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Foraminifera in the Holocene sediments at the shallow sea from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam) (0÷60 m of water depth)

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ABSTRACT

The shallow sea (0÷60 m of water depth) from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam) belongs to the internal shelf in Central Vietnam. This is quite a good geological structure for the land-sea interaction study, especially during the Holocene. Therefore, it is necessary to study the geological history of the area during the Holocene period. Foraminifera is the subject of geological studies to solve the environmental problems of sedimentary, stratigraphic, and paleogeography. However, at present, the research documents on Foraminifera in the sediments in Vietnam in general as well as in the research area in particular are still very modest. This paper presents research results of Foraminifera fauna in Holocene sediments from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam) (0÷60 m of water depth). 93 species, belonging to 48 genera, 28 families and 5 suborders Foraminifera have been identified based on the analysis of 59 available samples. Miliolina Delage et Hérouard, 1896 has 06 families, 18 genera and 40 species; Rotaliina Delage et Hérouard, 1896 has 12 families, 15 genera and 29 species; Textulariina Delage et Hérouard, 1896 has 03 families, 05 genera and 07 species; Lagenina Delage et Hérouard, 1896 has 03 families, 04 genera and 07 species; Globigerinina Delage et Hérouard, 1896 has 04 families, 06 genera and 10 species. The quality of the benthonic Foraminifers is dominant, clearly showing the geological environment of the shallow sea near shore, where the hydrodynamic regime is high and the salt concentration is not stable.

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1. Introduction

The shallow sea area (0÷60 m of water depth) from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam) belongs to the internal shelf of Central Vietnam. This is one of the areas having geological structures which is quite favorable for studying the process of land-sea interaction, especially in the Holocene period. It is therefore, the area has attracted a lot of attention from researchers in geology and sedimentology (Hoang, 2012; Ngo et al., 2020; Pham et al., 2020).

The research area is limited by the coordinates of 4 points given in Table 1. This area has complex topographical features like the general complexity of the Central Vietnam shelf. The width is not large, and the slope increases rapidly with the depth of the seafloor as shown by the contour lines distributed relatively thick at the depth of 0÷15 m, strong curves at the depth of approximately 15÷30 m, and at the depth of 30÷60 m the topographic contour lines run in the northwest-southeast direction (Figure 1). Changes in seafloor depth and slope rapidly, lead to hydrodynamic regime change which plays an important role in the distribution of sedimentary materials due to interaction with sea level fluctuations, wave activity, tides, and currents.

Table 1. Coordinates of the researched area.

N^0	North Latitude	East Longitude
1	16^{0}22’49.06”	107^{0}52’43.20”
2	16^{0}23’58.28”	108^{0}16’05.61”
3	15^{0}54’13.85”	108^{0}37’02.06”
4	15^{0}45’35.90”	108^{0}26’26.05”

Regarding the characteristics of surface sediments in the research area, they are divided according to the classification system of Folk R. (Hoang, 2012) including 7 types: Sand (S), gravelly sand (gS), muddy sand (mS), gravelly muddy sand (gmS), mud (M), gravel (G), sandy mud (sM) (Figure 1). In which most of the researched area is sand distributed along the coast from 0÷10 m of water depth. In the range of 10÷30 m of water depth, sand is interspersed with muddy sand, gravelly sand, and gravelly muddy sand. At a depth of more than 30 m, the sediments are mainly muddy sand and mud. In which mud occupies a larger area. In general, in the research area, the sediment is characterized by a decreasing particle size from the shore to the sea.

