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DIVERSITY OF FOSSIL ECHINOIDS (ECHINODERMATA) IN THE INDIAN SUBCONTINENT DURING THE LATE CRETACEOUS–PALAEOGENE

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ABSTRACT

The diversity of fossil echinoids in the Indian subcontinent with respect to the Late Cretaceous–Palaeogene palaeobiogeographic changes is discussed. The echinoid diversity in the Indian subcontinent shows an Eocene peak bounded by much lower diversities during the Cretaceous and the late Palaeogene (Oligocene) periods. The diversity remained very low through out most of the Oligocene epoch, indicating prolonged environmental deterioration related to climate cooling. Later, in the younger periods, it again increases considerably. Though the earliest report of echinoids in India and Pakistan is from the Permian sediments of Karakoram and Salt Range, they appear in appreciable numbers (from north to south) in the sediments of Jurassic succession of Himachal Pradesh, Rajasthan and Kachchh. Their prolific and diversified developments, however, is noticed in the Cretaceous and lower Palaeogene sediments in many parts of the Indian subcontinent. The majorities of the fossil elements constitute the Indo-Madagascar endemic center and express affinity with the fauna of European (western) Tethys. The increased faunal diversity from the Late Cretaceous onward points to the availability of the large number of ecological niches created possibly due to the increasing influence of tropical conditions. The closeness of the Indian echinoid fauna with that of the European (western) Tethys seems to be the result of palaeobiogeographic changes brought about by the northward drift of India during the Meso-Cenozoic times.

Keywords: Echinoids, Late Cretaceous–Palaeogene, Indian subcontinent, Taxonomic significance, Stratigraphic significance and Distribution

INTRODUCTION

Echinoid diversity is more closely associated with the abiotic control of global temperature than with the sea level (McKinney and Oyen, 1989). Though, the global temperature is seen to be an important controlling factor for echinoid diversity, McKinney *et al.* (1992) suggested that the biotic interactions and their properties must also be considered when assessing echinoid diversity.

Globally, the echinoids provide much information about biotic and climatic evolution in the early Cenozoic. They underwent a profound evolutionary radiation, from less than 200 known species in the Paleocene to over 1,000 species in the Eocene (McKinney *et al.*, 1992). The echinoids were then greatly decimated by the events towards the Late Eocene and the Oligocene epochs. Depending upon the biotic interactions, many orders within the Echinoidea show distinct trends of evolution, notably the rise of clypeasteroids at the expense of the cassiduloids. In addition, these provide excellent clues to the biotic crises that occurred at the Late Eocene. Today, the marsupiate (larvae brooding) echinoids are common in the cold environments and their appearance in Australia in the Late Eocene clearly marks the beginning of the cool climate. Since, the echinoids produce calcite tests that do not recrystallize, in contrast to many other marine groups that secrete aragonite, they are one of the best among all fossil groups for studying evolutionary patterns.

The echinoid diversity in the Indian subcontinent shows an Eocene peak bounded by much lower diversities during the Cretaceous and the late Palaeogene (Oligocene) periods. The Eocene peak occurred early in the Middle Eocene followed by a small to moderate diversity loss at the Lutetian / Bartonian boundary. A second, much larger loss occurred at the Eocene / Oligocene boundary, with major reductions of about 50% in nearly all echinoid orders. The diversity remained very low through out most of the Oligocene epoch, indicating prolonged environmental deterioration related to climate cooling evidenced by (a) the strong correlation between the diversity loss and the global temperature and (b) the onset of the cool climate in the late Eocene.

The earliest work on the echinoid fauna of India and Pakistan is by Grant (1837). This was followed by the contributions from Sowerby (1840), d'Archiac and Haime (1853), de Konick (1862), Blanford, H. F. (1862, 1863), Duncan (1865, 1887a, 1887b), Wynne (1872), Blanford, W. T. (1872, 1876, 1879), Kossamt (1873), Stoliczka (1873a, 1873b), Duncan and Sladen (1882 – 1886, 1883), Waagen (1885), Gregory (1893), Noetling (1897), Vredenburg (1906a, 1906b, 1921), Reed (1910, 1912), Fourtau (1918), Spengler (1923), Davies (1926, 1943), Das Gupta, H. C. (1929), Currie (1930), Chiplonkar (1937, 1939), Sahni and Bhatnagar (1958), Sahni and Sastry (1958). Later, Sengupta (1964), Khanna (1967), Chiplonkar and Badve (1972), Das Gupta (1975), Bhattacharya and Bhattacharya (1978), Srivastava (1878, 1982, 1988, 2003a, 2003b, 2004), Bhatia (1980), Tandon and Srivastava (1980), Aziz and Badve (1990, 2001), Srivastava and Mathur (1996), Srivastava and Singh (1999, 2001), Srivastava and Srivastava (1990), Srivastava *et al.* (1992) and Jain (2002) produced a wealth of the fossil echinoid data. The present work also notes some inconsistencies in the documented data relating to the taxonomic placement, proper comparison and designation of the lectotypes, etc. For example, the taxa recorded by Aziz and Badve (2001) need revision. It is from the same horizon and locality that Badve and Aziz (1983) had earlier recorded the echinoid taxa, which have already been placed in *Gongrochanus herschelianus* Kier, 1962 (Smith and Jeffery, 2000; Srivastava, 2003).

