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'KUMMERFORMS' IN PLANKTONIC FORAMINIFERA, ITS CAUSE AND DISTRIBUTION IN PACIFIC WATERS

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ABSTRACT

The 'kummerforms' are those abnormal specimens of the planktonic foraminifera in which the last chamber is either equal or smaller than the penultimate one. Such type of forms are observed in the present day oceanic waters and in fossil assemblages. The distribution and growth of such forms in the Pacific waters are quantified for the first time to correlate them with the environmental parameters. It is concluded that the development of kummerform is essentially an ontogenic character of the species and is not related with the factors responsible for the environmental stress, lack of proper food and increasing depth of water.

INTRODUCTION

The planktonic foraminifera are the free floating marine protozoans having an external calcareous test. The arrangement of the chambers in the test is generally in such a fashion that there is a constant increase in their size from the proloculum stage up to the last. However, in certain specimens abnormalities in this size increase have been observed specifically in the last chamber. Berger (1969) was first to critically examine this abnormality and he introduced a new terminology 'kummerform' (German *kummerlich* = measly, contemptively small) for those foraminiferal tests having the last chamber equal or smaller than those of the previous one (penultimate). In a later study, he (1970) observes that this definition does not apply to a very well known species *Orbulina universa* d'Orbigny in which the last chamber is always greater than the previous one. Instead, the kummerform Orbulinas are those in which the penultimate chambers are not completely enveloped by the last chamber. The kummerform development has been observed in the planktonic foraminiferal assemblage of the present day oceanic waters and in deep sea sediments and also in the fossil assemblages.

The cause of such abnormalities in growth has been variously explained by the different workers who correlated these features with the factors responsible for the environmental stress, lack of food, increasing depth of water and selective destruction of normal forms by the ocean currents at depth. Significant importance has thus been given for environmental and ecological interpretations based on such type of forms. It is therefore necessary to assess the role of various environmental factors responsible for the kummerform development by recording distribution and growth of kummerforms in varied oceanic water masses. The mid-oceanic water masses of the Pacific Ocean extending from the equator to the higher latitudes have been selected for the study.

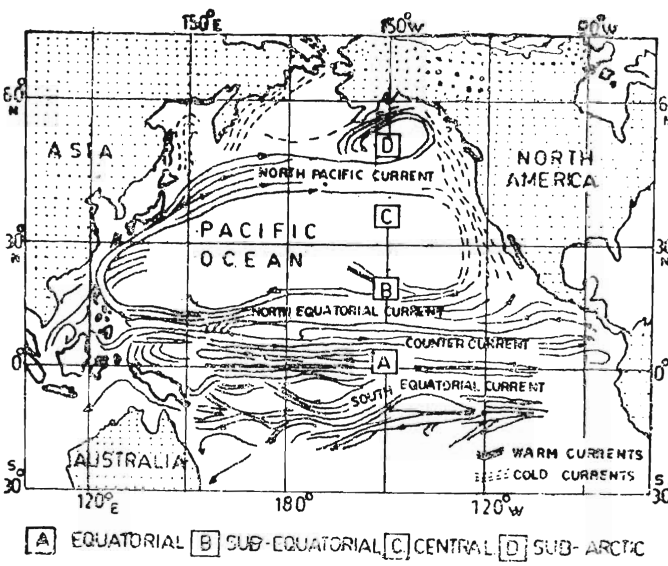


Fig. 1. Water masses and current directions in Pacific Occan.

SAMPLE DETAILS

A number of plankton tows were collected at several stations from diferent depths in the Pacific waters between Lat. 10°S to Lat. 55°N. The water masses within this region comprise—equatorial, sub-equatorial, central and sub-arctic types and are affected by the south and north equatorial currents and north Pacific currents (Fig. 1). The average temperature of the surface waters at the time of sampling in the summer months varies from 25°C for the equatorial, 20°C for the sub-equatorial, 12°C for the central and 5°C for the subarctic waters. The average salinity values for these waters are 35.20‰,

