*Journal of Geological Society of Sri Lanka Vol. 17 (2015), 11-17*
*J.W. Herath Felicitation Volume*

# TAPHONOMY OF RECENT BURROWS FROM EASTERN COAST, SRI LANKA

A.M.N.M. ADIKARAM[1,*], H.M.T.G.A. PITAWALA[2], H. ISHIGA[3] AND D.T. JAYAWARDHANE[4]

[1]*Department of Physical Sciences, Faculty of Applied Sciences, South Eastern University of Sri Lanka*

[2]*Department of Geology, Faculty of Science, University of Peradeniya, Sri Lanka*

[3]*Department of Geosciences, Graduate School of Sc. & Eng., Shimane University, Japan*

[4]*Department of Forestry and Environmental Sciences, Faculty of Applied Sciences, Sri Jayawardhanapura University, Sri Lanka*

[*]*Corresponding Author: e-mail: maduryaa@gmail.com*

## ABSTRACT

Quaternary sediment deposits of the Eastern coast of Sri Lanka were studied for the first time to understand the taphonomy of tube burrows and the impact of structure and mineralogy of the wall on the preservation of burrows, was interpreted. Photography and interpretations were made and described during the field observations on exposed trace fossils. Fine structures were identified using Scanning electron microscopy with energy dispersive x-ray spectroscopy. Simple vertical tube burrows were observed in a fine to medium sandy sediment bed which was above 4 m from the present mean sea level. The average diameter of the tubes was about 1 cm and the recorded maximum length was about 20 cm. Specimens are significant with circular color rims around the central holes. The internal wall of the tube was ornamented by microscopic honeycomb-like sclerite and fecal material secreted by the burrower and rich in iron oxide and clay minerals. Microbial activities on the wall have enhanced the early consolidation of the sediments of shallow marine environments, leading to filming cuticular organic matter, pyritization and aluminosilicatization processes. The environmental change from reducing to fully oxidizing conditions has strengthened the tubes commonly rimmed by iron oxides.

***Key words:*** *Tube burrows, Sclerite, Preservation, Eastern coast of Sri Lanka*

## INTRODUCTION

Different phases of taphonomy of a trace fossil directly offer a great deal of facts about original organism, paleoecology, paleobiological events, evolutionary history and paleoenvironment (Behrensmeyer, 1984; Allison and Bottjer, 2011). Understanding the taphonomic bias on preservation is important considering studies focusing on evolution histories and paleo-climate that are beneficial in future changes (Allison and Bottjer, 2011).

Animal burrows are common in near and shallow marine environments and they are mostly made of soft bodied organisms. Consortia of organic activities are important in the formation and preservation of such burrows by trapping and binding the sediments. The trapping and binding organic matter is either from the mucus that emits to facilitate the burrowing process in unconsolidated sediments or fecal pellets of the burrower (Bromley, 1996; Gingras et al., 2014). The metabolic activities of the microorganisms in decaying process of the organic matter further help in the burrow preservation (Ahn and Babcock, 2012).

Preserved burrows in Quaternary soft sediments are enriched in carbon, aluminosilicates and iron minerals and the environmental factors cause the stability of them. In general, pyrite is the first iron mineral to form the burrow wall and they occur as framboids or pseudomorphed crystals in the sedimentary matrix (Schieber, 2002; Löwemark and Schäfer, 2003; Vertazalo et al., 2010; Ahn and Babcock, 2012). Also, iron in water precipitates around burrow walls and get oxidized into maghemite, initially and then the bacterial sulfates are reduced to form pyrite (Gingras et al., 2014). Burrow preservation is further described in other decay resistance