DEVELOPMENT IN ECHINOID STUDIES

Echinoids, shallow benthic organisms, provide useful information about the marine environment,

Table 1: Distribution of taxa in the echinoid orders of India and Pakistan.

Sl. No.	Order	Number of genera	% of total population
1.	Arbacioida	02	01.72
2.	Cassiduloida	21	18.10
3.	Cidaroida	11	9.48
4.	Clypeasteroida	07	06.03
5.	Echinoida	02	01.72
6.	Hemicidaroida	06	05.17
7.	Holasteroida	05	04.31
8.	Holectypoida	08	06.89
9.	Orthopsida	01	00.86
10.	Phymosomatoida	08	06.89
11.	Salenioida	03	02.58
12.	Spatangoida	31	26.72
13.	Temnopleuroida	10	08.62
14.	Uncertain	01	00.86

palaeobiogeography and stratigraphy. Besides being useful in biostratigraphic correlation and palaeoecological aspects, they hold promise in palaeobiogeographic studies.

The diversity of echinoids during the Palaeozoic Period has been low in comparison with the post-Palaeozoic echinoids for failure to adapt to life in a wide variety of habitats; highest in the tropical and subtropical shelf seas and decreases markedly with increasing latitude and depth. It has also been observed by the author (Srivastava, 1996) that at the specific level, only a very few species are common, confirming that the echinoids are very sensitive to minor environmental changes. Moreover, most echinoid species are geographically restricted to some extent by geographical barriers, oceanic currents, nature of substratum, hydrodynamic regime, predation, salinity, temperature, food availability and depth (Mayr, 1954; Kier and Grant, 1965).

Though the echinoids appeared in United Kingdom (England and Scotland) during the Ordovician Period (Mannil, 1962), the earliest report of echinoids in India and Pakistan is from the Permian rocks of Karakoram and Salt Range and shows an European (western) Tethys affinity.

In India, the echinoid fauna are known Andaman Island, Assam, Gujarat, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Meghalaya, Rajasthan and Tamil Nadu while these are reported in Pakistan from Baluchistan, Kohat, Makran, Salt Range and Sind. The geographical distribution of the echinoid fauna in India and Pakistan along with their workers are given in Fig. 1.

Table 2: Distribution of taxa in the regular echinoid orders of India and Pakistan.

Sl. No.	Subclass	Order	Number of genera	% of genera
1.	REGULARIA (Total genera - 43)	Temnopleuroida	10	23.59
2.		Salenioida	03	06.97
3.		Phymosomatoida	08	18.60
4.		Orthopsida	01	02.32
5.		Hemicidaroida	06	13.95
6.		Cidaroida	11	25.58
7.		Arbacioida	02	04.65
8.		Echinoida	02	04.65

STRATIGRAPHIC SIGNIFICANCE

In the Indian subcontinent, the very low echinoid diversity during the Permian and Jurassic periods are followed by a pronounced rise in the Cretaceous Period and is at peak in the middle Palaeogene (Eocene Epoch) Period. The late Palaeogene (Oligocene Epoch) Period is a time of sustained low diversity, with increasing diversity later in the younger periods.

A total of 121 echinoid genera (Table 1; Figs. 2, 5) have been reported so far from the Indian subcontinent. Out of these, 43 genera, ranging in age from Permo-Carboniferous to Pliocene (Tables 2, 4; Fig. 6), constitute the regular and 73 genera, ranging

Table 3: Distribution of taxa in the irregular echinoid orders of India and Pakistan.

Sl. No.	Subclass	Order	Number of genera	% of genera
1.	IREGULARIA (Total genera - 73)	Spatangoida	31	42.46
2.		Holectypoida	08	10.95
3.		Holasteroida	05	06.84
4.		Clypeasteroida	07	9.58
5.		Cassiduloida	21	28.76
6.		Uncertain	01	01.36

