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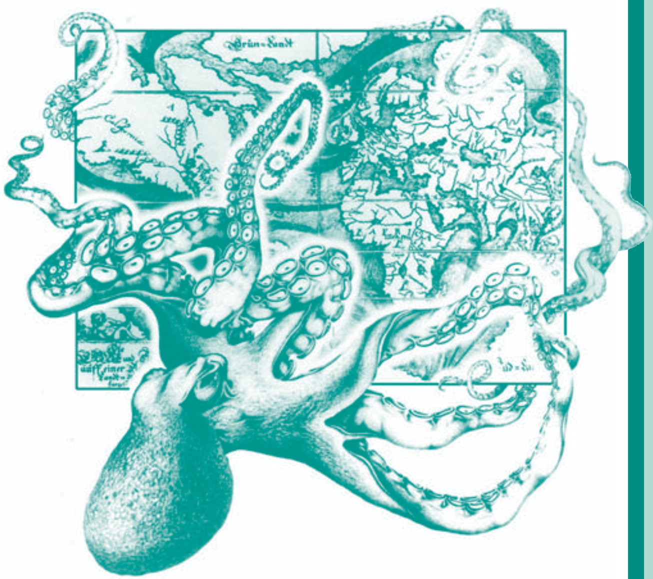

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[174] Deutsche Seewarte, Jahresbericht 1919-1920, 1921, S.19.
[175] Deutsches Hydrographisches Institut, Beobachtungen auf den deutschen Feuerschiffen der Nord- und Ostsee 1953, 1954, Einleitung.

Early multidisciplinary cooperation in oceanography

Götz-Bodo Reinicke and Hjalmar Thiel

A partial manuscript written in 1926 by participants in the expedition of RV Meteor (1925-1927) elucidates the vision of multidisciplinary oceanographic research by Alfred Merz. He had been the initiator and key person of this cruise until his death in Buenos Aires. The manuscript was never published. However, it is of historic value as an example of cooperation between marine science disciplines. We present it as an English translation, and consider the reasons for its dormancy over almost one century.

Frühe multidisziplinäre Kooperation in der Meereskunde. Teile eines Manuskriptes, das 1926 von Teilnehmern an der Expedition des Forschungsschiffes Meteor I (1925-1927) an Bord geschrieben worden war, beleuchten die Visionen über multidisziplinäre Zusammenarbeit in der Meereskunde von Alfred Merz, der Initiator und Schlüsselperson dieser Reise bis zu seinem Tode in Buenos Aires war. Diese Arbeit ist nicht publiziert worden. Sie besitzt jedoch einen historischen Wert als Dokument der Kooperation von Disziplinen der Meereswissenschaften. Wir haben den Text ins Englische übertragen und fragen nach Gründen für die fast 100-jährige Ruhephase des Manuskriptes.

Background

Multidisciplinary cooperation in oceanography has been well established since the late 1960s, when the German Research Council offered increased and longer-term funding for cooperative projects. It continous to the present day when modern, large European multidisciplinary research consortia work together successfully involving various countries, many institutions and a multitude of individuals. However, these developments have had a precursor already in the Deutsche Atlantische Expedition 1925-1927 on the Survey and Research Vessel Meteor, now usually referred to simply as Meteor I (Fig. 1).

The driving force behind this cooperative approach was Alfred Merz (1880-1925), Professor of Oceanography and Director of the Institut für Meereskunde in Berlin. Contemporary documents show that he was keen to organize multidisciplinary seminars for the scientists and students in his institute (STAHLBERG 1925, see also THIEL 2005). Merz was the key person in designing the Meteor cruise plan covering the South Atlantic along a network of stations on 14 east-west profiles. This was a new approach to oceanographic studies at the time, which were previously restricted to single north-south transects. In addition, Merz was seeking support for his physical investigations by chemical analyses and biological assessments for the description and explanation of water masses and current patterns throughout all depths.

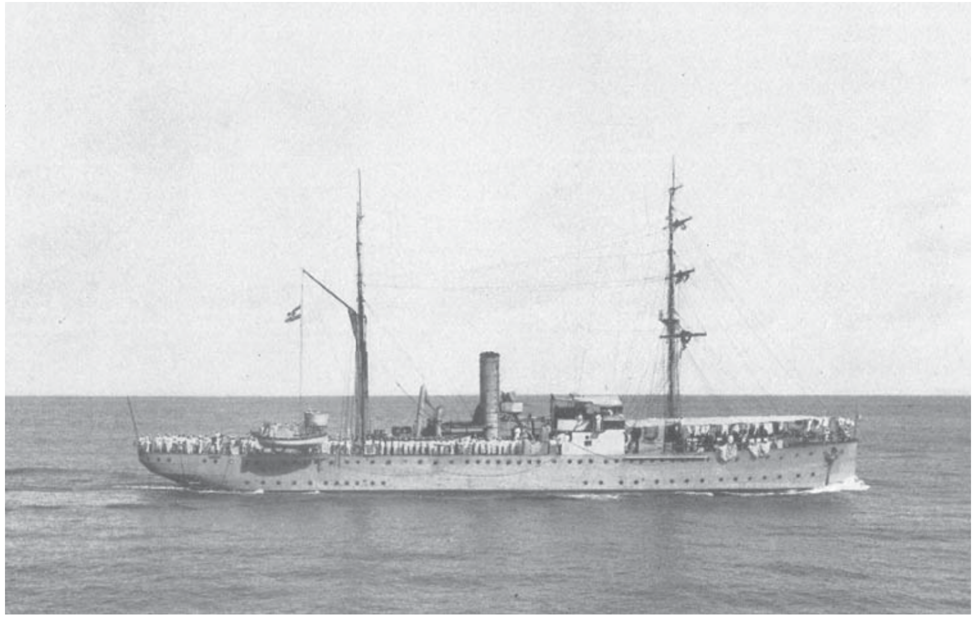

Fig. 1: The METEOR nearby the St.-Pauls rocks in the central Atlantic Ocean, coordinates 00°55'1"N, 29°20'45"W (Foto: from Spiess 1926, Fig. 1).

Various aspects of the METEOR Expedition have been the subjects of historical accounts. The predominating work of the physical oceanographers was described and discussed by WÜST (1964), BÖHNECKE (1976), EMERY (1980), SCHOTT (1987) and LENZ (1996), and the chemical and biological studies were reviewed by THIEL (2005). This latter paper mentioned Merz' insistence on the importance of multidisciplinary research and publication. It was discussed and adhered to by the scientists on board the METEOR and continued also after the death of Merz during the expedition.

Having crossed the South Atlantic several times along profiles between South America and Africa, the leading physical oceanographer, Georg Wüst (1890-1977), the chemical oceanographer, Hermann Wattenberg (1901-1944), and the biological oceanographer, Ernst Hentschel [1] (1876-1945), agreed to write a paper together on preliminary results gained during the first half of the expedition. This paper was delivered to Alfred Penck of the METEOR Commision for publication in the Sitzungsberichte der Berliner Akademie der Wissenschaften (the "Academy"), but it was never printed. Parts of the manuscript surfaced a few years ago from amongst documents, manuscripts and papers by Hentschel. It had been erroneously marked as 2nd Report ("II. Bericht", see below) and therefore not recognized earlier as the specific manuscript in question.

