



## EARLY EOCENE OSTRACODA FROM THE AKLI FORMATION OF BARMER BASIN, RAJASTHAN

M. L. NAGORI and S. C. KHOSLA\*

DEPARTMENT OF GEOLOGY, MOHANLAL SUKHADIA UNIVERSITY, UDAIPUR 313002, INDIA

\*Corresponding author e-mail: sckhosla1@yahoo.com

### ABSTRACT

Twenty-two ostracod species from the Akli Formation of Barmer Basin, Rajasthan are recorded and/or described for the first time. Two species – *Stigmatocythere barmerensis* and *S. shivkarensis* - are new. Nineteen species - *Aglaiocypris kutchensis* (Guha), *Paracypris siddiquii* Bhandari, *Phlyctenophora jhingrani* (Singh and Tewari), *Neocyprideis bhupendri* (Singh and Misra), *Cytheropteron rameshi* (Singh and Misra), *Paijenborchellina indica* (Khosla), *Neomonoceratina paraoertlii* Khosla and Nagori, *Schizocythere bikanerensis* Singh and Misra, *Actinocythereis valdiyai* (Singh and Misra), *Alocopocythere abstracta* Siddiqui, *A. longilinea* Siddiqui, *A. transcendens* Siddiqui, *Gyrocythere memorans* (Lubimova and Guha), *G. parvicarinata* Siddiqui, *Occultocythereis peristicta* Siddiqui, *Xestoleberis* sp. cf. *X. muelleriana* Lienenklaus, *Cytherella harudiensis* Khosla and Pant, *C. tawaica* Singh and Tewari, and *Cytherelloidea guhai* Khosla - are assigned to previously known species. One species – *Paracytheridea* sp. – is left in open nomenclature. Age and palaeoecology of the ostracod fauna are also discussed. The fauna is characteristic of Early Eocene in age and the beds of Akli Formation were deposited in near shore to lagoon environments.

**Key words:** Early Eocene, Akli Formation, Ostracoda, Shivkar, Kurla, Barmer.

### INTRODUCTION

The Barmer Basin, in the Thar Desert of western Rajasthan, has attained immense importance during the past two decades due to the discovery of rich hydrocarbons in it. The basin is northern most extension of the Cambay Basin, a more mature hydrocarbon province (fig. 1). It is about 200 km long, 40 km wide and a little less than 6 km deep NNW-trending rift system. It is very shallow in the north but considerably deep in the south. The sedimentary sequence in the basin is predominately Late Cretaceous-Early Tertiary in age and represents infilling the accommodation space created during active rifting. The sequence essentially comprises, in ascending order, Fatehgarh, Barmer Hill, Dharvi Dunger, Thumbli and Akli Formations. The basin fill overlies rift-basement rocks of the Precambrian Malani Igneous Suite and pre-rift sediments of the Mesozoic Lathi and Ghaggar-Hakra formations. Minor Deccan-related volcanic extrusive have also been reported from the basin (Dolson *et al.*, 2015; Farrimond *et al.* 2015).

During 1999 to 2004, 13 exploratory wells were drilled mainly in deeper parts of southern Barmer Basin and oil was discovered in a few wells viz. Guda-I (1999), Saraswati (2001), Raageshwari, Kaameshwari and Guda South-I (2003), but the finds were both volumetrically small at the time of discovery, and within relatively poor-quality reservoirs. In late 2004 a large, shallow fault block in the far northern part of the basin was tested and the well encountered the giant Mangala field. Unlike prior discoveries, this field had 360 m (1181 ft) of overall pay in the high reservoir quality Fatehgarh Formation. Discovery of nearby Aishwariya and Bhagyam fields followed shortly thereafter. Since the Mangala Field discovery, over 170 exploratory and appraisal wells have been drilled, with 33 discoveries, many in the high-quality shallow reservoirs in the north. By 2015, five fields - Mangala, Bhagyam, Aishwariya, Saraswati, and Raageshwari - were on production (Dolson *et al.*, 2015).

Consequence to the discovery of hydrocarbons in the Barmer Basin enormous scientific works, including stratigraphy, structure, geochemistry etc., has been carried out. Despite this fact, surprisingly our knowledge of the paleontological studies from the Late Cretaceous-Early Tertiary formations remains very meager. The micro-vertebrates and gastropods (*Campylostylus*) of the Fatehgarh Formation have been described/reported by Mathur *et al.* (2006), Compton (2009); bivalves, foraminifers, ostracods (*Cythereis* spp.), crab, Palm fruit (*Cocos sahnii*) of the Thumbli Formation (Kapurdi) by Borooah (1946, 1950), Kaul (1951), Siddiquie and Iqbaluddin (1963); and foraminifers (*Assilina daviesi*) and palynomorphs of the Akli Formation by Sahni *et al.* (2004), Tripathi *et al.* (2009). In the present paper the authors record a rich and well preserved sufficiently interesting ostracod assemblage, comprising 22 species, including two new, from the Akli Formation of Barmer.

### PREVIOUS WORK

Except for the reported occurrence of *Cythereis* spp. from the Fuller's Earth beds (Early Eocene) of Kapurdi by Borooah (1946), there is no other record of occurrence of ostracods from the Early Tertiary formations of the Barmer Basin. Ostracods, from the Paleocene-Eocene beds of other two sedimentary basins of western Rajasthan, however, are known in great details. From the Eocene beds of the Bikaner Basin they have been described/recorded by Jacob and Sastri (1950), Singh and Misra (1968), Khosla (1972), and Mangain and Chatterjee (1977), while from the Palaeocene-Eocene beds of the Jaisalmer Basin described/recorded by Khosla (1972), and Bhandari (1991, 1992, 1995, 1996). The former works include first exhaustive account of Eocene ostracods of Rajasthan by Khosla (1972) which describes 53 species, with 16 species and 2 subspecies new. The latter works include an Atlas of Paleogene Ostracods of Rajasthan by Bhandari (1996). It is an important reference work and describes 124 species.

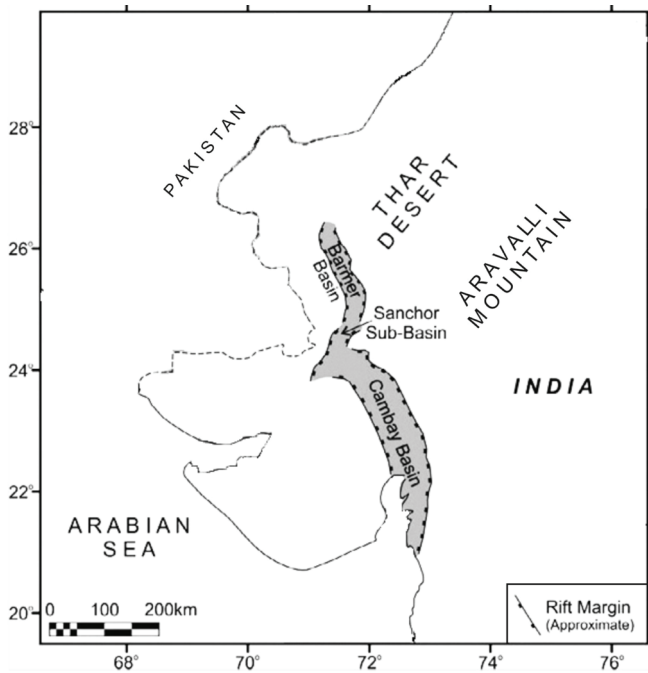


Fig. 1. A map showing location of Barmer Basin and the NNW trending connection with Combay Basin.

## AKLI FORMATION

The name Akli Formation was proposed by Siddiquie and Bahl (1965) after the nominative village for the bentonite clays and the associated rock types of the Barmer District. The formation was later on divided in two members, the lower Thumbli Member and the upper Akli Member by Das Gupta (1975). The Thumbli Member comprises essentially sandstone with lignite and bituminous clays, and the Akli Member consists of alternation of sandstone, sandy clay and bentonite layers with occasional gypsum and marl bands. The lower contact with Barmer Formation is unconformable, while the upper contact is disconformable with Mataji Ka Dungar Formation. The maximum thickness of this formation is about 280 m. Sisodia and Singh (2000) designated the two members as the Thumbli Shale Member and Kapurdi Fuller's Earth Member respectively. More recently Dolson *et al.* (2015) and Farrimond *et al.* (2015) in revised stratigraphic succession

of the Barmer Basin have assigned the above two members independent status of formations. The Thumbli Formation overlies the Dharvi Dunger Formation and the Akli Formation underlies the Mid-Miocene Nagarka Formation. The present authors have studied the ostracod fauna of the Akli Formation from two subsurface sections at Shivkar (= Sheokar) and Kurla (=Kudla) both east of Barmer town. The location of these sections is given in the sequel and also in fig. 2. The stratigraphic successions at the two localities (*supra cit.*) have been constructed from the litho logs and rock samples provided to the first author (MLN) by the Mineral Exploration Corporation Limited, Barmer. These subsurface sections are given in figs. 3 and 4 and distribution of ostracods in them in tables 1 and 2.

## AGE OF THE OSTRACOD FAUNA

The ostracod fauna recorded from the Akli Formation of Barmer Basin comprises twenty-two species. These belong to 7 families: 9 taxa to the family Trachyleberididae, 3 taxa each to the families Paracyprididae, Cytheruridae and Cytherellidae, 2 taxa to the family Schizocytheridae and one taxon each to the families Cytherideidae and Xestoleberididae. The distribution of these ostracods in western India and adjoining country is given in table 3 and their analysis in the sequel:

One species – *Paracytheridea* sp. - is left in open nomenclature, one species - *Xestoleberis* sp. cf. *X. muelleriana* Lienenklaus - is compared with previously known form and two species – *Stigmatocythere barmerensis* and *S. shivkarensis* – are new. These are at the present of little stratigraphic significance.

