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Research Article

ISSN : 2455-1953

JGSR

Journal of Geosciences Research

Vol. 8, No.2, July, 2023, pp. 170-178

Ostracodes Fauna from Core Sediments of Surinsar Lake of Jammu: Their Palaeoecological and Palaeoclimatic Implications

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Abstract

Surinsar Lake is one of the deepest fresh water lake situated in the Lower Siwalik Subgroup of Jammu, Jammu and Kashmir, India. In the present study, nine species of ostracodes have been recovered from the core sediments of Surinsar Lake, Udhampur district, Jammu and Kashmir, India. These species are identified as *Candona candida, C. lactea, C. neglecta, Stenocypris* sp., *Cypris subglobosa, Cypridopsis* sp., *Hemicypris pyxidata, Ilyocypris gibba, Potamocypris* sp. based on their morphological characters. Out of nine species, four species *Candona lactea, Candona neglecta, Ilyocypris gibba* and *Stenocypris* sp., has been already reported from Surinsar Lake and five ostracodes species *Hemicypris pyxidata, Potamocypris* sp., *Cypris subglobosa, Candona candida, Cypridopsis* sp. are recovered in addition to already reported species. A brief account on the palaeoecologic and palaeoclimatic implications of fauna recovered is discussed in the present study.

Keywords: Ostracodes, Core Sediments, Fresh Water Lake, Surinsar, Lower Siwalik Subgroup, Jammu, India

Introduction

The word ostracodes is derived from the Greek word Ostrakon ('a shell'). Ostracodes are one of the most diverse groups of living crustaceans and are represented by both extinct and extant species. More than 33000 extant and extinct species of ostracodes are belonging to 4500 genera and subgenera (Horne *et al.*, 2011). They belong to the phylum Arthropoda, Class Crustacea (Pennant, 1777) and Subclass Ostracoda (Latreille, 1806). The Myodocopa and Podocopa are the two subcategories of the ostracoda (Horne *et al.,* 2002) and are represented by marine and fresh water respectively. Ostracodes are tiny bivalve shell crustaceans that are frequently referred to as "seed shrimps" and are extremely varied in shape and ornamentation which vary greatly across their families (Martens and Horne, 2009). The form, composition, ornamentation, and carapace: valve ratio of ostracodes shells reflects the aquatic chemistry, hydrology, and ecology of their surroundings (Smith *et al.*, 2015). The changes in ostracodes shell pattern as a result of changing environmental conditions (Sunkad, 2004; Menzer *et al.*, 2005; Sheeba and Ramanujan, 2005).

Ostracodes have an excellent fossil record, primarily because they have a calcified bivalved shell with low magnesium calcite, which has a high fossilization potential and can be easily preserved in lake sediments (Kesling, 1951). The history of ostracodes starts with the first fossil of ostracodes found in rocks from the Ordovician period (485 to 443Ma ; Whatley *et al.*, 1993). The fossil record of non-marine ostracodes begins in the Carboniferous (Maddocks, 1982). One of the most significant proxies, fossil ostracodes is widely utilized to reconstruct the palaeoenvironment, palaeoclimate, and palaeoecology (Hussain and Cassey, 2016; Carbonel *et al.*, 1988). Their efficient preservation, relative abundance in the sediments, and sensitivity to the environment suggest rapid dispersion, making them helpful in systematic and ecological research. Lacustrine deposits are nearly sensitive recorder of climate change because they are one of the most major fossiliferous and annually laminated terrestrial archives (O'Sullivan, 1983). Surinsar is a well-known prominent freshwater lake situated north east of Jammu city at a distance of 40km by road. The Surinsar Lake belongs to Udhampur district of Jammu and Kashmir have longitude (75°02′30″E) and latitude (32°46′30″N) which falls in the toposheet No. 43P/2 and elevation of 637 meters above mean sea level (Fig. 1).

In the present study, we have recovered nine species of ostracodes from the core sediments of Surinsar Lake for their taxonomic, palaeoecologic, paleoenvironmental and palaeo-climatic studies.

Geological Setting

The Siwalik Group is a thick succession of freshwater molasses deposits with coarsening upward strata having a thickness of nearly 6000 meters which extend aerially about 2500 km from east to west along the south of Himalaya. The sedimentation began

