CHAPTER 8

THE PATTERN OF OIL DISCHARGE AND OIL MOVEMENTS FOLLOWING THE WRECK

The oil which escaped from the 'Torrey Canyon' was driven by the tidal movements of the water on which it lay and by the wind. Although, as is indicated later, tidal movements alone can give an appreciable to-and-fro movement of the oil with sometimes a residual movement remaining at the end of a tidal cycle, the movements of the oil over periods of several days will usually be determined mainly by the wind. In Fig. 32 are shown, from the excellent observations* made by R.A.F. Coastal Command based at St Mawgan, Cornwall, successive positions, for times between 20 March and 8 April 1967, of the very large patch of oil which was released from the 'Torrey Canyon' between the time when the tanker struck the Seven Stones Reef on 18 March and the evening of 20 March. By measuring the distances and directions between points marking the approximate centres of this patch on different occasions, the resultant oil movements between known times were determined. Over the same periods of time, vectors, giving wind distance (velocity of wind × time) and direction, were added geometrically to give resultant wind distances and directions with which the corresponding distances and directions of oil movement could be compared. For this purpose the wind velocities and directions were taken for 6-hourly intervals from the observations made at the land meteorological station nearest to the oil patch. The results of such comparisons are given in Table 26 (p. 161), which shows that the oil movement could have been very well predicted by assuming that the oil always moved in the same direction as the wind but with about 3·4 per cent of its velocity. This agrees well with the measurements made by Hughes (1956) on plastic envelopes floating close to the surface of the Atlantic Ocean. He found that the drift of such plastic envelopes was parallel to the surface winds, and that the velocity of drift was about 3·3 per cent of the velocity of these winds. The small difference between the factors 3·4 and 3·3 per cent indicates that the oil moves with almost, if not exactly, the velocity with which

* Different observers gave very consistent results for the positions of the heavier concentrations of oil. The observers themselves noted, however, that there was great difficulty in defining the areas of lighter pollution. Weather conditions, the state of the sea, and the criteria adopted by different observers all greatly affected the answers given.

