

Middle Eocene Ostracoda from the Tadkeshwar Lignite Mine, Cambay Basin, Gujarat

M. L. NAGORI, S. C. KHOSLA and S. R. JAKHAR

Department of Geology, Mohanlal Sukhadia University, Udaipur – 313 002

Email: mlnagori58@yahoo.com

Abstract: Previous work on the fauna and flora of the Cambay shale underlying as well as inter-bedded within the lignite seams of Vastan lignite mine, Gujarat allows the shale to be assigned a Lower Eocene age. However, there is no record of occurrence of any fossil from the sedimentary beds succeeding the shale-lignite sequence that might fix upper age limit of the Cambay shale. We record a characteristic Middle Eocene ostracod assemblage from the Nummulitic marl/limestone, immediately overlying the shale-lignite sequence from the Tadkeshwar lignite mine close to the Vastan lignite mine. The assemblage comprises 22 species, many of which widely occur in the Middle Eocene beds of Kachchh, Rajasthan and adjacent areas of Pakistan.

Keywords: Middle Eocene, Ostracods, Tadkeshwar Lignite Mine, Cambay Basin, Gujarat.

INTRODUCTION

The Early Tertiary beds in the northwestern Indian sub-continent are characterized by the presence of multiple brown coal (lignite) seams. In Pakistan these seams occur in the tectonically active areas in the Trans-Indus Ranges, while in India they extend from the Kalakot coalfields of Jammu and Kashmir in the north, through the Bikaner, Nagaur and Barmer basins of Rajasthan, to the Kachchh and Cambay basins of Gujarat in the south. In the Cambay basin the lignite is being mined at: (i) Vastan lignite mine, (ii) Tadkeshwar lignite mine and (iii) Rajpardi lignite mine for thermal power generation.

Significant contributions have been made on the fossil biotas of the Vastan lignite mine (21°25'47" N : 73°07'30" E) during the past one decade. The marine fish remains have been described and/or recorded by Rana et al. (2004), Bajpai and Kapur (2004), and Nolf et al. (2006); the mammals by Sahni et al. (2004, 2006), Rana et al. (2005), Bajpai et al. (2005a, 2005b, 2005c, 2006), Rose et al. (2006), and Kumar (2006); the avifauna by Mayr et al. (2007); the insects by Alimohammadian et al. 2005), the foraminifers by Saraswati (in Sahni et al., 2006), the brackish-marine ostracods by Bhandari et al. (2005); and the pollens by Samant and Tapaswi (2000 and 2001). The sedimentary sequence exposed in this mine has been referred to the Cambay Formation (Cambay shale). It has yielded only one age-diagnostic larger foraminifer, viz. *Nummulites burdigalensis burdigalensis*, which assigns the section to SBZ 10,

equivalent to the planktonic foraminiferal zone P6b of Berggren et al. (1995) and corresponds to the middle Ypresian (ca 52 Ma, Serra-Kiel et al. 1998). Besides the Vastan lignite mine, Early Eocene palynoflora has also been recorded from the Rajpardi lignite mine by Samant and Phadtare (1997), and otoliths from sub-surface clay in a borehole at Tadkeshwar by Samant and Bajpai (2001).

The fossil fauna and flora recorded from the Vastan and Rajpardi lignite mines (*supra cit.*) come from the Cambay shale either underlying the lignite or interbedded within it. This shale is considered to be a major hydrocarbon source rock in western India. It was deposited in a shallow marine environment with a regular influx of freshwater (brackish ?), probably representing an estuary or a protected bay with mangrove vegetation (Nolf et al., 2006). Surprisingly there is no record of occurrence of any fossil from the sedimentary beds immediately succeeding the shale-lignite sequence to fix its upper age limit.

With the intention to fill this lacuna in our knowledge, two of us (MLN and SRJ) collected samples from the Tadkeshwar lignite mine. The Nummulitic marl/limestone bed, immediately succeeding the lignite bed has yielded an interesting, sufficiently well preserved ostracod assemblage, comprising of 22 species. These are by and large ubiquitous species and have been reported from virtually all marine Middle Eocene localities of Gujarat, Rajasthan and Pakistan (*infra cit.*). The object of the present paper is to place on record the occurrence of this

characteristic Middle Eocene ostracod assemblage from Tadkeshwar lignite mine.

