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Long-term trends and changes in the hydrography of the Faroe-Shetland Channel region

By John B. Tait

Summary—Between the years 1927 and 1952 inclusive, more or less systematic temperature and salinity observations on two roughly parallel hydrographic cross-sections of the Faroe-Shetland Channel have revealed certain fluctuations, both dynamic and characteristic, which exemplify the phenomenon of marine climatic change.

Except perhaps in 1947, the Atlantic Current through the Channel evidently flowed more strongly in the autumn-winter than in the spring-summer seasons of the period from 1946 to 1952, and these autumnal-winter intensities themselves apparently increased in magnitude to a maximum in December 1951.

In the fourth decade, the oceanic water-mass in the Channel was infused with extra-Mediterranean water which has not appeared, save sporadically in isolated trace in the years before or since, and which from small beginnings in 1930–1931 showed maximum concentration in 1933–1934 and thereafter waned to extinction in 1938–1939.

Similar circumstances marked the appearance of first one, and then two, types of Arctic water-mass in the bottom layers of the Channel in the latter years of the fifth and the first years of the sixth decades.

Probably most oceanographers at least entertain the idea, and indeed, from much practice in a given oceanic region, many may have formed some sort of empirical conception in regard to the circulation of the oceans, to the effect that this phenomenon, besides varying seasonally and in greater or less degree annually, is subject also to longer-term fluctuation which may or may not be periodic in character. Such a conception, even discounting the probability of connection or connections between the respective phenomena, is similar to that of climatic change in regard to which much and various evidence has been adduced in recent years, e.g. glacier recession, timber line advance, seasonal mean atmospheric temperature changes, etc.

A major handicap to the adducement of oceanographic evidence of long-term fluctuation in hydrospheric conditions lies in the general inadequacy to date of the raw material of oceanographic observations. The collection and compilation of data of the necessary reliability is not yet of long duration—a prerequisite of effective research into the question of long-term fluctuation—and, moreover, has already been seriously interrupted by two world wars in those regions where it was being most intensively prosecuted. Nevertheless, it has been possible, for instance, to deduce from the trend of mean sea surface temperature in high northern latitudes that, during the past half-century or so, the Arctic region has on the whole been slowly warming up. A similar tendency to the extent of at least 0·5° C up to 1951 has recently been noted also in respect of the North Sea and English Channel regions.

Still another example of longer-term change in sea conditions than the familiar seasonal and annual variations is that instanced by Kemp (1938) in regard to the annual maximum phosphate content of English Channel waters between the third and fourth decades of the present century, with apparently correlated changes in the plankton, young fish, and, ultimately, adult fish populations of the region. These later indications, from an economic standpoint alone, point a moral which is not to be ignored, especially as much other real and circumstantial evidence points more or less strongly in the same direction. In the aggregate, this evidence which, piecemeal, tends to present a somewhat irregular and confusing picture from one region to another, and between one organic species and another, appears to fall more rationally into focus when considered from the standpoint of the characteristically different water-masses in the ocean, their fluctuations in circulation and in quantity (TAIT, 1952, p. 92).

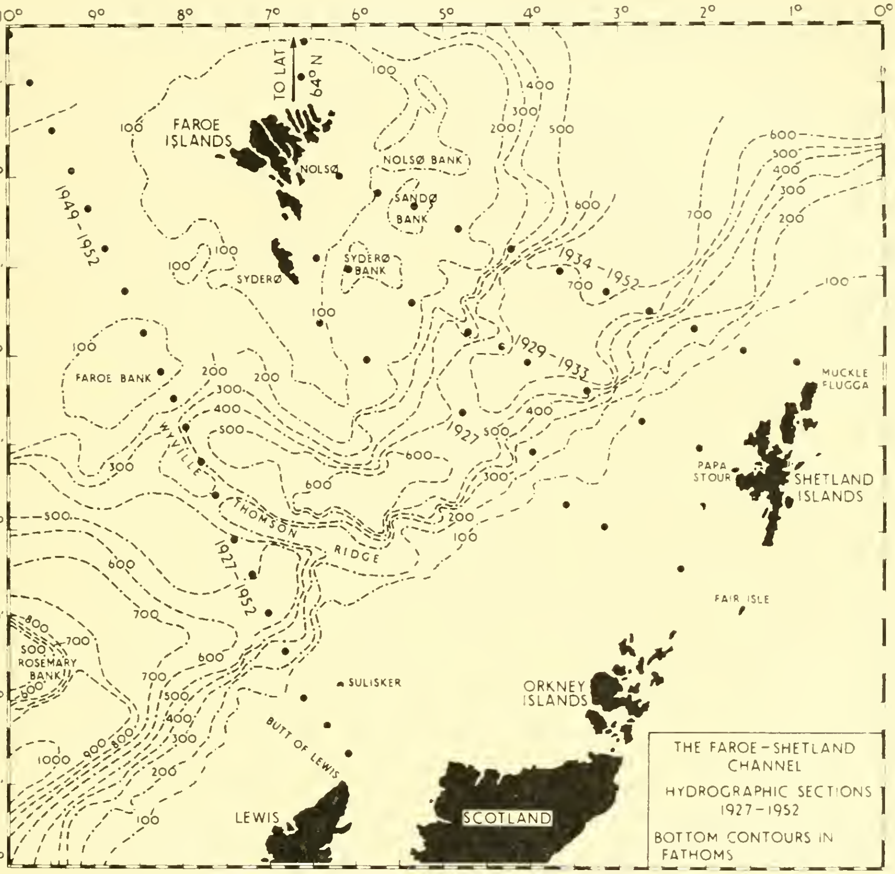


Fig. 1

In the seas about west and north-west Europe, for example, there are permanently present at least six different and, for the most part, converging and. to some extent, intermingling water-masses. These are the oceanic, continental, Arctic, Norwegian Sea, North Sea and Mediterranean water-masses, each with its characteristic temperature, but more especially salinity, and doubtless also other properties. A variety of biological and other evidence has given rise to the conception that the most significantly important of these, at least in many respects, is the oceanic water-mass. Special attention has accordingly been directed to the oceanic incursion into European seas in an endeavour quantitatively to assess its magnitude and variations. This has been done by the normal hydrodynamic method, stemming through HELLAND-HANSEN

(1905), HESSELBERG and SVERDRUP (1915), SVERDRUP (1933), JAKELLN (1936), JACOBSEN (1943), and others, from the Bjerknes' Circulation Theorem, of volume transport computation through two roughly parallel hydrographic sections laid approximately at right angles to the course of the Atlantic Current through the Faroe-Shetland Channel, scene of the pioneering oceanographical investigations of C. WYVILLE THOMSON in 1868 and 1869, which led up to the classic *Challenger* Expedition.

