Oceanographic Condition of Surface Water between the South End of Africa and Antarctica

Shigeru FUKASE*

アフリカ南端と南極大陸間の表層の海況について

深　瀬　茂*

CONTENTS

* 長崎海洋気象台. 第4次南極地域観測隊員. Nagasaki Marine Observatory. Member of the Japanese Atarctic Research Expedition, 1959-60.

要　旨

1956年より日本の南極観測が開始され，宗谷の往復航海中に海洋観測も実施されている．第4次観測の際には，水温，塩分，水素イオン濃度，溶在酸素量，燐酸塩，珪酸塩，アンモニヤ，亜硝酸塩，硝酸塩を測定し，また同時にプランクトンを採集し，珪藻類については各種類ごとに詳細な定量を行ない，撓脚類の分布も参考とした．これらの資料のほかに，Discovery Expedition (1932–51) その他の観測結果も利用して，アフリカ南端と南極大陸間の表層の海況を研究した．

この海域には亜熱帯収束線および南極収束線の存在が知られているが，水温，塩分その他化学成分の分析結果を解析したところ，南アフリカ沖合を南西流するアグリアス海流の南側に，東流する別な水塊が接触して顕著な収束線を形成していることが認められ，これをアグリアス収束線と命名し，この収束線と亜熱帯収束線との間に存在する水塊を，西風皮流北縁水と命名した．その結果この海域には3個の収束線が存在し，4個の水塊に分離される．すなわち北からアグリアス暖水塊，アグリアス収束線，西風皮流北縁水塊，亜熱帯収束線，亜寒帯上層水塊，南極収束線，南極表層水塊である．これらの水温，水質，その幅および変動について研究した．

珪藻類は92種が査定され，*Nitzochia seriata* が全域にわたって最も卓越している．西風皮流北縁水は暖流の性質を有し，かつ *Chaetoceros socialis* の卓越することにより他の水塊と区分され，亜寒帯上層水は *Nitzochia seriata* の細胞数が多く，かつその比率が高いことで他の水塊と区別されるなど，上記水塊分析の結果を裏付けることができた．撓脚類の分布もまた海況とよく一致し，さらに南極大陸近縁に存在すると言われている南極発散線の存在をも暗示すると考えられる．

INTRODUCTION

In the sea area between the south end of Africa and Antarctica, oceanographic observations have been carried out to some extent by different expeditions. Since the commencement of the Japanese Antarctic Research Expedition in 1956, surface oceanographic observations were made on board the research vessel "SOYA" and serial observations on board the research ship of Tokyo University of Fisheries "UMITAKA-MARU" which was in charge of the guard of the former in the first Japanese Antarctic Research Expedition (Nov. 1956–Apr. 1957).

It is well known that there are two conspicuous convergences, the Subtropical and the Antarctic, in this sea area. In addition to these, however, the author proposes another convergence between these two, after analyzing the physical and chemical data of observations obtained by the "SOYA", "UMITAKA-MARU", and by the Discovery Expedition. Accordingly, the sea area is divided into four water masses by these convergences.

The above conclusion of the author was confirmed not only by hydrographic data but also by the study of plankton samples collected by the author during the round trip to Antarctica by the "SOYA" in the 4th Japanese Antarctic Research Expedition (Nov. 1959–Apr. 1960), and by the records of the distribution of plankton in this sea area by the previous authors.

The diatom plankton of the Antarctic Ocean has been investigated in the Challenger, Deutsche Sudpolar, Valdivia, and Discovery Expeditions. As for copepods, many studies have been reported by GIESBRECHT (1902), WOLFENDEN (1908 and 1911), FARRAN (1929), and VERVOORT (1957), etc. The diatom distribution in the whaling ground of the

Antarctic Ocean has been reported by Japanese authors; TAMURA and SUGIURA (1949), TSUBATA (1950), HANZAWA and others (1951), SHIMOMURA (1952), and MARUMO (1953a, 1953b and 1957). With the samples collected by the "UMITAKA-MARU", SEO (1958) studied the relations of the density of plankton population, water color, and transparency. Since the commencement of the Japanese Antarctic Research Expedition, plankton sampling has been carried out by the "SOYA" in every voyage. TANAKA (1960) made an excellent study on copepods in the Indian Ocean and the Antarctic Ocean by the samples collected in the 2nd Expedition.

In this report, the author made a detailed analysis of oceanographic conditions not only by the physical and chemical elements, but also by biological elements, such as the geographical distribution of plankton, with a view to make the analysis more thoroughgoing. The present paper is the first report of the study on diatoms collected by the "SOYA", from the biogeographical and taxonomical standpoint. However, as for the genera *Navicula* and *Coscinodiscus*, no other than the total cell number of the genera are listed. The unpublished data of Dr. MARUMO on the geographical distribution of diatoms were very useful. The distribution of copepods was also studied in order to clarify the characters of water masses by referring to the records given by Dr. O. TANAKA.

Upon publishing the study, the author's cordial gratefulness is due to Prof. Dr. O. TANAKA, Prof. Dr. Y. MIYAKE for their advice and reviewing the manuscript. And the author expresses his gratitude to Dr. MASAMI KOIZUMI and Mr. MASAO HANZAWA for their kind advice, and to Dr. R. MARUMO, Mr. SADAO MURATA, Mr. KOTARO MORITA, Mr. YOSHIO SUZUKI, Mr. TSUTOMU AKIYAMA for assisting him in collecting data and to Miss TERUMI KANAYA for assisting him in writing this report. Thanks are also due to Mr. SUEICHIRO AKITA, Captain of the "SOYA", Dr. TATSUO TATSUMI, Leader of the 4th Japanese Antarctic Research Expedition, Dr. TETSUYA TORII, Subleader of J.A.R.E., Mr. YOSHIO SUZUKI, Mr. YOSHIO YOSHIDA, Mr. YOZO MATSUMOTO, Mr. TAKASHI MIYAHARA, and many other members of the "SOYA" observatory team for their help during the observation.

METHODS

For analysis of the oceanographic conditions, the author used mainly the data of the 4th Japanese Antarctic Research Expedition in which the author participated. In addition to this, the previous data of the "SOYA", "UMITAKA-MARU" and the Discovery Expedition were used as references. The surface observation was carried out throughout the cruise in the 4th Expedition between Cape Town and Antarctica, three times a day on the south-bound cruise and twice a day on the homebound cruise. The stations of observation are indicated by the stations 58 through 110 in Fig. 1. The stations where water temperature alone was measured at the interval of three hours are also indicated in Fig. 1. The methods of the observation are as follows:

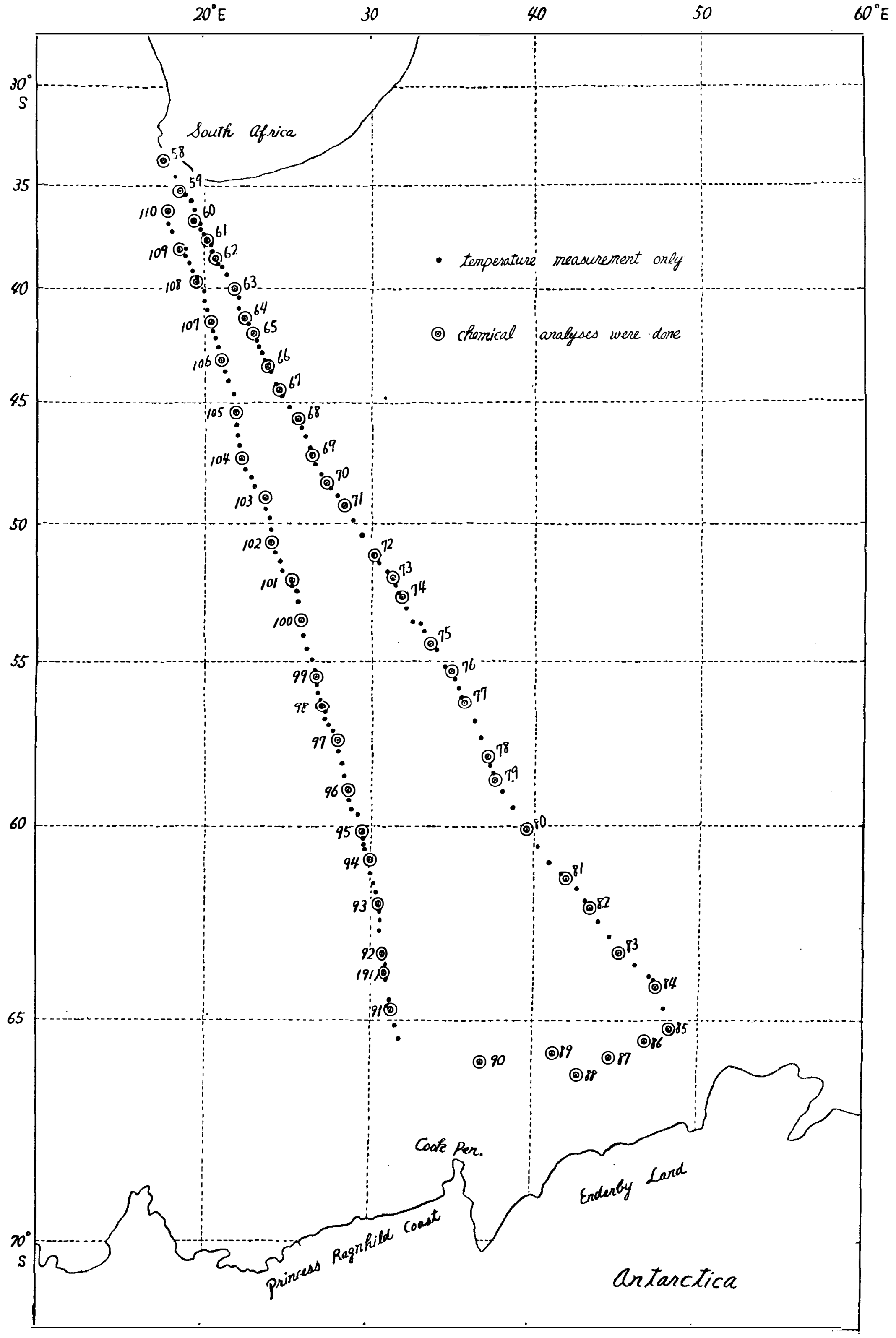

Fig. 1. Surface observation stations at the 4th Japanese Antarctic Research Expedition.

1. Physical and chemical observations

Temperature measurement of surface sea water: A 2-litre canvas bucket was used for the collection of the surface sea water samples, and the temperature was measured by ordinary thermometer.

Collection of surface sea water samples for chemical analysis: Water sample was collected by the above described bucket for the analysis on board the vessel and for the analysis of various elements after returning to Japan.

Chlorinity determination: After returning to Japan, the chlorinity titration was carried out by the Fajans-Miyake's Method by Mr. S. MURATA of Chiba University.

Dissolved oxygen determination: The analysis was made by the Winkler's Method within 24 hours after the sampling of the water. It was performed by Mr. Y. YOSHIDA on the south-bound cruise.

Measurement of hydrogen ion concentration: The electric method was employed together with the colorimetric method for this measurement.

Determination of inorganic phosphate: The Denigès Method was used for this analysis immediately after the sample was collected.

Determination of silicate: The silicomolybdic acid method was used immediately after the sample was collected.

Determination of ammonia: The Nessler's reagent, which was prepared according to Winkler's description, was used.

Determination of nitrite nitrogen: Analysis was made using the Griess-Romijn reagent immediately after the sample was collected.

Determination of nitrate Nitrogen: The Machida's Strychnine Method was employed for this analysis.

2. Biological observations

During the round-trip to Antarctica in the 4th Japanese Antarctic Research Expedition, the author collected plankton from the water surface by the following two methods.

1) Collection method of the microplankton sampling

Sample of the surface sea water was obtained by a sampling bottle of 350 cc which had previously contained 10 cc of picroformalin. This water sampling was made 3 times a day between Cape Town and Antarctica, and twice a day on the return trip between the two places. On return to Japan, 330 cc of sample was taken out and left over for several days. Then the clear liquid at the surface was removed. The rest was centrifuged and plankton was settled. The settled plankton was sampled by a pipette and finally microscopic examination was made. This method was used for microplankton, especially diatoms.

2) Collection method of the macroplankton sampling

For the macroplankton sampling, Motoda's plankton sampler was employed. This plankton sampler was a tube measuring 70 cm in length and 7.5 cm in diameter, with a 30cm long net made of bolting silk (GG 54) inside, mesh of which is equivalent to that of Müller gauze No. 3. It was towed approximately 1 meter below water surface for about 20 minutes at the speed of 10 knots. Between Cape Town and Antarctica, sampling was made at ten stations which are shown in Fig. 10.

RESULT

The distribution of various elements in the surface water between the south end of Africa and Antarctica observed by the 4th Japanese Antarctic Research Expedition is as follows:

1. Horizontal distribution of physical and chemical elements

Distribution of water temperature: The temperature around 15°C was observed from Cape Town to the Cape of Good Hope; 18°–20°C as far south as Sta. 60 (37°S) about 120 miles southward from the foregoing station; and a high water temperature area of more than 20°C continued from this station to Sta. 63 (40°S). The temperature of the region south of Sta. 63 suddenly decreased to 10.4°C at Sta. 66 (44°S), 2.1°C at Sta. 72 (51°S) and the temperature below-freezing-point continued from Sta. 83 (63°S) to the coast of Antarctica. On the homebound cruise, the water temperature was above zero at a station near the coast of the continent, but it increased from 2°C to 4°C near Sta. 103 (49°S) and suddenly increased from 10.6°C to 15.6°C between Sta. 106 and Sta. 107, and from 11.4°C to 22.9°C between Sta. 107 and Sta. 108. Thus, remarkable changes of water temperature were observed in this region.

Distribution of salinity: Salinity was quite high at the southern coast of South Africa, viz., above 35.40‰ as far as Sta. 65 (42°S), and below 34.00‰ from Sta. 67 (44°40′S) to Sta. 73 (52°S). In the seas farther south, salinity was around 34.00‰ as far as the coast of Antarctica without so much change.

Distribution of dissolved oxygen: The amount of oxygen was poor in the water region near South Africa measuring less than 5.0 cc/l. It increased from Sta. 64 (41°S) and reached to 7.0 cc/l at Sta. 67 (44°40′S) then the value of nearly 8.0 cc/l continued from there to the coast of Antarctica.

Distribution of hydrogen ion concentration: The value of more than 8.20 was observed in the water region near South Africa but it decreased southward and indicated 8.05 south of Sta. 69 (47°S), 8.00 or less south of Sta. 81 (61°S). It also indicated a tendency of decrease toward Antarctica.

Phosphate content of surface water: The value was fairly large in the water region near South Africa as far as Sta. 60 indicating 1.0–2.0 μg-atoms/l, and was poor from Sta. 61 (37°34′S) to Sta. 65 (42°S) indicating 0.3–0.6 μg-atoms/l. However, it was quite rich in the water region between Sta. 67 (44°40′S) and Antarctica indicating 2.0 μg-atoms/l or more.

Silicate content of surface water: The content was poor from the coast of South Africa to Sta. 66 (44°S) indicating 1 μg-atoms/l. It indicated 4-8 μg-atoms/l in the water region from Sta. 67 (44°40′S) to Sta. 71 (49°28′S); a remarkable increase up to

30 μg-atoms/l was analysed at Sta. 73 (52°S), which was followed by a further increase up to 40–55 μg-atoms/l from Sta. 85 (65°S) toward the south. The closer to Antarctica, the more increase of the silicate content was observed.

Ammonia content of surface water: The analysis of ammonia was performed only at a few stations. The content was generally large in the water regions near Africa and decreased toward antarctica, viz., 8 μg-atoms/l near Africa, 1 μg-atoms/l at Sta. 64 (41°S), 5 μg-atoms/l at Sta. 67 and 3 μg-atoms/l or less south of Sta. 71.

Nitrite nitrogen content of surface water: The content was almost negligible from the Cape of Good Hope to Sta. 63. A slight increase was noticed at Sta. 64 and Sta. 65, and the content remarkably increased in the south of Sta. 67 (44°40′S) as far as Antarctica with the value of 0.2–0.3 μg-atoms/l.

Nitrate nitrogen content of surface water: As only a few analyses of this element were performed, it is difficult to discuss its content in detail. Roughly speaking, the content in the surface water near South Africa was almost negligible. However, it measured 6.0 μg-atoms/l at Sta. 65 (42°S), more than 10 μg-atoms/l at Sta. 76 (55°S), and 16–20 μg-atoms/l near Antarctica. The last value is considerably high for a nitrate nitrogen content in the surface water. The rich content of 20 μg-atoms/l was observed near 50°S on the homebound cruise.

2. List of plankton

1) List of diatoms collected by the water sampling method

ALGAE

Class Bacillariophyceae

Order Centrales

Suborder Discineae

Family Melosiraceae

Genus *Melosira* Agardh

1) *Melosira sphaerica* Karsten

Genus *Planktoniella* Schütt

2) *Planktoniella sol* (Wallich) Schütt

Genus *Asteromphalus* Ehrenberg

3) *Asteromphalus heptactis* (Brébisson) Ralfs ex pritchard

4) *Asteromphalus Hookeri* Ehrenberg

5) *Asteromphalus parvulus* Karsten

6) *Asteromphalus regularis* Karsten

Family Thalassiosiraceae

Genus *Thalassiosira* Cleve

8) *Thalassiosira condensata* Cleve

Genus *Lauderia* Cleve

10) *Lauderia borealis* Gran

Genus *Schroderella* Pavillard

11) *Schrodellera delicatula* (H. Peragallo) Pavillard

Family Skeletonemaceae Lebour

Genus *Skeletonema* Greville

12) *Skeletonema costatum* (Greville) Cleve

Family Leptocylindraceae

Genus *Dactyliosolen* Castracane

13) *Dactyliosolen antarcticus* Castracane

14) *Dactyliosolen mediteraneus* Peragallo

Syn. *Dactyliosolen tenuis* (Claus) Gran

Genus *Leptocylindrus* Cleve

15) *Leptocylindrus danicus* Cleve

Genus *Guinardia* H. Peragallo

16) *Guinardia flaccida* (Castracane) Peragallo

Family Corethronaceae

Genus *Corethron* Castracane

17) *Corethron criophilum* Castracane

Syn. *Corethron valdiviae* Karsten

Corethron hystrix Hensen

Corethron inermis Karsten

Corethron Murrayanum Castracane

Corethron pelagicum Brun

Corethron hispidum Castracane

Suborder Solenüneae

Family Rhizosoleniaceae

Genus *Rhizosolenia* Ehrenberg

18) *Rhizosolenia alata forma gracillima* (Cleve) Grunow

19) *Rhizosolenia alata forma indica* (Peragallo) Hustedt

20) *Rhizosolenia alata forma inermis* (Castracane) Hustedt

Syn. *Rhizosolenia obtusa* Hensen

21) *Rhizosolenia antarctica* Karsten

22) *Rhizosolenia bidens* Karsten

23) *Rhizosolenia calcar-avis* M. Schultze

24) *Rhizosolenia curvata* Zacharias

Syn. *Rhizosolenia curva* Karsten

25) *Rhizosolenia cylindrus* Cleve

26) *Rhizosolenia delicatula* Cleve

27) *Rhizosolenia fragilissima* Bergon

28) *Rhizosolenia hebetata forma hiemalis* Gran

29) *Rhizosolenia hebetata forma semispina* (Hensen) Gran

30) *Rhizosolenia Shrubsolii* Cleve
31) *Rhizosolenia simplex* Karsten
32) *Rhizosolenia Stolterfothii* H. Peragallo
33) *Rhizosolenia styliformis* Brightwell
34) *Rhizosolenia styliformis* var. *longispina* Hustedt
35) *Rhizosolenia truncata* Karsten

Family Bacteriastraceae

Genus *Bacteriastrum* Shadbolt

37) *Bacteriastrum comosum* Pavillard

Family Chaetoceraceae

Genus *Chaetoceros* Ehrenberg

Subgenus *Phaeoceros*

38) *Chaetoceros atlanticus* Cleve
39) *Chaetoceros atlanticus* var. *neapolitana* (Schröder) Hustedt
40) *Chaetoceros atlanticus* var. *skeleton* (Schütt) Hustedt
41) *Cheatoceros Castracanei* Karsten
42) *Chaetoceros Chunii* Karsten
43) *Chaetoceros concavicornis* Mangin
    Syn. *Chaetoceros criophilum* Castracane
44) *Chaetoceros convoltus* Castracane
    Syn. *Chaetoceros Janischianum* Castracane
    Chaetoceros remotus Cleve et Grunow
45) *Chaetoceros dichaeta* Ehrenberg
46) *Chaetoceros pendulus* Karsten
47) *Chaetoceros pervianus* Brightwell
    Syn. *Chaetoceros convevicornis* Mangin M, Lebour
    Chaetoceros pervio-atlanticum Karsten
48) *Chaetoceros radiculus* Castracane
49) *Chaetoceros Schimperianus* Karsten

Subgenus *Hyalochaete*

50) *Chaetoceros affinis* Lauder
    Syn. *Chaetoceros schüttii* Cleve H. H. Gran
    Chaetoceros javanicum Cleve, W. E. Allen, E. E. Cupp
51) *Chaetoceros anastomosans* Grunow
52) *Chaetoceros brevis* Schütt
53) *Chaetoceros compressus* Lauder
    Syn. *Chaetoceros cotortum* Schütt
54) *Chaetoceros curvisetus* Cleve
    Syn. *Chaetoceros secundus* Cleve-Okamura.
55) *Chaetoceros decipiens* Cleve
56) *Chaetoceros didymus* Ehrenberg

57) *Chaetoceros distans* Cleve

58) *Chaetoceros Lorenzianus* Grunow

59) *Chaetoceros messanensis* Castracane

Syn. *Chaetoceros furca* Cleve H. H. Gran

60) *Chaetoceros neglectus* Karsten

61) *Chaetoceros pelagicus* Cleve

62) *Chaetoceros socialis* Lauder

63) *Chaetoceros subsecundus* (Grun) Hustedt

Syn. *Chaetoceros diadema* (Ehr.) Cleve

Family Biddulphiaceae

Genus *Biddulphia* Gray

64) *Biddulphia astrolabensis* Hendey

65) *Biddulphia sinensis* Greville

Genus *Hemiaulus* Ehrenberg

67) *Hemiaulus Hauckii* Grunow

68) *Hemiaulus membranacus* Cleve

69) *Hemiaulus sinensis* Greville

Genus *Cerataulina* Ehrenberg

70) *Cerataulina Bergonii* Peragallo

Family Eucampiaceae

Genus *Eucampia* Ehrenberg

71) *Eucampia balaustium* Castracane

72) *Eucampia cornuta* (Cleve) Grunow ex Van Heurck

73) *Eucampia zoodiacus* Ehrenberg

Genus *Climacodium* Grunow

74) *Climacodium Frauenfeldianum* Grunow

Order Pennales

Suborder Araphidineae

Family Fragilariaceae

Genus *Fragilaria* Lyngbye

75) *Fragilaria antarctica* Castracane

76) *Fragilaria granulata* Karsten

Genus *Asterionella* Hassall

78) *Asterionella japonica* Cleve

Genus *Thalassionema* Grunow

80) *Thalassionema nitzschioides* Hustedt

Syn. *Thalassiothrix nitzschioides* Grunow

Thalassiothrix curvata Castracane

Genus *Thalassiothrix* Cleve et Grunow

81) *Thalassiothrix antarctica* Karsten
82) *Thalassiothrix Flauenfeldii* Grunow
83) *Thalassiothrix heteromorpha* Karsten
84) *Thalassiothrix longissima* Cleve et Grunow