PREVIOUS WORK

As stated earlier there is no previous record of occurrence of ostracoda from the mine. However, Khosla (1994) has recorded an assemblage of 20 species from the *Pellatospira* bearing Eocene beds exposed in a *nala* cutting, about 2 km from Tadkeshwar (21° 22' N: 73° 03' E) on the Mangrol road. A checklist of these ostracods is: *Acanthocythereis bhujensis* (Tewari and Tandon), *Alocopocythere transcendens* Siddiqui, *Bairdoppilata poddari* Lubimova and Mohan, *Cushmanidea tewarii* Khosla, *Cytherella lakhpatensis* Khosla and Pant, *Cytheropteron kutchensis* (Guha), *Dentokrithe indica* (Tewari and Tandon), *Echinocythereis (Scelidocythereis) sahnii* (Tewari and Tandon), *Gyrocythere indica* (Tewari and Tandon), *Hermanites scopus* Siddiqui, *H. siddiquii* Khosla and Pant, *H. subquadra* Siddiqui, *Hornibrookella arcana* (Lubimova and Guha), *Neocyprideis bhupendri* (Singh and Misra), *Neonesidea indica* (Tewari and Tandon), *Paijenborchella trisulcata* Mandelstam, *Stigmatocythere calia* Siddiqui, *S. lumaria* Siddiqui, *Trachyleberis lakhpatensis* Khosla and Pant, and *Uroleberis kutchensis* Guha. On the basis of the ostracods Khosla (1994) assigned the beds a late Middle Eocene age. From Vastan lignite mine, about 12 km southwest of Tadkeshwar lignite mine, Bhandari et al. (2005) recorded 5 ostracod species, including 3 new, from a greenish-grey, whitish clay/marl within the clay/lignite seam horizon II. These species are: *Acanthocythereis vastanensis* Bhandari et al., *Cytherella kimensis* Bhandari et al., *Neocyprideis suratensis* Bhandari et al., *Alocopocythere abstracta* Siddiqui, and *Phlycetenophora meridionalis* (Lubimova and Mohan). According to Bhandari et al. (2005) ostracod assemblage suggests an early Eocene age and sediments that were deposited in a marginal to very shallow marine environment.

Other reported occurrences of ostracods are from the sub-surface Palaeogene sediments of the Cambay Basin by Raju et al. (1970), Guha (1965, 1974), Bhandari et al. (1991), Bhandari (1999), Bhandari and Raju (1991, 2000) and Singh and Porwal (1999).

LITHOSTRATIGRAPHY OF SECTION STUDIED

The ostracod microfauna recorded herein are from Tadkeshwar lignite mine (21°22'25" N: 73°04' E), Tadkeshwar, Surat district, Gujarat (fig. 1). A brief description of the section sampled is as follows:

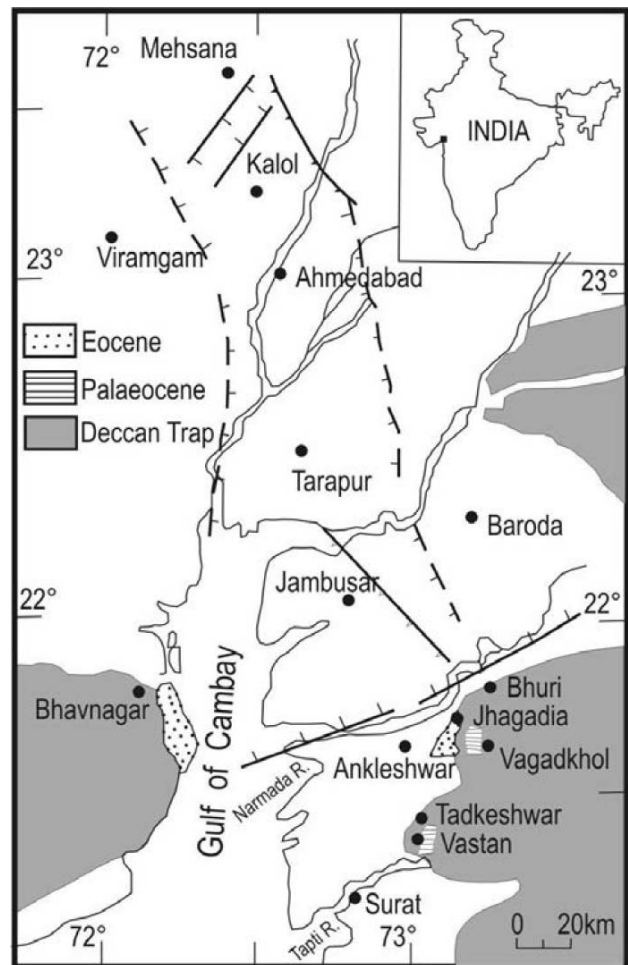


Fig.1. Location of Tadkeshwar lignite mine, Gujarat.

This section is approximately 8 m thick. It comprises a thick lignite seam (3 m) at the base, successively overlain by a Nummulitic marl/limestone bed (1.5 m) and a brown conglomerate bed (3.5 m). In all 5 samples (TD/1 to TD/5) were collected, but ostracods were recovered only from the Nummulitic marl/limestone (TD/2 to TD/4).

OSTRACOD FAUNA

Of the 22 species recorded in this paper, 21 species are assigned to the already known taxa. These are illustrated in Plates I and II. The references where original citation, description and illustration can be found are given in sequel.

Cytherella lakhpatensis Khosla and Pant, 1988, pp. 334-335, figs. 2 C-D.