There are special physical features of the Faroe-Shetland Channel region, as illustrated in Fig. 1, and of its waters, which make this a peculiarly appropriate site for an investigation of the kind indicated. As MOHN, the Norwegian meteorologist, first pointed out in 1887, by far the greater bulk, if not almost the entire mass of the oceanic water which pervades north-west European seas, flows within relatively restricted lateral limits through this Channel. It possesses, moreover, in the Wyville Thomson Ridge, a well-defined threshold from the North-Eastern Atlantic Ocean, thus defining, at its mean summit depth of about 550 metres beneath the sea surface, the thickness of the oceanic water-mass which, so far as is known, continuously passes in an east to north-easterly direction over it. Initially, then, as a first approximation, the level of zero horizontal current—the basis of conversion of relative into

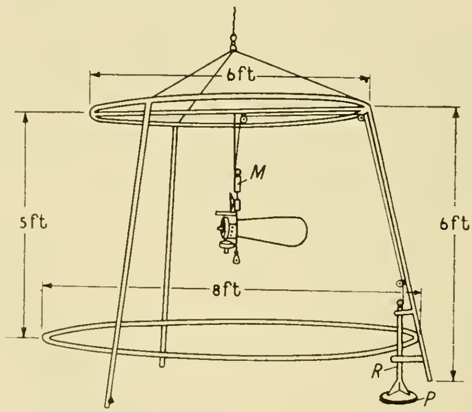


Fig. 2

absolute computational values—was assumed to lie at this depth of 550 metres over the major part of a hydrographic section between the Butt of Lewis, (the northmost point of the Outer Hebrides off the west Scottish coast), and Faroe Bank, the section thus passing obliquely across the Wyville Thomson Ridge and, as nearly as may be judged, at right angles to the general course of the Atlantic Current over it. Between those stations of the section which lie over the continental shelf and slope, zero horizontal potential was assumed at the mean bottom depth between successive pairs of stations, and the modification of the computational method introduced by HELLAND-HANSEN (1934) to suit such circumstances, applied.

As regards the assumption of zero horizontal current along the summit of the Wyville Thomson Ridge, this was experimentally confirmed in May 1953. In remarkably calm conditions, and after repeated testing in each instance at higher levels where considerable current of an order to be expected was in fact registered, an old-style but technically efficient Ekman current meter was, by means of the large, tubular, metal tripod illustrated in Fig. 2, deposited within one metre of the sea bottom, independently of the ship from which it was lowered, at no fewer than three well-spaced positions along the summit of the Ridge. The meter was activated and re-locked at precise instants by the operation of a moveable foot-plate, P, which, through its connecting rod, R, and an attached cord, released and withdrew the operative messenger M immediately on contact with, and on withdrawal from, the sea-bed. In all three instances zero current was registered during an interval of thirty minutes.

In view of the uncertainties of the normal dynamic computational method, however, the need was recognised from the outset of some form of corroboration of results obtained by its means. This was sought in similar dynamic computations of the volume transport of oceanic water through an approximately parallel and, within a matter of not more than two weeks, contemporary, hydrographic section across the debouchment of the Faroe-Shetland Channel proper into the Norwegian Sea, that is, between the Faroe and the Shetland Islands. As illustrated in Fig. 1, this section to begin with was situated in a more southerly position than that in which, from 1934 onwards, it became established.

For computation of the *absolute* oceanic volume transport through this more northerly section, in the absence of such a convenient feature as a submarine ridge as in the case of the southern section, the initial difficulty of determining the level of zero horizontal current was overcome in the light of the following reasoning.

Throughout the length of the Faroe-Shetland Channel to the Wyville Thomson Ridge, the situation has long been known, of an upper relatively warm and salt water-mass, the oceanic water-mass, over-riding a substantially colder and fresher water-mass which emanates from the deep waters of the Norwegian Sea; and also the fact that these two different water-masses move in contrary directions along the Channel. The more so, therefore, as cross-sectional representations of temperature and salinity distributions almost invariably reveal a well-marked boundary between these two water-masses, it is legitimate and reasonable to assume the existence of an interface of zero or negligible horizontal motion between them. The same diagrams in considerable number, by the obvious and increasing concentration of both isotherms and isohalines towards the isohaline of 35·00°/₀₀, which of course was zero. PETTERSSON'S definition of the lower limit of demarcation of oceanic water, indicate that this isohaline probably represents in cross-section also the said interface in the Faroe-Shetland Channel of negligible or zero horizontal current. In point of fact, after trials with the isohalines of 35·05°/₀₀ and 34·95°/₀₀ as zero reference bases, and subject to one other consideration which is applicable to both sections but not altogether relevant to the present issue, but which will be mentioned in another connection below, the closest agreements between the resultant oceanic volume transports through the two sections above cited when traversed within short intervals of each other, were obtained on the basis of zero horizontal potential along the 35·00°/₀₀ isohaline on the northern section.

