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Planktonic Foraminifers From Offshore Regions Near Taiwan

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ABSTRACT

The summary of the planktonic foraminiferal data of two cores from the East China Sea picked up during the Cruise V23/KM92 of the *R/V "Akademik Aleksandr Vinogradov"* **(ROC-Russia Marine Science Collaboration Project) is presented. The assemblage compositions and climatic group ratios are given. The late Quaternary sediment section is divided on the climatic stratigraphy basis. Paleotemperatures of mid-annual surface-water masses are adduced (on the basis of the scheme established earlier for this region).**

(Key words: Planktonic foraminifera, Taiwan offshore, Sediment)

1. INTRODUCTION

Micropaleontological investigations of the East China Sea region are rather numerous, but works concerning planktonic foraminifers are of the greatest interest among them (Li, 1990). Planktonic foraminifers of this area seem likely to have been studied first by Cheng and Cheng (1960, 1962, 1963); 24 species of them were identified with 7 predominant ones being recognized. Then 27 species and subspecies were found in the Taiwan Strait (Huang, 1983). Some research has been conducted by Chinese investigators in the last few years (Wang *et al.*, 1985: Wang and Wang, 1990; Li, 1990). Unfortunately, the bulk of work concerning planktonic foraminifers made by Taiwanese scientists (Shieh and Chen, 1990; Shieh *et al.*, 1991, 1992; Chen *et al.*, 1992) are unknown by Russian researchers, who have only quite recently become acquainted with them.

Little, if ever, has been reported regarding the most deep-sea parts of the sea. In due time this author made a series of studies on the East China Sea region too, including the Okinawa Trough (Tkalich, 1985, 1987a, 1987b, 1988a, 1988b, 1991, 1992, 1993; Vashchenkova and Tkalich, 1987). In doing so, they used the material from short cores picked up more than twenty years ago (Vasilyev and Derkachev, 1977).

In 1992, the Sino-Russian cooperative expedition, KEEP-MASS, was conducted (Chen and Bychkov, 1992), and long cores were first received from the Okinawa Trough. The

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author wasn't among the participants of the expedition but did take part in the preparation of the material.

This paper presents the planktonic foraminiferal data of two cores from the opposite edges (northern and southern) of the Okinawa Trough. The total summary of knowledge about the planktonic foraminifers of the East China Sea is presented later in this paper.

2. MATERIALS AND METHODS

Two cores picked up during the Cruise V23/KM92 of the *R/V "Akademik A. Vinogradov"* (Chen and Bychkov, 1992) served as the groundwork for the following study. Planktonic foraminifers from Core T17 (south-western edge of the Okinawa Trough, 25°08',100N, 122°35',570E, 1150 m depth) and Core E46A (north-eastern edge of the Okinawa Trough, 29°46',967N, 128°26',979E, 940 m depth) were investigated; also the shelf sediment matter of Core E38 (31°37',686N, 125°46',735E, 60 m depth), was scanned but planktonic foraminiferal species were found there only as unique individuals.

The samples were picked up every 5 cm (from the top to 40 cm) and every 10 cm (from 40 cm level to the bottom). These samples were treated in the conventional procedure: they were boiled and washed out through a 230-mesh (0.063 mm) sieve; then a batch with approximately 300 tests was scanned, the calculation of foraminifers was made in it, and at last, the whole probe was examined (so as not to miss rare species). All components were identified according to the Quaternary species taxonomy of Saito *et al.* (1981) (Table 1). Finally, 34 species of planktonic foraminifers were identified in Cores T17 and E46A (from 12 to 23 species per probe, 15 species on the average). Planktonic foraminifers were met in association with benthic ones within whole intervals of the cores; radiolarians were also found. Also ostracods and juvenile mollusc shells were sporadically recognized.

3. PALEOCLIMATIC RECONSTRUCTIONS

3.1 Previous Works

Planktonic foraminiferal distribution in the ocean is non-uniform and depends on temperature inversions, water density gradients, oceanic current directions, salinity, dissolution, oxygen contents, depths and biological factors (Zeitzschel, 1978, Zwaan, 1982). In action, only one parameter is of use in paleoclimatic reconstructions - the dependence of planktonic foraminiferal distribution on temperature, on which the method of paleotemperature analysis is based. This method was much used, and it evolved through different, but parallel ways in Russia (Barash, 1970, 1988; Barash and Blyum, 1974; Ivanova, 1983, 1988; etc.) and abroad (Imbrie and Kipp, 1971; Kipp, 1976). The combined feature was in the use of different types of relationships between foraminiferal group ratios and water temperatural parameters. Imbrie and Kipp (1971) based the standard statistical calculation of bottom-surface factor-analysis assemblages with ensuing determinations of their interrelations with present water temperatural values in terms of transfer functions. Semi-annual (winter and summer) data were used as parameters for paleoclimatic reconstructions.

In Russia, M. S. Barash and his colleagues followed other paths. They divided all planktonic foraminiferal species into four climatic groups-boreal, subtropical, tropical and equatorial. The criterion of the assignment was the maximal concentration principle the special maps of species contents were plotted in operation. At last, empirical tables of the dependencies

Table 1. Full composition of planktonic foraminifers found in sediments of Core T17 and Core E46A.

1. *Candeina nitida* d'Orbigny
2. *Globigerina bulloides* d'Orbigny
3. *G.digitata* (Brady)
4. *G.falconensis* Blow
5. *G.pachyderma* (Ehrenberg)
6. *G.quinqueloba* Natland
7. *G.rubescens* Hofker
8. *Globigerinella calida* (Parker)
9. *G.siphonifera* (d'Orbigny)
10. *Globigerinita glutinata* (Egger)
11. *G.uvula* (Ehrenberg)
12. *Globigerinoides conglobatus* (Brady)
13. *G.ruber* (d'Orbigny)
14. *G.sacculifer* (Brady)
15. *G.tenellus* Parker
16. *G.trilobus* (Reuss)
17. *Globorotalia crassaformis crassaformis* (Galloway & Wissler)
18. *G.crassaformis hessi* Bolli & Premoli Silva
19. *G.fimbriata* (Brady)
20. *G.inflata* (d'Orbigny)
21. *G.menardii* (d'Orbigny)
22. *G.scitula* (Brady)
23. *G.truncatulinoides* (d'Orbigny)
24. *G.tumida* (Brady)
25. *G.ungulata* Bermúdez
26. *Hastigerina pelagica* (d'Orbigny)
27. *Hastigerinella adamsi* (d'Orbigny)
28. *H. ridelli* Rögl & Bolli
29. *Neogloboquadrina dutertrei* d'Orbigny
30. *Orbulina universa* d'Orbigny
31. *Pulleniatina obliquiloculata* (Parker & Jones)
32. *P.okinawaensis* Notori
33. *Sphaeroidinella dehiscens* (Parker & Jones)
34. *Turborotalia anfracta* (Parker)

between climatic group content intervals and temperature values were prepared (mid-annual data were used as temperatural parameters). Barash's followers extended the data bank and the table scale. Subsequently, Ye. V. Ivanova (1983, 1988) refined Barash's results. She correlated several hundred bottom-surface sediment probes of planktonic foraminifers taken in different oceanic regions with the present mid-annual temperatures of surficial water masses at the sampling sites. She prepared her own table that made of possible to determine a wide range of paleotemperatural changes. It should be noted that her discrete table transfer function differs from Imbrie and Kipp's that in the possibility to add new data. Imbrie and Kipp's application of factor analysis results for transfer function construction must, in many cases, limit the action of this function to Imbrie and Kipp's own massive data only. Picking any other data massive leads necessarily to the calculation of a different-looking factor set and to the need for a new function formulation (Joreskog *et al.*, 1976). The subsequent adding this transfer function (Wang and Wang, 1990) isn't fully correct and clear. Ivanova's table however includes the direct correlation between species composition and temperature, which simplifies its use or its correction by any author.