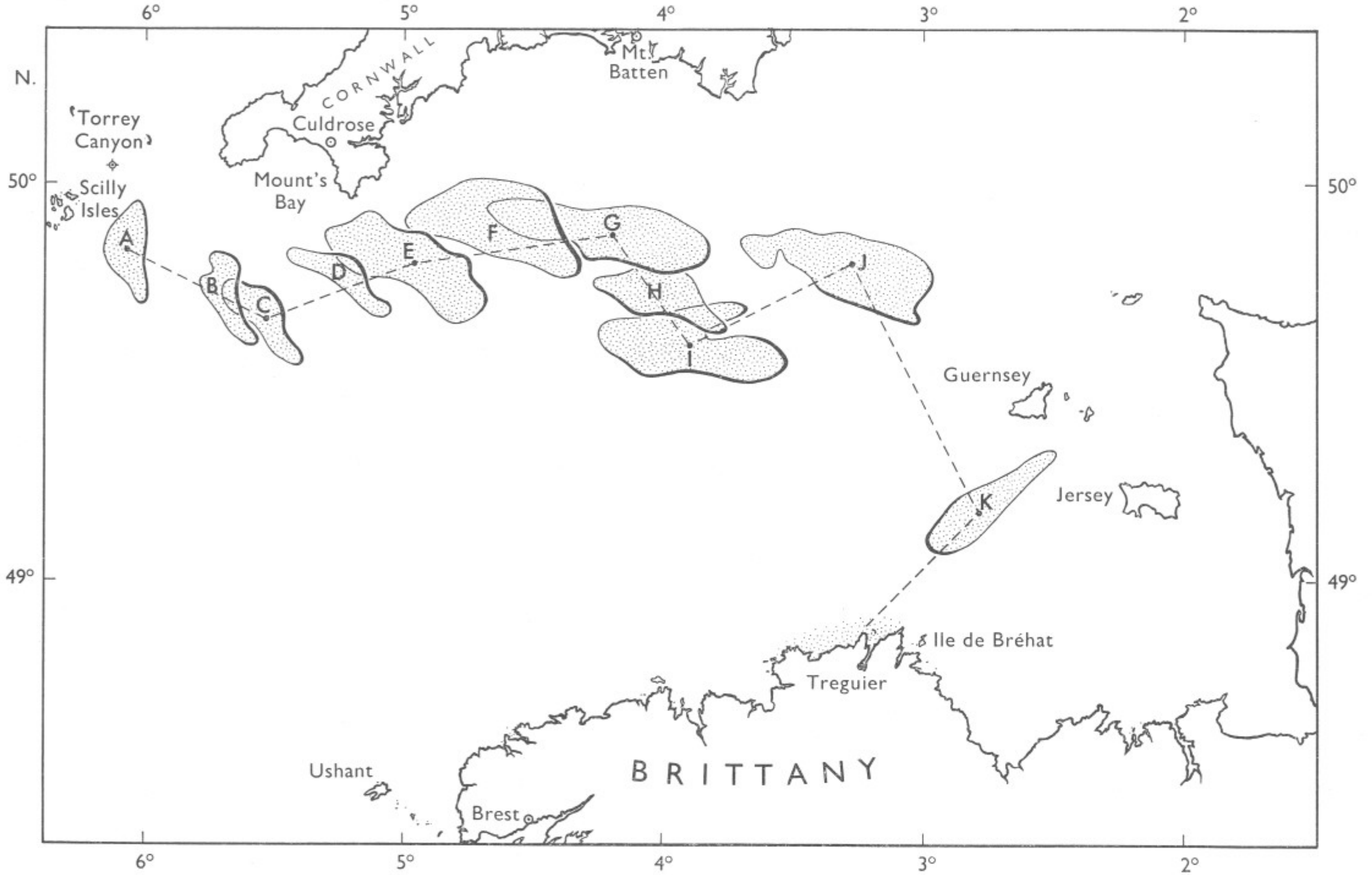


Fig. 32. This diagram, which is based on observations made by R.A.F. Coastal Command, shows successive positions of a single patch of oil as it drifted under the influence of wind and tide up the English Channel. The times were: A, 20 March, 07.00 h; B, 22 March between 06.00 and 08.00 h; C, 23 March, between 06.00 and 07.00 h; D, 25 March between 06.00 and 07.00 h; E, 26 March, 13.00 h; F, 27 March between 06.00 and 09.00 h; G, 28 March between 05.45 and 11.00 h; H, 30 March between 06.00 and 11.30 h; I, 1 April, 09.00 h; J, 4 April between 08.45 and 11.50 h; K, 8 April about midday.

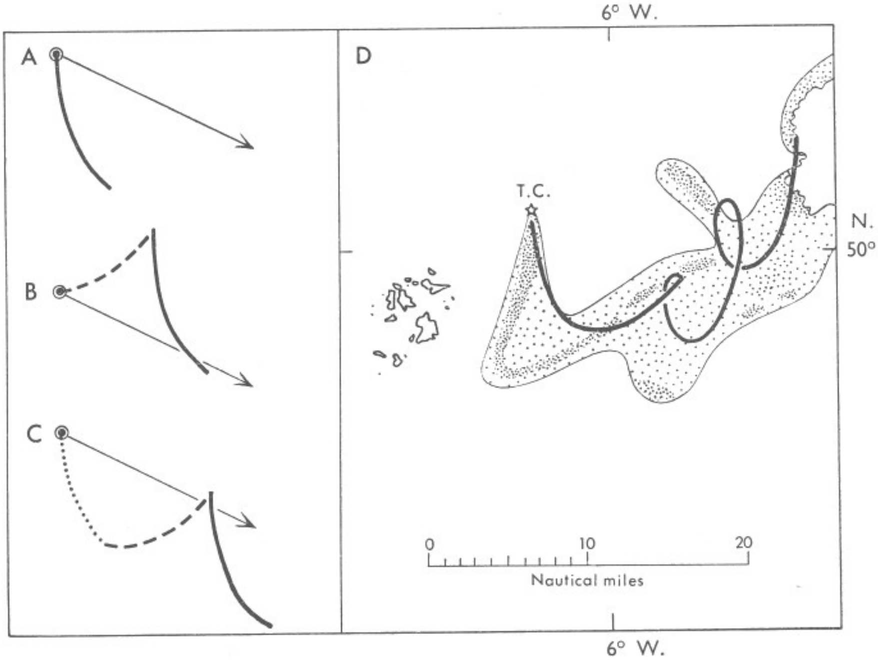


Fig. 33. A–C. If oil had leaked out of the ship at a steady *low* rate after 18.00 hours on 25 March and the wind had remained constant in direction and of strength 25 knots (in fact the wind was less strong and south-west over the first 6-hour period) the oil patch would be expected to have the shape shown: in A at about 00.00 h on 26 March, in B at about 06.00 h on 26 March, in C at about 12.00 h on 26 March. The patch of oil released in the first half tidal period is shown by the heavy black line; it is unchanged in shape in successive periods of time but pushed by the tide first to the north and then to the south of a line in the direction of the wind and passing through the wreck.