The fact of these agreements, most of which are very close as will be seen from Table I, in no fewer than twenty-one instances between the years 1927 and 1952, that is, in all cases save one in which during this period the two sections were accomplished more or less together, reflects favourably on the accuracy of the above assumption. Its experimental verification by current meter with the means then at disposal—it may the more readily be accomplished now since the ingenious inventions of

CARRUTHERS (1954) for warp- or cable-angle measurement and current meter anchoring have become known,—was of course less reliable on account of the necessity to suspend the current meter from a drifting ship. Nevertheless, in the

Table I

Volume transport of oceanic water (salinity >34·99°/₀₀*) through the linear hydrographic sections, (a) Faroe Bank to Butt of Lewis, and (b) Faroe Islands to Shetland (in* 1927 *to Fair Isle), when the pair of sections was traversed within an interval of* 14 *days*

Year	*Inclusive dates of Sections Day/Month*		*Volume transport km³/hr*	
	(a)	*(b)*	*(a)*	*(b)*
1927	18/8–20/8	7/8–9/8	1·4	1·7
1929	28/5–29/5	17/5–18/5	14·0	13·2
1931	27/5–28/5	16/5–18/5	2·5	2·2
1933	20/6–22/6	9/6–11/6	3·6	2·9
1935	27/5, 5/6–6/6	15/6, 17/6–19/6	5·5	5·7
1936	28/5, 2/6–4/6	5/6, 13/6–15/6	3·9	3·9
1937	28/5–30/5, 3/6	21/5–23/5	8·8	8·8
1938	26/6–27/6, 2/7–3/7	5/7–6/7	12·8	9·6
1939	26/6–27/6	17/6–18/6	8·3	8·3
1947	18/6–19/6	10/6–12/6	19·9	19·3
1948	3/5–4/5	8/5–10/5	5·9	6·2
1949	3/9–4/9	12/9–13/9	12·4	10·0
	11/11–12/11	22/11–24/11	13·9	14·3
1950	12/5–13/5	21/5–23/5	2·5	3·4
	16/6–17/6	27/6–29/6	6·1	5·5
	19/7–21/7	2/8–4/8	4·9	3·8
1951	18/5–20/5	1/6–2/6	3·5	13·2
	16/6–17/6	7/6–9/6, 16/6	14·7	13·5
	13/7–15/7	23/7–25/7	2·6	2·0
1952	8/5–11/5	18/5–19/5	3·4	3·1
	5/7–6/7	17/7–18/7	6·8	9·8
	4/11, 8/11–9/11	17/11–18/11	11·2	10·3

remarkably calm conditions prevailing, the endeavour was made with not unsatisfactory results within a few days of the corresponding experiments on top of the Wyville Thomson Ridge in the month of May 1953. The depth of the 35·00°/₀₀ isohaline having been estimated as at 260 metres by rapid hydrometric measurements at a position over the lower continental slope north-west of Shetland, the result of repeated short-interval current meter suspensions to this depth yielded the inconsiderable vector of only 0·63 centimetres per second. When the more accurate salinity determinations were made it transpired that the above-estimated depth of the 35‰ isohaline at the position concerned was less by some 12 or 13 metres than the probable true depth, so that sufficiently near confirmation of the basic assumption underlying the volume transport computations on this northern section may be said also to have been achieved. Unfortunately, the favourable conditions which had prevailed to this point broke down thereafter, thus precluding further similar experimentation at other positions on the section.

Table I gives the results of the volume transport computations on the foregoing lines through the above-mentioned two Faroe-Shetland Channel cross-sections in contemporary pairs. The unit of cubic kilometres per hour has been chosen in preference to the hitherto more usual unit of millions of cubic metres per second, as affording to fishery research biologists, in whose interest these investigations were primarily carried out, a more readily grasped conception of the phenomenon of the intensity of the oceanic incursion into north-west European fishery regions.

As already indicated, the agreement between the pairs of values is remarkably close in all cases except one, namely, that for the latter half of May 1951. The immediately succeeding values, referring to the second and third weeks of June, being not only in close mutual agreement, but in agreement also with the higher of the two values for the preceding period, suggest that the disagreement in respect of this earlier period was in fact real, and significant of a radical change in the intensity of the Atlantic Current within the short interval of the two latter weeks of May 1951.

For present purposes, however, the interest of Table I is mainly in such evidence as it yields of longer than annual variations in the intensity of the Atlantic Current in the Faroe-Shetland Channel. Because of the highly disproportionate seasonal, and to a somewhat less extent annual distributions of the values, this evidence can only be regarded on the whole as of a very tentative nature.

The majority of the entries in Table I relate to the months of May, June and July, especially the two former months. Considering these values apart, their range is very considerable, namely, taking the means of paired values, from about 2·3 km³/hr in July 1951, and 2·4 km³/hr in May 1931, to 19·6 km³/hr in June 1947, which in fact all but embraces the entire range of the values of Table I. It may of course be entirely fortuitous, the frequency of the values being insufficient for anything approaching positive assertion, but it can at least be observed that the highest spring-summer oceanic transports, as chronologically entered in Table I, occur in the years 1929, 1938, 1947, and 1951, that is, apparently after intervals of nine, nine, and four years respectively.

On the other hand, the lowest spring-summer values do not admit any similar inference of long-term periodicity. Their main feature in Table 1 would seem to be an unbroken succession of them in the six years from 1931 to 1936.

More or less in parenthesis at this still early stage in scientific oceanographical investigation, but nevertheless perhaps associated in some at present indefinable way with the subsequent phenomenon, brief notice may be taken in passing of the lowest transport value of all in Table I, namely that of 1·4 km³/hr for the third week of August 1927, and of the quite unique occurrence, so far as is known, of an iceberg within the limits of the North Sea, sighted on 23rd October 1927 about 30 miles ESE of the Outer Skerries of east Shetland (Marine Observer, 1928).

Oppositely, it may here also be pointed out that the highest transport value in Table 1 of almost 20 km³/hr occurred during a summer which was outstanding meteorologically over the greater part of the continent of Europe.

Further as regards the higher transports, however, it is to be noted that not all of these are recorded against the spring-summer months of May, June, and July, as witness, for instance, the figures for September and November 1949, and also that for November 1952. This feature of the results is considerably enhanced and extended when further available material is added to that of Table I. Besides the paired hydrographic sections there represented, no fewer than twenty-four single sections, a number of them traversed by the Danish research vessel *Dana*, and one due to the Norwegian vessel *Armauer Hansen*, embracing the same period of years, are available for dynamic computation on the same lines as those adopted for the Scottish sections. Single section computational results must, of course, lacking similar corroboration to those of the paired sections, be regarded as probably somewhat less reliable on that account. None the less, they are of no small value in extension of Table I, and have accordingly been incorporated along with the means of the paired values, in Table II, single section values being distinguished by an asterisk.

