Journal of Geoscience and Environment Protection, 2014, 2, 80-85
Published Online June 2014 in SciRes. http://www.scirp.org/journal/gep
http://dx.doi.org/10.4236/gep.2014.23011

Scientific Research

Planktonic Foraminifera Diversity in the Sea of Okhotsk and Correlation to Past Climate Change

A. Romanova*, **N. Iurchenko**

Far Eastern Geological Institute, Far Eastern Branch Russian Academy of Science, Vladivostok, Russia
Email: *sandra_ru@bk.ru

Received April 2014

Abstract

80 sediment stations and 4 sediment cores collected in the Sea of Okhotsk were used in this study in order to reveal additional proxy for past climate reconstruction based on planktonic foraminifera. Variation in diversity indices (Simpson, Shannon and equitability indices) along the sea became additional criteria for 5 biogeographical provinces based on planktonic foraminifera. All of them show different structure aspects of the planktonic foraminifera assemblages that is very informative in cases of high relative abundance of *N. pachyderma* sin. and influence of carbonate dissolution factor. During the last 100 ky the diversity indices were changed and we can assume the migration of biogeographical provinces borders: borders of the Northern province were moved to the central part in cold MIS 2, 4, structure of assemblages during MIS 3, 5 was close to the modern Central province but characterized by low total foraminiferal abundance in the sediments. The Simpson and Shannon indices are more sensitive to changes in structure of planktonic foraminifera assemblages when equitability index varies lightly during the Late Pleistocene-Holocene.

Keywords

Planktonic Foraminifera, Diversity Indexes, Late Pleistocene—Holocene, The Sea of Okhotsk

1. Introduction

The object of the study is the Sea of Okhotsk, largest Russian Far East Sea. As a source region of North Pacific Intermediate Water, the Sea of Okhotsk plays a significant role in the ventilation of the North Pacific (Tallay, 1991). Analyzing planktonic foraminifera in marine sediments assists us in reconstructing historical patterns of climatic fluctuations. Studying of planktonic foraminifera in Sea of Okhotsk has some challenges: low quantity of species, one taxon domination in some intervals, low percents of another species, influence of dissolution (Romanova, Cherepanova, & Gorbarenko, 2014). These facts don't allow us to use standard approaches for paleoclimate reconstructions using planktonic foraminifera. Our aims were to document variations in foraminiferal diversity indices to reveal the special characteristics of this proxy for interpreting the paleodata.

*Corresponding author.

How to cite this paper: Romanova, A., & Iurchenko, N. (2014). Planktonic Foraminifera Diversity in the Sea of Okhotsk and Correlation to Past Climate Change. *Journal of Geoscience and Environment Protection, 2,* 80-85.
http://dx.doi.org/10.4236/gep.2014.23011

2. Materials and Methods

80 sediment stations and 4 sediment cores were used in this study. Surface sediment samples were collected by multicorer (MC 800) and piston corer (upper 0 - 5 cm) during the Academician Lavrentev 55 and 42 cruises (**Figure 1**). Cores were collected from the central part of the sea by gravity cores during the Academician Nesmeyanov 25 and Academician Lavrentev 42 cruises (Gorbarenko et al., 2004). Cores were sampled at each 5 - 10 cm intervals for foraminiferal analysis. Samples were prepared by standard techniques of foraminiferal analysis (Barash, 1970). Planktonic foraminifera were identified using taxonomical classification of Loeblich and Tappan (1987). The basic chronology for the most studied core 936 is given by different analyses which result published before (Gorbarenko et al., 2004). Core 936 were divided into foraminiferal complexes that correspond to Marine Isotopic Stages (MIS) and correlated with another cores (LV 40 - 06, LV 40 - 18, LV 40 - 20) that don't have such depth of information (Romanova, 2013). Three diversity indices were calculated by software package PAST usually used for paleontological datasets (Harper, 1999). Simpson index measures concentration of dominance in the community from 0 to 1, taking into account the number of individuals(n) as well as number of taxa (i):

$$c = 1 - \sum\left(\frac{n_i}{n}\right)^2,$$

If Simpson index gives weight to general species Shannon index gives more weight to scarce species. It varies from 0 for assemblages with only a single taxon to high values for assemblages with many taxa:

$$H = -\sum -\frac{n_i}{n}\ln\frac{n_i}{n},$$

Equitability measures the evenness with which individuals are divided among the taxa present:

$$E = \frac{H}{\log S},$$

Diversity indices calculated for surface sediments gives initial model for interpreting data in cores.

