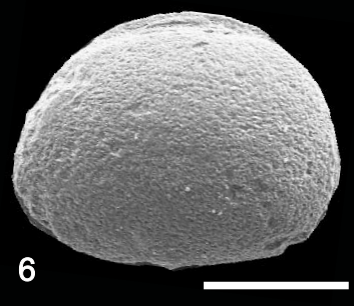
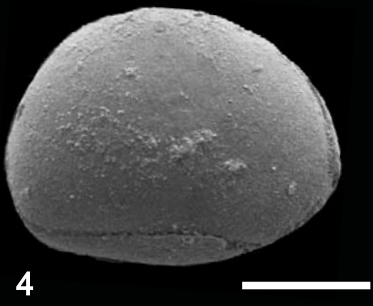
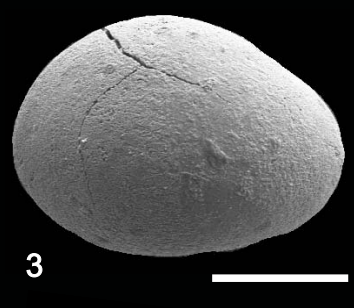


14



17





Ostracod Species	Madhya Pradesh					Maharashtra			Karnataka	Gujarat	Rajast	A. P.	U. P.
	Khargaon	Chhindwara	Mandla	Jabalpur	Cantonment	Nagpur	Chandrapur	Gulbarga	Kachchh	Kota	Adilabad	Lalitpur	
<i>Frambocythere tumiensis anjarensis</i> Bhandari & Colin	+	+	+			+	+	+	+	+	+	+	+
<i>Gomphocythere akalypton</i> Whatley <i>et al.</i>	+			+				+					+
<i>G. paucisulcatus</i> Whatley <i>et al.</i>	+	+	+			+	+	+		+			+
<i>G. strangulata</i> (Jones)	+	+				+	+		+	+	+	+	+
<i>Paracyprretta jonesi</i> Bhatia & Rana	+	+	+		+	+	+	+	+	+	+	+	+
<i>Stenocypris cylindrica</i> (Soweby)	+	+		+	+	+	+	+	+	+	+	+	+
<i>Zonocypris gujaratensis</i> Bhandari & Colin	+		+		+	+				+			
<i>Cypridopsis hyperectyphos</i> Whatley & Bajpai	+	+			+	+	+		+	+	+	+	+
<i>Eucypris intervalcanus</i> Whatley & Bajpai	+		+	+	+	+	+		+	+	+	+	+
<i>E. pelasgicos</i> Whatley & Bajpai	+	+	+	+	+	+	+		+	+	+	+	+
<i>Cyclocypris amphibolos</i> Whatley <i>et al.</i>	+	+	+		+	+	+		+		+	+	
<i>Cypria cyrtonidion</i> Whatley & Bajpai	+	+	+	+		+	+	+	+	+	+	+	+

+ Ostracods present