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A record of foraminiferal assemblage in tsunami sediments along Nagappattinam coast, Tamil Nadu

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This study documents the assemblages of foraminifera and its distribution pattern in the tsunami inundation areas of Nagappattinam coast. The maximum inundation locations were chosen on the tsunami-hit Nagappattinam coast (Vilundamavadi, Kameshwaram, Velankanni and Nagappattinam) for present faunal documentation. A total of 22 species belonging to 15 genera of benthic and one species of planktic foraminifera are identified in the tsunami sediments. Q-mode cluster analysis was carried out to understand the distribution pattern, which inferred five biotopes. This preliminary work on foraminiferal distribution infers that the benthic foraminiferal assemblages recorded in tsunami sediments are habitat of coastal to inner shelf environment.

Keywords: Benthic foraminifera, inundation sediments, Nagappattinam, tsunami record, tsunami sediments.

THE 26 December 2004 tsunami event has devastated several major coastlines in South Asia, including the Tamil Nadu coast, India. A high magnitude earthquake measuring 9.0 on the Richter scale with a shallow epicentre had triggered the tsunami in the northeast Indian Ocean. The waves propagated through the Bay of Bengal/Indian Ocean. Subsequently these waves have been transformed into a chain of catastrophic oscillations. These huge oscillatory waves struck the east coast of Tamil Nadu. Nagappattinam was the worst-affected area with large loss of property and life. This devastating earthquake occurred as thrust faulting on the interface of the Indian plate with the Burma microplate[1]. The tsunami event has left significant geological signatures with changes in coastal geomorphology and deposition of sediments along the coast, derived from the waves. Although tsunami events are rare in nature, scientific documentation of such a rare event of this magnitude goes a long way and serves as coastal management and mitigation measures for the future. The cost-effective method to monitor changes in environment and to assess the impact on biota by natural hazards can be provided by foraminiferal studies. The ecological distribution of Protozoa has applications in both modern and fossil environmental studies. The water circulation patterns along the coastal zones and in the oceans could be investi-

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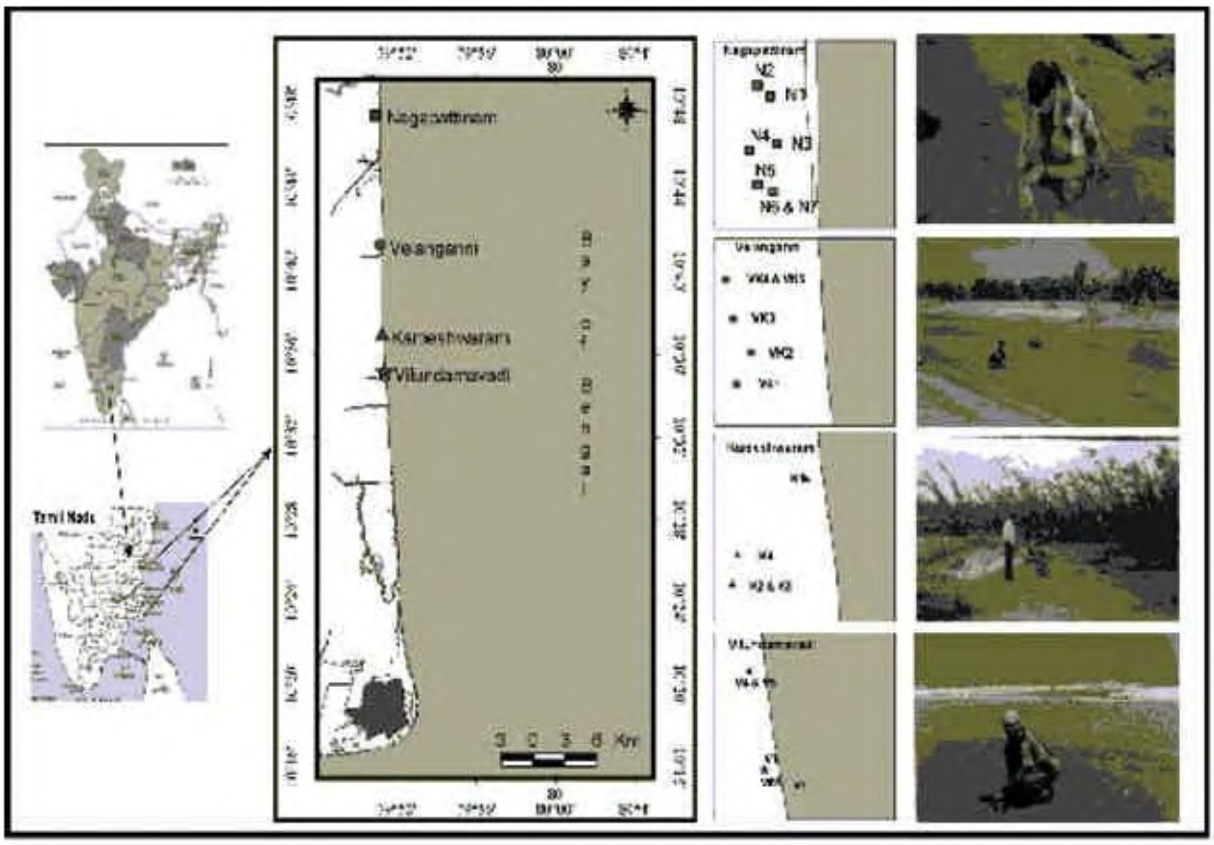

