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FOAM ON THE SEA

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Introduction

Strong winds are the most common causes of foam formation on the open sea. Breaking wave crests entrap air, forming a mass of white foam. The number and duration of the whitecaps thus formed are frequently used, in accordance with the Beaufort scale, to estimate wind force. Near shore, large quantities of foam are also produced by the action of waves breaking on the beach, especially on rocky shores. The duration and dissipation of patches of foam are of interest, not only as a reference for wind force, but because they offer an indication of the surface circulation and of the organic concentration of the waters.

Background

Sea water, unlike solutions of soap, oils, and fats, does not foam readily nor does the foam last long. By systematically shaking a filtered sample of sea water and studying photographic records of the foam produced, Abe and Miyake (1948) and Abe (1955) determined that the time necessary for sea water foam to dissipate to half of its volume, its half-life, is only 4 to 5 seconds. They further found that the half-life varies inversely with temperature and directly with salinity. When initially shaken, half of the bubbles are less than 0.2 mm. in diameter; after 6 seconds, the median diameter is about 0.4 mm. and, after 10 seconds, about 0.5 mm. Thus, the finer bubbles coalesce into larger ones.

Observations

In the Bay of Bengal, it was noted that, with a wind force of 4 and 5, the foam created by a breaking wave persisted from 3 to 10 seconds. However, at other places and under light wind conditions, patches of foam have been observed which persist for several minutes; also, long lines of slicks and foam are commonly observed in the coastal waters of India. These appear more prevalent off harbours and rivers, especially off the Godavari Delta. Here the water lines and patches of foam are found off rocky headlands and harbour entrances. In all cases, the foam at the surface appears to be related to sea surface slicks and to be concentrated by water circulation (Figs. 1 A-F, 2 G-K, N).

Relation to Slicks

Sea surface slicks are glassy patches or streaks on the sea. They occur on all oceans and lakes and are easily observed in periods of light wind. In such conditions the irregular patches of surface film damp the capillary wavelets causing brighter reflections of sky light from the glassy patches than from the rougher