3. Results and Discussion

3.1. Foraminifera Diversity and Dominance in Surface Sediments

There are seven species and subspecies in the Sea of Okhotsk (Romanova, 2013): *Neogloboquadrina pachyderma* (Ehrenberg, 1861) sinistral and dextral forms, *Globigerina bulloides* d'Orbigny, 1826, *Turborotalia quinqueloba* (Natland, 1938), *Globigerinita glitinata* (Egger, 1863), *G. uvula* (Ehrenberg, 1861) и *Globorotalia scitula* (Brady, 1882).

Diversity indices calculated for surface sediments showed different patterns (**Figure 2**).

In case with the Sea of Okhotsk index *c* showed the concentration of dominant species *N. pachyderma* sin. Maximum values (0.9 - 1) are in coastal, northern and south-eastern parts of the sea. There are also high *c* values in central part (0.8 - 1) that is conducted with influence of carbonate dissolution in some stations. Minimum *c* values (0.3 - 0.7) and maximum *H* values (0.9 - 1) are revealed in the central part close to 54˚ N. 4 - 7 species and subspecies were found here. Minimum *H* values (0) are also characterized monodominant assemblages of planktonic foraminifera in the coastal area. Low *H* values are in northern and Kuril regions characterized by presence of more dissolution resistant species in sediments. Maximum values of equitability (0.8 - 1) are represented in monodominant assemblages of northern and south-eastern regions of the sea. Minimum *e* values (0.2 - 0.3) are marked in assemblages with maximum number of taxa (6 - 7), which are commonly abundant in the central part. A map of species diversity (number of species) shows a good defined region of high diversity in the central part which characterized by slow accumulation processes, low input of terrigenous material from the coastal area and influence of warm currents from Pacific through Kuril inflows. A map of species equitability shows a broad belt of high species dominance (high equitability) beneath the northern part. Area of low dominance (low equitability) corresponds to the increased relative abundance of Pacific taxa and increased of *G. bulloides* abundance. As a result diversity indices might be additional criteria for distinguishing biogeographical

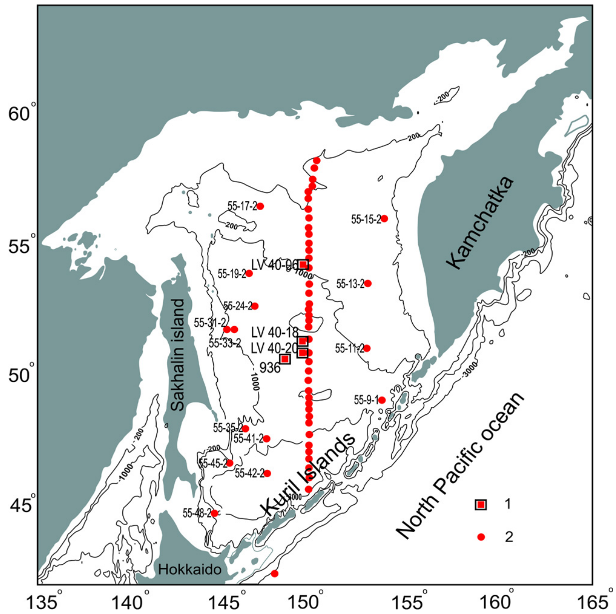

Figure 1. Locations of studied sediment stations (1) and cores (2).