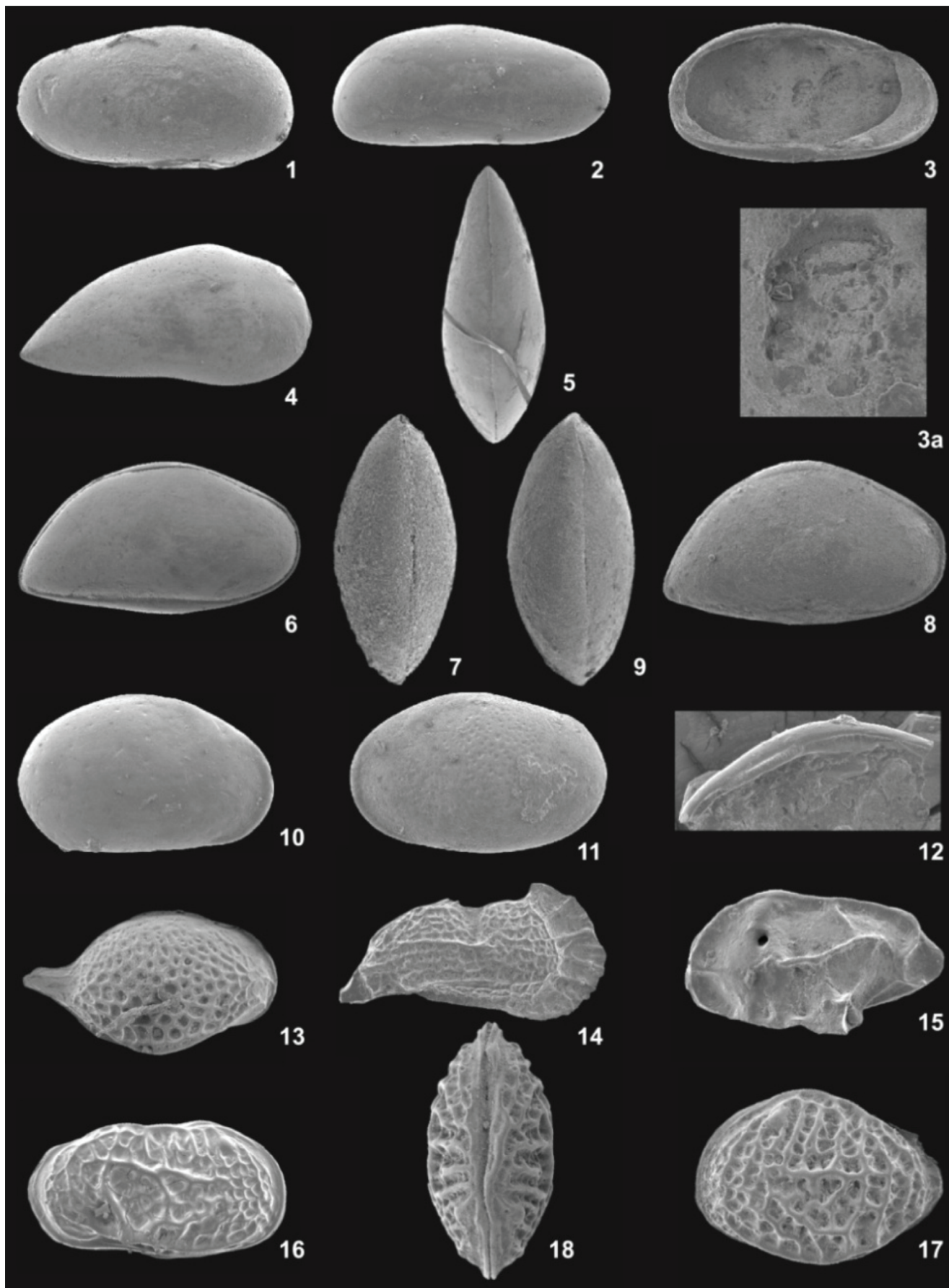
Two species - *Paracypris siddiquii* Bhandari and *Neomonoceratina paraoertlii* Khosla and Nagori – have been so far described from the Palaeocene beds of Jaisalmer and



Fig. 2. A map showing location of Shivkar and Kurla villages, Barmer District.

## PLATE I

Figs. 1-3a. *Aglaioocypris kutchensis* (Guha); 1, left valve (SUGDMF No. 1280), lateral view, x 56; 2, right valve (SUGDMF No. 1281), lateral view, x 67; 3, left valve (SUGDMF No. 1282), 3, internal view, x 61; 3a, central muscle scars enlarged. Fig. 4-5. *Paracypris siddiquii* (Guha); 4, right valve (SUGDMF No. 1283), lateral view, x 69; 5, carapace (SUGDMF No. 1284), dorsal view, x 72. Figs. 6-9. *Phlyctenophora jhingrani* (Singh and Tewari); 6, male carapace (SUGDMF No. 1285), right valve view, x 67; 7, male carapace (SUGDMF No. 1286), dorsal view, x 66; 8, female carapace (SUGDMF No. 1287), right valve view, x 65; 9, female carapace (SUGDMF No. 1288), dorsal view, x 60. Figs. 10-12. *Neocyprideis bhupendri* (Singh and Misra); 10, right valve (SUGDMF No. 1289), lateral view, x 58; 11, left valve (SUGDMF No. 1290), lateral view, x 62; 12, left valve (SUGDMF No. 1291, damaged), internal view, hinge elements enlarged. Fig. 13. *Cytheropteron rameshi* (Singh and Misra), right valve (SUGDMF No. 1292), lateral view, x 122. Fig. 14. *Paijenborchellina indica* (Khosla), right valve (SUGDMF No. 1293), lateral view, x 100. Fig. 15. *Paracytheridea* sp., left valve (SUGDMF No. 1294), lateral view, x 115. Fig. 16. *Neomonoceratina paraoertlii* (Khosla and Nagori), carapace (SUGDMF No. 1295), right valve view, x 98. Figs. 17-18. *Schizocythere bikanerensis* Singh and Misra; 17, left valve (SUGDMF No. 1296), lateral view, x 116; 18, carapace (SUGDMF No. 1297), dorsal view, x 124.



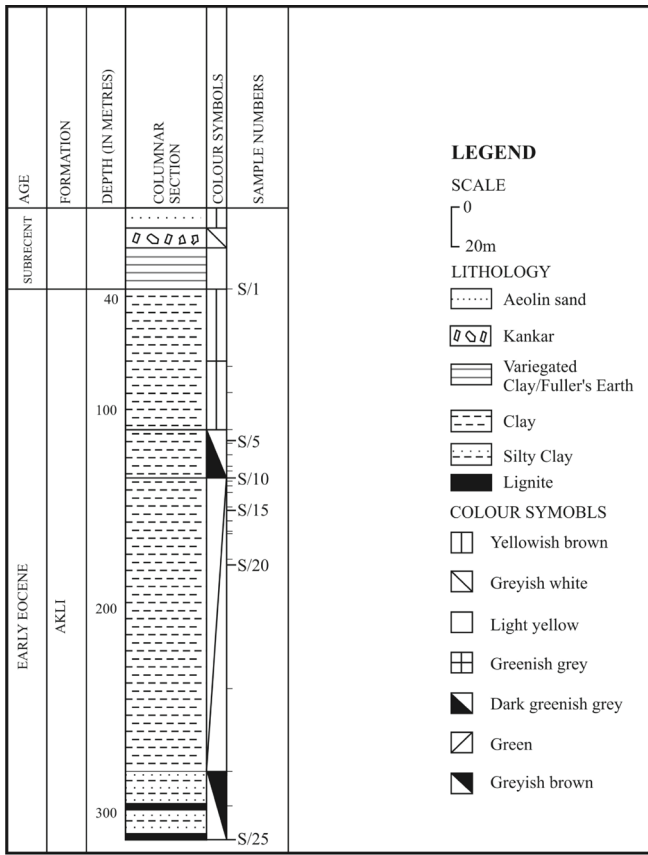


Fig. 3. Subsurface Stratigraphic Succession, Shivkar, Barmer District.

Rajahmundry respectively (Bhandari, 1992; Khosla and Nagori, 2002).

One species - *Phlyctenophora jhingrani* (Singh and Tewari) - has been recorded from the Early Eocene and the Palaeocene beds of Kachchh and Jaisalmer respectively (Khosla and Pant, 1988; Bhandari, 1996). It was originally described from the Early Eocene beds of Kalakot, Jammu and Kashmir (Tewari and Singh, 1966).

One species - *Cytherella harudiensis* Khosla and Pant - has been so far described from the Zones III and IV of the Babia Stage (Middle Eocene) of Kachchh (Khosla and Pant, 1988).

Two species - *Neocyprideis bhupendri* (Singh and Misra) and *Alocopocythere transcendens* Siddiqui - range from Early to Middle Eocene beds. The former species has been recorded from Bikaner, Kachchh, and Jaisalmer (Singh and Misra, 1968; Khosla, 1972; Khosla and Pant, 1988; Bhandari, 1996), while the latter species from Pakistan and Kachchh (Siddiqui, 1971; Khosla and Pant, 1988).

Eleven species - *Aglaioocypris kutchensis* (Guha), *Cytheropteron rameshi* (Singh and Misra), *Schizocythere*

*bikanerensis* (Singh and Misra), *Actinocythereis valdiyai* (Singh and Misra), *Alocopocythere abstracta* Siddiqui, *A. longilinea* Siddiqui, *Gyrocythere memorans* (Lubimova and Guha), *G. parvicarinata* Siddiqui, *Occultocythereis peristicta* Siddiqui, *Cytherella tawaica* Singh and Tewari, and *Cytherelloidea guhai* Khosla - have been widely recorded from the Early Eocene beds of Pakistan, Bikaner, Jaisalmer, Kachchh and Kalakot (Lubimova *et al.*, 1960; Tewari and Singh, 1966; Singh and Misra, 1968; Siddiqui, 1971; Khosla, 1972; Guha, 1974) and are characteristic of the Early Eocene age. Their occurrence in the Akli Formation of Barmer strongly suggests an Early Eocene age for these bed, equivalent to larger foraminifer assemblage zones - *Assilina granulosa-Lockhartia* and lower part of *Assilina daviesi-Nummulites burdigalensis* and planktonic foraminifer zones - P6b-P7 and P8-9 (in part) (Bhandari, 1996).

Further occurrence of *Phlyctenophora jhingrani* (Singh and Tewari) ranging from Paleocene to Early Eocene and *Alocopocythere transcendens* Siddiqui from Early to Middle Eocene are not inconsistent with the Early Eocene age for the Akli Formation. Other species viz. *Neomonoceratina paraoertlii*

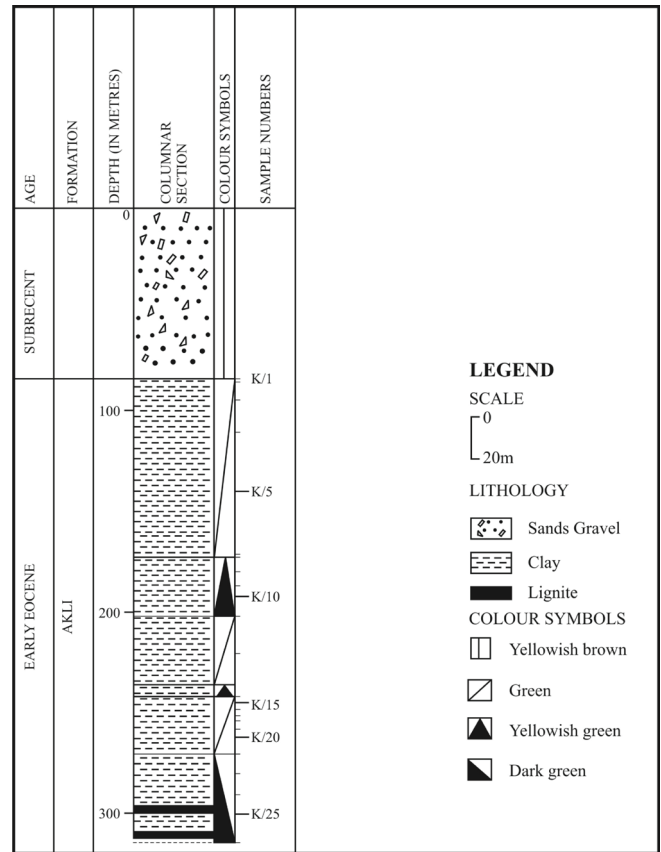


Fig. 4. Subsurface Stratigraphic Succession, Kurla, Barmer District.

PLATE II

Figs. 1-5. *Actinocythereis valdiyai* (Singh and Misra); 1, female right valve (SUGDMF No. 1298), lateral view, x 95; 2, female carapace (SUGDMF No. 1299), dorsal view, x 106; 3, female left valve (SUGDMF No. 1300), lateral view, x 98; 4, male right valve (SUGDMF No. 1301), lateral view, x 95; 5, male left valve (SUGDMF No. 1302), lateral view, x 95. Figs. 6-10. *Alocopocythere abstracta* Siddiqui; 6, male left valve (SUGDMF No. 1303), lateral view, x 87; 7, male right valve (SUGDMF No. 1304), lateral view, x 83; 8, female left valve (SUGDMF No. 1305), lateral view, x 96; 9, male left valve (SUGDMF No. 1306), lateral view, x 79; 10, male right valve (SUGDMF No. 1307), lateral view, x 74. Figs. 11-13. *Alocopocythere longilinea* Siddiqui; 11, male left valve (SUGDMF No. 1308), lateral view, x 93; 12, female left valve (SUGDMF No. 1309), lateral view, x 96; 13, male right valve (SUGDMF No. 1310), lateral view, x 88. Fig. 14. *Alocopocythere transcendens* Siddiqui, male left valve (SUGDMF No. 1311), lateral view, x 59.

