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BIDDULPHIA CHINENSIS GREV. AS INDICATOR OF OCEAN CURRENTS

F. C. MÜLLER MELCHERS

The large amount of Biddulphia chinensis Greville during certain years in plancton gatherings off the uruguayan coast (South Atlantic) and then again the almost complete absence of the same during other years have induced me to investigate the life cycle of this diatom more closely.

Biddulphia chinensis Greville, *New Diatoms* XIX, p. 81, f. 16.
A, Schmidt. *Atlas*, p. 122, figs. 22-24.
Odontella chinensis, Grunow. *Fr. Josefs Land*, p. 58.
Denticella sinensis, De Toni, *Sylloge*, p. 884.
Biddulphia sinensis, Ostenfeld & Schmidt, *Red Sea*, p. 152, f. 6.
Ostenfeld, *Koh Chang*, pág. 25, f. 21.
Gran. *Nordisch. Plankton*, f. 139.
Brockmann, *Nordseediat.* f. 6-d.
Okamura, *Diat. Japan*, p. 10, pl. 12.
Skvortzow, *Korean Str.* p. 109, pl. 8, f. 9.

In 1866 Greville describes Biddulphia chinensis from Hongkong harbour for the first time. I have retained the name given by Greville "Biddulphia chinensis" instead of "sinensis" on the understanding that names once given have the preference.

Soon after Bidd. chin. was then traced all along the Indo Pacific seas up to Japan. It was found in the Red Sea, Gulf of Aden, Arabic Sea, Gulf of Bengal. Madras. Gulf of Siam. Singapore. Sonda Streit. Banca. Java Sea. China coast. Formosa. Korean Streit and Japan. It was believed that Bidd. chin. represented a tropical warm water species with a definite salinity factor. This is not so as we shall see further down.

From Africa the only notice I have been able to find is from the german South Polar Expedition "GAUSS." 1901/1903. Heiden and Kolbe report Bidd. chin. from Simonstown. South Africa. On south african currents. T. A. Stespenson refers in "Intertidal Fauna

and Flora of South Africa'' page 219 ''South Africa has tropical connection with the Western Africa Tropics. While the Agulhas current encourages tropical forms to spread westwards along the South African coast.'' The down flowing currents along the East Africa coast and the Agulhas and Mozambique current may have displaced Bidd. chin. from the Indian Ocean to the Cape. It might also be, that Bidd. chin. drifted with the remnants of the South Equatorial current ''Brazil current'' from South America over to Africa, or along the border of the Westwind drift?

From Australia and New Zealand I know only one place up to now, but further investigations will surely show Bidd. chin. in other australian and Polynesia waters. D. Alleyne Crawford describes Bidd. chin. from Cook Streit, New Zealand in planeton gatherings during the month of August.

In Europe Bidd. chin. was first known in 1903, appearing in the North Sea and spreading through the Skagerak and Kattegat in to the Baltic. It was found on the coast of Norway, Denmark, Germany, Netherlands, Belgium, France and England. The most northerly point reached seems to be about 60º North. On the french coast, south of the Bretagne, in the Gulf of Biscay, the spanish and portuguese coasts to Gibraltar it is not known.

In the Mediterranean we do not find Bidd. chin. and it seems that it has not passed through the Suez Canal from the Red Sea., where it is well known. (Ostenfeld 1901) R. Gurney 1949 gives an account of animal migration through the Suez Canal, of crabs and prawns found on the Palestine coast. He writes ''Apart from the first section at Suez, where there is tidal ebb and flow, there is a nontidal current whichs flows slowly northwards from October to July.'' further down: ''Only during August and September is the current reversed. Consequently, floating larvae of Red Sea species can be carried nearly through the Canal.'' I call the attention to this fact, that if the larvae will float along the Canal the rest of the planeton will float as well. The mediterranean waters are much more adequate to the life of Bidd. chin. regarding salinity and temperature, but up to now no signs of Bidd. chin. are found in waters about Port Said or off the Palestine coast as far as I know.

From South — Central and North America we have the following findings:

1900	Cleve	Guiana coast 7ºN - 55ºW 10ºN - 55º45'W	March/June 1898

1917	Gomez de Faria y Marques da Cuhna	Rio de Janeiro. Brazil.
1917	Marques da Cunha y Olivera da Fonseca	Mar del Plata. Coast of Argentine.
1925	Gliesch	Torres. Rio Grande do Sul. Brazil.
1925	Hentschel	Rio Grande do Sul. Rio de la Plata. Argentine and Uruguay. Meteor Expedition.
1928	Frenguelli	Atlantic Ocean off Mar del Plata. Argentine.
1938	"	Bahia de San Blas 40º30'S Argentine.
	"	44º55' - 63ºW. Argentine.
1939	"	Rio de la Plata. Argentine.
1944	Osorio Tafall	Tampico. Gulf of Mexico.
1944	Müller Melchers	Atlantida 34º47' S - 55º44' W. Coast of Uruguay.
1945	"	Montevideo. Isla de Flores. Punta del Este. La Paloma. Santa Teresa. Coast of Uruguay.
1946	"	Puerto Quequen. Argentine. 36º5' S - 55º22' W off argentine coast.
1948	"	Port Lookout. Beaufort N.C. U.S.A.
1949	"	Camarones. 44º45'S - 66ºW. Argentine.