Cytherelloidea pseudoinvolens Khosla and Pant, 1988, p. 336, fig. 2 F

C. kharatarensis Bhandari, 1996, p. 64, pl. 40, figs. 1-2.

- Bairdoppilata kakdiensis* Khosla and Pant, 1988, p. 337, fig. 3 A-B
- Bairdia indica* Tewari and Tandon, 1960, pp. 148-149, text-fig. 1, figs. 1a-b.
- *Neonesidea indica* (Tewari and Tandon). - Khosla and Pant, 1988, p. 332.
- Schizocythere gujeratensis* Guha, 1968, p. 84, pl. 1, figs. 11-14, 16, 20.
- Paijenborchella trisulcata* Mandelstam in Rozieva, 1962, p. 82, pl. 24, figs. 4a-b.
- Dentokrithe indica* (Tewari and Tandon). Khosla and Haskin, 1980, p. 214, pl.1, figs. 14-19.
- Schizoptocythere ventrocosa* Siddiqui and Al-Furaih, 1981, pp. 888-889, figs. 5-6.
- Occultocythereis indistincta* Siddiqui, 1971, pp. 53-54, pl. 27, figs. 13-15; pl. 28, figs. 1-4.
- Occultocythereis peristicta*. Siddiqui, 1971, pp. 50-53, pl. 25, figs. 13-17; pl. 26; pl. 27, figs. 1-2.
- Acanthocythereis bhujensis* (Tewari and Tandon). - Guha, 1968, p. 155, figs. 22, 25, 28.
- Alocopocythere transcendens* Siddiqui, 1971, pp. 14-15, pl.1, figs. 4, 5, 8, 9; pl. 2, figs. 1-4, 6,7.
- Hemicythere sahnii* Tewari and Tandon, 1960, p. 157, text-fig. 4, figs. 1a-d. *Echinocythereis (Scelidocythereis) sahnii* (Tewari and Tandon). - Khosla and Pant, 1988, p. 332.
- Hermanites scopus* Siddiqui, 1971, pp. 45-46, pl. 23, figs. 4-10.
- Hermanites siddiquii* Khosla and Pant, 1989, pp. 4-5, fig. 2 A-B.
- Cythereis arcana* Lubimova and Guha, in Lubimova, Guha and Mohan, 1960, p. 33, pl. 3, figs. 1a-b. *Hornibrookella arcana* (Lubimova and Guha). Khosla and Pant, 1988, p. 332.
- Cf. *Hornibrookella ramanianaensis* Khosla and Pant, 1989, pp. 6-7, fig. 2 E-H.
- Cytheropteron kutchensis* (Guha), 1968, p. 87, pl. 1, figs. 17, 18, 21, 23, 26.
- Uroleberis kutchensis* Guha, 1968, p. 87, pl. 1, figs. 4, 8, 12.
- Uroleberis sohni* Khosla and Pant, 1989, pp. 8-9, fig. 3 E.

AGE

An analysis of the 22 ostracod species recorded from the Nummulitic marl/limestone bed of the Tadkeshwar lignite mine is given below:

- i. One species - *Semicythrura* sp. - is possibly new. It is at the moment left in open nomenclature.
- ii. Two species - *Bairdoppilata kakdiensis* Khosla and Pant, 1988 and *Occultocythereis peristicta* Siddiqui, 1971 -

- have been previously described and/or recorded from the Lower Eocene of Kachchh. The latter species was originally described from the Lower Eocene of Pakistan.
- iii. Two species - *Hornibrookella ramanianaensis* Khosla and Pant, 1989, *Uroleberis sohni* Khosla and Pant, 1989 - have been previously described from the Oligocene - Ramaniana Stage of Kachchh.
 - iv. Two species - *Schizocythere gujeratensis* Guha, 1968 and *Dentokrithe indica* (Tewari and Tandon, 1960) - extend from Lower to Middle Eocene and another species - *Neonesidea indica* (Tewari and Tandon, 1960) - extends from Middle Eocene to Oligocene in Kachchh. They are long ranging. Also, *D. indica* occurs throughout the Eocene and *N. indica* in the Middle Eocene of Rajasthan, and *S. gujeratensis* in the Middle Eocene beds of Pakistan (Siddiqui, 1981).
 - v. Fourteen species - *Cytherella lakhpatisensis* Khosla and Pant, 1988, *C. kharatarensis* Bhandari, 1996, *Cytherelloidea pseudoinsolens* Khosla and Pant, 1988, *Paijenborchella trisulcata* Mandelstam (in Rozieva, 1962), *Schizoptocythere ventrocosa* Siddiqui and Al-Furaih, 1981, *Occultocythereis indistincta* Siddiqui, 1971, *Acanthocythereis bhujensis* (Tewari and Tandon, 1960), *Alocopocythere transcendens* Siddiqui, 1971, *Echinocythereis (Scelidocythereis) sahnii* (Tewari and Tandon, 1960), *Hermanites scopus* Siddiqui, 1971, *Hermanites siddiquii* Khosla and Pant, 1989, *Hornibrookella arcana* (Lubimova and Guha, 1960), *Cytheropteron kutchensis* (Guha, 1968), and *Uroleberis kutchensis* (Guha, 1968) - have been previously described from the Middle Eocene of Kachchh and they appear to be its characteristic species. Beside Kachchh, *C. kharatarensis*, *H. arcana*, *E. (S.) sahnii*, and *U. kutchensis* occur in the Middle Eocene of Rajasthan. In Pakistan *A. transcendens* extends from Lower to Middle Eocene, while *O. indistincta*, *A. bhujensis* (= *Trachyleberis (Acanthocythereis) postcornis* Siddiqui), *A. transcendens*, *E. (S.) sahnii* (= *Echinocythereis (Scelidocythereis) rasilis* Siddiqui), *H. scopus*, *H. arcana* (= *Quadracythere (Hornibrookella) arcana*) occur restricted in the Middle Eocene of Pakistan.