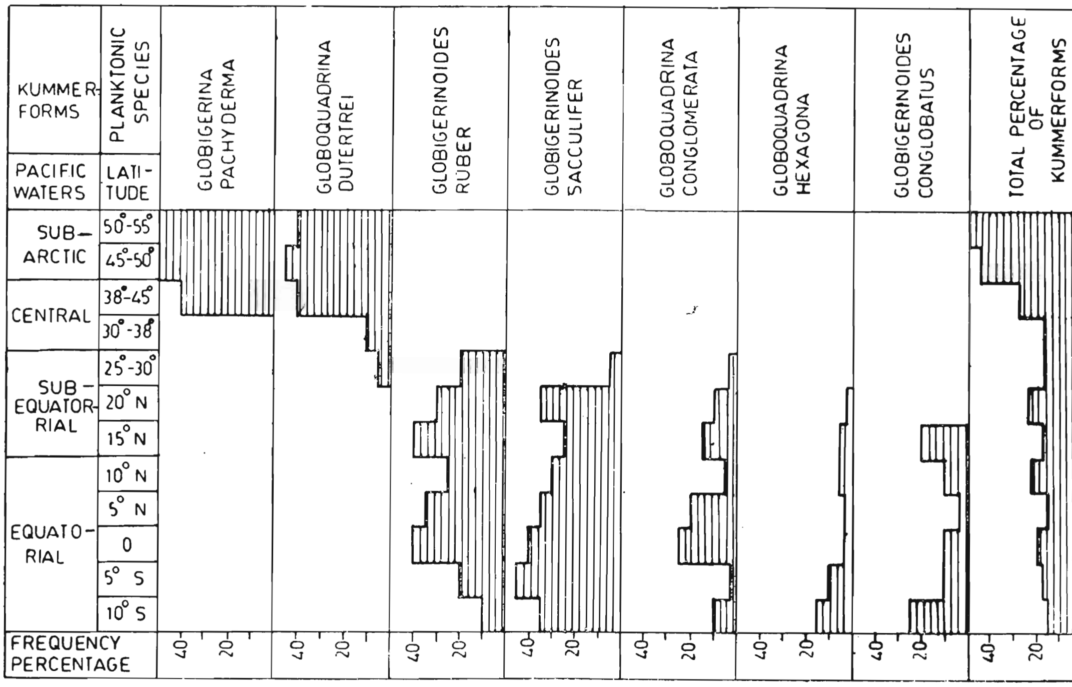


Fig. 2. Relative abundance of kummermorphic species in different water masses of Pacific Ocean.

34.80‰, 34.00‰ and 33.50‰ respectively. The samples are extremely rich in planktonic foraminifera. The total abundance of all types of planktonic foraminifera is as high as over 8000 specimens collected from 1000 cubic metres of equatorial water and it reduces to less than 1000 in sub-arctic waters. In all thirty species of planktonic foraminifera have been identified from this part of the Pacific Ocean.

DISTRIBUTION OF KUMMERFORMS

The kummerform development has been observed in a number of species recovered from the Pacific plankton samples. Their extent of development can be classified as common (over 20% of the entire planktonic foraminiferal assemblage) in—*Globigerina pachyderma* (Ehrenberg), *Globoquadrina dutertrei* (d'Orbigny), *Globigerinoides ruber* (d'Orbigny), *Globigerinoides trilobus sacculifer* (Brady); as less common (10-20%) in *Globigerinoides conglobatus* (Brady) and *Globoquadrina conglomerata* (Schwager) ; and as rare (less than 10%) in *Globigerina bulloides* d'Orbigny, *Globigerina calida* Parker, *Globoquadrina hexagona* (Natland), *Globorotalia hirsuta* (d'Orbigny), *Globorotalia tumida* (Brady), *Globorotalia menardii* (d'Orbigny) and *Orbulina universa* d'Orbigny. The frequency distribution of more common species having kummerform stage is given in figure 2. In rare cases, the penultimate chambers have been found to be kummermorphic and the last chamber attains a normal size. Parker (1962) has given illustrations of kummerform specimens (without mentioning them as kummerforms) of *Globigerina falconensis* Blow, *Globigerina rubescens* Hofker, *Globigerinella siphonifera* (d'Orbigny) and *Globigerinita humilis* (Brady) from the bottom sediments of the eastern half of the south Pacific. However, some of these taxa need revalidation and comparison with the taxa of central Pacific Ocean.

The extent of the kummerform development varies considerably in the samples collected from the different depths of water and at the different latitudes. The irregularity in their distribution may be partly explained by the mixing of different water masses and the ocean currents, whereas, an increase in the percentage of kummerform specimens with respect to the depth of water in general is evident (Table 1). It may be further observed that this increase with depth is better reflected for the stations situated at the lower latitudes (nearer to the equator) and this trend somewhat decreases or even reverses at the higher latitudes (nearer to the poles). The assemblage in the sub-arctic waters is dominated by *Globigerina pachyderma* (Ehrenberg) and *Globoquadrina dutertrei* (d'Orbigny) whose surface water specimens show a better kummerform development.