(Received : 05 May 2023 ; Revised Form Accepted : 06 June 2023)

https://doi.org/10.56153/g19088-023-0158-38

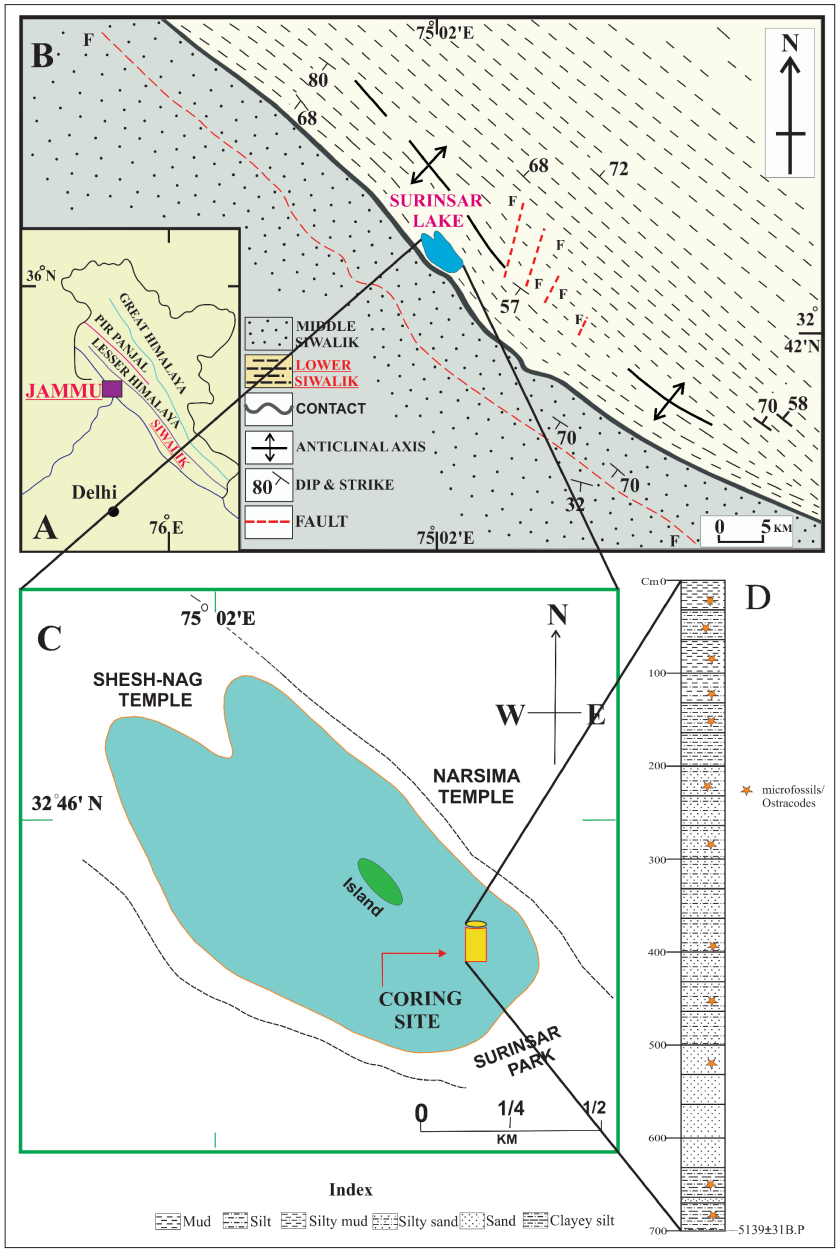

Fig. 1. A. Map of north India (modified after Das et al., 2006); B. Geological map of study area; C. Surinsar Lake and coring site D. Lithocolumn of Surinsar lake core sediments

in the Middle Miocene (18.3 Ma) and peaked in the Late Pleistocene (0.22 Ma) (Johnson *et al.*, 1985; Ranga Rao *et al.*, 1988) and represents composite aggradations due to several fluvial systems (Tandon, 1991). Tectonically, the Siwalik Group is separated from lesser Himalaya by Main boundary thrust (MBT) to the north and from Indo-Gangetic Plains by Himalayan Frontal Fault (HFF) to the south. Stratigraphically, the Siwalik Group is divided into three subgroups (Lower Siwalik Subgroup, Middle Siwalik Subgroup, Upper Siwalik Subgroup) and seven formations (Kamlial, Chinji, Nagri, Dhokpathan, Tatrot, Pinjor, Boulder Conglomerate) by Pilgrim (1934) which is used till date. The Siwalik exhibits coarsening upward sequence.

In Jammu region, all the formations of the Siwalik Group are well exposed. The local classification of Siwalik Group of Jammu region was given by a few workers (Ranga Rao *et al.*, 1988; Gupta and Verma, 1988; Gupta, 2000). A comparative lithostratigraphic classification of Siwalik of Jammu region is given in Table 1. The ostracodes recovered from core sediments of Surinsar Lake belong to the Lower Siwalik Subgroup (Mansar Formation) of Jammu Siwalik.