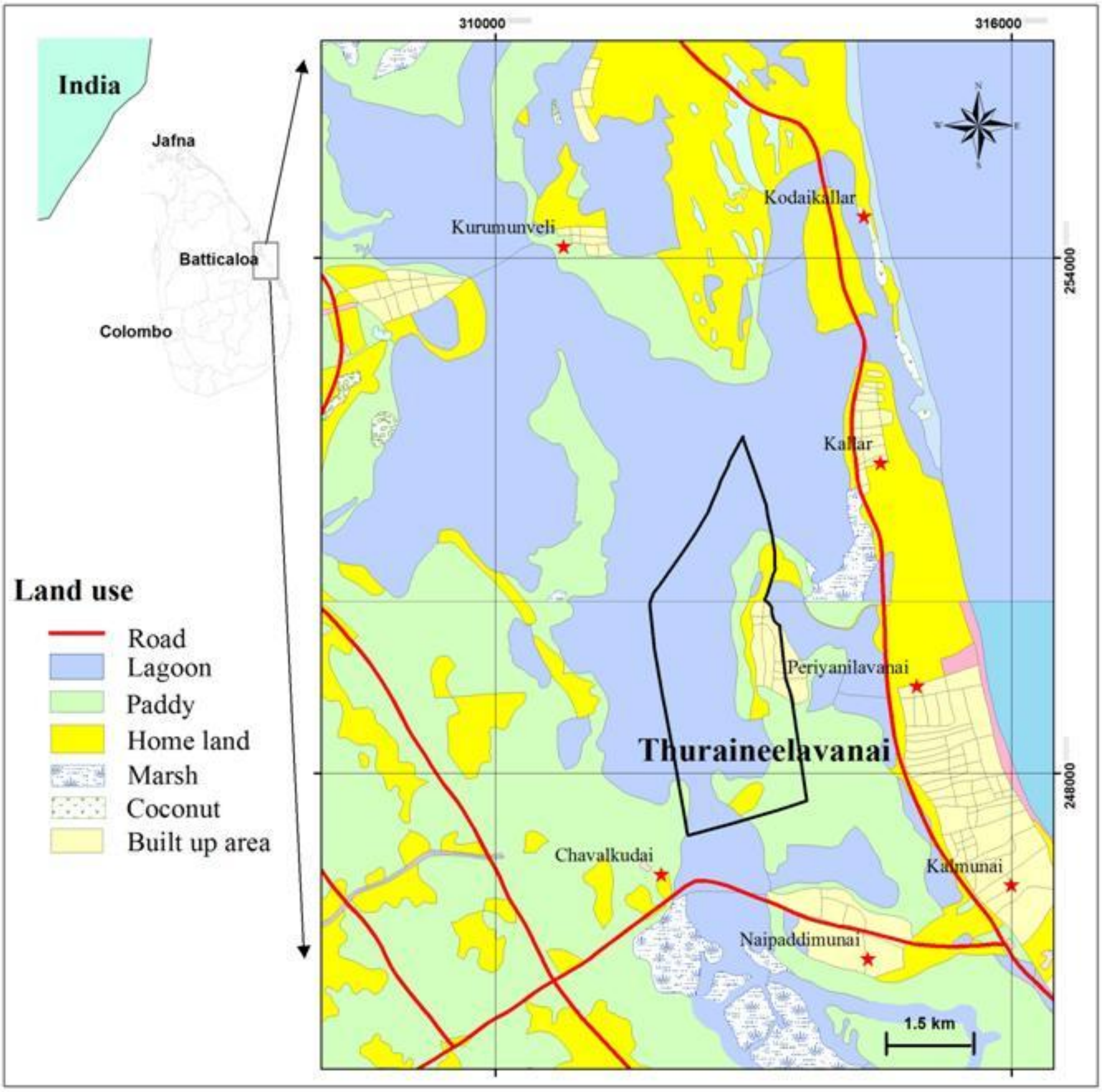


*Fig. 1 Map of Batticaloa, Sri Lanka showing the sampling location of Thuraineelavanai*

processes such as coalification and aluminosilicatization (Han et al., 2007).

In the present paper, we address the new observations of simple vertical tubular burrows that were found in the Quaternary sediments of near marine environment of Eastern Sri Lanka (Cooray and Katupotha, 1991). These burrows are only tentatively selected as the burrows of polychaetes by the authors since there are no systematic ichnological records. This is the first attempt to study on taphonomy of tube burrows related to its preservation in Quaternary sediments of Sri Lanka. Detailed taphonomic studies on well preserved tube burrow fossils in Quaternary soft sediments will contribute to a better understanding of preservation history.