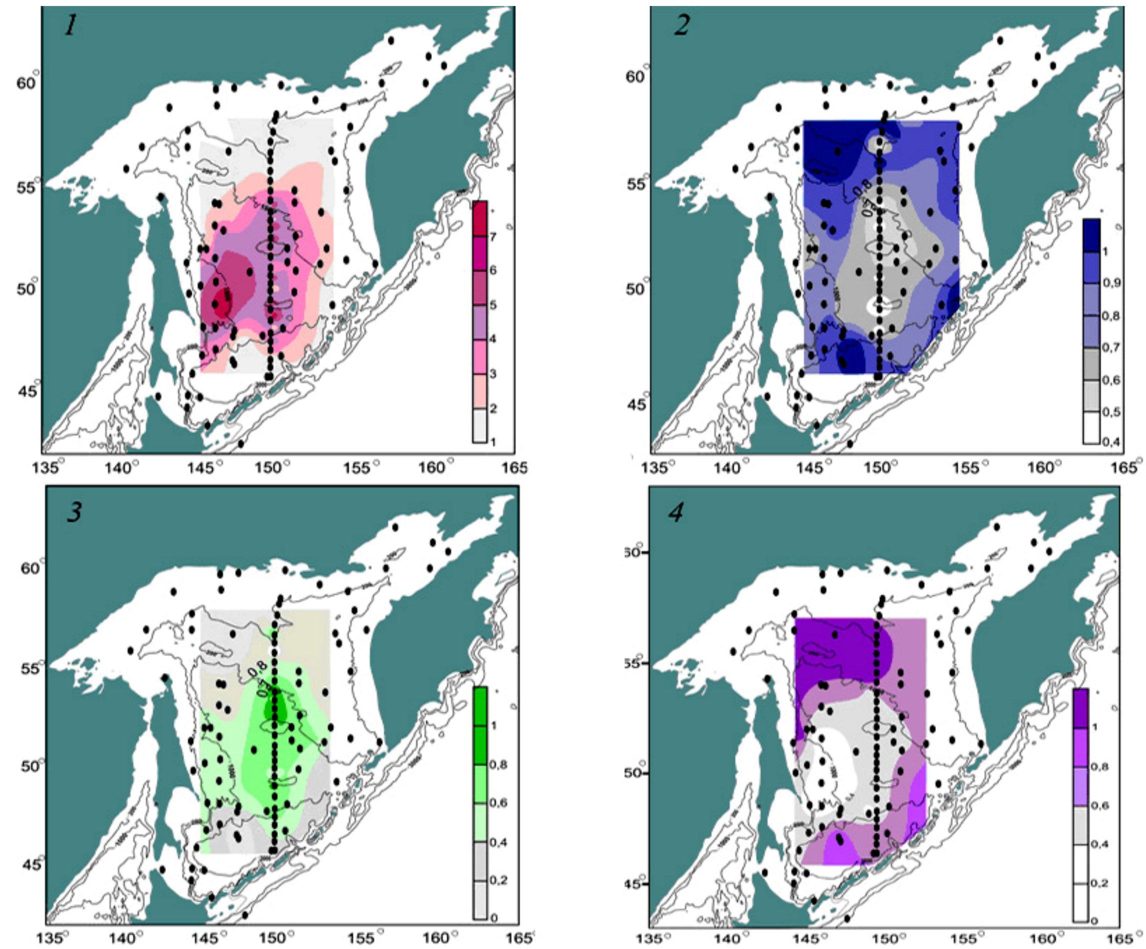

Figure 2. Diversity indexes and the number of taxons: 1: number of taxons; 2: Simpson index; 3: Shannon index; 4: equitability.

provinces (**Table 1**) in the Sea of Okhotsk by planktonic foraminifera that haven't been applied before this study.

3.2. Diversity Indices in the Cores

Applying data obtained from sediment stations we can assume border changes of biogeographical provinces during the last 100 ky. Each complex of planktonic foraminifera corresponds to major climate event or MIS 1 - 5 and characterized by specific proxies of planktonic foraminifera. Additionally we estimate total and relative abundance of planktonic foraminifera, found traces of dissolution in the cores sediments and compare it with calculated diversity indices. Results presented in **Table 2** as averaged dataset for four studied cores.