3.2 Model Adopted

The research region were differs from the quiescent oceanic areas studied by M. S. Barash and Ye. V. Ivanova; it is the region of the frontal zones of large current systems and the distinctive water-column stratification. Ivanova's table had to be adjusted because it didn't show reliable results (Tkalich, 1985, 1987, 1991, 1993). The planktonic foraminiferal data set on bottom-surface probes from the East China, South China and Philippine Seas, from this study were used. Foraminiferal species were divided into four climatic groups (boreal, subtropical, tropical and equatorial) according to Barash's and Ivanova's works (species arrangements to these groups are noted in Tables 2 and 3).

The correlative indicators for the temperatural state of water masses were the present mid-annual temperatures of surficial water layers. The corresponding data were taken and on the East China Sea and the western part of the Philippine Sea - from M. Koizumi's schemes (1962) and on other areas-from the Atlas of Temperature, Salinity and Density of Water in the Pacific Ocean (Muromtsev, 1963). The summary empirical scheme is given in Table 4. It was used for paleotemperatural determinations in the probes from core sections and for climatic stratigraphic divisions of Quaternary sediments. The end result temperature is the mean value of determinations made for each climatic group. Just this mean value correlates well with the present-day data.

3.3 Core T17

Thirty species of planktonic foraminifers were met is core T17 (Table 2). The tropical climatic group including 8 species is notedly predominant (in percentage of the total content of planktonic foraminiferal tests); its content fluctuates from 34.1% to 56.0%, 45.6% on the average (Figure 1). The equatorial group, which is rather numerous both in percentage (its content changes from 11.9% to 36.8%, 27.4% on the average) and in species quantity (12 species), holds the second place. The boreal group occupies the third position. In spite of the fact that it is displayed by as few as 4 species, its content ranges from 11.9% to 40.1%, 27.0% on the average. The subtropical group is in last place with minimal percentages (0.0% - 2.9%). The last-named fact is surprising for comparable latitudes (for the Philippine Sea, the Pacific Ocean, etc.), but it is usual for the southern and central parts of the East China Sea as it is established in other cores from this region (Tkalich, 1991, 1992).

It is known that the present-day mid-annual water temperature in the Core T17 site comprises 25.5°C - 26.0°C, and the temperature conditions of this region are more or less stable throughout the year (Koizumi, 1962). Paleotemperatures received by the procedure used here fluctuate moderately, from 23.5°C to 26.0°C (Figure 2). Therefore, not only paleotemperatures but also mainly climatic group ratios are used here for the stratigraphic division.

It is believed that the Pleistocene/Holocene boundary lies within the 160-170 cm interval. There, the boreal group content rises from 11.9% to 37.9% (from top to bottom), the tropical group content diminishes significantly (from 56.0% to 40.5%) and the equatorial group content changes grossly too (from 36.8% to 19.5%).

Two peaks of warmings are observed in the Holocene (Pleistocene/Holocene boundary lies just below the second one). Warning intervals (50-90 cm, 150-160 cm) exhibit the

Table 2. Species composition of Core T17.

SPECIES	ECOL.	Intervals, cm 5-15	25-35	35-40	40-50	50-60	60-70	70-80	80-90	100-110	110-120	128-140	140-150	150-160	160-170	170-180	180-190	190-200
Candeina nitida	E	1.2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.3	0.9	0.	0.	0.
Globigerina bulloides	B	2.4	12.6	18.1	13.5	10.	12.1	10.6	13.5	14.1	17.2	16.2	9.8	6.7	18.1	19.2	17.8	13.7
Globigerina digitata	E	1.2	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
Globigerina falconensis	S	0.	0.	0.	0.	0.	0.9	0.7	0.3	1.1	0.	0.3	0.8	0.	0.	0.	0.	0.
Globigerina pachyderma	B	0.	0.	0.	0.	0.	0.	0.7	1.2	0.	0.	0.	0.4	0.	0.	0.	0.	0.
Globigerina quinqueloba	B	2.4	2.6	1.6	3.8	4.2	0.9	0.7	2.8	3.8	3.1	0.	0.4	0.	0.	0.7	1.7	2.9
Globigerina rubescens	T	4.8	2.1	3.5	1.5	2.3	0.9	0.7	0.3	2.7	0.	2.	1.2	0.	1.7	0.	0.4	6.9
Globigerinella calida	S	0.	0.	0.	0.	0.	0.9	0.8	0.	0.	0.	0.	0.	0.	0.	0.	0.4	0.
Globigerinella siphonifera	E	3.6	1.1	2.4	0.	2.3	0.9	3.9	1.8	0.5	1.9	4.9	0.8	3.6	0.9	2.1	1.7	2.
Globigerinita glutinata	B	20.2	15.8	13.4	21.8	13.	17.2	12.7	7.4	22.2	9.8	6.8	5.9	5.2	19.8	10.2	13.6	17.6
Globigerinoides conglobatus	T	3.6	5.3	1.6	0.8	1.2	0.9	1.4	1.8	0.	3.1	0.7	2.8	8.2	0.8	7.2	0.4	1.
Globigerinoides ruber	T	7.1	6.3	7.8	12.	13.8	19.8	14.1	17.4	7.6	15.6	12.1	15.3	7.6	11.2	5.5	5.5	9.8
Globigerinoides sacculifer	E	3.6	4.2	3.1	2.3	5.	0.9	2.1	2.5	2.2	1.6	2.	1.5	3.9	0.8	0.7	3.	1.
Globigerinoides tenellus	T	0.	0.5	0.	0.	0.	0.	0.7	0.	0.	0.8	0.3	0.4	0.	0.	0.	0.4	0.
Globigerinoides trilobus	T	15.4	10.	5.5	5.2	4.6	3.4	2.8	5.5	7.	3.9	3.9	9.1	16.7	5.2	8.9	6.4	4.9
Globorotalia crassaformis	S	1.2	0.	0.	0.	0.	0.	0.	0.	0.5	0.	0.	0.	0.	0.	0.7	0.	0.
Globorotalia menardii	E	1.2	4.2	1.2	0.	0.8	0.9	2.1	0.	1.1	1.6	1.	0.8	2.4	2.5	0.	0.4	0.
Globorotalia scitula	S	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.7	0.	0.
Globorotalia truncatulinoides	S	0.	0.5	0.	0.	0.	0.	0.	0.9	0.	0.8	0.	0.	0.	0.9	0.	0.	0.
Globorotalia tumida	T	2.4	0.	1.6	0.	1.2	3.4	1.4	0.	1.1	0.	0.	1.2	1.8	0.	2.1	0.4	2.9
Globorotalia ungulata	E	1.2	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
Hastigerina pelagica	E	0.	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.4	0.	0.	0.	0.	0.
Hastigerinella adamsi	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Hastigerinella riedelli	E	0.	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.4	0.	0.	0.	0.	0.
Neogloboquadrina dutertrei	T	11.9	9.5	19.7	15.7	16.2	17.2	21.3	22.	18.3	16.4	32.6	24.	14.6	20.7	21.2	27.1	11.8
Orbulina universa	T	0.	0.5	1.6	0.8	0.	2.5	0.7	1.8	0.	0.8	3.6	2.	2.4	0.9	4.1	1.3	2.9
Pulleniatina obliquiloculata	E	16.6	21.1	18.1	21.	25.4	14.7	17.	19.3	17.3	23.4	13.6	22.4	25.4	14.7	16.4	19.1	19.6
Pulleniatina okinawaensis	E	0.	0.	0.	0.	0.	0.	0.7	0.3	0.	0.	0.	0.4	1.2	0.	0.3	0.	0.
Sphaeroidinella dehiscens	E	0.	3.7	0.	0.8	0.	0.	2.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
Turborotalia anfracta	S	0.	0.	0.8	0.8	0.	2.5	0.	1.2	0.5	0.	0.	0.	0.	0.9	0.	0.4	0.
Paleotemperatures	t°C	25.	26.	25.	25.	26.	25.5	25.5	26.	24.5	25.5	24.5	25.	26.	25.5	24.	25.	25.