Fig. 33 D. Here we compare an actual R.A.F. plot of oil distribution close to the 'Torrey Canyon' made at 13.00 hours on 26 March with a line, calculated like those of A, B and C, but covering three full tidal periods before 13.00 hours on the 26th. We have taken account of the fact that over roughly the first two-thirds of this period the wind was south-westerly and of a force about 13 knots and later rose to 24 knots and became west-north-west. We have not allowed for the fact that the tidal streams closer to Land's End are stronger and have a set generally in a more westerly and easterly direction than those close to the wreck; if we had corrected for this, the calculated curve would certainly give a better fit to the actual observations. The oil was discharged in great quantities and has of course spread out after leaving the wreck.

surface water would move. There is therefore no reason to suppose that any change in the condition of oil as it becomes older would affect its velocity.*

Figures 33 A–C use these calculations to show the kind of effects which

* Following damage to the tanker 'Gerd Maersk' in 1955 8000 tons of crude oil were pumped into the North Sea. The German Hydrographic Institute of Hamburg followed the movement of the oil in the shallow coastal waters off Germany and Denmark and came to the conclusion that the oil moved with the wind at about 4·2 per cent of its velocity (Tomczak, 1964). It is hoped to discuss the differences between their results and those of this report in a later communication.

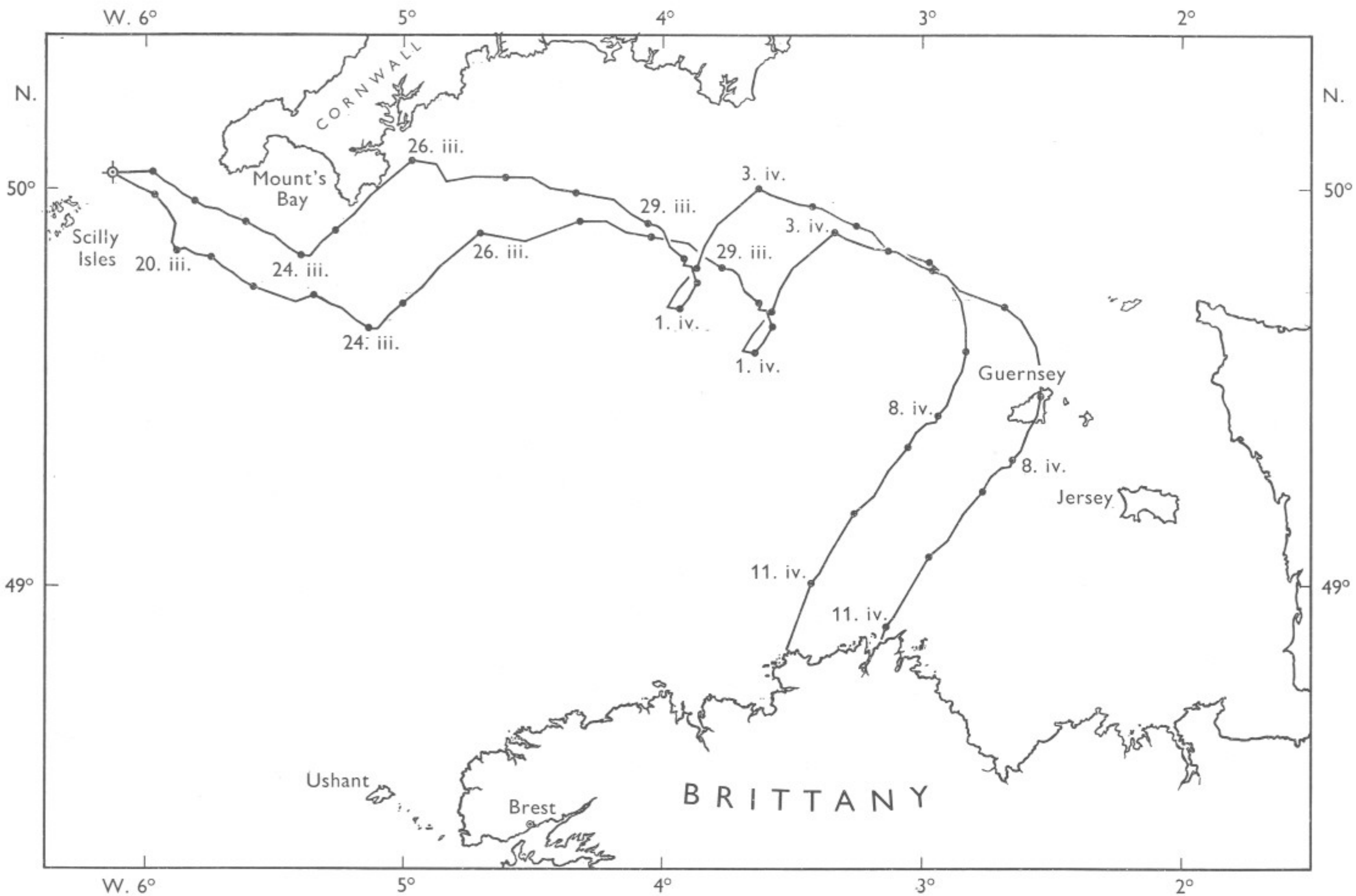


Fig. 34. These two tracks bracket the estimated movements of the oil which was released from the 'Torrey Canyon' between 09 00 h on 18 March and 12.00 h on 20 March. It has been assumed that the oil moved in the direction of the wind with 3·3 per cent of the wind's velocity. The dots on the lines mark 00.00 hours on successive days.

combined wind and tidal movements will have on oil movements, and Fig. 33D shows a plot of oil distribution made by Coastal Command on the afternoon of 26 March together with an estimated pattern of oil movement. It will be seen that the agreement is good except that the oil patch widened considerably as it moved away from the ship. A great part of this widening must certainly be due to the spreading of oil under its own weight. The effect of tidal movements and spreading of oil meant that the patches were often several miles wide and this should be borne in mind in the discussion which follows.