Material and Methods

The core samples was taken out from seven meters deep core of the Surinsar Lake in the year 1998 using a piston coring system, which is typically utilized in lacustrine settings because it can recover samples while maintaining the integrity of fragile sedimentary features, such as varves (Moore *et. al.*, 2001). All the core samples were subjected to the standard technique of maceration for the separation of ostracodes that started with the sub-slicing of the core samples at every 8cm interval, breakdown into fragments <1cm in diameter with the help of a rock splitter. Then

Table 1: Comparative local lithostratigraphic classification of Siwalik Group of Jammu

Group	Subgroups	Pilgrim, 1934 (Pakistan)	Ranga Rao *et al.,* 1988 (J&K)	Eliyas *et al.,* 2017 (J&K)	Gupta and Verma, 1988 (J&K)	Lithology
Siwalik	Upper Siwalik	Boulder Conglomerate	Tawi Conglomerate	Dughor Formation	Dughor Formation	Pebble, cobble to boulder sized clasts of different shape, size and composition within thin to thick lenses of sand. Clasts/matrix supported conglomerates
		Pinjor Formation	Nagrota Formation	Uttarbaini Formation	Marikhui Formation	Alternate bands of coarse-grained sandstone and conglomerate with minor mudstone. Bentonititized tuff band is present
		Tatrot Formation	Parmandal sandstone		Labli Formation	Fine to medium grained, light-colored sandstone with thin to thick bands of pebble, cobble conglomerate mudstone, soft and friable sandstone
	Middle Siwalik	Dhokpathan Formation		Mohargarh Formation	Mohargarh Formation	Medium to coarse grained, ashgrey colored, multostoryed sandstone with salt pepper texture and thin argillaceous bands.
		Nagri Formation		Dewal Formation	Dewal Formation	Medium to coarse grained, grey colored sandstone, comparatively less compact alternating mudstone/sandstone
	Lower Siwalik	Chinji Formation		Mansar Formation	Mansar Formation	Fine to medium, purplish-grey, hard, compact sandstone alternationg with siltstone /mudstone and minor intra-formational conglomerate.
		Kamlial Formation	–	–	–	–

soft fragmented core samples were soaked in water for about 8 to 12 hrs, which resulted in the disaggregation of the sediments. The disaggregated material was then macerated in running water using different set of sieves (40ASTM, 60ASTM, 80ASTM, 100ASTM, 120ASTM). The residue so obtained dried in the sunlight. The picking and identification of ostracodes carried out using binocular microscope. The photomicrographs of ostracodes were taken using camera attached with microscope and deposited in the micropalaeontology Laboratory under catalogue numbers OSLCS/01-09 (ostracodes from Surinsar lake core sediments).

Systematic Palaeontology

Subclass OSTRACODA Latreille, 1806
Order PODOCOPIDA Muller, 1894
Suborder PODOCOPINA Sars, 1866
Family CYPRIDIDAE Baird, 1845
Subfamily HETEROCYPRIDINAE Kaufmann, 1900
Genus *Stenocypris* Sars, 1889
Stenocypris sp.
(Fig. 2, 1a-c)

Referred Material: OSLCS / 01, 11 carapace

Locality**:** 2.5 to 4 meters core depth**,** Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup, Jammu

Diagnostic characters: Elongated; straight dorsal margin, curved ventral margin, rounded posterior and anterior margins, large left valve as compare to right valve, greatest height at anterior than posterior, smooth valve surface.

Dimensions**:** Length = 2.0mm, Width = 0.45mm, Height = 0.80mm

Remarks**:** The present specimen resembles *Stenocypris major* but distinct by dimensions and equal valve, the specimens also resemble *Stenocypris distincta* Victor and Fernando, 1979 in shape, but differ in length and width ratio.

Inhabitant**:** Rivers, lakes, springs, rice fields, benthic (Smith and Kamiya, 2006; Smith, 2011, Tanka *et al.*, 2015)

Subfamily CYPRINOTINAE Bronstein, 1947
Genus *Hemicypris* Sars, 1903
Hemicypris pyxidata Moniez, 1891
(Fig. 2, 2a-c)

Cyprinotus pyxidata Moniez 1892, p.134, Pl.10, Figs.23-27
Hemicypris pyxidata (Moniez), Sars 1903, p.25-26, Pl.3, Fig. 1, 1a-t.

Referred Material**:** OSLCS /02, 13 carapace

Locality**:** 2 to 5 meters depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu.

Diagnostic Characters**:** Large carapace**,** dorsally biconvex, laterally ovate, at middle of shell greatest width and height, left valve smaller than right valve, the right valve overlap left valve along ventral posterior and antero-dorsal margins, pitted valve surface, rounded anterior and posterior margins, valve surface punctuate, arched at the middle of valve.