Regarding the characteristics of microfossils, we chose the Foraminifera for research purposes. The reason: Foraminifer, Rhizopoda class, Sarcodina subphylum, Protozoa phylum (Loeblich et al., 1964; Loeblich and Tappan, 1988)

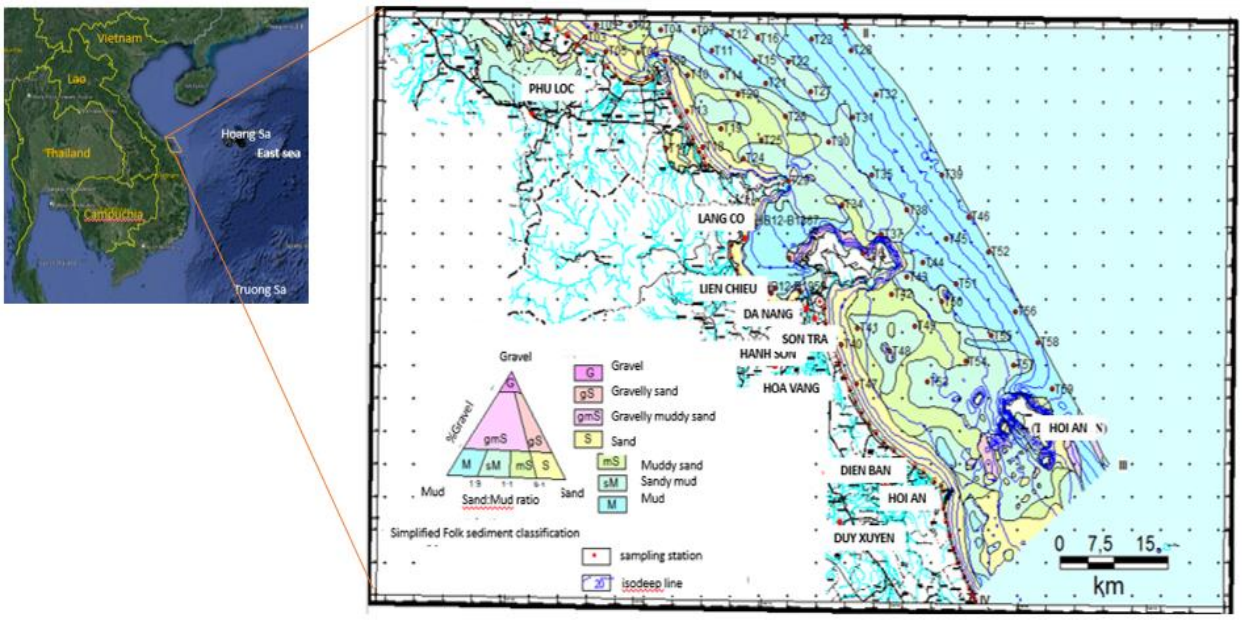

Figure 1. Diagram of sediment field distribution and location of sampling stations in the research area (Hoang, 2012).

are the subjects of research in geology to solve environmental problems of sedimentary formation, stratigraphy and paleogeography. However, at present, the research literature on this group of fossil organisms in marine sediments in Vietnam in general as well as in the studied area in particular is still very modest. The general scientific work on Foraminifera in our country is "Foraminifer Kainozoic in the continental shelf and surrounding areas in Vietnam " (Nguyen et al., 2006). Where 241 species, belonging to 90 generas, 49 families and 6 suborders of Foraminifera have been identified and described in detail. In addition, there are foram studies in coastal and deep sea areas (Ngo et al., 2015; Ngo et al., 2016; Ngo and Dang, 2021; Nguyen, 2018).

In recent years, the basic geological investigation of coastal and nearshore shallow sea has been promoted, including the research area. In those projects, one of the methods of palaeontology has been applied, which is the analysis of the Foraminifera to restore paleogeographic, paleoenvironmental and paleoclimatic conditions.

2. Materials and methods

2.1. Materials

This article presents the results of the analysis of 59 samples of paleontology (Foraminifera) in shallow sea sediments (0÷60 m of water depth) from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam) (Figure 1). Samples were collected by the Center for Marine Geology and Minerals during the implementation of the project "Investigation of geological features, geodynamics, mineral geology, environmental geology and prediction of geological hazards in the coastal area from Thua Thien Hue to Binh Dinh province, scale 1:100,000".