Figure 34 shows how the oil released from the 'Torrey Canyon' between 18 and 20 March would have moved if it had been drifting under the influence of wind alone with a velocity equal to 3·3 per cent of the wind velocity. The plot shows that this oil, the first great volume released from the ship, would have failed to reach the English shoreline but that part would have fetched up on the Channel Islands and the rest around Treguier in Brittany on about 11 April, three weeks after release. (The oil did in fact land in Brittany around Treguier at this time, see Chapter 9).

Figure 35 plots, in a similar way, estimated oil movements for oil released between 21 and 25 March. This shows, for example, that oil released at the beginning of this period would have been blown on to the shores around Mount's Bay on 25 March while oil released later in this period would have been driven first along the north Cornish coast and then ashore on 26 March. There would, of course, be a great deal of oil driven on to the beaches around Land's End over this time. These estimates reflect very well the actual course of oil pollution over this period.

The two available official estimates of oil release agreed that the largest single loss followed the breaking of the 'Torrey Canyon' by storm on the evening of 26 March. This volume was given as 30000 tons in one estimate and 48000 tons in the other, and the later figure of about 48000 tons will be assumed below. Figure 36 shows how this oil would have moved under the winds which prevailed between 26 March and 12 April. For most of this time, since the oil was in the open sea, we have followed Hughes (1956) in taking our winds as two-thirds of the appropriate geostrophic winds calculated from the isobaric plots.* As the figure shows, this enormous volume of oil would have entered Mount's Bay, skirted the Lizard and then, during a long period of north-westerly, northerly and finally north-easterly winds, would have been pushed past Ushant well into the Bay of Biscay without touching land at all.

* The wind speeds calculated from isobaric plots agreed very well with the observations of neighbouring meteorological stations except for the sea area around Ushant, where the calculated speeds were consistently lower than those reported by the meteorological station at Ushant.

