NATURAL SLICKS ON THE OCEAN

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ABSTRACT

Slicks are smooth glassy streaks or patches on the ocean. Prominent slicks are confined largely to near-shore areas where organic production is high. Experiments and observations are described which show that slicks are contaminate films of organic oil, probably derived primarily from diatoms which contain droplets of oil in their cells to assist in flotation and/or as an emergency food supply. Slicks are discernible because of their damping effect on small wavelets. The parallel slicks that develop in light to moderate winds result because the contaminate films pile up at the top of convergences in the homogeneous, wind-stirred layer above the thermocline.

INTRODUCTION

Slicks are smooth glassy patches or streaks on the surface of oceans or lakes which render a heterogeneous aspect to the water surface (Fig. 1). They are extremely common in coastal waters, bays, and lakes, often covering a large percentage of the surface, and they are most prominent when light breezes ripple the surface, the slicks damping out the small wavelets and forming a calm patch in water of higher surface roughness. Although observable from shipboard or from shore, they are most striking when viewed toward the sun from an airplane.

Although natural slicks are extremely common and widespread phenomena, they seem to have received little scientific consideration, since almost no reference is made to them in oceanographic literature. It is well known, of course, that artificial slicks form in harbor waters contaminated with refuse and oil; in some harbors these slicks create a serious fire hazard. In the open sea the wakes of ships are frequently marked by a slick for a considerable length of time after the passage of the vessel. In addition, artificially produced slicks formed by pouring oil on the water have been used by ships in distress, with doubtful success, in an attempt to prevent heavy seas from breaking over them. It is apparent even to the casual observer, however, that artificially produced slicks are grossly insufficient quantitatively to account for the great profusion of slicks encountered on the ocean. Frequently petroleum slicks can be distinguished from natural slicks because they often display high order interference colors.

Inquiries made of persons familiar with the sea produced no general conformity of opinion regarding the origin of natural slicks. Fishermen commonly ascribe them to local calm areas where the wind does not strike the surface; this opinion is held widely by yachtsmen also, many of whom, when racing sailboats, assiduously avoid these areas of supposed calm.[1] However, photographs of true slicks at short time intervals reveal that this "calm-spot" theory is untenable, because the slicks are persistent features which drift along with the surface current and change form rather slowly. Another common opinion is that they are related to oil seeps on the sea floor. It is true that extensive slicks, such as the one at Coal Oil Point near Santa Barbara, California, are produced locally by seeps, but obviously this does not serve as a plausible explanation for slicks in general.

Prior to undertaking the present study, it was the writers' belief that natural slicks were possibly films of oil derived from organisms in the sea, and because of the dearth of recorded scientific information on these interesting and widespread phenomena, it seemed worthwhile to investigate them further. This paper summarizes a few observations concerning the distribution and origin of natural slicks.

DISTRIBUTION OF NATURAL SLICKS

For the past few years the writers have recorded the distribution of slicks observed during rather extended journeys over the seas, and it was hoped that a study of their geographic distribution would yield significant information as to their cause. For example, if slicks are films of animal or vegetable oil, one would expect them to be most prominently developed in regions of high organic production, such as in coastal and insular water where upwelling and runoff supply the euphotic zone with nutrients. The following observations on the distribution of slicks demonstrate that this distribution actually was found to exist.

On a cruise to the Antarctic in December of 1946, rather prominently developed slicks were observed in the coastal waters of California, but they disappeared when the blue oceanic water was reached. Slicks were noted once again when the ship passed the Marquesas Islands, the only landfall en route to the Antarctic. As a general rule slicks were not observed in oceanic water, but some were faintly discernible in the South Pacific at Lat. 30° 48′ S and Long. 152° 24′ W when unusually smooth sea conditions prevailed. Upon reaching the

[1] In this respect slicks are apparently confused with true wind streaks or "cat paws." It should be noted here that smooth slick-like areas, such as those from tide rips and rip currents, frequently develop over turbulent water. The wake of a vessel is often smooth due to this surface turbulence as well as to the formation of an artificial slick from the ships' oil and refuse.