2.2. Methods

This article applies the analysis method of microfossils. The samples collected from the sea have been processed and analyzed at the Center for High-Tech Analysis of the Hanoi University of Mining and Geology.

The authors used a microscope to observe in detail the external and internal morphological structures and characteristic features of the fossils. Then compared with the first description of the species and genera by other authors, when there is a match, the scientific name of the fossil can be identified. After determining the species name, the author systematically arranged the species into the classification system of Foraminifera according to Loeblich and Tappan (1988) to capture the morphology of the fossil foraminifera. In this process, our Scanning Electron Microscope (SEM) was used to get clearer images than those obtained by the Microscope imaging method.

3. Results and discussion

3.1. The characteristics of genus and species composition

The results of the analysis of 59 samples in the research area 93 species have been identified which belong to 48 genera, 28 families and 5 suborders of the Foraminifera (Loeblich et al., 1964; Loeblich and Tappan, 1988). The species composition is more dominated by the Miliolina suborder, followed by the Rotaliina suborder (12 families, 15 genera and 30 species), then the Textulariina suborder (3 families, 5 genera and 7 species) and Globigerinina suborder (4 families, 6 genera and 10 species), the least is Lagenina suborder (3 families, 4 genera and 7 species).

3.1.1. Miliolina Delage et Hérouard, 1896 suborder has 6 families, 18 genera and 40 species

1 - *Spiroloculinidae* Wiesner, 1920 family includes 3 genera, the most abundant is *Adelosina* d'Orbigny, 1826 which has 6 species: 1 - *Adelosina costata* (Figure 2); 2 - *Ad. philippinensis*; 3 - *Ad. pulchella*; 4 - *Ad. semireticulata*; 5 - *Ad. Pseudoreticulata* and 6 - *Adelosina* sp.. *Spiroloculina* d'Orbigny, 1826 genus consists of 4 species: 1 - *Spiroloculina communis* (Figure 2); 2 - *Sp. penglaiensis*; 3 - *Sp. lucida* and 4 - *Spiroloculina* sp.. There are 2 species in *Cribrolinoides* Cushman et Leroy, 1939 genus: 1 - *Cribrolinoides* sp. and 2 - *Cribrolinoides curta*;

2. *Hauerinidae* Schwager, 1870 family has 9 genera. *Quinqueloculina* d'Orbigny, 1826 is the most dominant which includes 07 species: 1 - *Quinqueloculina akneriana* (Figure 2); 2 - *Q. boueana*; 3 - *Q. cuvieriana*; 4 - *Q. dosonensis*; 5 - *Q.*