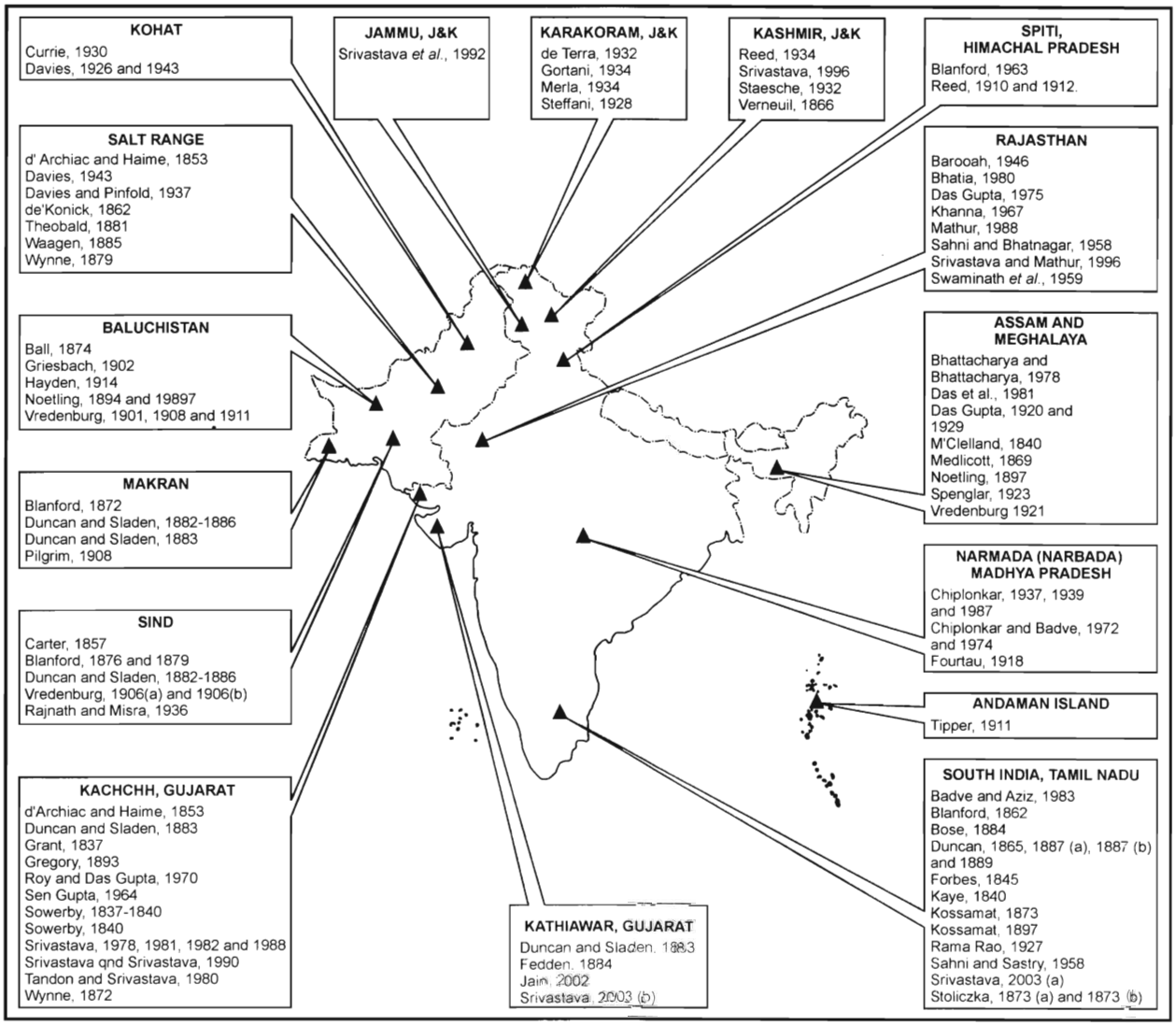

Fig.1. Distribution of echinoid fauna along with their workers in India and Pakistan.

in age from Jurassic to Pliocene (Tables 3,4; Fig. 7), constitute the irregular echinoids. However, five echinoid genera require proper taxonomic placement.

Regular echinoids: The earliest of the regular echinoids in India and Pakistan (Tables 2,4; Fig. 6) is from the Permo-Carboniferous (one genus) and Late Permian (two genera) sediments of Karakoram and Salt Range respectively when the occurrence of *Cidaris* and *Archaeocidaris* (Cidaroida) was observed in the Tethys Sea. While there is no record of echinoids from the Triassic Period, rare occurrence of echinoids (eight genera) is known from the Jurassic Period because of harsher environmental conditions. Out of these, only two

Table 4: Stratigraphic distribution of echinoid genera in India and Pakistan.

PERIOD	ECHINOID GENERA				Total number of genera	% of total genera
	Regular		Irregular			
	Number	% of total genera	Number	% of total genera		
Pliocene	04	07.27	06	05.55	10	06.13
Miocene	11	20.00	21	19.44	32	19.63
Oligocene	02	03.63	08	07.40	10	06.13
Eocene	15	27.27	37	34.25	52	31.90
Cretaceous	12	21.81	33	30.55	45	27.60
Jurassic	08	14.54	03	02.77	11	06.74
Permian	02	03.63			02	01.23
Permo - Carboniferous	01	01.81			01	00.61

Table 5: Stratigraphical distribution of fossil regular echinoid (Arbacioida and Cidaroida) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	PERMOCAR - BONIFEROUS	PERMIAN	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
ARBACIOIDA	*Coelopleurus*						+	+	+
	Goniopygus					+			
C	*Archaeocidaris*	+	+						
I	*Cidaris*		+	+	+	+	+	+	+
D	*Dorocidaris*				+				
A	*Eucidaris*							+	
R	*Goniocidaris*							+	+
O	(?) *Goniocidaris*							+	
I	*Phyllacanthus*					+			
D	*Porocidaris*					+			
A	*Prionocidaris*					+			
	Rhabdocidaris			+					
	(?) *Typocidaris*				+				