SIZE RELATIONSHIP

It has been stated by several authors including Berger (1970) that the percentage of kummerforms tends to increase with the specimen size, *i.e.* kummerform specimens are invariably large in size. This statement needs to be examined for different species thriving in different water masses. The species selected for the determination of the size relationship with the kummerform development are (i) the warm water species—*Globigerinoides ruber* (d'Orbigny), (ii) a cosmopolitan species—*Globigerinita*

Table 1 : Sample locations, depth of water, absolute abundance of total foraminifera and kummerform development in the Pacific Waters during the summer months.

Pacific Waters	Station nos.	Latitude	Depths of collection (in mts.)	Absolute abundance of Forams	Relative Percentage of kummerforms
Equatorial	1	10°S	0—200	8205	03.01
			200—500	0623	04.76
			500—800	0231	08.76
	2	05°S	0—200	7975	06.90
			200—500	0136	06.66
			500—800	0057	04.76
	3	0°	0—800	5847	16.61
	4	05°N	0—800	3187	12.77
	5	10°N	0—200	1727	04.52
			200—500	1547	11.95
			500—800	0599	07.54
Sub-Equatorial	6	15°N	0—200	2010	02.29
			200—500	0656	09.09
			500—800	0481	06.01
	7	22°N	0—200	2319	04.70
			200—500	0343	04.11
			500—1000	0060	14.29
	8	29°N	0—200	1273	05.80
			200—500	0263	09.63
			500—1000	0067	05.88
Central	9	36°N	0—500	1112	09.30
			500—800	0224	08.60
	10	43°N	0—200	1342	12.75
			200—500	0746	14.44
			500—800	0210	22.19
Sub-Arctic	11	49°N	0—1000	1538	22.19
	12	55°C	0—200	0906	60.48
			200—500	0439	43.35
			500—700	0241	36.80

glutinata (Egger), (iii) a tropical to temperate water species—*Globoquadrina dutertrei* (d'Orbigny), (iv) a temperate water species—*Globigerina bulloides* d'Orbigny and (v) a subarctic cold water species—*Globigerina pachyderma* (Ehrenberg) (Table 2).

No significant relationship between the development of kummerform and the size of the individual test was noticed in case of *Globigerina bulloides* d'Orbigny and *Globigerinita glutinata* (Egger). In case of *Globoquadrina dutertrei* (D'Orbigny), the kummerform development is of significant level for those specimens which are smaller in size (less than 350 microns in diameter) and are caught in more temperate waters than those thriving in tropical waters and are on the average 500 microns in diameter. Conversely, the kummerform development in *Globigerinoides ruber* (d'Orbigny) shows a direct correlation with the size of the individual tests. In case of *Globigerina pachyderma* (Ehrenberg), the more quadrate shaped tests (Plate I—1 and 2) with thicker and sugary texture wall have kummerform development as high as 80%. The more significant observations made here are that the kummerform development does not take place in case of juvenile as well as overgrown forms and is more common with those which have not attained the normal growth.

ENVIRONMENTAL SIGNIFICANCE

As stated earlier, significant emphasis has been paid to the role of kummerforms in ecological studies. A computerised correlation of the plankton samples in terms of various physico-chemical parameters of the Pacific water masses is attempted, (Table 3). These parameters either singularly or in groups play dominant role in