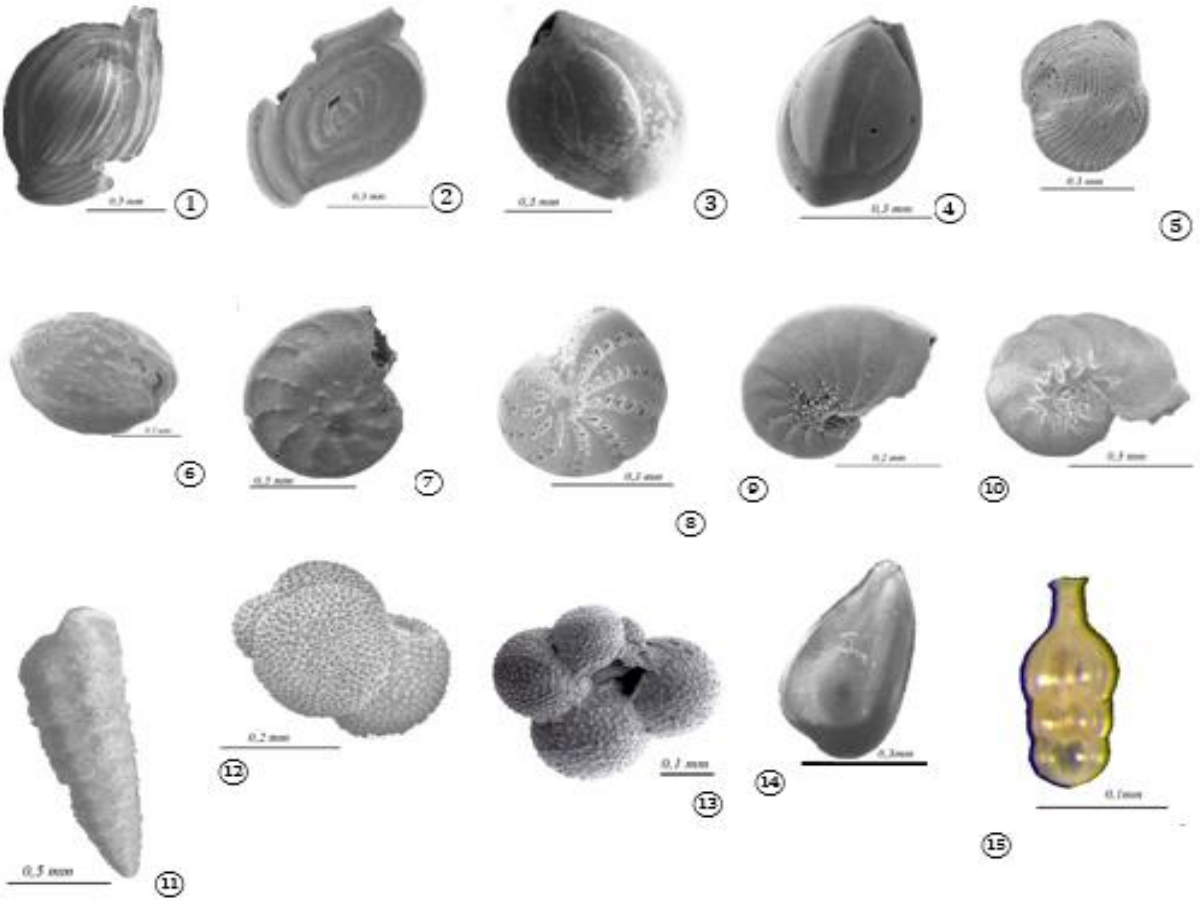

Figure 2. Some species of the Foraminifera in the research area.
①Adelosina costata; ②Spiroloculina communis; ③Quinqueloculina akneriana; ④Triloculina trigonula; ⑤Vertebralina striata; ⑥Pseudorotalia indopacifica; ⑦Operculina ammonoides; ⑧Elphidium advenum; ⑨Nonion sp.; ⑩Hanzawaia sp.; ⑪Textularia sp.; ⑫ Globigerinoides trilobus; ⑬Globigerina calida; ⑭Guttulina pacifica; ⑮Lagenonodosaria scalaris.

elongata; 6 - *Q. tonkinensis* and 7 - *Quinqueloculina* sp. 03 varieties with 2 species were founded: *Pyrgo* Defrance, 1824 genus (1 - *Pyrgo vespertilio* and 2 - *Pyrgo* sp.); *Triloculina* d'Orbigny, 1826 genus (1 - *Triloculina tricarinata* and 2 - *Tri.trigonula* (Figure 2)) and *Massilina* Schlumberger, 1893 genus (1 - *Massilina secans* and 2 - *Massilina* sp.); The remaining 05 genera varieties have 1 species each: *Schulumbergerina* Munier-Chalmas, 1882 (*Schlumbergerina* sp.); *Flintina* Cushman, 1921 (*Flintina bradyana*); *Siphonaperta* Vella, 1957 (*Siphonaperta agglutinans*); *Hauerina* d'Orbigny, 1839 (*Hauerina* sp.); *Ammomassilina* Cushman, 1933 (*Ammomassilina* sp.)

3. *Cornuspiridae* Schultze, 1854 family has only 01 genus (*Cornuspira* Schultze, 1854) namely 01 species (*Cornuspira involvens*).