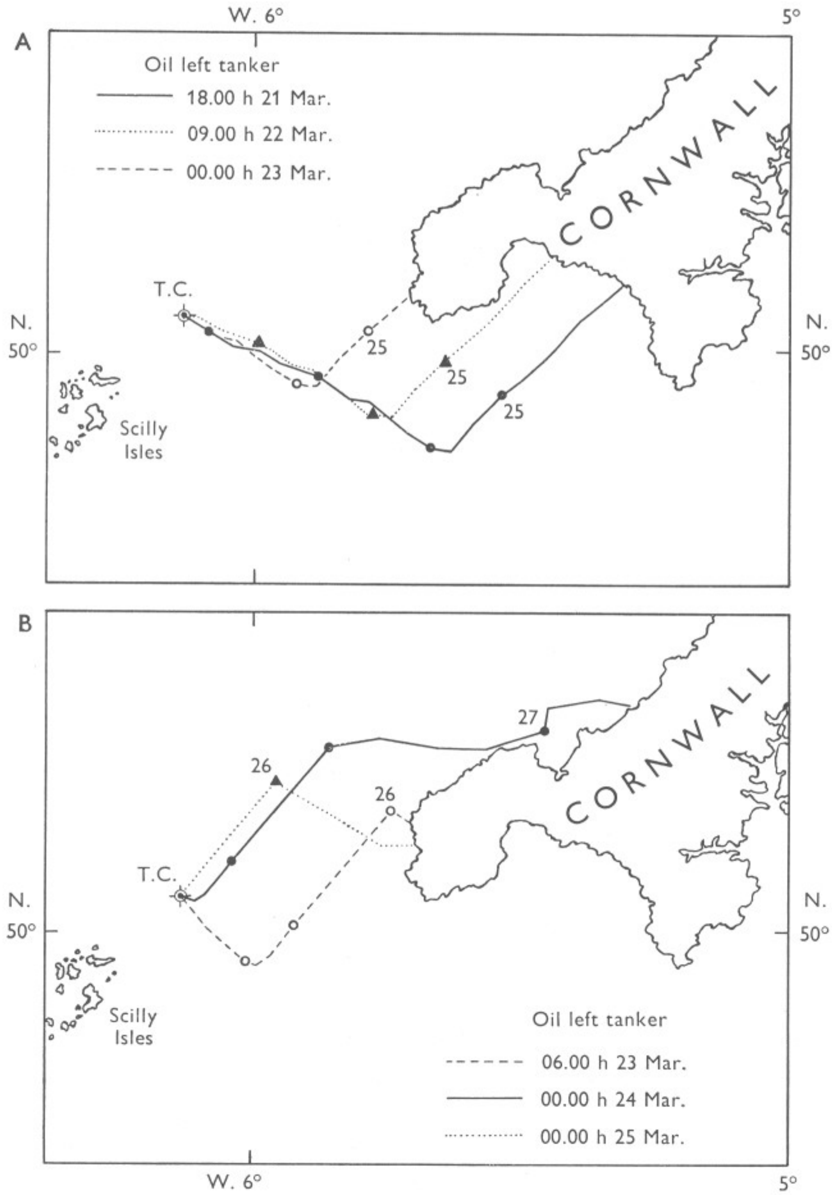


Fig. 35. A and B. This shows how oil leaving the 'Torrey Canyon', at various times in the period between 21 and 25 March, would have moved if it had travelled in the direction of the wind with 3·3 per cent of the wind's velocity. For an idea of how tides and the spreading of oil can affect such movements see Fig. 33D. The symbols on the lines mark 00.00 hours on successive days.

Fig. 36. This gives the estimated movements of the oil which was released from the 'Torrey Canyon' between 18.00 hours on 26 March and 00.00 hours on 29 March. This includes the oil released on the ship breaking up and most of the oil which was released (but not burnt) when the ship was bombed. It may be seen that this oil would not have reached any shore before passing Ushant. It has been assumed that the oil moved in the direction of the wind with 3·3 per cent of its velocity. The arrows give the directions of the tidal residuals at various places along the predicted path of the oil. The lengths of the arrows give the approximate distance by which the tides would have affected the oil movements. The dots on the lines mark 00.00 hours on successive days.

The air surveys showing oil distribution were mostly directed to finding the positions of patches of oil close to shore so that oil which had moved away from the shore is often not shown on the plots given by Coastal Command. It would have been almost impossible to interpret these surveys without some theory as to how the oil moved, and in no circumstance was