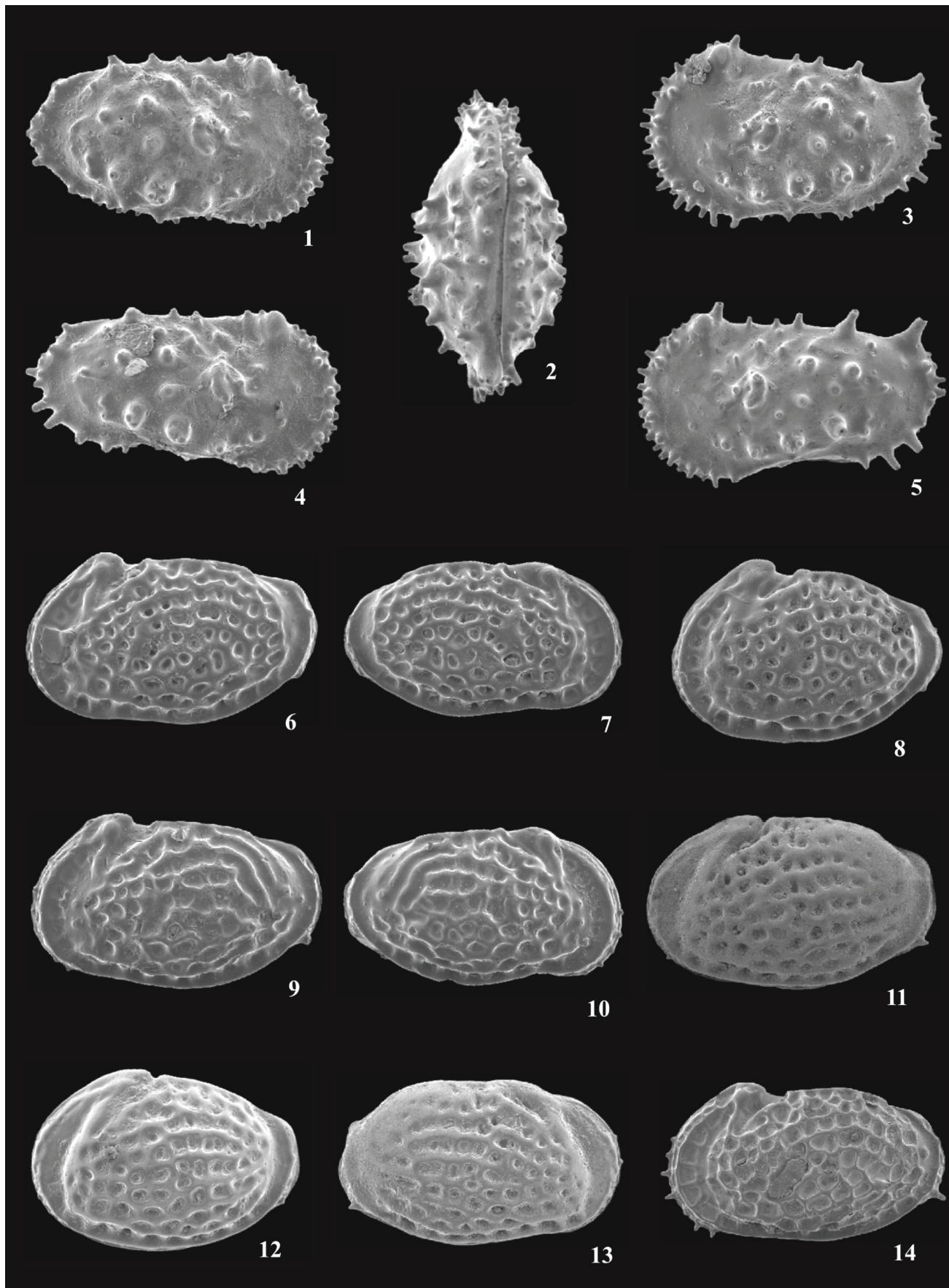


Table 1. Distribution of Ostracods in Subsurface Section, Shivkar, Barmer District

Sample Numbers	<i>Aglaioocypris kutchensis</i> (Guha)	<i>Paracypris siddiquii</i> Bhandari	<i>Phlyctenophora jhingrani</i> (Singh & Misra)	<i>Cytheropteron rameshi</i> (Singh & Misra)	<i>Neomonoceratina paraoertlii</i> Khosla & Nagori	<i>Schizocythere bikamerensis</i> Singh & Misra	<i>Actinocythereis valdiyai</i> (Singh & Misra)	<i>Alocopocythere abstracta</i> Siddiqui	<i>A. longilinea</i> Siddiqui	<i>A. transcendens</i> Siddiqui	<i>Gyrocythere memorans</i> (Lyubimova & Guha)	<i>Occultocythereis peristicta</i> Siddiqui	<i>Stigmatocythere barmerensis</i> n. sp.	<i>S. shivkarensis</i> n. sp.	<i>Cytherella harudiensis</i> Khosla & Pant	<i>C. tawaica</i> Singh & Tewari	Total
*S/1																	
S/2	3	1				7	11	15							11		48
*S/3																	
S/4	1					1	13										15
S/5	4							77					8	29			118
*S/6																	
S/7	16	4	2			19	162					7	1				211
S/8			1				6								7		14
S/9	1							10							14		25
*S/10																	
S/11	2	10		1	3			105				9	9	58			197
S/12	5					23	145										173
S/13	3					3	29										44
S/14		5	12					104				66	15	11			213
*S/15																	
S/16	2						26					1	3				32
*S/17																	
S/18	9	5				4	129							26			173
S/19	1	4	9			77	63			22	1	11	30	15			233
S/20							33			1				4			38
S/21	3					55	93			11	2			13			177
S/22	2						7										9
*S/23-25																	
Total	52	29	21	3	1	3	189	821	192	15	34	1	96	62	188	13	1720

\*Sample's barren of ostracods

Khosla and Nagori and *Paracypris siddiquii* Bhandari so for reported from the Palaeocene might be extending to the Early Eocene. Likewise *Cytherella harudiensis* Khosla and Pant, which has been previously described from the Zone III immediately overlying the Early Eocene beds of Kachchh, might be evolving from the Early Eocene form.

## PALAEOECOLOGY

The ostracod fauna recorded from the Akli Formation of the Shivkar Subsurface Section, Barmer in order of predominance comprises *Alocopocythere* (59.77%), *Cytherella*

(11.68%), *Actinocythereis* (10.99%), *Stigmatocythere* (9.19%), *Aglaioocypris* (3.02%), *Gyrocythere* (1.98%), *Paracypris* (1.68%), *Phlyctenophora* (1.22%), *Schizocythere* (0.17%), *Cytheropteron* (0.17%), and *Occultocythereis* (0.06%). Of the various ostracods which occur in this section, little is known about the ecology of the genera *Stigmatocythere* and *Gyrocythere* as they do not occur in the present day. Study of certain Recent species of the genera *Alocopocythere*, *Aglaioocypris*, and *Phlyctenophora* from the Abu Dhabi Lagoon, Persian Gulf by Bate (1971) suggests that these genera thrive well in near shore to lagoon environments. A Recent species of the genus *Alocopocythere* has also been described from the shallow water of Persian Gulf (Paik, 1977) and Mandvi beach, west coast of India (Jain, 1978), and of *Phlyctenophora* from the Chilka Salt Lake of east coast of India (Jain, 1976). The genera *Schizocythere* and *Occultocythereis* are also marine forms (Morkhoven, 1963). The genus *Cytherella* tolerates wide ecological conditions. Present day species have been recorded from brackish water (Omatsola, 1970), to all depths of marine environments (Morkhoven, 1963). The genus *Actinocythereis* is suggestive of infralittoral environment (Bold, 1971). The genus *Paracypris* is a marine form and mainly occurs in deeper water (Morkhoven, 1963). The genus *Cytheropteron* is a marine form and living species inhabit practically all depth of the present seas (Morkhoven, 1963).

The overall evidence furnished by the ostracod assemblage suggests that although some forms are indicative of deep water marine environments, the beds of Akli Formation of Shivkar Subsurface Section were deposited in near shore to lagoon environment. This inference is drawn on the basis of most dominant occurrence of the genus *Alocopocythere* (59.77%).

The ostracod fauna from the Akli Formation of Kurla Subsurface Section in order of predominance is *Alocopocythere* (49.89%), *Cytherella* (10.81%), *Gyrocythere* (9.21%), *Phlyctenophora* (7.06%), *Aglaioocypris* (4.96%), *Actinocythereis* (4.07%), *Paracypris* (2.78%), *Cytherelloidea* (2.78%), *Neocyprideis* (1.93%), *Xestoleberis* (1.71%), *Cytheropteron* (0.53%), *Paracytheridea* (0.1%), and *Paijenborchellina* (0.1%). Except for the genera - *Cytherelloidea*, *Neocyprideis*, *Xestoleberis*, *Paracytheridea*, and *Paijenborchellina* - which occur for the first time in this section the ecological significance of other genera has already been discussed and they are indicative of near shore to lagoon environment of deposition of beds of Akli Formation of this section. The genus *Cytherelloidea* inhabits shallow, warm marine water and occasionally also found in brackish (mesohaline) environment (Morkhoven, 1963). According to Sohn (1964) it is a good palaeotemperature indicator and in the present day seas it does not survive in temperatures less than 10°C (50°F). The genus *Neocyprideis*, which is encountered only in the topmost horizon of the section, occurs predominantly in a brackish water environment (Keij, 1957; Morkhoven, 1963; Oertli, 1967). The ecological data

## PLATE III

Figs. 1-4. *Alocopocythere transcendens* Siddiqui; 1, female left valve (SUGDMF No. 1312), lateral view, x 68; 2, male carapace (SUGDMF No. 1313), dorsal view, x 57; 3, female carapace (SUGDMF No. 1314), dorsal view, x 65; 4, female right valve (SUGDMF No. 1314), lateral view, x 64. Figs. 5-8. *Gyrocythere memorans* (Lyubimova and Guha); 5, female left valve (SUGDMF No. 1316), lateral view, x 61; 6, female carapace (SUGDMF No. 1317), dorsal view, x 65; 7, female right valve (SUGDMF No. 1318), lateral view, x 60; 8, male left valve (SUGDMF No. 1319), lateral view, x 58. Figs. 9-13. *Gyrocythere parvicarinata* Siddiqui; 9, male left valve (SUGDMF No. 1320), lateral view, x 64; 10, male carapace (SUGDMF No. 1321), dorsal view, x 66; 11, female left valve (SUGDMF No. 1322), lateral view, x 66; 12, female right valve (SUGDMF No. 1323), internal view, x 58; 13, female carapace (SUGDMF No. 1324), dorsal view, x 63. Figs. 14-15. *Occultocythereis peristicta* Siddiqui; 14, female carapace (SUGDMF No. 1325), right valve view, x 127; 15, male carapace (SUGDMF No. 1326), right valve view, x 120.