[1] The authors are great-grandson and grandson of E. Hentschel

Although the manuscript is incomplete, lacking the contribution by Wattenberg, the summary and the plate with figures, we regard it as a valuable document. It demonstrates Merz' ideas of multidisciplinary cooperation and the endeavor of the scientists on board the METEOR to apply this approach.

Explanations

We present the German document, written on board the METEOR in 1926 as an English translation. The original German text (referred to as "the manuscript") is a typewritten carbon copy, produced in the orderly room on board the RV METEOR. A newly typed version is available from the archive of the Deutsches Meeresmuseum, Stralsund (DMM Archive No. 4.7.6.).

For easier treatment and better understanding, we have provided a relatively free translation, also because of particularly long and complicated sentences in the manuscript. The METEOR cruise was based on 14 profiles, mainly in west-east or east-west direction. These were termed "profiles". For this first publication two north-south transects were constructed, selecting certain stations from the profiles. These were termed "longitudinal transects" or just "transects". Occasionally we have added a few words for clarity, indicated by […], the references given in footnotes in the manuscript were moved to the end of this paper. We apply the names of basins, water masses and currents as given by Wüst and Hentschel in English translation. The more detailed knowledge of the oceans gained during the last 60 years does not allow in all cases to apply the actual terms.

In the manuscript (below), Hentschel does not describe the method applied for plankton collection and analysis. Briefly, he received subsamples from the water the physicists collected in their casts for salinity measurements and made life counts of nanoplankton under a microscope after centrifuge concentration according to Lohmann (1920). Extensive information about the applied method is provided by Hentschel (1928).

The manuscript refers to "one plate" [missing] to show the course of the two transects derived from the profile stations, supplemented by a set of stations from an earlier cruise by the [RV] DEUTSCHLAND, the German Antarctic Expedition 1911-1912 going south into the Weddell Sea in "Fig. 1". As a substitute, we provide a chart taken from DEFANT (1927b, fig. 54, p. 366) which demonstrates the two longitudinal transect tracks carrying the numbers of the referenced profile stations in agreement with Wüst's part of the manuscript (Fig. 2). The southern ends of these graphs agree with two hand drawn pencil outlines between 30°- 65° S in an overall chart of the expedition profiles in Hentschel's personal print copy of SPIESS (1926, p. 15, in the DMM-Archive). Further, two figures of Hentschel ["Fig. 7 and 8"] are missing with the original plate. Therefore we provide a set of graphs taken from HENTSCHEL (1928, Fig. 38: "Planktonverteilung auf dem Ostschnitt") to exemplify his evaluation of plankton data along the "eastern transect" (Fig. 3). In the bibliography literature referenced in the original manuscript is marked by an asterisk.

The translated remains of the paper

The German Atlantic Expedition on the Survey- and Research Vessel Meteor
II. Report.

On interactions between physical, chemical and biological characteristics
of the water along two longitudinal transects through the South Atlantic Ocean
by Prof. Dr. Ernst Hentschel, Dr. Hermann Wattenberg and Dr. Georg Wüst,
members of the expedition.
With one plate. [missing]

I. Formulation of questions

In his first report on the expedition of Meteor A. MERZ (1925) already considered the close cooperation of the representatives of the various disciplines, which should be an essential feature of this expedition, and this has actually been the case from the very beginning. It was expected that by investigating the same water samples, applying physical, chemical and biological methods and the evaluation of the data collected under aspects of the participating sciences, would result in a clear mutual promotion [of the results]. Such "systematic hydrographic assessment of a whole ocean" as Merz had it in mind as a goal, should by this [cooperation] increase considerably the scientific value. The main aim of the expedition, however, the question of the oceanic circulation, had to support all aspects of these investigations as well as itself being supported by all disciplines.

In this report, we present a first attempt as a result of this cooperation to prove connections between various characteristics of the seawater. For two series of stations of this expedition we describe the isolines of the various characteristics, isohalines, isotherms, plankton isolines [Hentschel uses the term "Isoplankten"] etc. and try to determine whether the course of the different sorts of isolines would reveal the expected connections, and particularly how their course would be related to the circulation in the deep ocean. Naturally, the likely success of such an attempt increases with the richness of the available material. If one describes, as in this paper, a marine region stretching out over 50 degrees of latitude by about 20 stations, some aspects that remain obscure may be resolved when the complete material of the expedition is evaluated. However, we do not intend to publish final results, but rather to demonstrate how the working methods of this expedition led to the results strived for.

The relevant results are presented in the following three independent chapters. It starts with G. Wüst describing the temperature and salinity data, followed by the interpretation of the course of the currents. H. Wattenberg describes the results of the special chemical investigations, and finally E. Hentschel reports on the biological material. The introduction to the first chapter including a map (referred as Fig. 1 [missing]) elucidates also the selection of the stations considered which together mark two transects mainly in north-south direction through the South Atlantic Ocean.