In this table, the high figure of 13·3 km³/hr for the month of June 1929 as derived by Helland-Hansen (1934) clearly supports the mean value of 13·6 km³/hr in respect of the previous month; and the introduction of an additional year, namely 1934, on the basis of single sections only, but in no fewer than three separate assessments, in no way impairs the inference already tentatively made as regards the apparent succession of low summer oceanic transports between 1931 and 1936 inclusive. Likewise, the slightly high figure of 9·3 km³/hr for May 1938 probably anticipates in truth the subsequent increase to 11·2 km³/hr some six weeks later, and the assessments for June and July 1939 would appear to be very similarly related.

It is only from the year 1949 onwards that autumn-winter transports are available, and these, to 1952 inclusive, reveal conditions which, although hitherto perhaps occasionally suspected on empirical circumstantial evidence, are here for the first time given quantitative expression. In each of the four years concerned, the oceanic volume transports through the Faroe-Shetland Channel were evidently of greater intensity than the preceding spring-summer incursions. It is material also that the years are consecutive, for, from the standpoint of long-term variations, it would almost appear from the values given that the successive autumnal accessions to the intensity of the oceanic influence in the Channel themselves increased annually to a high maximum in December 1951. It can be taken as practically certain that the phenomenon of greater autumn-winter than spring-summer oceanic transports is not an annual occurrence, the combination of circumstantial with the factual evidence of Table II and such assessments as are available for earlier years (Helland-Hansen, 1905, and Robertson, 1905, 1907, 1909a, 1909b, 1913), suggesting that this oceanographic feature, like that of the succession of low summer transports between 1931 and 1936 inclusive, occurs in groups of years, and recurs only at more or less long-term intervals of the order each of at least several years. Qualitative evidence in

Table II

Oceanic volume transport through the Faroe-Shetland Channel

Year	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
						Km³/hr.						
1927								1·5				
1929					13·6	13·3*						
1931					2·4							
1933						3·3						
1934				4·8*	4·4*		3·1*					
1935						5·6						
1936						3·9						
1937					8·8							
1938					9·3*	11·2						
1939						8·3	10·4*					
1946								5·0*				
1947						19·6	15·8*					
1948					6·1	8·9*		4·7*				
1949			7·3*		5·2*		11·5*		11·2		14·1	
1950			15·7*		3·0 4·2*	5·8	4·4	3·7*			12·3*	
1951					3·5*	13·8	2·3	2·7*	10·0*	10·8*		23·4*
1952		11·9*	14·5*		3·3	7·5	8·3				10·8	

* Single section results

support of the suggestion is contained in another aspect of the results of this comprehensive investigation of the hydrography of the Faroe-Shetland Channel which is about to appear elsewhere* *in extenso*.

It was mentioned earlier that the remarkably close agreements recorded between the contemporary paired sections across the Channel depended also in a number of cases, and as it turned out depended very materially in some instances, on a certain condition which referred to both sections. This condition was the re-inclusion of apparently aberrant original observations of temperature or salinity, principally