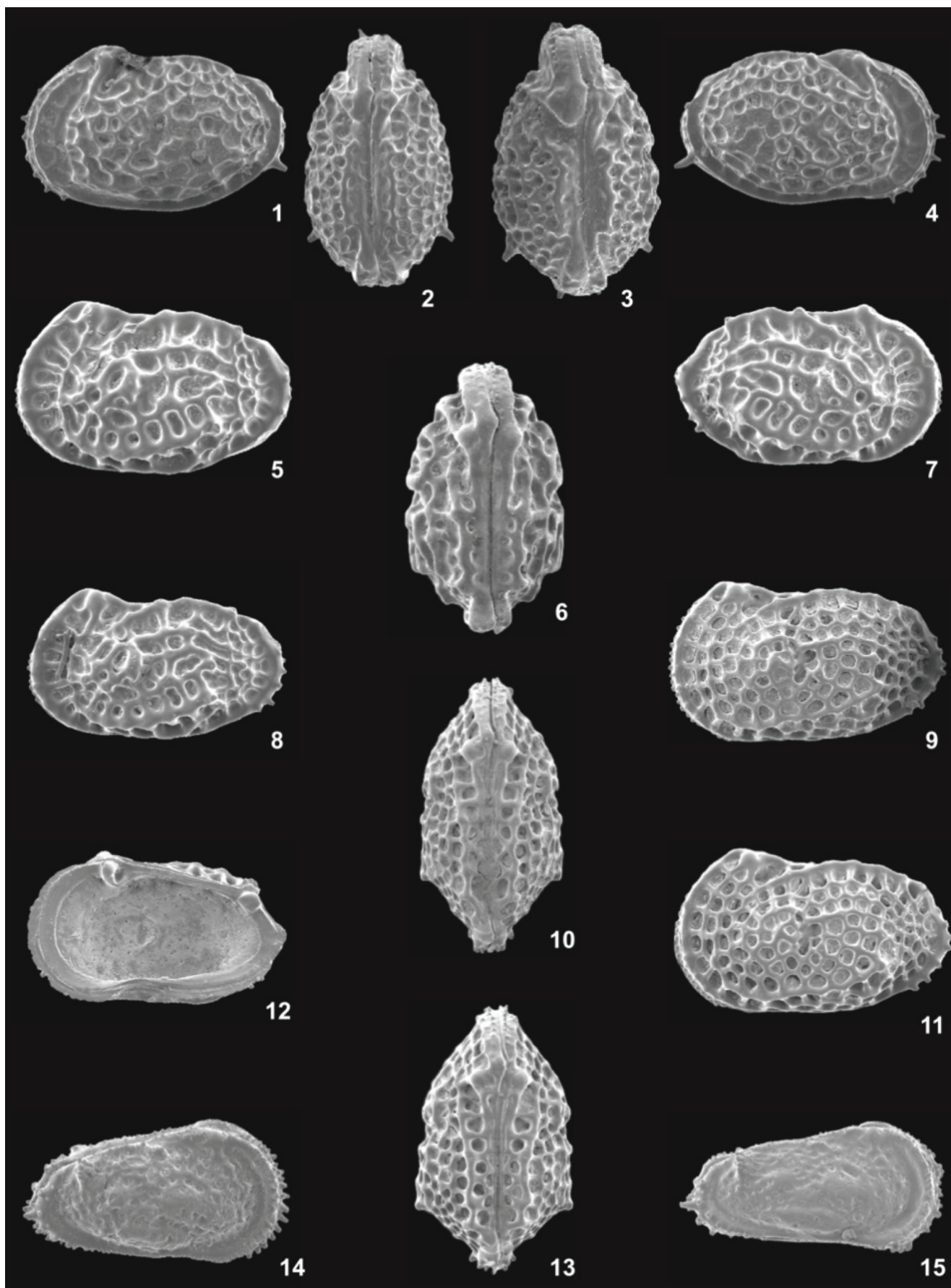


Table 2. Distribution of Ostracods in Subsurface Section, Kurla, Barmer District

Sample Numbers	<i>Aglaioocypris kutchensis</i> (Guha)	<i>Paracypris siddiquii</i> (Bhandari)	<i>Phlyctenophora jhingrani</i> (Singh & Tiwari)	<i>Neocyprideis bhupendri</i> (Singh & Misra)	<i>Cytheropteron rameshi</i> (Singh & Misra)	<i>Paijenborchellina indica</i> (Khosla)	<i>Paracytheridea</i> sp.	<i>Actinocythereis valdivyai</i> (Singh & Misra)	<i>Alocopocythere abstracta</i> Siddiqui	<i>A. longilinea</i> Siddiqui	<i>A. transcandens</i> Siddiqui	<i>Gyrocythere parvicarinata</i> Siddiqui	<i>Ooculocythereis persistica</i> Siddiqui	<i>Xestoleberis</i> sp.	<i>Cytherella harudiensis</i> Khosla & Pant	<i>C. tawaica</i> Singh & Tewari	<i>Cytherelloidea guhai</i> Khosla	Total
K/1	4	18											16					38
*K/2-6																		
K/7	9	36							97						3			145
K/8	10	20						7	105						8			150
*K/9																		
K/10	1									20					1			22
K/11	34	6	6	5	1	1	38			134		12		47		24		319
*K/12-20																		
K/21	8								92		86	31			42	1		260
*K/22-26																		
Total	42	26	66	18	5	1	1	38	110	222	134	86	43	16	59	42	25	934

\*Sample's barren of ostracods

pertaining to most of the living species of the genus *Xestoleberis* suggests that it thrives well from brackish water to shallow marine environments (Morkhoven, 1963; Bate, 1971; Bold, 1971). Record of Recent species of the genera *Paijenborchellina* and *Paracytheridea* from the Abu Dhabi Lagoon, Persian Gulf by Bate (1971) suggests that these genera thrive well in near shore to lagoon environments.

The overall evidence furnished by the ostracod assemblage suggests that the beds of Akli Formation of Kurla Subsurface Section were deposited in environment nearly similar to that of Shivkar Subsurface Section. This inference is drawn again on the basis of abundant occurrence of genus *Alocopocythere* (49.89%). During the deposition of topmost horizon environment might have become brackish water as is evident from the occurrence of *Neocyprideis*.

## SYSTEMATIC DESCRIPTIONS

The authors have arranged the genera described in this work as per classification of Ostracoda adopted in Moore and Pitrat (1961). Only the new species are described in detail. Routine descriptions of already known species have been omitted for sake

of brevity. However, brief morphological comments have been given under the heading "Remark". The specimens illustrated in the paper have been deposited in the Micropalaeontology Laboratory, Department of Geology, Mohan Lal Sukhadia University, Udaipur, India. The reference to specimens is designated in text and plate explanations by SUGDMF 1280 – 1343. All dimensions are given in mm.

*Subclass* **Ostracoda** Latreille, 1806

*Order* **Podocopida** Müller, 1894

*Suborder* **Podocopina** Sars, 1866

*Superfamily* **Cytheracea** Baird, 1850

*Family* **Paracypridae** Sars, 1923

*Genus* **Aglaioocypris** Sylvester-Bradley, 1947

*Aglaioocypris kutchensis* (Guha, 1974)  
(Pl. I, figs. 1-3)

*Bythocypris kutchensis* Guha, 1974, pp. 160-161, pl. 2, figs. 10, 21.

*Aglaioocypris kutchensis* (Guha). - Khosla and Pant, 1988, p. 331.

*Material*: Fifty-two specimens from the Shivkar Subsurface Section and 42 from the Kurla Subsurface Section.

*Remarks*: The species was initially described as *Bythocypris kutchensis* by Guha (1974) from the Kakdi Stage (Early Eocene) of Kachchh. Later on Khosla and Pant, 1988, who also studied the species from the Kakdi Stage, transferred it to the genus *Aglaioocypris*. The species is characterized by elongate carapace in lateral view, with greatest height, half of length, near middle; central muscle scars six in number, three in anterior row, two in posterior row and a large scar dorsal to these rows.

<i>Dimensions</i> :	Length	Height	Width
Left valve, SUGDMF 1280	0.88	0.45	--
Right valve, SUGDMF 1281	0.75	0.36	--
Left valve, SUGDMF 1282	0.79	0.39	--

*Genus* **Paracypris** Sars, 1866

*Paracypris siddiquii* Bhandari, 1992  
(Pl. I, figs. 4-5)

*Paracypris siddiquii* Bhandari, 1992, pp. 54-55, pl. 9, fig. 9. – Bhandari, 1996, p. 106, pl. 81, figs. 1-4.

*Material*: Twenty-nine specimens from the Shivkar Subsurface Section and 26 from the Kurla Subsurface Section.

*Remarks*: The species has so far been described from the subsurface Sanu Formation (Late Palaeocene), Jaisalmer Basin (Bhandari, 1996). It has following characteristics: carapace elongated, subtriangular in lateral view, and lanceolate in the dorsal; greatest height and width anteriorly; dorsal margin angulated at greatest height; posterior end pointed.

## PLATE IV

Figs. 1-6. *Stigmatocythere barmerensis* n. sp.; 1, holotype (SUGDMF No. 1327), male left valve, lateral view, x 77; 2, paratype I (SUGDMF No. 1328), male carapace, dorsal view, x 66; 3, paratype II (SUGDMF No. 1329), male right valve, lateral view, x 87; 4, paratype III (SUGDMF No. 1330), female left valve, lateral view, x 108; 5, paratype IV (SUGDMF No. 1331), female carapace, dorsal view, x 68; 6, paratype V (SUGDMF No. 1332), female right valve, lateral view, x 112. Figs. 7-9. *Stigmatocythere shivkarensis* n. sp.; 7, holotype (SUGDMF No. 1333), left valve, lateral view, x 89; 8, paratype I (SUGDMF No. 1334), carapace, dorsal view, x 91; 9, paratype II (SUGDMF No. 1335), right valve, lateral view, x 98. Figs. 10-12. *Xestoleberis* sp. cf. *X. muelleriana* Lienenklaus; 10, right valve (SUGDMF No. 1336), lateral view, x 94; 11, carapace (SUGDMF No. 1337), dorsal view, x 89; 12, left valve (SUGDMF No. 1338), lateral view, x 88. Fig. 13-14. *Cytherella harudiensis* Khosla and Pant; 13, carapace (SUGDMF No. 1339), left valve view, x 72; 14, carapace (SUGDMF No. 1340), dorsal view, x 70. Fig. 15. *Cytherella tawaica* Singh and Tewari, carapace (SUGDMF No. 1341), left valve view, x 100. Figs. 16-17. *Cytherelloidea guhai* Khosla; 16, left valve (SUGDMF No. 1342), lateral view, x 113; 17, right valve (SUGDMF No. 1343), lateral view, x 113.