P. T. Cleve is the first to record Bidd. chin. in american seas. His gatherings were made during march and june 1898 in the Guiana current. Ostenfeld 1909 believes that the specimens found by Cleve do not belong to Bidd. chin., but to Biddulphia regia fma.

tropica. I do not know the material gathered by Cleve, but the drawings made by Ostenfeld (1909 p. 365 fig. 2), are very similar to specimens of Bidd. chin. found on this coast during the summer time. Japanese material from Challenger gatherings show the same kind. It is very unlikely that a plancton specialist like. Cleve should have made such a mistake. In 1917 the records of Bidd. chin. from South America begin. Since 1943 I have gathered plancton samples along the uruguayan coast during the whole year. At the same time I have tried to collect other samples from the Americas. Dr. Osorio Tafall 1944 gives his account on gatherings off Tampico in the Gulf of Mexico. He suggests at the same time, that if found in the Guiana current and Gulf of Mexico, Bidd. chin. should be found in Florida current and the Gulf stream. Thanks to samples received from Dr. H. J. Humm of Beaufort N.C.-U.S.A. (now Tallahassee Florida) I found in one of the many gatherings sent to me a large quantity of Bidd. chin. This gathering was taken at Cape Lookout during the month of October in the Gulf stream waters. Williams in his paper on: Marine Algal Ecology at Cape Lookout page 10 writes: "The current which is most significant to the flora, however, is the nearby Gulf Stream, which brings warm waters to this area, maintains oceanic salinities, and is the medium of dispersal of algae from the tropics." Bidd. chin. journeys along the the Gulf stream as already suggested by Osorio Tafall. It is not a stationary tropical warm water species and will thrive in cold water as well. The various gatherings from along the coast of South America, below the equator, show this fact. We find Bidd. chin. at Rio de Janeiro in the warm water of the Brazil current, and in unintermitted findings as far south as Camarones on the argentine coast where the waters are influenced by the north flowing Malvinas (Falkland Islands) cold water current. Possibly, if gatherings further south were availeble, traces of temperate cold water type of Bidd. chin. still would be found. It may be that the origin of Bidd. chin. was originaly from tropical seas. (Red Sea, Indian Ocean and adjacent seas). Gatherings from these locations show a more slender build of a warm water species with the spines further apart. On the other hand we have the heavier and more coarse forms from the cold temperate seas. Here spines and horns are closer together. This is the type found on the uruguayan and argentine coast as well as in the North Sea. In Japan in winter this diatom was of first importance during November in Aomori Bay. (Kokubo and Tamura 1931.) On the China coast it is reported as common from October to December at 0°C, less common in February and March. (Chin. 1939. Tsingtao). The samples examind by Frenguelli from San Blas were collected September 7. 1932, the water temperature beeing 9°C. Bidd. chin. is found on the

eastern coasts of the continents. From East Africa it is not known, but very little systematic research is known from these parts. It is not known from the western coast, neither from South — Central or North America.

Regarding the sudden appearance of Bidd. chin. in the North Sea Ostenfeld gives the following explanation: "It has beeen drawn in from afar by the aid of man, that is to say, carried along from distant oceans by ship, e. g. attached to the outside of a ship, or living in the water of the hold or in the water of a used bucket or the like." (1909. p. 364). This is most improbable. On the outside of a ship it might be, but in the water of the hold, where no daylight reaches and the water of the bilge is contaminated by oil film and other foreign matter, it is by no means apt to keep plancton diatoms living during several weeks. Ships have come by the thousands from the Indo Pacific Ocean, around the Cape and through the Suez Canal since a very long time. Why should Bidd. chin. appear only as late as 1903 in the North Sea? Systematic plancton recording has only started at the end end of the last century. Bidd. chin. may have been mistaken for Bidd. mobiliensis or Bidd. regia, as it has happend may a time. Bidd. chin. will have a spontaneous flowering till beeing supreme in the plancton. I have noted this phenomena on the coasts of Uruguay and Argentina. It will predominate for a month or more, only to disappear just as quick as it came. In 1945 we had such a flowering and since then Bidd. chin. has nearly disappeared from the uruguayan inshore plancton. I have noted that this will happen with other plancton diatoms as well. For instance with Chaetoceros peruvianus and Bacteriastrum delicatulum. They appear suddenly in large quantities and then during several years diappear completely from the coastal plancton. It may be that these diatoms retire out to the sea and they would be found there, at several miles off the coast in the range of oceanic waters. I have no access to these parts. My gatherings are from the coast and oceanic plancton is not available to me.

Sumarizing all the above expounded it is most probable, that Bidd. chin. spreads into the ocean currents and is drifted along with these. It must have been an enormous sudden flowering of this diatom that called the attention to its appearance in the North Sea, like that enormous flowering that I have been able to investigate on this coast in December 1945, where it was supreme excluding all other diatoms. That it was not found in the North Sea before 1900, is surely to be put to misinterpretion of the three Biddulphia forms that will live together. To a certain extent it is possible to confound these, when only a few specimens of one or the other appear in a plancton comunity.

My explanation of the appearance of Biddulphia chinensis in the North Sea is the following. Biddulphia chinensis is not a tropical warm water species only and therefor will thrive in temperate and cold temperate water just as well. Biddulphia chinensis flows with the ocean currents and may be used to indicate these. Biddulphia chinensis drifted with the Gulf strean and so reached the English Channel and past into the North Sea most probable a long time ago. Biddulphia chinensis seems to be an ubiquitious plancton diatom.

Regarding the ecological side of Biddulphia chinensis several interesting observations have been made.