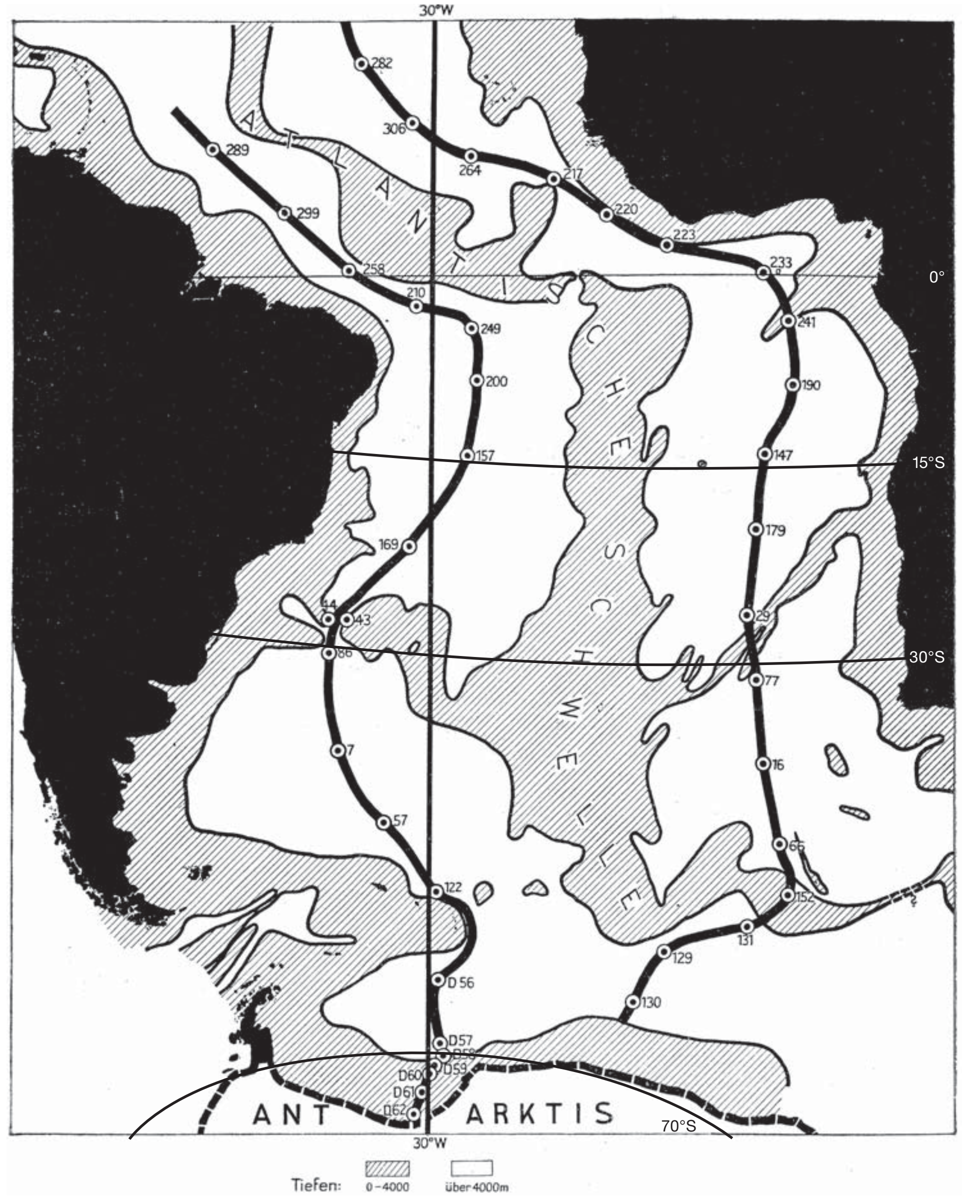

Fig. 2 Position of stations for the [longitudinal] transects (missing, chart reproduced and modified from Fig. 54 of DEFANT 1927a, p. 366): Course of transects for temperature and salinity east and west of the Central Atlantic Ridge ("Mittelatlantische Schwelle", also represented by the data given in Figs. 12-15 in WÜST 1927, p. 132-133). The manuscript refers to the stations between 15° S - 70° S. Numbers refer to profile stations, D-numbers in the Weddell Sea reflect earlier investigations by RV Deutschland.

II. Salinity, temperature and deep water currents

The new ideas on the nature of the Atlantic deep water circulation which constitute the working hypothesis of our expedition was particularly elaborated by A. Merz on the basis of a longitudinal section of temperature and salinity in 30°W. Such an isolated section, the only one to be designed because of the rare data available for the central parts of the Atlantic Ocean, could naturally be viewed only as a first approximation and had still to be evaluated as uncertain, particularly for the region between 25°S and 70°S.

To date [summer 1926] the expedition has conducted the first 7 profiles [in W – E direction and vice versa] with a total of 184 stations according to the plan devised by Merz. It is already possible to construct two longitudinal transects between 15°S and 70°S, the one through the western and the other one through the eastern Atlantic Ocean. To arrive at a typical longitudinal transect through the western basin, we chose all the stations of our expedition which fall into the deepest regions of the Brazil and Argentine Basins supplemented by stations D 56 – D 61 from the expedition of the [RV] Deutschland [German Antarctic Expedition 1911-1912] extending south into the Weddell Sea. This longitudinal transect deviates from the transect (at about 25°W) which was anticipated by Merz for the particular evaluation of the [physical] oceanography, chemical and biological data, because our acoustical echo sounder profiles had lead us to new insights on the dimension of the western Atlantic valley. Our new western transect starts in the central part of the Brazil Basin, runs more or less parallel to the Brazilian coast, passes through the narrow gap with depths in excess of 4000 m depth between the Rio Grande Ridge and the Brazilian continental slope. It arrives in the Weddell Sea after crossing the Argentine Basin and the South-Sandwich Deep [Trench], nestling close to the South Antill Arc [along the slopes of South Orkney and South Sandwich Islands].

The eastern longitudinal transect covers, according to the proposal by Merz, the central deepest parts of the Angola Basin, crosses the Walvis Ridge, the basin off Southwest Africa, the Atlantic-Indian Ridge and extends into the South Polar Sea to 64°S. Figure 1 [missing in the manuscript, replaced as Fig. 2] gives the positions of the two transects and the depth profiles of the seafloor. It shows that in the transect design the morphological highs were avoided where possible, to arrive at a common idea of the two deep currents hopefully along their axis. [One incomprehensible sentence omitted.]

The longitudinal transect along 30°W [earlier proposed by Merz] runs along the western basins of the South Atlantic Ocean. Our new western transect largely agrees with Merz's proposal, also in the area between 30°S and 55°S, where the course had remained hypothetical. The imagination of Merz on the main components of the Atlantic circulation becomes excellently confirmed by our new transects. Of course, the processing of the new and richer observational data leads to a number of complications in the general circulation system. This is considered in the following sections.

The western transect

A conspicuous phenomenon of the uppermost layer extending 600-800 m deep, covering the depth range of the surface currents and the subtropical undercurrent, is the depth of the isohalines and the isothermes at 30°S. In the South Atlantic the highest values of salinity and temperature are located between 300 m and 700 m depth at 33°S, and not as a priori expected, below the subtropical salinity maximum of surface waters in 15°S. The current map of MEYER (1923) shows that our transect crosses the convergence line between the Brazil and Falkland currents at about 35°S. There, the warm and high salinity water masses of the Brazil current sink and cause the accumulation of a warm and salt-rich water layer, proved down to about 700 m. This southern convergence region constitutes a counterpart to the northern convergence area of the Sargasso Sea. However, a decisive difference in the north is that – for similar dynamic reasons as in the south – the area of highest salinity enrichment is also at the surface, and the accumulation of warm and salt-rich water is shown to reach as deep as 2000 m. Yet, in the South Atlantic Ocean the maximum of surface salinity and the convergence region deviate from each other by about 20° longitude. It is remarkable that this convergence situation almost coincides with an eminent morphological obstacle, the Rio Grande Ridge. The water masses of the North Atlantic deep current and of the bottom current are blocked, and this region around 30°S proves to be an obstacle and disturbance zone for two reasons: surface and deep water currents are slowed down and diverted in their track by the existence of vertical components. Also, in the development and structure of the intermediate current our transects exhibit new features. From the Weddell Sea cold and salt-poor melting waters penetrate northwards and sink to the level of about 100 m at about 64°S, whereas at the surface warmer and, due to precipitation, salt-poor current tongues are transported into the west wind drift. In analogy to the subtropical undercurrent we refer to the south polar water masses, spreading out below the surface waters, as the Antarctic undercurrent. This can be clearly followed at a depth of 100 m until about 53°S. This cold polar water sinks between 50°S and 60°S at a remarkable front, which separates the west wind drift into a southern cold zone and a northern warmer mixed water area. The steep course of the isotherms and their considerable crowding, penetrating nearly vertically down to about 1500 m, indicate that this front has deep-reaching effects. At more than 1000 m depth the water masses exhibit the same structure as in surface waters and demonstrate the difference in water mass origin. It was MEINARDUS (1923) who first realized the climatic importance of this situation, DRYGALSKI (1926) recognized its oceanographic significance. In no other part of the whole Atlantic Ocean one does find a similarly extended and deep-reaching borderline, which hydrographically is to be interpreted as a convergence line. With the downward transport of the polar water masses there is a mixing of the warmer and, at the surface, salt-poorer water of the west wind drift. Therefore, both water masses constitute the roots of the intermediate current, which sinks down to about 800 m depth between 40°S and 50°S. It transports the subantarctic intermediate water, and Merz had already questioned whether the term "Subantarctic Current" as chosen by BRENNECKE (1921) or "Antarctic Current" should be applied to it. We give preference to the first term, because this current, fed mainly from two sources, sinks down to its typical depth level in the subantarctic region. It arrives at its deepest depth in about 1000 m at 33°S, where vertical components exist at the northern limit of the west wind drift. The current slows down as shown by the narrowing of the isohalines (34.20 and 34.30 ‰) along the current axis. In its course to 10°S the salinity minimum rises by about 300 m. The new results on oxygen concentration support our earlier dynamic calculations that north of 25°S the subantarctic water moves rather slowly (MERZ and WÜST 1922, 1923). Its vertical extension is indicated by the salinity-poor intermediate layer (with less than 34.50 salinity), which measures about 450 m, 600 m and 800 m depth at 10°, 20° and 30° southern latitude, respectively.