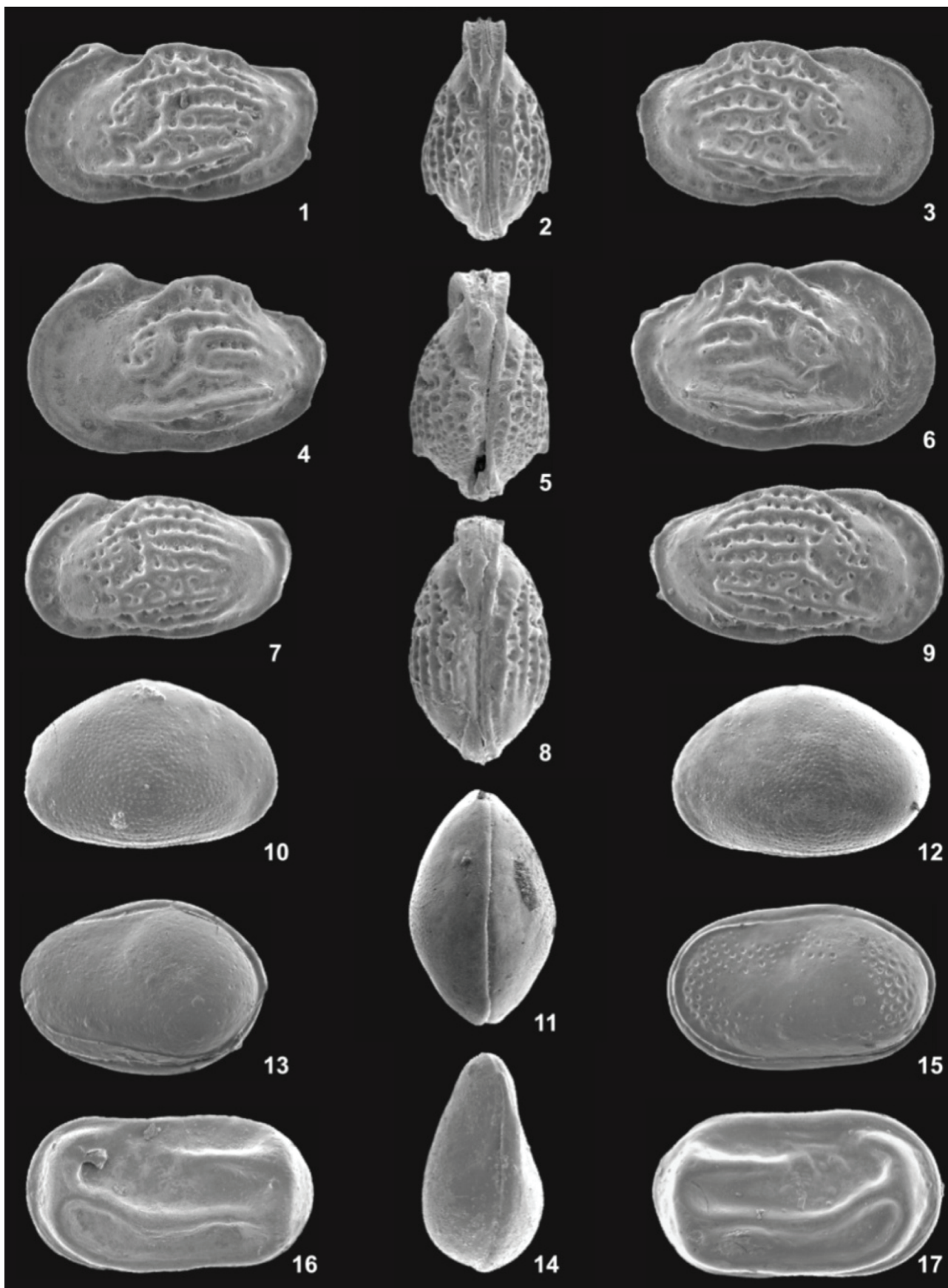


Table 3. Distribution of Akli Ostracods in western India and Pakistan

Akli Formation, Barmer	Bikaner	Jaisalmer	Kachchh	Pakistan	J & K Himalaya	Simla Himalaya	Rajahmundry
<i>Aglaiocypris kutchensis</i> (Guha)			E. Eocene				
<i>Paracypris siddiquii</i> Bhandari		Palaeocene					
<i>Phlyctenophora jhingrani</i> (Singh and Tewari)		Palaeocene	E. Eocene		E. Eocene	E.-M. Eocene	
<i>Neocyprideis bhupendri</i> (Singh and Misra)	E. Eocene	E. Eocene	M. Eocene				
<i>Cytheropteron rameshi</i> (Singh and Misra)	E. Eocene	E. Eocene	E. Eocene			E. Eocene	
<i>Paijenborchellina indica</i> (Khosla)	E. Eocene	E. Eocene	E. Eocene				Palaeocene
<i>Paracytheridea</i> sp.							
<i>Neomonoceratina paraoertlii</i> Khosla and Nagori							Palaeocene
<i>Schizocythere bikanerensis</i> Singh and Misra	E. Eocene	E. Eocene	E. Eocene			P.-E. Eocene	
<i>Actinocythereis valdiyai</i> (Singh and Misra)	E. Eocene		E. Eocene				
<i>Alocopocythere abstracta</i> Siddiqui	E. Eocene	E. Eocene	E. Eocene	E. Eocene		E. Eocene	
<i>A. longilinea</i> Siddiqui		E. Eocene		E. Eocene			
<i>A. transcendens</i> Siddiqui			M. Eocene	E.-M. Eocene		P.-M. Eocene	
<i>Gyrocythere memorans</i> (Lyubimova and Guha)	E. Eocene	E. Eocene					
<i>G. parvicarinata</i> Siddiqui	E. Eocene	E. Eocene	E. Eocene	E. Eocene			
<i>Occultocythereis peristicta</i> Siddiqui		E. Eocene	E. Eocene	E. Eocene			
<i>Stigmatocythere barmerensis</i> n. sp.							
<i>S. shivkarensis</i> n. sp.							
<i>Xestoleberis muelleriana</i> Lienenklaus	E. Eocene	E. Eocene	E. Eocene				
<i>Cytherella harudiensis</i> Khosla and Pant			M. Eocene				
<i>Cytherella tawaica</i> Singh and Tewari	E. Eocene	E. Eocene	E. Eocene		E. Eocene		
<i>Cytherelloidea guhai</i> Khosla	E. Eocene	E. Eocene	E. Eocene				

Abbreviations E. = Early; E.-M. = Early - Middle; M. = Middle; P.-E. = Palaeocene - Early; P.-M. = Palaeocene - Middle

#### Dimensions:

	Length	Height	Width
Right valve, SUGDMF 1283	0.69	0.33	--
Carapace, SUGDMF 1284	0.68	0.33	0.27

carapace in lateral view and biconvex in the dorsal; greatest height less than half of length anterior to middle, and width near middle; posterior margin narrowed, ventrally angulated; central muscle scars six in number, three scars in anterior row, two in posterior row and a large scar dorsal to these rows.

#### Genus *Phlyctenophora* Brady, 1880

*Phlyctenophora jhingrani*  
(Singh and Tewari, in Tewari and Singh, 1966)  
(Pl. I, figs. 6-9)

*Paracypris jhingrani* Singh and Tewari, in Tewari and Singh, 1966, p. 122, pl. 2, figs. 5a-d. - Guha, 1974, pp. 161-162, pl. 2, fig. 14.

*Phlyctenophora jhingrani* (Singh and Tewari, in Tewari and Singh, 1966). - Khosla and Pant, 1988, p. 331. - Bhandari, 1996, p. 120, pl. 96, figs. 1-2.

**Material:** Twenty-one specimens from the Shivkar Subsurface Section and 66 from the Kurla Subsurface Section.

**Remarks:** This species was originally described as *Paracypris jhingrani* by Singh and Tewari (in Tewari and Singh, 1966) from the Early Eocene beds of Kalakot, Jammu and Kashmir. Later on Khosla and Pant (1988), who recorded the species from the Kakdi Stage (Early Eocene) of Kachchh, transferred it to the genus *Phlyctenophora*. The occurrence of the species from the Early Eocene of Kachchh was also recorded earlier by Guha (1974). The species is characterized by elongate

#### Dimensions:

	Length	Height	Width
Carapace, SUGDMF 1285	0.69	0.39	0.32
Carapace, SUGDMF 1286	0.73	0.43	0.33
Carapace, SUGDMF 1287	0.74	0.44	0.33
Carapace, SUGDMF 1288	0.82	0.45	0.36

**Family** *Cytherideidae* Sars, 1925

**Subfamily** *Cytherideinae* Sars, 1925

**Genus** *Neocyprideis* Apostolescu, 1956

*Neocyprideis bhupendri* (Singh and Misra, 1968)  
(Pl. I, figs. 10-12)

*Schuleridea bhupendri* Singh and Misra, 1968, p. 32, pl. 8, figs. 7-9.

*Neocyprideis bhupendri* (Singh and Misra, 1968). - Khosla, 1972, p. 486, pl. 1, fig. 15; pl. 4, fig. 2. - Khosla and Pant, 1988, p. 331. - Bhandari, 1996, p. 96, pl. 72, figs. 1-2.

**Material:** Eighteen specimens from Kurla Subsurface Section.

*Remarks:* The species was originally described as *Schuleridea bhupendri* by Singh and Misra (1968) from the Early Eocene beds of Bikaner Basin, and subsequently transferred to *Neocyprideis bhupendri* by Khosla (1972). Besides Bikaner Basin, it has been recorded from the Early Eocene beds of Kachchh (Khosla and Pant, 1988), and Jaisalmer Basin (Bhandari, 1996). The species has subovate carapace in lateral view, valve surface faintly pitted; hinge in right valve consisting of anterior and posterior crenulated teeth connected by a groove, and complementary elements in left valve.

*Dimensions:*

	Length	Height	Width
Right valve, SUGDMF 1289	0.79	0.49	--
Left valve, SUGDMF 1290	0.77	0.50	--
Left valve, SUGDMF 1291	0.77	0.50	--

**Family Cytheruridae Müller, 1894**

**Genus Cytheropteron Sars, 1966**

*Cytheropteron rameshi* (Singh and Misra, 1968)  
(Pl. I, fig 13)

*Cytherura rameshi* Singh and Misra, 1968, pp. 31-32, pl. 8, figs. 4-6.

*Semicytherura rameshi* (Singh and Misra, 1968). - Khosla, 1972, p. 495, pl. 3, fig. 11. *Cytheropteron rameshi* (Singh and Misra, 1968). - Khosla and Pant, 1988, p. 331. - Bhandari, 1996, p. 70, pl. 45, figs. 1-2.

*Material:* Three specimens from the Shivkar Subsurface Section and 5 from the Kurla Subsurface Section.

*Remarks:* This species was originally described as *Cytherura rameshi* by Singh and Misra (1968) from the Early Eocene beds of Bikaner Basin. Later on Khosla (1972) transferred it to the genus *Semicytherura* and thereafter Khosla and Pant (1988) assigned it to the genus *Cytheropteron*. Besides Bikaner Basin, the species has been recorded from the Early Eocene beds of Kachchh (Khosla and Pant, 1988), Jaisalmer Basin (Bhandari, 1996) and Simla Himalaya (Mathur, 1977). Carapace in this species is subovate in lateral view; each valve with a ventral wing-like lateral prolongation; posterior margin drawn out in a short caudal process above mid-height; inner lamella of moderate width; vestibulum present along anterior margin.

*Dimensions:*

	Length	Height	Width
Right valve, SUGDMF 1292	0.37	0.20	--

**Genus Paijenborchellina Kuznetsova, 1957**

*Paijenborchellina indica* (Khosla, 1972)  
(Pl. I, fig. 14)

*Paijenborchella (Eupaijenborchella) indica* Khosla, 1972, p. 494, pl. 3, figs. 14-15, pl. 5, fig. 11.

*Paijenborchellina kutchensis* Guha, 1974, p. 172, pl. 2, fig. 3

*Paijenborchellina indica* (Khosla, 1972). - Khosla and Pant, 1988, p. 331. - Bhandari, 1996, p. 100, pl. 76, figs. 1-6.

*Material:* Single specimen from the Kurla Subsurface Section.

*Remarks:* The species was initially described as *Paijenborchella (Eopaijenborchella) indica* from the Early Eocene beds of Bikaner Basin by Khosla, 1972 (subgeneric name misspelled as *Eupaijenborchella*). Later on Khosla and Pant (1988) transferred it to genus *Paijenborchellina*.

Besides Bikaner Basin, the species has been recorded from the Early Eocene beds of Kachchh (Khosla and Pant, 1988) and Jaisalmer Basin (Bhandari, 1996). The species has following characteristics: carapace subtriangular in lateral outline; valve surface marked by a vertical sulcus and ornamentation consisting of reticulation and ridges, two ridges horizontal, one near middle traversing sulcus and other near ventral margin, six ridges near anterior margin.