The specimens on this coast of Uruguay are generally single or united into short streight chains of two, very seldom of three or four individuals. The valve body is cushionlike with a nearly flat central part, on each side two large spines and two shorter processes or horns inserted on the shoulders. These horns are hollow and united with the valve. In some cases of division these were found to contain cromatophora. The sculpturing of the upper part of the valve is coarser than the middle connecting bands. These latter being more weakly silicified. The number of areola are about 10/11 in 0.01 m/m and of 14 rows in 0.01 m/m in the middle part.

The following measurements in millimetres give the sizes from gatherings taken on the uruguayan and argentine coast:

ATLANTIDA 34º47'S - 55º44'W.		transapical axis	apical axis
smallest type	Müller Melchers	from 0.064 to 0.080	0.128 to 0.180
medium		0,123	0.168
		0.130	0.224
maximum		0.280	0.201
		0.336	0.196
MAR DEL PLATA. Argentina	Frenguelli	—.—	0.090 to 0.177
BAHIA SAN BLAS. Argentina	"	0.061	0.121
PUERTO QUEQUEN. Argentina	Müller Melchers	0.090 to 0.140	0.126 to 0.224
36º5'S - 55º22'W. cff argentine coast	" "	0.280 to 0.308	0.308 to 0.364
CAPE LOOKOUT N.C. U. S. A.	" "	0.140 to 0.168	0.224 to 0.280

The size of the most frequent type is about 0,090 by 0.145. All above measurements are of the body without the spines. Winter gatherings, during May to August, have shown that the size of the cells is generally longer than broad, while during the summer months, January to March they are broader than long. The girdle band demarcation is only well visible on dry valves. The cromatophora of normal cells are represented by leaflike rhombic flakes (fig. 1) that may be more or less elongated or rounded. Most of the cromatophora have a small globule formed grain attached to them. In some two or three. They seem to be of fatty matter. The colour of the cromatophora is of a brownish graygreen. At the time of division this colour changes to a golden yellowish brown. It seems that the chlorophyll is overcovered by Xantophyll (Carotin or Diatomin.) At the same time the cromatophora change into roundish elongated bodies.

Interesting observations could be made regarding the life history of Biddulphia chinensis. The division generally starts by a conglomeration of cromatophora in one or two corners of the diatom. (fig. 2). Or the cromatophora will be sucked to the upper and lower parts of the valve. (fig. 3) A bridge is then formed between these (fig. 4), till the nucleus divides and two bags are formed (fig. 5) in which the spines and horns are formed. It seems that the latter are the only parts of the new valve that harden their silex right at the beginning. Both spines and horns are bent inwards at first, facing the mother cell spines. (fig. 6 sideview, 7 front.) As the spines harden together with the shoulder of the new valve they are projected by the turgor in the bag of the valve into their right position. (fig. 7, 8, 9, 10.) Fig. 10 shows various bubbles of cromatophora blowing up the two shouders with spines and horns. The nucleus is suspended by cromatin threads in the middle of the valve and is placed against one of the broad sides (fig. 1) surrounded by a star of cromatophora that are also united by cromatin threads. When the division has taken place the nucleus adheres to the new valve down or upwards in a cluster of cromatophora. (fig. 5) The new valves are of the same size as the mother cell, as only the part bearing the spines is renewed. The old sides of the mother valve lenghten and form the rest of the new diatom. This will also be noted as the longitudinal sides when breaking apart stand out over the new formed specimens.