genera, namely *Cidaris* and *Salenia*, extend to the younger horizon and the remaining six genera restricted to the Jurassic Period. The prolific and diversified development of echinoids during the Cretaceous (12 genera) and Eocene (15 genera) periods indicates that during these periods, the environmental conditions were most favourable for development and growth of many new echinoid niches. It is interesting to note that all the Cretaceous genera except *Cidaris* and *Salenia* were found restricted to the Cretaceous Period and a new set of echinoids appeared during the Eocene Period. Out of the 15 Eocene genera, only three genera namely *Cidaris*, *Coelopleurus* and *Opechinus*, extend to the younger horizon and the remaining 12 genera are restricted to the Eocene Period. During the Oligocene Period (two genera) a new taxon is *Coelopleurus* added to the already existing genera, namely *Cidaris*. A new set of echinoids (11 genera) appeared during the Miocene Period and out of these, six genera namely, *Eucidaris*, (?) *Goniocidaris*, *Grammechinus*, *Hipponoe*, *Lepidopleurus* and

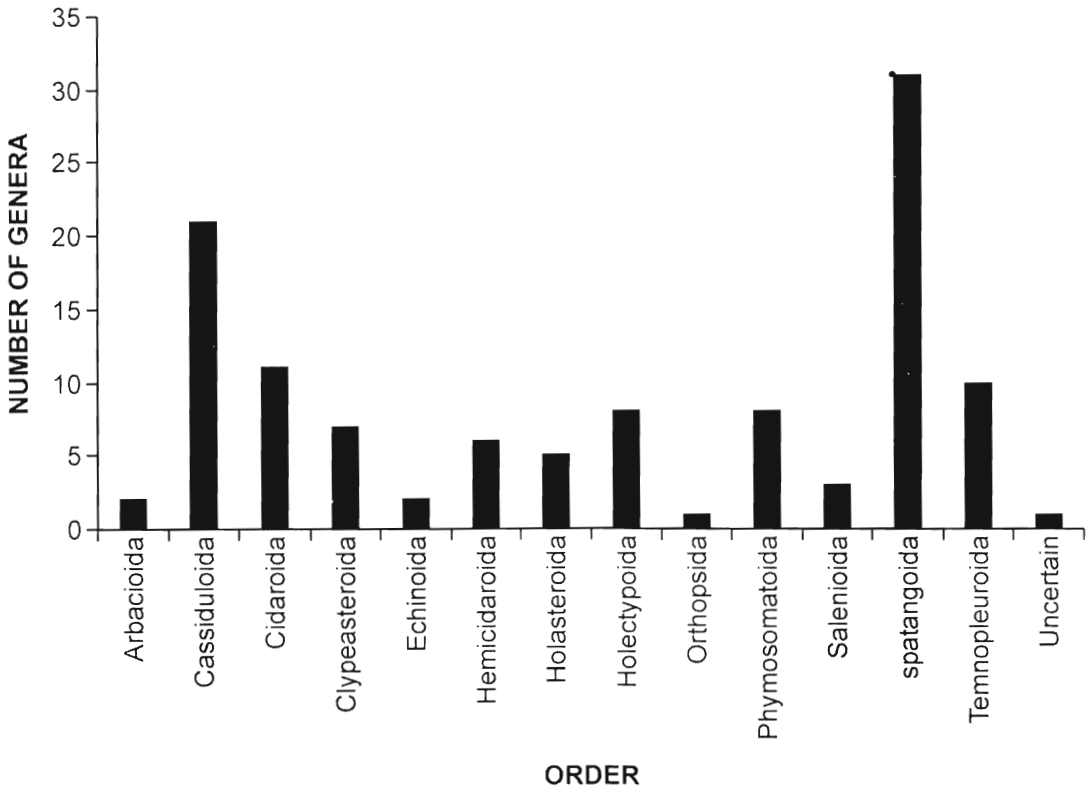

Fig. 2. Relative abundance of genera in the orders of echinoids of India and Pakistan.

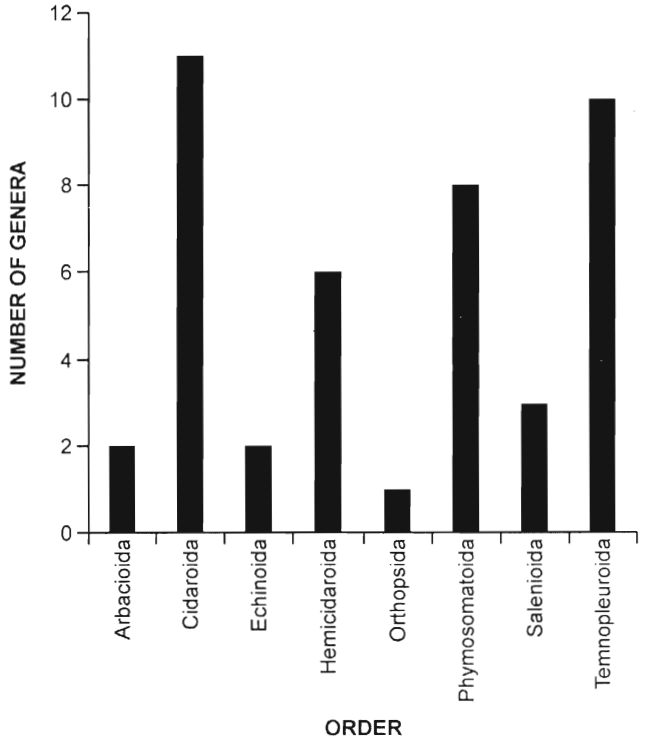

Fig. 3. Relative abundance of genera in the orders of Regular echinoids of India and Pakistan.