From the analysis given above it is apparent that of the 21 species recorded from the Nummulitic marl/limestone of the Tadkeshwar lignite mine as many as 14 species are characteristic of the Middle Eocene and 3 others are not inconsistent with this age. The latter either range from Lower to Middle Eocene or from Middle Eocene to Oligocene. On the basis of majority of the recorded ostracods, a Middle Eocene age is evident.

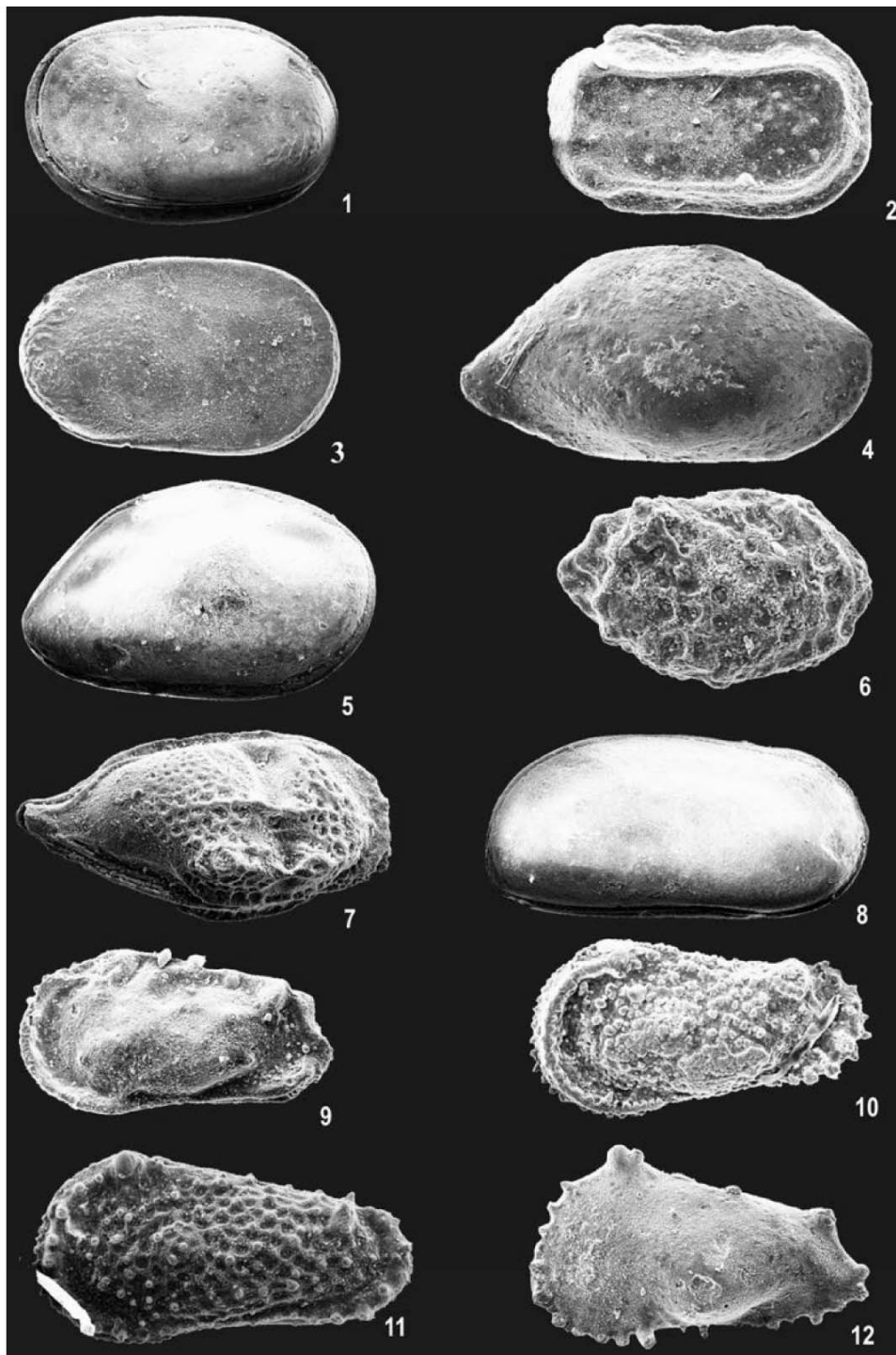


Plate I. *Cytherella lakhpatensis* Khosla and Pant 1, a carapace, right valve view, L 0.62 mm. **2.** *Cytherelloidea kharatarensis* Bhandari 2, a carapace, right valve view, L 0.53 mm. **3.** *Cytherelloidea pseudoinsolens* Khosla and Pant 3, a carapace, right valve view, L 0.62 mm. **4.** *Bairdoppilata kakdiensis* Khosla and Pant 4, a right valve, lateral view, L 1.04 mm. **5.** *Neonesidea indica* (Tewari and Tandon) 5, a carapace, right valve view, L 0.77 mm. **6.** *Schizocythere gujaratensis* Guha 6, a carapace, right valve view, L 0.48 mm. **7.** *Paijenborchella trisulcata* Mandelstam 7, a carapace, right valve view, L 0.70 mm. **8.** *Dentokrithe indica* (Tewari and Tandon) 8, a carapace, right valve view, L 0.80 mm. **9.** *Occultocythereis indistincta* Siddiqui 9, a carapace, left valve view, L 0.43 mm. **10.** *Occultocythereis peristicta* Siddiqui 10, a carapace, left valve view, L 0.44 mm. **11.** *Acanthocytheries bhujensis* (Tewari and Tandon) 11, a male carapace, left valve view, L 0.64 mm. **12.** *Schizoptocythere ventricosa* Siddiqui and Al-Furaih 12, a right valve, lateral view, L 0.61 mm.