Dimensions**:** Length = 0.91mm, Height = 0.56mm, Width = 0.50mm

Remarks**:** The specimens understudy from core sediments of Surinsar Lake assigned to *Hemicypris pyxidata* (Moniez, 1891). The first reports on *H. pyxidata* from Pinjor Formation of Upper Siwalik Subgroup near Chandigarh India by Bhatia and Khosla (1967). Following this, Mathur (1972) reported this species from Tatrot and Pinjor Formations. Further, Bhatia (1995) reported this species from Tatrot formation near Kanthra. Furthermore, Bhatia *et al.* (2001) and Bhandari and Kundal (2008) reported this species from the Barakhetar and Uttarbaini sections of Nagrota Formation, Upper Siwalik Subgroup of Jammu region. Khosla *et al.* (2017) recorded *Hemicypris pyxidata* from the Churia group of Nepal. Besides this, extant specimens of this species reported from Chilika lake (Jain, 1977), Ponds of Kutch (Jain, 1979), Punjab (Battish, 1981), rice fields of Srilanka (Neale, 1977), and Pools of Madurai (Victor and Fernando, 1979).

Inhabitant**:** Shallow water environment near edges of lakes or ponds

Genus *Potamocypris* Brady, 1870
Potamocypris sp. Bhatia, 1968
(Fig. 2, 3a-c)

***Referred Material*:** OSLCS / 03, 16 carapace

***Locality*:** 2 to 7meters core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Medium carapace, sub triangular, compressed, greatest height at the middle, width of specimens is half of the carapace, right valve overlapping left valve, symmetrically arched dorsal margin, concave ventral margin, rounded anterior and posterior margins, smooth valve surfaces

***Dimensions*:** Length = 0.54mm; Height = 0.32; Width = 0.20mm

***Remarks*:** This species closely resembles with *Potamocypris* sp. earlier this species reported from the Karewas of Kashmir. *Potamocypris* sp. also described by Jain (1977) collected from the Chilka Lake area.

***Inhabitant*:** Fresh water lacustrine environment (cool, slightly alkaline, freshwater with abundant vegetation (Bhatia and Singh, 1971a,b; Singh, 1973). In Kashmir valley, this species lives in association with *Ilyocypris bradyi* Sars, *Darwinula stevensoni* Brady and Robertson, *Cyclocypris laevis* Mueller, *Candona lactea* Baird and *Cypridopsis vidua* Mueller.

Subfamily CYPRIDINAE Baird, 1845
Genus *Cypris* Muller, 1776
Cypris subglobosa Sowerby, 1840
(Fig. 2, 4a-c)

Cypris subglobosa Sowerby 1840, Pl.47, Fig.3
Cypris subglobosa (Sowerby) Baird 1859, p.232, Pl.63, Fig.2
Cypris subglobosa (Sowerby) Bhatia 1968, Pl.1, figs. 2a-g: Pl.5, fig.10.
Cypris subglobosa (Sowerby) Bhatia and Singh 1977, Pl.1, figs. 4-6
Cypris subglobosa (Sowerby) Jain 1977, Pl.1, fig. 1, a-c, p.356-359
Cypris subglobosa (Sowerby) Malik and Bhat 1995, p.81-82.

***Referred Material*:** OSLCS / 04, 20 carapace

***Locality*:** 1.32 to 7meters core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

Diagnostic Characters: Carapace shape laterally sub globular; left valve smaller than right valve; convex dorsally, straight ventrally, anterior rounded, compressed posterior end, inflated valve, maximum width posterior to middle, valve surface with minute small pits all along surface.

Dimensions: Length=1.40mm, Height=.90mm, Width =115mm

***Remarks*:** *Cypris subglobosa* is a Holarctic as well as Oriental provinces species. This species originally described by Sowerby, 1840 and reported from near Munoor, north of Kooran River, India. This species was also reported from the Upper Karewas of Kashmir (Bhatia, 1968).

***Inhabitant*:** Abundantly in freshwater lakes, ponds, rice fields (Tressler, 1959; Petkovski, 1964)

Family Ilyocpridida Kufmann, 1990
Subfamily Ilyocpridinae
Genus *Ilyocypris* Brady and Norman, 1989
Ilyocypris gibba Ramdohar, 1808
(Fig. 2, 5)

Ilyocypris gibba (Ramdohar), Staplin, 1963, pl. 160, figs. 36-38, P. 758-797.
Ilyocypris gibba (Ramdohar), Bhatia and Singh, 1977, pl.2, figs. 14-15.
Ilyocypris gibba (Ramdohar), Jain, 1977. P. 356-389, pl. 11-49-b.

***Referred Material*:** OSLCS / 05, 04 carapace

***Locality*:** 2.6 to 3.5 meter core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Carapace is sub-reniform in lateral outline; well rounded anterior and posterior margins; moderately wide inner lamella; Dorsal and central muscle scars are poorly visible due to some impurity on the carapace, small depression on valves marked two mandibular scars.