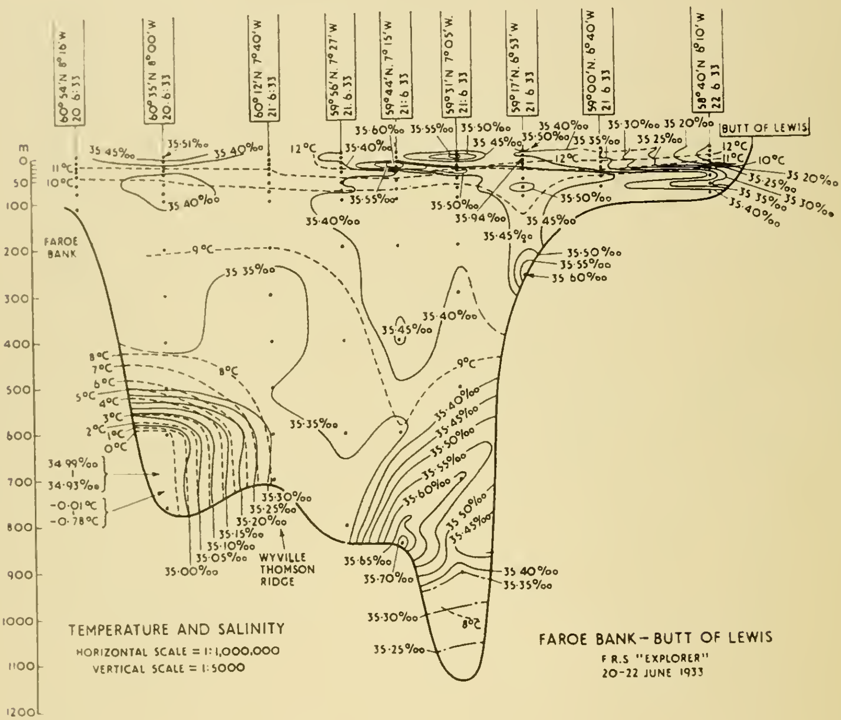


Fig. 3

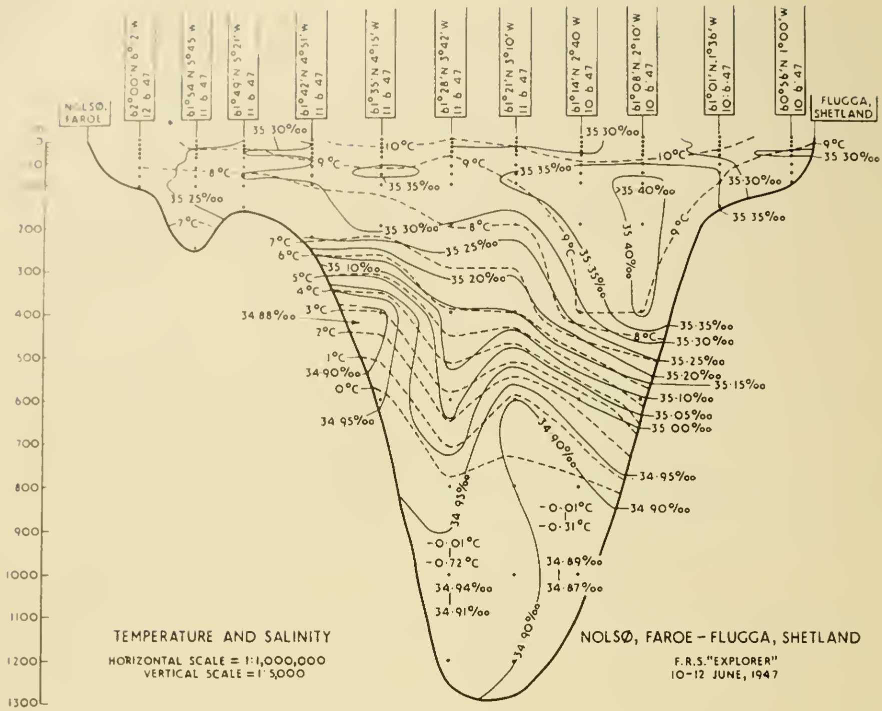
the latter, which by former standards were customarily excluded, or replaced by interpolation from smooth curves, if they implied more or less radical inversion of density in the vertical water column. In the present investigation, the years in which this condition of reinsertion of such observations had most frequently to be applied were those between 1931 and 1936 inclusive, when considerable numbers of high and even of extraordinarily high salinity values were registered, of maximum magnitude and frequency in the year 1933 in the Faroe-Shetland Channel, in 1934 in the northern North Sea, and almost without exception as subsurface values. It was in the latter region, in fact, that these recurring abnormally high salinity records were first

* In the Scottish Home Department's series of " Marine Research " publications.

noticed and recognised, after investigation (TAIT 1935), to be true records, indicative, it was then empirically concluded, of abnormally powerful oceanic incursion into the region. As illustrated in Figure 1 of this reference, a not insignificant aspect of the geographical incidence of these abnormal northern North Sea salinity observations in adducement of evidence towards their reality, links that particular research with the results of an investigation into the current system of the region (TAIT, 1937).

The dynamic results of Table II, however, in respect of the Faroe-Shetland Channel, belie the earlier conclusion reached in interpreting these abnormal North Sea observations, clue to the origin and meaning of which was found on the Butt of Lewis to Faroe Bank hydrographic section of June 1933 (Fig. 3). Here, on and off the southern slope of the Wyville Thomson Ridge, there occurred in the depths of 840 metres and 700 metres at two adjacent stations the high salinities of 35·73‰ and 35·61‰ respectively, with related high observations, although of lower order, both above and below the latter especially. The two outstanding values, in conjunction with the simultaneously recorded temperatures at the same depths, furnish densities (σ_t) of 27·74 and 27·63 respectively, that is, within the bracket which SVERDRUP, JOHNSON, and FLEMING (1942, p. 670) cite as characteristic and significant of the North Atlantic Ocean intermediate layer of so-called Mediterranean water effluent. It is clear from Fig. 3 that the above salinity records signify the core of such a body of Mediterranean water impinging upon the southern slope of the Wyville Thomson Ridge, and thereby, by the consequent turbulent motion which the trends of isotherms, and especially of isohalines, almost invariably indicate in this region, becoming disintegrated, to appear in the upper water levels northward of the Ridge,—but only extremely seldom at the surface—as isolated high salinity nuclei within the body of the oceanic water-mass, the maximum salinity of which here normally lies between 35·35‰ and 35·45‰. Such isolated nuclei did in fact occur on the Faroe-Shetland Channel sections of 1931 (as Table II indicates, there was no 1932 section), 1933, 1935, 1936, and 1938, being absent, however, from the 1934 and 1937 sections. Despite the increased frequency of traverse of these sections since 1946, high salinity values suggestive of Mediterranean water intrusion into the oceanic water-mass have occurred only sporadically, as in May 1948, August 1951, and November 1952, and then only as singular records on the southern section over the threshold to the Channel. It may be that, by application of the principle of discarding apparently aberrant observations, previous indications of the presence of Mediterranean water in the Faroe-Shetland Channel, and even within the northern North Sea, have thus been lost. It is safe to say, however, that this is a phenomenon which, substantially, occurs only once in a while, and probably, as in the fourth decade, in groups of years, in other words it is a phenomenon of only long-term recurrence.