4. *Ophthalmidii-dae* Wiesner, 1920 family has 01 genus: *Edentostomina* Collins, 1958 with 02 species: 1. *Edentostomina cultrata* and 2. *Edenostomina* sp.

5. *Peneroplidae* Schultze, 1854 family with 03 genera: *Peneroplis* de Montfort, 1808 has 02 species: 1 - *Peneroplis* sp. and 2 - *Peneroplis planatus*. *Coscinospira* Ehrenberg, 1839 has 01 species (*Coscinospira hemprichii*) and *Dendritina* d'Orbigny, 1826 genus include 02 species: 1 - *Dendritina cuvieri* and 2 - *Dendritina* sp.

6. *Ficherinidae* Millett, 1898 family has 1 genus *Vertebralina* d'Orbigny, 1826 with 2 species 1 - *Vertebralina striata* (Figure 2) and 2 - *Vertebralina* sp.

3.1.2. The Rotaliina Delage et Hérouard, 1896 suborder has 12 families, 15 genera and 29 species

1. *Rotaliidae* Ehreberg family, 1839 is the most dominant, with 03 genera: *Ammonia Brunnich*, 1772 including 04 species: 1 - *Ammonia annectens*; 2 - *A. beccarri*; 3 - *A. japonica* and 4 - *Ammonia* sp.. *Pseudorotalia* Reis et Merling, 1958 genus has 03 species: 1 - *Pseudorotalia indopacifica* (Figure 2); 2 - *P. Schroeteriana* and 3 - *Pseudorotalia* sp.. *Asterorotalia* Hofker, 1950 includes 02 species: 1 - *Asterorotalia gaimardii* and 2 - *A. multispinosa*;

2. *Nummulitidae* Blainville, 1827 family has 02 genera *Operculina* d'Orbigny, 1826 with 02 species 1 - *Operculina* sp. and 2 - *Operculina ammonoides* (Figure 2). *Heterostegina* d'Orbigny, 1826 genus has 01 species of *Heterostegina* sp.

3. *Elphidiidae* Galloway, 1933 family has 01 genus *Elphidium* de Montfort, 1808 with 05 species 1 - *Elphidium advenum* (Figure 2); 2 - *E. crispum* ; 3 - *E. hispidulum*; 4 - *E. jenseni* and 5 - *Elphidium* sp.

4. *Cibicididae* Cushman, 1927 family with 01 genus: *Cibicides* de Montfort, 1808 has 02 species 1 - *Cibicides refunens* and 2 - *Cibicides* sp..

5. *Amphisteginidae* Cushman, 1927 family has 01 genus: *Amphistegina* d'Orbigny, 1826 includes 02 species: 1 - *Amphistegina lessoni* and 2 - *A. Madagascariensis*.

6. *Nonionidae* Schultz, 1854 family with 01 genus: *Nonion* de Montfort, 1808 consists 02 species 1 - *Nonion japonicum* and 2 - *Nonion* sp. (Figure 2).

7. *Eponididae* Hofker, 1951 family has 01 genus: *Eponides* de Montfort, 1808 with 1 - *Eponides repandus* and 2 - *Eponides* sp..

8. *Bolivintidae* Glaesner, 1937 family has 01 genus: *Bolivina* d'Orbigny, 1839 having 01 species: *Bolivina* sp..

9. *Gavelinellidae* Hofker, 1951 family has 01 genus: *Hanzawaia* Asano, 1944 with *Hanzawaia* sp. species (Figure 2).

10. *Bagginidae* Cushman, 1927 family with *Cancris* de Montfort, 1808 genus, species Cancris sp..

11. *Rosalinidae* Reiss, 1963 family has 01 genus: *Rosalina* d'Orbigny, 1826 and species *Rosalina* sp.

12. *Calcarinidae* Schawager, 1876 family has 01 genus: *Calcarina* d' Orbigny, 1826 and 01 species (*Calcarina spengleri*).