As in our earlier transect [MERZ and WÜST 1922 / 1923], the current is characterized by an intermediary minimum in temperature, which extends deeper than the minimum in salinity, as earlier described. The rise of the current north of 33°S becomes also evident in the temperature.

The North Atlantic deep current, coming from the north, meets our transect at 10°S extending over a depth range of 2600 m. Its core layer lies at a depth of 2250 m, and its lower boundary at 4000 m. Until 23°S it sinks by about 250 m. Penetrating further south it is obstructed by the Rio Grande Ridge, closing the basin to the south, which was already discerned by MERZ and WÜST (1922/1923). Only a narrow passage opens for the current, the Rio Grande Gap which, according to our echosoundings, is located entirely on the Brazilian side and about 4500 m deep. The damming effect seems to be at its minimum above this depression and the current reaches its maximum speed. This may explain, in opposition to the deflection power of Earth' rotation to the left, that on the right hand flank of the current we find the highest salinities and temperatures. The damming effect extends over 800 m as shown by the course of the 34.90 isohaline. The extent of the current reduces to 1600 m above the ridge, while immediately behind the ridge begins the immense ascent of the North Atlantic deep water measuring some 2200 m. MERZ (1925) was the first to propose this though being unable to prove it by observations. Our [latitudinal] profiles I, III, V now verify this assertion. Due to mixing processes the current now loses in intensity and vertical extension as indicated by the inversions of temperature (2.5°C isotherme) which are repeated vertically three times at station 57 (48.5°S). The current sends a final stream from 55°S to about 64°S into the Weddell Sea between 500 m and 1500 m depth. This was shown by Merz in his analyses of the data collected by Brennecke, and this is now verified by the observations at [our] station 122 [Fig. 2].

Our [latitudinal] profiles provide new information on the question of the formation of the bottom water and, related to this, of the Antarctic bottom current. It is not possible to derive the enormous water masses of the antarctic deeps, filling the south polar basin below 1500 m, exclusively from shelf water sinking to great depth down the Antarctic steep slope during winter, as BRENNECKE (1921) had proposed. Without doubt, the temperature measurements collected during the winter ice drift of the [RV] DEUTSCHLAND, demonstrate an intense cooling of the water along the steep slope of the Weddell Sea, where the warm intermediate layers of the Atlantic and Indian Ocean waters are no longer present. Even so, our profiles, representing the summer conditions, show deepening of the isolines at the continental slope. This indicates the possible formation of bottom water by sinking shelf water and simultaneous mixing with the intermediate layer to a restricted extent during winter. But what causes the strange layering in the Antarctic deep water which, in the western transect, is only weakly indicated by the rather rare observations in the Weddell Sea, but is substantiated by several series in the eastern transect for the South Polar Basin. This is explained by the existence of the coldest water columns at the northern limits of the Antarctic Ocean rather than in the highest latitudes. The strong upwarp of the isolines, 800-1200 m, between 60°S and 70°S is located where the Atlantic and the Indian Ocean's intermediate layers are separated by a somewhat cooler and salt-poorer water column which, however, does not eliminate the intermediate layer. This suggests that in the central parts of the Weddell Sea and the South Polar Sea the surface layers sink during fall and winter due to intensive cooling and freeze desalination, forming the deep water by mixing with slightly warmer and saltier intermediate water. In this zone, according to the current map of MEYER (1923), the convergence areas are located (at about 69°S, 35°W and 60°S, 35°E). This would be similar to high northern latitudes as proved by NANSEN (1912). In contrast to the view of BRENNECKE (1921), the deep water proves to be not completely homohalinous. The new technique of chlorine determination allowed us to detect a distinct decline in salinity from 34,68 [‰] in the Intermediate Layer to 34.64 [‰] at 4000-5000 m depth. The salinity decrease is paralleled by a decrease in temperature from 0.40°C at 400 m depth to -0.50°C at 4000-5000 m depth. Towards the seafloor a slight increase seems to exist in both factors according to our measurements, which for the temperature could be explained by an adiabatic effect. However, it should be noted that the data from water samples brought up with a piston corer and the measurements of temperature in the propeller bottom water sampler may not be reliable because of possible slight deviations. [The bottom water sampler – Wüst uses the term "Propellerrahmen" – was lowered top and bottom open and both ends were closed with lids, which were pressed against the openings by the rotation of a propeller mechanism activated by the water flow from heaving.]

The deep water flows northwards, fills the bottom layers of the Argentine Basin, is dammed at the Rio Grande Ridge and only partially penetrates the Rio Grande Gap into the Brazil Basin. A sharp boundary between the bottom current and the North Atlantic deep current is not discernible in the salinity, but is expressed in a converging of the isothermes. The vertical extent of the bottom current south of the Rio Grande Ridge measures about 1000 m and to its north decreases to about 600 m.

The eastern transect

In general, the eastern transect shows similar characteristics to the western one. However, there are significant differences between the two in the extent of current development particularly based on the effects of [seafloor] morphology. Whereas along the western transect the current elements find basins and valleys at depths of more than 4000 m, in the east the separate basins below 3000 m to 4000 m have no connections. Two large ridges – the Walvis Ridge and the Atlantic-Indian Ridge –

totally prevent any water exchange at great depths. The southern convergence area [of the western transect] is mirrored in the eastern one in an accumulation of warm and salt-rich water. Situated at 28°S, it relates to the more northern position of the convergence line (comp. current map of MEYER 1923), and extends down to about 800 m. Also in the east, the convergence region meets with a conspicuous morphological structure (Walvis Ridge).

We found the cold Antarctic undercurrent in the South Polar Sea at a depth of 75-200 m was distinctly overlain by a definite warm surface layer [Deckschicht] resulting from the fortunate weather conditions during our venture to the south. The undercurrent slowly subsides towards the north and can be followed considerably further to the north than in the western sector, until 49°S.