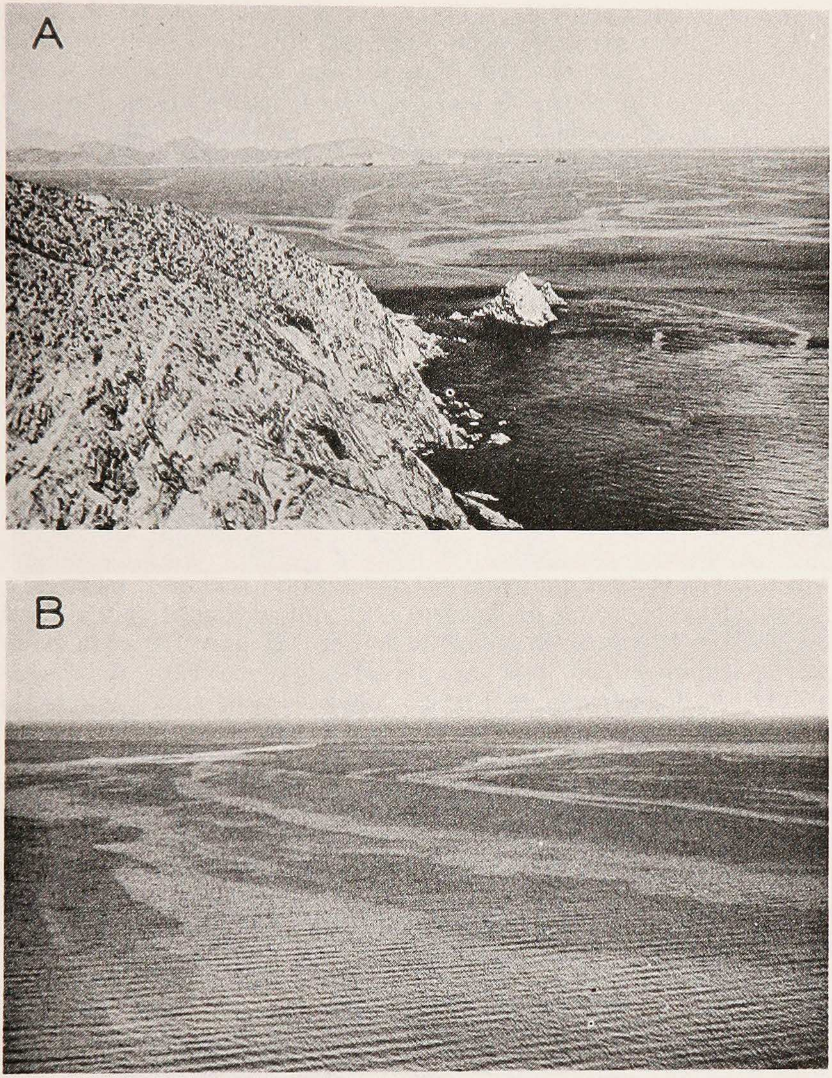

Figure 1.
Aerial photos of slicks in the Gulf of California taken with infra-red film, which accents the streaks. *A*. A prominent irregular pattern of slicks under quiet conditions in the lee of an island. *B*. The typical linear pattern of slicks under conditions of light wind. Official U. S. Navy photographs.