3.1.3. Textulariina Delage et Hérouard, 1896 suborder has 3 families, 5 genera and 7 species

1. *Textulariidae* Ehrenberg, 1838 family has 02 genera, each genus has 01 species: *Textularia* Defrance, 1824 genus with *Textularia* sp. (Figure 2); *Bigeneria* d'Orbigny, 1826 genus with the *Bigenerina* sp.

2. *Lituolidae* Blainville, 1827 family includes 02 genera: *Trochammina* Parker et Jones, 1859 genus has 02 species 1 - *Trochammina japonica* and 2 - *Trochammina* sp. *Ammobaculites* Cushman, 1910 genus has 01 species (*Ammobaculites* sp.).

3. *Hormosinidae* Haeckel, 1894 family has 01 genus: *Reophax* Montfort, 1808 with 02 species 1 - *Reophax excentricus* and 2 - *Reophax* sp.

3.1.4. Globigerinina Delage et Hérouard, 1896 suborder includes 4 families, 6 genera and 10 species

1. *Globigerinidae* Carpenter, Parker et Jones, 1862 family has 3 genera. The most dominant is the genus: *Globigerinoides* Cushman, 1827 with 3 species: 1 - *Globigerinoides ruber*; 2 - *G. trilobus* (Figure 2) and 3 - *G. sacculifer*. The remaining 02 varieties each contribute 01 species: the genus *Globigerina* d'Orbigny, 1826 (species *Globigerina calida* (Figure 2)); genus *Globigerinella* Cushman, 1827 (species *Globigerinella* Cushman, 1827)

2. *Hastigerinidae* Bolli, Loeblich et Tappan, 1957 family has 01 genus: *Hastigerina* Thomson, 1876 with 01 species *Hastigerina pelagica*.

3. *Globorotaliidae* Cushman family, 1927 contributes 01 genus: *Globorotalia* Cushman, 1927 with 02 species: 1 - *Globorotalia menardyi* and 2 - *Globorotalia* sp..

4. *Catapsydracidae* Bolli, Loeblich and Tappan, 1957 family has 01 genera with 02 species 1 - *Globoquadrina* sp. and 2 - *Globoquadrina siphonifera*.

3.1.5. Lagenina Delage et Hérouard, 1896 suborder has 3 families, 4 genera and 7 species.

1. *Vaginulidae* Reuss, 1850 family is the most dominant with 2 genera: *Lagenonodosaria* Silvestri, 1900 has 02 species 1 - *Lagenonodosaria scalaris* (Figure 2) and 2 - *Lagenonodosaria* sp.. *Lenticulina* Lamarck, 1804 has only 01 species *Lenticulina* sp..

2. *Polymorphinidae* d'Orbigny, 1839 family has 01 genera, *Guttulina* d'Orbigny, 1839 with 03 species 1 - *Guttulina* sp.; 2 - *G. striata* and 3 - *G. pacifica* (Figure 2).

3. *Glandulinidae* Reuss, 1860 family has 01 genus *Glandulina* d'Orbigny, 1839 with 01 species *Glandulina laevigata.*

3.2. Paleoecological characteristics

The analysis results show that the characteristics of the Foraminifera in the research area are mostly benthonic Foraminifera species. They are not only diverse in taxonomic compositions (genera, species) but also rich in a number of individuals. In the analysis of sand samples, the conservation level as well as the number of fossils are low, the finer grain samples have better conservation levels and are richer in species compositions. At a depth of > 30 m, there are some floating life forms (planktonic foraminifera) belonging to the Globigerinina suborder with a higher level of conservation and a bigger number of individuals.