## STUDY AREA AND PHYSICAL SETTINGS

### GEOLOGY AND GEOGRAPHY

The coastal area of Batticaloa district, Sri Lanka, is composed of younger Quaternary sediment deposits that extend along the Eastern coastal region (Katupotha, 2007). The Batticaloa lagoon is formed due to the isolation of the water bodies by complex barrier systems and further developed by shoreline changes (Fig. 1). The width of the sediment band of the lagoon barrier complex is narrow and exposed fresh or weathered bedrock is visible at a location 2 km away from the present coastline. The Precambrian metamorphic basement includes biotite and granitic gneisses (Cooray, 1984). Fine to medium size, moderately sorted sediments are found on the weathered bedrock.

Well rounded to sub rounded quartz grains (about 85%) form the major mineral type with minor amounts of heavy minerals. Average thickness of the sediment layer is about 3 m. The sediment bed with preserved tube burrows has a red crust that is slightly covered with vegetation. The area shows hummocky topography with an average height of 4 m above MSL.


*Fig. 2 Broken tube burrows specimens*

### CLIMATIC CONDITIONS

The annual rainfall of the study area varies between 1200-1900 mm, in which rainfall by Northeastern monsoons (November to February) and the inter-monsoon are dominated (Panabokke et al, 2002). One third of the year falls in the dry season with an average temperature of 33-38 °C (Panabokke et al, 2002). Typically Thuraineelaveli area is characterized by annual floods (November to February) and droughts (May to August).

## MATERIALS AND METHODS

The trace fossils were initially studied in November, 2014 under natural exposure. These were standing perpendicular to the sediment deposition of the Thuraineelaveli in Batticaloa District, Sri Lanka. Dimensions and geometry of such natural occurrences were recorded by photography. A total of 25 loose specimens was collected to carry out detailed analysis. Polished cross sections were prepared using sandpaper on selected specimens and fine structures were identified using Scanning Electron Microscopy (SEM images) was done with Energy Dispersive

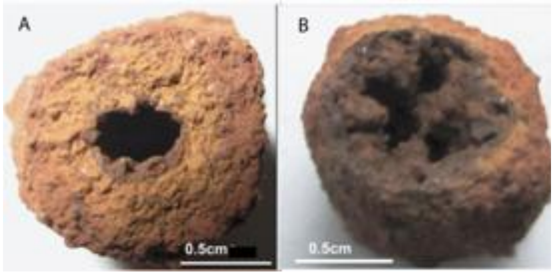


*Fig. 3. Cross sections of the tube burrows. A and B are two selected specimens. Color rims around the center hole shows dark inner wall and reddish outer wall with yellow color low oxidized zone in between.*

X-ray Spectroscopy (EDS) at the Department of Geology, University of Peradeniya, Sri Lanka. Prior to the EDS analysis, specimens were coated with gold

## RESULTS AND DISCUSSION

### DESCRIPTION OF TRACE FOSSILS

Tube burrows found in Quaternary sediments of near marine environment in Eastern Sri Lanka are simple with vertical to near vertical geometry and prolongs perpendicular to the sediment beds. The recorded maximum length of the specimens is 20 cm. Branching of these fossils was rarely observed and is Y–shaped (Fig. 2). The external diameter of the tube is less than 1 cm and the internal diameter is less than 5 mm. The fossil has a near circular outer cross section and irregular internal cross section where the burrow wall is distinct with its irregularity (Fig. 3). Mineralized walls are observed as colored rims around the central hole in cross section. The inner wall is dark in color and outer wall is red. Between the inner and the outer walls, a yellow color rim was observed. The color rims around the internal wall indicates the oxidation conditions. In three dimensions the irregularities are elongated striations that are oblique and perpendicular to the tube axis. Burrows are not densely crowded in the area. Traces are preserved in rounded sand deposits.