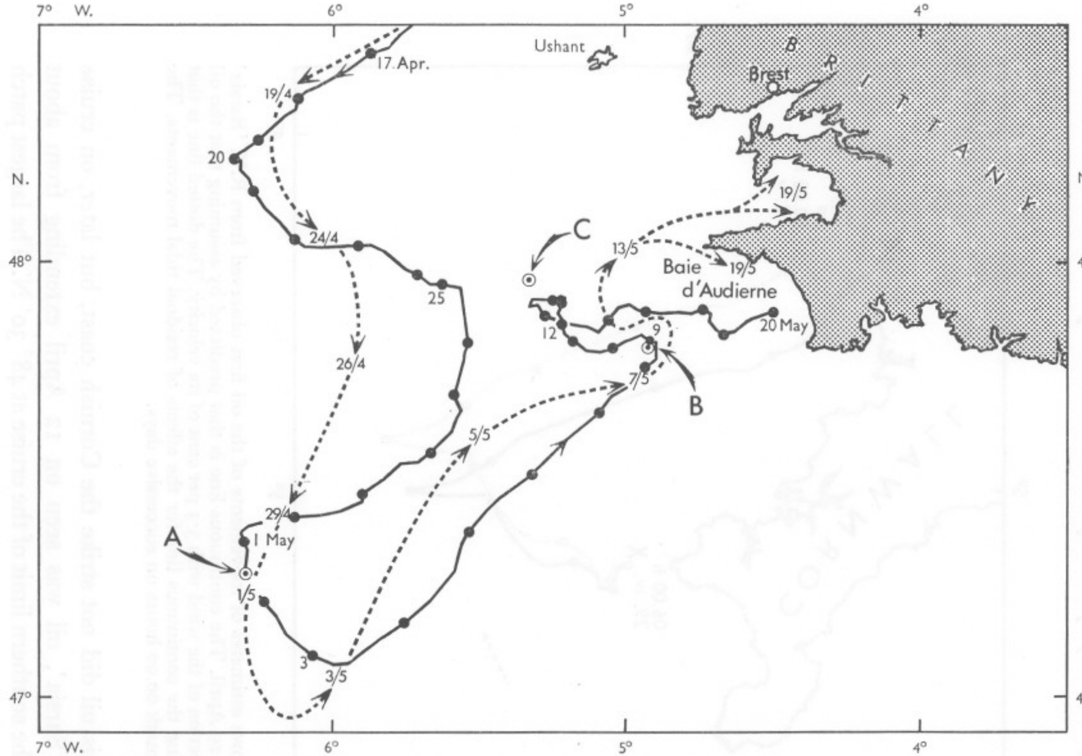


Fig. 37. This shows estimated movements of a large patch of oil which was observed in position A on 1 May by the French. It has been assumed that oil would move in the direction of the wind with 3·3 per cent of the wind's velocity. Estimates have been made working forwards to 20 May and backwards from 1 May to 17 April. B is the position of this oil on 9 May (given by French Navy). C is the position, on 12 May, of the largest 'patch' of oil seen from R.V. 'Sarsia' during a survey of oil in this region. The observed positions B and C are close to those predicted and the oil is shown as having come from the direction expected (see Fig. 36) of oil released from the 'Torrey Canyon' between 26 and 30 March. The dots on the lines mark 00.00 hours on successive days. The pecked line shows an actual track of oil movement as plotted by the French Navy and supplied to us after our own report had been completed.

this more true than in attempting to follow the oil released from the 'Torrey Canyon' during the period between 26 and 30 March. The air surveys do show, however, a very large patch of oil in Mount's Bay on 29 March and, at the same time, a large area covered with oil was seen in the same position (49° 35′ N., 05° 00′ W.) by the Plymouth Laboratory's vessel R.V. 'Sarsia'

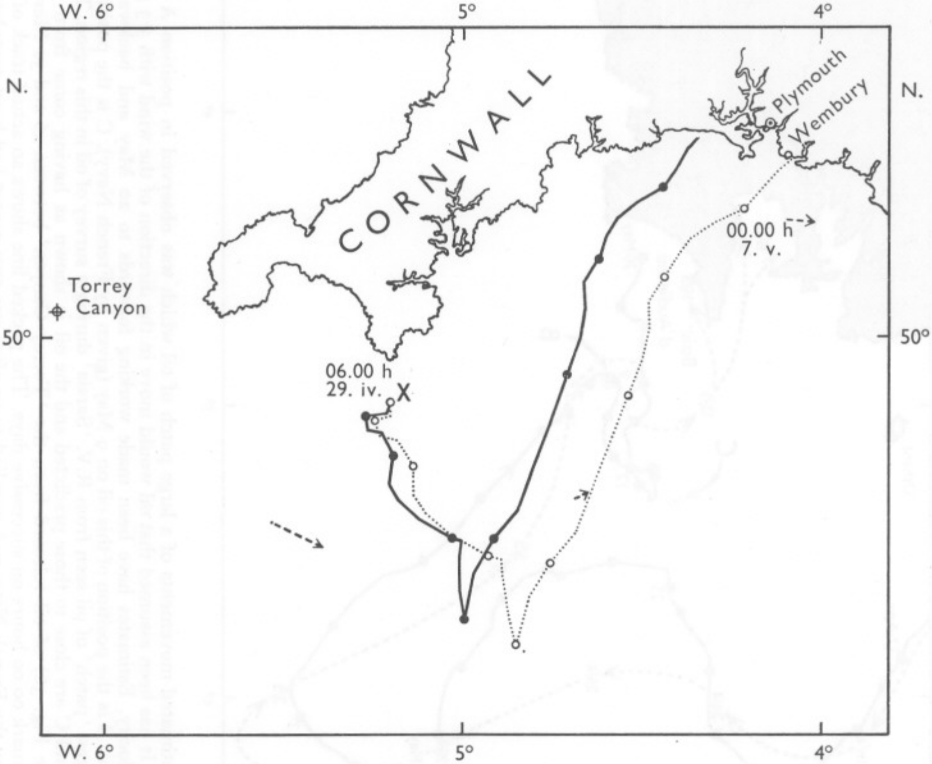


Fig. 38. This shows estimates of movements of the oil first observed from R.V. 'Sarsia' at position X on 29 April. The continuous line is that predicted by assuming that the oil moves in the direction of the wind with 3·3 per cent of its velocity. The dotted line is that given by correcting the continuous line for the effects of residual tidal movements. The dots on the line mark 00.00 hours on successive days.

(cruise I). This oil did not strike the Cornish coast, but later, on cruise III of R. V. 'Sarsia', oil was seen on 12 April extending from about 48° 50′ N. to the southern limit of the cruise at 48° 30′ N. The largest patch of oil seen was found at approximately 48° 50′ N., 05° 10′ W. This is most easily explained by its being 'Torrey Canyon' oil which had moved in the direction predicted by the plots shown on Fig. 36 but about 20 miles less far to the south. Beyond Ushant oil patches were followed by the French Navy and Air Force, and Dr P. Courtot of the Faculté des Sciences de

Brest has very kindly sent us some of their observations. On 1 May the French reported a main 'patch' of oil at 47° 17′ N., 06° 17′ W. (25 km by 1 km, with its long axis orientated at 260° and said later to consist of spots of oil 300 square metres in surface area and 3 cm thick) and secondary patches at 47° 35′ N., 06° 05′ W.; 47° 25′ N., 06° 35′ W.; and 47° 18′ N., 06° 48′ W. Starting from the position of the main patch of oil on 1 May, estimated positions of this oil, before and after this date, are shown on Fig. 37, where these estimates may be seen to agree well with observations of the oil patches.