Suborder Biraphidineae
Family Naviculaceae
Genus *Pleurosigma* W. Smith

85) *Pleurosigma directum* Grunow

Genus *Tropidoneis* Cleve

87) *Tropidoneis antarctica* (Grunow) Cleve

Family Nitzschiaceae
Genus *Nitzschia* Hassall

89) *Nitzschia closterium* (Ehrenberg) W. Smith
90) *Nitzschia delicatissima* Cleve
91) *Nitzschia pungens* var. *atlantica* Gran
92) *Nitzschia seriata* Cleve

2) List of diatoms collected by the plankton sampler

1) *Planktoniella sol* (Wallich) Schütt
2) *Skeletonema costatum* (Greville) Cleve
3) *Dactyliosolen antarcticus* Castracane
4) *Leptocylindrus danicus* Cleve
5) *Corethron criophilum* Castracane
6) *Rhizosolenia alata forma gracillima* (Cleve) Grunow
7) *Rhizosolenia alata forma inermis* (Castracane) Hustedt
8) *Rhizosolenia curvata* Zacharias
9) *Rhizosolenia cylindrus* Cleve
10) *Rhizosolenia fragilissima* Bergon
11) *Rhizosolenia hebetata forma semispina* (Hensen) Gran
12) *Rhizosolenia Shrubsolii* Cleve
13) *Rhizosolenia Stolterfothii* H. Peragallo
14) *Rhizosolenia styliformis* Brightwell
15) *Rhizosolenia styliformis* var. *longispina* Hustedt
16) *Bacteriastrum elongatum* Cleve
17) *Chaetoceros atlanticus* Cleve
18) *Chaetoceros Chunii* Karsten
19) *Chaetoceros coarctatus* Lauder
20) *Chaetoceros concavicornis* Mangin
21) *Chaetoceros convoltus* Castracane
22) *Chaetoceros dichaeta* Ehrenberg

23) *Chaetoceros pendulus* Karsten
24) *Chaetoceros pervianus* Brightwell
25) *Chaetoceros anastomosans* Grunow
26) *Chaetoceros affinis* Lauder
27) *Chaetoceros compressus* Lauder
28) *Chaetoceros curvisetus* Cleve
29) *Chaetoceros didymus* Ehrenberg
30) *Chaetoceros laciniosus* Schütt
31) *Chaetoceros Lorenzianus* Grunow
32) *Chaetoceros messanensis* Castracane
33) *Chaetoceros neglectus* Karsten
34) *Chaetoceros pelagicus* Cleve
35) *Chaetoceros socialis* Lauder
36) *Chaetoceros teres* Cleve
37) *Hemiaulus Hauckii* Grunow
38) *Eucampia cornuta* (Cleve) Grunow ex Van Heurck
39) *Climacodium Frauenfeldianum* Grunow
40) *Fragilaria antarctica* Castracane
41) *Fragilaria granulata* Karsten
42) *Asterionella japonica* Cleve
43) *Thalassionema nitzschioides* Hustedt
44) *Thalassiothrix antarctica* Karsten
45) *Thalassiothrix Flauenfeldii* Grunow
46) *Thalassiothrix longissima* Cleve et Grunow
47) *Pleurosigma directum* Grunow
48) *Nitzschia closterium* (Ehrenberg) W. Smith
49) *Nitzschia delicatissima* Cleve
50) *Nitzschia seriata* Cleve

3) List of copepods collected by plankton sampler

Station 1

Nanocalanus minor (Claus)
Paracalanus parvus Giesbrecht
Clausocalanus arcuicornis (Dana)
Centropages chierchiae Giesbrecht
Pseudodiaptomus nudus Tanaka
Acartia negligens Dana
Oncaea venusta Philippi
Sapphirina gemma Dana
Sapphirina scarlata Giesbrecht
Corycaeus lautus Dana

Corycaeus crassiusculus Dana
Corycaeus giesbrechti F. Dahl
Corycaeus concinnus Dana
Corycaeus pacificus F. Dahl
Corycaeus Asiaticus F. Dahl
Corycaeus africanus F. Dahl?
Corycaeus agilis Dana

Station 2

Paracalanus parvus Giesbrecht
Calocalanus pavo (Dana)
Centropages chierchiae Giesbrecht
Labidocera acuta (Dana)
Oithona plumifera Baird
Oncaea venusta Philippi
Corycaeus agilis Dana
Macrosetella gracilis (Dana)

Station 3

Nanocalanus minor (Claus)
Calanoides carinatus (Kröyer)
Calocalanus Pavo (Dana)
Calocalanus plumulosus (Claus)
Calocalanus styliremis (Giesbrecht)
Clausocalanus arcuicornis (Dans)
Centropages chierchiae Giesbrecht
Candacia aethiopica (Dana)
Acartia negligens Dana
Oncaea venusta Philippi
Sapphirina gemma Dana
Sapphirina scarlata Giesbrecht
Sapphirina angusta Dana
Corycaeus concinnus Dana
Corycaeus agilis Dana
Corycaeus crassiusculus Dana
Corycaeus rostratus Giesbrecht
Macrosetella gracilis (Dana)

Station 4

Calanoides carinatus (Kröyer)
Clausocalanus arcuicornis (Dana)
Centropages chierchiae Giesbrecht

Station 5

Calanus tonsus Brady
Calanus simillimus Giesbrecht
Clausocalanus laticeps Farran
Oithona similis Claus

Station 6

Oithona similis Claus
Nauplius of *Eucalanus*
Calanus sp. Copepodite stage I

Station 7

Oithona similis Giesbrecht
Calanus sp. Copepodite stage II

Station 8

Nanocalanus minor (Claus)
Centropages aucklandicus Kramer
Oithona similis Giesbrecht

Station 9

No copepoda was collected.

Station 10

No copepoda was collected.

DISCUSSIONS

PART I. Analyses of Physical and Chemical Conditions

1. Location of the Subtropical Convergence and the water temperature at its center

The surface water temperature was observed by the "SOYA" observatory team at an interval of three hours on her four voyages on both ways in the sea area between Cape Town and Antarctica. The data of the surface temperature of the 1st and 2nd Expeditions were obtained from "The results of Marine Meteorological and Oceanographical Observations, Supplement 1960. pp. 99–103 and 108–113." The data of the 3rd and 4th Expeditions are shown in Appendices 1) and 2). The data obtained at each voyage are shown in Fig. 2. The origin of the abscissa axis in the figure is 35°S, near the Cape of Good Hope and on the right end is 65°S, near Antarctica, neglecting the longitudinal location. The record of the 1st Expedition in December 1956 shown at the top of Fig. 2 indicates that higher temperature of around 20°C was observed in the region between 35°S and 39°30′S, and that there was the first fall of temperature just before 40°S and a remarkable decrease in temperature was observed at 43°S, 46°30′S, 48°30′S, 50°40′S, 52°S and 55°S, respectively; seven falls in all. Such sudden

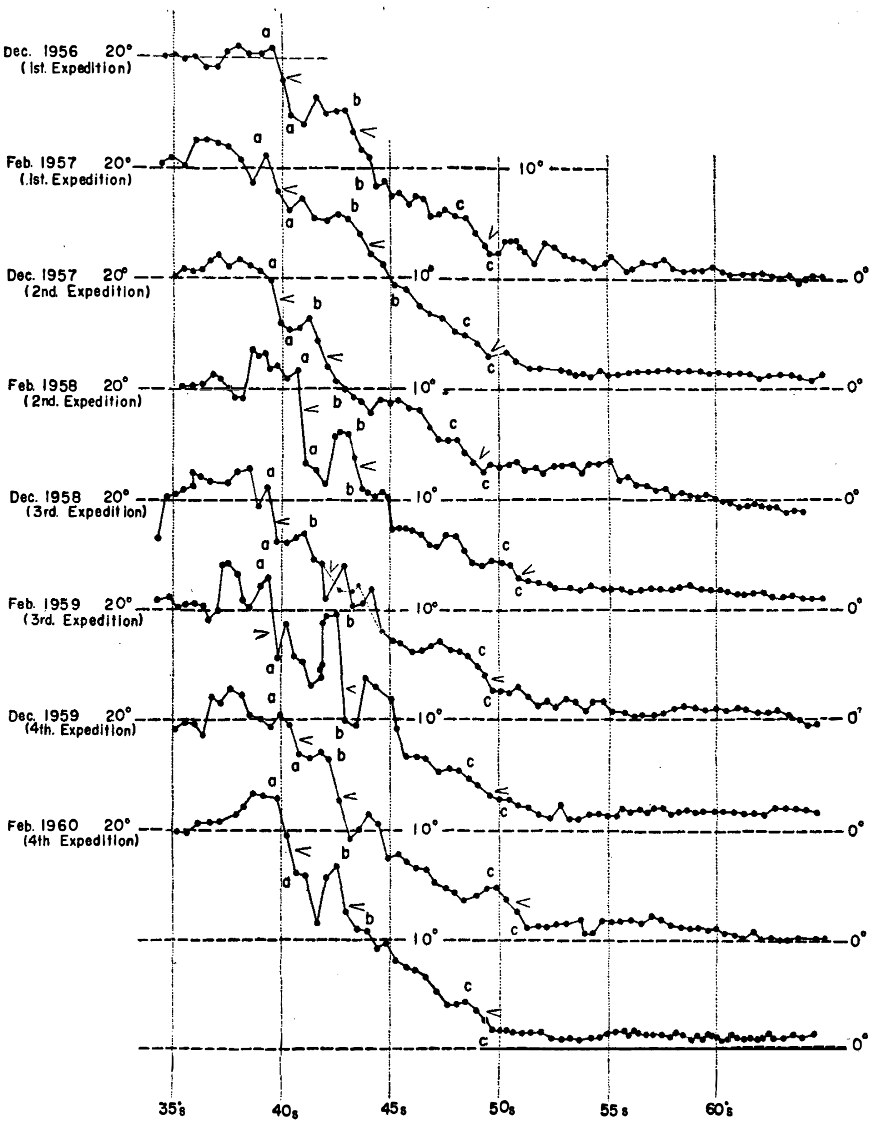

Fig. 2. Surface temperature between the south end of Africa and Antarctica. a–a : Agulhas Convergence Region, b–b : Subtropical Convergence Region, c–c : Antarctic Convergence Region, < : center of each convergence.

changes of temperature were observed also in other voyages in the some sea area. Under such circumstances it is hard to determine the location of a convergence only by the temperature of surface sea water. Therefore, the location of a convergence and the water temperature at its center were determined by investigating the relations of water temperature to salinity, dissolved oxygen, pH, phosphate, nitrite nitrogen and silicate, using the data obtained in the Discovery Expedition and the Japanese Antarctic Research Expeditions.

A. Analysis of the data of the Descovery Expedition

The author has made a research on the relation between the sea water temperature and the results of chemical analysis of surface water in the sea area between the south end of Africa and Antarctica during the Discovery Expedition. A list of the Discovery reports of which the data are used in this report is shown at the end

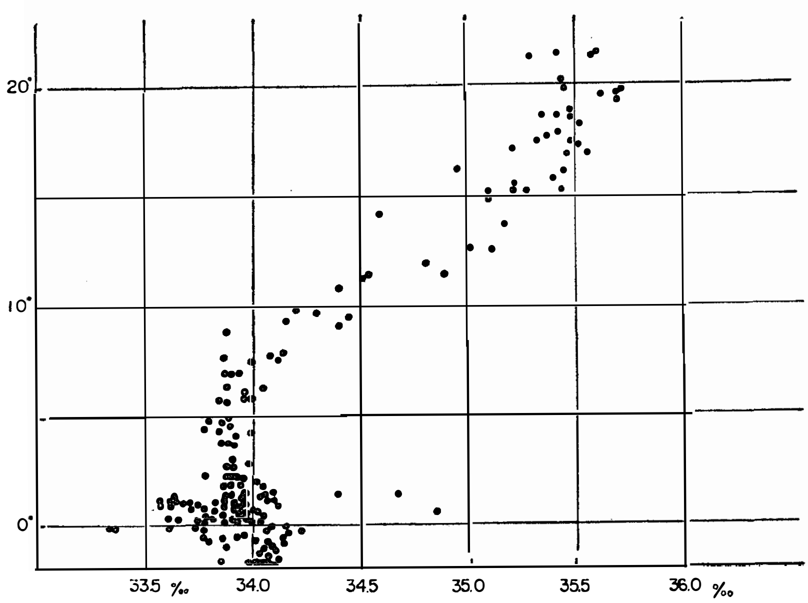

Fig. 3-1. Temperature-salinity relation between the south end of Africa and Antarctica (after Discovery Reports).

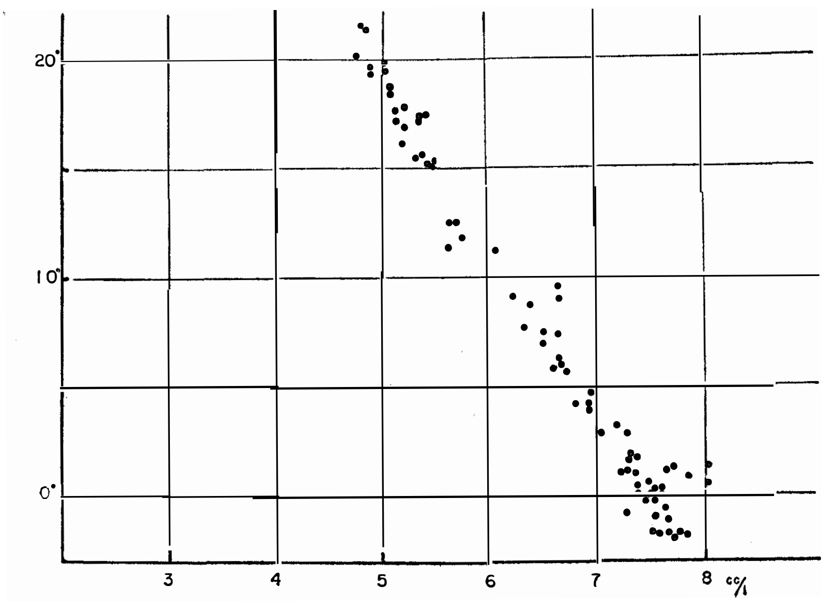

Fig. 3-2. Temperature-dissolved oxygen relation (after Discovery Reports).

of this chapter.*

1) Relation between water temperature and salinity (Fig. 3-1)

There are two water masses in the sea area between the south end of Africa and Antarctica; on water mass having higher temperature and higher salinity, and the other having lower temperature and lower salinity. In the former, water temperature exceeds 14.8°C and salinity is above 35.10‰, whereas, in the latter, temperature is below 8.7°C with salinity below 34.15‰.

2) Relation between water temperature and dissolved oxygen (Fig. 3-2)

The amount of dissolved oxygen at the surface usually increases with the decrease

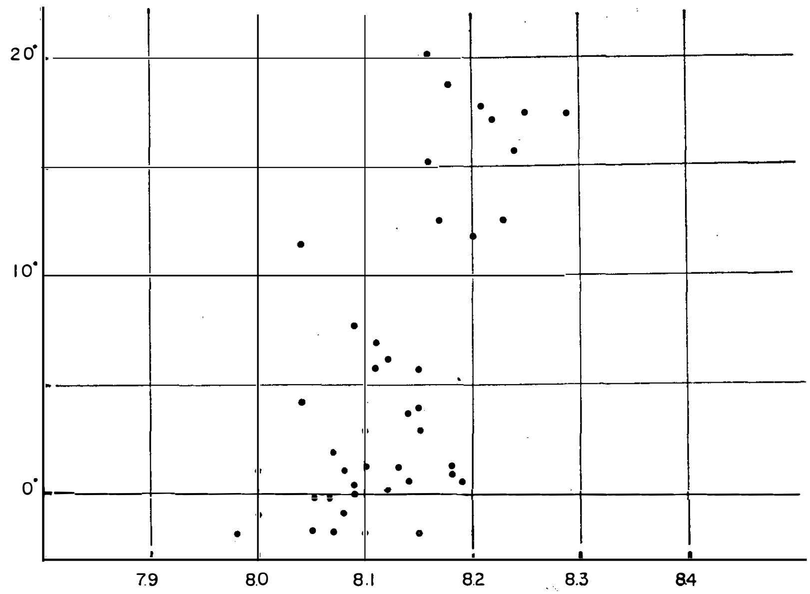

Fig. 3-3. Temperature-pH relation (after Discovery Reports).

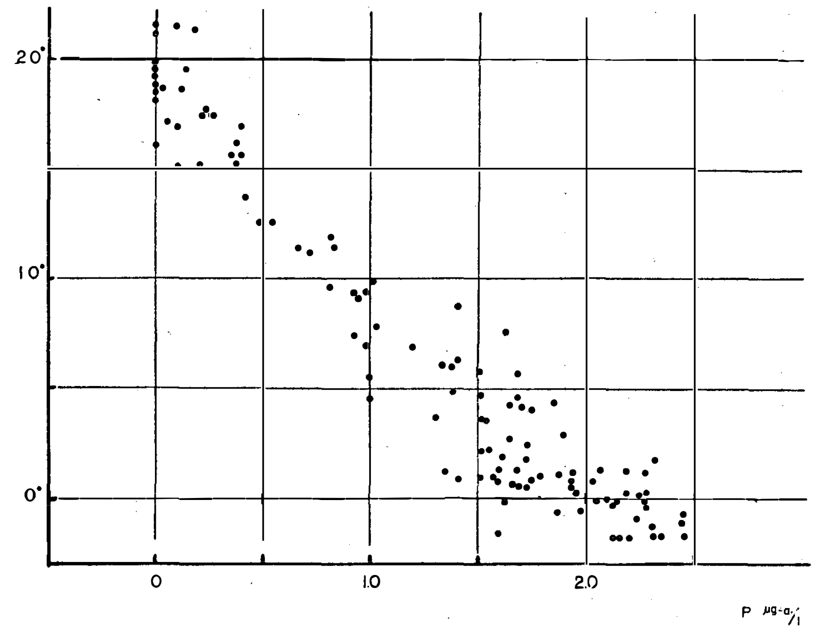

Fig. 3-4. Temperature-phosphate relation (after Discovery Reports).

of water temperature. Accordingly, the amount of dissolved oxygen in the high temperature region is below 5.50 cc/l while it is above 6.30 cc/l in the low temperature region.

3) Relation between water temperature and hydrogen ion (Fig. 3-3)

Generally, pH falls with the fall of water temperature. It is above 8.16 in the high temperature region and below 8.19 in the low temperature region.

4) Relation between water temperature and phosphate (Fig. 3-4)

The concentration of phosphate in sea water varies considerably according to the character of the water mass, and furthermore it is greatly affected by the presence of phytoplankton. The temperature-phosphate relation is similar to the temperature-

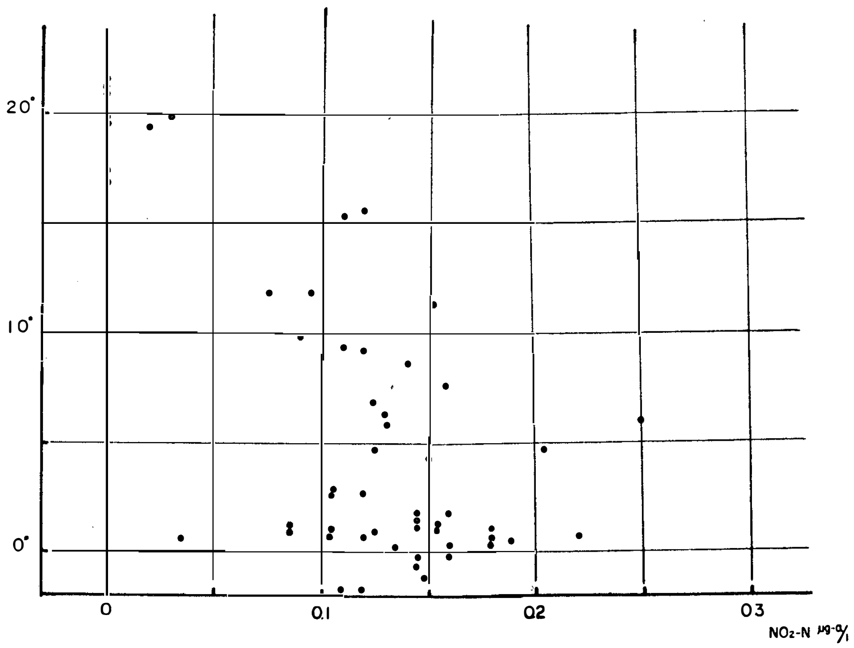

Fig. 3-5. Temperature-nitrite nitrogen relation (after Discovery Reports).

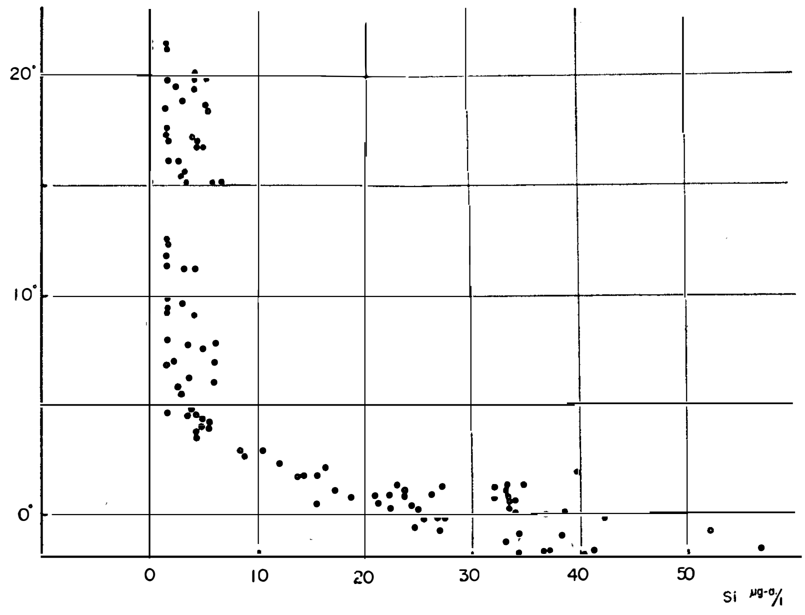

Fig. 3-6. Temperature-silicate relation (after Discovery Reports).

dissolved oxygen relation as described above. The amount of phosphate is below 0.40 μg-atoms/l in the high temperature region, and is above 0.90 μg-atoms/l in the low temperature region, likely in any other cold water.