### SEM OBSERVATIONS

Quartz grains of the tube burrow are tightly compacted in the iron matrix. The iron matrix is composed of tiny octahedral pyrite crystals and clay minerals enriched in aluminum and silicon

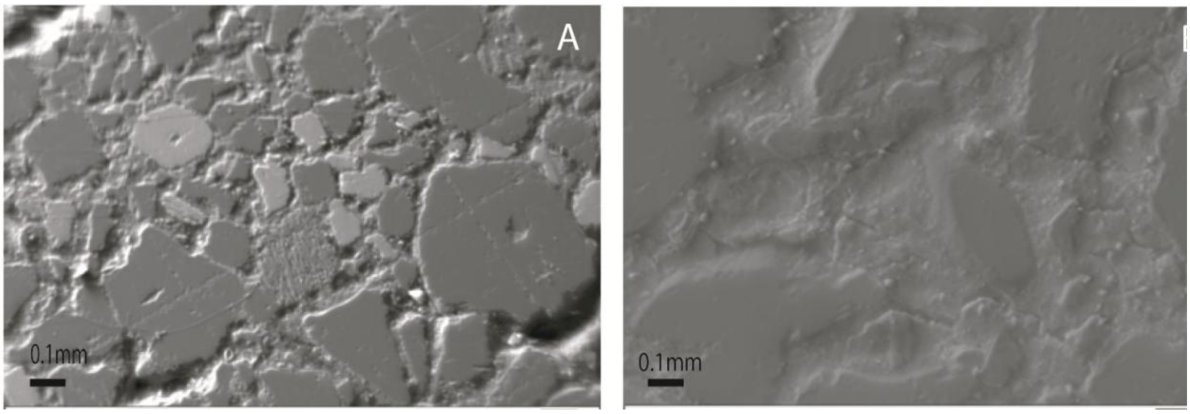


*Fig. 4 SEM images of a tube burrow. A. Burrow has compacted fine to medium grains in a clayey matrix. B. Tiny pyrite octahedral crystals could be observed in the clayey matrix.*

oxides (Fig. 4). The mucus secreted by the burrower traps the fine grains by soaking them and facilitates the vertical tube to stand alone (Bromley, 1996). The diameter of the tube burrow depends on the amount of mucus secreted by the organism and deposited in each direction during its locomotion through the burrow. The inner wall striations might be structures created due to parapodium or tiny spines of the trace maker during the locomotion in the soft sediments (Fig. 5) (Chamberlain, 1975, Han et al., 2007). The inner lining of the tube has no external material except the wall ornamentation. The margins of the internal wall include honeycomb-like structures (in 2D cross section) that show circular arrangements around the internal wall (Fig. 6 A and B). The ornamentation with honeycomb-like structures of the specimens could be a sclerite of a polychaete that lived in shallow marine environments (Chamberlain, 1975; Barwis, 1985) or detritus of the animal that made brick works on the burrow wall (Bromley, 1996). The interior of honeycomb-like structures is filled with finer spherules (Fig. 6 C and D). Comparatively, EDS analysis indicates iron and oxygen content of these finer spherules and the wall of the sclerite is high with less carbon content (Table 1). The innermost wall of the tube burrow shows distribution of angular shape microscopic particles (Fig. 6 B). In contrast, tiny crystals of this innermost wall of tube show high amounts of aluminum, carbon and silicon with dominant iron component (Table 1).

## FOSSIL PRESERVATION

The structures preserved in the present samples indicate sclerite of the original animal. Building of the innermost part of the wall might be due to locomotion of the burrower while spreading the fecal material around. The ferric iron concentration of the wall was probably original and/or might be resultant due to an activity of the organisms. It has been noted that in low pH environments, the microbacterial activities of polychaetes could destroy the original