On 29 April oil patches were observed off the Lizard and surface drifters were placed in the sea close to this oil. Figure 38 shows estimates of how this oil would have moved driven by wind alone (continuous line) and by wind and tide together (dotted line). These predicted that this oil would reach shores close to Plymouth on 7 May, and a little oil did in fact come ashore at Wembury three miles east of Plymouth Sound on 8 May. Several surface drifters were found close by in the days that followed but it is not known when these first came ashore.*

The observations and predictions shown on Figs. 32–38 and summarized in Table 27 are thus in good agreement with one another. If the main patch of oil reported by the French on 1 May (position A of Fig. 37) is identified as part of that found over a month earlier, on 29 March, in Mount's Bay, reliance on estimates based on the oil being driven by the wind alone at 3·3 per cent of its velocity would have indicated the direction in which the oil moved very well. It would, however, have overestimated the distance moved by about 20 per cent. Two likely explanations of this possible discrepancy are:

(1) A generally northerly current of the surface water opposing the southerly movement of the oil past Ushant. This current would have to have an average velocity of about $\frac{1}{20}$ knot to account for the whole discrepancy.

(2) A reduction in the ratio of oil velocity/wind velocity in conditions of sustained wind and high seas such as obtained in the seas around Ushant over the period following 6 April.

The Nature Conservancy report and our own observations show that, although the pollution was more extensive in Cornwall, the pollution was much heavier in Brittany. It was officially estimated that about 48 500 tons of oil were released between 18 and 26 March. Our estimates are that some 18 500 tons of this oil drifted towards the Cornish coast and that about 30 000 tons drifted up the Channel. Both of these masses oil were sprayed

* The first of them was found by a member of the general public at Wembury on 12 May, and the fact that a member of the Plymouth staff who looked for drifters a few days later found two more suggests that such drifters are not always quickly found by the general public.

at sea with large quantities of detergent. Even if we assume that detergent spraying at sea did not substantially reduce the oil mass, evaporation and detergent dispersal together would have reduced the weight of oil by some 30 per cent. Consequently, the maximum amount of oil which landed on the Cornish beaches can be estimated at some 13 000 tons, and the quantities reaching France and the Channel Islands at about 21 000 tons.

These estimates of the quantities of oil may be compared with the amounts of detergent used in Cornwall. Up to about 5 May about $2\frac{1}{2}$ million gallons of detergent were used—that is, about 10 000 tons—and a rough balance sheet would therefore read 13 000 tons of oil landing on our beaches with about 10 000 tons of detergent being used to disperse it. Now it seems that if the detergent is used to best advantage it can disperse about four times its volume of oil. We know, however, from our own and from other people's observations that ideal ratios of this kind would be impossible to achieve in practice and that detergent was often not used in the best conditions and was sometimes used in excess. The balance found between volumes of detergent and oil is therefore not a surprising one.

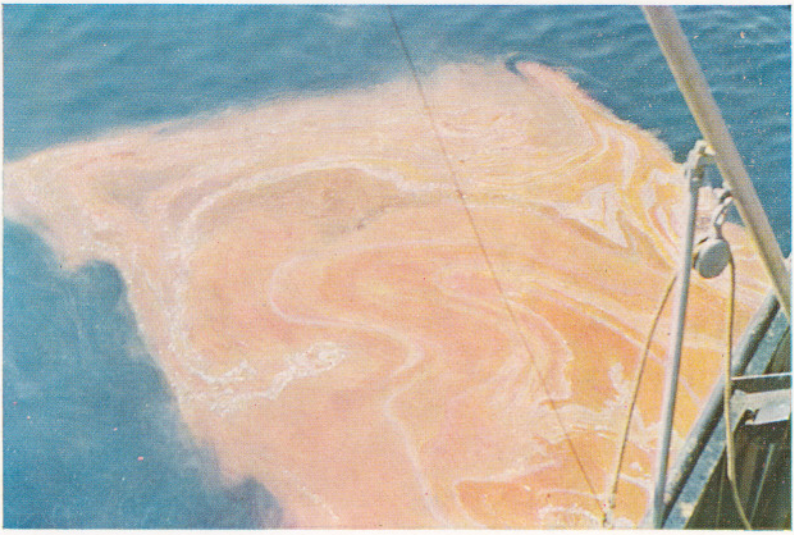
Thirteen thousand tons of oil may seem rather a small amount to cause so much damage but, when it reached the beaches, the oil was often in an emulsion whose composition was approximately 70 per cent sea water and 30 per cent oil, so that 13 000 tons of oil could give, for example, a continuous strip of oil-and-water emulsion 10 metres wide, 2 cm thick along a continuous length of over 200 kilometres of shore (cf. Figs. 8–10).