*Dimensions:*

	Length	Height	Width
Right valve, SUGDMF 1293	0.43	0.23	--

**Genus Paracytheridea Müller, 1984**

*Paracytheridea* sp.  
(Pl. I, fig. 15)

*Material:* Single specimen from the Kurla Subsurface Section.

*Remarks:* Valve elongate-subquadrate in lateral outline and alate ventrally; dorsal margin nearly straight sloping down posteriorly, ventral margin obscured by overhanging wing; anterior margin broadly rounded; posterior margin drawn out in a caudal process below mid-height; surface marked by a vertical sulcus extending from mid-dorsal region to mid-ventral region; a keel-like anterior marginal ridge which continues ventrally at the outer periphery of wing, in posteroventral region produced in a backwardly directed spine; the keel-like ridge continues further to posteroventral margin as upwardly curved ridge; a median longitudinal ridge running across the sulcus from median region to posterodorsal region; an anteriorly convex vertical ridge near posterior margin; two short ridges, an oblique in mid-dorsal region, posterior to sulcus, other longitudinal in mid-anterior region; rest of the area uneven and smooth.

*Dimensions:*

	Length	Height	Width
Left valve, SUGDMF 1294	0.39	0.20	--

**Family Schizocytheridae Howe, 1961**

**Genus Neomonoceratina Kingma, 1948**

*Neomonoceratina paraoertlii* Khosla and Nagori, 2002  
(Pl. I, fig. 16)

*Neomonoceratina paraoertlii* Khosla and Nagori, 2002, pp. 119-201, figs. 3.1, 3.2.

*Material:* Single specimen from the Shivkar Subsurface Section.

*Remarks:* The species has so far been described from the Early Palaeocene Inter-trappean beds of Duddukuru, West Godavari District, Andhra Pradesh, east coast of India (Khosla and Nagori, 2002). It has following characteristics: carapace elongate, subrectangular in lateral view, compressed, sides more or less parallel, in dorsal view, surface distinctly reticulate, meshes with 5 or 6 pores, and a depression between ventral ridge and margin.

*Dimensions:*

	Length	Height	Width
Carapace, SUGDMF 1295	0.47	0.23	0.20

Genus *Schizocythere* Triebel, 1950*Schizocythere bikanerensis* Singh and Misra, 1968  
(Pl. I, figs. 17-18)

*Schizocythere bikanerensis* Singh and Misra, 1968, p. 29, pl. 7, figs. 8-10. – Khosla, 1972, p. 487, pl. 2, fig. 2. – Khosla and Pant, 1988, p. 331. – Bhandari, 1996, p. 128, pl. 104, figs. 1-2.

**Material:** Three specimens from the Shivkar Subsurface Section.

**Remarks:** The species has been described/recorded from the Early Eocene beds of Bikaner Basin (Singh and Misra, 1968; Khosla, 1972), Kachchh (Khosla and Pant, (1988), and Jaisalmer Basin (Bhandari, 1996). The characteristics of the species are: carapace pear-shaped in lateral view; posterior margin drawn out in a caudal process near mid-height; valve surface ornamented by deep reticulation, arranged concentrically, edges of reticulate meshes raised into low ridges, anterior marginal ridge distinct.

**Dimensions:**

	Length	Height	Width
Left valve, SUGDMF 1296	0.38	0.27	--
Carapace, SUGDMF 1297	0.37	0.27	0.20

**Family** *Trachyleberididae* Sylvester-Bradley, 1948

**Genus** *Actinocythereis* Puri, 1953

*Actinocythereis valdiyai* (Singh and Misra, 1968)  
(Pl. II, figs. 1-5)

*Cythereis spinellosa* var. *valdiyai* Singh and Misra, 1968, p. 34, pl. 10, figs. 1-3.

*Trachyleberis spinellosa* Khosla, 1972, pp. 492-493, pl. 2, fig. 10; pl. 4, fig. 12. (not *Cythereis spinellosa* Lubimova and Guha, in Lubimova et al. 1960, pp. 31-32, pl. 2, fig. 10).

*Actinocythereis valdiyai* (Singh and Misra, 1968). – Khosla and Pant, 1988, p. 331.

**Material:** One hundred eighty-nine specimens from the Shivkar Subsurface Section and 38 from the Kurla Subsurface Section.

**Remarks:** The species was originally described as *Cythereis spinellosa* var. *valdiyai* from the Early Eocene beds of Bikaner Basin by Singh and Misra (1968). Later on it was transferred to the genus *Actinocythereis* by Khosla and Pant (1988) who recorded it from the Early Eocene beds of Kachchh. Since the species was quite distinct from *Cythereis spinellosa*, it was designated as *Actinocythereis valdiyai*. The form described as *Trachyleberis spinellosa* by Khosla (1972) belongs this species. *Actinocythereis valdiyai* has following characteristics: carapace subquadrate in lateral view; posterior cardinal angle well marked in left valve and with a spine pointing upwards; eye tubercle large and glassy with a spine at its base; valve surface ornamented by spines/nodes arranged in more or less three longitudinal rows, dorsal, median and ventral, a few spines/nodes also present in between these rows.

**Dimensions:**

	Length	Height	Width
Female right valve, SUGDMF 1298	0.57	0.32	--
Female carapace, SUGDMF 1299	0.53	0.31	0.29
Female left valve, SUGDMF 1300	0.55	0.35	--
Male right valve, SUGDMF 1301	0.59	0.30	--
Male left valve, SUGDMF 1302	0.58	0.31	--

Genus *Alococythere* Siddiqui, 1971*Alococythere abstracta* Siddiqui  
(Pl. II, figs. 6-10)

*Alococythere abstracta* Siddiqui, 1971, p. 17, pl. 3, figs. 5-11; pl. 4, fig. 1. – Khosla and Pant, 1988, p. 331. – Bhatia and Bagi, 1990, p. 28, pl. 1, fig. 11. – Bhandari, et al., 1991, p. 160. – Bhandari, 1996, p. 32, pl. 8, figs. 1-4.

*Leguminocythereis lunejensis*. – Khosla, 1972, p. 490, pl. 2, fig. 9; pl. 4, fig. 7 (non, Guha, 1967, p. 21, pl. 1, figs. 3, 6, 8).

**Material:** Eight hundred twenty-one specimens from the Shivkar Subsurface Section and 110 specimens from the Kurla Subsurface Section.

**Remarks:** The species has been described/recorded from the Early Eocene beds of Pakistan (Siddiqui, 1971), Jaisalmer Basin (Bhandari, 1996), Kachchh (Khosla and Pant, 1988), Cambay Basin (Bhandari, 1996) and Himachal Pradesh (Bhatia and Bagi, 1990). The form described as *Leguminocythereis lunejensis* by Khosla (1972) from the Early Eocene beds of Bikaner Basin is junior synonym of *Alococythere abstracta*. It is characterized by bean-shaped carapace in lateral view; posteroventral margin straight; subcentral tubercle with seven reticules in two rows, four in upper and three in lower; surface ornamented by reticulation, a short vertical ridge extending down from eye tubercle, and a deep furrow posterior to ridge. The specimens illustrated in plate II, figs. 9-10 show typical outline of *A. abstracta* but exhibit three inclined furrows in posterodorsal region. They are tentatively included herein in this species at the present.

**Dimensions:**

	Length	Height	Width
Male left valve, SUGDMF 1303	0.60	0.35	--
Male right valve, SUGDMF 1304	0.60	0.31	--
Female left valve, SUGDMF 1305	0.50	0.35	--
Male left valve, SUGDMF 1306	0.66	0.39	--
Male right valve, SUGDMF 1307	0.68	0.39	--

*Alococythere longilinea* Siddiqui, 1971  
(Pl. II, figs. 11-13)

*Alococythere longilinea* Siddiqui, 1971, pp. 18-19, pl. 4, figs. 10-13; pl. 5, figs. 1-3, 6. – Bhandari et al., 1991, p. 160. – Bhandari, 1996, p. 34, pl. 10, figs. 1-2.

**Material:** One hundred ninety-two specimens from the Shivkar Subsurface Section and 222 from the Kurla Subsurface Section.

**Remarks:** The species has been described/recorded from the Early Eocene beds of Pakistan (Siddiqui, 1971), Cambay Basin and Jaisalmer Basin (Bhandari, 1996). It is characterized by ovate lateral outline; surface ornamented by reticulation arranged in longitudinal lines with weak ridges, anterodorsal furrow and a short vertical ridge.

**Dimensions:**

	Length	Height	Width
Male left valve, SUGDMF 1308	0.56	0.35	--
Female left valve, SUGDMF 1309	0.50	0.34	--
Male right valve, SUGDMF 1310	0.56	0.34	--

*Alococythere transcendens* Siddiqui  
(Pl. II, fig. 14; pl. III, figs. 1-4)

*Alococythere transcendens* Siddiqui, 1971, pp. 14-15, pl. 1, figs. 4, 5, 8, 9; pl. 2, figs. 1-4, 6, 7. – Khosla and Pant, 1988, p. 331.

**Material:** Fifteen specimens from the Shivkar Subsurface Section and 134 from the Kurla Subsurface Section.

**Remarks:** The species was originally described from the Early and Middle Eocene beds of Pakistan (Siddiqui, 1971). It has been also recorded from the Middle Eocene bed of Kachchh (Khosla and Pant, 1988). The species has bean-shaped carapace in lateral outline; posteroventral margin rounded; subcentral tubercle distinct with four reticules; valve surface ornamented with deep reticulation, a vertical ridge extending downward from eye tubercle, and a furrow posterior to ridge.

**Dimensions:**

	Length	Height	Width
Male left valve, SUGDMF 1311	0.83	0.46	--
Female left valve, SUGDMF 1312	0.68	0.44	--
Male carapace, SUGDMF 1313	0.77	0.44	0.41
Female carapace, SUGDMF 1314	0.74	0.41	0.43
Female right valve, SUGDMF 1315	0.72	0.42	--

**Genus *Gyrocythere*** Siddiqui, 1971

*Gyrocythere memorans* (Lubimova and Guha, 1971)  
(Pl. III, fig. 5-8)

*Trachyleberis memorans* Lubimova and Guha, in Lubimova *et al.*, 1960, pp. 38-39, pl.3, fig. 5.

*Anticythereis memorans* (Lubimova and Guha). Khosla, 1972, pl. 2, fig. 4; pl. 4, fig. 4.

*Gyrocythere memorans* (Lubimova and Guha). Bhandari, 1996, p. 82, pl. 57, figs. 1-4.

**Material:** Thirty-four specimens from the Shivkar Subsurface Section.

**Remarks:** The species was originally described as *Trachyleberis memorans* from the Early Eocene beds of Kachchh (Lubimova and Guha, in Lubimova *et al.* 1960). Later on Khosla (1972) transferred it to *Anticythereis memorans*, thereafter, Bhandari (1996) further transferred it to *Gyrocythere memorans*. In this species surface of each valve is coarsely reticulate and has a dorsal ridge slightly protruding above the margin, a ventral ridge sloping upwards posteriorly, a prominent subcentral tubercle, a crescent-shaped depression posterior to it. The hinge is amphidont / heterodont type.

**Dimensions:**

	Length	Height	Width
Female left valve, SUGDMF 1316	0.80	0.50	--
Female carapace, SUGDMF 1317	0.74	0.45	0.44
Female right valve, SUGDMF 1318	0.80	0.47	--
Male left valve, SUGDMF 1319	0.82	0.50	--

*Gyrocythere parvicarinata* Siddiqui, 1971  
(Pl. III, figs. 9-13)

*Gyrocythere parvicarinata* Siddiqui, 1971, pp. 40-41, pl. 20, figs. 1-4, 6-8, 12. - Khosla and Pant, 1988, p. 331. – Bhandari, 1996, pp. 80, pl. 56, figs. 1-2.