***Dimensions*:** Length 0.66mm, Height= 0.36mm, Width= 0.21mm

***Remarks*:** The present specimens are identical with *Ilycypris gibba* (Ramdohar, 1808) This species is living in permanent and temporary running water condition with sufficient currents (Stapling, 1963a). *Ilycypris gibba* lives in association with *Ilycypris bradyi*, *Candonopsis kingsleii* and *Darwinulina stevensoni* in fresh waters lakes and ponds margins. In India, this species reported from lakes of Kashmir and Punjab (Singh, 1977; Bhatia and Singh, 1977). This species also reported from Dharwad (Mannikeri and Vaidya, 1994) and Perumal lake, Tamilnadu (Ravi *et al.*, 2007).

Inhabitant: Ilycypris gibba found in permanent and temporary running water and marginal parts of the lakes/ponds.

Subfamily Candoninae Daday, 1900
Genus *Candona* Baird, 1845
Candona neglecta Sars 1887
(Fig. 2, 6a-c)

Candona neglecta Sars 1887, p.279-288, Pl. 15, figs. 6-7, Pl.19, figs. 1-21.
Candona neglecta (Sars) Bhatia, 1968, p.465-483, Pl. 1-5, Pl. 3, figs. 1a-f, Pl.5, figs. 5-7..
Candona neglecta (Sars) Singh, 1977, p.366-381, Pl. IX- 16-20, Pl. X- 1-2.

***Referred Material*:** OSLCS / 06, 05 carapace

***Locality*:** 2 to 7 meter core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Shape more or less triangle, narrow and well rounded anterior margin; transversely posterior margin, tapering anteriorly and complex dorsal margin, beak shaped postero-ventral area and straight, slightly concave ventral margin, smooth valve surface, wide anterior vestibule, muscle scar pattern (a subcentral rosette of five scars and one dorsal elongate scar) and hinge structure (merodont) are the characteristic features of the genus.

***Dimensions*:** Length = 1.16mm; Height = 0.55mm; Width = 0.27mm

***Remarks*:** This species was reported from the Karewas of Kashmir by Bhatia (1968).

Inhabitant: Commonly distributed in freshwater such as lakes, ponds, standing water bodies and different regions of north America, north Africa, Asia, Europe, middle east, turkey, Indian subcontinent (Holmes, 1937; McKenzie, 1964; Bhatia and Singh, 1970).

Subfamily Candoninae Dady, 1900
Genus *Candona* Baird, 1845
Candona lactea Baird, 1850
(Fig. 2, 7a-c)

Candona lactea (Baird) Bhatia, 1968, Pl.2, fig. 5, A. C., Pl. 5, figs. 1-2 p.472.
Candona lactea (Baird) Bhatia and Singh 1971, Pl.1, fig. 5, p.218.
Candona lactea (Baird) Singh 1977, p. 366-381, Pl. IX-8-10.
Candona lactea (Baird) Malik and Singh 1994, p. 5-11, Pl. 2, fig. 6, I-IX.

***Referred Material*:** OSLCS / 07, 06 carapace

***Locality*:** 2 to 7 meter core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Moderately inflated, small to medium sized shell, elongate-ovate bean shaped, smooth and very thin, normal pore canals is the characteristic of shell and prominent, inter-lamella moderate, ventral margin complex, inner lamella towards anterior and is broader than posterior, outline of the shell is sub-reniform and duplicature is narrow.

***Dimensions*:** Length 0.53 to 0.66mm, Height=0.30 to 0.36mm, Width=0.17 to 0.21mm

Remarks: The specimen's understudies have similar characters like shape, size inner lamella with *Candona lactea* Baired. This species was reported by Bhatia and Khosla (1967) from the Upper Siwalik Subgroup near Chandigarh, Upper Karewas of Kshmir by Bhatia (1968) and fresh water lakes of Kashmir Valley (Bhatia and Singh, 1971), Tatrot Formation (Mathur, 1972), Sub-Recent Marlstone, Haryana (Bhatia and Khosla, 1977), Mansar Lake, Jammu and Kashmir (Malik and Singh, 1994), mudstone horizon underlying volcanic ash beds, Nagrota Formation, Upper Siwalik Subgroup of Jammu (Bhatia et al., 2001; Bhandari and Kundal, 2008; Kundal, 2022).

***Inhabitant*:** Cold- hardy species (Staplin, 1963a), *Candona lactea* Baird is a fresh water species; however, it is also reported from the polyhaline waters (Mckenzie, 1964).

Subfamily Candoninae Daday, 1900
Genus *Candona* Baird, 1845
Candona candida Mueller, 1776
(Fig. 2, 8)

***Referred Material*:** OSLCS/08, 03 carapace

***Locality*:** 2 to 7 meter core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Elongated carapace, reticulate in posterior half, right valve slightly smaller than left valve, broad posterior margin and rounded, anterior margin narrow and compressed, rounded posterio-ventral, anterior end compressed, maximum width near posterior to middle, convex ventral margin, dorsal margin slightly concave.