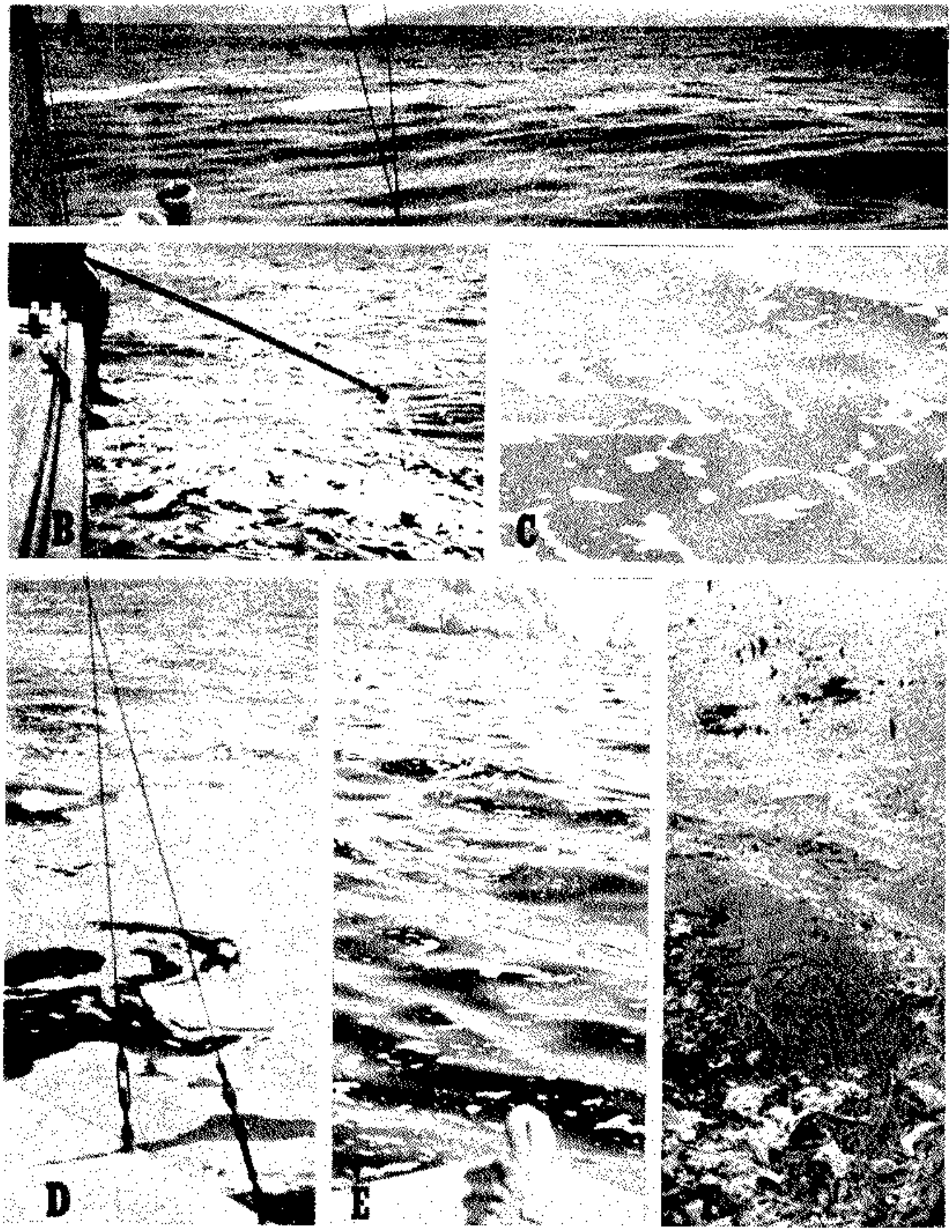

FIG. 1. Examples of Foam on the Sea.

A. Slick with series of foam patches. B. Irregular but continuous foam line in slick. C. Persistent dispersed foam in slick (off California coast). D. Patch of almost continuous foam cover. E. Persistent foam under light wind (off Mexican coast). F. Foam and associated kelp, eel grass, and discoloured scum.

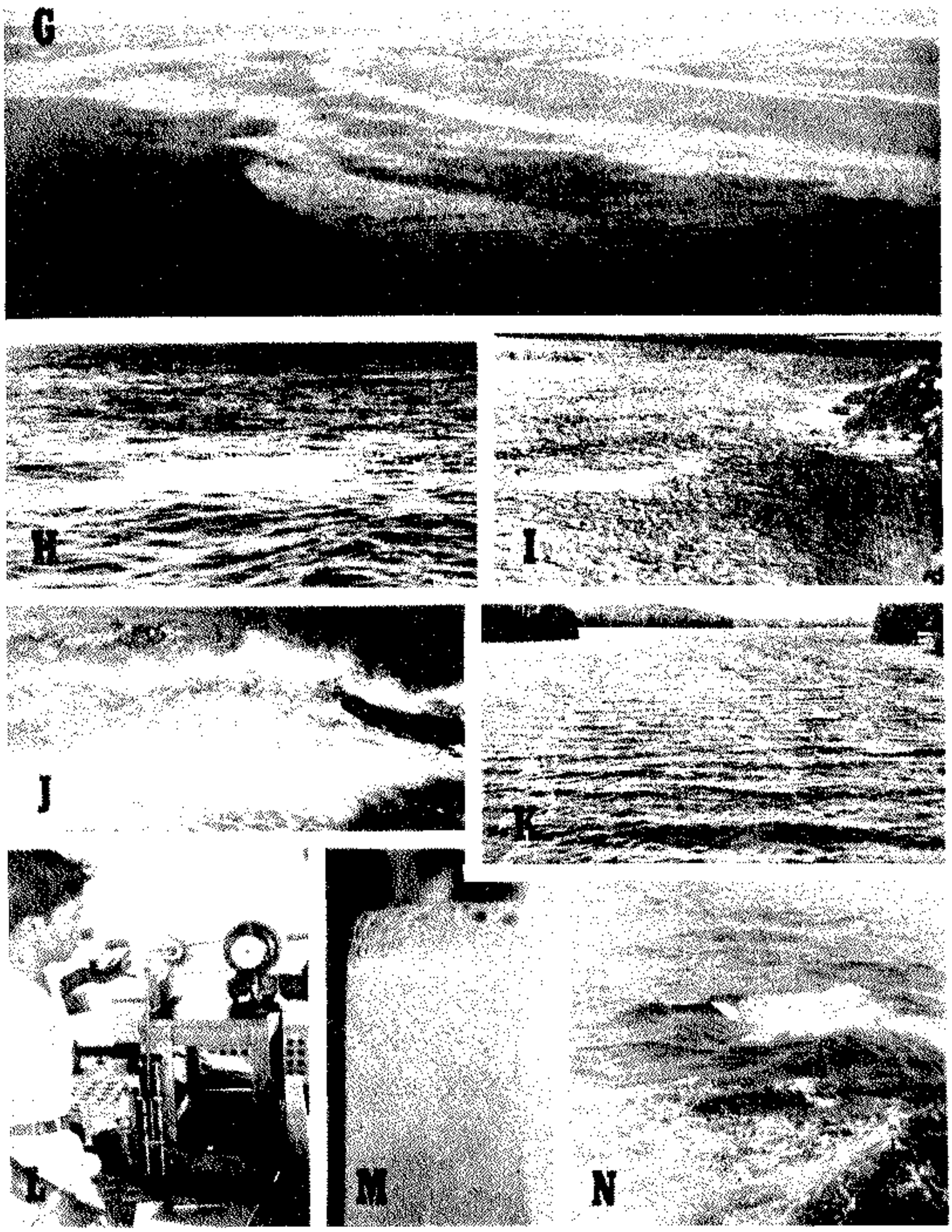

FIG. 2. Examples of Foam on the Sea and Foam Studies.