5) Relation between water temperature and nitrite nitrogen (Fig. 3-5)

According to the result of chemical analysis conducted by the 2nd Japnese Antarctic Research Expedition in December 1957, the amount of nitrite nitrogen seems to be closely related to the sea water temperature.[22] But the Discovery Expedition data show that the amount at the surface of the south coast area of South Africa is considerably large in winter, whereas only a trace amount was observed in summer, December through April. Accordingly, it is presumed that the amount of nitrite considerably changes according to the season of a year in this area. The Discovery data of nitrite in summer are given in Fig. 3-5. Though there are considerable fluctuations, the content is below 0.03 μg-atoms/l in the high temperature region and increases in the low temperature region as the temperature decreases to as low as 4°C.

B. Analysis of the data obtained by the 4th Japanese Antarctic Research Expedition

TORII who participated in the 2nd Japanese Antarctic Research Expedition reported that there was a great difference in the contents of various chemical elements between the two water masses separated by the Subtropical Convergence. Analyses of these elements were repeatedly conducted in other expeditions. Figs. 4-1 and 4-2 show a

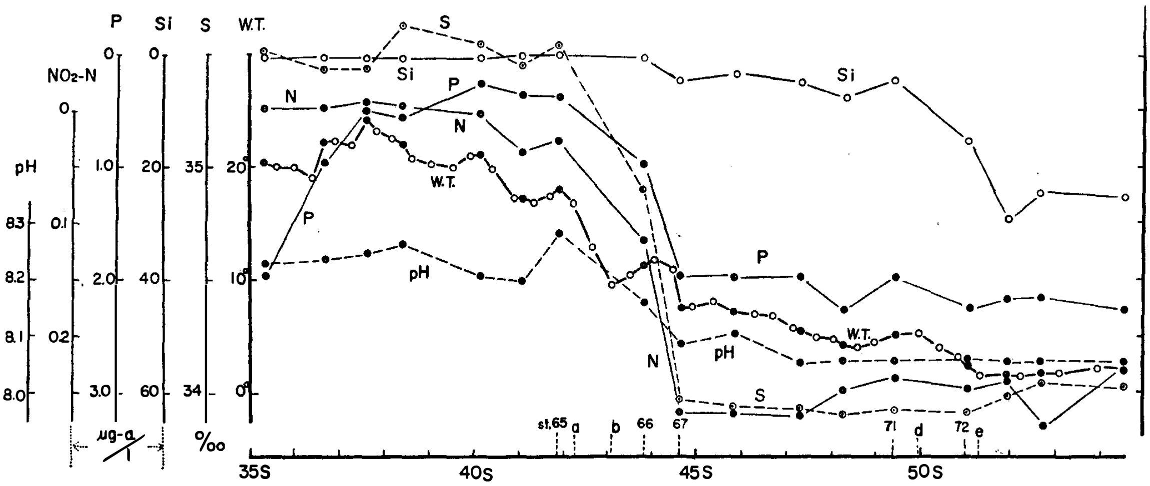

Fig. 4-1. Variation of temperature, salinity, silicate-Si, phosphate-P, nitrite-N and pH between the south end of Africa and Antarctica (Dec. 1956).

part of the results of analysis made by the author in the cruise of the 4th Japanese Expedition (December 1959- February 1960). The abscissa is same as in Fig. 2 and the coordinate shows the contents of various chemical elements. As to nitrite nitrogen, phosphate and silicate, the zero point is placed on the upper part of the coordinate. In 41°55'S (Sta. 65 in Fig. 4-1), water temperature was 17.6°C, salinity 35.53‰, dissolved oxygen 5.54 cc/l, pH 8.28, phosphate 0.4 μg-atoms/l, and nitrite nitrogen 0.05 μg-atoms/l. When these values are compared with the data of the Discovery Expedition, they all correspond to those observed in the high temperature region, as indicated in Fig. 3-1.

At the next station, Sta. 66 in 43°51'S, the water temperature was 10.4°C, salinity 34.89‰, pH 8.15, oxygen 6.27 cc/l, phosphate 1.0 μg-atoms/l, and nitrite 0.12 μg-atoms/l. These values show the characters of an intermediate water mass between the high temperature region and the low temperature region. In the middle of these two stations, we have only temperature measurements at four stations, of which the results show a sudden fall of temperature from 16.3°C (*a* in the Fig.) to 9.1°C (*b* in the Fig.) in a short distance of only 55' in latitude. The most conspicuouos convergence in the Antarctic Circumpolar Ocean is the Antarctic Convergence, which can be traced all around the Antarctic Continent. The water that merges in this Convergence has a low salinity, but it has a low temperature and consequently a relatively high density. Two more convergences are found in middle and low latitudes; namely, the Subtropical and the Tropical Convergences. The Subtropical Convergence is located where the density of the upper layers rapidly increases towards the poles. This Subtropical Convergence lies in the area where there is a steep gradient in water temperature, and consequently, the remarkale gradient of water temperature between Sta. *a* and Sta. *b* can be regarded as the convergence region.

At the third station (Sta. 67 in the Fig.), the water temperature was 7.1°C, salinity 33.96‰, oxygen 7.01 cc/l, phosphate 2.0 μg-atoms/l, and nitrite nitrogen 0.27 μg-atoms/l. These values represent the typical character of the low water temperature region. A remarkable difference in characters was observed between two water masses, one with the temperature of 15°C to 17°C north of the convergence region and the other with the temperature of 9°C or less south of the convergence. This difference is the most remarkable one found in the entire sea area between the south end of Africa and Antarctica. It is clear, judging from the results of the previous observations in this area, that the convergence formed between these above-described two water masses is the Subtropical Convergence.

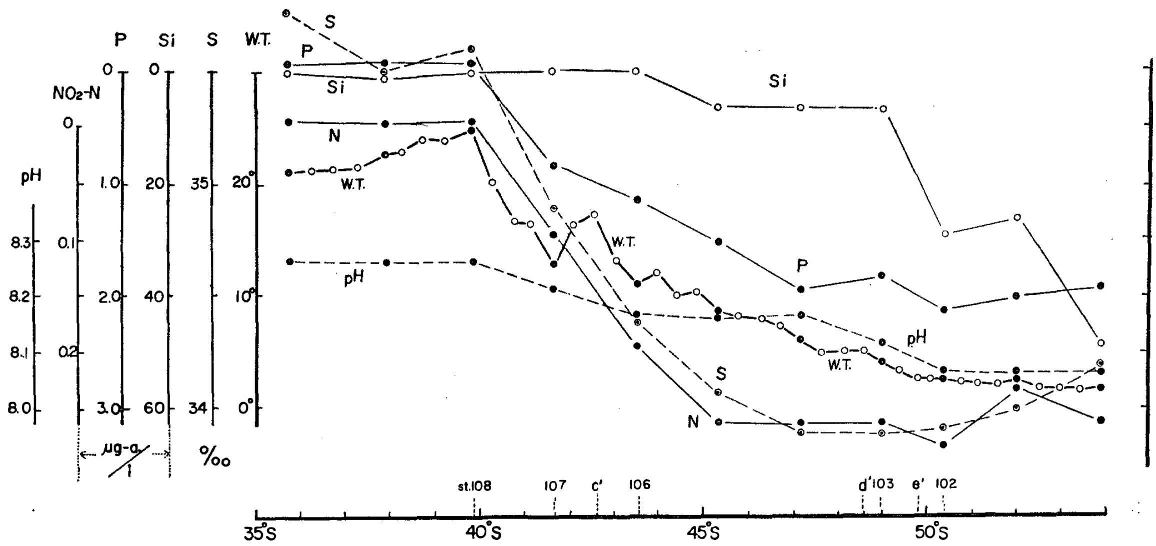

Fig. 4-2. Variation of temperature, salinity, silicate-Si, phosphate-P, nitrite-N and pH between the south end of Africa and Antarctica (Feb. 1960).

On the return cruise of the 4th Japanese Expedition (February 1960, *see* Fig. 4-2), analyses were made at three stations, 108, 107 and 106. The water at Sta. 108 represents the character in the high temperature region; Sta. 107, the intermediate water region; and Sta. 106, the low temperature region. There is a region of sea surface temperature higher than 16°C between Sta. 107 and Sta. 106. The region south of Station *c'* (only temperature was measured) where a steep gradient of water temperature was observed is supposed to be the Subtropical Convergence and the region south of Station 108 characterized by the remarkable temperature gradient is another convergence, the Agulhas Convergence, which will be discussed later.

Using the same method of analysis of the water temperature observed since the 1st Japanese Expedition, the range of the water temperatures in the Subtropical Convergence Region is shown in Table 1. Table 1 shows that the region of temperatures ranging from 11°C to 15°C is always included in the convergence region in which the temperature of the center is 13°C. Table 2 indicates the results of the chemical analyses made by T. TORII and N. ONO, who participated in the 3rd Japanese Expedition, and by the author himself in the 4th Japanese Expedition. These results were obtained at the stations near the Subtropical Convergence. From this table, it

Table 1. Water temperature range in the Subtropical Convergence Region observed at stations in front and the rear of the Subtropical Convergence.

Dec. 1956 (1 st Japanese Expedition)	15.1°— 8.3°C
Feb. 1957 (〃 〃 〃)	15.4 — 9.4
Dec. 1957 (2 nd Japanese Expedition)	16.3 — 10.0
Feb. 1958 (〃 〃 〃)	15.9 — 10.9
Dec. 1958 (3 rd Japanese Expedition)	16.7 — 10.2
Feb. 1959 (〃 〃 〃)	19.8 — 9.8
Dec. 1959 (4 th Japanese Expedition)	16.3 — 9.1
Feb. 1960 (〃 〃 〃)	16.5 — 10.9

Table 2. Oceanographic data of the Japanese Antarctic Research Expedition observed at stations in front and the rear of the Subtropical Convergence.

Date	Location		Temp.	S	O_2	pH	P	NH_3-N	NO_2-N	NO_3-N	Si
	S	E	°C	‰	cc/l		μg-a./l	μg-a./l	μg-a./l	μg-a./l	μg-a./l
Dec. 13. 1957	41-17	25-02	15.6	35.34	5.74	8.14	0.4	12.0	0.02	—	tr.
Dec. 14. 1957	44-36	28-42	8.5	34.25	6.68	8.00	1.0	2.8	0.08	—	3
Mar. 4. 1958	42-44	21-00	15.8	35.50	5.48	8.00	0.7	6.8	0.06	—	7
Mar. 3. 1958	45-12	21-42	7.5	33.96	6.59	7.90	1.1	3.6	0.09	—	5
Dec. 26. 1958	41-58	24-58	14.1	35.08	5.53	8.18	0.8	5.6	0.05	—	tr.
Dec. 27. 1958	43-41	26-37	10.9	34.33	6.01	—	1.0	5.0	0.05	—	tr.
Feb. 20. 1959	40-39	18-04	15.4	35.17	5.58	8.24	—	—	—	—	tr.
Feb. 19. 1959	42-35	20-42	19.8	35.41	5.11	8.20	—	—	—	—	1
Feb. 18. 1959	46-20	22-27	6.6	33.89	6.70	8.02	—	—	—	—	5
Dec. 20. 1959	41-55	22-47	17.6	35.83	5.54	8.28	0.4	—	0.05	7.5	0
Dec. 21. 1959	43-51	24-05	10.4	34.89	6.27	8.15	1.0	—	0.12	—	1
Mar. 1. 1960	39-50	19-58	24.1	35.57	—	8.25	0	4.0	0	0	1
Mar. 1. 1960	41-40	20-20	12.2	34.76	—	8.20	0.9	1.0	0.11	tr.	1
Feb. 29. 1960	43-32	21-15	10.4	34.36	—	8.15	1.2	2.0	0.20	4.0	1

can be said that at the station where the water temperature is below 12.2°C, the water shows a character of cold water mass or of intermediate water mass closely set to cold water mass; and in the region where water temperature is above 14.1°C, the water has a character of warm water mass or of intermediate warm water mass. Therefore, it is reasonable to regard the water temperature at the center of the convergence region to be between 14.1°C and 12.2°C, that is 13°C. This opinion is confirmed by the data of the Discovery Expedition.

2. Location of the Antarctic Convergence and water temperature at its center

The diagram of temperature and salinity in Fig. 3–1 indicates that there are two water masses on each side of the boundary line where the water temperature is about 3°C, but, there is no difference in salinity between two water masses. The relation between water temperature and silicate (Fig. 3–6) shows that the amount of silicate ranges from 0 to 6 μg–atoms/l in the regions between the high temperature region of 24°C and the low temperature region of 3.7°C, whereas, in the region near Antarctica where water temperature is below 2.9°C, the silicate content suddenly increases up to 50 μg–atoms/l, that is, about ten or several tens times as much as that found in the Agulhas Region.

Almost the same results as those of the Discovery Expedition have been reported by the Japanese Antarctic Research Expeditions. The analysis made by the author on the oceanographic conditions indicated the following values (Fig. 4–1); in 49°28′S (Sta. 71 in the Fig.), water temperature was 4.8°C, salinity 33.91‰, silicate 5 μg–atoms/l; in 51°05′S (Sta. 72 in the Fig.), water temperature was 2.1°C, salinity 33.89‰, silicate 16 μg–atoms/l. There is an increase of silicate by 11 μg–atoms/l. It is presumed that these water masses are easily determined by the difference in the silicate content of the two water masses. Between Stations *d* and *e*, with an interval of only 1°23′ in latitude, a drop of water temperature is remarkable, and so this region is presumed to be the Antarctic Convergence Region. The oceanographic condition observed on the return cruise is shown in Fig. 4–2. Based on the analysis made at Sta. 103 and Sta. 102, the region between *d′* and *e′* may be defined as the Antarctic Convergence Region. According to the data of the Discovery Expedition, the water temperature at the center ranged from 2.9°C to 3.7°C in the Antarctic Convergence. Since the result of measurements made by the Japanese Expedition obtained at Sta. 103 gave the water temperature of 3.4°C and the lower silicate content of 8 μg–atoms/l, it is reasonable to assume the water temperature at the center of this convergence to be about 3.2°C, which is a little lower than the one observed at Sta. 103. In Fig. 2, c–c indicates the Antarctic Convergence Region observed by the Japanese Expedition.

3. Agulhas Convergence existing near 40°S

The horizontal distribution diagram of the water temperature shows, as a rule, that the interval of isothermal lines becomes narrower in the region where there is

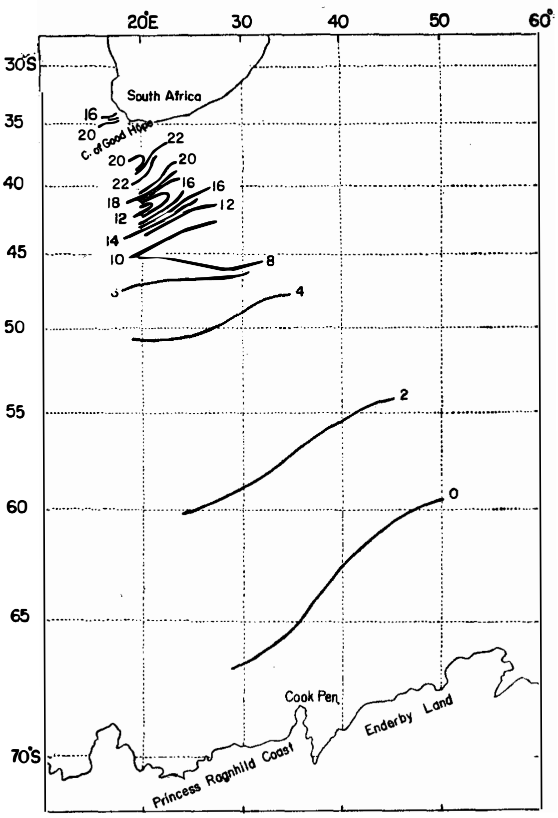

Fig. 5. Distribution of surface water temperature (2nd Japanese Antarctic Research Expedition).

a large gradient in water temperature (Fig. 5). The author drew a horizontal distribution diagram of the surface water temperature at every integral one degree centigrade using the data obtained by the "SOYA", and measured in meridional direction the interval of the isothermal lines. A sum of the observed values obtained by eight observations is shown in mile in Fig. 6. The minimum value at 13°C clearly indicates the Subtropical Convergence. In the region with water temperature around 18°C, the value in the meridional direction is much smaller, viz, there is a remarkable discontinuity of the temperature. This can be confirmed also by Fig. 2 which shows the surface temperatures between the south end of Africa and Antarctica. For instance, in the 1st Japanese Expedition in December 1956, the temperature difference of 6.2°C in a distance of one degree of latitude (a–a in Fig.) was observed and on the homeward cruise in the 2nd Expedition in February 1958, the difference was as big as 8.4°C in a distance of only 27 minutes in latitude.

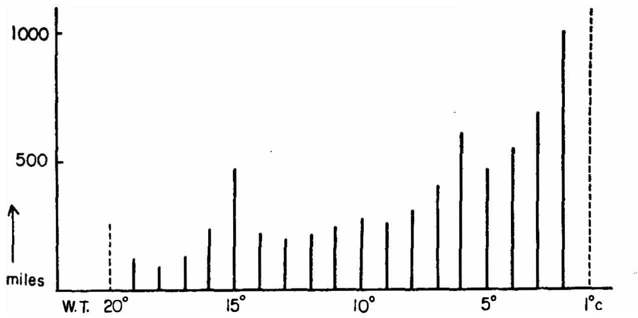

Fig. 6. The interval in meridional direction of the isothermal lines at every integral degree centigrade (a sum of the values obtained by eight observations is shown in mile).

In Fig. 7 the streamlines of the surface currents off southern Africa which were given by A. DEFANT are reproduced, which indicate also the conspicuous Agulhas Current. This Current flows toward southwest along the southern coast of South Africa. The eastward current from the Atlantic Ocean contacts the southern periphery of the Agulhas Current and forms a number of eddies of various sizes. Based on the streamlines by tracing the contact line of the two currents, line A was obtained as shown with a dotted line in Fig. 7. This line is located in 39°S, SSE of the Cape of Agulhas, where 18°C water prevails, across which the "SOYA" passed in every voyage. It is clear that this contact line is a convergence where the eastward current submerges below the southern edge of the Agulhas Current which flows in the southwest direction.

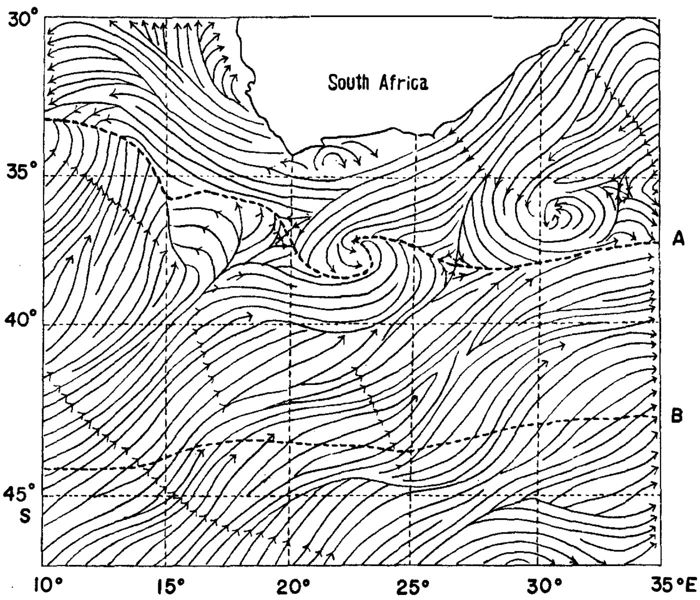

Fig. 7. Streamlines of currents off South Africa (after A. DEFANT but lines A and B by author).

Judging from this diagram and the width of the Agulhas Current, it is presumed that the convergence extends in nearly east-west direction from the offing southwest of South Africa and reaches the offing south of Madagascar. As this is a remarkable convergence and is located along the southern edge of the Agulhas Current, it may well be called as "Agulhas Convergence".

As stated above, the center of the convergence lies where water temperature is 18°C and, though it shows meridional dislocations in some occasions, the north edge of the convergence region was found within 30 miles south or north of 39°30′S, seven times out of eight observations, and the center of the region with the water temperature 18°C was in the locality within 30 miles from 40°S. The only exception was a southward dislocation of the center by about one degree in latitude on the return cruise in February 1958 (Figs. 2 and 9).

The location of the Subtropical Convergence in the water region south of South Africa will be described in detail in Paragraph 5, but the center of the Convergence as an average is located in 43°S. The dotted line B was drawn by the author as a tentative location of the Convergence.

4. Water masses and their characters

Owing to the presence of the Agulhas Convergence, the region between the south end of Africa and Antarctica can be divided into four water masses. The name and the character of each water mass are given in Table 3.

A. Agulhas Warm Water

This water mass is a warm water mass system having high temperature and salinity but poor nutrient, and is well known as the Agulhas Current. However, according to T. TORII et al. ammonia is considerably rich.

Table 3. Water masses and their characters.

	Temp. °C	S ‰	O_2 cc/l	pH	P μg-a./l	NH_3-N μg-a./l	NO_3-N μg-a./l	Si μg-a./l
A. Agulhas Warm Water	19<	35.30<	5.25>	8.10<	0.2>	4.0<	0.03>	2>
B. North Edge Water of Westerly Wind Drift	14-17	35.10-35.60	5.10-5.75	8.14<	0.7>	4.0<	0.06>	7>
C. Subantarctic Upper Water	4-9	33.75-34.25	6.25-7.15	7.90-8.15	0.7-2.0	4.4>	0.12<	7>
D. Antarctic Surface Water	3>	34.29>	7.00<	8.19>	1.3<	4.4>	0.28<	8<

B. North Edge Water of Westerly Wind Drift

South of the Agulhas Convergence, there is a water mass with the water temperature ranging between 14°C and 17°C. The author wishes to propose to call it "North Edge Water of Westerly Wind Drift", for the following two reasons: a) The maximum width of this mass in the meridional direction was 2°30′ in latitude or about 150 miles in December 1956 and February 1957, and the minimum width about 1°30′ or about 90 miles in December 1957, December 1958, February 1959 and December 1959. In February 1958, it was especially narrower than usual and was about 40 miles in width. Though the width of this water mass sometimes varied, its existence proved to be stable since it was always observed in each voyage. b) The character of this water mass is warm, and as indicated in Table 3, it is similar in chemical characters to that of the Agulhas Warm Water having poor nutrients and high salinity, but is quite

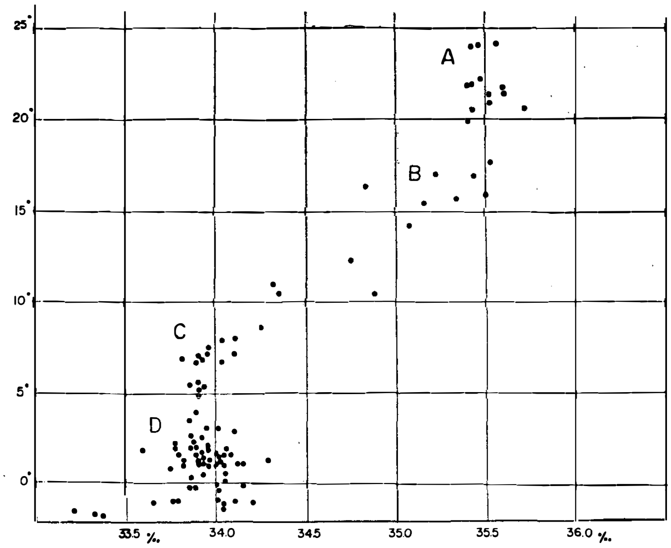

Fig. 8. Temperature-salinity relation and water masses between the south end of Africa and Antarctica (after the Japanese Antarctic Research Expedition).
A: Agulhas Warm Water. B: North Edge Water of Westerly Wind Drift. C: Subantarctic Upper Water. D: Antarctic Surface Water.

different from the Subantarctic Upper Water existing on the south of the North Edge Water. However, as far as the water temperature is concerned, the North Edge Water has such a temperature as would be obtained by mixing of the Agulhas Water and the Subantarctic Upper Water in the ratio of 1 : 1, which is considerably different from the mixing ratio estimated by the salinity of the water. The North Edge Water is indicated by B in the temperature-salinity diagram based on the data of the Japanese Antarctic Research Expedition (Fig. 8). This B mass, as shown in the Figure, is not located along the straight line between A (Agulhas Warm Water) and C (Subantarctic Upper Water), but a considerable aberration can be noted. Therefore, it is difficult to conclude that the North Edge Water is an intermediate water resulting from direct mixing of the two water masses A and C in this sea area. The Agulhas Current flows westerly in the water area south of South Africa, and then it splits into three branches. One of them turns, back and re-enters the Indian Ocean (DEFANT, 1961). Therefore, the essential part of the North Edge Water seems to be this turned-back-branch of the Agulhas Current. However, when this branch turns back in the offing southwest of South Africa, it must be mixed with another water mass in a complicated manner to become a different water mass with the above-described character, being located in the shape of a belt in the north edge of the Westerly Wind Drift and flowing towards east.