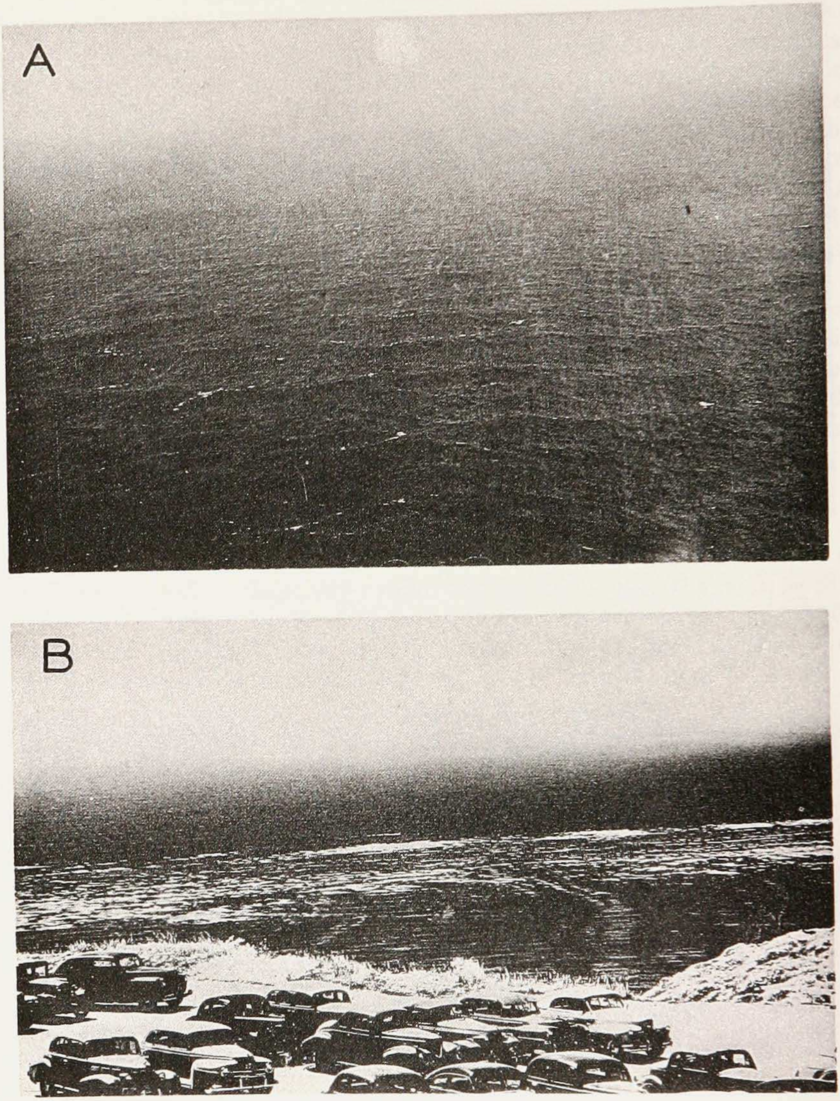

Figure 2.

Photographs of slicks off southern California. *A*. Slicks marking Cortes Bank, 100 miles off southern California. Note that slicks have lined up parallel to the wind direction. Incipient white caps show that sea state is Beaufort 3. With a further increase in sea state the slicks would be destroyed. *B*. Photo taken with infra-red film shows slick patches near San Diego, marking kelp beds which are formative areas for prominent slicks. Note also parallel slicks moving inshore from the kelp beds. Official U. S. Navy photographs.

green Antarctic water, where organic production is notably high in summer, prominent well developed slicks were frequently observed, especially near the ice pack. Aerial observers who were questioned reported generally good development of slicks in the near-shore waters. Slicks were seen but once on the high seas during the homeward passage; but these, found in a subtropical area (Lat. 20° S and Long. 175° W) under unusually calm conditions, were only faintly discernible. However, well developed slicks were found in Australian coastal waters, and especially striking slicks were seen in the insular waters of American Samoa. When the coastal waters of California were reached, prominent slicks were found again.

On a round trip flight from California to New Zealand in February 1949, the sea surface was examined for slicks whenever visibility permitted. They were noted from San Francisco Bay to a distance of 60 miles off the coast. They appeared again in the coastal waters around the southeastern Hawaiian Islands, especially on the leeward side, in the vicinity of the Samoan and Fiji islands, and near the New Zealand Coast. In only one oceanic area, between Lat. 25–30° S, were slicks strongly developed.

A cruise from San Francisco to the Hawaiian Islands and thence to the Aleutian Islands in July 1947 revealed an almost complete absence of slicks in the open Pacific. A moderate development of slicks was sometimes observed in the Bering Sea and, on the return passage along the coast, well developed slicks were observed in the Gulf of Alaska.

Throughout the coastal waters off southern California, where the writers have made numerous cruises and flights, slicks are widespread, but they are most prominent near the coast, especially in the lee of the kelp beds and around the islands. On one flight, a large bank (Cortes Bank) which rises to within a few fathoms of the surface was found to be marked by slicks (Fig. 2A). This suggests the possibility that slicks might sometimes furnish an indication of the presence of shoals.

Slicks are by no means entirely confined to the open ocean, because bays and fresh water lakes typically display the most prominent slicks. It is interesting to note, however, that during a recent flight across Great Salt Lake in Utah no prominent slicks were observed. This may be related to an unusually low organic productivity in this lake due to its high salinity.

It seems apparent, then, that prominent slicks are confined to the coastal and inshore waters and are largely absent from the deep oceanic waters where organic production is generally believed to be about one per cent of that of coastal water.