Also the origin of the subantarctic intermediate current lies more to the north and is in accordance with the doming of the front ["Scheidegrenze"] mentioned which MEINARDUS (1923) locates at 47°S in the east. Based on the closer convergence of the isohalines in the current direction we infer that this current is more weakly developed. The current axis runs 100 m higher in the east. We interpret this tilt of the intermediate layer as an effect of the deviating force caused by the rotation of the Earth [Coriolis-effect]. This is also responsible for the lesser vertical extension of the current and the weaker manifestation of the intermediate salinity and temperature maxima. The area enclosed by the 34.5‰ isohaline that demarks the current has the following vertical extensions: 400 m, 400 m, and 550 m depth at 10°, 20° and 30° southern latitude, respectively.

This superbly illustrates the damming effect of the Walvis Ridge on the North Atlantic deep current. This current enters our transect at 10°S in about 2000 m depth and subsides in its core level because of the damming effect of the ridge until 25°S down to 3600 m depth. It passes this barrier only as a narrow tongue above 3000 m. South of the ridge, presumably influenced by another damming (Atlantic-Indian Ridge), it rises rather steeply to about 1000 m at 52°S. The minor development of the subantarctic intermediate current and the parallel weaker development of the North Atlantic deep current explain why the thermal differences of the two currents in the east are much less pronounced than in the west. The temperature inversion measures only a few 1/100°C (0,01°-0,04°C) in the east and is missing at the two stations further north in the transect. The final extensions of the deep current in the South Polar Ocean can only be followed as far as 55°S. A colder and somewhat salt-poorer water column separates this Atlantic from Indian Ocean water, which apparently hugs the Antarctic steep slope in about 500 m depth as a relatively warm and salt-rich coastal current. It is the same Indian Ocean water, which was first observed in its last traces in the Weddell Sea (BRENNECKE 1921). Closer to its region of origin we observed this water in a more pronounced form.

Our stations worked during the [expedition's] southerly venture resulted in the first clear picture of the thermal and salinity stratification at great depths in the South Polar Sea. We already considered the problem of origin of the deep water when describing the western transect. The Atlantic-Indian Ridge allows only the upper parts of the Antarctic bottom water to penetrate northwards. Its extension is rather limited in comparison with the western basin and rarely measures more than 500 m

in the Southwest Africa basin. Based on our rather sparse echo soundings at 2900 m depth, it seems that the sill depth increases towards the east. However, according to our temperature measurements (above the floor of the cape basin the depth would not far exceed 4000 m). At the Walvis Ridge the Antarctic bottom current finds its end. To the north of the ridge, depths in excess of 4000 m are filled with homohaline ([salinity] 34,88-34,90 ‰) and almost homothermal (2,40°-2,49°C) water masses. These owe their formation to the mixing of the dammed parts of the North Atlantic deep and the North Atlantic bottom waters. Our stations 147, 179 and 29 show a slight temperature increase towards the seafloor (0.03°-0.06°C), presumably exhibiting the adiabatic effect in this homogeneous water.

Our treatment of the [two] transects demonstrates that the modifications of the general system of the meridional deep circulation are predominantly influenced by effects of the [bottom] relief. MERZ (1925) was the first to realize this to its extent. Additionally, by combining the results for the two [north-south] transects, we moved one-step closer to our aim, which Merz particularly had in mind: the three-dimensional description of the circulation. The solution can be expected only after the hydrodynamic treatment of the [latitudinal] profiles which are the essential components of Merz' expedition plan. Our experiences gained so far leave no doubt that in our two [longitudinal] transects the course of the lines is leveled out because of the great distances between stations. The treatment of the near-distant stations of the profiles will present us with many complications in the general system of the deep circulation.

[III Chemical investigations (missing)]

IV Plankton distribution

The two biological [longitudinal] transects are based on the same Meteor stations as the chemical and physical ones. However, each station was supplemented by its two neighboring stations of the specific [latitudinal] profile (except for stations 120 – 132), e.g. for station 86 the numbers of stations 85 – 87 are combined. The values are obtained by counts of plankton centrifuged in living condition and are expressed as numbers per liter. The water volumes involved measured 540 ml for depths of 700 m and below, less in samples from upper levels, 30 – 200 ml from surface waters. The counts used for drawing the graphs do not relate to a specific group of organisms, nor to the total plankton, but rather on those four organism groups, which, together, dominated below the epipelagic zone, and on all seven profiles. They made up the total centrifuge plankton in many of the samples from the deep sea. Below the depth of about 1000 m the numbers are not much less than for the total plankton. At 2000 m depth, for example, they account for about three quarters.

The four groups are:

1. olive-green cells, obviously Chroococcacea
2. spherical, oval zooflagellates
3. flagellates of the genus Rhynchomonas
4. colorless gyymnodines, i. e. a group of the Peridiniacea

It did not seem appropriate, to apply the total plankton counts instead of restricting the counts to the sums from the four groups. This was due to [taxonomic] insecurities that may easily occur for deep-sea samples, and also because the rich and predominantly vegetable surface layer plankton under deviating life conditions would have made the material all too non-homogenous [for count comparisons throughout all depths].

Drawing the lines of equal plankton densities – plankton isolines [Hentschel uses the term “Isoplankten”] – had to be constructed without rigid interpolation, because the deep-sea data are too scattered spatially and are too low, to arrive at the level of certainty provided by data from the surface layers. Both transects demonstrate such a correspondence in their main characteristics that they can be described together (Plate 1, Fig. 7 and 8 [missing, compare Fig. 3]).

At about 30° S both of our transects cut through a seafloor ridge, the Rio Grande Ridge in the west, the Walvis Ridge in the east. Above these structures the plankton isolines rise rather steeply and sharply delimit a minimum area of plankton development to the north of 30°S, which is also apparent at the surface, from a maximum area towards the south. Between 2000 m and 4000 m a tongue of the minimum area extends southwards, rises and can still be recognized at the surface in 50° or 60° southern latitude. This structure separates a large water body from the far south, which in places contains relatively high plankton values, from a water mass down to a depth of about 2000 m between 30°S and 50°S. Along the eastern transect the minimum area north of 30°S is expressed throughout all depths. However, it is only narrow and becomes replaced already at 20°S by a tongue from the maximum area extending from the surface down to close to the sea floor. Along the western transect the situation is similar, but less distinct. At the northern limits of both transects, the course of the curves remains provisional for now.

The generally close agreement between the two transects supports the conclusion that in principle the distribution of plankton in the South Atlantic Ocean is correctly presented and the curves are not accidental or misleading in their essentials. This view will also be supported if it is possible to demonstrate connections between plankton data, chemical and physical characteristics of the water, and finally with the morphological structures of the sea floor and the current patterns. Such interpretation should first be made for the east transect where relationships to the deep currents appear unmistakable. The basis for this is provided by the sketch of the course of the currents devised by MERZ (1925) for the western half of the Atlantic Ocean, and the above descriptions by Wüst.