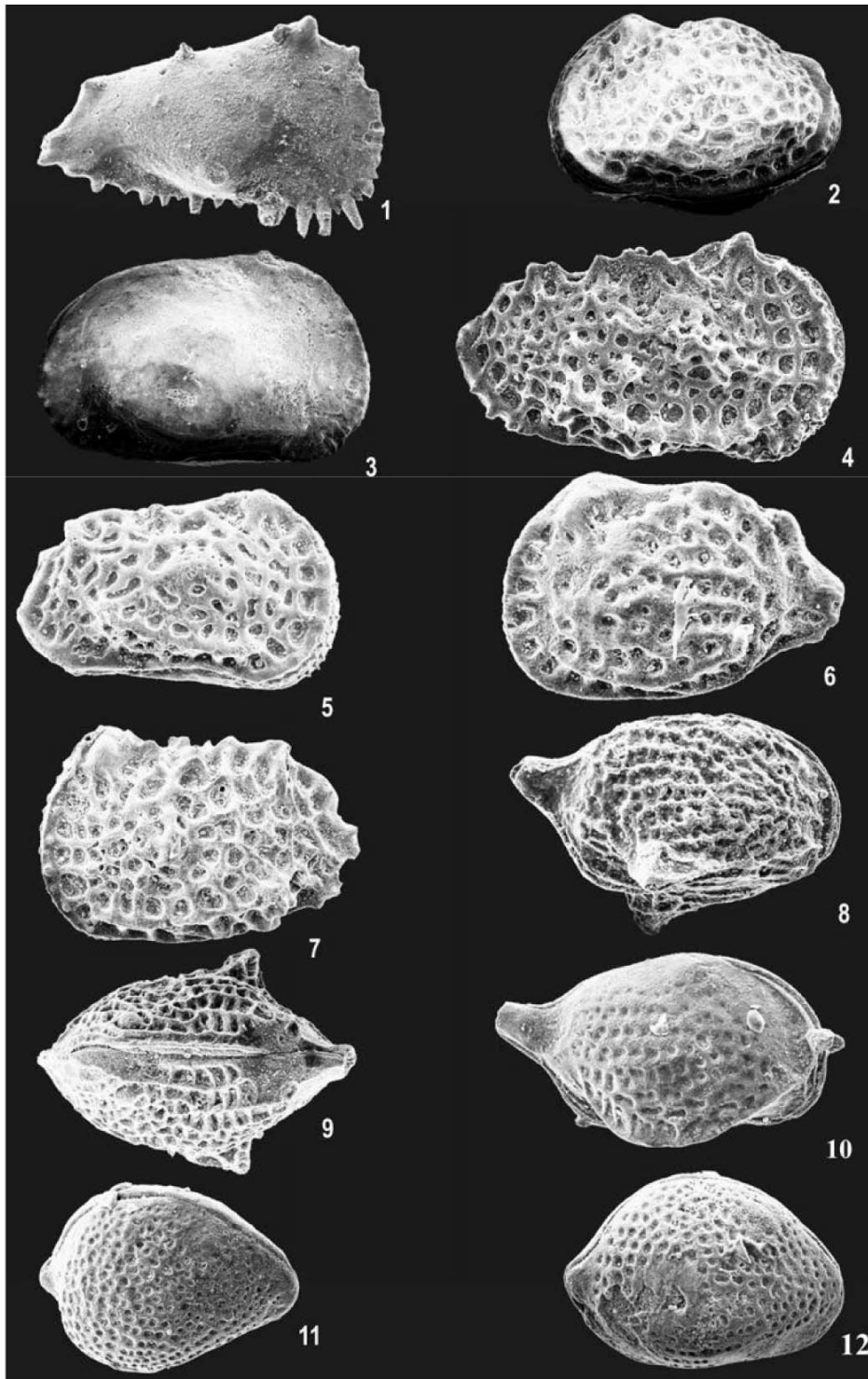


Plate II. 1. *Schizoptocythere ventricosa* Siddiqui and Al-Furaih 1, a left valve, lateral view, L 0.56 mm. 2. *Alocopocythere transcendens* Siddiqui 2, a female carapace, left valve view, L 0.64 mm. 3. *Echinocythereis (Scelidocythereis) sahnii* (Tewari and Tandon) 3, a carapace, right valve view, L 0.74 mm. 4. *Hermanites scopus* Siddiqui 4, a carapace, right valve view, L 0.80 mm. 5. *Hermanites siddiquii* Khosla and Pant 5, a female carapace, right valve view, L 0.54 mm. 6. *Hornibrookella arcana* (Lyubimova and Guha) 6, a left valve, lateral view, L 0.53 mm. 7. *Hornibrookella ramaniaensis* Khosla and Pant 7, a left valve, lateral view, L 0.67 mm. 8-9. *Semicytherura* sp. 8, a carapace, right valve view, L 0.45 mm. 9, a carapace, dorsal view, L 0.42 mm. 10. *Cytheropteron kutchensis* (Guha) 10, a carapace, right valve view, L 0.48 mm. 11. *Uroleberis kutchensis* Guha 11, a carapace, right valve view, L 0.45 mm. 12. *Uroleberis sohni* Khosla and Pant_ 12, a carapace, right valve view, L 0.42 mm.

In addition, the Nummulitic marl/limestone of the Tadkeshwar lignite mine is equivalent to the *Pellatispira* bearing Eocene beds exposed near Tadkeshwar (21°22' N: 73°03' E) in Surat District, with which it has 12 species – *C. lakhpatensis*, *N. indica*, *P. trisulcata*, *D. indica*, *A. bhujensis*, *A. transcendens*, *E. (S.) sahnii*, *H. scopus*, *H. siddiquii*, *H. arcana*, *C. kutchensis*, and *U. kutchensis* - common.

Acknowledgements: The authors are thankful to Prof. R.C. Whatley, U.K. for kindly reviewing the paper and making useful suggestions; to the Head, Department of Geology for providing Library and Laboratory facilities, including SEM; to the SAP Coordinator for extending grant to carrying out field work: and to the Management of the Tadkeshwar lignite mine for permission to collect samples.