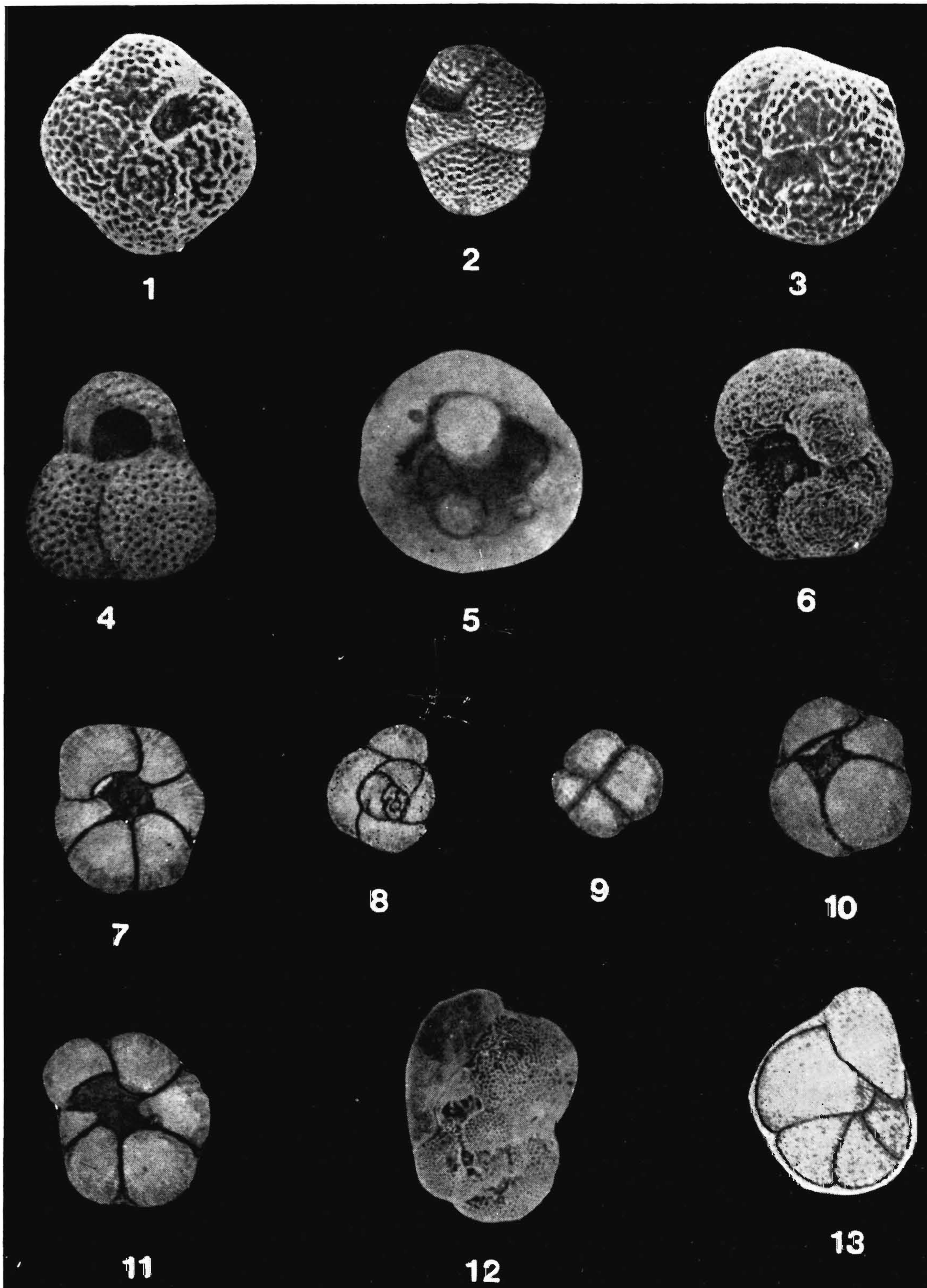
Table 2 : Test size groupings and the relative percentage of the kummerform specimens in five planktonic species.

Water mass and latitudes		Relative percentage of kummerforms in					
		Equatorial		Sub-Equatorial		Central	Sub-Arctic
Kummerform species	Size groups (in microns)	10° S-0°	0°-10°N	10°-20°N	20°-30°N	30°-45°N	45°-55°N
Globigerinoides ruber	>280	52.99	54.16	40.81	60.71	51-25	
	280—200	32.47	37.50	32.65	28.57	27.50	
	<200	14.53	08.33	26.44	10.71	21.25	
Globigerinita glutinata	>300	16.21	31.37	33.69	32.47	48.80	
	300—240	48.69	47.05	36.95	52.99	20.23	
	<240	35.00	21.56	29.34	14.52	30.96	
Globoquadrina dutertrei	>450			16.66	16.66	28.57	
	450—350			66.66	58.33	30.71	
	<350			16.66	25.00	30.71	
Globigerina bulloides	>280					33.33	47.78
	260—220					44.44	23.89
	<220					22.22	28.31
Globigerina pachyderma	>280					55.00	50.27
	280—220					25.00	34.97
	<220					20.00	14.75

Table 3 : Computerised correlation analysis between the distribution of kummerform species and the environmental parameters

Environmental parameters Kummerform Species	Latitude (higher)	Surface waters	Deep waters	Depth increase	Tempera-ture	Salinity	Oxygen	Phosphate	Nitrate	Phyto-plankton concen-trations
Globigerina pachyderma	0.704	0.286	0.467	—0.026	—0.628	0.099	0.245	0.344	0.164	0.239
Globoquadrina dutertrie	0.614	0.788	0.462	0.467	—0.571	0.054	0.187	0.158	0.069	0.381
Globigernoides ruber	—0.568	0.326	0.668	0.541	—0.765	0.321	0.416	0.321	0.416	0.129
Globigerinoides sacculifer	—0.486	0.492	0.512	0.489	—0.623	0.121	0.231	0.298	0.226	0.248
Globigerinoides conglobatus	—0.431	0.398	0.647	0.562	—0.648	—0.094	0.142	0.210	0.186	—0.078
Globoquadrina conglomerata	—0.486	0.432	0.586	0.541	—0.581	0.216	0.108	0.158	0.069	0.214
Globigerina bulloides	0.668	0.586	0.467	—0.481	—0.668	0.094	0.148	0.208	0.245	0.129
Globoquadrina hexagona	—0.486	0.532	0.418	—0.432	—0.504	0.127	0.245	0.186	0.164	0.381
Total Kummerforms	0.667	0.568	0.589	0.481	—0.581	0.121	0.231	0.268	0.286	0.226