***Dimensions*:** Length 1.3mm, Height=0.51, Width=0.5mm

***Remarks*:** The specimen under study resembles with *Candona candida* Mueller, 1776 in morphological characters and hence referred as *Candona candida*. It is distinct from *Candona compressa* (Koch, 1838*), Candona fabaeformis* (Fischer, 1854), *Candona laceta* (Baird, 1850), *Candona neglecta* (Sars, 1887) by their shape and dimensions. In India, this species was earlier reported by Bhatia and Singh (1970) from the fresh water lakes, ponds, cool and running water bodies with rich vegetations of Kashmir valley.

***Inhabitant*:** Cosmopolitan species, tolerate wide temperature variation ranging from arctic to subtropical (Winkler, 1962), depth variation from <1meters to 29.5meters (Akatova and Jarvekulg, 1965).

Subfamily Cypridopsinae Kaufmann, 1900
Genus *Cypridopsis* Brady, 1867
Cypridopsis sp.
(Fig. 2, 9)

Referred Material: OSLCS / 09, 07 carapace

***Locality*:** 2 to 7 meter core depth, Surinsar fresh water lake, 40 km northeast of Jammu city, Lower Siwalik Subgroup Jammu

***Diagnostic Characters*:** Sub triangular carapace, greatest height at the middle, left valve smaller than right valve, arched dorsal margin, the valve is truncated on either side from the middle, straight ventral margin, obliquely rounded anterior margin, posterior margin subrounded and narrow, narrowly compressed anterior end, surrounded posterior end, smooth valve surface.

***Dimensions*:** Length 0.55mm, Height=0.31 to 0.36mm, Width=0.17 to 0.23mm

***Remarks*:** This species has been reported from the mudstone horizon underlying ash beds of Jammu (Bhandari and Kundal, 2008) and is resemble with the *Cypridopsis vidua* Muller, 1776 having concave ventral margin.

***Inhabitant*:** Fresh water lakes and ponds

Paleoclimatic and Palaeoecological Implications

Ostracodes live in many aquatic habitats, including marine, brackish, freshwater, and even terrestrial habitats, as well as intestinal parasites (Carbonel *et al.*, 1988), and as a result, they have the most extensive fossil record of any living group of arthropods since Palaeozoic Era (Moore, 1961). Freshwater ostracodes are regarded as one of the best biological indicators of paleoecology, paleoclimatic, and paleoenvironmental changes in contemporary studies of non-marine waters, from stable, deep lakes to temporary ponds, except for acidic water bodies where the calcitic carapace is affected by dissolution (Holmes 1992, 1996; Griffiths and Holmes, 2000; Holmes and Chivas, 2002; Horne *et al.*, 2012). Freshwater ostracodes are sensitive to the surrounding environmental conditions of their habitat and an amazing archive of the geological past and serve as stratigraphic markers (Moore, 1961, Howe, 1969). Ostracodes have unique ecological effects, especially on depth, substrate, salinity, temperature ranges, or PH. Ostracodes