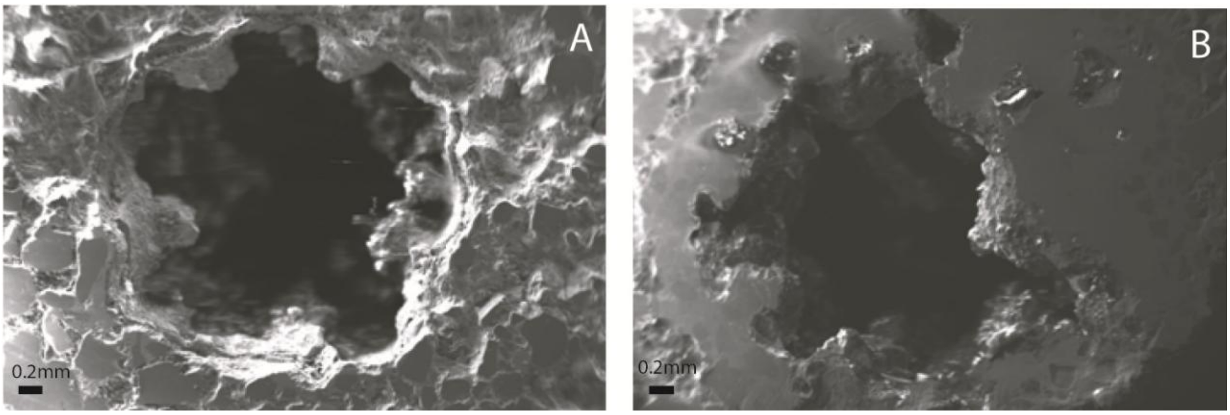


*Fig. 5 SEM images of the irregular internal cross section of the tube burrows. A and B are two different sections*

mineralogy of clay minerals and form iron rich clay minerals (Needham et al., 2004). They might be rich in aluminum ferrous silicates such as chamosite or berthierine (Palmer and Wilson, 1990; Needham et al., 2004). Hence, innermost part of the burrow wall of studied samples could have originated from minerals such as chamosite or berthierine from pellets of polychaetes.

Pyritization of the above minerals and subsequent oxidation may have improved the wall preservation. Probably the spherules of the sclerite are framboids of pyrite. Literature recorded pyrite as the most probable original mineral in iron rich fossil preservation, which at present shows by replicated iron oxides, however, without sulfur in the chemistry (Schieber, 2002; Löwemark and Schäfer, 2003; Vertazalo et al., 2010; Ahn and Babcock, 2012). Except iron, the chemistry of the present samples indicates high percentages of carbon, silicon and aluminium (Table 1). Because of the absence of sediment deposition over the area, some of the surface organic carbon might have been oxidized. The oxidation condition of iron, indicating red to orange color, is a characteristic of an aerobic environment. However, the presence of high carbon content associated with burrow wall indicates the activity of microbes in bio-deformations during the preservation processes (Aller and Aller, 1986; Wetzel and Uchman, 2012). Perhaps, these carbons may have been preserved in the form of cuticular organic matter followed along the organic films of burrow walls (Zhu et al., 2005). Hence, the fossil preservation of the tube burrows could have occurred due to cuticular organic matter and mineralization processes such as pyritization and aluminosilicatization of the original minerals secreted by the burrower which mediated by micro bacterial activities (Han et al., 2007).