Diversity indices for complex V (MIS 5) have similar values as majority values for assemblages from the central part of the sea. It must be explained by relatively high number of species (4 - 5) at the paleoassemblage. Averaged diversity indices for complex VI are the same that can be explained by presence of scarce species in certain intervals of MIS 4 that might be reflects short period of warming. Generally complex 4 has all characteristics of the northern part of the Central province that also confirmed by another criteria (**Table 2**). Complex III in spite of relatively small total abundance of foraminifera in the sediments comparing with complex I has all diversity characteristics of the Central province. Shannon index shows high values due to the presence of 6 species but low relative abundance of scarce species the equitability index is still low. Simpson index becomes lower with decreasing of *N. pachyderma* sin. in the sediments during MIS 3. Such structure of paleoassemblage might be formed in conditions close to modern one. Presence of *N. pachyderma* dex. (up to 6%), *T. quinqueloba* (up to 5%), *G. scitula* (up to 1%), *G. glutinata* (up to 1%) indicate the strengthening of Pacific inflow into the Sea of Okhotsk during certain periods of MIS 3. Complex II is characterized as "the coldest" one. Diversity indices are close to the values of Northern province. This period is characterized by strong sea-ice conditions that induced to low concentration of foraminifera in the sediments and total domination of *N. pachyderma* sin. in paleoassemblage. *N. pachyderma* sin. is one of the species that can live in ice where algal biomass in winter is high compared to the water column, perhaps indicating an overwintering strategy (Dieckmann et al., 1991). Complex I is characterized by sharp increasing of total abundance. Diversity indices reflect the structure of paleoassemblage that mostly depends on decreasing percents of *N. pachyderma* (60-78%), increasing of *G. bulloides* abundance up to 28 %, *T. quinqueloba* up to 8 % and presence of *N. pachyderma* dex., *G. scitula*, *G. glutinata*.

Table 1. Biogeographical provinces of the Sea of Okhotsk based on planktonic foraminifera.

Province	Sediments	T (˚C), S (‰)	P	F	Assemblages	*c* *H*, *e*
Coastal	Sand	8 - 10˚C 28 - 30‰	+-	0-0,1	*N. pachyderma* sin.—100%	-
Northern	Aleurite clays	10 - 11˚C 32.5 - 33‰	+ -	12	*N. pachyderma* sin.—92% *G. bulloides*—8%	0.87 0.2 0.88
Central	Thin aleurite clays	11 - 12˚C 32.4 - 32.5‰	+ -	381	*N. pachyderma* sin.—65% *G. bulloides*—22% *T. quinqueloba*—7% *N. pachyderma* dex.—3% *G. glutinata*—<1% *G. uvula*—<1% *G. scitula*—<1%	0.57 0.64 0.57
Southern	Sand, aleurite	13 - 14˚C 33‰	-	-	Presence of *G. ruber* *G. conglobatus*	-
South Eastern	Thin aleurite clays	9 - 10˚C 32.5‰	+	110	*N. pachyderma* sin.—85% *G. bulloides*—12% *G. quinqueloba*—<1% *N. pachyderma* dex.—2% *G. glutinata*—<1% *G. uvula*—<1%	0.79 0.36 0.71

Note: D—traces of dissolution; F—foraminiferal number or total abundance of foraminifera (shells/g of dry sediments); *c*, *H*, *e*—diversity indices.

Table 2. Complexes of planktonic foraminifera in the Sea of Okhotsk in cores 936, LV 40 - 06, LV 40 - 18, LV 40 - 20.

Complex	max F	c, H, e	Characteristics of paleoassemblage	D	Province
I	2749	0.4; 0.7-1; 0.4	Relative abundance of *N. pachyderma* sin down to 54%; *G. bulloides* up to 40%, presence of *N. pachyderma* dex., *G. glutinata*, *T. quinqueloba*, *G. scitula*, *G. uvula*	+-	Central
II	108	0.7; 0.3, 0.7	*N. pachyderma* sin. up to 100%; *G. bulloides* down to 5.6%, presence of *N. pachyderma* dex	-	Northern
III	603	0.4; 0.8; 0.5	*N. pachyderma* sin 43% - 84% *G. bulloides* up to 38% *N. pachyderma* dex. (up to 6%), *T. quinqueloba* (up to 5%), *G. scitula* (up to 1%), *G. glutinata* (up to 1%)	+-	Central
IV	21	0.7; 0.5; 0.6	*N. pachyderma* sin. up to100%; in some intervals presence of *G. scitula*, *G. quinqueloba*; *G. bulloides* up to 20%	-	Northern part of the central province
V	346	0.7; 0.5; 0.6	*N. pachyderma* 60% - 78%; *G. bulloides* up to 28%; *T. quinqueloba* up to 8%; presence of *N. pachyderma* dex., *G. scitula*, *G. glutinata*	+-	Central