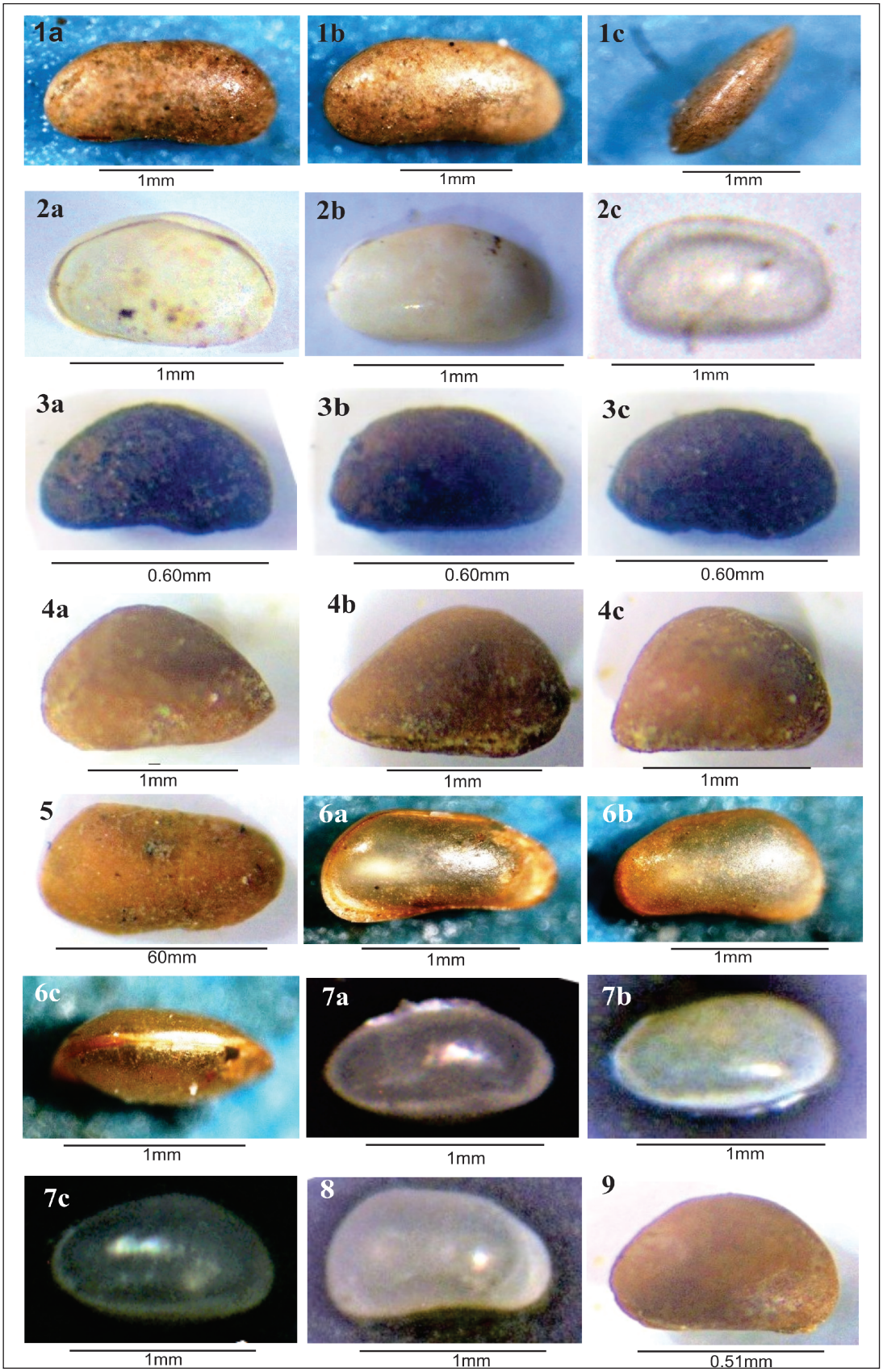

Fig. 2. *Stenocypris* sp. (OSLCS / 01): Carapace 1a. right lateral view, 1b. left lateral view, 1c. dorsal view; *Hemicypris pyxidata* (OSLCS / 02): Carapace 2a. right lateral view, 2b. left lateral view, 2c. right lateral view; *Potamocypris* sp. (OSLCS / 03): Carapace 3a. right lateral view, 3b. left lateral view, 3c. left lateral view; *Cypris subglobosa* (OSLCS / 04): Carapace 4a. left lateral view, 4b. right lateral view, 4c. right lateral view; *Ilyocypris gibba* (OSLCS / 05): Carapace 5. left lateral view; *Candona neglecta* (OSLCS / 06): Carapace 6a. left lateral view, 6b. right lateral view, 6c. left lateral view; *Candona lactea* (OSLCS / 07): Carapace 7a. left lateral view, 7b. right lateral view, 7c. left lateral view; *Candona candida* (OSLCS / 08): Carapace 8. female right valve; *Cypridopsis* sp. (OSLCS / 09): Carapace 9. Male, right lateral view

distribution is influenced by a wide range of physical and chemical factors, including water depth, temperature, turbidity, silt in the substratum, salinity, alkalinity, dissolved oxygen concentration, and more. Ostracodes can reveal information on how regional climate affects changes in precipitation, runoff, or groundwater in the case of shallow lakes and wetlands. Deep, geologically stable lakes, on the other hand, can record long-term paleoclimatic changes (Frogley *et al.*, 2002). Ostracodes are valuable paleoenvironmental markers because the shape and structure of their carapaces frequently reflect the ecology of the animals. A detailed report on the depositional environment of Jurassic beds of Bela Island using ostracodes faunal zones was presented by Kumari (2022). The preservation of a wide range of instars may suggest a low-energy environment, whereas the predominance of adult valves may indicate a high-energy environment (Brouwers, 1988).

In the present study nine species of ostracodes such as *Candona candida, C. lactea, C. neglecta, Stenocypris* sp., *Cypris subglobosa, Cypridopsis* sp. *Hemicypris pyxidata, Ilyocypris gibba* and *Potamocypris* sp. have been discussed to interpret paleoclimate and paleoecology.