G. Slicks and foam lines similar to those off Godavari Delta. H. Concentrated patch of foam in the open sea. I. Concentrated patch of foam off Visakhapatnam breakwater (right). J. Breaking waves creating foam. K. Foam concentrated in wind slicks (in Canadian lake). L. Mechanically shaking samples of sea water for foam study. M. Foam layer produced by shaker. N. Breaking wind wave—the usual means of producing foam on the sea.

ones, thus making the rougher patches appear darker. At night, the phenomenon is reversed: the slicks appear darker than the surrounding water. Slicks have been described by Ewing (1950), Dietz and La Fond (1950), and Southward (1953). Their formation is attributed to the presence of a contaminating film in association with several types of water circulation.

One type of narrow slick is oriented parallel to the direction of strong wind. Such slicks are related to cellular near-surface circulation caused by the wind, and always have foam on them (Fig. 2K). However, the most common slicks are associated with a vertical or convergence type of circulation in which the surface water converges and sinks (Fig. 1A, B, E). This type of circulation is demonstrated by a lowering of the thermocline under a slick. Examples are shown in Fig. 3A, B.

Investigation of the relationship between internal waves and slicks (La Fond, 1959) has shown that a slick is associated with every major depression in a shallow thermocline. Although the position of the slick with respect to the internal wave varied, it was normally found to be slightly forward of the center of the trough. In fact, 80 per cent of all observations showed that sea surface slicks occur between the trough and the preceding crest of internal waves. This region corresponds to the maximum downward motion associated with simple internal waves. This phenomenon undoubtedly accounts for the long, glossy slicks observed off the east coast of India, and which have been described as rotary currents (La Fond, 1954). In some places, as off the Godavari Delta, convergences are created by the discharge of fresh water into the sea. At the water mass boundary, chemical reaction and large scale killing of organisms take place. As a result of this mass mortality, the sea surface in this region, observed from the air, resembles long, white rivers of foam parallel to the shore (Fig. 2G).

Although these visible organic films on the surface of slicks are normally only a few molecules thick, they may become thicker, depending on the organic content of the water at the surface and the sharpness of the convergence. For example, converging and sinking water concentrate the surface film in narrow lines, and the organic fractions, being lighter than the water, accumulate at the surface. In such areas, long lines of slicks, and in most cases, foam are found. The distribution of foam under these conditions, therefore, is an indication of convergent circulation, of the organic content of the water surface, and of the probable existence of a previously churned water mass.

Relation to Plankton

Organic production in the sea off the east coast of India varies greatly with time and locality; for example, off Waltair, the production of diatoms is most abundant in the spring and near the coast (Ganapati *et al.*, 1956). This is attributed to the high concentration of nutrients brought to this area by localized upwelling near shore. In March, the near-shore waters contain an abundance of phytoplankton, which is followed in April by a rich concentration of zooplankton. Therefore, more film and more persistent foam are likely to be produced in this season than during the rest of the year. Also, the patches of foam are frequently coloured, yellow or brown, indicative of the foreign matter present.

In April, it was noted that with a wind force 4, the foam duration of white caps was about 20 seconds in the upwelling zone as compared with 10 seconds