Figure 1. Location map of Nagappattinam coast and sample collection points.

gated and monitored through foraminiferal studies, besides understanding the freshwater influx[2]. The fossil foraminiferal study also help in assessing the palaeo-depth, palaeo-salinity and palaeo-environment and useful in palaeo-geographic reconstruction and ecological studies. The present communication records the distribution of foraminiferal assemblage and its possible source from which the faunal assemblage derived into beaches along the Tamil Nadu coast.

The study area covers parts of the east coast of Nagappattinam district, which has been worst affected by the tsunami. The area lies between N 10°34′59.8″: E 79°50′59.9″. Field observations reveal that this event has left significant deposits in patches along Nagappattinam beaches (Figure 1). The sediment deposits record the tsunami inundation for more than 1 km in open coastal settings and up to 4 km in rivers and backwaters. Tsunami sediments were recognized by their colour and grain gradation into clay lenses towards land. A total of 24 tsunami samples were systematically collected from four locations (Nagappattinam (N), Kameshwaram (K), Vilundamavadi (V) and Velankanni (VK)) during the first week of January 2005. These locations experienced maximum inundation by tsunami waves. Black-coloured and muddy sediments occurring as isolated patches with thickness varying from 2 to 3 cm were used for the present study. A total of 22 foraminiferal species were sorted, quantified and systematically identified from the tsunami sediments (Table 1).

The foraminifers recognized in tsunami sediments are illustrated in Figures 2–6. The foraminiferal assemblages are represented by *Adelosina laevigata*, *Ammobaculites exiguus*, *Ammonia beccarii*, *A. dentatus*, *Asterorotalia trispinosa*, *Bolivina striatula*, *Elphidium delicatulum*, *E. hispidulum*, *E. macellum*, *E. norvangi*, *Jadammina macrescens*, *Lagena* sp., *Nonion scaphum*, *Nonion boueanum*, *Quinqueloculina cultrata*, *Q. seminula*, *Q. strigillata*, *Edentostomina cultrata*, *Spiroloculina depressa*, *Spiroloculina nobilis* and *Textularia agglutinans*.

Q-mode cluster analysis identifies five biotopes associations in the tsunami sediments (Figure 7).

Cluster-A comprises sample locations V2, V4, N1, N2, N5, K4 and VK2, and defines biotope 1. This biotope is dominated by *N. scaphum*, *Q. seminula* followed by *A. beccarii*, *E. hispidulum* and *E. delicatulum* significantly.

Cluster-B which covers sample locations VK4, VK5, K1 and N4, defines biotope 2. This biotope is dominated by *Q. seminula*, *N. scaphum* followed by sub-dominant *A. beccarii*, *E. hispidulum* and *A. dentatus*.