Stenocypris sp. is habitat of warm water with shallow depth found in lakes and ponds (Singh, 1973). The species is also reported infrequently from the rice fields of Kashmir valley in association with *Ilyocypris bradyi* (Singh, 1973). *Hemicypris pyxidata* prefers to live in fresh water environment (Morkhoven, 1962). Various workers (Jain, 1977, 1979; Neale, 1977; Battish, 1981; Victor and Fernando, 1979; Bhatia *et al.*, 2001) recorded extant species *H. pyxidata* from different parts of India (dried mud of Chilka lake, fresh water ponds of Kutch, fresh water pond in Punjab, rice field of Srilanka, rock pools of Madurai). This species tolerates fresh to brackish water permanent to semi-permanent water bodies (Bhatia *et al.*, 2001). *Hemicypris pyxidata* was discovered in the freshwater ponds and lakes of the Dharwar of Karanatka preferring depth of 1 to 3 meters and average temperature of 25°C average (Mannnikeri and Vaidya, 1990). This species also reported in association with charophytes from fresh water Palaeolake section at Barakhetar in the Nagrota Formation of Upper Siwalik Subgroup of Jammu (Bhandari and Kundal, 2008; Kundal, 2022). *Potamocypris* sp. found commonly in freshwater both permanent water bodies as well as in temporary ponds. This species abundantly found in rich vegetation with shallow marginal parts of the lakes and ponds (Hoff, 1942; Staplin, 1963b). It is also reported from the rice fields (Moroni, 1967). In Kashmir valley, this species abundantly occurs in stagnant ponds and streams in association with *Eucypris* sp., *Potamocypris staplni*, *Cypris pubera* (Singh, 1973). *Cypris subglobosa* is a habitat of fresh water lakes, ponds, pools and rice fields (Klie, 1933; Tressler, 1959; Petkovski, 1964). This species mostly occurs in association with *Canodona lactea* and *C. neglecta*. *Ilyocypris gibba* is a habitat of varying temperature ranging from 5°C to 25°C, but it can also tolerate the extreme temperatures ranging between -10°C to 43°C (Margalef, 1947). This species commonly found in permanent as well as temporary running water bodies with high energy current action (Hoff, 1942; Staplin, 1963). *I. gibba* species also inhabitat of rain water pools, ditches, muddy bottoms, permanent ponds, rice fields and lakes (Holmes, 1937; Straub, 1952; Petkovski, 1958; Coope *et al.*, 1961; Fox, 1967; Moroni, 1967). *Ilyocypris gibba* is occurs in association with *Ilyocypris bradyi* and *Heterocypris icongruens. Candona lactea* is a cold –hardy species fresh water species (Staplin, 1963a); however this species also occurs in polyhaline waters (McKenzie, 1964). In Kashmir valley, the species living in clear, fresh and alkaline water lakes/ bodies. *Candona candida* is a cosmopolitan species tolerates temperature ranging from arctic to subtropical (Winkler, 1962) with a depth ranging from one meter to thirty meters (Akatova and Jarvekulg, 1965). This species is capable of living in varied habitats such as fresh, clear, shallow, permanent water bodies with moderate vegetation and commonly found in marshes, bogs, swamps, ditches, ponds, pools, springs, streams, and lakes (Brady, 1910; Holmes, 1937; Coope *et al.*, 1961; Winkler, 1962; Staplin, 1963). In India, this species reported from the ponds and lakes of Kashmir valley (Singh 1973; Bhatia and Singh, 1970). *Candona neglecta* is inhabitant of marginal part of lakes, muddy ponds, spring waters, pools and ditches (Holmes, 1937; Fox, 1965). Though it is a fresh water species, it also found slightly in brakish water (Klie, 1933). *Cypridopsis* sp. is a very active, powerful swimmer and cosmopolitan species and has wide variety of habitat and commonly occurring in permanent still water bodies with rich aquatic vegetation such as ditches, lakes and pond. It is occurring at the depth of about 70 meters with a temperature of about 20°C. This species prefers muddy bottom with rich vegetation (Brady and Norman, 1889), although this species also found in slow running water bodies with rich vegetation like streams, rice fields and canals (Meisch, 2000; Roca and Baltana, 1993).

Conclusions

It is for the first time that nine species of ostracodes fauna including *Candona candida, C. lactea, C. neglecta, Stenocypris* sp., *Cypris subglobosa, Cypridopsis* sp. *Hemicypris pyxidata, Ilyocypris gibba* and *Potamocypris* sp. are recovered from the seven meter deep core sediments of Surinsar Lake of Jammu. The recovered ostracodes fauna are inhabitant of fresh water lakes and suggests a moderate to warm climatic conditions prevailed during the deposition of core sediments.

Authors' Contributions

SNK: Writing - Original Draft, Reviewing and Editing, Formal Analysis. **MI:** Data Curation, Software, Validation. **MAM:** Investigation, Conceptualization, Supervision.

Conflict of Interest

The authors declare no conflicts of interest.

Acknowledgements

The authors are thankful to the HOD Geology, University of Jammu for laboratory facilities. One of us Mr. Mohd Imtiaz is thankful to CSIR, New Delhi for financial support under Senior Research Fellowship. The authors are also thankful to BSIP, Lucknow for Core Samples under Project No. DST/ESS/CA/A-4-22/96.

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