The polar water masses, sinking in the south and flowing northwards at depth, are characterized by relatively high plankton values. These water masses, as clearly expressed also in the course of the plankton isolines, are split into two parts of which the Walvis Ridge dams the northern one. Below both parts seem to lie plankton-poor, stagnating bottom water. The water of the North Atlantic deep current, slowly rising from 30°S onwards, should correspond with the relatively plankton-poor region, and it slides from below in between the two extended maximum areas at the surface. The effect of this current on plankton production seems to be still apparent at the surface at 60°S, where it is no longer provable in the salinity conditions. The water

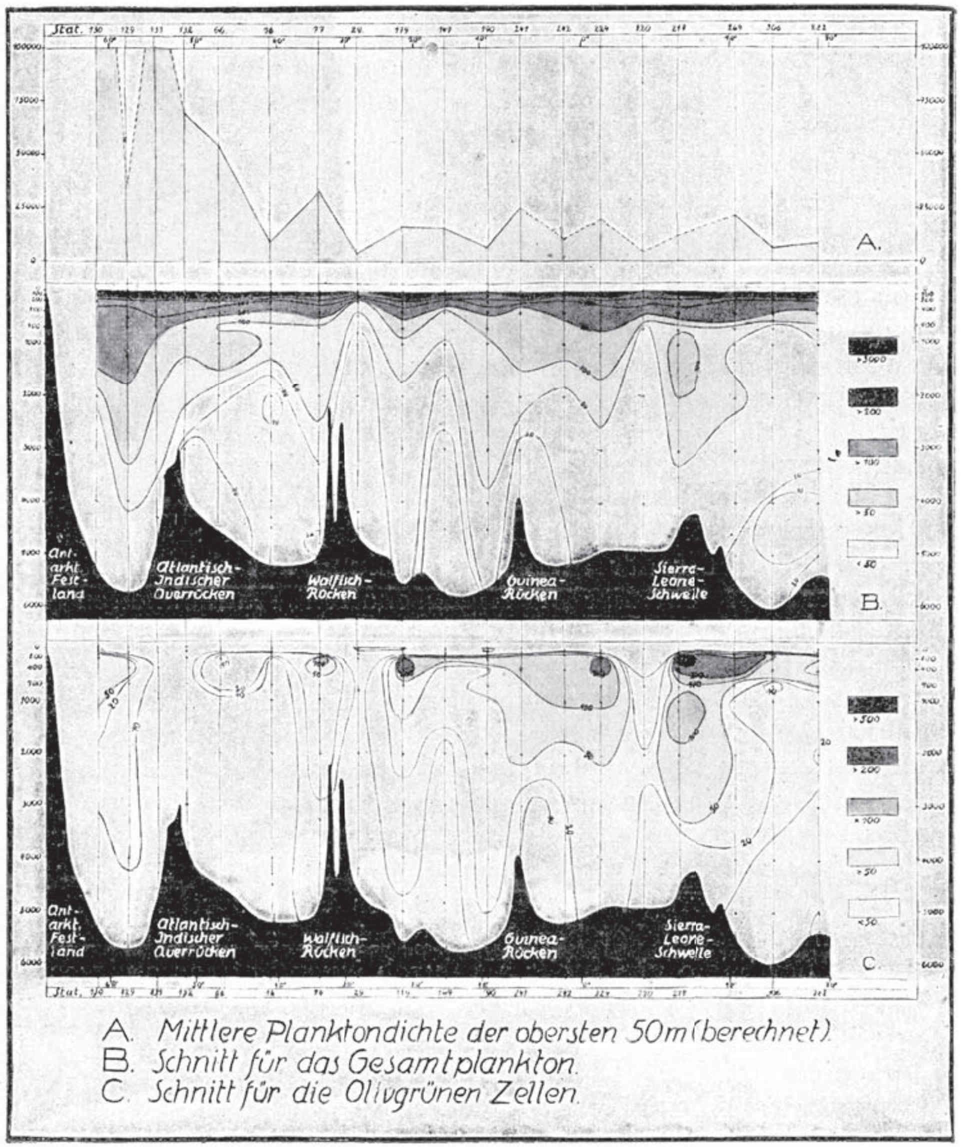

Fig. 3: Plankton distribution along the East Transect (from HENTSCHEL, 1928). – A. Mean plankton densities in the uppermost 50 m layer (calculated) [not considered in this paper]; B. Transect section of total plankton abundance; C. Transect section for olive-green cell counts. Values in B and C give the mean of counts from stations on the transect and from the two respective neighboring stations (e.g. 147 includes 146 and 148) on the profiles, normalized to 1000 ccm. X-axis in B. and C give depth values in meters. Legend bars on the right site indicate densities, i.e. cell numbers per 1000 ccm.

masses down welling at 30° and 50°S, moving north partially in the subantarctic intermediate current, and partially in the subtropical undercurrent, should form the second large and relatively plankton-rich region which reaches down deepest at 30°S and 35°S. These relationships between water movement and plankton density would be characterized by "young" water, coming from the ocean surface and being relatively plankton-rich, and "old" water, already separated from the surface for quite a time and being relatively plankton-poor. However, old water reaching the surface again close to the upwelling area and under the influence of light will become plankton-rich, as already assumed by Brandt (1916/20). If regions further north are investigated, also considering the western transect, it becomes clear that the relationships between current tracks and plankton isoline tracks by no means always exist, and may even seem to contradict each other locally.

According to the course of the plankton isolines along the western transect the North Atlantic deep current should rise between 40°S and 50°S for 1000 m, i. e. in an area that, according to the salinity conditions, clearly belongs to the Antarctic intermediate current. Additionally, it appears that in both transects between 30°S and 50°S water sinks down to 2000 m depth as a northward directed component. This is rather implausible. North of 30°S the search to discover such simple relationships fails completely. The plankton distribution would lead to the assumption that between 30°S and 15°S water masses would rise and sink vertically. This is contradicted most sharply by the proof of distinctive horizontal movements in this area, as indicated by the distribution of salinity.

At this stage of data evaluation we have to concede that changes in plankton isolines in the directions of the currents, i.e. horizontal transport with water masses, occur relatively slow [in comparison to changes in vertical transport by sinking of organic particles and vertical migration (see this following paragraph)]. Whether and to what extent this happens depends on the masses of water transported, on its characteristics and its speed. Because changes in plankton densities proceed disproportionally faster in vertical than in horizontal direction, the vertical components of the currents will have a more intensive effect on the course of the plankton isolines. Additionally, we know that the chemical properties of the water, e.g. its content of the so-called limiting factors [in the sense of Liebig] and of poisons, already at rather low differences may result in strong biological effects. Therefore, existing limited mixing with other water bodies or changes of biochemical processes, e.g. as a result of damming, biological effects may already totally mask the course of the currents.

These reflections may bring us also closer to understanding the most prominent deviation in the course of the plankton isolines, the disappearance of the dominating effect of the horizontal currents on the distribution of plankton between 30°S and 15 °S. The separation of the ocean at the latitudes of the ridges by damming and disturbance zones was shown by the above explanations of Wüst and Wattenberg [the latter missing in the recovered document]. Obviously, the changes of the living conditions for the plankton are so far-reaching that one cannot speak only of a disturbance but rather of a total suppression of the current influence. An accurate evaluation of the described biological conditions of both the transects may only become available after intensive treatment of the total relevant material of this expedition. However, this account should be sufficient to show that the methods applied in our plankton research are suitable to allow a count-based overall portrayal and far-reaching explanation of the biological conditions in the ocean. The applicability of the elaborated counts is deduced from the close correspondence in the east and the west transects, and also from the partially narrow connection between plankton distribution and current courses.