The varieties and species of benthonic species found in our research area are mostly of an ecological group that can adapt to different salt levels such as *Ammonia beccarri*, *Elphidium hispidulum*, *Spiroloculina communis*, *Trochammina japonica*, *Nonion japonicum*. Those forms are capable of adapting to living conditions with high salinity fluctuations, typical for coastal estuarine environments. Besides, some species have features of flattened morphology, easy to swing (disc-shaped, flattened sphere), solid shells, able to adapt to a strong dynamic environment thus name for examples: *Operculina* sp., *Ammonia annectens*, *Ammonia japonica*, *Cornuspira involvens*, *Spiroloculina penglaiensis*, *Amphistegina madagascariensis* and several species of the Elphidium genus.

4. Conclusion

Based on the results of analyzing the composition of Foraminifera species in the shallow sea from Phu Loc (Thua Thien Hue) to Hoi An (Quang Nam), the following conclusions have been made:

In the sediments of the study area, 93 species belonging to 48 genera, 28 families and 5 suborders of the Foraminifera as per the classification of Loeblich and Tappan, have been identified. Where the benthonic foraminifers have 4 suborders (24 families, 42 genera and 83 species), the plankton Foraminifers have 1 suborder (4 families, 6 genera and 10 species). The quality of the benthonic Foraminifers is dominant, showing clearly the geological environment of the shallow sea near shore, where the hydrodynamic regime is high and the salt concentration is not stable.

Three species of Foraminifera are valid for Holocene dating: *Flintina bradyana*, *Globigerina calida*, *Siphonaperta agglutinans*.

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Contribution of authors

Binh Van Phan, Hieu Huu Nguyen, Quyen Minh Nguyen, Hien Thu Thi Bui - collected the samples; Chi Kim Thi Ngo - prepared the manuscript; Lac Van Mai - manuscript review.

References

Hoang, V. L. (2012). Mapping surface sediments from Tu Hien (Thua Thien Hue) to Binh Son (Quang Ngai) (0÷60 m of water depth). *Center for Planning - Investigation of Northern marine resources and environment*. 57 pages.

Loeblich, A. R., Tappan, H., & Moore, R. C. (1964). Treatise on invertebrate paleontology, Part C, Protista 2. *Geol. Soc. Am., Univ. Kansas Press, Lawrence*, 869pp.

Loeblich, A. R. Jr., & Tappan, H. (1988). Foraminiferal genera and their classification. Department of Earth and Space sciences and Center for the study of Evolution and the origin of Life University of California, Los Angeles. 21-114.

Ngo, T. K. C., Mai, V. L., & Dao, V. N. (2016). Foraminifers in the marine sedimentation of the coastal zone in Thua Thien Hue area. *Journal of Geology*, No 355. 83-90.

Ngo, T. K. C., Mai, V. L., & Dao, V. N. (2015). Foraminifera complexes in the sediment of surface layer in Thua Thien Hue - Da Nang coastal zone (0÷30 m of water depth). *Journal of Mining and Earth Science*, No 51. 13-20.

Ngo, T. K. C., & Dang, V. B. (2021). Characterization of foraminifera in the southern East Sea during the late Holocene. *Journal of Mining and Earth Sciences Vol. 62, Issue 6.* 8 - 13.

Ngo, T., Vu, D. A., Van Phan, B., & Nguyen, H. Q. (2020). Quality characteristics of Ilmenit minerals in the south central of Vietnam by SEM and QEMSCAN analysis. *Journal of Mining and Earth Sciences*, Vol. 61(1), 71-81.

Nguyen, N. (2018). Holocene Foraminifera fauna at the region of Phan Vinh island, Truong Sa archipelago and some related problems. *Vietnam Journal of Marine Science and Technology*, 18(1). 39-51.

Nguyen, N., Nguyen, H. C., & Do, B. (2006). Foraminifer Kainozoic in the continental shelf and surrounding areas in Vietnam. *Vietnam Academy of Science and Technology, Hanoi.* 392 pages.

Pham, N. S., Dang, V. B., Nguyen, H. H., & Ngo, T. K. C. (2020). Characteristics of sediment provenance in the southwestern East Sea. *Journal of Mining and Earth Sciences Vol*. 61, Issue 5. 11 -19.