C. Subantarctic Upper Water

This is a cold water mass that exists between the Subtropical Convergence and the Antarctic Convergence. It is much different from the North Edge Water mass in as much as it has low salinity and rich nutrient. The amount of silicate is, according to the results of the Japanese Expedition, somewhat larger than that of the North Edge Water (Figs. 4-1 and 4-2).

D. Antarctic Surface Water

This is the coldest water mass with low salinity and rich nutrient. It extends to the south of the Antarctic Convergence and can be distinguished from the Subantarctic Upper Water by the rapid increase of the silicate content.

The water in the convergence region where the water masses are in contact with each other is formed by direct mixing and comes to have an intermediate character between the water masses lying south and north of the convergence.

5. Locality of water masses and convergences

Considerable fluctuations of the location of the water masses and of the convergence regions were observed in each expedition. The fluctuations since the 1st Japanese Expedition, are schematically shown in Fig. 9, classifying each water mass by the water temperature and its gradient. "A", "B", "C" and "D" represent the four water masses mentioned before respectively, and "(a)", "(b)" and "(c)" represent the respective convergence regions. The Subtropical Convergence Region indicated by "(b)" is the widest while the Agulhas Convergence Region is the narrowest. In one

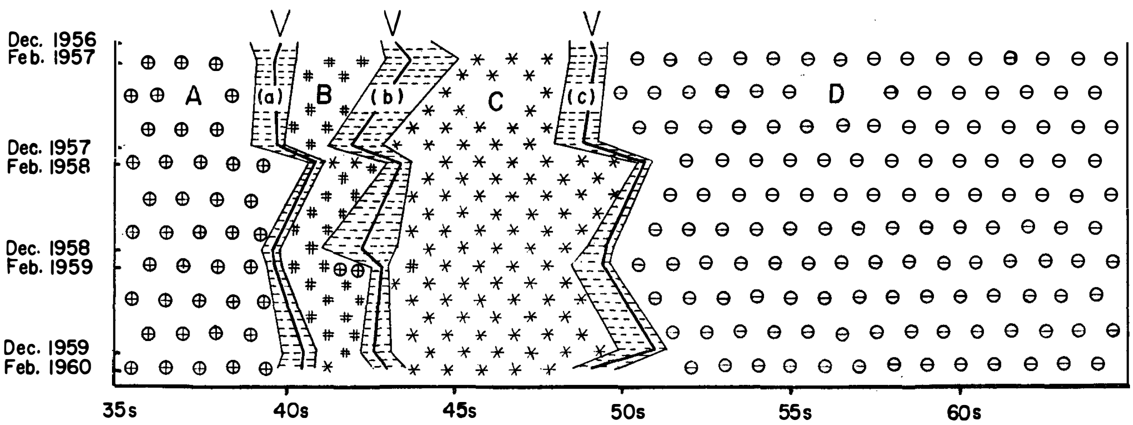

Fig. 9. Water masses and convergence regions between the south end of Africa and Antarctica.

A: Agulhas Warm Water.
B: North Edge Water of Westerly Wind Drift.
C: Subantarctic Upper Water.
D: Antarctic Surface Water.
(a): Agulhas Convergence Region.
(b): Subtropical Convergence Region.
(c): Antarctic Convergence Region.
>: Center of each convergence.

and the same convergence region, the width considerably differs from year to year; for instance, in the Subtropical Convergence, the width ranged from 28 miles (February 1959) to 130 miles (December 1958). When the convergence region is narrow, it is usual that water from other water masses flows into the boundary of the region, and this causes a complicated sea condition. For instance, the Subantarctic Upper Water was observed in the North Edge Water in February 1958 as shown in Fig. 9; the Agulhas Warm Water in the North Edge Water, and the North Edge Water in the Subantarctic Upper Water in February 1959. In the period of December 1957 through February 1958, there was a large fluctuation of sea condition in the convergence regions, and all convergence lines fluctuated by 60 to 90 miles toward south.

As to the temperature gradient in the convergence region, the mean value per one degree of latitude obtained from observed values in the course of eight observations was 8.4°C in the Agulhas Convergence, 6.9°C in the Subtropical Convergence and 2.3°C in the Antarctic Convergence. Thus, the temperature gradient in the Agulhas Convergence in the largest, while that in the Antarctic Convergence is the smallest. The mean location of the center of each convergence determined on the basis of water temperature was 40°S for the Agulhas Convergence, 43°S for the Subtropical Convergence and 49°30′S for the Antarctic Convergence. The distance of fluctuation at the center of convergences was fluctuated in meridional direction 80 miles in the Agulhas Convergence, 115 miles in the Subtropical Convergence and 130 miles in the Antarctic Convergence. Table 4 indicates the location of the center at each observation.

Table 4. The location of the convergences at each observation.

	Agulhas Conv.	Subtr. Conv.	Antar. Conv.
Dec. 1956 (1st Expedition)	40°— 02′S	43°— 02′S	49°— 15′S
Feb. 1957 (〃 〃)	39 — 45	43 — 51	49 — 25
Dec. 1957 (2nd Expedition)	39 — 45	41 — 55	48 — 55
Feb. 1958 (〃 〃)	40 — 56	43 — 30	50 — 43
Dec. 1958 (3rd Expedition)	39 — 40	42 — 22	49 — 33
Feb. 1959 (〃 〃)	39 — 45	42 — 55	49 — 30
Dec. 1959 (4th Expedition)	40 — 30	42 — 35	50 — 30
Feb. 1960 (〃 〃)	40 — 30	43 — 00	49 — 00

6. Conclusion based on the analyses of physical and chemical conditions

In addition to the Subtropical Convergence and the Antarctic Convergence between the south end of Africa and Antarctica, there is one other convergence in that area between the Agulhas Current and another current flowing easterly in the south; this convergence was named by the author as the "Agulhas Convergence", and the water mass between the Agulhas Convergence and the Subtropical Convergence as "North Edge Water of Westerly Wind Drift".

There are four water masses and three convergences alternately. The physical and chemical characters of each water mass and differences among the water masses were studied. Water temperature at the center of each convergence was 18°C in the Agulhas Convergence, 13°C in the Subtropical Convergence and 3.2°C in the Antarctic Convergence; and the mean location of each was 40°S for the Agulhas Convergence, 43°S for the Subtropical Convergence and 49°30′S for the Antarctic Convergence.

The Agulhas Warm Water and the North Edge Water have a character of warm water, and can be distinguished from each other by the difference of water temperature. The Subantarctic Upper Water and the Antarctic Surface Water have a character of cold water and the silicate content remarkably differs between the two.

The author has also explained the fluctuation of location of these water masses and convergences in the period of December 1956 through February 1960.

*1) Discovery Reports, **21**, 1941.
Stations 844–855 (Apr. 1932).
Stas. 1158–1168 (Mar. 1933).
2) Discovery Reports, **22**, 1942.
Stas. 1361–1373 (May 1934).
Stas. 1554–1560 (Mar.–Apr. 1935).
3) Discovery Reports, **24** (a), 1944.
Stas. 1608–1630 (Sept. 1935).
Stas. 1788–1801 (June 1936).
4) Discovery Reports, **24** (b), 1947.
Stas. 2086–2092 (Sept. 1937).

Stas. 2340–2350 (Apr. 1938).
Stas. 2374–2380 (July 1938).
Stas. 2411–2419 (Aug. 1938).
Stas. 2447–2453 (Oct. 1938).
Stas. 2478–2485 (Nov. 1938).
Stas. 2517–2525 (Dec. 1938).
Stas. 2559–2576 (Jan.-Feb. 1939).
Stas. 2611–2626 (Mar. 1939).

5) Discovery Reports, **25**, 1949.
Stas. ws 918–ws 922 (Mar. 1936).

6) Discovery Reports, **28**, 1957.
Stas. 2867–2874 (Aug. 1951).

PART II. Analysis of the Oceanographic Condition by the Plankton Distribution

1. Distribution of diatoms collected by the water sampling method

1) The cell number of diatoms

According to MARUMO (1953 b), the average settling volume of a total of 138 plankton samples collected at the whaling ground in the Antarctic Ocean was 23.5 cc/m^3, and the maximum was 220 cc/m^3. Also HART, HENDEY and BODEN reported that there was a great amount of plankton in the Antarctic Seas and that the productivity in the polar seas was remarkably large.

There has scarcely been any report on the distribution of the cell number of diatoms obtained by the water sampling method in the Antarctic Region, except for MARUMO's report on the southern region of the western part of the Pacific (1957). According to the report, the total cell number of diatom rapidly increased from below 10^3/l to above 10^5/l as it comes from the warm water region to the region below 50°S, and below 60°S the density was all from 10^5/l to 10^6/l.

The result of the 4th Japanese Expedition did not necessarily show such a distribution as stated above. Figs. 11–1 through 11–3 show the total cell number and the cell number of the dominant genera at each station. The south-bound cruise (Fig. 11–1) took place in the latter part of December 1959, and the samples were then collected off Enderby Land (Fig. 11–2), and the homebound cruise (Fig. 11–3) took place in the latter part of February 1960.

Throughout the south-bound cruise the cell number was the largest at Sta. 84 where it amounted up to 225,000/l. However, it was 3,300/l at Sta. 85 and was only 1,148/l at Sta. 60 off the coast of South Africa. Thus the cell number at each station varied greatly and the distribution was quite irregular. Generally speaking, however, there are two peaks; one between Sta. 64 and Sta. 67 and the other between Sta.

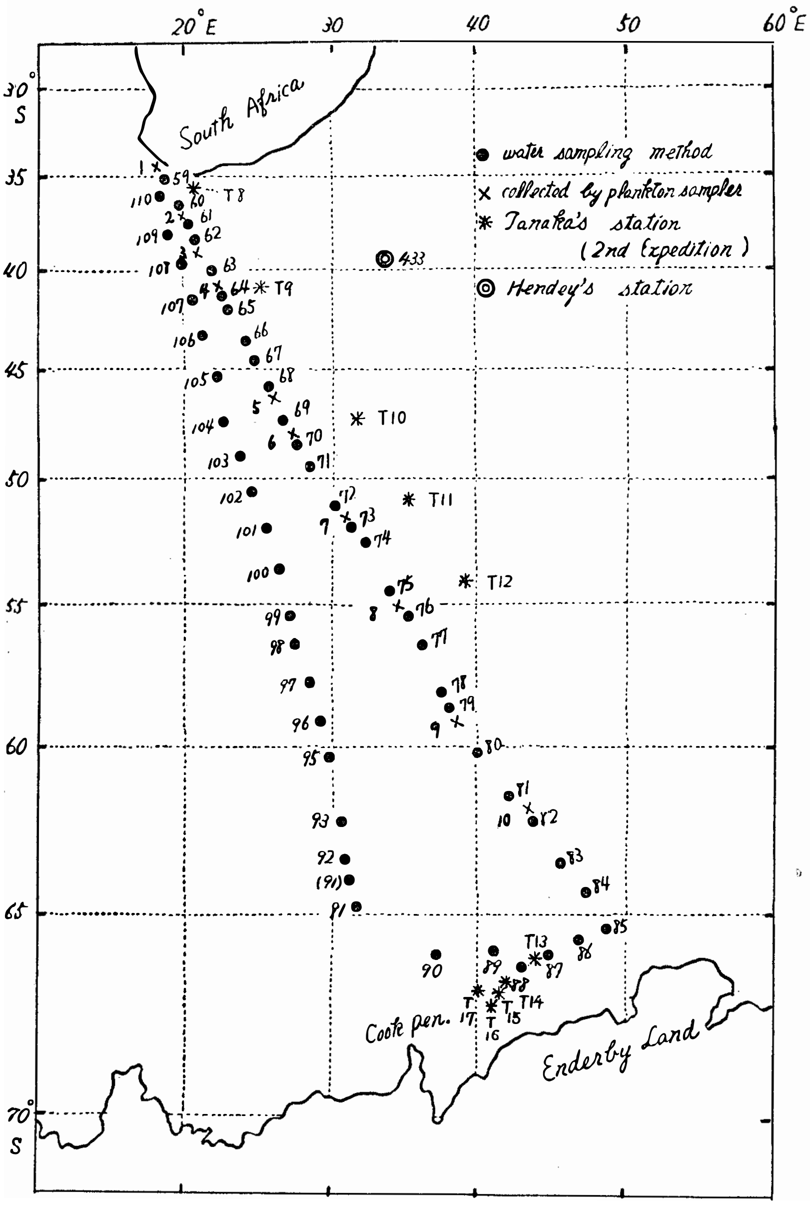

Fig. 10. Stations where plankton was collected.

74 and Sta. 76.

Stations 85 through 90 off Enderby Land were located along the pack ice line which runs from east to west. A maximum of 4,800/l was observed at Sta. 87, and 1,300/l at Sta. 90 which showed a marked difference from that of Sta. 84. The uneven distribution of the plankton was observed by the "UMITAKA-MARU" in the 1st Expedition among various stations near the coast line of the Antarctic Continent, although they are close to each other. For instance, off the Cook Peninsula, the transparency was from 20 m to 30 m while in another westward sea area near 69°S, 24°E the sea was turbid because of an increase of plankton, and the transparency was only 4–7 meters. In the 4th Expedition the author observed a transparency of 46 m in 67°38′S and 33°41′E off the eastern coast of the Cook Peninsula.[6] The transparency

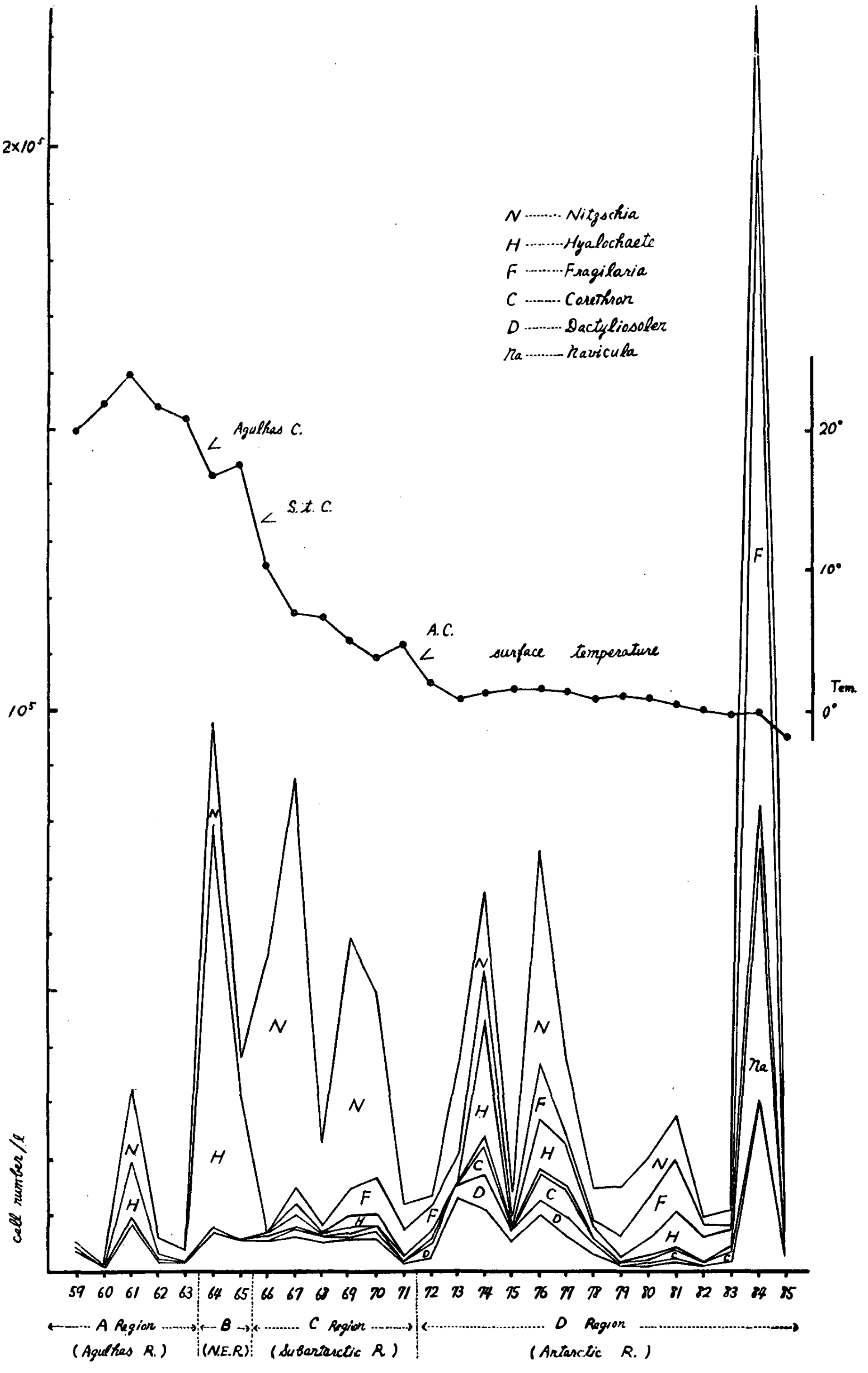

Fig. 11-1. The cell number of diatoms, important genus and surface water temperature (south-bound voyage).

of water in the sea off Enderby Land is seemingly affected by nothing but plankton and its remains. The plankton from this water area has not been examined by microscope yet, but the cell number as macroscopically observed is very small.

Among the nutrient salts which are related to an increase of plankton, the author has analyzed phosphate, nitrite nitrogen, ammonia, and nitrate nitrogen. Except for

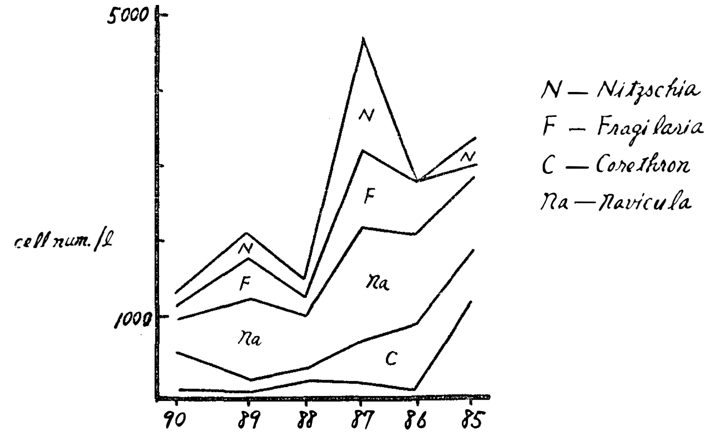

Fig. 11-2. The cell number of diatoms, important genus and surface water temperature (off Enderby Land).

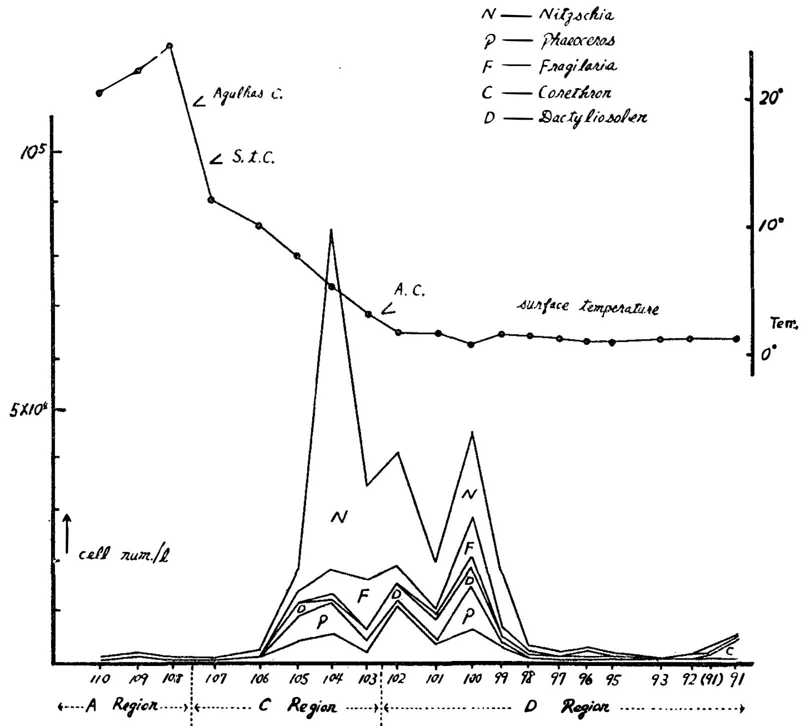

Fig. 11-3. The cell number of diatoms, important genus and surface water temperature (homebound voyage).

the last one, the three elements are shown in Fig. 4-1 and Fig. 4-2. Stations 59–63, 110–108 are located in the sea area above 40°S near South Africa, and both nutrients and the cell number of diatoms are few in these stations (Figs. 11-1 and 11-3). In the region south of the Subtropical Convergence the amount of nutrient salts is generally enough for a great increase of diatom. But, as seen from the cell number at each of the two stations, one with a small cell number and a large transparency of 46 m and the other with the cell number of 225, 000/l (Sta. 84), the amount of the nutrient salts does not seem to be a single factor to determine the amount of diatom.

However, the lack of sunshine must be considered as a cause to impede the increase of diatoms in the ice sea close to the continent. It has been expected that the population of diatoms within the pack ice line was small, and in fact the cell number was considerably few between Stas. 91 and 98 in the Antarctic Seas on the return cruise. It was only 360/l at Sta. 93. It is one of the subjects to be studied that there is an irregularity in the quantitative distribution of plankton off Enderby Land and the Cook Peninsula.