NATURE AND ORIGIN OF SLICKS

In order to ascertain whether slicks are contaminate films on the surface of the ocean, several surface tension measurements were made with duNouy surface tension apparatus, which measures the force required to pull a platinum wire ring off the surface of a liquid. The samples tested were collected from water surrounding the slicks, from water a meter below the slicks, and from water at the surface of the slicks themselves. It was found that all of the samples, when allowed to stand without agitation for at least several minutes, gave readings slightly less than the reported values for pure sea water; the water from the slicks gave the lowest values. It appears that sea water is generally covered with at least a monomolecular contaminate film and that piles of such a layer exist in slicks, thus forming a skin many molecules thick.

While collecting the water samples it was noted that slicks are typically marked by foam and that bubbles, formed by stirring the water, persisted for a much longer period than they did in the water outside of the slick. This further demonstrates the presence of a film. Further examination of the slicks reveals that they are found at zones of converging or descending water which are appreciably warmer than the surrounding water and which are marked by a considerable amount of floating sea weed and small particulate detritus.

In order to determine what substances in the ocean might produce slicks, the following experiment was performed. A chemically clean white enamel pan was filled with distilled water, the surface of which was then lightly sprinkled with talc. The surface thus prepared was touched with droplets of various crushed organic substances, including kelp, fish, zooplankton, and phytoplankton. In all cases, when the droplet touched the water, the talc-covered portion of the water in the immediate vicinity was rapidly repelled, showing displacement by the formation of a surface film. This indicates that a wide variety of organisms in the sea are potential slick producers. A crushed mixture of phytoplankton consisting largely of diatoms gave a particularly strong reaction. This is not surprising, for diatoms are known to synthesize droplets of oil in their cells to provide a food reserve and to assist in flotation (Sverdrup, Johnson, and Fleming, 1942: 765; Cupp, 1943: 26). Also, analyses of diatom lipids (Clarke and Mazur, 1941) show the abundant presence of free fatty acids and other substances that are potential slick producers. Because of the quantitative importance of phytoplankton in the ocean, it is believed that they are largely responsible for the production of slicks. Of course marine animals may also contribute oil to form slicks. In fact, the writers have noted that the spot where a whale has surfaced is marked by a faint but quite persistent slick. However, marine animals probably are quantitatively unimportant as compared to phytoplankton, and in any case, much of their oil results from grazing upon the diatoms.

It is interesting to note here that although the best slicks off California are associated with the kelp beds (Fig. 2), a sample of the giant kelp *Macrocystis* gave only a weak slick-producing reaction in the talc-covered water. It is likely, therefore, that the slicks associated with kelp beds may not be produced directly by the kelp but rather by the attached diatoms and other forms that abound in the kelp.

Droplets of oil released by organisms which are lighter than and immiscible with water must rise to the surface. Because water has a higher surface tension than that of any other naturally occurring liquid, many oils spread into a thin film. Any oil with a molecular structure which possesses a polar group and a nonpolar portion capable of self cohesion will tend to spread into a monomolecular layer if the sum of the air-oil tension plus the water-oil tension is less than the air-water tension. The rapidity with which the film spreads is proportional to the amount by which the air-water tension exceeds the sum of the air-oil tension plus the water-oil tension. The calming effect of an oil film on capillary waves increases with the air-oil tension. Lamb (1932: 631) quotes earlier writers as saying that the calming effect of oil on water waves is due to the *variations* of tensions caused by the extensions and contractions of the oil film.

Under completely calm conditions, the entire surface of the ocean appears smooth and glassy. Slicks are not readily distinguishable until small wavelets, which require a critical wind speed of about 110 cm/sec (two miles per hour) and essentially a zero fetch, are generated. Although slicks can sometimes be distinguished from the surrounding water by a slight difference in texture and color, they show up primarily when the damping out of small wavelets causes a smooth glassy patch on an otherwise rough surface. When light winds prevail, slicks have a patchy form, but as the winds increase they tend to line up into evenly spaced streaks parallel to the wind (Fig. 2). These parallel streaks apparently develop when the slick material collects along small wind-induced convergences associated with the helical circulating cells of water in the homogeneous layer above the thermocline (Langmuir, 1938; Woodcock, 1944).[2] If the

[2] Subsequent to the transmittal of this paper for publication, Ewing (1950) has given evidence to show that the slick bands form at convergences above the troughs of internal waves. However, since internal waves may be induced in large part by wind-induced circulation, Ewing's observations are not necessarily in conflict with the belief that the slicks form along wind-induced convergences.

sea state increases to three or higher, the slicks appear to be destroyed by the mixing associated with the formation of white caps.

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