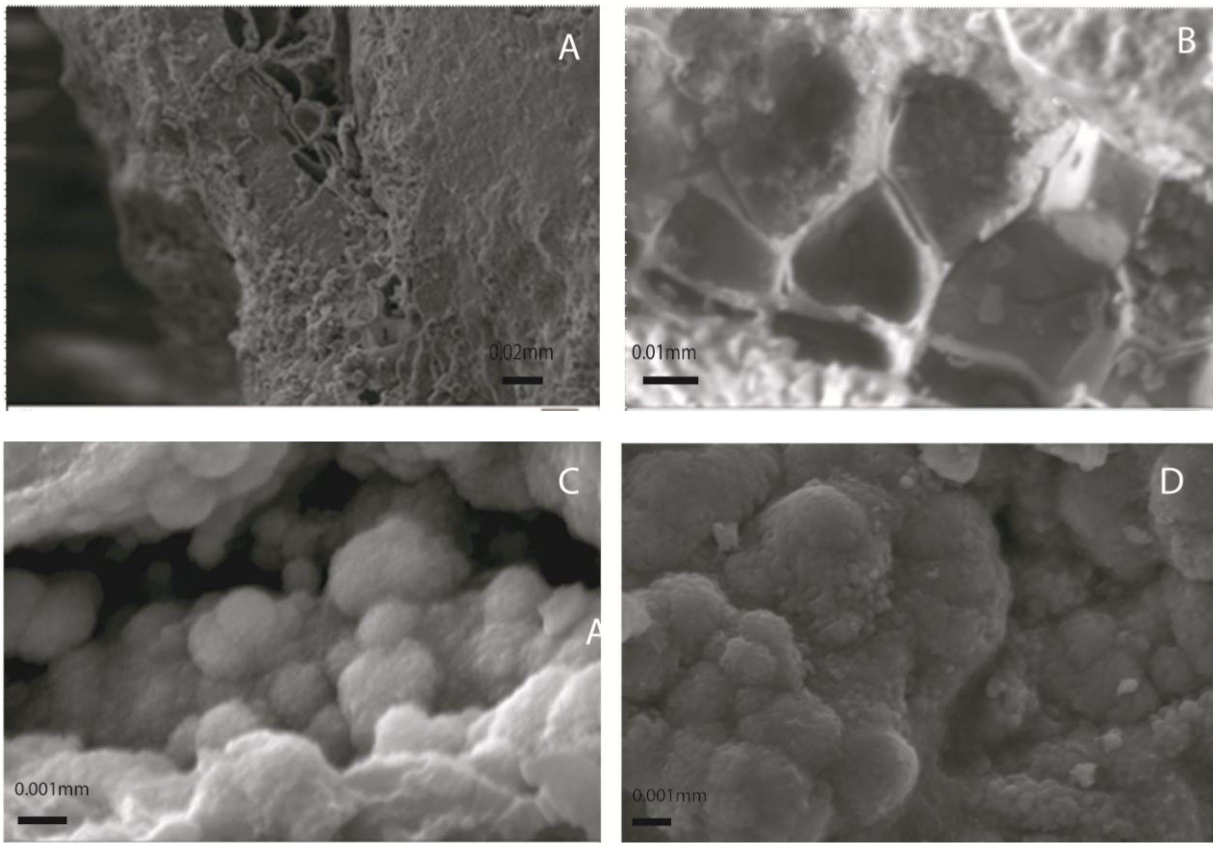


*Fig. 6 SEM images of the internal wall lining of the tube. A. Sclerite shows honeycomb like structure. B. The innermost part of the inner wall has angular loose crystals probably chamosite or berthierine. C. and D Framboids of pyrite filled the honeycomb like structure.*

*Table 1 EDS analysis comparing the spherules inside the sclerite, cover of sclerite and tiny crystals of the inner wall*

| Element | Weight (%) | | | | | |
|---|---|---|---|---|---|---|
| | **Spherules inside the sclerite** | | **Cover of sclerite** | | **Tiny crystals of the inner wall** | |
| | **Specimen 1** | **Specimen 2** | **Specimen 1** | **Specimen 2** | **Specimen 1** | **Specimen 2** |
| C | 5.32 | 2.18 | 14.78 | 11.06 | 9.76 | 7.33 |
| O | 48.77 | 26.94 | 51.07 | 44.67 | 53.29 | 38.22 |
| Al | 1.37 | 0.66 | 1.50 | 1.72 | 22.88 | 2.71 |
| Si | 1.20 | 0.50 | 1.30 | 1.87 | 3.37 | 1.72 |
| Fe | 43.35 | 69.72 | 30.60 | 39.99 | 7.90 | 50.03 |
| Pb | - | - | 0.75 | 0.96 | - | - |
| Ni | - | - | - | - | 2.25 | - |
| Ti | - | - | - | - | 0.22 | - |
| Ag | - | - | - | - | 0.32 | - |

## CONCLUSIONS

Taphonomic study on the burrow wall of tube burrows found in Quaternary sediments of the Eastern coast of Sri Lanka indicates that the burrow preservation was due to the ornamentation of the internal wall structure and secondary mineralogy that bound the grains. The activities of the trace maker and secondary microbially mediated biomineralization under preferable environments have facilitated the preservation.

The internal burrow wall ornamentation is due to the structures produced by the sclerite and the fecal material around the burrow wall. The mineralogy of the ornamented wall indicates micro bacterial mediated pyritization and aluminosilicatization which have strengthened the tubes under aerobic shallow marine environments. Formation of cuticular organic matter in and around the organic films of the burrow wall also assisted the preservation process. Exposure of the environment to fully oxidized conditions has facilitated the strengthening of tube burrows.

## REFERENCES

Ahn, S.Y. and Babcock, L.E. (2012) Microorganism – Mediated preservation of Planolites, a common trace fossil from the Harkless Formation, Cambrian of Nevada, USA, Sedimentary Geology, 263-264: 30-35.