The cell number observed on the homebound cruise was generally smaller than that observed on the south-bound cruise. As stated above the cell number was less than 5, 000/l between Stas. 91 and 98 in the Antarctic Region. It was also small between Stas. 110 and 106 near South Africa. Only in the central part of the observed area the cell number remained within the limit of 10^4/l which is an ordinary cell number found in the Antarctic Ocean.

2) Distribution of the dominant genera

Figs. 11–1 to 11–3 show the total cell number and the cell number of the dominant genera. Throughout the entire area, the genus *Nitzschia* is dominant in cell number at majority of the stations. This genus involves 4 species; *Nitzschia seriata, N. delicatissima, N. closterium* and *N. pungens* var. *atlantica*. Among them *Nitzschia seriata* is the most dominant species which is distributed all over the area from the warm water region to the Antarctic Seas except only five stations where the species was entirely absent. *Nitzschia pungens* var. *atlantica*, however, was distributed only in the warm water area off South Africa. *Fragilaria* is the second dominant genus and predominated over the other genera at 11 stations in the area investigated. The genus *Navicula* was dominant in the section off Enderby Land.

The succession of the dominant genera found from South Africa to Antarctica was as follows: From Stas. 59 to 63, genus *Nitzschia* and warm water species such as subgenus *Hyalochaete* were dominant. At Stas. 64 and 65, the subgenus *Hyalochaete* was dominant, of which *Chaetoceros socialis* was most dominant. From Stas. 66 to 79, genus *Nitzschia* was dominant, followed by *Fragilaria* and *Hyalochaete* (*chaetoceros neglectus*). From Stas. 80 to 82 three genera, *Fragilaria, Nitzschia* and *Hyalochaete* occupied 2/3 of the total cell number.

Off Enderby Land, four genera, *Nitzschia, Fragilaria, Corethron* and *Navicula* put together exceeded 90% of the components.

The generic composition at the time of the homebound cruise was relatively simple. From Stas. 91 to 98 it consisted of three genera, *Fragilaria, Nitzschia* and *Corethron*; from Stas. 99 to 107 *Nitzschia* dominated together with *Fragilaria*; from Sta. 108 to the Cape of Good Hope the composition was similar to that found in the south-bound cruise.

It is to be noticed that the plankton collected by the water sampling method is

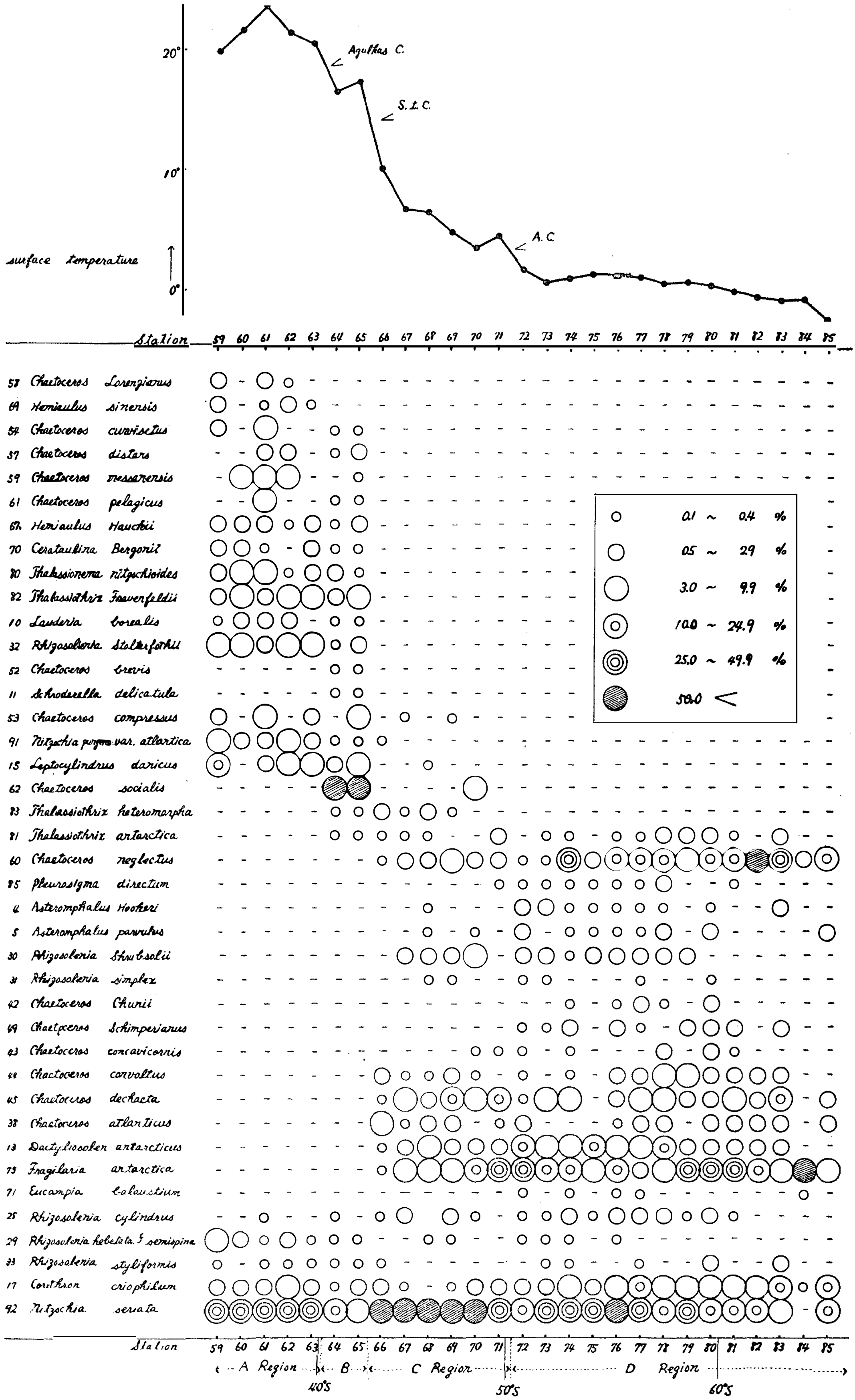

Fig. 12. Distribution of diatoms, their rough percentage and surface water temperature at the south-bound cruise.

generally smaller in size than that collected by the net sampling method.

3) Distribution of species

It has been well known that the species which survive and propagate are specified by the character of a water mass. They are classified into warm water species and cold water species according to the water temperature, and into neritic and oceanic according to the region. Some species widely adapt themselves to environments and are distributed from the tropical region down to the polar region. It is of great interest that the area investigated by the 4th Expedition covered all over the areas extending from the warm water region over 22°C to the region below freezing point. The data of diatoms collected by the water sampling method are shown in APPENDIX 4). The dominant species at each station on the south-bound cruise and rough percentages of their distribution are shown in Fig. 12, excluding those species occurring only at one station and those which seemed to be less related to the water mass. The water temperature at each station is shown at the upper part of the figure.

In Part I the author has analyzed the physical and chemical data of the observed regions and has concluded that there were four water masses, with a convergence existing between every two water masses. It seems probable that Agulhas Convergence lay between Sta. 63 and Sta. 64, the Subtropical Convergence between Sta. 65 and Sta. 66, and the Antarctic Convergence between Sta. 71 and Sta. 72 in the course of the 4th Expedition. Therefore, the station included in each of the water masses are as follows:

A. Agulhas Warm Water Region....59–62, 108–110.

B. North Edge Water of Westerly Wind Drift Region....64, 65.
   Station 107 may be included in this region, but an intrusion of the Subantarctic Upper Water was observed at this station (Fig. 9).

C. Subantarctic Upper Water Region....66–71, 103–107.

D. Antarctic Surface Water Region....72–85, 86–90 (off Enderby Land), 91, (91) –93, 95–102.

a. The species distributed only in the Region A: In this region the water temperature was above 20°C and only warm water species were observed.

2) *Planktoniella sol* (wallich) Schütt

This species was observed at Station 109 but is distributed as far south as 50°S in the Antarctic Ocean.[9]

12) *Skeletonema costatum* (Greville) Cleve

Observed at Stations 61 and 109, and was collected in small number. This is a neritic species. It increases sometimes remarkably in the bays and is very common along the coast of Japan.

16) *Guinardia flaccida* (Castracane) Peragallo

Observed at Stations 59 and 60. It is a neritic species and is common along the coast of Europe and Japan.

23) *Rhizosolenia calcar-avis* M. Schultze

Collected only at Station 61. This species is abundant in the region south and east of South Africa.[9]

37) *Bacteriastrum comosum* pavillard

This is a warm water species which was observed only at Station 61.

39) *Chaetoceros atlanticus* var. *neapolitana* (Schröder) Hustedt

Observed only at Station 61. This variety is distributed throughout temperate and tropical seas but differs in its geographical distribution from that of *Chaetoceros atlanticus*. It is also common in the Kuroshio Region of the southern part of the East China Sea.

40) *Chaetoceros atlanticus* var. *skeleton* (Schütt) Hustedt

Observed at the same station as 39).

55) *Chaetoceros decipiens* Cleve

Observed only at Station 61. It was found in considerable quantities around the coast of South Africa to approximately 40°S and has been recorded from 49°S by HENDEY. The species is widely distributed in the North Atlantic, North European seas, and also in the coast of Japan.

56) *Chaetoceros didymus* Ehrenberg

This species was collected only at Station 61, but is distributed as far south as 40°S. It is a neritic species which is usually found in the warm water regions and is common also in the adjacent seas of Japan.

58) *Chaetoceros Lorenzianus* Grunow (Fig. 12)

This species was distributed at Stations 59, 61 and 62 on the south-bound cruise, and at Stations 109 and 110 on the return cruise. It was observed in 49°S, south of South Africa.[9] This species is an important one in the warm water region, and occurs abundantly also in the neighbouring waters of Japan.

65) *Biddulphia sinensis* Greville

Observed only at Station 61. It is a warm water species.

68) *Hemiaulus membranacus* Cleve

Observed at Stations 60 and 108. This is a warm water species.

69) *Hemiaulus sinensis* Greville (Fig. 12)

Observed at Stations 59, 61, 62 and 63. This is a neritic species in the warm water region.

b. The species distributed only in the Region B: As this region is very narrow, there are only two stations in this region as stated above. Accordingly, the species collected at these two stations were very few.

11) *Schroderella delicatula* (H. Peragallo) Pavillard (Fig. 12)

Observed at Stations 64 and 65. It is a neritic and warm water species, very common in the Japanese waters. It is distributed as far south as 39°S.[9]

51) *Chaetoceros anastomosans* Grunow

Observed only at Station 64. It is sometimes abundant in the East China Sea.

52) *Chaetoceros brevis* Schütt (Fig. 12)

Observed at the same station as the preceding species. It is commonly distributed in the north seas, the Indian Ocean, and the adjacent waters of Japan.

63) *Chaetoceros subsecundus* (Grunow) Hustedt

A small number was observed at Station 65. This is a neritic species.

73) *Eucampia zoodiacus* Ehrenberg

Observed only at Station 64. Distributed in warm water and also common in the adjacent seas of Japan.

c. The species distributed in the Regions, A and B: As clearly shown in Fig. 12, various species are distributed throughout these two regions. They are warm water species.

10) *Lauderia borealis* Gran (Fig. 12)

Observed at Stations 59–62, 64, 65 and 109. Common in the warm water region.

32) *Rhizosolenia Stolterfothii* H. Peragallo (Fig. 12)

Observed at Stations 59 through 65, 109 and 110. It is widely distributed from the tropical region to the Antarctic Sea. It is also very common in the East China Sea.

50) *Chaetoceros affinis* Lauder

Observed at Stations 61, 62, 64, 65, 108 and 110. It is a neritic species which occasionally increases to a large quantity. It is also common in the adjacent waters of Japan.

54) *Chaetoceros curvisetus* Cleve (Fig. 12)

Observed at Stations 59, 61, 64 and 65. This is a neritic and warm water species, and is abundant along the coast of Japan.

57) *Chaetoceros distans* Cleve (Fig. 12)

Observed at Stations 61, 62, 64 and 65.

59) *Chaetoceros messanensis* Castracane (Fig. 12)

Observed at Stations 60, 61, 62, 65 and 106. It is an oceanic species and is distributed in the tropical and subtropical regions.

61) *Chaetoceros pelagicus* Cleve (Fig. 12)

Observed at Stations 61, 64, 65 and 109. It is a warm water species. However, it was recorded from 47°S.[9]

70) *Cerataulina Bergonii* Peragallo (Fig. 12)

Observed at Stations 59, 60, 61, 63, 64 and 65. It is neritic and warm water species, and is common in the East China Sea.

78) *Asterionella japonica* Cleve

Observed at Stations 59, 61 and 65. It is a neritic and warm water species, and is very common in the bays and coasts of Japan.

80) *Thalassionema nitzschioides* Hustedt (Fig. 12)

Observed at Stations 59 through 65 and 109. HENDEY has reported its occurrence in approximately the same distribution as in the present observation. It is a common species and sometimes shows a considerable amount of increase in some localities. It is also very common in the Japanese waters.

82) *Thalassiothrix Frauenfeldii* Grunow (Fig. 12)

Observed at Stations 59 through 65, 109 and 110. A warm water species. Common in the Japanese waters as the preceding species.

d. The species distributed throughout the three Regions, A, B and C: The region is located between the water temperature of 3.3°C and 23°C, and the diatoms in this region generally have a wide geographical distribution.

14) *Dactyliosolen mediteraneus* Peragallo

Observed at Stations 61, 66, 68, 70, 105 and 106. Although the species was found at Sta. 70 located at 48°S, HENDEY recorded the occurrence of this species from 56°S. This is also a common species in the Japanese waters.

15) *Leptocylindrus danicus* Cleve (Fig. 12)

Observed at Stations 59, 61–65, 68, 109 and 110. In the Antarctic Ocean this species has been recorded as far south as 53°S.[9] It is a neritic one and is widely distributed also in the Arctic and North Atlantic as well as in the Japanese waters.

47) *Chaetoceros pervianus* Brightwell

Observed at Stations 61, 64 and 105. An oceanic species having a wide distribution in the areas extending from the cold water region to the tropics. In the Antarctic Ocean as reported by some authors.[1,9,15]

53) *Chaetoceros compressus* Lauder (Fig. 12)

Observed at Stations 59, 61, 63, 65, 67 and 69. A neritic species having a wide distribution and is occasionally found in a large number. Between South Africa and Antarctica, it has been recorded from the northern area of 62°S.[9] It is an important species of the west coast of Kyushu and the east coast of the mainland of China.

62) *Chaetoceros socialis* Lauder (Fig. 12)

Observed at Stations 64, 65 and 70. A large quantity of this species was observed at Stations 64 and 65, and it was so plentiful that the cell number amounted to 74% and 62% of the total number of diatoms at each station. This is a small neritic species and is distributed from the cold water area to the temperate regions.

67) *Hemiaulus Hauckii* Grunow (Fig. 12)

Observed at Stations 59 through 65, 106 and 108. This species is distributed in the warm water region. It is also common in the warm waters near Japan.

72) *Eucampia cornuta* (Cleve) Grunow ex Van Heurck

Observed at Stations 61, 64 and 65. The distribution is similar to that of the preceding species. In the area south of South Africa, HENDEY has recorded this species as far south as 37°S.

74) *Climacodium frauenfeldianum* Grunow

Observed at Stations 61, 106, 108 and 110. It is a warm water species and is distributed around South Africa. In this region it has been recorded as far south as 37°S.[9] It is a common species in the vicinity of Japan.

91) *Nitzschia pungens* var. *atlantica* Cleve (Fig. 12)

Observed at Stations 59–66, 106, 108, 109 and 110. It is a neritic species and is distributed in the warm water region. It was also found in the East China Sea.

e. The species distributed throughout the two Regions, B and C:

76) *Fragilaria granulata* Karsten

Observed at Stations 64, 66, 104, 106 and 107. In this region, the distribution as far south as 42°S has been reported.[9]

83) *Thalassiothrix heteromorpha* Karsten (Fig. 12)

Observed at Stations 64–69, 105 and 106.

f. The species distributed in Region C:

8) *Thalassiosira condensata* Cleve

Observed only at Station 66. This species is often numerous along the coast of South Africa.[9]

24) *Rhizosolenia curvata* Zacharias

Observed only at Station 68. A typical Subantarctic species widely spread throughout the southern ocean, often in a large number.[9] The distribution of this species north of 53°S has been marked.[9),11]

g. The species distributed in Region D: Region D is the Antarctic Region, of which water temperature is below 3.3°C south of Stations 72 and 102. Only cold water species were found in this region.

1) *Melosira sphaerica* Karsten

Observed only at Station 101. This species has been observed south of 50°S.[9] It is an Antarctic species but few in number.

21) *Rhizosolenia antarctica* Karsten

Observed only at Station 75. This species has been reported in the Antarctic Seas by BODEN and KARSTEN.

35) *Rhizosolenia truncata* Karsten

Observed at Stations 84, 86, 87 and 88, i.e., at the stations off Enderby Land. It is a true Antarctic species and it has been reported from the Bellingshausen Sea,[9] near the Weddell Sea[8] and 50°S south area of South Africa.[11]

41) *Chaetoceros Castracanei* Karsten

Observed at Stations 76 and 102. It is a common species in the Antarctic Ocean.

42) *Chaetoceros Chunii* Karsten (Fig. 12)

Observed at Stations 74, 76, 77, 78, 80 and 110. It is often observed around the South Georgia Is., the South Shetland Is., and in the Bellingshausen Sea.[9] It is quite a common species in the Antarctic Sea.

64) *Biddulphia astrolabensis* Hendey

Observed at Stations 100 and 101. It has been reported from the Antarctic Ocean by HENDEY.

71) *Eucampia balaustium* Castracane (Fig. 12)

Observed at Stations 72, 74, 76, 77 and 84. In the 4th Expedition this species was collected only in the Antarctic Region but it has also been observed in the east coast of South Africa.[9]

h. The species distributed throughout the two Regions, C and D: Various species are included in this group. However, most of them are those usually found in the cold water.

3) *Asteromphalus heptactis* (Brébisson) Ralf ex Pritchard

Observed at Stations, 66, 74 and 100. In the Antarctic Ocean this species has been found north of 60°S.[9),11]

4) *Asteromphalus Hookeri* Ehrenberg (Fig. 12)

Observed at Stations 68, 72–78, 80, 83, 98 and 101–103. Though this species was not observed in Region A and Region B, it has a wide distribution from the temperate region to the subpolar region.[9]

5) *Asteromphalus parvulus* Karsten (Fig. 12)

Observed at Stations 68, 70, 72, 74–78, 80, 85, 91, 93, 95, 97 and 100–102. It is a cold water species and is common in the Bellingshausen Sea.[9]

6) *Asteromphalus regularis* Karsten

Observed at Stations 68, 73, 74, 75, 80, 100, 101, 102 and 105. It has almost the same trend of distribution as the preceding species, and is abundant in spring season near South Georgia in the South Atlantic.[9]

13) *Dactyliosolen antarcticus* Castracane (Fig. 12)

Observed at Stations 66–83, 91, (91), 93, 95 and 97–106. This is a characteristic species of the Subantarctic and Antarctic regions and was often observed at many stations south of 43°S. It is particularly important in spring near the Antarctic Convergence Region.[8]

20) *Rhizosolenia alata forma inermis* (Castracane) Hustedt

Observed at Stations 69–74, 76, 81–83, 87–91, (91) and 95–105. This species is very common in the Subantarctic and Antarctic, and also abundant in the northern cold waters.

22) *Rhizosolenia bidens* Karsten

Observed at Stations 100, 101 and 103. This is a cold water species which is common around the South Georgia Is., the South Shetland Is., and the South Sandwich Group.[9]

30) *Rhizosolenia Shrubsolii* Cleve (Fig. 12)

Observed at Stations 67–70, 72–78 and 97–105. It is abundant in the Subantarctic Seas and also distributed near the coast of South Africa.[9,11]

31) *Rhizosolenia simplex* Karsten (Fig. 12)

Observed at Stations 68, 69, 72, 73, 77, 80, 100, 101, 103 and 105. It is a dominant species in the Subantarctic Zone. However, it is not, according to HENDEY, a true Antarctic water species.

38) *Chaetoceros atlanticus* Cleve (Fig. 12)

Observed at Stations 66–69, 71, 72, 76, 77, 80–83, 85, 99–102 and 104–107. This is a typical northern oceanic species, but is widely distributed also in the Antarctic Ocean and is especially abundant in the Subantarctic Region. HART observed a small number of this species in the Weddell Sea and the Bellingshausen Seas but a considerable number near 65°S outside of the Ross Sea.[15]

43) *Chaetoceros concavicornis* Mangin (Fig. 12)

Observed at Stations 70–72, 74, 78, 80, 81, 90, 93, 95–98 and 100–104. This species is well known among the diatoms distributed in the Antarctic Ocean. The percentage occupied by this species in this region sometimes exceed, according to HENDEY, 90% of the total number of diatoms, but was not so abundant in the 4th Expedition.

44) *Chaetoceros convolutus* Castracane (Fig. 12)

Observed at Stations 66–70, 72, 74, 76–83, 91, 93 and 97–106. A common species in the Antarctic Ocean. In the Japanese waters it is distributed in the northern cold area. 45) *Chaetoceros dichaeta* Ehrenberg (Fig. 12)

Observed at Stations 66–74, 76–83, 85, 86, 91, 93 and 97–106. A well known species densely distributed in the Antarctic Ocean. It is also found in the cold water region of the northern hemisphere.

48) *Chaetoceros radiculum* Castracane

Observed at Stations 67, 75, 76, 101 and 102. It is a characteristic species in the southern seas but occurs only in a small quantity.

49) *Chaetoceros Schimperianus* Karsten (Fig. 12)

Observed at Stations 72–74, 76, 77, 79, 80, 81, 83 and 104. This is a cold water species distributed in the Antarctic Ocean. It has also been collected from around the South Georgia Is. and in the Weddell Sea,[9] but it is always few in cell number.

60) *Chaetoceros neglectus* Karsten (Fig. 12)

Observed at Stations 66–85, 90 and 97–101. It is the best known species among subgenus *Hyalochaete* distributed in the Antarctic Ocean and is sometimes found in an enormous amount. This species has also been collected along the east coast of South Africa.[9],[11]

75) *Fragilaria antarctica* Castracane (Fig. 12)

Observed at Stations 66 through 107, except the Stas. 82 and 106. This species is found in great number in the Antarctic Ocean. As stated above, this species was dominant at eleven stations, particularly at Sta. 84 where the cell number was 114,000/l.

85) *Pleurosigma directum* Grunow (Fig. 12)

Observed at Stations 71–78, 81, 95, 98, 101, 102 and 104. This species is abundant in the polar waters and has a fairly wide distribution. It has been collected from the region south of 31°S.[9]

87) *Tropidoneis antarctica* (Grunow) Cleve

Observed at Stations 74, 84 and 103. Southern region of South Africa this species has been collected at many stations in the area from 49°S to 54°S.[11]

i. The species distributed throughout three Regions, B, C and D: Four species of diatom were found throughout three regions. Each of them has a wide distribution.