Note. Climatic groups: B - boreal, S - subtropical, T - tropical, E - equatorial

Table 2. (Continued)

SPECIES	ECOL.	Intervals, cm															
		200-210	210-220	230-245	245-260	260-270	270-280	300-310	310-320	320-330	330-340	340-350	350-360	372-380	380-390	400-410	420-430
Candeina nitida	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Globigerina bulloides	B	11.	18.5	16.7	20.7	14.8	10.7	15.	12.2	16.9	13.9	18.8	14.7	14.2	16.9	10.5	15.6
Globigerina digitata	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Globigerina falconensis	S	0.4	0.	0.	0.	0.	0.	1.2	0.	0.	0.	0.	0.	1.	0.	0.	0.
Globigerina pachyderma	B	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Globigerina quinqueloba	B	0.4	1.5	1.3	2.	1.1	0.	2.	0.	0.8	0.	0.	1.2	1.4	0.5	0.6	0.
Globigerina rubescens	T	2.2	1.5	2.3	2.6	1.5	1.4	0.8	1.6	0.8	1.4	0.9	3.2	6.2	1.5	1.1	1.5
Globigerinella calida	S	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.5	1.1	2.2
Globigerinella siphonifera	E	1.5	0.5	0.	0.	0.	1.4	0.8	0.8	0.8	0.7	3.5	0.6	0.5	1.4	0.	0.
Globigerinita glutinata	B	8.5	8.	9.6	5.9	8.5	14.3	4.2	2.4	7.9	3.5	9.6	8.7	20.4	14.	14.3	15.6
Globigerinoides conglobatus	T	0.4	2.	0.6	5.9	7.	0.	4.6	2.	3.1	3.5	2.6	1.9	2.9	3.9	1.1	3.7
Globigerinoides ruber	T	17.2	20.	19.2	14.5	7.8	10.	12.3	15.3	13.8	11.1	8.7	9.9	14.8	14.5	16.	4.4
Globigerinoides sacculifer	E	1.5	1.5	2.3	1.3	2.6	1.4	4.2	4.8	3.1	0.7	4.4	1.9	0.	2.4	2.2	2.2
Globigerinoides tenellus	T	1.5	0.5	0.	0.	0.	0.8	0.	0.	0.4	0.	0.4	0.7	1.	0.5	0.	0.7
Globigerinoides trilobus	T	4.	3.	5.1	5.3	11.9	13.6	5.8	4.8	3.9	4.1	3.9	7.	9.5	4.4	5.5	3.
Globorotalia crassaformis	S	0.4	0.	0.	0.7	0.	0.	0.	0.	0.8	0.	0.	0.	0.	0.	0.	0.
Globorotalia menardii	E	2.2	0.	3.5	3.9	0.	5.	3.3	2.4	0.4	3.5	0.	0.6	0.	0.5	4.4	7.4
Globorotalia scitula	S	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.
Globorotalia truncatulinoides	S	0.	0.	0.	0.	0.	0.	0.8	0.8	0.	0.	0.	0.	0.	0.5	0.6	0.7
Globorotalia tumida	T	2.6	1.5	0.3	0.7	0.	0.	0.8	0.	0.	0.	0.	0.	1.9	0.	0.	0.
Globorotalia ungulata	E	0.	0.	0.	0.	0.	0.	0.	0.8	0.	0.	0.	0.	0.	0.5	0.	0.7
Hastigerina pelagica	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Hastigerinella adamsi	E	0.	0.	0.	0.	0.	0.	0.8	0.	0.	0.	0.	0.	0.	0.	0.	0.
Hastigerinella riedelli	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Neogloboquadrina dutertrei	T	22.7	16.	21.2	15.5	18.2	21.4	23.8	32.3	19.7	31.9	20.5	23.3	14.3	12.4	18.2	20.8
Orbulina universa	T	2.2	0.	0.	3.9	2.2	1.4	0.8	0.	2.4	1.4	2.2	1.9	0.5	2.4	0.6	0.
Pulleniatina obliquiloculata	E	20.9	25.	17.6	17.1	21.5	17.9	18.8	19.8	25.2	24.3	23.6	23.7	11.4	21.8	23.2	21.5
Pulleniatina okinawaensis	E	0.	0.5	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Sphaeroidinella dehiscens	E	0.4	0.	0.3	0.	2.2	0.	0.	0.	0.	0.	0.9	0.	0.	1.4	0.6	0.
Turborotalia anfracta	S	0.	0.	0.	0.	0.	0.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Paleotemperatures	t°C	25.	25.	25.	25.	25.	25.	25.	25.5	25.5	25.5	26.	25.	23.5	25.	26.	26.

Note. Climatic groups: B - boreal, S - subtropical, T - tropical, E - equatorial.

Table 3. Species composition of Core E46A.