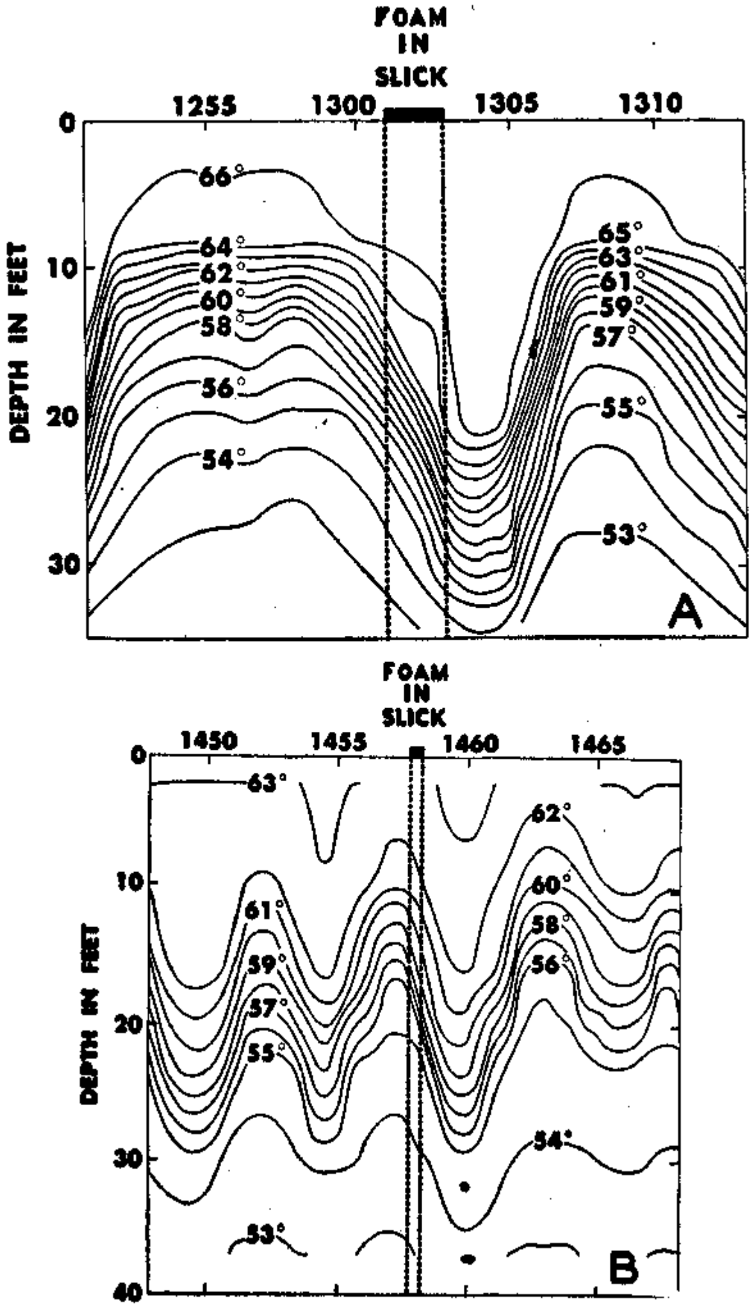

FIG 3. Examples of Vertical Temperature structure and its relation to the concentration of foam and slicks at the surface.

farther out to sea. This difference is attributed to the bubble-stabilizing effect of the near-shore plankton.

It is also quite possible that the accumulated organic matter undergoes decomposition with the formation of gas, which may account for the low pH in slicks.

Another source of bubbles is the seasonal spring heating. Water which is saturated with air and other gases in the winter becomes supersaturated as the water warms.

Gas bubbles may also be produced by the action of internal waves. If saturated water is brought up from one depth to a lesser one, the water may become supersaturated as a result of the decrease in hydrostatic pressure. This vertical displacement may amount to more than 30 feet in shelf waters.

In addition to the reduced pressure at the crest of internal waves, there is usually some turbulence associated with the thermocline. This is indicated by the distortion of objects when viewed through it as well as the distortion of a dye marker when it is dropped through the water. It is believed that this turbulence may trigger the liberation of gas in the form of small bubbles from water supersaturated by rising temperature or decreasing pressure. These bubbles may persist though clinging to organic matter and may remain concentrated in the slick.

Laboratory Tests

To study the nature of persistent foam in water off the east coast of India, samples of both the sea water and the foam were collected from the Visakhapatnam breakwater. Other samples were collected in the surf off Waltair, Lawson's Bay, and 20 miles offshore on oceanographic cruises conducted by the Andhra University.

The foam samples were microscopically examined and chemically analyzed for salinity, phosphate, and pH. In addition, parts of the samples were subjected to vigorous shaking in a specially developed electric shaker, similar to that used by Abe and Miyake (1948) (Fig. 2L). The foam resulting is shown in Fig. 2M.

The microscopic examination revealed large numbers of both phytoplankton and zooplankton and considerable amounts of copepods in various stages of decomposition and other detrital material.

The foam resulting from shaking sea water and that from shaking a mixture of sea water and foam from a plankton-rich area were compared. The half-life of the foam formed from foam-free sea water was about 3 seconds; that of the foam formed from the mixture of foam and water was greater. This demonstrated the effectiveness of plankton in reducing surface tension and prolonging the life of foam.

SUMMARY

Foam on the sea is produced in several ways. Wind-created whitecaps are, in the open sea, the most common kind of foam. Bubbles and foam may also develop from decaying matter which has accumulated in slicks, from heating of

the water, from surface and internal wave turbulence in gas-saturated water, from the reduction of pressure by internal wave motion, and finally from the interaction of water masses.

Sea water off the east coast of India does not readily produce foam, except when the water contains a high concentration of organic matter. Plankton blooms during the upwelling season are especially effective in stabilizing foam. At this time organic matter and foam become concentrated as a surface film or slick. This material reduces the surface tension and tends to retain any bubbles formed in the slick as well as those which are transported by convergence circulation into the slicks. Thus foam on the sea is not only an indication of wind force, but its persistence is also an indication of organic content and convergence circulation.

Acknowledgment

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