19) *Rhizosolenia alata forma indica* (Peragallo) Hustedt

Observed at Stations 64, 65, 67, 89 and 100–106. This species is common also in the tropical region.

28) *Rhizosolenia hebetata forma hiemalis* Gran

Observed at Stations 64–66, 72–74 and 105–107, covering the area between 46°S and 53°S.

81) *Thalassiothrix antarctica* Karsten (Fig. 12)

Observed at Stations 64–68, 71, 73, 74, 76–81, 83, 87, 91, (91), 92, 93 and 95–105. This is very common in the Antarctic Ocean. It has a wide distribution in the South Atlantic, the Pacific and the Indian Oceans.[9]

90) *Nitzschia delicatissima* Cleve

Observed at Stations 64–66, 68, 76, 78–84, 101–103, 106 and 107. This is a northern species which is often found in a large quantity in the Arctic Seas. In the Antarctic Ocean it has been reported from the outside of the Ross Sea.[15]

j. The species distributed all over Regions A, B, C and D: Most of the species of this group are rich in cell number and are important constituents in the Antarctic Seas.

17) *Corethron criophilum* Castracane (Fig. 12)

Observed at every Station, 59 through 110, except Sta. 68. This species is most common in the Antarctic Seas. HENDEY classified this species into five "phases": criophilum, hispidum, histrix, inermis and pelagicum. In the 4th Expedition, the author did not follow this classification.

18) *Rhizosolenia alata forma gracillima* (Cleve) Grunow

Observed at Stations 59–66, 72, 73, (91), 92, 96, 98–101, 104–108 and 110. This species has a wide distribution and is also found in the tropical region. It is common also in the Japanese waters.

25) *Rhizosolenia cylindrus* Cleve (Fig. 12)

Observed at Stations 61, 64, 66, 67, 69, 70, 72–81, 93, 98, 99, 101, 102, 105, 107 and 108. This is a common species in the warm water but it was observed as far south as 62°S.

26) *Rhizosolenia delicatula* Cleve

Observed at Stations 59, 60, 74, 77, 99, 100, 101, 103 and 105. In the Antarctic Ocean it is distributed as far south as 65°S.[1]

27) *Rhizosolenia fragilissima* Bergon

Observed at Stations 59–65, 93, 95, 96, 99, 100, 103, 108, 109 and 110. The southern limit of the distribution was found at Sta. 93 situated in 62°S.

29) *Rhizosolenia hebetata forma semispina* (Hensen) Gran (Fig. 12)

Observed at Stations 59–65, 68, 69, 72, 73, 74, 76, 100, 103 and 105. This is a common species in the Antarctic Ocean.

33) *Rhizosolenia styliformis* Brightwell (Fig. 12)

Observed at Stations 59, 62–66, 73, 74, 77, 80, 82, 91, (91), 95, 96, 98–105 and 107–110. This species is quite widely distributed in the ocean including the tropical region, and is also common in the Japanese waters.

34) *Rhizosolenia styliformis* var. *longispina* Hustedt

Observed at Stations 61, 74, 76, 77, 80, 81, (91), 93, 95, 97, 100–104, 106–108 and 110. The distribution is similar to that of the preceding species. It is common in the East China Sea.

46) *Chaetoceros pendulus* Karsten

Observed at Stations 60–63, 74, 76, 77, 81, 93, 95, 98, 100, 102 and 105. This is an oceanic species which is widely distributed in the ocean including the Japanese waters. In the Antarctic Ocean, this species has been reported by HENDEY and MARUMO but it is not found in a large number.

84) *Thalassiothrix longissima* Cleve et Grunow

Observed at Stations 59–66, 68, 73, 75, 87, 88, 91, 93, 101, 106, 107, 109 and 110. This species is widely distributed even in the warm water, but sometimes observed in a great quantity in the cold water region.

89) *Nitzschia closterium* (Ehrenberg) W. Smith

Observed at Stations 59–69, 71–91, 93, 96 and 98–110. This species has been recorded in the Antarctic Ocean around the South Georgia Is., the South Sandwich Group,[9] 68°S 154°E,[1),15] the south of South Africa, and the north of 55°S.[11] This species is also found in the East China Sea.

92) *Nitzschia seriata* Cleve (Figs. 12 and 13)

Observed at Stations 59–83, 85, 88, 90, (91), 92, 93 and 95–110. This species is distributed from the tropical to the polar regions. This species is sometimes found in an enormous quantity in the coastal regions but it was especially abundant in the latest Observation between the Stations 66 and 70 and exceeded more than 60% of the catch of diatoms in the area. It is evident that this species is the most important one in the Sub-antarctic Region.

The distribution of the species stated above may be summarized as follows: Twenty-five species were observed in Region A, Region B, and Regions A and B that extend from the south coast of South Africa to Sta. 65. They are warm water species. These species were distributed between Sta. 110 and Sta. 108 on the return cruise. There were 26 species observed south of Sta. 66, viz., in Region C, Region D, and Regions C and D and they are cold water species. On the return cruise these species were distributed in the area south of Sta. 107. Twelve species listed in the clause j were observed in the regions with water temperatures differing between the coast of South Africa and Antarctica, and they are eurythermal species. Besides these, *Rhizosolenia alata f. indica, Thalassiothrix antarctica, Nitzschia delicatissima* seem to be eurythermal ones. The general aspect of distribution of the diatoms in the observed areas may be known from the study of HENDEY. According to his report, many warm water species were observed down to Sta. 433 (39°37′S 33°06′E) from the coast of South Africa as shown in Fig. 10. And from the above statement it is supposed that the southern boundary of distribution of the warm water species lies on the line a little south of Sta. 433.

Only 13 species were observed between Sta. 59 and Sta. 63 (Region A) and these species are, of course, warm water species. *Nitzschia seriata* was dominant in this region and occupies 25%–39% of the total diatoms at each station. The similar constitution was observed between Sta. 108 and Sta. 110 on the return cruise. On the other hand, many kinds of warm water species were found in the region between Sta. 64 and Sta. 65 or in Region B. Among them the most dominant species was *Chaetoceros socialis* which was 73.9% of the total cell number found at Sta. 64 and 62.3% at Sta. 65. Thus, the constitution in Region B is completely different from that found in Region A. For instance, the total cell number was much more in Region B than in Region A as shown in Fig. 11–1. At the next station, Sta. 66, cold water species dominanted over warm water species, and a remarkable difference was observed between these two stations in the constitution of species. The distribution of plankton is, as seen above, determined by the distribution of the water masses. These water masses of Regions A through D are in good accord with the masses described in Part I, which are based on the analyses of physical and chemical elements of the water masses. The region between Sta. 59 and Sta. 63 (Stas. 108 to 110) is the Agulhas Warm Water Region, the region between Sta. 64 and Sta. 65 is the North Edge Water of Westerly Wind Drift Region, and the region from Stas. 66 to 71 (Stas. 107 to 103) is the Subantarctic Upper Water Region.

The entire region from south of Sta. 66 to Antarctica has the character of cold water. The Antarctic Convergence is located between Sta. 71 and Sta. 72 and the water region is divided into two water masses by the convergence. In this region the distribution of diatoms is rich both in species and in quantity. Among them *Rhizosolenia simplex* and *Rhizosolenia Shrubsolii* are believed to be confined only to the Subantarctic Region. However, these two species are found also in the areas much further south of the Antarctic Convergence. Accordingly, it is difficult to find the boundary between the Subantarctic and Antarctic Regions. It will be known that *Chaetoceros Schimperianus* and *Eucampia balaustium* are the species which are always found near the Antarctic Convergence. But, in the 4th Expedition, these species were found only in a very small quantity. Consequently, it is also difficult to determine the relation between water mass and plankton distribution. One the other hand, the distribution of genus *Nitzschia* in the Subantarctic Region is worth attention; the occurrence of this genus is very remarkable in the area south of Station 66 (Figs. 11–1 and 12). On the south-bound cruise the cell number of *Nitzschia seriata* was particularly dense from Sta. 66 to Sta. 70 and the average value of the cell number in these five stations

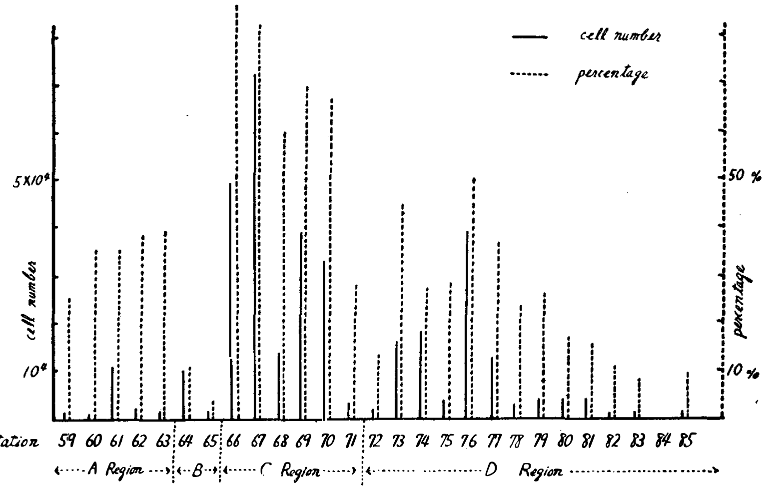

Fig. 13. The cell number and percentage of *Nitzschia seriata* at the south-bound voyage.

was 41,500/l (Fig. 13). The northern area of the Antarctic Region is in the second rank in quantity of *Nitzschia,* but the cell number was 37,400/l at Sta. 76, and at other stations it was less than 20,000/l. These figures are much smaller than those found at the five Stations, 66 to 70. The percentage of this species at Station 68 was 60%, that at Station 66 was 86% of the total diatoms whereas it was 50% at Station 76. On the homebound cruise the maximum cell number of *Nitzschia seriata* was 66,140/l or 78% of the total cell number at Sta. 104 in the southern area of the Subantarctic Region. As is known from the above, it is quite difficult to determine properly the boundary between the Subantarctic Upper Water and the Antarctic Surface Water by the distribution of diatoms observed in the 4th Expedition, but it can be assumed that the Subantarctic Upper Water is the area where *Nitzschia seriata* is very dominant.

The Antarctic Region is characterized by the simple composition of diatoms. Three to five species dominate in the Antarctic Ocean, and those species put together occupied over 80% of the total catch at each station: In the region between Sta. 72 and Sta. 78 the diatom communities consisted of *Nitzschia seriata, Fragilaria antarctica, Chaetoceros neglectus, Corethron criophilum* and *Dactyliosolen antarcticus*; between Sta. 79 and Sta. 87 *Nitzschia seriata, Fragilaria 'antarctica* and *Chaetoceros neglectus.*

At Sta. 84 the population was very dense, being composed of *Fragilaria antarctica* with the cell number 115,000/l or about 51% of the catch, accompanied by *Navicula sp.* and *Nitzschia closterium.* The diatom constitution of the Antarctic region at the time of the homebound cruise was similar to that of the south-bound cruise; the dominant species were *Nitzschia seriata, Fragilaria antarctica* and *Dactyliosolen antarcticus* with the participation of *Chaetoceros dichaeta* to the above three species, and these species were dominant at Stas. 100, 104 and 105, with the exception of *Corethron criophilum* which was 70% of the total cell number at Sta. 91. In addition to *Fragilaria antarctica, Nitzschia seriata,* and *Corethron criophilum, Navicula sp.* was important off Enderby Land.

Table 5. Percentage of the important species collected by plankton sampler.

Sta. 1	*Rhizosolenia alata forma gracillima* *Nitzschia seriata* *Chaetoceros Coarctatus*	93.8% 1.4 〃 1.0 〃
Sta. 4	*Thalassionema nitzschioides* *Thalassiothrix longissima* *Nitzschia seriata* *Climacodium Frauenfeldianum*	33.8% 16.0 〃 15.1 〃 11.1 〃
Sta. 3	*Thalassionema nitzschioides* *Climacodium Frauenfeldianum* *Nitzschia seriata* *Rhizosolenia alata f. gracillima* *Chaetoceros messanensis*	74.0% 5.3 〃 4.8 〃 3.8 〃 2.9 〃
Sta. 4	*Chaetoceros socialis* *Nitzschia seriata* *Thalassionema nitzschioides*	45.2% 20.3 〃 13.9 〃
Sta. 5	*Nitzschia seriata* *Fragilaria antarctica* *Nitzschia closterium*	54.9% 14.4 〃 14.2 〃
Sta. 6	*Nitzschia seriata* *Chaetoceros dichaeta* *Chaetoceros atlanticus*	47.5% 26.2 〃 3.5 〃
Sta. 7	*Chaetoceros concavicornis* *Fragilaria antarctica* *Nitzschia seriata*	45.1% 39.0 〃 5.2 〃
Sta. 8	*Fragilaria antarctica* *Nitzschia seriata* *Chaetoceros concavicornis*	36.1% 32.9 〃 16.3 〃
Sta. 9	*Fragilaria antarctica* *Corethron criophilum* *Chaetoceros concavicornis* *Thalassiothrix antarctica* *Nitzschia seriata*	52.3% 15.5 〃 13.8 〃 8.5 〃 4.8 〃
Sta. 10	*Chaetoceros concavicornis* *Fragilaria antarctica* *Rhizosolenia styliformis* *Corethron criophilum* *Chaetoceros neglectus* *Chaetoceros atlanticus* *Nitzschia closterium* *Nitzschia delicatissima* *Nitzschia seriata*	19.2% 14.7 〃 10.8 〃 9.2 〃 6.9 〃 6.5 〃 6.1 〃 5.6 〃 5.2 〃

2. Distribution of diatoms collected by the plankton sampler

The collection was performed at ten stations as shown in Fig. 10. As stated before, Müller gauze No. 3 was used but it was proved unsuitable for collection of diatoms. Accordingly, the result of the collection seems to have no value other than the qualitative one. However, the species collected at each station and their percentages may suggest the characteristics of the water mass at the station. Table 5 shows the dominant species and their percentage.

Sta. 1 is located closer to the coast of South Africa and the diatom consisted only of *Rhizosolenia alata f. gracillima.* This is entirely different in composition from other stations. This region seems to be scarcely affected by the Agulhas Current.

Stas. 2 and 3 are located approximately in the same region as Stas. 61 and 62, or in the Agulhas Warm Water Region. *Nitzschia seriata* and the warm water species were observed at both stations.

Sta. 4 and Sta. 64 are located nearly in the same region. The dominant species was *Chaetoceros socialis,* and occupied 45% of the total cell number. A similar constitution of diatom was observed at this Station. This Station is, of course, located in the region of the North Edge Water of Westerly Wind Drift.

Stas. 5 and 6 are located near Stas. 68 and 70. At these stations *Nitzschia seriata* was decisively dominant, and this is the characteristics of the Subantarctic Region. This species occupies about 50% of the catches at each station. This result was similar to that obtained by the water sampling method. While the species at Stas. 5 and 6 consisted mainly of *Nitzschia seriata,* it consisted, at Sta. 7, of a mixture of *Chaetoceros concavicornis* and *Fragilaria antarctica.* The difference in composition of diatoms in the two regions is so large that they may be readily ascribed to different water groups. At Stas. 7 and 8 the constitution was similar as shown in Table 5.

At Sta. 9 the diatom was similar in composition to Sta. 8 as *Fragilaria antarctica* was dominant at both stations, but there was a remarkable difference between Sta. 10 and Sta. 9 as shown in Table 5.

Thus, the results obtained by the plankton sampler method are similar to that obtained by the water sampling method.

3. Distribution of copepods

There is an excellent study of TANAKA on copepods with the samples obtained by the 2nd Japanese Antarctic Research Expedition. The copepods collected from the surface water by the plankton sampler in the 4th Expedition were also studied by him. A list of copepods at each station is shown in the chapter on results. The stations are shown in Fig. 10: Stas. T8–T17 represent those in the 2nd Expedition and Stas. 1–10 represent those in the 4th Expedition. The distribution of important species are shown in Fig. 14.

At Stations 1–3 near South Africa, only warm water species, numbering thirty-nine, were distributed. Especially Sta. T8 and Sta. 3 are well represented by the warm water species; in other words, the Stations are involved in the Agulhas Warm Water Region. WOLFENDEN (1908) has reported the distribution of Subtropical species in the southern region of the Indian Ocean that the species extend as far south as 30°S. However, in the present Expedition, the species were observed as far south as 38°S where the Agulhas Convergence has, more or less, an influence on the distribution of the species.

Station	1	T8	2	3	T9	4	5	T10	6	T11	7	T12	8	9	10	T13	T14	T15	T16	T17
Paracalanus aculeatus	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acrocalanus gracilis	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clausocalanus furcatus	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calocalanus pavo	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calocalanus plumulosus	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudodiaptomus nudus	+	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Candacia aethiopica	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Labidocera acuta	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acartica negligens	+	4	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oithona nana	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oithona plumifera	-	1	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oncaea media	-	240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sapphirina gemma	+	2	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corycaeus asiaticus	+	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corycaeus dahli	-	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corycaeus agilis	+	79	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corycaeus rostratus	-	28	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macrosetella gracilis	+	1	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calanoides carinatus	-	2	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paracalanus parvus	+	161	+	+	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clausocalanus arcuicornis	+	13	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Centropages chierchiae	+	125	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calanus tonsus	-	-	-	-	8	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Clausocalanus laticeps	-	-	-	-	4	-	+	2	-	-	-	-	-	-	-	-	-	-	-	-
Oncaea venusta	+	14	+	+	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Undinula vulgaris	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Calanus simillimus	-	-	-	-	-	-	+	-	-	-	-	5	-	-	-	-	-	-	-	-
Oithona similis	-	18	-	-	3	-	-	33	+	10	+	-	+	-	-	14	4	-	-	-
Ctenocalanus vanus	-	-	-	-	-	-	-	2	-	-	-	3	-	-	-	3	-	31	11	39
Calanus propinquus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	7	2	15
Calanoides acutus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	18	17	21
Rhincalanus gigas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	10
Pareuchaeta sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	7
Scolecithricella glacilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	11	9	14
Racovitzanus antarcticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	2
Metridia gerlachei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	16	28	29
Oithona frigida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	-
Oncaea conifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	48	20	77
Oncaea curvata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62	6	108
Oncaea notopus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	4
Tisbe racobitzal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Station	1	T8	2	3	T9	4	5	T10	6	T11	7	T12	8	9	10	T13	T14	T15	T16	T17
					40°S					50°S					60°S					

Fig. 14. Stations where copepods were detected (4th Exp.) and individual number (2nd Exp.) between the south end of Africa and Antarctica (identified by O. TANAKA).

At Stas. T9 and 4, species were few in number. Only seven species were collected in either of the 2nd and 4th Expeditions. Of the species shown in Fig. 14, *Paracalanus parvus*, *Clausocalanus arcuicornis*, *Oncaea venusta*, and *Calanoides carinatus* had a wide distribution in the surface water. *Centropages chierchiae* was widely distributed and was abundant near the coast of South Africa. *Calanus tonsus* and *Clausocalanus laticeps* are Subantarctic species (TANAKA). Accordingly, the distribution of copepods in this region was remarkably different from that in the Agulhas Region as stated above, and the difference in distribution seems to be caused by the difference of water mass in which they live. There is, of course, a boundary between these two water masses, which was found between Sta. T8 and Sta. T9 in the 2nd Expedition. The water mass which involves Stas. T9 and 4 is clearly the North Edge Water of Westerly Wind Drift.

Only two species *Calanus tonsus*, and *Clausocalanus laticeps*, representatives of the Subantarctic species, were detected at Stas. T9, 5 and T10. On the other hand, a very poor copepods community was found at each station from Sta. 6 to Sta. T12 being represented by only three species or less (Fig. 14). These species are *Oithona similis*, a cosmopolitan species, and *Calanus simillinus*, an Antarctic species distributed between 50°S and 60°S (VERVOOT, 1957). It may well be regarded from the distribution of the species as stated above that there is the boundary between two water regions, the one including Sta. 5 and Sta. T10 and the other including Stas. 6 to 10. The boundary of these two water masses is the Antarctic Convergence, bounded on the north by the Subantarctic Region and on the south by the northern region of the Antarctic Surface Water. In these regions the copepods were very poor in both quality and quantity.

According to TANAKA, twenty-three species of copepods were detected from Sta. T13 to Sta. T17, of which fifteen had been reported as true Antarctic species and they are large in number. Accordingly, in the Antarctic, another boundary is supposed to exist between two water areas; the northern region is poor in copepods and the southern region is rich.

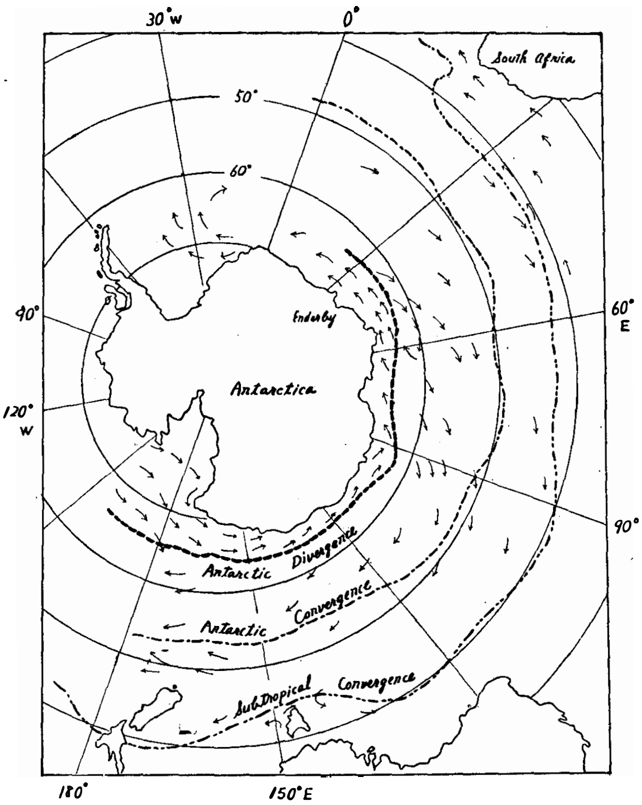

Fig. 15. Location of divergence and convergences, and surface currents in the Antarctic Sircumpolar Ocean (after DEACON and U. S. Navy Hydrographic Office, Washington D. C.).