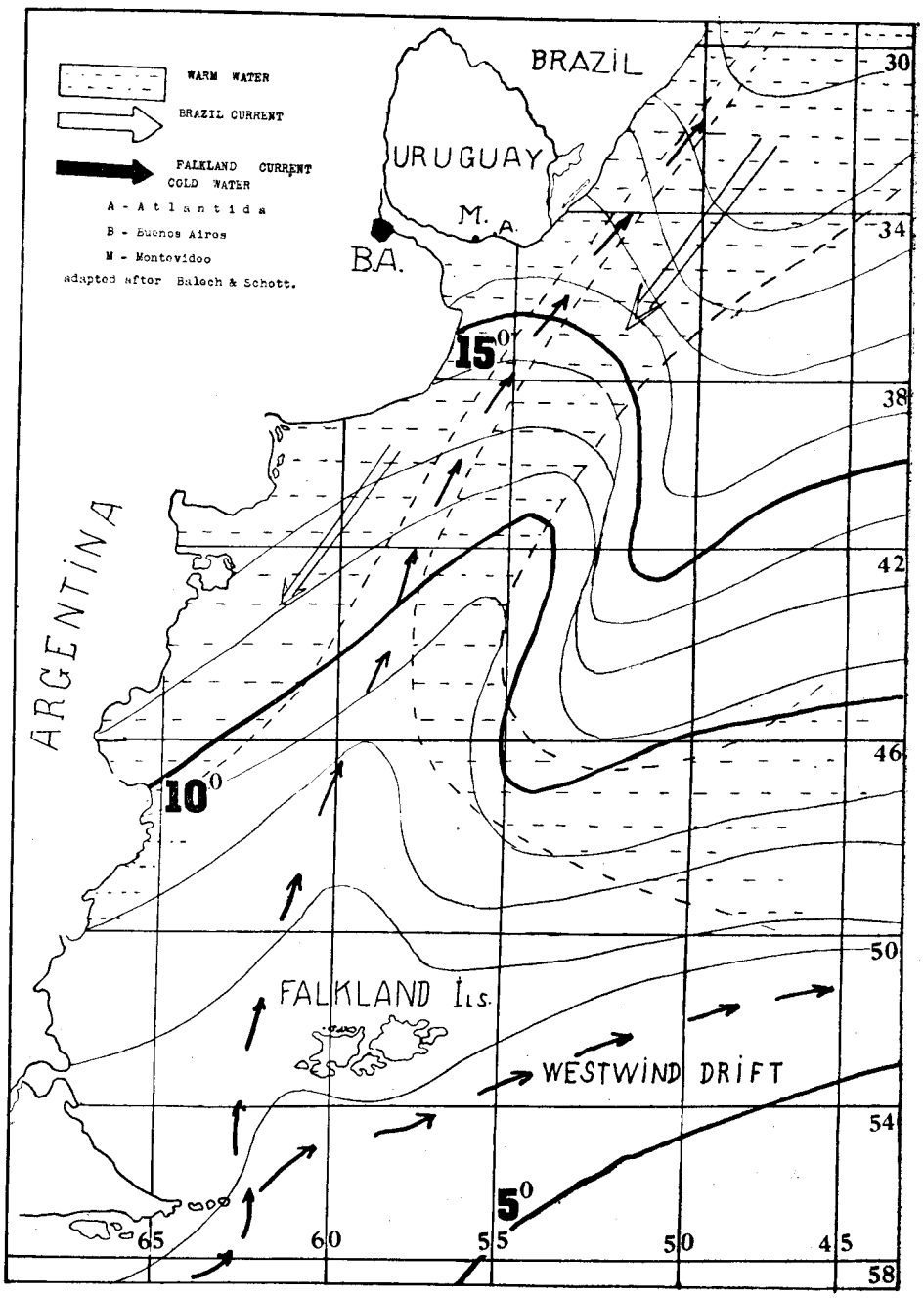
On very rare occasions microspores were found. (fig. 13) The cases of these known at Atlantida are very few. Microspores are not known to me from the argentine coast. The microspores were formed in large transparent bags, two bags to each specimen. The microspores consisted of rounded balls, 6 or 8 and up to 20 balls

to each bag. These small spherical bodies were partly covered with oval platelike cromatophora and small granulations, the nature of which could not be acertained. In these cases no movement was seen of, or in the the round bodies. It seems to be a prephase of the following case, that was found only once in ten years of continous plancton investigation. (fig. 14) Here we have the same rounded bodies in a transparent bag, but this time without cromatophora or granulations, filled up with pear shaped bodies, compressed slightly at their middle. These bodies were not motile when observation began. It was possible to observe the rupture of the small globes and one by one the small bodies escaped into the large bag. There they at once started do dance from side to side, or spinning around themselves. No flagella were seen. But there must have been as shown by the movement of these pear shaped bodies. The microspores were completely transparent. The movement went on for 40 minutes and then ceased. Fresh seawater had been added during the whole observation. Being a very hot day, 36°C in the shade, may have influenced the observation. This was made at 11.30 A.M. No other case of living microspores on this coast is known to me. Several times specimens with the prephase have been observed in Biddulphia chinensis. In Coscinodiscus asteromphalus, Coscinodiscus commutatus and Actinocyclus spec. as well as Ditylum Brightwellii and Chaetoceros decipiens I have found microspore formation, all of these not in the motile state., but on the whole this phenomena is very scarce at Atlantida.

Biddulphia chinensis is sometimes found invaded by a small diatom, very scarecely silicified. This same diatom will also invade Bacteriastrum hyalinum, Dytilum Brightewllii and Chaetoceros compressus. Judging by the outlines of its form as well as the cromatophoras it may be a Nitzschia species.

During January 1946 (southern summer) the whole plancton gatherings were invaded by Bicoeca spec. specially on Biddulphia chinensis, Ditylum Brightwellii and Coscinodiscus commutatus. In gatherings from January 1948 Biddulphia chinensis was found infected by large flagellates, these were found in the cell mowing about in the whole body. The flagellates were dividing freely. The species could not be identified.

A very interesting observation on Biddulphia chinensis are the various teratological forms that are found nearly every year. These were first described by Freguelli 1938. In nearly all gatherings and during the whole year these abnormalities are found. Monstruosities



surface temperature and ocean currents along the coast of Uruguay and Argentine

in spines and horn formation, as well as the general outlines of the whole bodies have been found. Specially during July (winter) and January/Febr. (summer). Instead of the two normal spines and horns there will be two or three spines at one corner and no horns. Or the horns missing or mutilated. These phenomena are even observed in specimens that have not terminated their division and still attached to their mother cell, the latter being normal.