Yet another example, this time with reference to the deep waters of the Faroe-Shetland Channel, may be cited from this investigation as suggestive of probably similar long-term fluctuation. What have hitherto been accepted as the normal deep water temperature and salinity distributions in the Channel, i.e., below the oceanic water-mass, are almost uniform conditions in both characters, namely, thermal registrations at or near zero temperature Celsius, and salinity records of around 34·92‰ to 34·94‰. These properties define the origin of the deep Channel water as from deep levels of the Norwegian sea to the northward. Since the effective commencement of observations in the Faroe-Shetland Channel at the beginning of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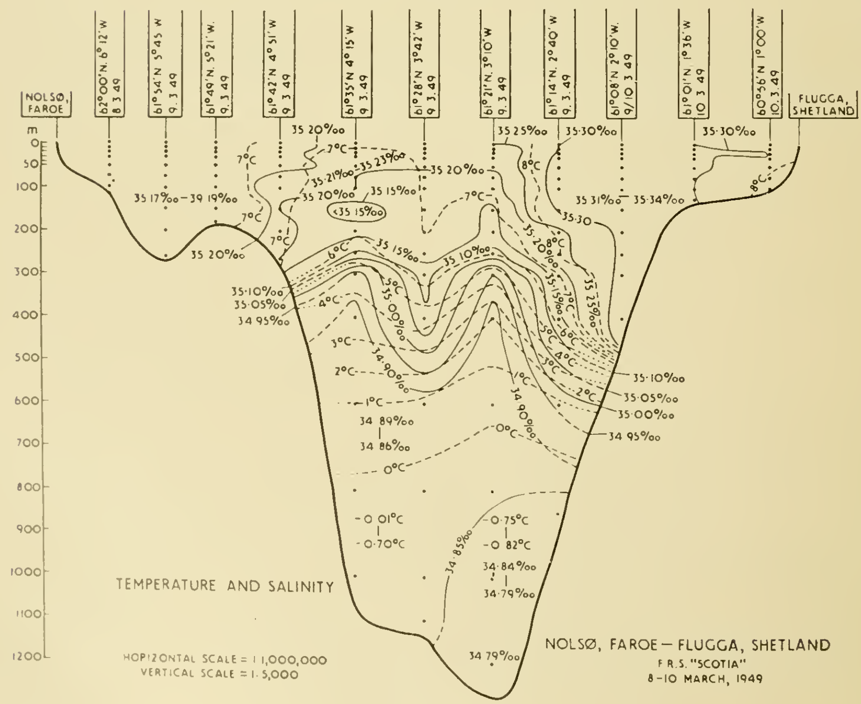
F.R.S. "EXPLORER"
10–12 JUNE, 1947

Fig. 4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HORIZONTAL SCALE = 1:1,000,000
VERTICAL SCALE = 1:5,000
NOLSØ, FAROE – FLUGGA, SHETLAND
F.R.S. "SCOTIA"
8–10 MARCH, 1949

Fig. 5

the present century, little if any specific notice has been taken of the relatively infrequent occurrence of salinity values below 34·90‰. There is, however, clear evidence in the tabulated observations of a frequency concentration of such low salinity records, from 34·82‰ to 34·88‰ with occasional instances of 34·76‰ to 34·79‰, in the years between 1907 and 1910 inclusive, such as occurred again towards the end of the fifth and the beginning of the sixth decades.

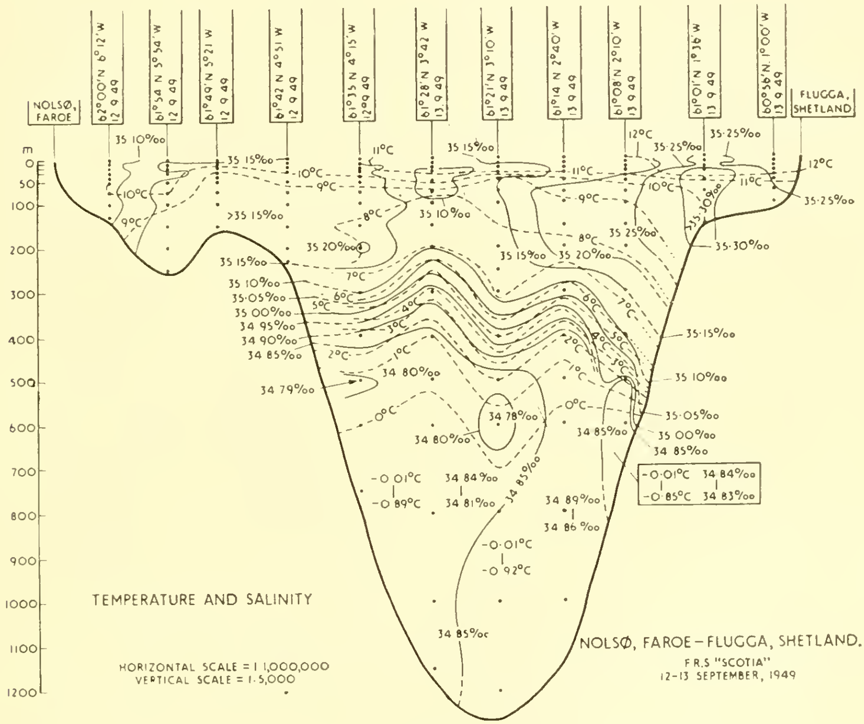

Fig. 6

Apart from a singular, isolated, 34·87‰ salinity record in July 1934, no Faroe-Shetland deep water salinity value below 34·90‰ was encountered in the years between 1931 and 1939 inclusive. Similar isolated results were again evident in July and August 1946, but by the month of June 1947 (Fig. 4) almost one-half of the deep water mass underlying the oceanic water-mass was of the relatively low salinity of 34·87‰ to 34·89‰, and had a higher minimum temperature than the neighbouring deep Norwegian Sea water-mass. It seems clear from HELLAND-HANSEN and NANSEN (1909) that this low salinity (34·86‰–34·89‰) intrusion into, and sometimes displacement of, the deep Norwegian Sea water-mass of the Faroe-Shetland Channel, is Arctic water emanating from the deeper layers of the East Icelandic Arctic Current and found in depths of about 300 to 400 metres " from the continental slope off the east coast of Iceland along the slope of the Faroe-Iceland Ridge and off the Faroes, past the Faroe-Shetland Channel." Evidently, however, this Arctic water layer does