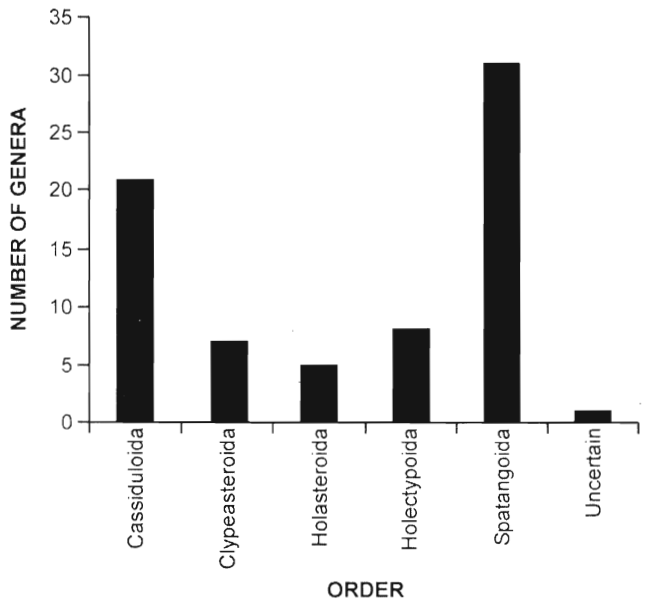

Fig. 4. Relative abundance of genera in the orders of Irregular echinoids of India and Pakistan.

Temnechinus were found restricted to this period. During the Pliocene Period (four genera) a new echinoid taxon *Salmacis*, is added to the already existing three genera, *Cidaris*, *Goniocidaris* and *Temnopleurus*.

Irregular echinoids: The irregular echinoids (Tables 3,4; Fig. 7) in the Indian subcontinent appeared in the Jurassic Period (three genera). Out of these three genera only one genus, *Holecypus*, extends to the Cretaceous Period, while the other two restricted to this period. The Cretaceous Period saw a prolific and diversified development (33 genera). Out of these genera, 18 were found restricted to this period while seven extend up to the Eocene Period. From the Eocene assemblage only one genus, *Echinocyamus*, extends up to the Oligocene Period. A new set of echinoids (37 genera) appears during the Eocene Period. Out of these genera, 19 were found restricted to this period while the remaining genera extend to the younger horizons. During the Oligocene Period (eight genera), only one new echinoid taxon *Eupatagus* (*Gymnopatagus*), is added to the already existing seven genera. During the Miocene Period, out of 21 echinoid genera, 10 made their first appearance, the remaining continuing from the older horizons. Among the 10 first appeared genera, only three genera, *Brissus*, *Echinodiscus* and *Lovenia*, extend to the Pliocene Period. During the Pliocene Period (six genera), one new echinoid taxon *Laganum*, is added to the already existing five genera.

The lack of diversity and periods of diversification during the Triassic and Jurassic times may be explained by the

Table 6: Stratigraphical distribution of fossil regular echinoid (Phymosomatoida) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	PERMOCAR - BONIFEROUS	PERMIAN	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
PHYMOSOMATOIDA	*Acanthechinus*					+			
	Aeolopneustes					+			
	Cyphosoma					+			
	Eurypneustes					+	+		
	Micropsis					+			
	Phymosoma				+				
	Polycyphus				+				
	Stomechinus			+					

Table 7: Stratigraphical distribution of fossil regular echinoid (Hemicidaroida and Echinoida) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	PERMOCAR - BONIFEROUS	PERMIAN	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
HEMICIDAROIDA	*Diplopodia*				+				
	Diplopodia (*Tetragramma*)				+				
	Heterodiadema				+				
	Polydiadema				+				
	Pseudocidaris			+					
	Pseudodiadema			+					
ECHINOIDA	*Echinometra*					+			
	Echinus					+		+	

reassembly of Laurasia. During the Permian period, the Indian Plate was situated nearer to the South Pole, away from the Equator and the environmental conditions in the Tethys Sea were not favourable for growth and development of the echinoid fauna. The breaking of the Indian Plate from the Gondwanaland during the Late Jurassic–Early Cretaceous Period, its northerly shift (anticlockwise) towards the Equator and the maximum diversification of the echinoid fauna during the Cretaceous Period in the Indian subcontinent is in accordance with the observations made by Valentine (1970). He noted that the time of joining of the continents is the period of low diversity while the time of fragmentation of the