SPECIES	ECOL.	Intervals, cm																		
		0-4	4-10	10-20	30-40	50-60	70-80	100-110	120-130	140-150	170-177	190-200	210-220	220-230	230-240	250-260	260-270	280-290	290-300	300-306
Globigerina bulloides	B	1.6	4.6	5.1	3.9	6.6	4.1	10.1	8.	6.7	3.4	8.5	8.2	5.	3.3	4.9	3.7	2.3	3.4	1.4
Globigerina digitata	E	0.	0.	0.6	0.	0.	0.5	0.	0.	0.	0.	0.	0.6	0.	0.	0.6	0.	0.	0.	0.
Globigerina falconensis	S	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.5	0.	0.	0.3
Globigerina pachyderma	B	0.	0.	0.6	0.	0.5	0.9	1.6	0.	0.	0.	0.6	0.	0.	0.7	0.	0.9	0.	0.7	0.7
Globigerina quinqueloba	B	0.	0.5	0.	0.	0.	0.5	3.2	0.6	1.3	0.	0.	2.5	4.1	0.7	2.4	0.9	0.6	0.	0.
Globigerina rubescens	T	0.	0.	0.	0.	0.	0.5	1.1	0.	0.	0.3	0.	0.	0.	0.3	0.	0.	0.	0.	0.
Globigerinella calida	S	0.	0.6	0.6	0.5	1.5	0.	0.	0.7	1.	0.3	1.1	0.	0.	1.3	1.2	0.	0.6	0.3	0.
Globigerinella siphonifera	E	4.8	1.5	2.5	0.5	0.5	0.5	1.6	2.5	1.3	1.7	1.1	1.9	0.5	1.3	1.2	1.4	2.3	4.5	1.7
Globigerinita glutinata	B	0.5	0.5	0.6	0.	0.5	0.9	2.1	1.2	1.3	0.7	3.4	0.6	1.7	1.3	1.2	0.9	0.	1.4	0.
Globigerinita uvula	S	0.	0.	0.	0.	0.	0.	0.	0.6	0.	0.	0.	0.6	0.	0.	0.	0.	0.	0.	0.
Globigerinoides conglobatus	T	5.4	2.5	3.2	4.2	3.1	2.2	4.8	1.2	1.6	5.5	1.1	2.2	0.5	3.3	3.	2.3	7.6	4.1	3.5
Globigerinoides ruber	T	5.4	11.1	11.4	9.6	8.1	15.8	8.5	13.5	14.3	11.3	22.1	16.1	25.3	12.7	24.3	16.3	18.9	17.2	16.3
Globigerinoides sacculifer	E	5.4	3.	8.2	1.3	3.3	4.1	2.1	3.7	3.2	2.7	1.7	0.6	0.5	1.3	1.2	1.9	4.5	1.7	3.1
Globigerinoides tenelius	T	0.	0.	0.	0.	0.	0.	0.	1.2	1.	0.	0.	0.6	0.	0.7	0.6	0.	0.	0.	0.
Globigerinoides trilobus	T	8.6	5.6	2.5	7.	8.1	8.2	7.6	9.2	6.4	10.2	1.7	4.4	4.1	6.	6.1	2.3	6.2	4.5	1.4
Globorotalia crassaformis	S	1.6	2.5	0.	1.6	1.5	0.5	2.1	1.2	0.6	1.4	2.3	0.7	1.5	0.7	0.	0.5	0.	0.	0.3
Globorotalia crassaformis hessi	S	0.	0.5	0.	0.3	0.	0.	0.5	0.	0.	0.3	0.3	0.	0.	0.	0.	0.	0.	0.	0.
Globorotalia fimbriata	E	0.	0.	0.6	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Globorotalia flexuosa	E	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Globorotalia inflata	S	5.4	7.6	3.8	7.8	8.4	4.9	1.6	3.7	5.7	4.8	9.6	9.5	9.4	7.3	8.5	5.1	6.8	5.2	14.9
Globorotalia menardii	E	4.3	0.5	3.8	4.2	1.	3.1	1.6	0.6	1.9	2.	1.1	0.7	0.	0.7	0.	0.	1.1	0.3	1.
Globorotalia scitula	S	0.	0.	0.	0.	0.	0.	0.	0.	0.3	0.8	1.1	0.	0.	0.	0.6	0.	0.	0.7	0.
Globorotalia truncatulinoides	S	1.6	1.8	1.3	0.	2.5	1.8	1.6	0.6	0.6	1.4	1.2	2.5	2.	1.3	1.8	1.9	0.	2.	2.8
Globorotalia tumida	T	1.1	1.5	1.3	0.8	1.	0.9	0.5	0.6	0.	1.	0.6	1.3	0.5	0.	0.	2.8	0.6	1.4	0.7
Globorotalia ungulata	E	0.	0.	0.6	0.5	0.	0.5	0.	0.	1.3	0.3	0.	0.	0.	0.7	0.	0.	0.	0.3	0.
Neogloboquadrina dutertrei	T	34.	39.5	37.9	32.3	39.6	33.1	34.4	42.9	28.9	33.1	31.2	31.9	32.2	40.5	33.9	42.8	34.4	37.8	25.6
Orbulina universa	T	4.8	5.3	4.4	9.9	3.6	4.1	6.3	0.6	9.2	4.1	3.4	5.7	7.6	5.3	6.1	2.8	3.4	6.2	16.
Pulleniatina obliquiloculata	E	15.	10.4	10.4	15.1	10.2	12.4	8.2	7.4	13.4	14.7	7.9	8.8	4.1	10.6	2.4	13.	10.1	7.6	9.3
Sphaeroidinella dehiscens	E	0.5	0.5	0.6	0.5	0.	0.	0.	0.	0.	0.	0.	0.6	0.	0.	0.	0.	0.6	0.	1.
Turborotalia anfracta	S	0.	0.	0.	0.	0.	0.5	0.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.7	0.
Paleotemperatures	t°C	27.	25.5	26.5	26.	25.	26.	25.	25.5	25.5	26.	24.	24.5	24.5	25.5	25.	25.5	26.	26.	26.
Paleotemperatures, determined when *N.dutertrei* and *P.obliquiloculata*. were excluded	t°C	26.	25.	25.	24.5	24.	25.	24.	25.	24.5	25.	22.5	23.	23.	24.	22.5	24.	25.5	24.	24.5

Note. Climatic groups: B - boreal, S - subtropical, T - tropical, E - equatorial.

Table 4. Correlation of the planktonic foraminiferal climatic group contents and mid-annual temperatures of the surface water layers.