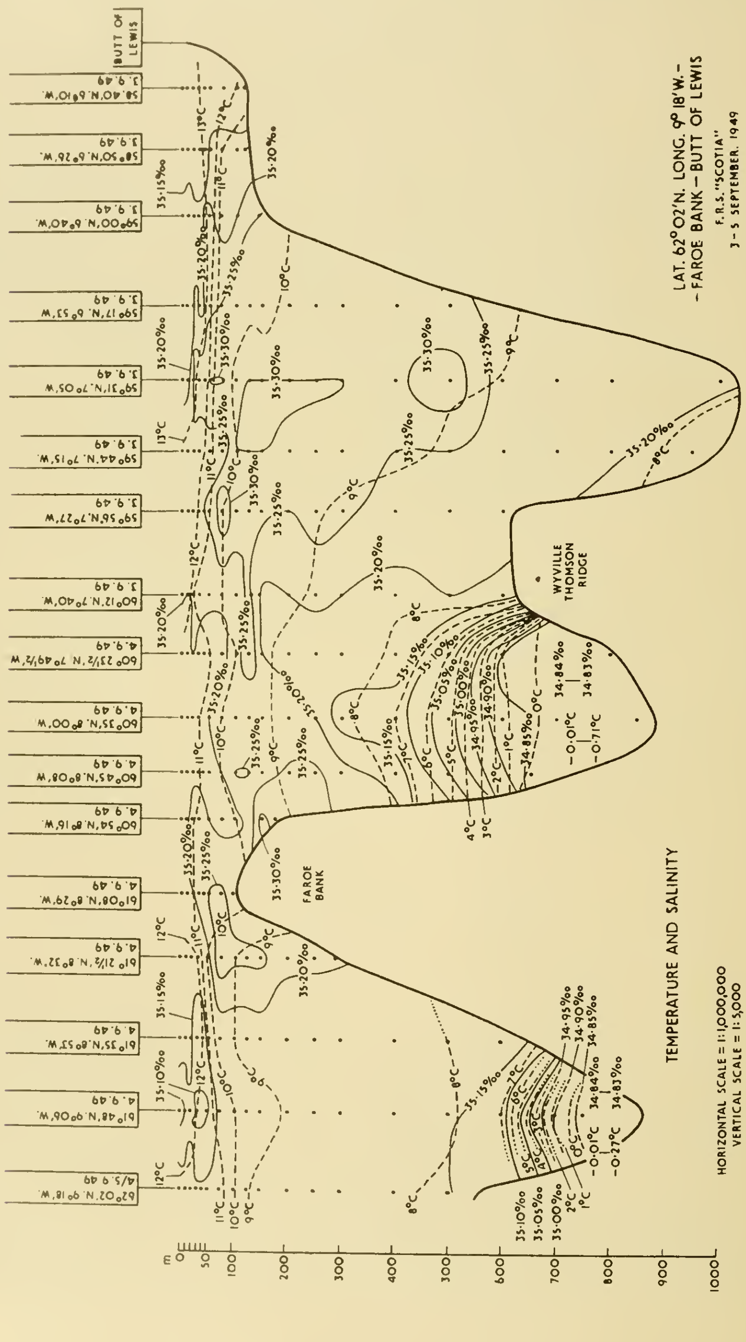

Fig. 7

not in fact at all times bypass the Channel in its eastward trend across the southern reaches of the Norwegian Sea.

Except for a single 34·89 ‰ record in August 1948, this year appears to have been devoid of any Arctic water in the Channel, but in early March 1949 (Fig. 5), deep water conditions there were radically different from those normally anticipated. The expected Norwegian Sea water bottom layer was then entirely displaced below about 350 to 700 metres by the Arctic water-mass, being sandwiched in a narrow undulatory band in cross-section between it and the uppermost oceanic water-mass. Not only so, but apparently still another water-mass of still lower temperature and lower salinity (34·79 ‰ to 34·84 ‰) than the above-defined Arctic water-mass seems to have underlain to some extent the latter in the deepest part of the Channel against

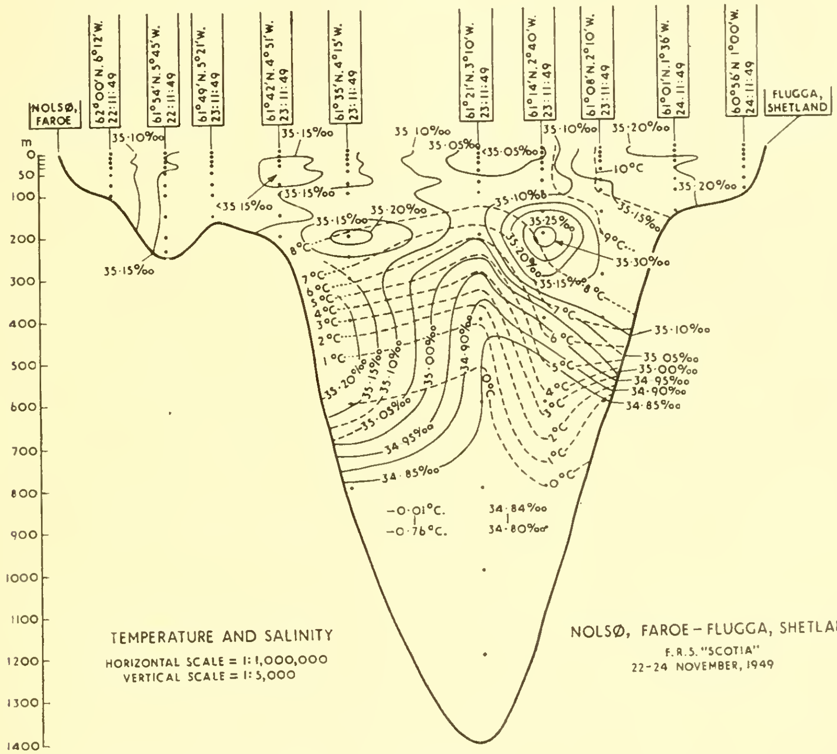

Fig. 8

the bottom of the continental slope. There is sufficient reason to designate this new water-mass surface Arctic water, thus distinguishing it from the intermediate Arctic water-mass immediately above it in the Channel region. At the end of April 1949 the intermediate Arctic water-mass was located at the southern extremity of the Channel, in its toe, so to speak, between the Wyville Thomson Ridge and the Faroe Bank. Five months later, in September 1949 (Fig. 6), not only did surface Arctic water occupy more than half of the deep-water cross-sectional area of the northern part of the Channel, the two Arctic water-masses together there again 'supporting' only a narrow band of Norwegian Sea water beneath the oceanic mass—except against the continental slope where surface Arctic water appears to have been directly contiguous with the underside of the oceanic layer—but surface Arctic water also, as distinct from intermediate Arctic water, was encountered in the deep toe of the Channel as well as in similar depths of the other, i.e. north-western, side of Faroe Bank, the Butt of Lewis to Faroe Bank section having on this occasion been extended considerably northwestwards (Fig. 7).