Hustedt 1930/37 attributes cases of teratology to disturbances during the auxospore state. I would put it to disturbances during division. Auxospores in Biddulphia species are known to me only once in Biddulphia mobiliensis during ten years of plancton gatherings on this coast. But dividing specimens are found in nearly all gatherings. To my opinion the often very violent changes in temperature and (or) salinity may produce these abnormalities. It can happen that the salinity being about 33.31 o/oo will change in a very short time, in a few hours or less to 15 o/oo or less. This happens generally by change of wind, turning from NE or SE to heavy W or WSW, so that the masses of water from the Rio de la Plata are pressed against the uruguayan coast producing the drop in salinity. During north winds that may prevail during several days the ocean waters will be driven back and large amounts of brackish or fresh water from the river flows along the uruguayan coast. Influxes of ocean water will occur that bring an instantaneous drop in temperature. As the coastal waters are very shallow the mowing of the ocean and river waters tend do overlap. This has been ascertained by Dr. F. de Buen Lozano on the uruguayan coast near La Paloma (May 1951 investigation not published as yet.) How far these changes are influenced by ocean currents is difficult to say. That they do so has been shown by the different populations of diatoms and other planctonic members that occur with the change of temperature and salinity. For instance the Rio de la Plata will always bring the prevailing diatom of this plancton: Coscinodiscus commutatus. On the other hand as warm water or temperate species we have Chaetoceros coarctatus, a diatom that appears only with high salinity populations. A rare Tintinoidea, Tintinopsis tocantinensis known from the brazilian coast has been found at Atlantida. The influence of the warm Brazil current flowing south along the uruguayan and argentine coast is divided by the cold Malvinas (Falkland Islands) current. It is evident that these currents have influence on the life cycle of plancton diatoms. The coastal currents in the very shallow waters will change quickly. All these events are surely of considerable importance during the state of division. From the belgian coast Meunier, 1910 plate X. f. 12 gives a drawing. He writes; "multiplication anormale de soies entre les deux valves nouvelles."

— but he does not say anything what may have been the cause. Dr. Chr. Brockmann of Bremerhaven sent to me several slides with Biddulphia chinensis from different parts of the North Sea. Double spines on one shoulder were found in this material and also valves with one shoulder void of spines and horns. After many observations during January 1951 I have come to the following conclusion. The plancton flowing along the ridge of high and low salinity is influenced during the division by the change of the turgor pressure in the valve. Specimens were found showing the horns malformed from these waters. As said above "when horns and spines are formed, these seem to be blown up by the turgor." Specimens were found where the horn in formation was badly deformed and the spines bent. The pressure of the turgor changes when the equivalent outer presure of surrounding ocean water is disturbed. Small differences in salinity may not be noted, but at times of great influxes of low or high salinity, as may happen on this coast, the balance of inner pressure is badly disturbed. Considering that the horns and valves are one, without partition, the inner pressure acts directly on this part. The spines seem to have no direct outlet to the inner part of the valve, but there must be some small orifice that does not show.. Also in the case of the spines they behave equally, they are badly inflated. The production of more spines than normal may as well be caused by a drop of salinity, so as to highten the floating powers of the valve. I do not insist that the forgoing is the right explanation to these abormalities. What produces these teratological and multispined forms has still to be further investigated. It is hoped that more gatherings from this coast further out at sea, with sufficient data on salinity, temperature and current frequencies will give the answer to this problem.

I have to thank the following friends for various assistance to this paper. To Prof. E. Balech, Dr. E. H. Cordero † and Dr. H. J. Humm for plancton gatherings. To Dr. J. Frenguelli for facilitating to me his vast library. Dr. Chr. Broockmann for slides, samples and information on the North Sea plancton. To Mr. R. Ross for a slide of Japan Plancton and to Mr. R. Thomsen for discussing with me many problems of this paper.
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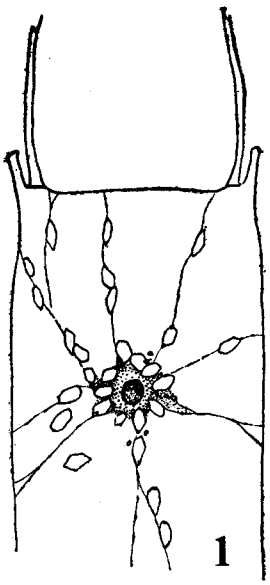
Photographs and drawings originals by
F. C. Müller Melchers.
Atlántida.

PLATE I

1. normal cell before dividing.
2.3.4. phases during division.
5. after dividing.
6. side view showing the blowing up of the spine.



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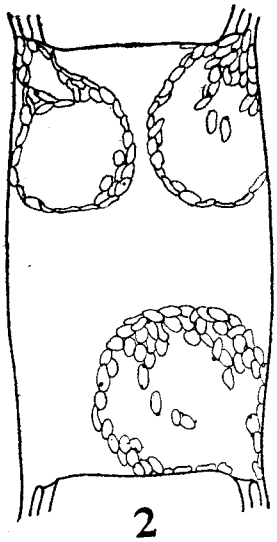

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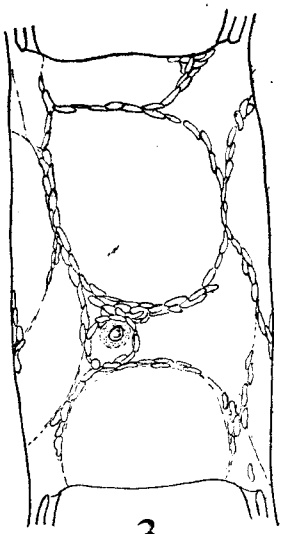

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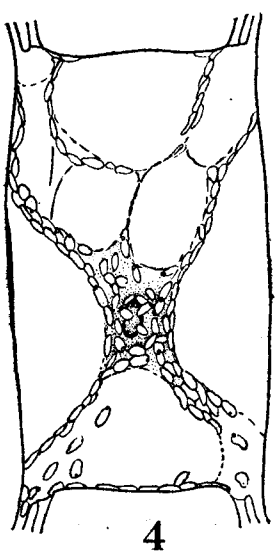