B	S	T	E	T+E	T°C
30.5 -20.5	43.0-41.0	-	6.0- 7.5	34.0-39.5	21.0
20.5 -17.5	41.0-39.0	-	7.5- 8.0	39.5-44.5	21.5
17.5 -15.0	39.0-36.5	-	8.0- 9.5	44.5-50.0	22.0
15.0 -12.5	36.5-33.5	-	9.5-11.0	50.0-56.0	22.5
12.5 -10.0	33.5-30.5	-	11.0-12.5	56.0-61.5	23.0
10.0 - 8.0	30.5-27.5	-	12.5-14.0	61.5-67.0	23.5
8.0 - 6.5	27.5-24.5	-	14.0-16.0	67.0-72.0	24.0
6.5 - 5.5	24.5-21.5	-	16.0-18.0	72.0-76.0	24.5
5.5 - 4.5	21.5-18.5	-	18.0-20.0	76.0-80.0	25.0
4.5 - 3.5	18.5-15.5	-	20.0-22.5	80.0-84.0	25.5
3.5 - 2.75	15.5-13.0	>59.0	22.5-25.5	84.0-86.5	26.0
2.75- 2.25	13.0-11.0	59.0-57.0	25.5-28.5	86.5-87.0	26.5
2.25- 1.75	11.0- 9.0	57.0-54.5	28.5-31.5	87.0-88.0	27.0
1.75- 1.25	9.0- 7.0	54.5-52.0	31.5-35.5	88.0-89.0	27.5
1.25- 0.75	7.0- 5.0	52.0-49.0	35.0-39.5	89.0-89.5	28.0
0.75- 0.50	5.0- 3.5	49.0-45.0	39.5-44.5	89.5-90.0	28.5
0.50- 0.25	3.5- 2.0	45.0-41.0	44.5-49.5	90.0-90.5	29.0
0.25 -0.10	2.0- 1.0	41.0-37.0	49.5-54.5	90.5-90.75	29.5
0.10- 0.00	1.0- 0.0	<37.0	>54.5	>90.75	30.0

Note. Climatic groups: B - boreal, S - subtropical, T - tropical, E -equatorial; T°C - the surface-water mid-annual temperature accepted. The result temperature is taken as the mean of the values determined on the each of groups.

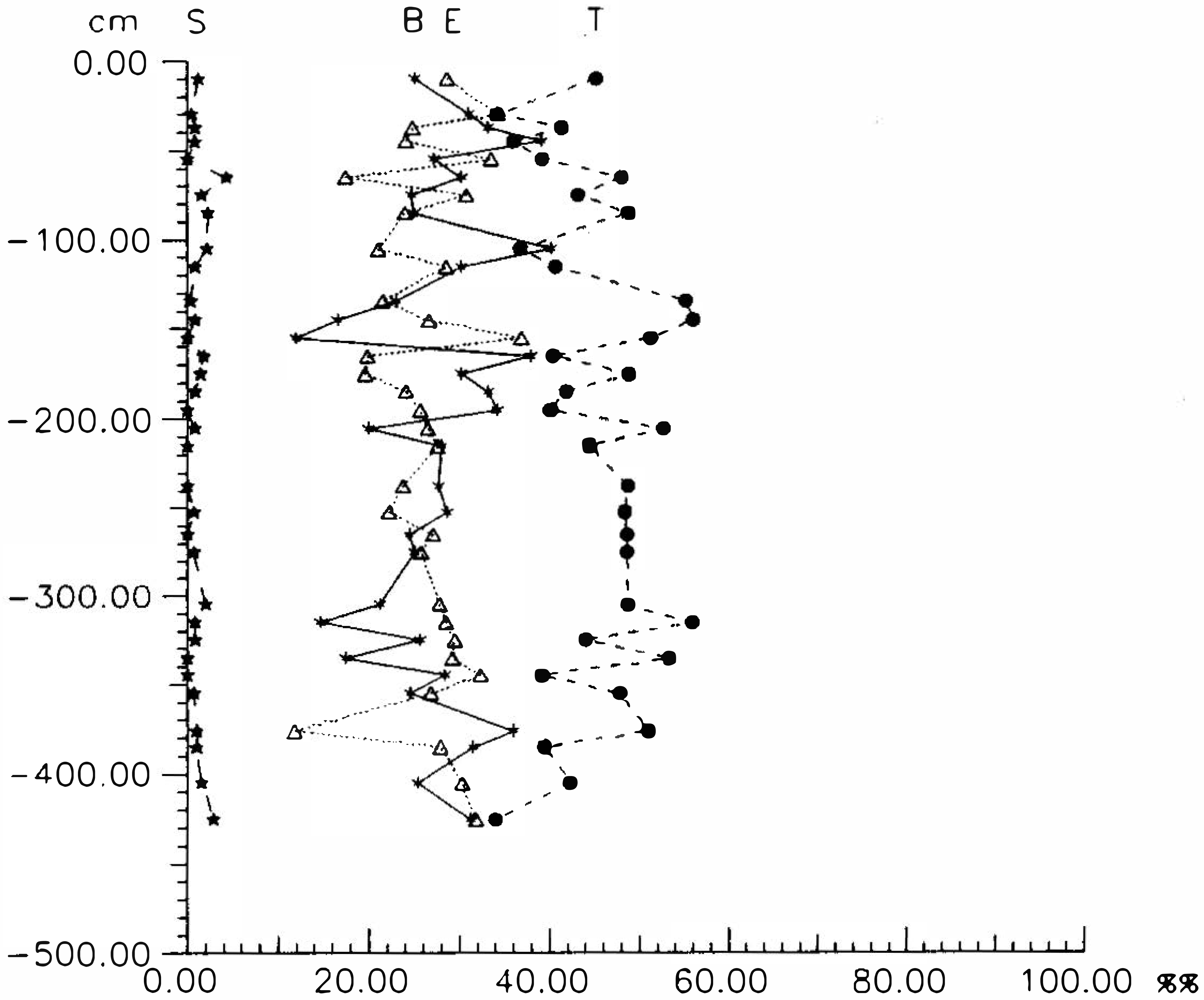

Fig. 1. Climatic group fluctuations for St. T17: B - boreal, S - subtropical, T - tropical, E - equatorial groups.