Table 8: Stratigraphical distribution of fossil regular echinoid (Orthopsida, Salenioida and Temnopleuroida) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	PERMOCAR - BONIFEROUS	PERMIAN	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
ORTHOPSIDA	*Orthopsis*				+				
	Recrosalenia			+					
SALENIOIDA	*Salenia*			+	+	+			
	(?) *Salenia*			+					
TEMNOPLEUROIDA	*Arachniopleurus*					+			
	Dictyopleurus					+			
	Grammechinus							+	
	Hipponoe							+	
	Lepidopleurus							+	
	Opechinus							+	
	Progonechinus					+			
	Salmacis								+
	Temnechinus							+	
	Temnopleurus							+	+

Table 9: Stratigraphical distribution of fossil irregular echinoid (Cassiduloida, Holasteroida and Uncertain) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
CASSIDULOIDA	*Botriopygus*		+				
	Cardiopygus		+				
	Cassidulus		+	+			
	Catopygus		+				
	Echinobrissus		+				
	Echinolampas			+	+	+	
	Eolampas			+			
	Erhodia			+			
	Gongrochanus		+				
	Ilarionia			+			
	Limpasiaster		+				
	Neocatopygus			+			
	Nucleolites		+				
	Nucleolites (*Cassidulus*)		+				
	Nucleolites (*Pygorhynchus*)		+				
	Paralampas			+			
	Phylloclypeus			+			
	Plesiolampas		+	+			
	Progongrochanus		+				
	Rhynchopygus			+			
	Tamililampas		+				
HOLASTEROIDA	*Cardiaster*		+				
	Collyrites	+					
	Hemipneustes		+				
	Holaster		+				
	Pygorhytis	+					
UNCERTAIN	*Amblypygus*			+			

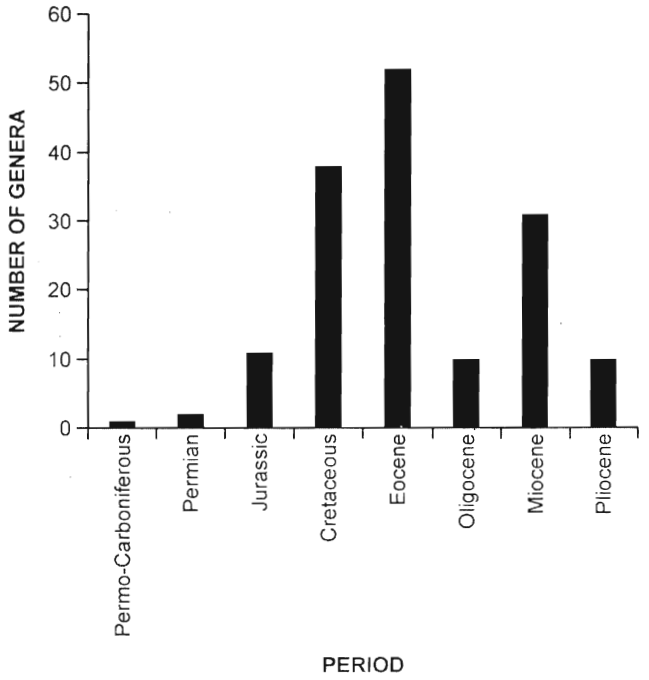

Fig. 5. Stratigraphic distribution of echinoids of India and Pakistan.

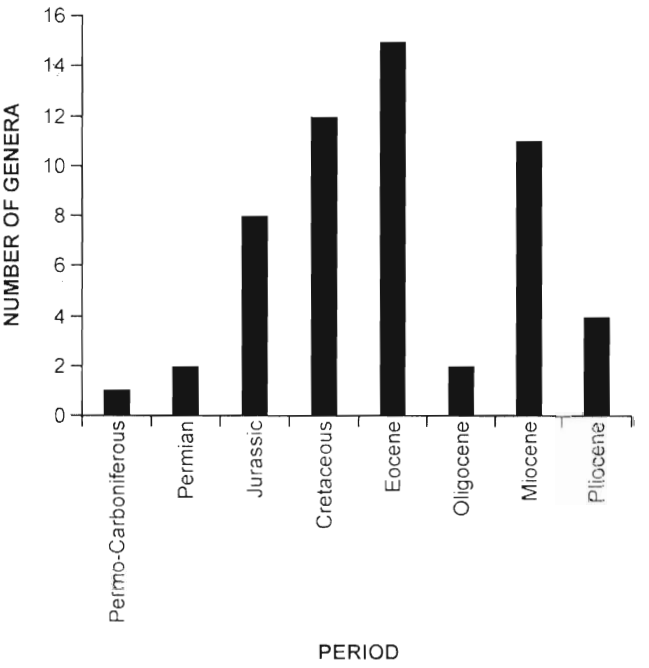

Fig. 6. Stratigraphic distribution of Regular echinoids of India and Pakistan.

continents is the period of diversification.