[End of original manuscript]

Arguments for paper rejection

All matters concerning the Meteor were handled by the "Meteor Commission" whose chairman was Albrecht Penck, Professor of geography at the University of Rostock. Penck was also responsible for publications by the scientists on board the Meteor. The publisher, that is Penck in the name of the Akademie der Wissenschaften, rejected the manuscript, presumably after consultation with the commission. The arguments of the academy, particularly on the biological chapter, are best expressed by Albert Defant, the successor of Merz as director of the Institut für Meereskunde in Berlin, who participated in the cruise for the last three months. In a letter to His Excellency Schmidt-Ott, President of the Research Council, DEFANT (1927b) writes that he understands the viewpoint of the commission very well, but that he had rarely read a manuscript as full of doubts and uncertainties as the part written by Hentschel.

It is not the aim of this paper to rehabilitate the biological part or even Hentschel as the intensively criticized author, but we try to understand why this example of early multidisciplinary cooperation – probably the overall first such effort – fell into oblivion. Reading the two chapters that survived, hidden in Hentschel`s documents for more than ninety years, we do not recognize the "many doubts and uncertainties" voiced by DEFANT (1927b) though we do realize the difference between the physical and the biological chapters. The account of Wüst is not only based on salinity, temperature and depth data collected by the team of physical oceanographers of this cruise but also on earlier results. It discribes and names already certain water masses and currents, and integrates his own results into one general concept for the structure of water masses in the South Atlantic Ocean. Hentschel fitted his results into this structure, but no earlier biological data were available for comparison or to support his findings. At that time, he worked in a totally new field on a blank map. The method of studying microplankton by centrifuging small samples had first been employed by LOHMANN (1920) during the Deutschland cruise to the Antarctic (1911-1912) along a transect from the Biscay to Buenos Aires. However, Lohmann had restricted his collections to the upper 200 m and his results had no significance for Hentschel's data evaluation. Systematic plankton counts down to the deep seafloor had never been executed before and Hentschel had to prove that this method would result in data sets of value for the interpretation of water masses and currents: that is, biological oceanography supplementing and supporting physical oceanography, according to the vision of Merz. Therefore it seems unsurprising that Hentschel, in preparing a preliminary paper already during the cruise, remained rather cautious with his interpretations at this stage of data collection. Only later during the cruise, comparing plankton counts and chemical data together with Wattenberg, the two arrived at conclusions about how to relate data sets of chemical and biological assessments to each other and at system relevant explanations (see HENTSCHEL and WATTENBERG 1930, Thiel 2005). Modern tools of multivariate analyses were not available in those days.

Also the discrepancy between the characteristics of the oceanographic disciplines and the corresponding differences of their practitioners may have provoked some misevaluation. Whereas physical and chemical oceanographers were working with clear and large data sets measured with sophisticated instruments, the limited biological data available were based on few and time-consuming counts with estimated means and variations. This leads to cautious and probably hesitant interpretations. Changes in biological factors, i. e. in abundances of organisms, during horizontal transport and through sinking of or due to feeding on living or dead particulate matter and by vertical migration may probably not have been visualized in the minds of physical oceanographers, who used to think about rather stable water mass characteristics like temperature and salinity. Penck and Defant may have seen the resulting lack of balance in the strength of scientific arguments between the manuscript chapters as indicating dubious values and uncertainties as a manifestation of the exact physical and chemical sciences versus the non-exact life sciences. Later cooperative efforts in oceanography support this suggestion, when the German Research Council demanded close cooperation between disciplines in special research groups, i. e. the "Sonderforschungsbereiche" in the late 1960s and the following years. Marine scientists had to learn how to communicate with colleagues from the other disciplines, and frequently this was an arduous, long-term process. The late development of numerical modelling in biological oceanography, partially conducted by physical oceanographers, is an example of different time scales in the development of scientific disciplines. In the 1920s the situation may not have been any better, particularly for scientists like Penck, Defant and other commission members who had not had the benefit of multidisciplinary discussions in the many debates in research planning groups and on board the METEOR during the 15 cruise months before manuscript drafting.

Further, it appears to us that disapproval of the manuscript may not have been based only on the quality of the data. The order of authors and priority of publication might have been a factor, possibly a decisive one, in the paper's rejection. We do not know whether, in early days of oceanography, rules existed for the order of authors in cooperative publications. In the manuscript, it seems that an alphabetical order was chosen. Applying academic positions as a measure of seniority, Wüst would have ranked before Wattenberg. We do not know anything about the feelings of persons some 90 years ago, but we can imagine a degree of unhappiness between physical oceanographers, when the first scientific publication originating from a large research project, developed, proposed and conducted within physical oceanography, with biology and chemistry as junior partners, would be published with the first author being a biologist. Multidisciplinary cooperation and clear restriction to the over-

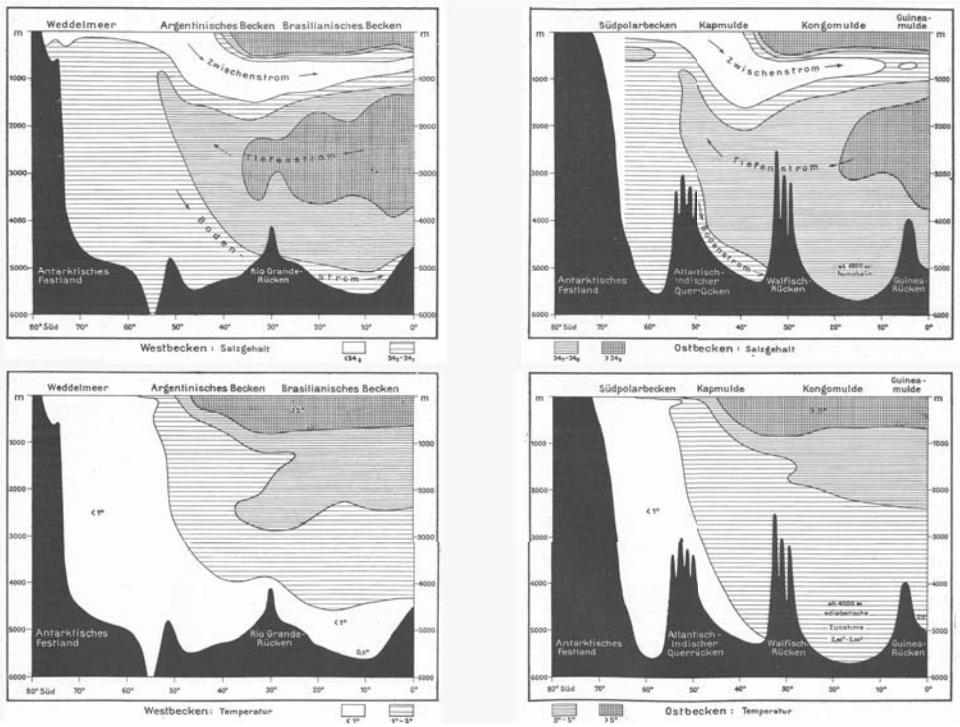

Fig. 4a-d: Southern sections of salinity and temperature charts (reproduced from Figs. 12-15 of WÜST 1927, p. 132-133) along the western and eastern transects (0° to 80°S). Signatures for salinity scale <34.5 / 34.5-34.7 / 34.7-34.9 / >34.9 and for temperature <1° / 1°-3° / 3°-5° / >5°C.

arching physical problem as strictly demanded by Merz, and the demonstration of these cooperative efforts were probably overruled by alphabetical priority. This evaluation is also supported by two notes in the diary of Captain SPIESS (1926), who additionally became scientific cruise leader after the death of Merz. In both cases, he mentions the manuscript under the order of authors "Wüst, Hentschel, Wattenberg".