Table 1. Foraminiferal frequency of tsunami sediments

	Sample locations and code																				
	Vilundamavadi					Kameshwaram				Velankanni					Nagappattinam						
	V1	V2	V3	V4	V5	K1	K2	K3	K4	VK1	VK2	VK3	VK4	VK5	N1	N2	N3	N4	N5	N6	N7
lis	2	0	0	0	0	0	1	1	2	2	0	1	1	1	0	0	3	2	3	2	2
(Cushman)																					
	0	0	0	0	2	0	5	0	0	3	1	0	0	1	1	0	0	0	1	0	0
(Cushman & Bronnimann)																					
(Linne')	8	14	24	15	16	9	12	19	12	18	14	12	16	14	16	8	12	11	12	8	17
(Parker & Jone s)	5	7	15	8	5	15	6	2	5	13	7	8	6	4	11	11	10	4	17	9	10
	3	4	1	3	8	3	10	1	4	4	2	6	3	0	4	6	6	4	5	6	7
(d'Orbigny)																					
(Cushman)	4	0	4	4	0	0	1	1	0	2	0	3	3	1	0	2	4	8	4	5	2
	13	2	13	7	5	3	0	10	3	13	8	2	1	8	6	11	2	12	12	18	13
(Bermudez)																					
(Cushman)	10	11	4	12	14	7	25	0	9	12	14	9	4	14	4	11	8	16	18	25	14
(Fichtel & Moll)	0	0	1	2	0	2	0	2	3	4	2	4	6	5	2	1	3	2	4	2	2
	1	0	0	1	1	1	0	1	2	0	0	0	3	0	0	2	1	1	2	0	2
(Buzas, Smith & B eem)																					
(d'Orbigny)	0	1	2	0	1	1	0	2	0	2	0	0	1	2	1	1	0	0	2	0	0
(Brady)	0	0	0	0	1	4	1	1	0	2	1	1	4	5	0	0	0	6	0	0	5
sp.	0	0	0	0	1	0	0	0	0	1	0	0	2	1	0	0	0	1	0	0	1
	41	68	34	52	28	30	29	22	51	36	69	13	39	24	51	58	28	23	47	35	42
(Fichtel & Moll)																					
(d'Orbigny)	8	8	4	5	2	6	7	8	6	7	12	2	4	3	7	4	5	4	6	6	8
	2	0	0	2	2	3	2	0	1	2	0	0	1	2	2	2	1	3	1	2	4
(Brady)																					
(Linne')	28	27	28	50	28	55	41	36	25	27	28	16	47	46	35	29	26	52	45	36	29
lata (Linne')	1	2	2	1	0	0	0	2	3	3	3	2	1	3	1	0	2	2	2	3	4
	0	0	0	0	1	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
(d'Orbigny)																					
	0	0	0	1	1	5	1	0	1	0	2	1	1	0	1	0	1	1	2	1	1
(d'Orbigny)																					
(Reuss)	0	1	2	1	0	1	0	0	1	1	0	1	0	1	0	0	1	1	1	2	1
	1	0	0	1	0	0	1	0	2	2	1	0	0	2	1	0	0	0	2	1	0
(d'Orbigny)																					
g/dry sediments)	127	145	134	165	116	145	142	108	130	154	166	81	143	137	144	146	113	153	186	161	164