TAXONOMIC SIGNIFICANCE AND DISTRBUTION

The taxonomic distribution of fossil echinoid fauna of the Indian subcontinent (Tables 1,2,3; Figs. 2, 3, 4) reflects that among the regular echinoids (Table 2; Fig. 3), Cidaroida (Table 5) were maximum (11 genera), followed by Temnopleuroida (Table – 8; 10 genera), Phymosomatoida (Table 6; eight genera), Hemicidaroida (Table 7; six genera), Salenioida (Table 8; three genera), Arbacioida and Echinoida (Tables 5,7; two genera each) and Orthopsida (Table 8; one genus) while among the irregular echinoids (Table 3; Fig. 5), Spatangoida (Table 11) constituted the maximum number (31 genera) of echinoids, followed by Cassiduloida (Table 9; 21 genera), Holectypoida (Table 11; eight genera), Clypeasteroida (Table 10; seven genera), Holasteroida (Table 9; five genera) and an Uncertain order (Table 9; one genus).

Considering the whole population of the fossil echinoid taxa, it has been observed that the Spatangoida predominates over all the echinoids. These are followed by Cassiduloida, Cidaroida, Temnopleuroida, Holectypoida and Phymosomatoida, Clypeasteroida, Hemicidaroida, Holasteroida, Salenioida, Echinoida and Arbacioida and finally Orthopsida and an Uncertain order.

FAUNAL ANALYSIS

1. A total of 121 echinoid genera have been reported so far from India and Pakistan. Out of these, 43 genera (35.53%)

Table 10: Stratigraphical distribution of fossil irregular (Clypeasteroida) echinoid genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
CLYPEASTEROIDA	*Clypeaster*			+	+	+	+
	Echinocyamus		+	+	+		
	Echinodiscus					+	+
	Fibularia					+	
	Laganum						+
	Mortonia					+	
	Tridium			+			

Table 11: Stratigraphical distribution of fossil irregular echinoid (Spatangoida and Holectypoida) genera in India and Pakistan.

ORDER	PERIOD→ (AGE) ↓ GENUS	JURASSIC	CRETACEOUS	EOCENE	OLIGOCENE	MIOCENE	PLIOCENE
	Breynia			+	+	+	
	Brissopatagus			+			
S	*Brissopsis*			+		+	
	(?) *Brissopsis*					+	
	Brissus					+	+
P	*Ditrimaster*		+	+			
	Eupatagus (*Eupatafus*)			+	+	+	
	Eupatagus (*Gymnopatagus*)				+		
A	*Hemiaster*		+	+			
	Hemiaster (*Hemiaster*)			+			
	Hemiaster (*Malwaster*)		+				
T	*Hemiaster* (*Mecaster*)		+	+			
	Heteraster		+				
A	*Linthia*		+	+			
	Lovenia					+	+
	Macropneustes (*Macropneustes*)			+			
N	*Maretia*					+	
	Meoma (*Schizobrissus*)			+		+	
	(?) *Meoma* (*Schizobrissus*)					+	
G	*Metalia*					+	
	Micraster		+	+			
	Moira (*Moiropsis*)			+		+	
O	(?) *Moira* (*Moiropsis*)					+	
	Opissaster		+	+			
D	*Prenaster* (*Prenaster*)			+			
	Proisaster		+				
	Schizaster			+	+	+	+
A	*Schizaster* (*Paraster*)			+			
	Schizaster (*Schizaster*)			+	+	+	
	Toxaster		+				
	Troschelia					+	
H	*Conulus*		+				
O	*Discoidea*		+				
L	*Galerites*			+			
E	*Globator*		+				
C	Holectypoid genus indet.			+			
T	*Holectypus*	+	+				
Y	*Pygopyrina*		+				
P	*Pyrina*		+				
O							
I							
D							
A							

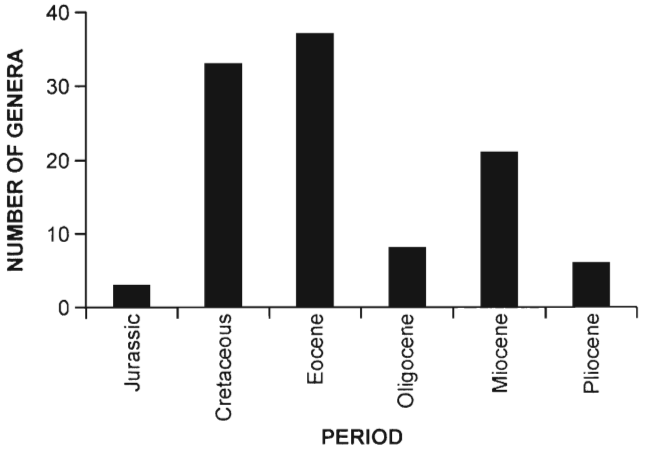

Fig. 7. Stratigraphic distribution of irregular echinoids of India and Pakistan.

constitute the regular and 73 genera (60.33%) irregular echinoids besides, five echinoid genera (03.06%) require proper taxonomic placement.