controlling the growth and distribution of the planktonic assemblage. However, some of the physical factors, such as latitude, depth, temperature and average salinity have been found to have a significant effect on the development of kummerforms in certain species. For example, the increasing temperature is favourable for kummerform development in *Globigerinoides ruber* (d'Orbigny) and has a negative correlation in case of *Globigerina pachyderma* (Ehrenberg) and *Globoquadrina dutertrei* (d'Orbigny). Hecht and Savin (1974), on the other hand, suggested the increasing temperature as a factor of environmental stress (considered as favourable for the kummerform development) in case of *Globoquadrina dutertrei* (d'Orbigny). It is rather interesting to record that the factors which can be better classified under the environmental stress as they are related with the nutrients and food such as phosphates, nitrates, oxygen, nitrogen and phytoplankton abundance etc. appear to be unrelated and do not show



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any distinct trend in correlation with the frequency distribution of kummerforms. It is also important to note that these physical factors, as enumerated, do not play the same role in the development of kummerforms in most of the species studied from the Pacific Ocean. The higher frequency of kummerform specimens observed in the sub-arctic waters do not attribute the factor of environmental stress as the sub-arctic waters are invariably rich in nutrients.

From the above study, it is evident that the kummerform development has not been consistent and uniform in most of the specimens or in the species recovered from one set of samples or from the samples belonging to a single environmental regime. Hence, the environmental factors may not be essentially considered as the cause for the development of this abnormal feature. It is, however, suggested that the kummerform chamber reduces the buoyancy of the individual specimen, enabling it to reside in a deeper, but more compatable or preferred environment. Since the planktonic foraminifera lack self swimming power, they have to adjust themselves according to the surrounding water masses. By reducing the volume of the test, an individual can choose a better suited environment at a relatively deeper level in water where the impact of the surface water current and the environmental variabilities are the least. It is also possible for a few individuals to return to their original environment through the process of normal development after the kummerform stage. In such cases the penultimate chambers have been found to be slightly smaller than the succeeding ones.

CONCLUSIONS

It is thus concluded that the kummerform development is essentially an ontogenic feature (requirement and growth of the individual), more or less, independent of the surrounding physical conditions. The individual chooses the kummerform stage towards its own benefit. The preference to this abnormality may not be due to certain environmental parameters to which an individual and not the entire assemblage is sensitive. It is still not evident how an individual develops the sensitivity to these parameters and adopts the kummerform stage. Without having proper understanding of the physico-chemistry and biology of the oceanic waters, it is not logical to place enough significance on the kummerform study towards the ecological and environmental interpretations.

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EXPLANATION OF PLATE

Plate 1

Kummerform specimens of planktonic foraminifera

1. *Globigerina pachyderma* (Ehrenberg), ventral view, subarctic waters, ×230.
2. *Globigerina pachyderma* (Ehrenberg), ventral view, last chamber highly reduced, subarctic waters, ×260.
3. *Globigerina pachyderma* (Ehrenberg), side view slightly tilted towards the ventral side showing the kummerform chamber, subarctic waters, ×230.
4. *Globigerinoides ruber* (d'Orbigny), ventral view, Equatorial waters, ×230.

5,9. *Globoquadrina dutertrei* (d'Orbigny), ventral views, 5 slightly tilted, subsequatorial waters, ×200.

6. *Globoquadrina dutertrie* (d'Orbigny), ventral view, penultimate chamber kummerformic, last chamber of normal size, central waters, ×180.
7. *Globoquadrina conglomerata* (Schwager), ventral view, equatorial waters, ×200.
8. *Globigeri-noides trilobus sacculifer* (Brady), equatorial waters, dorsal side, ×200.

10. *Orbulina universa* d'Orbigny, penultimate chamber covering the earlier chambers partially, equatoral waters, ×200.
11. *Globoquadrina hexagona* (Natland), ventral view, ×60.
12. *Globorotalia hirsuta* (d'Orbigny), dorsal view, subequatorial waters, ×60.
13. *Globorotalia menardii* (d'Orbigny). ventral view, equatorial waters, ×120.