References

- ALIMOHAMMADIAN, H., SAHNI, A., PATNAIK, R., RANA, R.S. and SINGH, H. (2005) First record of an exceptionally diverse and well preserved amber-embedded biota from Lower Eocene (~52 Ma) lignites, Vastan, Gujarat. *Curr. Sci.*, v.89(8), pp.1328-1330.
- BAJPAI, S. and KAPUR, V.V. (2004) Oldest known gobiids from Vastan Lignite Mine (Early Eocene), District Surat, Gujarat. *Curr. Sci.*, v.87(4), pp.433-435.
- BAJPAI, S., KAPUR, V.V., DAS, D.P., TEWARI, B.N., SARAVANAN, N. and SHARMA, R. (2005a) Early Eocene Land Mammals from Vastan Lignite Mine, District Surat (Gujarat), Western India. *Jour. Palaeont. Soc. India*, v.50(1), pp.101-113.
- BAJPAI, S., KAPUR, V.V., THEWISSEN, J.G.M., TEWARI, B.N. and DAS, D.P. (2005b) First fossil Marsupials from India: Early Eocene *Indodelphis* n. gen. and *Jaegeria* n. gen. from Vastan Lignite Mine, District Surat, Gujarat. *Jour. Palaeont. Soc. India*, v.50(1), pp.147-151.
- BAJPAI, S., KAPUR, V.V., THEWISSEN, J.G.M., DAS, D.P. AND TEWARI, B.N., SHARMA, R. and SARAVANAN, N. (2005c) Early Eocene Primates from Vastan Lignite Mine, Gujarat, India. *Jour. Palaeont. Soc. India*, v.50(2), pp.43-54.
- BAJPAI, S., KAPUR, V.V., THEWISSEN, J.G.M., DAS, D.P. and TEWARI, B.N. (2006) New Early Eocene cambaythere (Perissodactyla, Mammalia) from the Vastan Lignite Mine (Gujarat, India) and an evaluation of cambaythere relationships. *Jour. Palaeont. Soc. India*, v.51(1), pp.101-110.
- BERGGREN, W.A., KENT, D.V., SWISHER, C.C., III, and AUBRY, M.P. (1995). A revised Cenozoic geochronology and chronostratigraphy. *In:* W.A. Berggren, D.V. Kent and J. Hardenbol (Eds.), *Geochronology, Time Scales and Global Stratigraphic Correlation. A Unified Temporal Framework for an Historical Geology*. Soc. Econ. Paleont. and Min. (SEPM) Spec. Publ., v.54, pp.129-212.
- BHANDARI, A. (1996) Atlas of Paleogene Ostracodes of Rajasthan Basins. *Paleontographica Indica*, no.4, pp.1-157.
- BHANDARI, A. (1999) Non-marine Ostracoda from the subsurface of the Cambay Shale (Eocene) of Gujarat, India and their palaeoecological significance. *Rev. Españ. Micropal.*, v.30(3), pp.1-10.
- BHANDARI, A., GUPTA, P.K. and JUYAL, N.P. (1991) Integrated Exploration Research in Cambay Basin: Some Aspects of Paleogene Stratigraphy. *In:* J. Pandey, and V. Banerjee (Eds.), *Proceedings of Conference on Integrated Exploration Research, Achievements and Perspectives*, KDM Institute of Petrol. Expl., Dehradun, pp.159-167.