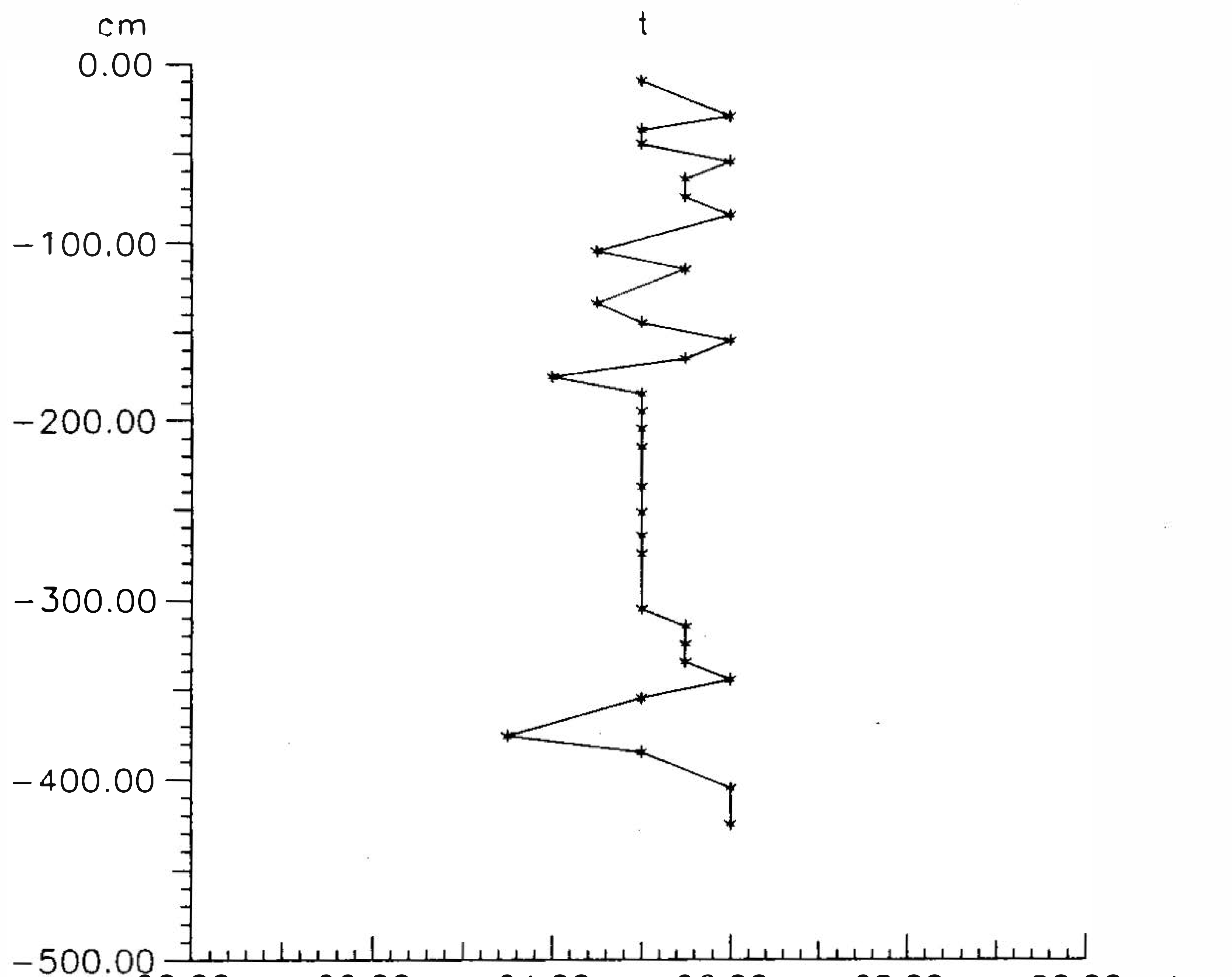

Fig. 2. Paleotemperatural curve (t) for St. T17.

increase in the equatorial and tropical group percentages (at the sacrifice of these species as *Neogloboquadrina dutertrei, Pulleniatina obliquiloculata, Globigerinoides ruber*, etc.) and, at the same time, the reduction of the boreal group content. It should be noted that the increase in the subtropical group role is observed there, even if it is very small. Coolings are characterized by the significant contents of the boreal group (*Globigerina bulloides, G. quinqueloba, Globigerinita glutinata*) with the reduction of the equatorial group role and, to a smaller degree, the tropical group content. Warmings are characterized by 25.5°C-26.0°C paleotemperatures and coolings by 24.5°C - 25.0°C paleotemperatures.

Some warm and cool episodes are singled out in the Pleistocene. There paleotemperatures come to 23.5°C - 24.0°C in coolings and to 25.0°C - 26.0°C in warmings. The cool event near the boundary with the Holocene (the 170-180 cm interval) can be correlated with last glaciation. There the boreal group content is maximal, and the equatorial group content is minimal for the whole core length; the tropical group percentages essentially diminish too. The identification of other Pleistocene episodes calls for further investigation.

3.4 Core E46A

Twenty-nine species of planktonic foraminifers were found in Core E46A (Table 3). The tropical climatic group including 8 species is notedly predominant (as in Core T17) with its content fluctuating from 59.3% to 74.0% (Figure 3). The equatorial group holds the second place in percentage just as in Core T17 (5.1% - 30.0%), but it has only 8 species. The subtropical group, in contrast with Core T17, occupies the third place in tenns of percentage (5.7% - 18.3%) and is rather numerous in unmber of species (9 species). The boreal group from 4 species fluctuates in the content from 2.1% to 17.0% and holds the last place. Some decrease in the quantity of the equatorial species in Core E46A took place

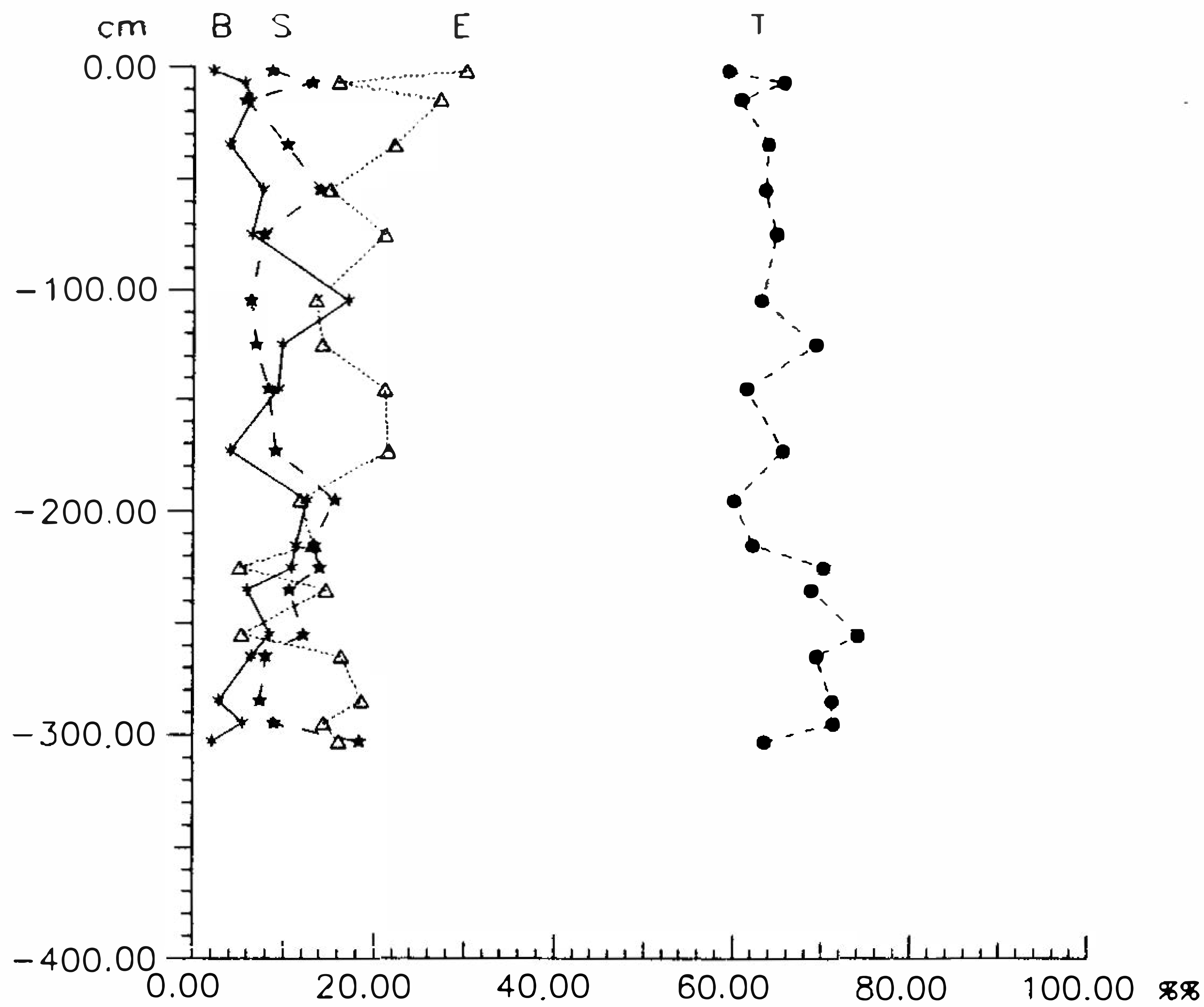

Fig. 3. Climatic group fluctuations for St. E46A: B - boreal, S - subtropical, T - tropical, E - equatorial groups.