According to the hydrographical data of the 4th Expedition, the water temperature changed by about 3°C between northern area and southern seas in the Antarctic Surface Water Region, but no remarkable differences were observed in the chemical properties. However, KUMAGORI and YANAGAWA have reported that the Westerly Wind Drift of the Antarctic Ocean gradually changes its direction towards south near 55°S as the strong Westerly Wind declines in the latitudes between 45°S and 55°S, and near 60°S the current joins the westward current which flows along the coast of Antarctica and is usually called as the East Wind Drift. According to this report, the region poor in copepods from Sta. T11 to Sta. 10 is located in the central and southern areas of the Westerly Wind Drift where the wind gradually wanes, and Sta. T13 through Sta. T17 are included in the area where the Westerly Wind Drift joins the westward current. It has been reported that the Antarctic Divergence exists in the water area near Antarctica as indicated in Fig. 15. This Divergence is located near 63°S off Enderby Land. The currents flow in opposite direction on each side of the Divergence. TANAKA has reported a boundary between Sta. 12 and Sta. 13 which may probably indicates the Antarctic Divergence.[21]

4. Conclusion based on the distribution of plankton

Diatoms were collected from the surface water between the south end of Africa and Antarctica by the water sampling method and by the Motoda's plankton sampler. Generally speaking, the cell number is small in the warm water region near the coast of South Africa and large in the Subantarctic Region. In the Antarctic Region, the cell number differed greatly according to the station. For example, the cell number at Sta. 84 was 225,000/l whereas the same at Sta. 93 was only 360/l. The density of diatoms off Enderby Land remained within the limit of 10^3/l which is rather a small value expected in the Antarctic Seas.

Nitzschia seriata was the most dominant species throughout the entire regions. Besides this species, there were many warm water species from the coast of South Africa to Sta. 63. This region is the Agulhas Warm Water Region which was explained in Part I.

At Stas. 64 and 65, *Chaetoceros socialis* was dominant and the diatom constitution of this region was remarkably different from other regions. Since a fairly large number of warm water species was observed in this region, it is evident that these stations are located in the North Edge Water of Westerly Wind Drift.

Nitzschia seriata was especially dominant in the Subantarctic Upper Water Region.

In the Antarctic Surface Water Region, *Fragilaria antarctica, Dactyliosolen antarcticus, Chaetoceros dichaeta, Chaetoceros neglectus* and *Corethron criophylum* were abundant, in addition to *Nitzschia seriata*. Off Enderby Land, *Navicula sp.* showed a fairly large percentage of distribution.

In the Agulhas Warm Water Region, many warm water species of copepods are found and in the North Edge Water Region the Subantarctic species are detected. *Calanus tonsus* and *Clausocalanus laticeps*, representatives of the Subantarctic species, *Oithona similis*, a cosmopolitan species, and *Calanus simillimus*, an Antarctic species, were collected. The copepods are very poor in the northern area of the Antarctic Region, whereas, the true Antarctic species is abundant off Enderby Land. A large difference in the composition of copepods fauna as seen above between the northern and southern areas within the Antarctic Region may suggest that the Antarctic Divergence lies between these two areas.

SUMMARY

It has been well known that there are Subtropical Convergence and Antarctic Convergence on the water surface between the south end of Africa and Antarctica. As a result of the analyses based on the physical and chemical conditions of the area by the Japanese Expedition, it was revealed that another remarkable convergence existed near 40°S. This convergence was named "Agulhas Convergence." Hence, four water masses exist in the water area. The water mass located between the Agulhas Convergence and the Subtropical Convergence was named "North Edge Water of Westerly Wind Drift." The existence of these water masses was also confirmed by the study of the distribution of plankton in the surface water.

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APPENDICES

1) Data of surface water temperature between Cape Town and Antarctica obtained by the "SOYA" in the 3rd J. A. R. E. (observed by the meteorological staff)

Date	Time	Location		W. T.	Date	Time	Location		W. T.
		Lat. S	Long. E	(C)			Lat. S	Long. E	(C)
Dec. 1958					Dec. 1958				
24	12	34-23	18-18	16.5	28	21	49-24	32-30	4.1
	15	34-49	18-30	20.2	29	0	49-47	32-58	2.7
	18	35-11	18-56	20.4		3	50-11	33-27	2.7
	21	35-33	19-16	20.9		6	50-34	33-55	2.5
25	0	35-56	19-44	21.4		9	50-57	34-23	2.9
	3	35-56	19-44	22.3		12	51-24	34-50	2.1
	6	36-20	20-06	22.1		15	51-50	35-17	1.4
	9	36-45	20-28	21.6		18	52-17	35-43	1.8
	12	37-36	21-13	21.6		21	52-40	36-10	1.3
	15	38-03	21-35	22.5	30	0	53-10	36-37	1.9
	18	38-31	21-58	22.7		3	53-35	37-04	1.8
	21	38-59	22-21	19.4		6	54-01	37-30	0.9
26	0	39-23	22-42	21.0		9	54-26	37-56	1.7
	3	39-52	23-06	16.2		12	54-54	38-25	1.8
	6	40-19	23-28	16.2		15	55-22	38-54	0.9
	9	40-45	23-51	16.5		18	55-51	39-22	0.7
	12	41-11	24-16	16.7		21	56-18	39-51	0.4
	15	41-38	24-40	14.5	31	0	56-45	40-20	0.5
	18	41-38	25-05	13.8		3	57-13	40-48	0.5
	21	42-03	25-30	11.0		6	57-39	41-17	0.7
27	0	42-56	25-52	14.0		9	58-06	41-46	1.0
	3	43-21	26-17	10.2		12	58-36	42-17	1.2
	6	43-46	26-41	10.7		15	59-06	42-47	1.1
	9	44-12	27-07	11.9		18	59-34	43-17	1.0
	12	44-40	27-33	7.9		21	60-04	43-47	1.1
	15	45-08	28-00	7.1	Jan. 1959				
	18	45-35	28-26	6.9	1	0	60-31	44-18	1.0
	21	46-02	28-52	6.1		3	61-00	44-48	1.2
28	0	46-29	29-19	6.2		6	61-28	45-17	1.1
	3	46-55	29-45	6.7		9	61-55	45-48	0.8
	6	47-22	30-12	7.0		12	62-23	46-24	0.9
	9	47-48	30-38	6.4		15	62-52	47-03	1.0
	12	48-13	31-07	6.2		18	63-21	47-41	0.6
	15	48-36	31-35	5.7		21	63-49	48-20	0.2
	18	49-00	32-03	4.9	2	0	64-13	48-53	−0.3

Date	Time	Location		W. T.
		Lat. S	Long. E	(C)
Jan. 1959				
2	3	64-36	49-26	−0.3
	6	65-02	50-08	−1.3
	9	65-24	50-56	−1.3
	12	65-41	51-31	−1.6
	15	65-40	51-07	−1.2
	18	65-36	50-25	−1.5
	21	65-33	49-28	−1.7
	24	65-23	49-08	−1.6
Feb. 1959				
12	0	67-28	31-06	−0.4
	3	67-07	31-39	−0.1
	6	67-15	32-14	−1.7
	9	67-18	32-19	−1.5
	12	67-13	32-19	−1.5
	15	66-56	32-05	−1.0
	18	66-29	31-45	0.2
	21	66-00	31-25	0.3
13	0	65-32	31-06	1.3
	3	65-05	30-47	1.9
	6	64-37	30-28	1.7
	9	64-09	30-10	1.9
	12	63-40	30-00	2.0
	15	63-10	29-49	2.1
	18	62-41	29-38	2.1
	21	62-12	29-28	1.5
14	0	61-44	29-14	1.6
	3	61-15	29-04	1.5
	6	60-47	28-54	1.6
	9	60-19	28-45	1.8
	12	59-52	28-39	1.8
	15	59-26	28-33	1.8
	18	59-02	28-29	1.7
	21	58-39	28-25	1.8
15	0	58-19	28-21	1.7
	3	57-58	28-17	1.6
	6	57-36	28-13	2.0
	9	57-14	28-05	1.9
	12	56-53	27-55	1.8
	15	56-31	27-47	1.9
	18	56-08	27-38	1.8
Feb. 1959				
15	21	55-45	27-29	1.9
16	0	55-25	27-12	1.3
	3	55-05	26-58	1.4
	6	54-39	26-47	1.6
	9	54-12	26-37	1.5
	12	53-46	26-24	1.2
	15	53-19	26-09	1.1
	18	52-52	25-54	2.4
	21	52-25	25-39	1.2
17	0	51-55	25-25	1.5
	3	51-27	25-07	2.0
	6	51-00	24-52	2.4
	9	50-32	24-37	2.9
	12	50-05	24-23	2.9
	15	49-38	24-09	3.2
	18	49-09	23-55	4.1
	21	48-40	23-41	4.9
18	0	48-13	23-27	5.4
	3	47-45	23-13	5.5
	6	47-16	22-59	5.2
	9	46-49	22-42	6.5
	12	46-20	22-27	6.8
	15	45-51	22-13	6.8
	18	45-21	21-59	9.1
	21	45-03	21-50	11.7
19	0	44-25	21-33	12.8
	3	43-59	21-21	13.7
	6	43-31	21-08	9.6
	9	43-04	20-56	9.8
	12	42-36	20-43	19.8
	15	42-09	20-26	19.3
	18	41-58	20-05	18.8
	21	41-56	19-35	14.7
20	0	41-54	19-03	14.5
	3	41-51	18-27	13.8
	6	41-27	18-10	13.0
	9	41-04	18-05	15.2
	12	40-39	18-05	15.6
	15	40-15	18-07	18.6
	18	39-51	18-09	15.5

Date	Time	Location		W. T.	Date	Time	Location		W. T.
		Lat. S	Long. E	(C)			Lat. S	Long. E	(C)
Feb. 1959					Feb. 1959				
20	21	39–27	18–11	22.8	22	3	37–16	16–41	18.8
21	0	39–03	18–13	22.0		6	37–10	16–58	19.4
	3	38–40	18–15	20.1		9	36–47	16–58	19.0
	6	38–18	18–14	20.7		12	36–25	17–04	20.3
	9	38–01	18–11	23.1		15	36–03	17–12	20.4
	12	37–42	18–10	24.0		18	35–41	17–20	20.4
	15	37–23	18–02	24.0		21	35–17	17–29	20.1
	18	37–10	17–38	19.9	23	0	34–52	17–39	21.0
	21	37–12	17–06	19.4		3	34–23	17–52	20.8
22	0	37–14	16–35	18.9					

2) Data of surface water temperature between Cape Town and Antarctica obtained by the "SOYA" in the 4th J. A. R. E. (observed by the meteorological staff)

Date	Time	Location		W. T.	Date	Time	Location		W. T.
		Lat. S	Long. E	(C)			Lat. S	Long. E	(C)
Dec. 1958					Dec. 1958				
18	9	33-54	18-21	15.1	23	0	50-25	29-35	3.6
	12	34-18	18-18	18.1		3	50-54	30-07	2.6
	15	34-43	18-30	19.1		6	51-21	30-28	1.1
	18	35-09	18-43	19.4		9	51-50	30-55	1.1
	21	35-35	18-57	19.7		12	52-15	31-22	1.1
19	0	36-01	19-12	19.6		15	52-40	31-49	1.4
	3	36-27	19-26	18.7		18	53-06	32-18	1.4
	6	36-53	19-40	22.0		21	53-55	32-43	1.7
	9	37-19	19-54	21.5	24	0	53-58	33-11	0.6
	12	37-44	20-13	22.7		3	54-23	33-37	0.6
	15	38-11	20-25	22.1		6	54-48	34-06	1.6
	18	38-38	20-41	20.3		9	55-14	34-35	1.7
	21	39-05	20-58	19.9		12	55-40	34-57	1.7
20	0	39-31	21-15	19.5		15	56-09	35-18	1.8
	3	39-58	21-31	20.5		18	56-37	35-39	1.6
	6	40-25	21-49	19.4		21	57-07	36-02	2.1
	9	40-53	22-06	16.8	25	0	57-30	36-31	1.9
	12	41-21	22-24	16.4		3	57-56	37-01	1.3
	15	41-46	22-41	17.0		6	58-23	37-33	1.2
	18	42-14	22-59	16.3		9	58-49	38-05	1.0
	21	42-42	23-18	12.6		12	59-13	38-41	1.1
21	0	43-09	23-37	9.1		15	59-39	39-19	0.8
	3	43-36	23-54	10.0		18	60-04	39-57	1.0
	6	44-04	24-14	11.4		21	60-29	40-35	0.6
	9	44-32	24-30	10.4	26	0	60-54	41-15	0.5
	12	44-57	24-53	7.2		3	61-18	41-54	0.2
	15	45-25	25-15	7.6		6	61-43	42-34	0.5
	18	45-52	25-36	6.9		9	62-08	43-14	0.0
	21	46-19	25-58	6.5		12	62-32	43-54	0.1
22	0	46-46	26-20	6.3		15	62-57	44-35	0.0
	3	47-13	26-42	5.2		18	63-22	45-15	0.0
	6	47-40	27-04	4.6		21	63-47	45-57	0.0
	9	48-07	27-26	4.2	27	0	64-11	46-39	−0.1
	12	48-34	27-51	3.6		3	64-36	47-21	0.0
	15	49-02	28-17	4.0		6	64-59	48-04	−0.1
	18	49-30	28-43	4.7		9	65-17	48-37	−1.6
	21	49-58	29-09	4.7					

Date	Time	Location		W. T.	Date	Time	Location		W. T.
		Lat. S	Long. E	(C)			Lat. S	Long. E	(C)
Feb. 1959					Feb. 1959				
22	0	65-36	32-20	0.7	27	3	52-29	25-53	1.0
	3	65-20	32-01	1.0		6	52-01	25-23	1.6
	6	64-46	31-44	1.2		9	51-36	25-07	1.5
	9	64-33	31-28	1.4		12	51-11	24-51	1.5
	12	63-58	31-12	1.2		15	50-46	24-36	1.6
	15	63-34	30-58	1.4		18	50-24	24-25	1.7
	18	63-12	30-44	1.1		21	50-06	24-14	1.7
	21	62-52	30-32	1.1	28	0	49-47	24-01	1.8
23	0	62-40	30-39	1.1		3	49-24	23-46	2.8
	3	62-26	30-35	1.4		6	49-00	23-31	3.4
	6	62-11	30-27	1.1		9	48-36	23-15	4.2
	9	61-56	30-18	1.0		12	48-10	23-01	4.1
	12	61-38	30-11	1.1		15	47-42	22-53	4.0
	15	61-21	30-05	1.0		18	47-14	22-46	5.3
	18	61-04	30-01	1.1		21	46-46	22-37	6.5
	21	60-49	29-56	1.3	29	0	46-18	22-26	7.2
24	0	60-37	29-52	1.0		3	45-50	22-14	7.5
	3	60-26	29-48	0.9		6	45-22	22-03	7.8
	6	60-12	29-42	1.0		9	44-51	21-52	9.6
	9	59-58	29-33	1.2		12	44-28	21-42	9.2
	12	59-45	29-24	1.2		15	44-00	21-30	10.6
	15	59-30	29-14	1.1		18	43-32	21-15	10.9
	18	59-12	29-01	1.2		21	43-02	21-00	12.3
	21	58-54	28-48	0.9	Mar. 1959				
25	0	58-35	28-35	1.3	1	0	42-36	20-46	16.5
	3	58-16	28-22	1.5		3	42-07	20-32	15.6
	6	57-56	28-08	1.2		6	41-40	20-20	11.4
	9	57-34	27-53	1.2		9	41-11	20-10	15.7
	12	57-14	27-34	1.4		12	40-44	20-06	16.0
	15	56-54	27-12	1.4		15	40-17	20-03	19.4
	18	56-31	27-03	1.6		18	39-50	19-58	22.9
	21	56-13	26-58	1.5		21	39-16	19-37	23.0
26	0	56-02	26-56	1.5	2	0	38-46	19-18	23.1
	3	55-49	26-51	1.6		3	38-18	19-01	22.0
	6	55-28	26-44	1.6		6	37-58	18-49	21.3
	9	55-05	26-36	1.4		9	37-18	18-24	20.7
	12	54-44	26-27	1.1		12	36-47	18-08	20.6
	15	54-18	26-17	1.0		15	36-16	18-08	20.5
	18	53-51	26-09	0.9		18	35-46	18-08	19.7
	21	53-24	25-59	1.0		21	35-14	18-08	19.8
27	0	52-56	25-48	1.0	3	0	34-40	18-08	20.2

3) Result of surface observation between Cape Town and Antarctica obtained by the "SOYA" in the 3rd J. A. R. E.
(observed by N. ONO)

Date	Time	Location		W. T.	pH	S	O_2	P	Si	NH_3-N	NO_2-N
		Lat. S	Long. E	(C)		‰	cc/l	µg-a./l	µg-a./l	µg-a./l	µg-a./l
Dec. 1958											
24	12-00	34-23	18-18	19.8	—	34.10	5.75	0.1	Nil	3.2	Nil
25	11-40	37-33	21-11	21.8	8.20	35.41	4.74	Nil	〃	4.0	〃
	17-40	38-26	21-54	22.6	8.12	35.37	4.60	—	〃	—	—
26	05-40	40-15	23-25	16.3	8.20	35.34	5.36	0.2	〃	4.0	Nil
	11-20	41-06	24-10	16.9	8.18	35.23	5.28	0.5	〃	5.0	〃
	17-20	41-58	24-58	14.1	8.18	35.08	5.53	0.8	〃	5.0	0.05
27	05-20	43-41	26-37	10.9	—	34.33	6.01	1.0	〃	5.0	0.05
	11-00	44-30	27-24	8.0	8.10	34.12	6.25	0.7	〃	4.0	0.07
	17-00	45-24	28-16	6.9	8.02	33.91	6.43	1.6	〃	3.0	0.20
28	05-00	47-13	30-03	7.1	7.96	34.11	6.35	0.9	〃	3.0	0.07
	11-00	48-04	30-57	6.6	8.00	34.04	6.56	1.0	〃	3.0	0.10
	17-00	48-51	31-52	5.2	8.00	33.93	6.61	1.4	〃	2.0	0.12
29	05-00	50-26	33-45	2.6	8.03	33.87	6.90	0.8	2	2.0	0.07
	11-00	51-13	34-40	2.1	8.15	33.89	7.19	0.8	1	2.0	0.07
30	11-00	54-44	38-15	1.7	7.88	33.93	7.33	0.9	1	2.0	0.20
31	11-00	58-25	42-05	1.2	7.80	33.82	7.35	1.2	2	1.6	0.10
Jan. 1959											
1	11-00	62-14	46-12	0.8	7.70	33.75	7.42	1.6	4	2.0	0.80
	17-40	63-18	47-36	0.4	7.71	33.93	7.43	1.6	4	1.6	0.12
2	23-00	64-04	48-42	− 0.4	7.70	34.02	7.44	1.6	4	1.6	0.80
	11-00	63-38	51-26	− 1.7	7.90	33.33	7.16	1.6	5	1.6	0.60
3	11-00	65-48	46-43	− 1.5	7.95	33.22	7.60	0.9	5	1.6	0.60
Feb. 1959											
13	11-00	63-50	30-03	2.0	7.60	33.78	7.37	—	—	—	—
14	11-30	59-56	28-39	1.8	7.65	33.60	7.26	—	25	—	—
15	12-00	56-53	27-56	1.6	7.92	33.89	7.18	—	—	—	—
16	12-00	53-46	26-24	1.1	7.90	34.12	7.45	—	35	—	—
17	12-00	50-05	24-23	2.9	8.00	34.11	7.36	—	20	—	—
18	12-00	46-20	22-27	6.6	8.02	33.89	6.70	—	5	—	—
19	12-00	42-35	20-42	19.8	8.20	35.41	5.11	—	1	—	—
20	12-00	40-39	18-04	15.4	8.24	35.17	5.58	—	Nil	—	—
21	12-00	37-40	18-12	24.0	8.10	35.46	4.48	—	1	—	—
22	12-00	36-25	17-06	21.3	8.12	35.62	4.91	—	Nil	—	—

4) The data of diatoms, between the south end of Africa and Antarctica, obtained by the "SOYA" at the 4th Japanese Antarctic Research Expeditio