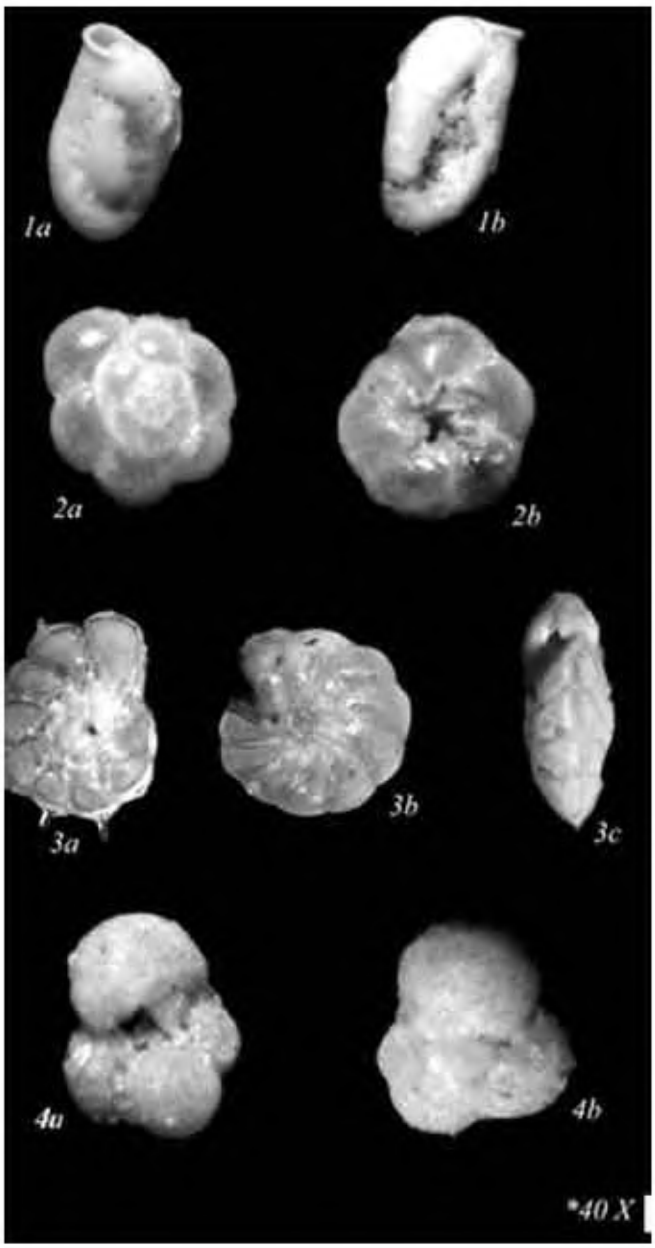

Figure 2. 1. *Quinqueloculina tropicalis* (Cushman): ***a***, ***b***, Side view. 2. *Ammonia beccarii* (Linne): ***a***, Dorsal view and ***b***, Ventral view. 3. *Ammonia dentatus*: ***a***, Dorsal, ***b***, Ventral and ***c***, Apertural view. 4. *Globigerina bulloides* (d'orbigny): ***a***, Umbilical and ***b***, Spiral view.

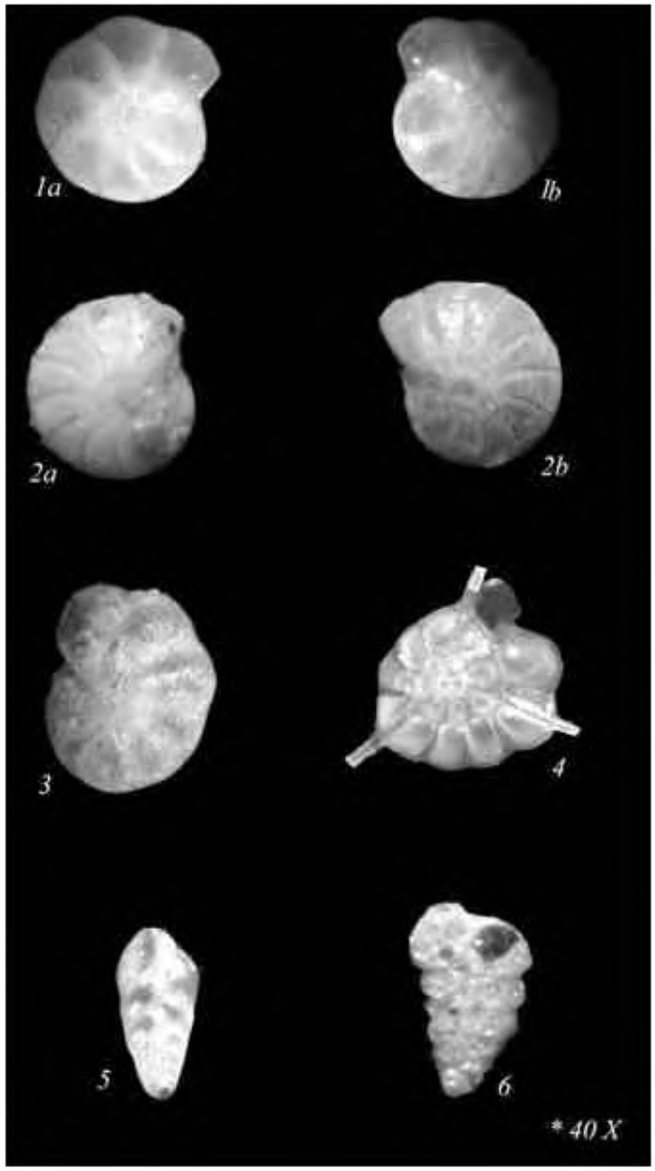

Figure 3. 1. *Elphidium norvangi*: ***a***, ***b***, side view. 2. *E. delicatulum* (Bermudez): ***a***, ***b***, side view. 3. *E. hispidulum:* side view (Cushman). 4. *Asterorotalia trispinosa*: dorsal view (Thalmann). 5. *Bolivina striatula*; side view (Cushman). 6. *Textularia agglutinans:* side view (d'orbigny).

Biotope 3 is represented by Cluster-C (sample location K2 and N6). This is dominated by *Q. seminula*, and *N. scaphum* followed by less dominant *E. hispidulum*, *E. delicatulum*, *A. beccarii* and *Asterorotalia trispinosa*.