- BHANDARI, A. and RAJU, D.S.N. (1991) Tertiary sea level changes and transgressive/ regressive cycles in Cambay, Kutch and Rajasthan basin. A review. *In:* J. Pandey, and V. Banerjee (Eds.), *Proceedings of Conference on Integrated Exploration Research, Achievements and Perspectives*, KDM Institute of Petrol. Expl., Dehradun, pp. 169-177.
- BHANDARI, A. and RAJU, D.S.N. (2000) Paleogene biofacies, paleoecological sea level fluctuations in Tarapur-Cambay Block, India. *Bull. ONGC*, v.37(2), pp.197-213.
- BHANDARI, A., SINGH H. and RANA, R.S. (2005) A note on occurrence of ostracodes from the Vastan Lignite Mine, Gujarat. *Jour. Palaeont. Soc. India*, v.50(1), pp.141-146.
- GUHA, D.K. (1965) Palaeogene Ostracoda of the family Cytherellidae from subsurface of Cambay, Gujarat State, western India. *Jour. Geol. Soc. India*, v.6, pp.143-148.
- GUHA, D.K. (1968) Ostracoda from Middle Eocene of Kutch, Gujarat State, western India. *Bull. ONGC*, v.5(1), pp.83-92.
- GUHA, D.K. (1974) Marine Ostracoda from Tertiary of Kutch and Cambay. *Panjab Univ., Centre Adv. Study Geol.*, Publ. no.10, pp.156-176.
- KHOSLA, S.C. (1994) Ostracoda from the Eocene beds of Tarkeshwar, Surat-Broach region, Gujarat. *Jour. Geol. Soc. India*, v.43, pp.15-21.
- KHOSLA, S.C. and HASKINS, C.W. (1980) *Dentokrithe*, a new genus of Ostracoda. *Micropaleontology*, v.26(2), pp.211-215.
- 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 Jour. Earth Sci.*, v. 15(4), pp.325-346.
- KHOSLA, S.C. and PANT, P.C. (1989) Ostracoda from the Eocene and Oligocene beds of Kachchh Gujarat. Part II – Families Hemicytheridae, Cytheridae, Loxoconchidae, Paracytherideidae, Xestoleberididae and Candonidae. *Indian Jour. Earth Sci.*, v.16(1), pp. 1-10.
- KUMAR, K. (2006) Comments on 'Early Eocene land mammals from Vastan Lignite Mine, District Surat (Gujarat), western India' by Bajpai, S. et al. published in *Journal of the Palaeontological Society of India* 50, 1: 101-113, 2005. – *PalArch's Jour. Vert. Palaeont. Series.1, 2*, pp.7-13.
- LUBIMOVA, P.S., GUHA, D.K. and MOHAN, M. (1960) Ostracoda of Jurassic and Tertiary deposits from Kutch and Rajasthan