Station	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Location Lat. S	35-20	36-43	37-34	38-24	40-13	41-08	41-55	43-51	44-40	45-52	47-23	48-17	49-28	51-05	51-57	52-40	54-33	55-23	56-39	58-08	58-58	60-05	61-26	62-15	63-22	64-45	65-17	65-28	65-56
Long. E	18-49	19-35	20-05	20-33	21-41	22-15	22-47	24-05	24-36	25-36	26-51	27-36	28-42	30-12	31-06	31-49	33-48	34-42	35-41	37-15	38-18	39-58	42-07	43-26	45-15	47-37	48-32	46-55	44-40
Date	1959 12-18	12-19	12-19	12-19	12-20	12-20	12-20	12-21	12-21	12-21	12-22	12-22	12-22	12-23	12-23	12-23	12-24	12-24	12-24	12-25	12-25	12-25	12-26	12-26	12-26	12-27	12-27	12-27	12-28
Time (G. M. T.)	1915	0500	1045	1625	0440	1030	1600	0435	1005	1800	0410	1010	1750	0415	1010	1500	0410	1000	1815	0420	1005	1805	0400	1005	1803	0407	1000	1820	0400
Num. of total Diatomeae /l	5022	1148	32415	5886	4413	95821	37864	57198	88270	23260	59404	49650	12744	13433	36795	67394	13390	74745	37079	14514	15444	20990	27744	9484	11006	225012	3336	2790	4768
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Diatomeae	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1. Melosira sphaerica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coscinodiscus total	—	0.8	—	—	—	—	—	—	0.1	1.1	1.3	0.7	1.1	3.6	4.3	0.6	1.1	0.7	0.7	0.5	0.2	—	0.5	—	0.5	0.3	0.7	—	—
2. Planktoniella sol	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3. Asteromphalas heptactis	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—
4. A. Hookeri	—	—	—	—	—	—	—	—	—	0.1	—	—	—	0.8	1.6	0.2	0.1	0.3	0.2	0.3	—	0.1	—	—	0.5	—	—	—	—
5. A. parvulus	—	—	—	—	—	—	—	—	—	0.1	—	0.1	—	2.1	—	0.2	0.3	0.1	0.1	0.6	—	0.5	—	—	—	—	2.2	—	—
6. A. regularis	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	0.1	0.2	0.1	—	—	—	—	0.1	—	—	—	—	—	—	—
7. A. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	—	0.2	0.3	—	—	—	—	—	—	—
8. Thalassiosira condensata	—	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9. T. sp.	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10. Lauderia borealis	0.2	0.8	2.9	1.5	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11. Schroderella delicatula	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12. Skeletonema costatum	—	—	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13. Dactyliosolen antarcticus	—	—	—	—	—	—	—	0.1	0.9	4.0	1.2	2.6	1.1	16.3	5.3	9.5	13.7	3.6	9.9	11.9	0.9	1.1	2.1	1.0	2.0	—	—	—	—
14. D. mediteraneus	—	—	0.1	—	—	—	—	1.3	—	2.1	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15. Leptocylindrus danicus	17.7	—	2.8	6.1	9.1	0.9	4.1	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16. Guinardia flaccida	1.2	1.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17. Corethron criophilum	0.5	0.8	1.4	6.4	1.0	0.3	0.6	0.7	0.4	—	0.3	1.4	1.1	2.2	0.6	8.0	2.0	6.7	12.6	6.4	4.7	4.6	6.4	4.6	17.7	0.1	19.4	28.4	11.7
Rhizosolenia total	30.7	20.9	4.0	9.1	9.8	0.9	3.0	0.6	1.6	4.1	1.8	3.8	0.6	2.1	2.4	1.1	1.1	2.3	3.6	2.7	1.8	1.5	1.4	1.3	1.6	—	—	—	1.1
18. Rhizosolenia alata f. gracillima	13.6	7.1	0.3	1.2	0.1	0.1	0.5	0.1	—	—	—	—	—	0.1	0.2	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—
19. R. alata f. indica	—	—	—	—	—	0.1	0.5	—	0.2	0.8	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20. R. alata f. inermis	—	—	—	—	—	—	—	—	—	—	0.1	0.4	0.6	0.3	0.1	0.1	—	0.2	—	—	—	0.1	0.4	1.0	0.9	—	—	—	1.1
21. R. antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—
22. R. bidens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23. R. calcar-avis	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24. R. curvata	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25. R. cylindrus	—	—	0.1	—	—	0.1	—	0.4	0.5	—	0.8	0.4	—	0.1	0.3	0.5	0.4	1.5	1.7	0.7	0.2	0.5	0.4	—	—	—	—	—	—
26. R. delicatula	0.8	1.6	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	—	—	0.1	—	—	—	—	—	—	—	—	—	—
27. R. fragilissima	6.7	2.4	0.7	2.9	2.9	0.3	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28. R. hebetata f. hiemalis	—	—	—	—	—	0.1	0.1	0.2	—	—	—	—	—	0.2	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—
29. R. hebetata f. semispina	4.3	2.0	0.2	0.9	0.1	0.1	0.1	—	—	0.3	0.1	—	—	0.3	0.1	0.1	—	0.1	—	—	—	—	—	—	—	—	—	—	—
30. R. Shrubsolii	—	—	—	—	—	—	—	—	0.8	2.5	0.9	3.0	—	0.9	1.5	0.3	0.7	0.5	1.2	1.2	0.8	—	—	—	—	—	—	—	—
31. R. Simplex	—	—	—	—	—	—	—	—	—	0.1	0.1	—	—	0.1	0.1	—	—	—	0.1	—	—	0.1	—	—	—	—	—	—	—
32. R. Stolterfothii	5.1	7.8	2.5	3.8	6.6	0.4	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33. R. styliformis	0.1	—	0.1	0.3	0.1	0.1	0.1	0.1	—	—	—	—	—	—	0.1	0.1	—	—	0.1	—	—	0.5	—	—	0.5	—	—	—	—
34. R. styliformis var. longispina	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	0.1	0.2	—	—	0.1	0.2	—	—	—	—	—	—
35. R. truncata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.8	—	0.7	0.8
36. R. sp.	—	—	—	—	—	—	—	—	—	0.3	—	—	—	0.2	—	0.1	—	0.1	0.4	0.7	0.4	0.4	0.5	0.3	0.3	—	—	—	—
37. Bacteriastrum comosum	—	—	7.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetoceros total	4.3	4.7	29.2	14.0	0.8	75.3	68.1	4.7	7.3	3.7	15.3	11.4	15.2	1.4	3.9	38.7	1.4	18.7	32.3	25.5	10.5	21.3	27.9	54.7	41.3	1.5	22.3	2.6	—
Phaeoceros total	—	0.8	1.1	1.2	0.1	0.1	—	3.9	5.4	2.6	11.6	7.5	14.7	1.2	3.5	7.7	0.1	6.7	12.9	12.4	5.4	7.8	7.1	4.6	16.3	—	4.3	2.6	—
38. Chaetoceros atlanticus	—	—	—	—	—	—	—	3.2	0.4	1.1	0.9	—	0.3	0.5	—	—	—	0.1	2.1	0.7	—	2.7	1.2	2.0	0.5	—	2.9	—	—
39. C. atlanticus var. neapolitana	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40. C. atlanticus var. skeleton	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
41. C. Castracanei	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
42. C. Chunii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—	0.3	0.5	0.2	—	0.8	—	—	—	—	—	—	—
43. C. concavicornis	—	—	—	—	—	—	—	—	—	—	—	0.3	0.3	0.3	—	0.1	—	—	—	0.9	—	1.1	0.2	—	—	—	—	—	—
								0.6	0.1	0.1	0.8	0.1	—	0.3	—	0.2	—	0.6	0.9	5.0	3.7	1.4	1.4	0.8	2.5	—	—	—	—

d of Africa and Antarctica, obtained by the " SOYA " at the 4th Japanese Antarctic Research Expedition (Plankton organisms in 330 cc sea water were settled and centrifuged).

72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	(91)	92	93	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110
1-05	51-57	52-40	54-33	55-23	56-39	58-08	58-58	60-05	61-26	62-15	63-22	64-45	65-17	65-28	65-56	66-13	65-59	66-01	64-56	63-51	63-16	62-13	60-12	59-12	57-56	56-31	55-28	53-51	52-01	50-24	49-00	47-14	45-22	43-32	41-40	39-50	37-58	35-46
0-12	31-06	31-49	33-48	34-42	35-41	37-15	38-18	39-58	42-07	43-26	45-15	47-37	48-32	46-55	44-40	43-07	41-08	37-13	31-49	31-08	30-46	30-28	29-42	29-01	28-08	27-03	26-44	26-09	25-23	24-25	23-31	22-46	22-03	21-15	20-20	19-58	18-49	18-08
																			1960																			
2-23	12-23	12-23	12-24	12-24	12-24	12-25	12-25	12-25	12-26	12-26	12-26	12-27	12-27	12-27	12-28	12-28	12-28	12-29	2-22	2-22	2-22	2-23	2-24	2-24	2-25	2-25	2-26	2-26	2-27	2-27	2-28	2-28	2-29	2-29	3-1	3-1	3-2	3-2
0415	1010	1500	0410	1000	1815	0420	1005	1805	0400	1005	1803	0407	1000	1820	0400	1005	1800	0400	0505	1225	1730	0540	0600	1800	0600	1800	0610	1800	0600	1800	0600	1800	0600	1800	0600	1800	0600	1800
3433	36795	67394	13390	74745	37079	14514	15444	20990	27744	9484	11006	225012	3336	2790	4768	1522	2131	1301	5020	2374	686	360	1791	2849	1754	2585	17355	44400	19425	41301	34542	84662	18090	2188	563	436	1497	908
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—
3.6	4.3	0.6	1.1	0.7	0.7	0.5	0.2	—	0.5	—	0.5	0.3	0.7	—	—	—	—	—	—	0.4	1.7	1.4	0.7	0.4	2.1	0.9	2.1	0.4	1.3	0.5	0.1	0.4	0.2	—	—	—	0.3	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—
—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
0.8	1.6	0.2	0.1	0.3	0.2	0.3	—	0.1	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.4	—	—	0.4	0.2	0.1	—	—	—	—	—	—	—
2.1	—	0.2	0.3	0.1	0.1	0.6	—	0.5	—	—	—	—	2.2	—	—	—	—	—	0.2	—	—	1.4	0.3	—	0.5	—	—	0.2	0.1	0.1	—	—	—	—	—	—	—	—
—	0.1	0.2	0.1	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1	—	—	0.1	—	—	—	—	—
—	—	—	—	—	0.2	—	0.2	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	0.2	0.4	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.7	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.3	—
16.3	5.3	9.5	13.7	3.6	9.9	11.9	0.9	1.1	2.1	1.0	2.0	—	—	—	—	—	—	—	0.6	2.7	—	5.6	1.3	—	5.1	5.1	5.5	9.2	26.2	8.2	4.2	1.0	10.6	4.1	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.7	2.1	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15.7	22.0
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2.2	0.6	8.0	2.0	6.7	12.6	6.4	4.7	4.6	6.4	4.6	17.7	0.1	19.4	28.4	11.7	11.8	11.0	42.2	78.7	3.8	11.7	23.6	9.4	8.5	8.7	5.4	0.3	0.8	1.2	0.1	0.3	0.1	0.3	—	1.8	0.7	0.3	1.8
2.1	2.4	1.1	1.1	2.3	3.6	2.7	1.8	1.5	1.4	1.3	1.6	—	—	—	1.1	1.8	0.4	1.1	1.2	2.5	0.9	6.9	2.5	1.9	7.0	6.0	5.1	3.2	1.9	0.7	4.1	5.6	4.4	5.3	16.2	7.9	7.1	16.2
0.1	0.2	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	0.4	0.9	—	—	0.4	0.3	0.2	—	0.1	0.1	—	—	0.2	0.4	2.1	4.1	0.5	—	2.6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1	0.3	0.1	0.9	0.5	—	—	—	—
0.3	0.1	0.1	—	0.2	—	—	—	0.1	0.4	1.0	0.9	—	—	—	1.1	1.8	0.4	0.4	0.8	0.6	—	—	0.3	0.2	3.1	1.0	0.1	0.2	0.2	0.3	0.6	0.7	0.7	—	—	—	—	—
—	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	—	0.1	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.1	0.3	0.5	0.4	1.5	1.7	0.7	0.2	0.5	0.4	—	—	—	—	—	—	—	—	—	—	—	—	2.5	—	—	—	0.5	1.1	—	0.1	0.1	—	—	0.1	—	1.8	0.5	—	—
—	—	0.2	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.1	0.2	—	0.1	—	0.2	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.6	1.2	0.4	—	—	1.8	0.2	—	—	0.3	—	—	—	—	2.8	3.2	6.6
0.2	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	2.3	6.4	—	—	—
0.3	0.1	0.1	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	0.1	—	0.2	—	—	—	1.7	2.2
0.9	1.5	0.3	0.7	0.5	1.2	1.2	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.1	2.3	0.8	1.0	0.1	0.1	2.5	4.3	1.2	—	—	—	—	—
0.1	0.1	—	—	—	0.1	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	0.1	—	0.1	—	0.4	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.7	3.5
—	0.1	0.1	—	—	0.1	—	—	0.5	—	—	0.5	—	—	—	—	—	—	—	0.4	0.8	—	—	0.5	0.8	—	0.8	0.7	0.3	0.3	0.1	0.3	0.3	0.2	—	1.6	2.8	0.5	0.9
—	—	0.1	—	0.1	0.2	—	—	0.1	0.2	—	—	—	—	—	—	—	—	—	—	0.6	—	0.8	0.5	—	1.4	—	—	0.1	0.1	0.1	0.1	0.1	—	0.5	2.3	1.4	—	0.4
—	—	—	—	—	—	—	—	—	—	—	—	0.8	—	0.7	0.8	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0.2	—	0.1	—	0.1	0.4	0.7	0.4	0.4	0.5	0.3	0.3	—	—	—	—	—	—	0.7	—	—	—	—	—	—	1.1	1.2	0.4	0.6	0.7	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1.4	3.9	38.7	1.4	18.7	32.3	25.5	10.5	21.3	27.9	54.7	41.3	1.5	22.3	2.6	—	—	—	2.1	1.4	—	—	8.4	5.3	14.3	13.4	9.8	8.2	31.7	10.3	1.9	8.9	7.0	35.1	7.8	2.9	—	—	—
1.2	3.5	7.7	0.1	6.7	12.9	12.4	5.4	7.8	7.1	4.6	16.3	—	4.3	2.6	—	—	—	0.7	1.4	—	—	8.4	5.3	14.3	11.9	8.4	6.5	30.3	10.2	1.9	8.9	7.0	35.1	7.3	2.9	—	—	—
0.5	—	—	—	0.1	2.1	0.7	—	2.7	1.2	2.0	0.5	—	2.9	—	—	—	—	—	—	—	—	—	—	—	—	—	4.8	1.7	6.3	0.1	—	0.1	7.5	0.7	1.8	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—
—	—	0.3	—	0.3	0.5	0.2	—	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
0.3	—	0.1	—	—	—	0.9	—	1.1	0.2	—	—	—	—	—	—	—	—	0.7	—	—	—	1.4	5.0	14.3	6.2	2.8	—	1.0	0.9	0.3	0.3	0.1	—	—	—	—	—	—
0.3	—	0.2	—	0.6	0.9	5.0	3.7	1.4	1.4	0.8	2.5	—	—	—	—	—	—	—	0.5	—	—	1.4	—	—	2.1	1.9	0.3	7.7	1.8	0.7	0.1	0.1	1.0	2.1	1.1	—	—	—

42. C. Chunii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—	0.3	0.5	0.2	—	0.8	—	—	—	—	—	—	—	—	—	—	—
43. C. concavicornis	—	—	—	—	—	—	—	—	—	—	—	0.3	0.3	0.3	—	0.1	—	—	—	0.9	—	1.1	0.2	—	—	—	—	—	—	—	—	0.7	—
44. C. convoltus	—	—	—	—	—	—	—	0.6	0.1	0.1	0.8	0.1	—	0.3	—	0.2	—	0.6	0.9	5.0	3.7	1.4	1.4	0.8	2.5	—	—	—	—	—	—	—	0.
45. C. dichaeta	—	—	—	—	—	—	—	0.2	4.8	1.4	10.0	7.1	14.1	0.1	3.4	5.2	—	2.6	9.0	5.6	1.2	1.1	3.3	1.8	12.3	—	1.4	2.6	—	—	—	—	0.
46. C. pendulus	—	0.8	0.1	1.2	0.1	—	—	—	—	—	—	—	—	—	—	0.1	—	0.1	0.1	—	—	—	0.4	—	—	—	—	—	—	—	—	—	—
47. C. pervianus	—	—	0.2	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
48. C. radiculus	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
49. C. Schimperianus	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	1.8	—	2.9	0.4	—	0.5	0.7	0.7	—	1.0	—	—	—	—	—	—	—	—

Station	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
Num. of total Diatomeae /l	5022	1148	32415	5886	4413	95821	37864	57198	88270	23260	59404	49650	12744	13433	36795	67394	13390	74745	37079	14514	15444	20990	27744	9484	11006	225012	3336	2790	4768	1522	2131	1301	502
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Hyalochaete total	4.3	3.9	28.1	12.8	0.7	75.2	68.1	0.4	1.9	1.1	3.7	3.9	0.6	0.3	0.4	31.0	1.3	12.0	19.4	13.1	5.1	13.5	20.8	50.1	25.0	1.5	18.0	—	—	—	—	1.4	—
50. C. affinis	—	—	8.7	5.2	—	0.3	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
51. C. anastomosans	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
52. C. brevis	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
53. C. compressus	2.6	—	5.7	—	0.7	—	3.4	—	0.4	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
54. C. curvisetus	1.2	—	3.5	—	—	0.4	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
55. C. decipiens	—	—	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
56. C. didymus	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
57. C. distans	—	—	0.7	1.8	—	0.1	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
58. C. Lorenzianus	0.5	—	1.2	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
59. C. messanensis	—	3.9	4.2	5.5	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
60. C. neglectus	—	—	—	—	—	—	—	0.4	1.5	1.1	3.5	0.9	0.6	0.3	0.4	31.0	1.3	12.0	19.4	13.1	5.1	13.5	20.8	50.1	25.0	1.5	18.0	—	—	—	—	1.4	—
61. C. pelagicus	—	—	3.7	—	—	0.4	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
62. C. socialis	—	—	—	—	—	73.9	62.3	—	—	—	—	3.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
63. C. subsecundus	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64. Biddulphia astrolabensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
65. B. sinensis	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
66. B. sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	0.4	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
67. Hemiaulus Hauckii	0.5	0.8	1.0	0.3	0.5	0.3	0.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
68. H. membranacus	—	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
69. H. sinensis	0.5	—	0.1	0.6	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70. Cerataulina Bergonii	0.7	1.6	0.2	—	1.1	0.2	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
71. Eucampia balaustium	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—	0.2	—	0.1	0.2	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—
72. E. cornuta	—	—	0.2	—	—	0.1	0.3	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
73. E. zoodiacus	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
74. Climacodium Frauenfeldianum	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75. Fragilaria antarctica	—	—	—	—	—	—	—	0.1	3.3	5.2	8.2	12.8	41.0	34.8	10.6	11.8	9.4	14.1	1.9	7.4	25.1	33.1	32.6	22.8	7.4	50.9	4.3	25.8	21.5	17.7	25.3	13.8	11.
76. F. granulata	—	—	—	—	—	0.4	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77. F. sp.	—	—	—	—	—	—	—	—	1.2	1.0	1.4	0.1	1.1	15.3	24.9	1.2	41.5	2.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78. Asterionella japonica	1.7	—	0.2	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79. Synedra sp.	—	—	—	—	—	—	—	—	0.2	6.4	—	—	—	—	0.1	—	—	0.3	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80. Thalassionema nitzschioides	1.9	5.5	3.9	0.3	1.1	0.5	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
81. Thalassiothrix antarctica	—	—	—	—	—	0.1	0.1	0.1	0.1	0.1	—	—	0.9	—	0.1	0.2	—	0.1	0.1	0.5	1.2	0.6	0.4	—	0.5	—	—	—	0.4	—	—	—	0.
82. T. Frauenfeldii	0.5	9.4	2.3	4.9	8.2	1.3	3.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
83. T. heteromorpha	—	—	—	—	—	0.1	0.1	0.8	0.2	0.6	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
84. T. longissima	1.4	3.1	0.7	5.5	4.8	0.5	1.2	0.5	—	0.4	—	—	—	—	0.1	—	0.1	—	—	—	—	—	—	—	—	—	—	—	0.4	1.2	—	—	0.
Navicula total	2.9	8.6	1.0	—	3.3	0.1	0.3	0.8	2.2	3.7	1.8	0.4	5.6	6.7	0.4	0.3	0.3	0.1	1.1	1.7	1.4	1.6	1.0	2.3	6.2	33.5	30.2	42.6	32.1	46.1	48.9	25.6	6.
85. Pleurosigma directum	—	—	—	—	—	—	—	—	—	—	—	—	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.5	—	—	0.2	—	—	—	—	—	—	—	—	—	—
86. Amphiprora sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.1	—	—	0.4	—	—	—	—
87. Tropidoneis antarctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—
88. T. sp.	—	—	0.2	1.2	0.8	—	0.1	0.1	—	—	0.4	—	—	—	—	0.1	—	—	—	0.3	0.2	—	—	—	—	—	—	—	—	—	—	—	—
89. Nitzschia closterium	3.1	3.1	5.2	1.8	19.7	4.7	5.9	2.8	0.7	1.9	2.3	—	4.5	1.2	0.9	0.5	0.2	0.1	0.4	9.9	6.5	3.4	6.2	2.0	12.8	11.6	10.1	—	31.7	16.6	14.4	14.5	0.
90. N. delicatissima	—	—	—	—	—	3.5	7.3	1.4	—	5.6	—	—	—	—	—	—	—	0.1	—	8.7	21.0	15.1	5.9	0.8	2.9	0.1	—	—	—	—	—	—	—
91. N. pungens var. atlantica	6.7	1.6	0.7	9.5	0.7	0.1	0.4	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
92. N. seriata	25.6	36.1	34.7	38.5	39.2	10.9	3.5	85.8	82.0	59.6	65.9	66.7	27.4	13.1	44.6	27.2	28.1	50.1	36.1	23.1	26.3	16.7	15.4	10.6	6.9	—	10.8	—	—	3.5	—	0.7	—

—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—																				
—	0.3	0.5	0.2	—	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
—	—	—	0.9	—	1.1	0.2	—	—	—	—	—	—	—	—	0.7	—	—	—	1.4	5.0	14.3	6.2	2.8	—	1.0	0.9	0.3	0.3	0.1	—	—	—	—	—	—
—	0.6	0.9	5.0	3.7	1.4	1.4	0.8	2.5	—	—	—	—	—	—	—	0.5	—	—	1.4	—	—	2.1	1.9	0.3	7.7	1.8	0.7	0.1	0.1	1.0	2.1	1.1	—	—	—
—	2.6	9.0	5.6	1.2	1.1	3.3	1.8	12.3	—	1.4	2.6	—	—	—	—	0.9	—	—	2.8	—	—	3.6	3.5	1.4	19.6	0.9	0.4	8.6	6.5	26.1	4.5	—	—	—	—
—	0.1	0.1	—	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	2.8	0.3	—	—	0.2	—	0.2	0.2	0.2	—	—	0.1	—	—	—	—	—
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0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.2	—	—	—	—	—	—	—	—
—	2.9	0.4	—	0.5	0.7	0.7	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—
75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	(91)	92	93	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110
13390	74745	37079	14514	15444	20990	27744	9484	11006	225012	3336	2790	4768	1522	2131	1301	5020	2374	686	360	1791	2849	1754	2585	17355	44400	19425	41301	34542	84662	18090	2188	563	436	1497	908
%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1.3	12.0	19.4	13.1	5.1	13.5	20.8	50.1	25.0	1.5	18.0	—	—	—	—	1.4	—	—	—	—	—	—	1.5	1.4	1.7	1.4	0.2	—	—	—	—	0.5	—	1.4	2.4	3.6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.4	—	1.8
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1.3	12.0	19.4	13.1	5.1	13.5	20.8	50.1	25.0	1.5	18.0	—	—	—	—	1.4	—	—	—	—	—	—	1.5	1.4	1.7	1.4	0.2	—	—	—	—	—	—	—	—	—
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9.4	14.1	1.9	7.4	25.1	33.1	32.6	22.8	7.4	50.9	4.3	25.8	21.5	17.7	25.3	13.8	11.0	70.1	49.9	16.7	52.0	48.3	18.0	36.0	13.1	17.6	3.5	7.3	30.4	6.0	13.1	—	5.7	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.4	—	0.9	12.3	—	—	—
41.5	2.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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—	0.1	0.1	0.5	1.2	0.6	0.4	—	0.5	—	—	—	0.4	—	—	—	0.2	1.5	5.2	2.8	1.7	3.1	3.6	2.6	0.6	0.7	0.9	0.5	0.5	0.2	0.1	—	—	—	—	—
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0.1	—	—	—	—	—	—	—	—	—	—	—	0.4	1.2	—	—	0.2	—	—	1.4	—	—	—	—	—	—	0.1	—	—	—	—	1.6	0.9	—	3.3	1.8
0.3	0.1	1.1	1.7	1.4	1.6	1.0	2.3	6.2	33.5	30.2	42.6	32.1	46.1	48.9	25.6	6.1	3.4	7.0	12.5	3.7	3.9	4.1	3.9	2.5	1.0	2.0	2.1	1.0	0.1	0.4	1.8	5.3	17.2	1.3	6.2
0.1	0.1	0.1	0.5	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	—	—	0.2	—	—	0.1	0.1	—	0.1	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	1.1	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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—	—	—	0.3	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.6	0.2	1.1	0.2	0.1	0.1	—	0.1	0.1	0.2	—	—	0.7	—
0.2	0.1	0.4	9.9	6.5	3.4	6.2	2.0	12.8	11.6	10.1	—	31.7	16.6	14.4	14.5	0.4	—	—	2.8	—	0.4	—	0.5	1.1	0.3	9.3	15.5	0.4	1.1	0.3	2.3	0.9	10.3	5.0	4.4
—	0.1	—	8.7	21.0	15.1	5.9	0.8	2.9	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	0.8	0.2	—	—	2.3	10.7	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.9	—	2.1	0.7	8.8
28.1	50.1	36.1	23.1	26.3	16.7	15.4	10.6	6.9	—	10.8	—	—	3.5	—	0.7	—	15.5	23.6	16.7	22.4	19.3	33.9	29.0	60.4	34.6	41.6	61.9	49.4	78.1	22.4	69.0	43.5	34.4	51.1	24.7