Cluster-D (biotope 4) covers sample locations V1, V3, V5, N3, N7, K3 and VK1. This biotope is dominated by *N. scaphum* and *Q. seminula* followed by sub-dominant *A. beccarii*, *E. hispidulum*, *E. delicatulum* and *A. dentatus*.

Cluster-E recognized as biotope 5 is represented by sample location VK3, dominated by *Q. seminula*, *N. scaphum* and lesser population of other recorded species.

The dominant species in the five biotopes are *Q. seminula* and *N. scaphum*, which constitute about 52% of the total assemblage. *E. excavatum*[3] usually occurs at mid-low tide levels[6]. The samples are grouped in terms of relative species abundances into five sample associations, with reference to the inferred environments of their constituent species associations. *Elphidium* spp. are characteristic of mid-low tidal, moderately sheltered environment. In modern sea, *E. advenum* is common under sheltered situations, often in low salinity zones in the inner shelf. *Quinqueloculina* spp. is abundant in inner shelf environ-

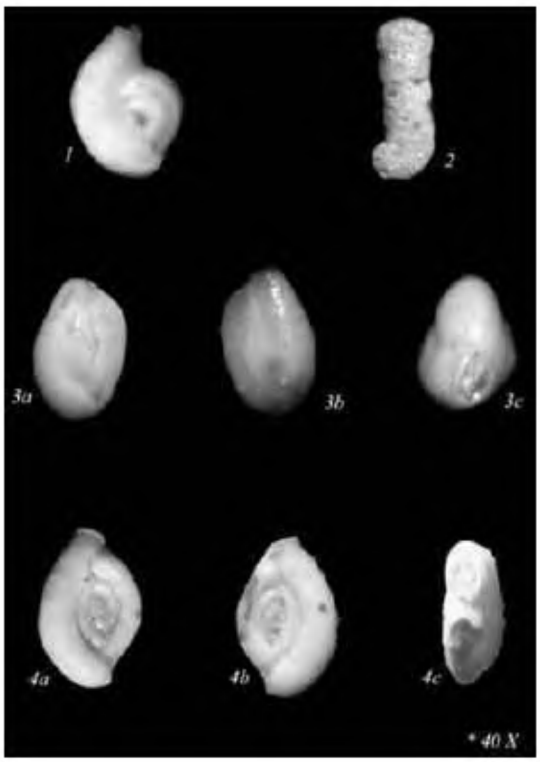

Figure 4. 1. *Quinqueloculina cultrata:* side view (Brady). 2. *Ammobaculites exiguous:* side view (Cushman and Bronnimann). 3. *Q. seminula* (Linne): ***a***, ***b***, side and ***c***, Apertural view. 4. *Spiroloculina depressa* (d'orbigny). ***a***, ***b***, side and ***c***, apertural view.

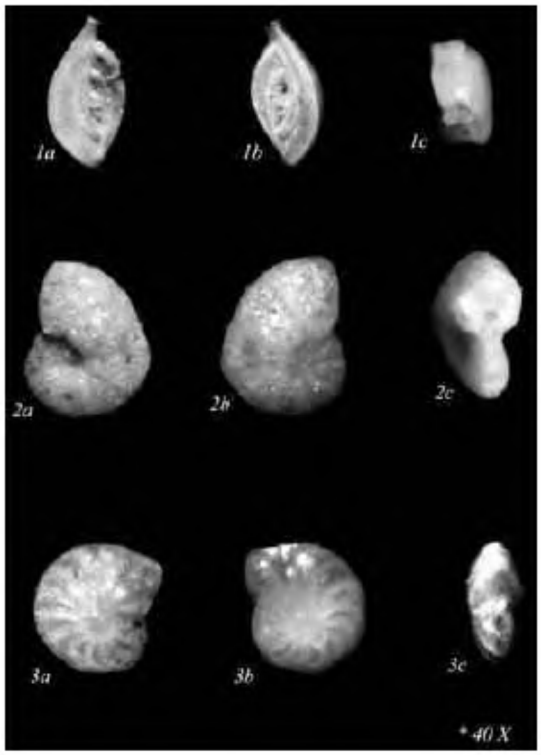

Figure 5. 1. *Spiroloculina nobilis:* ***a***, ***b***, side view and ***c*** apertural view. 2. *Jadammina macrescens* (Brady): ***a***, ventral; ***b***, dorsal and ***c***, apertural view. 3. *E. macellum* (Fichtel and Moll). ***a***, ***b***, side and ***c***, apertural view.