at a sacrifice in the lack of the thin-wall species such as *Candeina nitida, Hastigerina pelagica, Hastigerinella ridelli, Pulleniatina okinawaensis.*

Palpeotemperature estimates made for the section of this core give unexpectedly high values in comparison with those of neighbouring areas (Tkalich, 1991, 1992). It can be connected both with poor preservation of the thin-wall species mentioned above and with the intensive supply of species peculiar to large currents. Recalculation with the elimination of the most characteristic current species (*Neogloboquadrina dutertrei and Pulleniatina obliquiloculata*) leads to more reasonable results (Table 3, Figure 4, 5), but the results can still be slightly high.

In the recalculation case, paleotemperatures for the Core E46A section top reached up to 26°C (Figure 4). This is higher than the present-day temperature (24.5°C) for this core location (Koizumi, 1962). The absence of upper Holocene layers is most likely to be found in Core E46A, and the top of the section falls within the Holocene optimum.

The lowest temperature, in the recalculation case, was approximately 2°C below the recent ones (22.5°C, Figure 4); this cool interval (190-200 cm) is related to the last glaciation in the Pleistocene. The lower layers of the core could, possibly, be referred to the preceding interglacial time (25.5°C). The layers between the top and 190 cm are characterized by intermediate paleotemperatures (24.0°C - 25.0°C).

Doubts are cast upon the Pleistocene/Holocene boundary location. Here only the upper 50 cm layer is considered to belong to the Holocene. It is interesting that the rare index-species for the Holocene (*Globorotalia fimbriata*) is recognized in this core. The boundary between different sediment types passes where the sandy sediments of the upper part changes to the silty layers of the lower part. The exact separation of Holocene calls for further investigation.

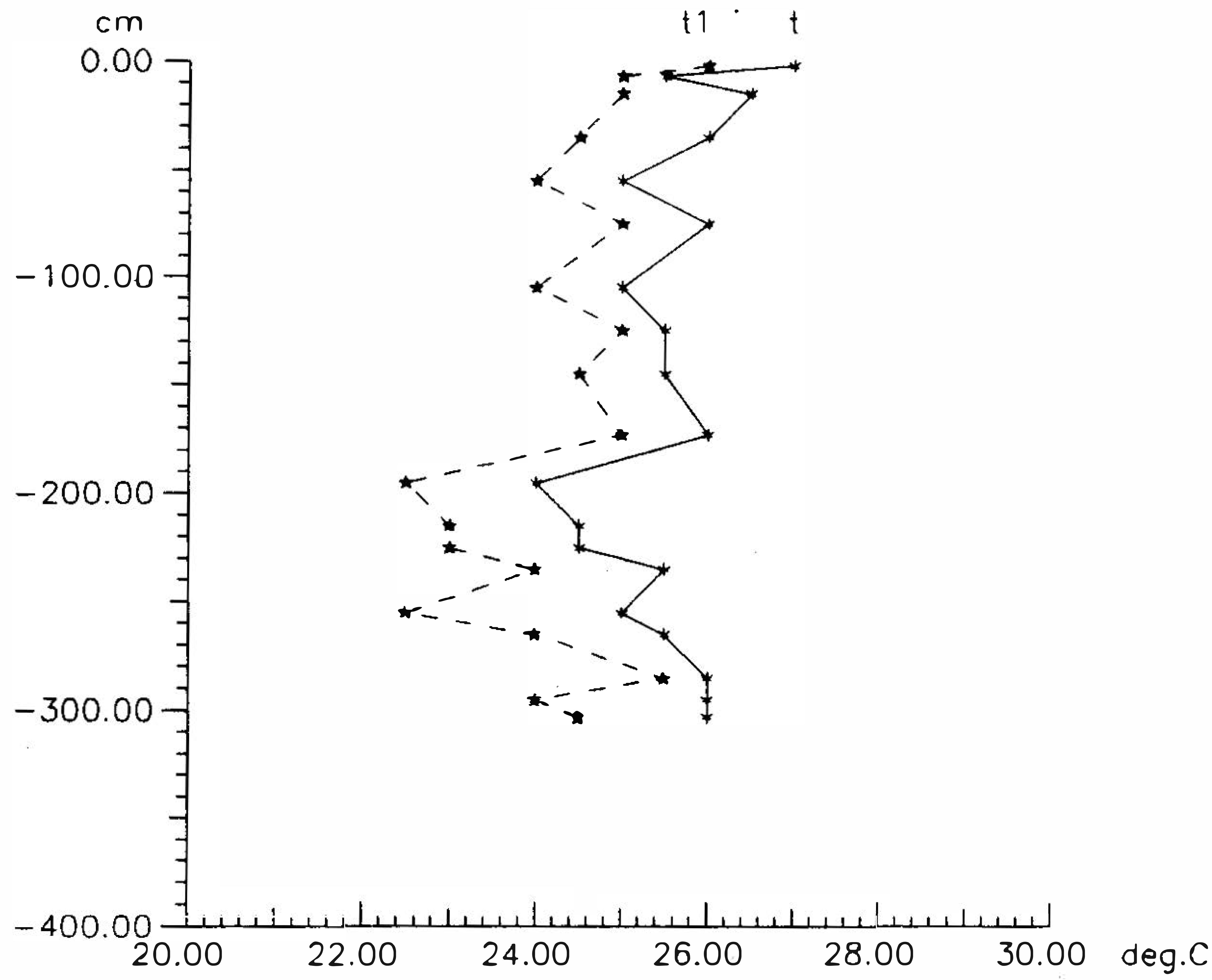

Fig. 4. **Paleotemperatural curves for St. E46A: t - usual, t1 - for a set without two current-system species.**