Note: Each complex corresponds to MIS 1-5. D—traces of dissolution; max F—maximum of foraminiferal number or total abundance of foraminifera (shells/g of dry sediments); *c*, *H*, *e*—diversity indices.

4. Conclusion

Therefore, we conclude that diversity indices can be additional proxy for paleooceanologial changes that should be used in comprehensive foraminiferal analysis in case with the Okhotsk foraminiferal fauna that has some challenges in studying. Diversity indices show different aspect of changes in structure of foraminiferal assemblages: dominance of *N. pachyderma* sin., increasing role of another taxa, evenness with which individuals are divided among the taxa present. A map of species diversity (number of species) shows a good defined region of high diversity in the central part with slow accumulation rates, low terrigenous dilution and influence of warm Pacific waters. Use of the Shannon diversity index enhances and clarifies this region of high diversity. We assume that Shannon and Simpson indices are more representative and sensitive to changes in structure of assemblages that is caused by environmental changes. Equitability index is not so indicative because in case of small number of species (1 - 2) and dominance of one species it repeats the Simpson index. Correlation the data obtained from sediment station with cores data showed that borders of the biogeographical provinces were moved from the northern part to the central during cold MIS 2, 4. Structure of assemblages during MIS 3, 5 was close to the modern Central province but characterized by low total foraminiferal abundance in the sediments.

Acknowledgements

The authors would like to express their sincere appreciation to Dr. M. Cherepanova for fruitful suggestions and comments, and to Dr. S. Gorbarenko, A. Derkachev for provided material. We also appreciate Prof. V. Pushkar, Prof. M. Kuchera and N. Lubke for their help and constructive critics. This research was supported by grant FEB RAS 14-III-B-08-186.

References

Barash, M. (1970). *Planktonic Foraminifera in North Atlantic Sediments*. Moscow publ.

Dieckmann, G. , Spindler, M. , Lange, M. A. , Ackley, S. F. & Eicken, H. (1991): Antarctic Sea Ice: A Habitat for the Foraminifer Neogloboquadrina Pachyderma. *Journal of Foraminiferal Research, 21,* 182-189. http://dx.doi.org/10.2113/gsjfr.21.2.182

Gorbarenko, S. A., Southon J. R., Keigwin L. D., Cherepanova M. V., & Gvozdeva I. G. (2004). Late Pleistocene-Holocene Oceanographic Variability in The Okhotsk Sea: Geochemical, Lithological And Paleontological Evidence. *Palaeogeography Palaeoclimatology Palaeoecology, 209,* 281-301. http://dx.doi.org/10.1016/j.palaeo.2004.02.013

Harper, D. A. T. (Ed.) (1999). *Numerical Palaeobiology*. New York: John Wiley & Sons.

Loeblich, A. R., & Tappan, H. (1987). *Foraminiferal Genera and Their Classification.* New York: Van Nostrand Rienhold

Co.

Romanova, A. (2013). Paleogeography of Sedimentation in Sea Of Okhotsk during Late Pleistocene-Holocene (Based on Data from Planktonic Foraminifera Analysis). *Reporter KRASSC. Earth Sciences, 21,* 183-194.

http://repo.kscnet.ru/id/eprint/487

Romanova, A., Cherepanova, M., & Gorbarenko, S. (2014). Planktonic Foraminifera as Paleoenvironmental Proxies of Upper Quaternary Sedimentation in the Okhotsk Sea. *Russian Journal of Pacific Geology*, *33*, 89-101.

Talley, L. D. (1993). Distribution and Formation of North Pacific Intermediate Water. *Journal of Physical Oceanography*, *23*, 517-537. http://dx.doi.org/10.1175/1520-0485(1993)023<0517:DAFONP>2.0.CO;2