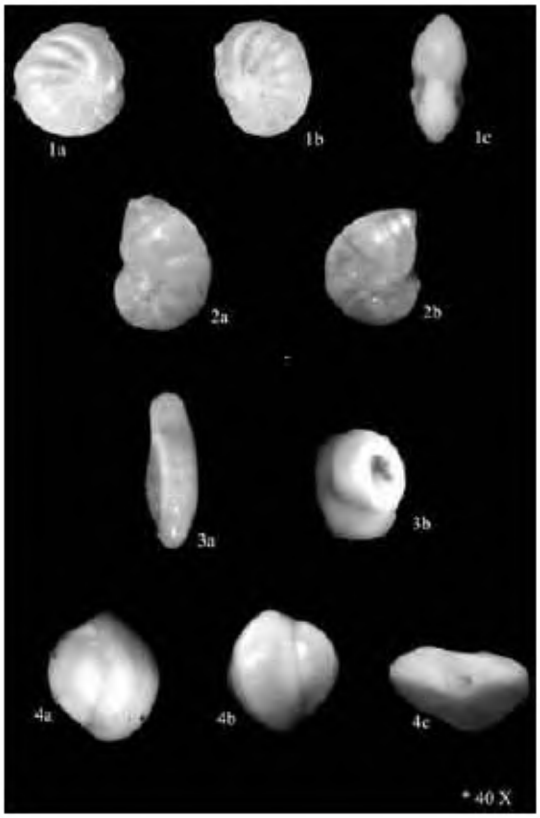

Figure 6. 1. *Nonion boueanum* (d'orbigny): ***a***, ***b***, side view and ***c***, apertural view. 2. *Nonion scaphum* (Fichtel & Moll). ***a***, ***b***, Side view. 3. *Edenstomina cultrata* (Brady): ***a***, side view; ***b***, apertural view. 4. *Quinqueloculina strigillata*: ***a***, ***b***, side view; ***c***, apertural view.

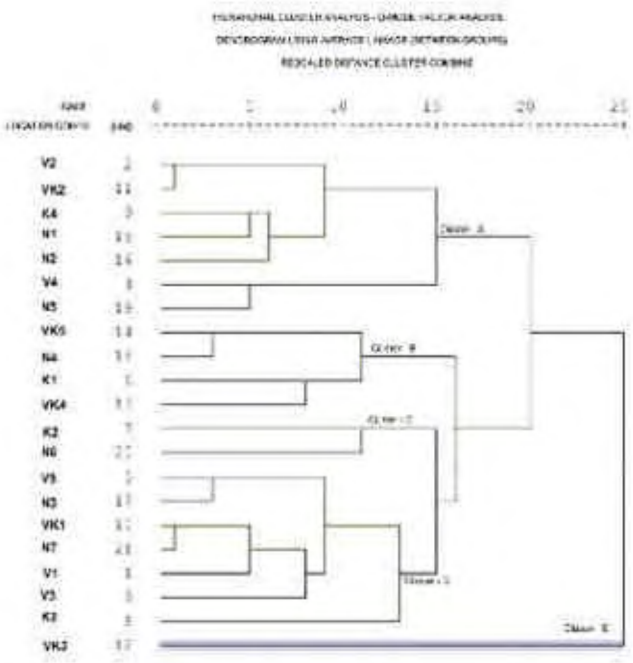

Figure 7. Hierarchial Q-mode cluster analysis of Nagappattinam tsunami deposits.

ment[4,5,7]. *Nonionella* spp. are found in moderately quiet, fine sediment environment at deep inner shelf, sheltered from oceanic water circulation[2]. *A. beccarii* is widespread in shallow subtidal and intertidal lower estuarine environments with reduced salinity[3,5]. The faunal association in the study area is dominated by *Q. seminula* and *N. scaphum* and less-dominated by *Elphidium* spp. and *Quinqueloculina* spp. indicative of mid to low tidal and inner shelf environments. This suggests that the tsunami sediments deposited in the Nagappattinam coast have been brought from inner shelf environment.

The foraminiferal assemblages recorded in the sediments brought by the tsunami waves are inferred to have been derived from the shallow neritic zone along the Nagappattinam coast. Q-mode cluster analysis reveals spatial variation of foraminiferal assemblage distribution and recognize five biotopes along Nagappattinam coast. These changes in foraminiferal assemblage may be attributed to micro niches that control faunal distribution and also current circulation patterns along the coastal zones. This study will serve as a reference for further investigations that are underway along the east coast of India.

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