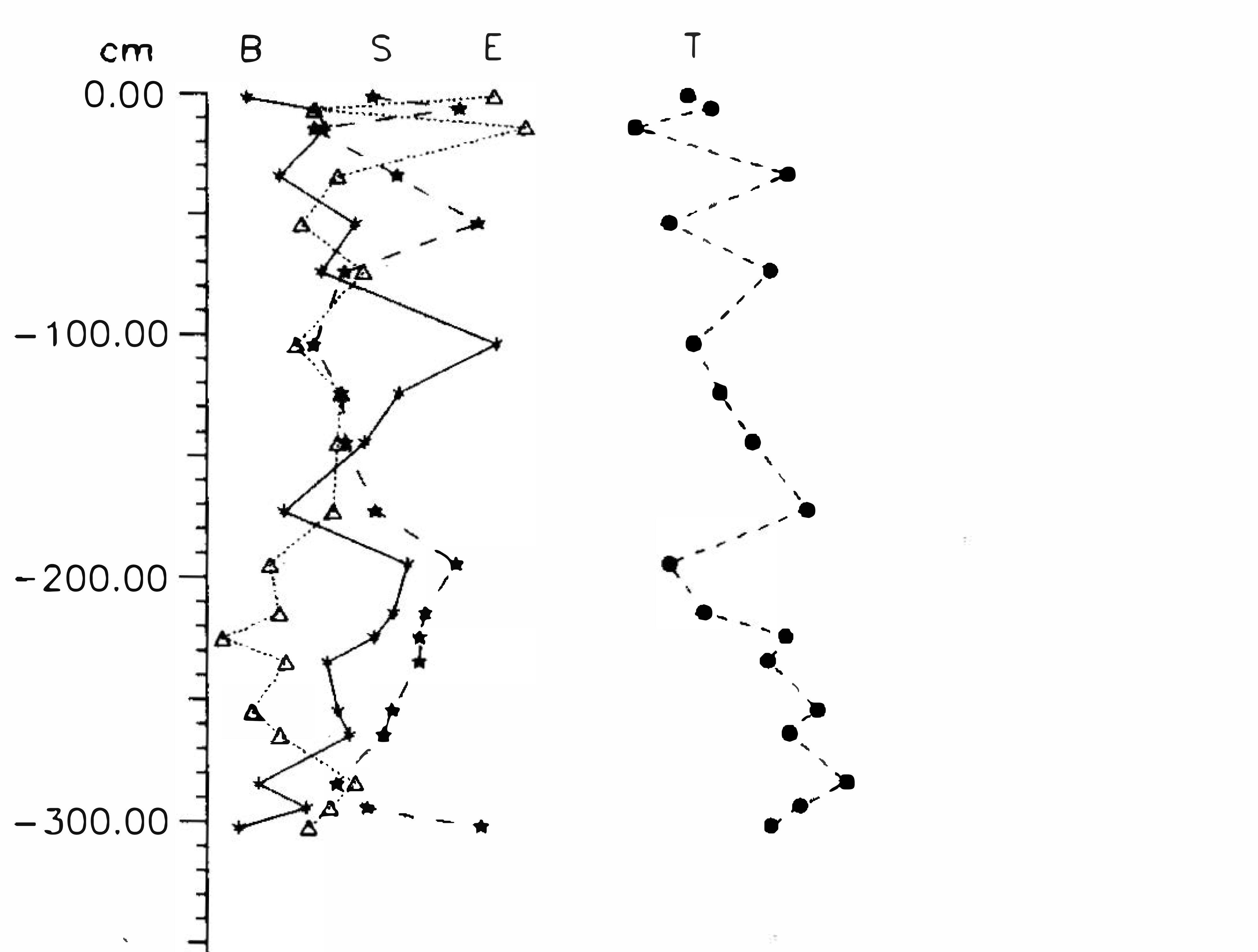

Fig. 5. **Climatic group fluctuations for St. E46A without two current- system species: B - boreal, S - subtropical, T - tropical, E - equatorial groups.**

4. CONCLUSIONS

The species composition of planktonic foraminifers for two cores (T17 and E46A) is closely analogous. The species dominating along the whole length of these cores are *Neogloboquadrina dutertrei, Pulleniatina obliquiloculata, Globigerinoides ruber, Globigerinoides trilobus.* Other species such as *Globigerina digitata, G.pachyderma, Globigerinella calida, Candeina nitida, Globorotalia crassaformis, G. scitula, G. ungulata, G.truncatulinoides, Sphaeroidinella dehiscens, Hastigerina pelagica, Hastigerinella ridelli,* etc., occur occasionally. These species comprise more than 60% of the total quantity of the planktonic foraminiferal tests. The rare index-species for the Holocene (*Globorotalia fimbriata*) is noted in the Core E46A top. In spite of some distinctions, planktonic foraminiferal distribution in the given cores follows the regularities established in the adjacent cores (Tkalich, 1991, 1992). The main differences between the northern (Core E46A) and southern (Core T17) sites, as well as between the East China Sea region and the adjacent areas, lie in species and climatic group ratios. In the East China Sea, especially in its southern and central parts, climatic group ratios are different-looking from the ones for the adjacent areas at the same latitudes.

Firstly, it can be observed that the planktonic foraminiferal thanathocoenosis is characterized by the contrasting set of species (in their ecology): equatorial and, concurrently, boreal species have a high content (with a very minor quantity of subtropical and the predominance of tropical ones). In movement from the south to the north, these contrasting features become smoothed, and the role of the subtropical group species rises (relative to those of the boreal group). These regularities are noted in adjacent cores too (Tkalich, 1991, 1992). Secondly, the presence/absence alternation for planktonic foraminifers or their detectable abundance changes within minor areas (Cheng and Cheng, 1964; Tkalich, 1991, 1992) can be noted.

These two features are usual for the assemblages from frontal zones of large current systems where the junction of several water masses with different temperatures and salinity values takes place, as well as the marked stratification of water column and phenomena of upwelling and water circulations are often observed.

This is underlined by the fact that the species *Neogloboquadrina dutertrei* and *Pulleniatina obliquiloculata* are among the dominat ones, but it should be noted that they just describe these large current systems (Torderlund and Bé, 1971). The fact of an especially intensive supply of these two species in Core E46A site has called for the elimination of them from the set in paleotemperature calculations. Besides, the whole group of dominants listed above is characterized by its maximal concentration at the high ($35^o/_{oo}$) salinity common to these systems (Bé and Hutson, 1977).

Based on the data concerning quantity dynamics of the planktonic foraminifers, warm- and cool-water species ratios and species number changes along core horizons, it has been possible to single out the core intervals for cool and warm periods and to isolate the Holocene. The Pleistocene/Holocene boundary lies in the 160-170 interval in Core T17 and near 50 cm in Core E46A (in the latter case, the upper Holocene layers are absent and the top of the section falls within the Holocene optimum). The empirical table composed on the climatic group ratio basis (Table 4) have been used for the estimation of the mid-annual surface-water paleotemperatures.

The equatorial group composition of Core E46A is depleted in thin-wall species. It can be connected not only with the northern core site, but with burial (sedimentation) features (in Core E46A coarser sediments have been found) as well. Therefore, estimates for this core display excessively high paleotemperatural values; the recalculation gives more reliable results when the set without two current-system species is taken.

Therefore, it is estimated that extreme Holocene paleotemperatures were reached: in warmings - 26.0°C, in coolings - 24.5°C (for both core sites); extreme Pleistocene paleotemperatures were reached: in warmings - 25.5°C in the North and 26.0°C in the South, in coolings - 22.5°C in the North and 23.5°C in the South. If these values are plotted to Koizumi's scheme (1962), the displacement of mid-annual isotherms occurring within 1.5 latitudinal degrees can be observed.

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