Knowing Hentschel through family ties, his private diaries from the cruise and other archived documents, we believe that he would have agreed to Wüst becoming the first author. At that time however such a proposal probably could not be raised for discussion. Therefore, the early manuscript may have been rejected due to unresolved priorities and became hidden under misleading keywords in the documents of Hentschel. However, DEFANT (1927a) published a map of the completed transects including all 14 profiles (Fig. 2), extending to about 7°N (in the west) and to about 19°N (in the east), mainly referring to Wüst's treatment of profile data on temperature and salinity (WÜST, 1927). Later in the text he acknowledges the "diligence, tireless dedication and cooperation of the scientific members of the expedition", also naming them all personally.

One might expect that the ideas of this cooperation would have entered the cruise reports Nos III and IV, but this is true to only a limited extent. WÜST (1927) added data gained during further east – west profiles presumably to the figures of the two north – south transects, originally proposed for the cooperative paper, and published them, somewhat extended, in his third cruise report (Figs 4a-d, reproduced from WÜST, 1927). He refers to the eastern and the western oxygen north to south transects constructed by Wattenberg and his attempt to predict current velocities from horizontal O_2-decrease (compare WATTENBERG 1927 a). In the same paper Wattenberg relates his results on alkalinity and phosphoric acid to organism abundances, and Hentschel (1927 a) discusses some of his results in relation to temperature distribution and water masses. Also the fourth reports of HENTSCHEL (1927 b) and WATTENBERG (1927 b) point to the cooperative efforts, particularly emphasized by Wattenberg, describing the character of this expedition and the merits of Merz: For the first time for an oceanic expedition, he had appointed a staff covering a range of disciplines who, during the cruise, could treat comprehensively the marine science problems in chemistry, [physical] oceanography, biology, geology and mineralogy. Only Hentschel and Wattenberg, who collaborated closely in data evaluation during the cruise legs and harbor calls – and became lifelong friends – jointly published on phosphorus concentrations and plankton abundances (HENTSCHEL and WATTENBERG 1930, compare also THIEL 2005).

Thus, 100 years ago Merz was already expressing ideas of a multidisciplinary approach to oceanography in the broad sense of a modern science in his seminars. Presumably he also did this in his teaching, and most decisively in his cruise demands. The scientists on board the Meteor followed his impetus successfully, but the first publication from this cruise, demonstrating their new advent to oceanography, was not accepted for publication and the early cooperative issues remained hidden and unrecognized for almost a century.

Acknowledgements

The authors express their thanks for thorough advice on the manuscript provided by Dr. Anthony L. Rice regarding the English text, especially the translation of the "historical German language" and the correct transcription of older oceanographic terms. The editors of the "History of Oceanography Yearbook" deserve merits for accepting the almost 100 years old manuscript for late publication. We further acknowledge the Deutsches Meeresmuseum for hosting Hentschel's scientific inheritance in its archive and Dr. Peter Danker-Carstensen for his efforts to critically review and index the documents.

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Erinnerungen an den deutschen Ozeanographen Dr. Franz Zorell (1898-1956)

Ingo Hennings

Seit August 2014 sind die sogenannten „Nachlasssplitter“ zum Leben des deutschen Ozeanographen Dr. Franz Zorell öffentlich zugänglich und daher kann erst jetzt, eine längst überfällige Würdigung von Zorell, erfolgen. Schwerpunktmäßig werden hier die Episoden während des Nationalsozialismus und die Zeit im Nachkriegsdeutschland betrachtet. Zorell war als Ozeanograph vor dem Zweiten Weltkrieg bei der Deutschen Seewarte in Hamburg und während des Zweiten Weltkrieges beim Marineobservatorium in Greifswald beschäftigt. Er machte umfangreiche hydrographische und ozeanographische Messungen während Expeditionen an Bord von Forschungs- und Fischereischutzschiffen, wie Poseidon, Zieten, Atlantis und Meteor. Zorell war auch Mitglied der „Widerstandsgruppe Westermann“ in Hamburg, die sich aus ehemaligen Kommunisten, Sozialdemokraten und Parteilosen zusammensetzte und gegen den Nationalsozialismus agierte. Im Jahre 1935 wurde Zorell vom Hanseatischen Oberlandesgericht in Hamburg wegen Beihilfe zur Vorbereitung zum Hochverrat, zu zwei Jahren Gefängnis verurteilt, die er im Konzentrationslager (KZ) Hamburg-Fuhlsbüttel ableistete. Nach dem Zweiten Weltkrieg baute Zorell eine private hydrographische Station in Iffeldorf/Oberbayern auf. Im Jahre 1955 erhielt er einen positiven Wiedergutmachungsbescheid vom Bundesminister für Verkehr der Bundesrepublik Deutschland. Anfang 1956 ist Zorell, aufgrund seiner langen, schweren Erkrankung mit 57 Jahren verstorben.

Memories of the German Oceanographer Dr. Franz Zorell (1898-1956). Since August 2014 so called “incomplete papers” of the life of the German oceanographer Dr. Franz Zorell has been made accessible to the public. Therefore, only now it can take place a long overdue appreciation of Zorell. Here, primarily the National Socialism and the time in postwar Germany are examined more closely. Before the Second World War, Zorell was employed as an oceanographer at the German Marine Observatory in Hamburg and during the Second World War at the Marine Observatory in Greifswald. He carried out extensive hydrographic and oceanographic measurements during expeditions from on board research and fishery protection vessels like Poseidon, Zieten, Atlantis and Meteor. Zorell had been also a member of the resistance group “Westermann” in Hamburg, which was composed from former Communists, Socialists and independents, which acted against the National Socialism. In 1935 Zorell was sentenced to two years in prison from the Hanseatic Higher Regional Court in Hamburg because of aiding and abetting for preparation of high treason, which he spent in the concentration camp in Hamburg-Fuhlsbüttel. After the Second World War, Zorell built up a private hydrographic station in Iffeldorf/ Upper Bavaria. In 1955 he received a positive compensation notification from the Federal Minister of Transport of the Federal Republic of Germany. In the beginning of 1956 Zorell died with 57 years due to his long and serious disease.

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