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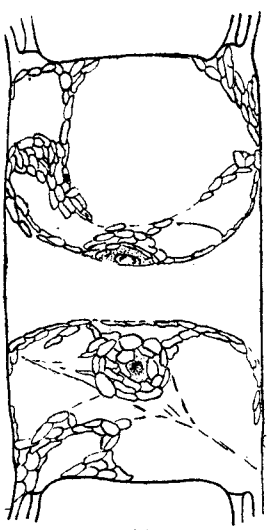

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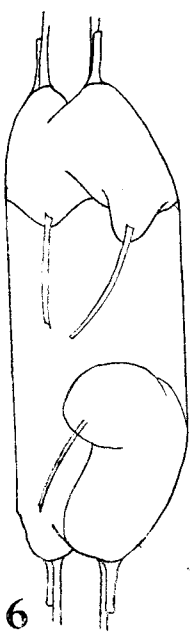

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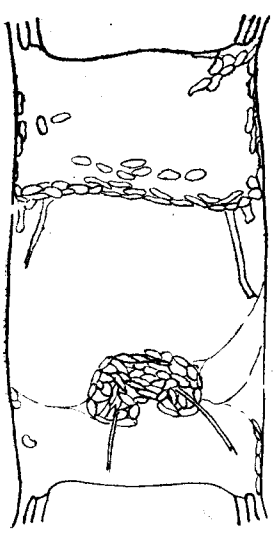
Plate II

7. front view of down turned spines.
8.9. forming of spines after division.
10. upthrusting of spines on sloulders after division.
11. location of spines and horns after division.
12. the new valve seperating after division.



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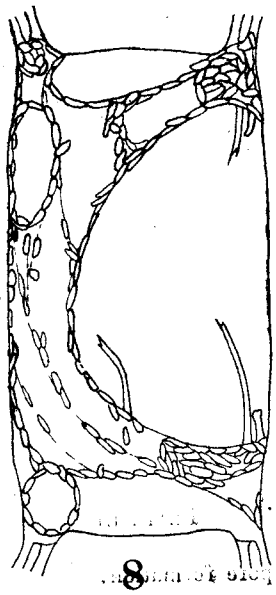

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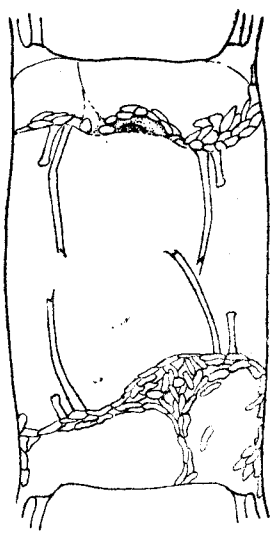

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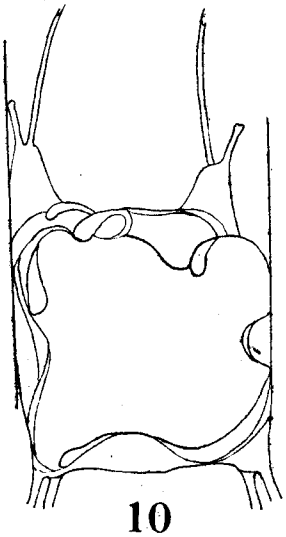

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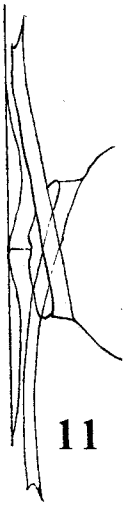

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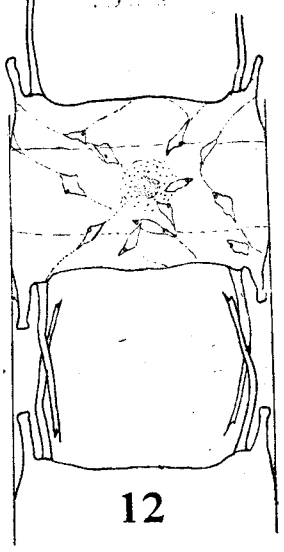

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Plate III

13. prephase of microspore formation.
14. bursting of microspores.
15.22 various teratological forms of spines and horns, as well as multiple spines.