*Anticythereis memorans mudhensis* Khosla, 1972, p. 487, pl. 2, figs. 5-6; pl. 4, fig. 5; pl. 5, fig. 4.

**Material:** Eighty-six specimens from the Kurla Subsurface Section.

**Remarks:** The species has been described/recorded from the Early Eocene beds of Pakistan (Siddiqui, 1971), Kachchh (Khosla and Pant, 1988) and Jaisalmer Basin (Bhandari, 1996). The form described as *Anticythereis memorans mudhensis* from the Early Eocene beds of Bikaner Basin (Khosla, 1972) is junior synonym of *G. parvicarinata*. In this species valve surface is marked by a subcentral tubercle, concentrically arranged reticulation and three longitudinal ridges, median ridge being faint and short extending posteriorly from subcentral tubercle.

**Dimensions:**

	Length	Height	Width
Male left valve, SUGDMF 1320	0.77	0.45	--
Male carapace, SUGDMF 1321	0.74	0.44	0.41
Female left valve, SUGDMF 1322	0.74	0.47	--
Female right valve, SUGDMF 1323	0.79	0.44	--
Female carapace, SUGDMF 1324	0.74	0.43	0.43

**Genus *Occultocythereis*** Howe, 1951

*Occultocythereis peristicta* Siddiqui, 1971  
(Pl. III, figs. 14-15)

*Occultocythereis peristicta* Siddiqui 1971, pp. 50-53, pl. 25, figs. 13-17; pl. 26, figs. 1-15; pl. 27, figs. 1-2. – Khosla and Pant, 1988, p. 331. – Bhandari, 1996, p. 94, pl. 69, figs. 1-4.

*Occultocythereis khoslai* Guha, 1974, p. 185, pl. 2, figs. 6 and 17.

**Material:** Single specimen from the Shivkar Subsurface Section and 43 from the Kurla Subsurface Section.

**Remarks:** This species has been recorded from the Early Eocene beds of Pakistan (Siddiqui, 1971), Kachchh (Khosla and Pant, 1988) and Jaisalmer (Bhandari, 1996). The form *Occultocythereis khoslai* described by Guha (1974) is junior synonym of *O. peristicta*. This species has following characteristics: carapace subquadrate in lateral view; valve surface marked by an elongate anteromedian swelling, a posterodorsal process, a longitudinal ridge in mid-ventral area, a faint tubercle in posteromedian area and sparse reticulation; anterior marginal rim high and with small tubercles; anterior and posterior margins fringed with spines.

**Dimensions:**

	Length	Height	Width
Female carapace, SUGDMF 1325	0.37	0.21	0.13
Male carapace, SUGDMF 1326	0.39	0.19	0.13

**Genus *Stigmatocythere*** Siddiqui, 1971

*Stigmatocythere barmerensis* n. sp.  
(Pl. IV, figs. 1-6)

**Name:** After Barmer District, Rajasthan.

**Material:** Ninety-six specimens from the Shivkar Subsurface Section.

**Diagnosis:** A species of the genus *Stigmatocythere* with six longitudinal ridges and a marginal rim; inter-area between ridges in median and posteromedian regions with feeble reticulation.

**Description:** Sexual dimorphism distinct, males being more elongate, less high and wide than females. Carapace

subquadrate in lateral view, with greatest height at anterior cardinal angle and length at mid-height. Left valve slightly over-reaches right valve in region of anterior cardinal angle and posterodorsal slope. In left valve dorsal margin centrally arched due to overhanging of surface ridge, otherwise nearly straight; in right valve dorsal margin intricate; ventral margin distinctly concave in front of middle; anterior margin broadly rounded; posterior margin narrow, upturned, truncated in lower part; in dorsal view carapace inflated, greatest width at posterior 1/4 of length, ends compressed. Eye and subcentral tubercles present. Valve surface ornamented by six longitudinal ridges and a marginal rim. Of the longitudinal ridges, dorsal ridge originates a little above subcentral tubercle, making an arc overhangs the mid-dorsal margin; ventral ridge starts from the anteroventral region and slopes up posteriorly, terminating in a spine; four low ridges in median and posteromedian regions; inter-area between ridges with feeble reticulation; marginal rim springing from the eye tubercle runs along anterior, ventral and posterior margins; a row of reticules on inner side of anterior rim; rest of the area smooth. Inner lamella moderately wide; line of concrescence and inner margin coincides; selvage strong. Hinge amphidont/heterodont.

*Dimensions:*

	Length	Height	Width
Holotype, SUGDMF 1327, male left valve	0.66	0.35	--
Paratype I, SUGDMF 1328, male carapace	0.59	0.32	0.35
Paratype II, SUGDMF 1329, male right valve	0.61	0.32	--
Paratype III, SUGDMF 1330, female left valve	0.50	0.31	--
Paratype IV, SUGDMF 1331, female carapace	0.50	0.32	0.35
Paratype V, SUGDMF 1332, female right valve	0.49	0.31	--

*Discussion:* The species is herein assigned to the genus *Stigmatocythere* Siddiqui, 1971. Though it lacks the strongly curved ridge, diagnostic of the genus, running from the eye-tubercle to the anterodorsal corner of the subcentral complex, it is very similar in other details to the described species of the genus. The present species closely resembles the type species, *Stigmatocythere obliqua* described from the Early Eocene beds of Pakistan by Siddiqui (1971), in overall shape and ornamentation but differs in details. The later species is characterized by strong reticulation with three longitudinal ridges. *S. portentum* Siddiqui, 1971, described from Middle Eocene beds of Pakistan, also differs from the present species in having three distinct longitudinal ridges, besides a short, curved ridge on the ventral side of the subcentral tubercle running towards the anterior end. *Stigmatocythere (Stigmatocythere) multicosata* Khosla and Nagori, 1988, described from the Early Miocene of Kerala differs in having five longitudinal ridges instead of six as present in *Stigmatocythere barmerensis* n. sp.

*Stigmatocythere shivkarensis* n. sp.  
(Pl. IV, figs. 7-9)

*Name:* After the locality Shivkar.

*Material:* Sixty-two specimens from the Shivkar Subsurface Section, Barmer District.

*Diagnosis:* A species of *Stigmatocythere* with nine moderately high longitudinal ridges, inter-area distinctly reticulated.

*Description:* *Stigmatocythere shivkarensis* n. sp. is similar to *S. barmerensis* n. sp. in lateral and dorsal views but less high and inflated. Valve surface ornamented by nine moderately high longitudinal ridges, with inter-area distinctly reticulate; dorsal ridge curved and weakly overhangs the margin in median region; ventral ridge lacks posterior spine; marginal rim springing from eye tubercle runs along anterior, ventral and posterior margins; a row of reticules on inner side of anterior rim; mid-anterior and mid-posterior areas smooth. Internal characters not known.

*Dimensions:*

	Length	Height	Width
Holotype, SUGDMF 1333, left valve	0.53	0.29	--
Paratype I, SUGDMF 1334, carapace	0.54	0.30	0.31
Paratype II, SUGDMF 1335, right valve	0.54	0.30	--

*Discussion:* *Stigmatocythere shivkarensis* n. sp. resembles *S. barmerensis* n. sp. in overall shape and ornamentation but differs in having moderately high ridges with distinct reticulation. The later species has strongly developed dorsal ridge considerably overhanging the margin; ventral ridge terminating in a distinct spine; inter-area between ridges with feeble reticulation.

*Family* **Xestoleberididae** Sars, 1928

*Genus* **Xestoleberis** Sars, 1866

*Xestoleberis* sp. cf. *X. muelleriana* Lienenklaus  
(Pl. IV, figs. 10-12)

Cf. *Xestoleberis muelleriana* Lienenklaus, 1900, p. 531, pl. 21, fig. 5. – Keij, 1957, p. 166, pl. 11, fig. 11.

*Xestoleberis* sp. cf. *X. muelleriana* Lienenklaus. – Khosla, 1972, pp. 495-496, pl. 3, fig. 21. – Bhandari, 1996, p. 144, pl. 120, figs. 1-2.

*Material:* Sixteen specimens from the Kurla Subsurface Section.

*Remarks:* Carapace subovate in lateral view, with greatest height near middle; dorsal margin strongly arched; ventral margin weakly convex; anterior margin obliquely rounded; posterior margin evenly rounded; in dorsal view carapace inflated, narrowed in front and rounded behind; greatest width posterior to middle; valve surface ornamented by concentrically arranged pits. *Xestoleberis* spot present. The specimens recorded from Barmer resemble closely *Xestoleberis muelleriana* Lienenklaus, originally described from the Oligocene beds of Western Germany, in shape. In India this species has been recorded from the Eocene beds of Rajasthan (Khosla, 1972; Bhandari, 1996) and Kachchh (Khosla and Pant, 1988).

*Dimensions:*

	Length	Height	Width
Right valve, SUGDMF 1336	0.48	0.33	--
Carapace, SUGDMF 1337	0.47	0.33	0.28
Left valve, SUGDMF 1338	0.52	0.34	--

*Suborder* **Platycopina** Sars, 1866

*Family* **Cytherellidae** Sars, 1866

*Genus* **Cytherella** Jones, 1849

*Cytherella harudiensis* Khosla and Pant, 1988  
(Pl. IV, figs. 13-14)

*Cytherella harudiensis* Khosla and Pant, 1988, pp. 333-334, figs. 2A-B.

**Material:** One hundred eighty-eight specimens from the Shivkar Subsurface Section and fifty-nine from the Kurla Subsurface Section.

**Remarks:** *Cytherella harudiensis* has so far been described from the Zones III and IV of Babia Stage (Middle Eocene) of Kachchh (Khosla and Pant, 1988). The species is characterized by carapace ovate in lateral view, with greatest height 2/3 of length posterior to middle; wedge-shaped in dorsal view, inflated posteriorly and tapering anteriorly; right valve considerably larger than the left; valve surface distinctly pitted and with a broad shallow depression in mid-dorsal area.

**Dimensions:**

	Length	Height	Width
Carapace, SUGDMF 1339	0.61	0.45	0.32
Carapace, SUGDMF 1340	0.56	0.43	0.31

*Cytherella tawaica* Singh and Tewari  
(in Tewari and Singh, 1966)  
(Pl. IV, fig. 15)

*Cytherella tawaica* Singh and Tewari, in Tewari and Singh, 1966, p. 127, pl. 2, fig. 3a-d. – Khosla, 1972, p. 482, pl. 1, fig. 4. – Bhandari, 1996, p. 60, pl. 36, figs. 1-2.

**Material:** Thirteen specimens from the Shivkar Subsurface Section and 42 from the Kurla Subsurface Section.

**Remarks:** The species was originally described from the Early Eocene beds of Kalakot, Jammu (Singh and Tewari, in Tewari and Singh, 1966). It has been later on recorded from the Early Eocene beds of Bikaner (Khosla, 1972), Kachchh (Khosla and Pant, 1988), and Jaisalmer (Bhandari, 1996). The species is characterized by subrectangular outline in lateral view and wedge-shaped in the dorsal; valve surface pitted near anterior and posterior margins; a broad shallow depression in mid-dorsal area.

**Dimensions:**

	Length	Height	Width
Carapace, SUGDMF 1341	0.48	0.31	0.28

*Genus Cytherelloidea* Alexander, 1929

*Cytherelloidea guhai* Khosla, 1972  
(Plate IV, figures 16-17)

*Cytherelloidea guhai* Khosla, 1972, p. 483, pl. 1, figs. 6-7; pl. 5, fig. 2. – Khosla and Pant, 1988, p. 331. – Bhandari, 1996, p. 62, pl. 38, fig. 1-2.