- (Jaisalmer), India. Bull. Geol. Min. Metall. Soc. India, no.22, pp.1-61.
- MAYR, G., RANA, R.S., SAHNI, A. and SMITH, T. (2007) Oldest fossil avian remains from the Indian subcontinental plate. Curr. Sci., v. 79(9), pp.1266-1269.
- NOLF, D., RANA, R.S. and SINGH, H. (2006) Fish otoliths from the Ypresian (early Eocene) of Vastan, Gujarat, India, Bull. Inst. Roy. Sci. Nat. Belgique, v.76, pp.105-118.
- RAJU, D.S.N., GUHA, D.K., BEDI, T.S., KUMAR, P. and BHATT, D.K. (1970) Microfauna, biostratigraphy and paleoecology of the Middle Eocene to Oligocene sediments in western India. Publ. Centre Adv. Studies, Geol. Panjab Univ, Chandigarh, v. 7, pp.155-178.
- RANA, R.S., KUMAR, K. and SINGH, H. (2004) Vertebrate fauna from the subsurface Cambay Shale (Lower Eocene) Vastan Lignite Mine, Gujarat, India. Curr. Sci., v. 87(12), pp.1726-1733.
- RANA, R.S., SINGH, H., SAHNI, A., ROSE, K.D. and SARASWATI, P.K. (2005) Early Eocene Chiropterans from a new mammalian assemblage (Vastan Lignite Mine, Gujarat, Western Peninsular Margin): Oldest Known Bats from Asia. Jour. Palaeont. Soc. India, v. 50(1), pp. 93-100.
- ROSE, K.D., SMITH, T., RANA, R.S., SAHNI, A., SINGH, H., MISSIAEN, P. and FOLIE, A. (2006) Early Eocene (Ypresian) continental vertebrate assemblage from India, with description of a new anthracobunid (Mammalia, Tethytheria). Jour. Vert. Paleont., v.26(1), pp.219-225.
- ROZIEVA, T.R. (1962) Ostracoda of Paleogene deposits Turkmenistan. Acad. Sci., Turkmenistan, Geol. Inst., pp.5-139.
- SAHNI, A., RANA, R.S., LOYAL, R.S., SARASWATI, P.K., MATHUR, S.K., TRIPATHI, S.K.M., ROSE, K.D. and GARG, R. (2004) Western margin Palaeocene-Lower Eocene lignites: biostratigraphic and paleoecological constraints. 2nd APG Conference cum Exhibition, Khajuraho, pp. 1-18.
- SAHNI, A., SARASWATI, P.K., RANA, R.S., KUMAR, K., SINGH, H., ALIMOHAMMADIAN, H., SAHNI, N., ROSE, K.D., SINGH, L. and SMITH, T. (2006) Temporal Constraints and Depositional Palaeoenvironments of the Vastan Lignite Sequence, Gujarat: Analogy for the Cambay Shale Hydrocarbon Source Rock. Indian Jour. Petrol. Geol., v.15(1), pp.1-20.
- SAMANT, B. and BAJPAI, S. (2001) Fish otoliths from the subsurface Cambay Shale (Lower Eocene), Surat Lignite Field, Gujarat (India). Curr. Sci., v.81(7), pp.758-759.
- SAMANT, B. and PHADTARE, N.R. (1997) Stratigraphic palynoflora of the Early Eocene Rajpardi lignite, Gujarat and the lower age limit of the Tarkeshwar Formation of South Cambay Basin, India. Palaeontographica, v.245, pp.1-108.
- SAMANT, B. and TAPASWI, P.M. (2000) Fungal remains from Surat Lignite deposits (Early Eocene) of Gujarat, India. Gondwana Geol. Magz., v.15(2), pp.25-30.
- SAMANT, B. and TAPASWI, P.M. (2001) Palynology of the Early Eocene Surat Lignite deposits of Gujarat, India. Jour. Palaeont. Soc. India, v.46, pp.121-132.
- SERRA-KIEL, J., HOTTINGER, L., CAUS, E., BROBNE, K., FERRANDEZ, C., JAUHRI, A.K., LESS, G., PAVLOVEC, R., PIGNATTI, J., SAMSO, J.M., SCHAUB, H., SIREL, E., STRUOGO, A., TAMBAREAU, Y., TOSQUELLA, J. and ZAKREVSAYA, E. (1998) Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. Bull. Soc. Geol. France, v.2, pp.281-299.
- SIDDIQUI, Q.A. (1971) Early Tertiary Ostracoda of the family Trachyleberididae from west Pakistan. Bull. British Museum (Nat. Hist), suppl. 9, pp.1-98.
- SIDDIQUI, Q.A. and AL-FURAIH, A.A.F. (1981) A new Trachyleberid ostracod genus from the Early Tertiary of Western Asia. Palaeont., v.24(4), pp.877-890.
- SIDDIQUI, Q.A. (1981) Some species of the genus *Schizocythere* from the early Tertiary shelf sea of Pakistan. In: Neale and Brasier (Eds.) Microfossils from Recent and Fossil Shelf Seas, Ellis Horwood Ltd., Chichester, England, pp.231-239.
- SINGH, P. and PORWAL, D.K. (1999) Paleogene ostracods from the Cambay-Tarapur Block, Cambay Basin. Geosci. Jour., v.20(2), pp. 93-141.
- TEWARI, B.S. and TANDON, K.K. (1960) Kutch microfauna-Lower Tertiary Ostracoda. Proc. Nat. Inst. Sci. India, ser.B, v.26(4), pp.148-167.

(Received: 10 November 2011; Revised form accepted: 10 April 2012)