Aller J.Y. and Aller, R.C. (1986) Evidence for localized enhancement of biological associated with tube and burrow structures in deep-sea sediments at the HEEBLE site, western North Atlantic, Deep Sea Research Part A. Oceanographic Research Papers, 33: 755-790.

Allison, P.A. and Bottjer, D.J. (2011) Taphonomy: Bias and process through time, Topics in Geobiology 32, DOI 10.1007/978-90-481-8643-3_1.

Barwis, J.H. (1985) Tubes of the modern polychaete *Diopatra cuprea* as current velocity indicators and as analogs for *Skolithos-Monocraterion*, In Biogenic structures: Their use in interpreting depositional environments, Curran, H.A. (ed.), Spec. Publ., Soc. Econ. Paleont. Mineral., 35, pp 225-235.

Behrensmeyer, A.K. (1984) Taphonomy and the Fossil Record: The complex processes that preserve organic remains in rocks also leave their own traces, adding another dimension of information to fossil samples, American Scientist, 72: 558-566.

Bromley, R.G. (1996) Trace Fossils. Biology, Taxonomy and Applications, 2nd ed. London.

Chamberlain, C.K. (1975) Recent lebensspuren in nonmarine aquatic environments, In Frey, R.W. (ed.) The Study of Trace Fossils: Berlin, Springer-Verlag, pp 431-458.

Cooray, P.G. (1984) An Introduction to the Geology of Ceylon. Naional Museum of Ceylon publications, Colombo, pp 340.

Cooray, P.G. and Katupotha, K.N.J. (1991) Geological evolution of the coastal zone of Sri Lanka. Proceedings of Symposium on causes of coastal erosion in Sri Lanka, Colombo. pp 5-26.

Gingras, M.K., Zonneveld, J.P. and Konhauser K.O. (2014) Using X-Ray radiography to observe Fe distribution in bioturbated sediment, Experimental Approaches to Understanding Fossil Organisms Topics in Geobiology, 41: 195-206.

Han, J., Liu, J., Zhang, Z., Zhang, X. and Shu, D. (2007) Trunk ornament on the palaeoscolecid worms Cricocosmia and Tabelliscolex from the Early Cambrian Chengjiang deposits of China. Acta Palaeontologica Polonica 52 (2): 423–431.

Katupotha, K.N.J. (2007) Coastal Landforms, The National Atlas of Sri Lanka, Second Edition, Survey Department of Sri Lanka. pp 40-42.

Löwemark, L. and Schäfer, P. (2003) Ethological implications from a detailed X-ray radiograph and 14C study of the modern deep-sea Zoophycos, Palaeogeography, Palaeoclimatology, Palaeoecology, 192: 101–121.

Needham, S.J, Worden, R.H. and McIlroy, D. (2004) Animal-sediment interactions: the effect of ingestion and excretion by worms on mineralogy, Biogeosciences, 1: 113–121.

Palmer, T.J. and Wilson, M.A. (1990) Growth of ferruginous oncoliths in the Bajocian (Middle Jurrasic) of Europe, Terra Nova, 2: 142-147.

Panabokke C.R., Pathirana S.R.K. and Wijekoon D. (2002) Water quality of agro-wells in the coastal sand aquifer in Trincomalee District. Symposium proceedings on the Use of Groundwater for Agriculture in Sri Lanka, University of Peradeniya, Sri Lanka, pp 85-98.

Schieber, J. (2002) The Role of an Organic Slime Matrix in the Formation of Pyritized Burrow Trails and Pyrite Concretions, Palaios, 17: 104–109.

Vertazalo, J.J., Löwemark, L., Papunen, H., Kotilainen, A.T. and Whitehouse, M.J. (2010) Pyritic and baritic burrows and microbial filaments in postglacial lacustrine clays in the northern Baltic Sea, Journal of the Geological Society, London, 167: 1185–1198.

Wetzel, A. and Uchman, A. (2012) Hemipelagic and Pelagic Basin Plains, Developments in Sedimentology, 64: 673-701.

Zhu, M.Y., Babcock, L.E. and Steiner, M. (2005) Fossilization modes in the Chengjiang Lagerstätte (Cambrian of China): testing the roles of organic preservation and diagenetic alteration. Palaeogeography, Palaeoclimatology, Palaeoecology, 220: 31– 46.