2. The taxonomic distribution of the echinoid orders is given in Table 1 and Fig. 2.
3. The Stratigraphic distribution of the echinoid genera is shown in Table 4 and Fig. 5.
4. It is interesting to note that out of 121 fossil echinoid genera, only one genus, *Cidaris*, has a long stratigraphic range from the Permian to the Pliocene, while the majority of them are restricted to their respective periods or have very short stratigraphic range.
5. The taxonomic status of many echinoid genera viz. *Conoclypeus* Agassiz, *Discoidea* Leske, *Echinoconus* Breynius, *Euspatangus* Agassiz and an indeterminate echinoid genus and their species recorded and described earlier from the Indian subcontinent needs re-examination as these has not been mentioned in the Treatise (Moore, 1966). Further, many recorded echinoids have been placed in synonymy with the other echinoid genera in the Treatise (Moore, 1966). The details are given below:

Sl. No.	Echinoid genus	Kept under synonym of
1.	*Botriopygus* d' Orbigny	*Pygorhynchus* L. Agassiz
2.	*Cyphosoma* L. Agassiz	*Phymosoma* Haime
3.	*Dorocidaris* A.agassiz	*Cidaris* Leske
4.	*Echinobrissus* Gray	*Nucleolites* Lamarck
5.	*Eocidaris* Desor	*Archaeocidaris* M'Coy
6.	*Eolampas* Duncan & Sladen	*Pseudopygaulus* Coquand
7.	*Hipponae* Gray	*Tripneustes* L. Agassiz
8.	*Lepidopleurus* Duncan & Sladen	*Leptopleurus* Lambert & Thiery
9.	*Paralampas* Duncan & Sladen	*Rhynchopygus* d'Orbigny
10	*Phylloclypeus* de Loriol	*Clypeolampas* Pomel
11.	*Pyrina* Desmoulin	*Conulus* Leske
12.	*Typocidaris* Pomel	*Stereocidaris* Pomel

RECOMMENDATIONS AND SUGGESTIONS

The taxonomic status of the majority of the echinoid fauna described from the Indian subcontinent by previous workers is still uncertain. The generic placement of the echinoid taxa, though, in the clypeasteroids, cassiduloids and spatangoids is correct up to a certain extent, but at the specific levels it requires a proper and thorough re-examination. Many species of the genera in the above orders reported from the Indian subcontinent have been erected on minor morphological variations. If properly studied, they can be placed in a single species or assigned properly.

While reviewing the spatangoid echinoids of the Indian subcontinent, Srivastava (2004) attempted to assign 40 echinoid taxa to their genera and designated lectotypes of the new species described by the earlier workers. Among the clypeasteroids, Duncan and Sladen (1882 – 86) kept many potentially distinguishable fossil forms under a single species *Echinocyamus polymorpha* (Duncan and Sladen) that, it seems, can be split into different species, when viewed in respect of features such as shape and size of the test, position of the apical system, shape and size of the ambulacral petals and peristome. On the other hand, the forms shown to represent *Echinocyamus nummuliticus* Duncan and Sladen and its varieties distinguished on the basis of variations in shape and size of the test, position of the apical system, shape and size of the ambulacral petals and peristome can be considered just minor variants. They should be placed under a single species of the genus *Echinocyamus* van Phelsum. Likewise, *Clypeaster carteri* Duncan and Sladen, *C. sowerbyi* Duncan and Sladen and *C. simplex* Duncan and Sladen appear to be ecologic variants and can be considered to represent a single species. Their separation into distinct species merely on the basis of the slight variations in shape, size of the test, position of the apical system, shape and size of the ambulacral petals, etc., is not justified. Among the cassiduloids, several species of *Echinolampas* Gray erected on minor variations concerning shape, size of the test and other features can be merged into two or three species only. The species of the genus *Plesiolampas* Duncan and Sladen present the same problem and require re–examination and proper placement. Among the regular echinoids, numerous species of *Coelopleurus* Agassiz, *Cidaris* Klein, *Goniocidaris* Desor, *Temnechinus* Forbes and *Temnopleurus* Agassiz, too, are taxonomically not justified and merit reconsideration.

The comparisons of these species with those from the adjoining areas in the Tethyan region is insufficient and the lectotypes of the new species described by most of the earlier workers (d'Archiac and Haime, 1853; Currie, 1930;Davies, 1943; Duncan, 1865, 1887(a), 1887(b); Duncan and Sladen, 1882 – 86, 1883; Fourtau, 1918; Gregory, 1893; de Konick, 1862, etc.) are yet to be designated. These problems have cast doubt over their usefulness in stratigraphic studies. In order to make them useful stratigraphically, it is necessary to study and update taxonomically the fossil echinoids of the Indian subcontinent in the light of taxonomic revisions and recommendations as presented in the new literature.

The study ought to involve re-examination of the old collections of the fossil echinoid housed in various museums of the Geological Survey of India and other Indian institutions. This may generate basic data on fossil echinoids, which can later be evaluated in terms of biostratigraphy. Each biostratigraphic zone represents a stratigraphic interval with distinctive faunal elements. The sequence of several such intervals with respective characteristic assemblages of fossils (echinoid data in the present context) may provide a multipurpose system in stratigraphy that could be used as a basis for (a) reckoning time, (b) studying evolutionary changes in the echinoid

fauna and (c) estimating the changing conditions of environment through the stratigraphic column. This information could also be of help in studying palaeobiogeography and evolutionary trends of certain groups of echinoids, notably spatangoids, clypeasteroids and cassiduloids which occur in large numbers in the Late Cretaceous - Palaeogene deposits and also in Recent seas.

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