By November of the same year (Fig. 8), the surface Arctic water-mass *totally* underlaid intermediate Arctic, Norwegian Sea, and oceanic waters across the northern part of the Channel, there being relatively very little apparently of either of the two sandwiched water-masses present at all.

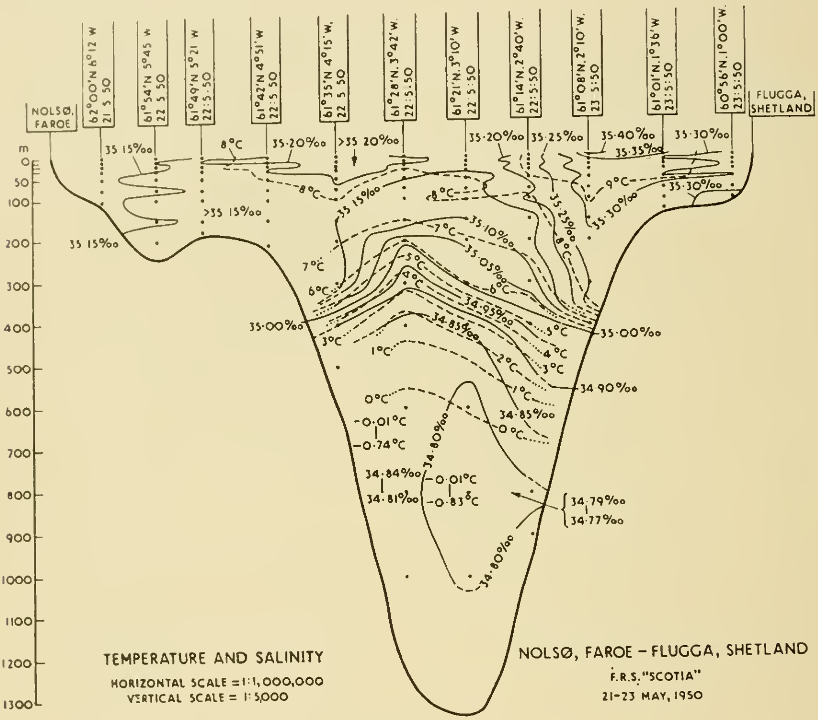

Fig. 9

This was still relatively the position in the latter half of May 1950 (Fig. 9) with, however, a substantial cross-sectional area of still lower (34·79‰–34·77‰) salinity water within surface Arctic mass, probably indicating still more intensive influence from this source than in the previous year in the deeper Channel layers. By the beginning of the following August there were signs on the northern section of Norwegian Sea water beginning to displace both types of Arctic water along the continental slope to the considerable depth of nearly 1,100 metres, although the latter, i.e. the Arctic waters, still formed the main bulk of the bottom waters over the greater part of the section.

Three months later, in November 1950, only the intermediate Arctic water-mass and no surface Arctic water, was found on the northern section, and even this was in process of cleavage in mid-section by Norwegian Sea water as illustrated in Fig. 10.

The intermediate Arctic water-mass was entirely absent from the toe of the Channel by May 1951, and almost totally excluded by Norwegian Sea water from the depths of the northern section in June. There was no evidence whatever of its presence on the same section by the month of October, and only an isolated trace appeared two months after.

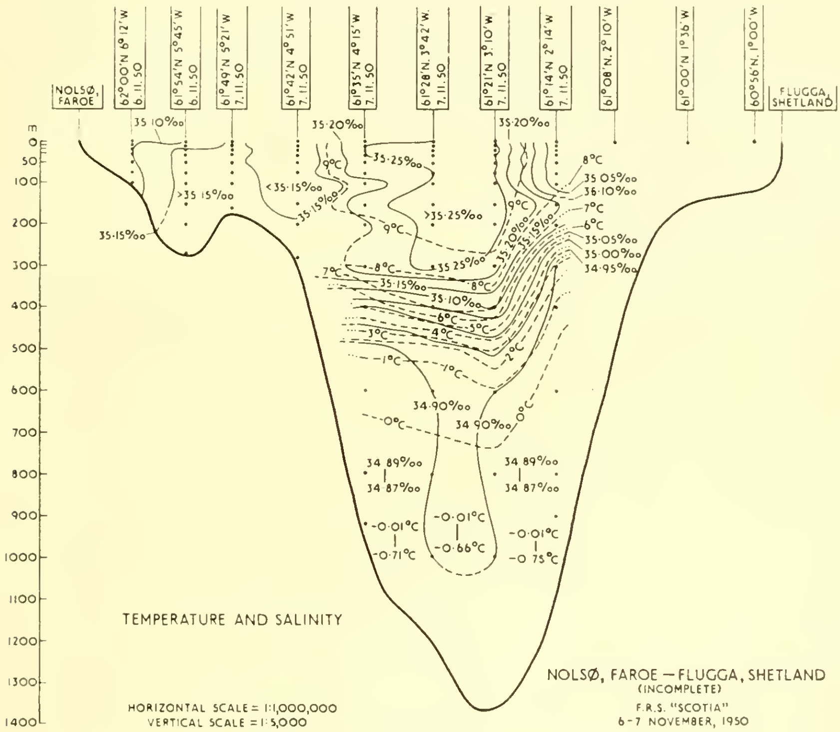

Fig. 10

A return of both Arctic water types was recorded along the entire length of the Faroe-Shetland Channel in May and June 1952, but both were obviously receding from the region one month later, and towards the end of the year had left only isolated " nuclear " traces within the Norwegian Sea water-mass.

Once again, then, a phenomenon has been witnessed over a group of years which seems not to have been in evidence for at least a number of years previously: and at all events in respect of the Faroe-Shetland Channel region, the conception of long-term trends and changes in hydrographic, including dynamic, conditions seems amply to be in accordance with observational facts. Only systematic and sufficiently intensive and continuous observations on similar lines to those practised in the past few years particularly can serve further to elucidate these interesting and doubtless, in several respects, more or less highly important geophysical phenomena.

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