Although the pollution of our coasts was very serious we were greatly favoured by the fact that for most of the two months following the stranding of the ship the winds were northerly or north-easterly. If, for example, south-westerly winds had blown from 1 to 5 April the pollution along our shores would certainly have been three or four times heavier.

Conclusions

(1) Once a large patch of oil has been identified at sea its position subsequently can be predicted with fair accuracy by assuming that it moves in the direction of the wind at about 3·3 per cent of the wind's velocity. This means that very expensive blanket aerial surveys are not necessary since aircraft can be directed by predictions of the wind drift of oil. These predictions are simple to make and merely require wind speeds and directions which can be found either by calculation from the isobars on the meteorological charts or from the observations of wind by local weather stations. Allowance should, of course, be made for ocean currents and tidal streams where these are very strong.

(2) Patches of oil remain as patches for long periods. This is shown in



A

B

C

(*Facing p.* 161)

Table 26. *Assessment of oil movement in terms of wind movement (see page 150)*

Change in position of oil patch (Fig. 32)	Vector distance in nautical miles		$\frac{\text{Oil velocity}}{\text{Wind velocity}} \times 100$	Direction of movement	
	Oil	Wind		Oil	Wind
A to B	23·3	834	2·79	116°	120°
B to E	23·8	911	2·61	69°	73°
E to G	29·9	633	4·72	81°	98°
G to I	20·3	556	3·65	145°	152°
I to J	27·1	849	3·19	63°	70°
J to K	41·7	1081	3·86	153°	123°
A to J	227	6687	3·39	91°	95°

the successive observations such as those described on Figs. 32 and 37. It is certainly not safe to assume, as many people have done, that oil patches become very rapidly dispersed at sea.

(3) Even with moderate winds the position of a patch of oil can change greatly in a relatively short time. Thus the patch shown in Fig. 32 moved about 90 nautical miles eastward between observations A and I in about 10 days and the patch whose movements are shown in Fig. 26 moved southwards from the Lizard to Ushant in about 14 days. This means that, if coastal authorities are to be given reasonable warning of threatened pollution, aerial observations should not be confined to waters close to shore but that the main patches of oil should be followed at intervals decided from estimates based on wind velocities and directions.

(4) Boom defences are very worthwhile for, if pollution can be held at bay even for a short time, a change of wind direction may remove the threat entirely.

(5) If pumping of oil on to the sea ('Gerd Maersk'), or the bombing of a wrecked tanker ('Torrey Canyon'), or any other process which would release oil at sea is contemplated, the time at which this is done should be chosen in the light of the forecasts of winds. If for example, the 'Torrey Canyon' had been broken by bombing on 24 March and the oil contained in the ship released, then several times more oil would have polluted the English coastline.

PLATE 28

A, Biscay, west of Pointe du Raz, 47° 55′ N., 05° 12′ W., 12 May. Dense swarm of the planktonic dinoflagellate *Noctiluca*, as seen from R.V. 'Sarsia's' bridge. The white powder is craie de Champagne. **B**, 47° 55·2′ N., 05° 19′ W., 12 May. Similar view of *Noctiluca* swarm, with small lumps of oil. **C**, Trégastel-Plage (Côtes du Nord), 21 June. Machine skimming off surface layers of oily sand. In the sea is a milk-white detergent/oil emulsion formed after recent spraying of rocks to left of photograph. This drifted across the beach on the rising tide.

Table 27. *History of oil releases from the ship, and their subsequent fate*

Date of oil release	How oil was released	Where oil was blown ashore	When first blown ashore	When wind set offshore	Where oil was on 8 May	Rough quantities of oil based on official estimates
18 March 19 March 20 March	Ship aground 09.00 h 18 March; some oil tanks breaking and then ship subject to wave action and losing oil	Channel Islands and N. coast of Brittany	7 April 11 April	3 May	Mostly ashore in Channel Islands or France	30000 tons (about 21000 tons after loss of more volatile fractions)
21 March 22 March 23 March 24 March 25 March		Land's End S. Cornish Coast N. Cornish coast	25 March 25 March 26 March	29 March 29 March 8 or 9 April	Some ashore on Cornish coast (largely mixed with detergent and washed into sand) or dispersed at sea and widely spread	18500 tons (about 13000 after loss of the more volatile fractions)
26 March 27 March 28 March	Ship broken by storm approx. 19.00 h 26 March	Not ashore on 8 May	.	.	In Bay of Biscay	48500 tons (loss by evaporation was probably over 50% before this oil was dealt with by the French)
29 March 30 March	Ship bombed at 16.00 h 28 March and again on 29 and 30 March	A little on S. Cornish coast	2 April	13 April		20000 tons said to be mostly burnt by bombing