**Material:** Twenty-five specimens from the Kurla Subsurface Section.

**Remarks:** *Cytherelloidea guhai* Khosla has been previously described/recorded from the Early Eocene beds of Bikaner (Khosla, 1972), Kachchh (Khosla and Pant, 1988) and Jaisalmer (Bhandari, 1996). It is characterized by subrectangular outline in lateral view; valve surface ornamented by two pronounced horizontal ridges in lower half and a third discontinuous one in upper half, the three horizontal ridges being connected with vertical marginal ridge at each end.

**Dimensions:**

	Length	Height	Width
Left valve, SUGDMF 1342	0.45	0.24	--
Right valve, SUGDMF 1343	0.46	0.27	--

## CONCLUSIONS

A rich and interesting marine ostracod fauna, comprising 22 species, including two new, has been described / recorded for the first time from the Akli Formation of Barmer Basin, Rajasthan.

The fauna is characteristic of Early Eocene age and has been widely recorded from these beds of Pakistan, Kachchh, Cambay, Jaisalmer, Bikaner, Simla Hills, and Kalakot, Jammu and Kashmir.

The evidence furnished by ostracods suggests that the beds of the Akli Formation were deposited in near shore to lagoon environment.

## ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Geology, Mohanlal Sukhadia, Udaipur for providing Laboratory and Library facilities; to Professor P. K. Saraswati and Dr. Shilpa, Department of Earth Sciences, IIT Bombay, Powai, for their permission and assistance respectively in doing SEM photography of ostracod fauna; to Drs. Arjun Singh Rathore for preparing the plates and to (Mrs.) Maya Chaudhary for figures and tables accompanying the paper. We are also thankful to the Mineral Exploration Corporation Limited, Barmer for making available samples and litho-logs of Shivkar and Kurla Subsurface Sections for study.

## REFERENCES

- Bate, R. H.** 1971. The distribution of Recent Ostracoda in the Abu Dhabi Lagoon, Persian Gulf. In, *Oertli, H. J. ed., Paléocologie des ostracodes, Colloque Pau (1970), Centre Recherches Pau-SNPA, Bulletin 5* supplement: 239-256.
- Bhandari, A.** 1991. Late Eocene Ostracoda from the Jaisalmer Basin, Rajasthan. *Journal of the Palaeontological Society of India*, **36**: 43-49.
- Bhandari, A.** 1992. Late Paleocene Ostracoda from the subsurface of Jaisalmer Basin, Rajasthan. *Journal of the Geological Science*, **13** (1): 39-75.
- Bhandari, A.** 1995. Early Eocene ostracodes from subsurface of Jaisalmer Basin, Rajasthan. *Journal of the Geological Science*, **15** (1): 73-99.
- Bhandari, A.** 1996. Atlas of Paleogene Ostracodes of Rajasthan Basins. *Paleontographica Indica*, **4**: 157 p.
- Bhatia, S. B. and Bagi, H.** 1990. A note on some Early Eocene ostracodes from the Subathu Formation, Morni Simla Hills, Lesser Himalayas. *Journal of the Palaeontological Society of India*, **35**: 25-31.
- Bold, W. A. Van Den** 1971. Ostracode associations, salinity and depth of deposition in the Neogene of the Caribbean region. In, *Oertli, H. J. ed., Paléocologie des ostracodes, Colloque Pau (1970), Centre Recherches Pau-SNPA, Bulletin 5* supplement: 449-460.
- Boroah, S. K.** 1945. The occurrence of Laki Series in Jodhpur State. *Current Science*, **15**(11): 317.
- Boroah, S. K.** 1950. Fossil fish and crab in the Fuller's Earth beds at Kapurdi, Jodhpur, Rajasthan. *Current Science*, **19**(5): 165.
- Compton, P. M.** 2009. The Geology of the Barmer Basin, Rajasthan, India, and origin of its major oil reservoir, the Fatehgarh Formation. *Petroleum Geoscience*, **15**: 1-15.
- Das Gupta, S. K.** 1975. Revision of the Mesozoic-Tertiary stratigraphy of the Jaisalmer Basin, Rajasthan. *Indian Journal of Earth Sciences*, **2**(1): 77-94.

- Dolson, J., Burley, S. D., Sunder, V. R., Kothari, V., Naidu, B., Whiteley, N. P., Farrimond, P., Taylor, A., Direen, N. and Ananthkrishnan, B.** 2015. The discovery of the Barmer Basin, Rajasthan, India, and its petroleum geology. *American Association of Petroleum Geologists Bulletin*, **99**: 433-465.
- Farrimond, P., Bodapati, S. N., Stuart, D. B., Dolson, J., Whiteley, N. and Kothari, V.** 2015. Geochemical characterization of oil and their source rocks in the Barmer Basin, Rajasthan, India. *Petroleum Geoscience*, **21**: 301-321.
- Guha, D.K.** 1967. Ostracoda from Oligocene subgroups of Cambay, western India. *India, Oil and Natural Gas Commission, Bulletin* **4**(1): 17-22.
- Guha, D. K.** 1974. Marine Ostracoda from Tertiary of Kutch and Cambay. *Publication Centre of Advanced study in Geology, Panjab University*, **10**: 156-176.
- Jacob, K. and Sastri, V. V.** 1950. Some new microforaminifera from the Fuller's Earth, Bikaner, Rajasthan. *Science and Culture*, **16**(2): 80-82.
- Jain, S. P.** 1976. Holocene Ostracoda from the Chilka Lake, Orissa. *VI Indian Colloquium Micropaleontology and Stratigraphy, Proceeding*, 126-134.
- Jain, S. P.** 1978. Recent Ostracoda from Mandvi beach, west coast of India. *Indian Geologists Association, Bulletin*, **11**(2): 89-139.
- Kaul, K. N.** 1951. A Palm fruit from Kapurdi (Jodhpur, Rajasthan Desert) *Cocos sahnii*. *Current Science*, **20**(5): 138.
- Khosla, S. C.** 1972. Ostracodes from the Eocene beds of Rajasthan, India. *Micropaleontology*, **18**(4): 476-507.
- Khosla, S. C. and Nagori, M. L.** 2002. Ostracodes from the Inter-trappean beds (Early Palaeocene) of east coast of India. *Paleontological Research*, **6** (2): 191-210.
- Khosla, S. C. and Nagori, M. L.** 1988. The genus *Stigmatocythere* from the Quilon beds (Lower Miocene) of Kerala, India. In *Hanai, T., Ikeya, N. and Ishizaki, K. (Eds.), Evolutionary Biology of Ostracoda its fundamentals and applications, Developments in Palaeontology and Stratigraphy, Elsevier*, **11**: 105-120.
- Khosla, S. C. and Pant, P. C.** 1988. Ostracoda from the Eocene and Oligocene beds of Kachchh, Gujarat, Part I - Families Cytherellidae, Bairdiidae and Trachyleberididae. *Indian Journal of Earth Sciences*, **15**(4): 325-346.
- Keij, A. J.** 1957. Eocene and Oligocene Ostracoda of Belgium. *Institute Royal Science Natural Belgique Memoir*, **136**: 1-210.
- Lienenklaus, E.** 1900. Die Tertiär Ostrakoden des mittleren Norddeutschlands. *Zeitschrift Deutschen Geologischen Gesellschaft*, **52**: 497-550.
- Lubimova, P. S., Guha, D. K. and Mohan, M.** 1960. On Ostracoda of Jurassic and Tertiary deposits from Kutch and Rajasthan (Jaisalmer), India. *Bulletin Geological, Mining and Metallurgical Society of India*, **22**: 1-61.
- Mamgain, V. D. and Chatterjee, B. P.** 1977. Eocene Ostracoda from Kolyatji area, Rajasthan. *Record Geological Survey of India*, **108**: 42-50.
- Mathur, N. S.** 1977. Ostracoda from the Subathu Formation (Upper Paleocene to Middle Eocene), Simla Hills. *Research Bulletin Science, Panjab University, Chandigarh*, **28** (3-4): 113-130.
- Mathur, S. K., Mathur, S. C. and Loyal, R. S.** 2006. First Microvertebrate Assemblage from the Fatehgarh Formation (Cretaceous), Barmer District, Western Rajasthan. *Journal Geological Society of India*, **67**: 759-769
- Moore, R. C. and Pitrait, C. W.** 1961. *Treatise on Invertebrate Paleontology, Part Q, Arthropoda 3, Ostracoda*, Geological Society of America and University Kansas Press, Lawrence, xxiii +442 p
- Morkhoven, F. P. C. M.** 1963. Post-Paleozoic Ostracoda, their morphology, taxonomy, and economic use. *Elsevier, Amsterdam*, **2**: 1-478.
- Omatsola, M. E.** 1970. On the occurrence of Cytherellids (Ostr. Crust.) in a brackish-water environment. *University Uppsala, Geological Institute, Bulletin, New Series*, **2**(10): 91-96.
- Oertli, H. G.** 1967. Essai d'interpretation ecologie des association d'ostracodes de l'Eocene Superieur et de l'Oligocene de corneillesen-Parisis. *Centre Recherches Pau-SNPA, Bulletin*, **1**(2): 367-373.
- Paik, K. H. O.** 1977. Regionale untersuchungen Zur Verteilung der Ostracoden im Persischen Golf und im Golf von Oman. "Meteor" Forschungsergebnisse. *Reiche C*, **28**: 37-76.
- Sahni, A., Rana, R. S., Loral, R. S., Saraswati, P. K., Mathur, S. K., Rose, K. D., Tripathi, S. K. M., Garg, R.** 2004. Western margin Palaeocene-Lower Eocene lignite: Biostratigraphic and palaeoecological constrains. *Proceedings of 2<sup>nd</sup> APG Conference cum Exhibition, Khajurho*: 1-22.
- Siddiqui, Q. A.** 1971. Early Tertiary Ostracoda of the Family Trachyleberididae from West Pakistan. *Bulletin of the British Museum (Natural History) Geology, Supplement* **9**: 1-98.
- Siddiquie, H. N. and Behl, D. P.** 1965. Geology of the bentonite deposits of Barmer District, Rajasthan. *Memoirs of the Geological Survey of India*, **96**: 1-96.
- Siddiquie, H. N. and Iqbaluddin** 1963. Occurrence of Paleocene and Eocene beds in the Barmer district, Rajasthan. *Current Science*, **32**: 575.
- Singh, S. N. and Misra, P. C.** 1968. New genus and species of ostracodes from Fuller's Earth, Kolayatji, Rajasthan, India. *Journal of the Palaeontological Society of India*, **11**: 26-37.
- Sohn, I. G.** 1964. The Ostracoda genus *Cytherelloidea*, a possible indicator of Palaeotemperature. *Pubblicazioni della Stazione Zoologica di, Napoli. Suppl.* 529-534.
- Sisodia, M. S. and Singh, U. K.** 2000. Depositional environment and hydrocarbon prospects of the Barmer Basin, Rajasthan, India. *Nafta, Zagreb (Croatia)*, **51**(9): 309-326.
- Tewari, B. S. and Singh, P.** 1966. Ostracoda from the Nummulitic beds of Kalakot, Jammu and Kashmir State., *Panjab University, Centre Advanced Study Geology Publication*, **3**: 117-130.
- Tripathi, S. K. M., Kumar, M. and Srivastava, D.** 2009. Palynology of Lower Palaeogene (Thanetian-Yresian) coastal deposits from the Barmer Basin (Akli Formation, Western Rajasthan, India): Palaeoenvironmental and palaeoclimatic implications. *Geologica Acta*, **7**: 147-160.

Manuscript received : November 2017

Manuscript accepted : February 2019