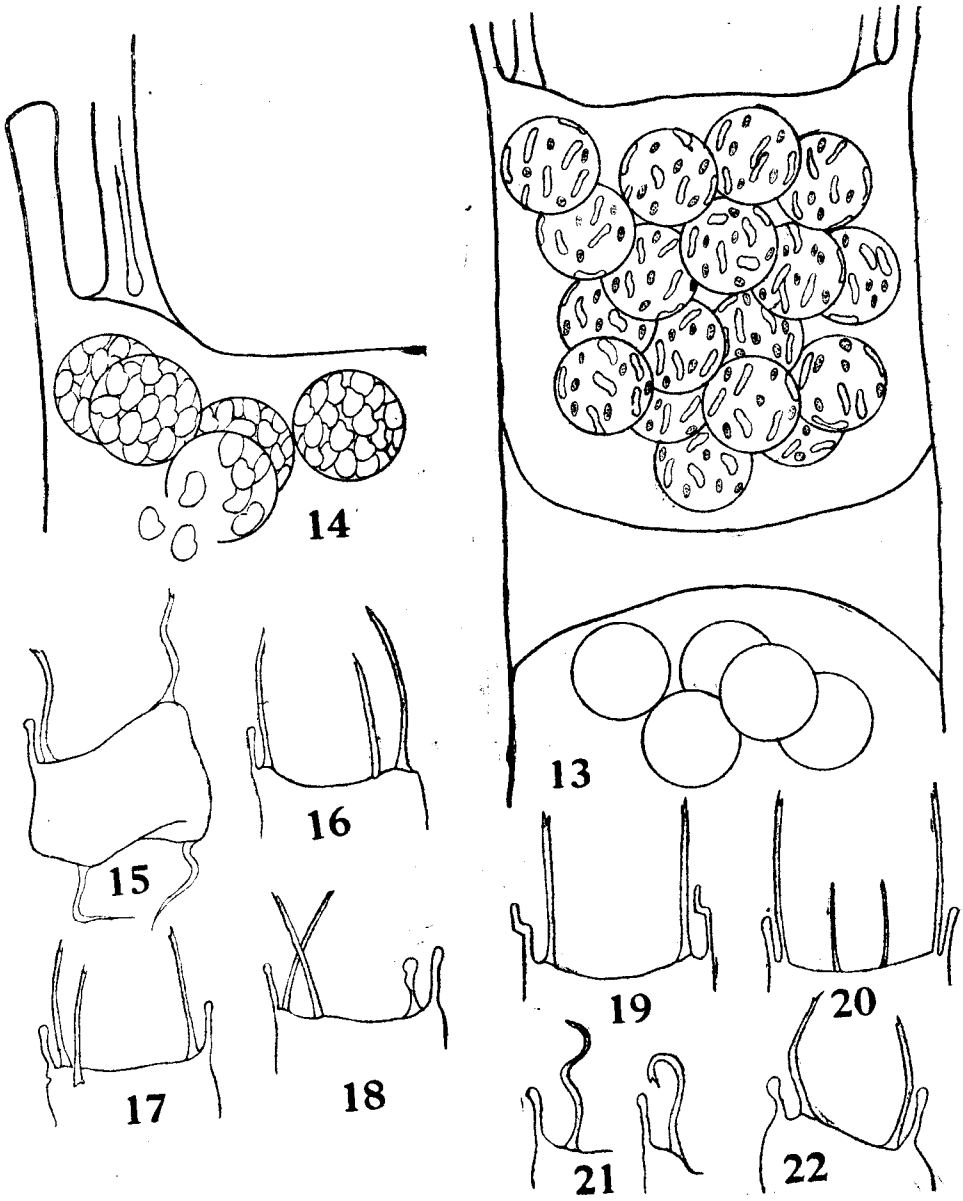
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PLATE IV

Biddulphia chinensis from the North Sea slides by Dr. Chr. Brockmann. Bremerhaven.

A. Biddulphia chinensis.
B. Biddulphia mobiliensis.
C. Biddulphia regia.
D. Biddulphia chinensis. Shoulder without spine and horn.
E. " " With double spines.

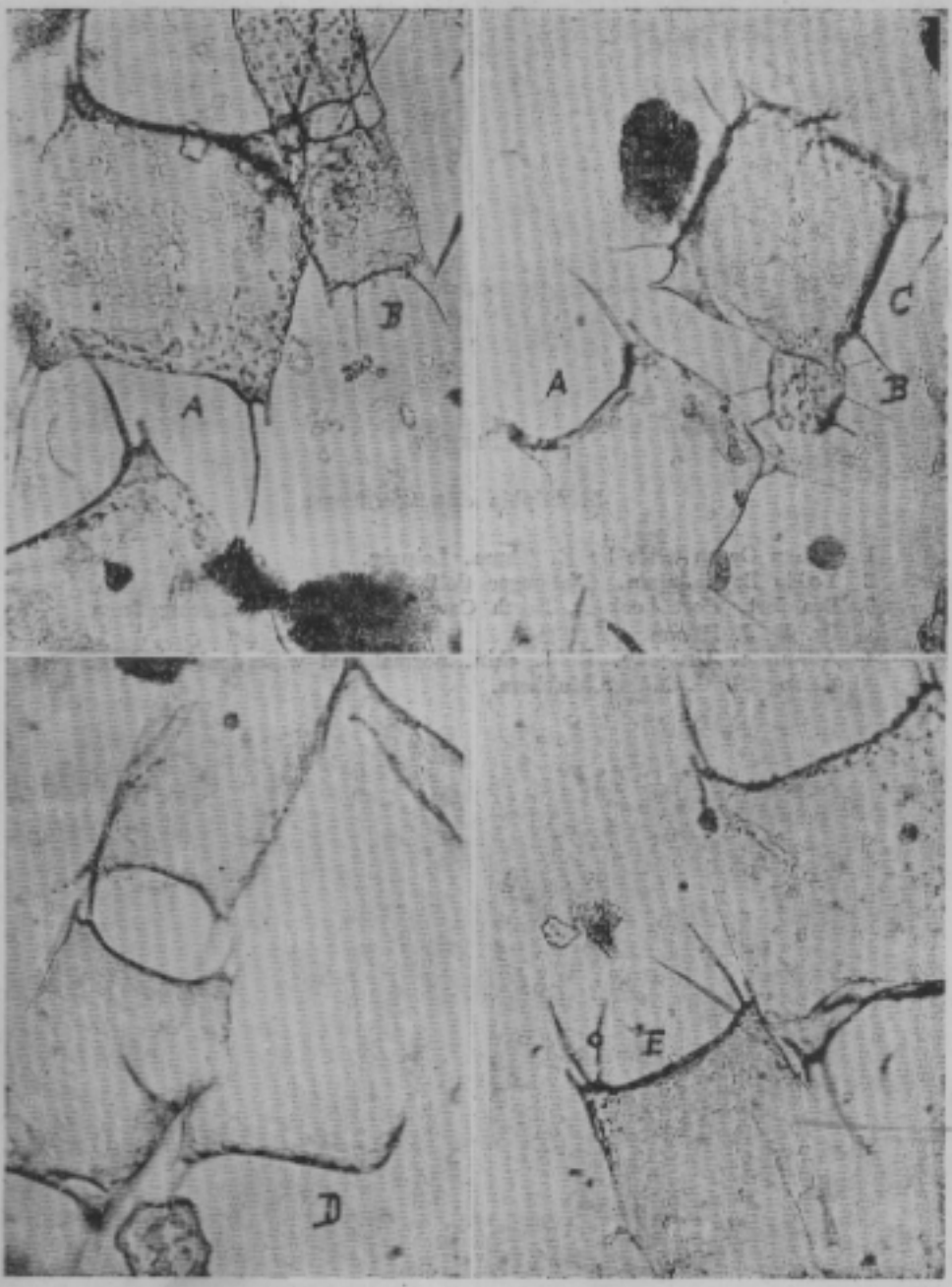
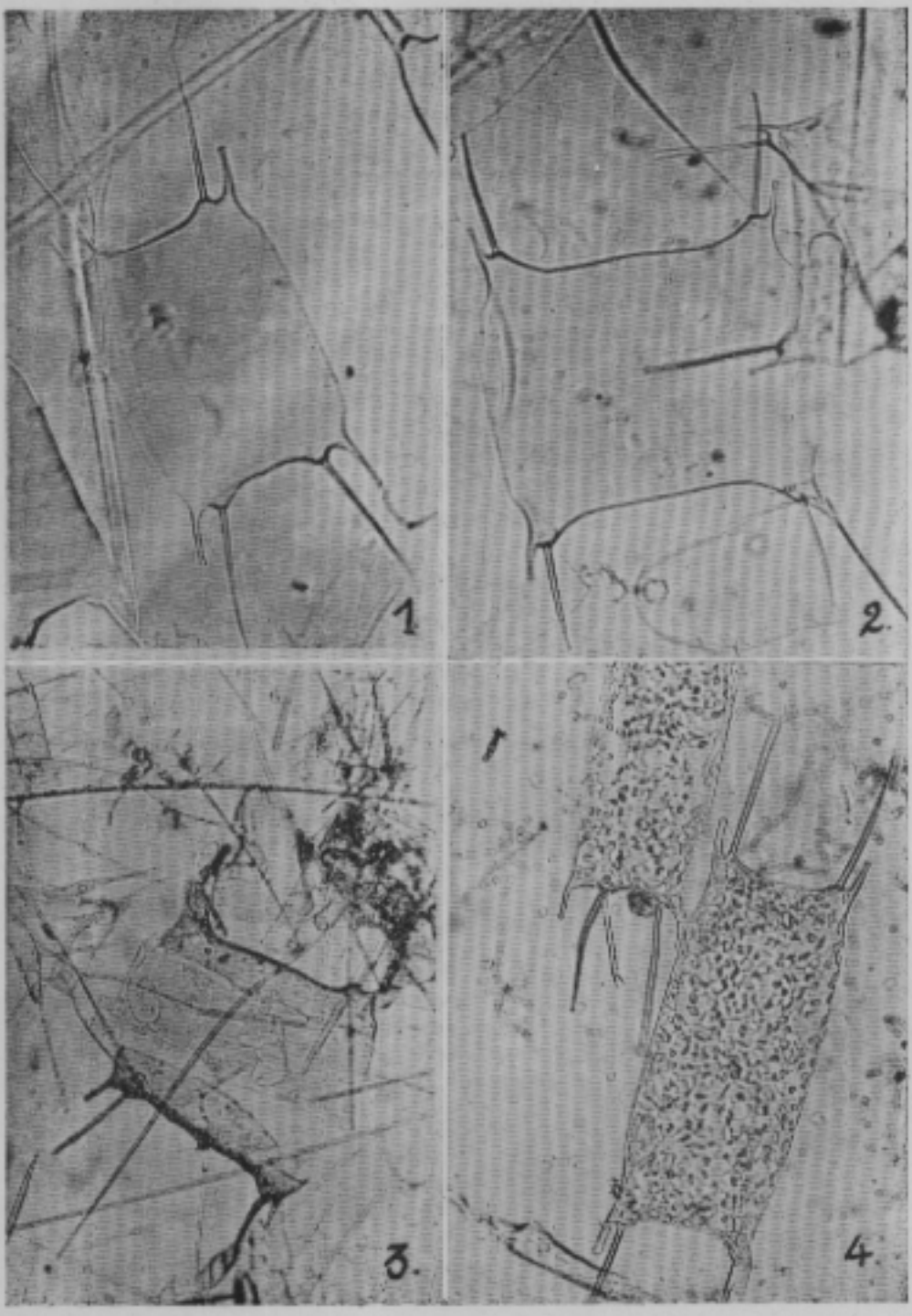

A
B
A
B
C
D
E

PLATE V

Biddulphia chinensis from:

1 Indian Ocean - slide by E. Thum. Leipzig.
2 Yeddo Bay. Japan. Challenger Coll. Brit. Museum 15941.
3 Beaufort. Port Lookout, North Carolina. U.S.A. gathering from Dr. H. J. Humm.
4 Atlántida. Uruguay. Bidd. chin. normal and with double spines. gathering F. C. Müller Melchers.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