AERIAL PHOTOGRAPHS IN THE GEOLOGICAL STUDY OF SHORE FEATURES AND PROCESSES

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INTRODUCTION

IN RECENT years aerial photography has received ever increasing application to scientific work. Because aerial photos have many uses, they become an important and sometimes an indispensable geological tool. The aerial or bird's-eye view of terrain is an exceedingly useful one because from an aerial photo one can, at a glance, see patterns which would require long and tedious groundwork to unravel. Color, tone, shadow, and form on photos bring out much geomorphic and some bedrock data. Besides showing geological detail, the photos serve as useful base maps for plotting, and assist in ground travel as well. The aerial camera can be rapidly transported to even the most inaccessible areas. Also, aerial photographs permit taking the "field" into the laboratory, where specialists can make observations and measurements; then the photo may be filed as a permanent record. The writer's wartime flying experience with the 311th Photo Mapping Wing of the Army Air Forces has indicated to him that certain types of geological groundwork can be greatly simplified and expedited if high-altitude vertical photographs can be obtained, and if one can make low altitude visual reconnaissance flights during which the photographing of selected subjects is possible.

Aerial photos are especially useful in studying shore features and processes because of the presence of a wealth of physiographic features and because of the active processes which constantly change the shoreline. This is fortunate, as the geologist is keenly interested in this three-way boundary between the atmosphere, hydrosphere, and lithosphere. So much natural energy is expended in this zone that the shoreline is a birthplace of many physiographic features resulting from sedimentation or erosion. The geologist frequently refers to the present-day shoreline for help in unravelling the record of the ancient sequences of marine sedimentary rocks that now cover a large portion of the continents.

SHORE FEATURES

The most striking aspect of air photographs of shorelines is the camera's ability to see underwater features in shoal water. The depth to which submerged features may be photographed depends upon the intensity and the angle of incidence of light, the roughness of the sea surface, the nature of the bottom, and the transparency of the water. Photos taken away from the sun on clear days with quiet sea conditions show features at a considerable depth. Judging from the depth at which a white object, such as a Secchi disk, can be seen when lowered overside from a vessel, the depth at which the bottom is photographically discernible varies from a few feet in turbid water to 10 to 40 feet in phytoplankton-rich coastal water, and to 40 to 100 feet in oceanic water. In usually clear water, the bottom may be visible at even greater depth. When Navy ships first arrived at Bikini Atoll for the Atom Bomb tests, objects on the bottom could be seen at a depth of 180 feet. Oceanic water is most transparent to blue light with a wave length of 0.48μ, whereas coastal water is most transparent to green light of 0.53μ wave length or higher; thus film which is selective and is sensitive to such wave lengths is most satisfactory for photographing underwater features. Infra-red photography, which is so useful in penetrating haze, is of no value in under-

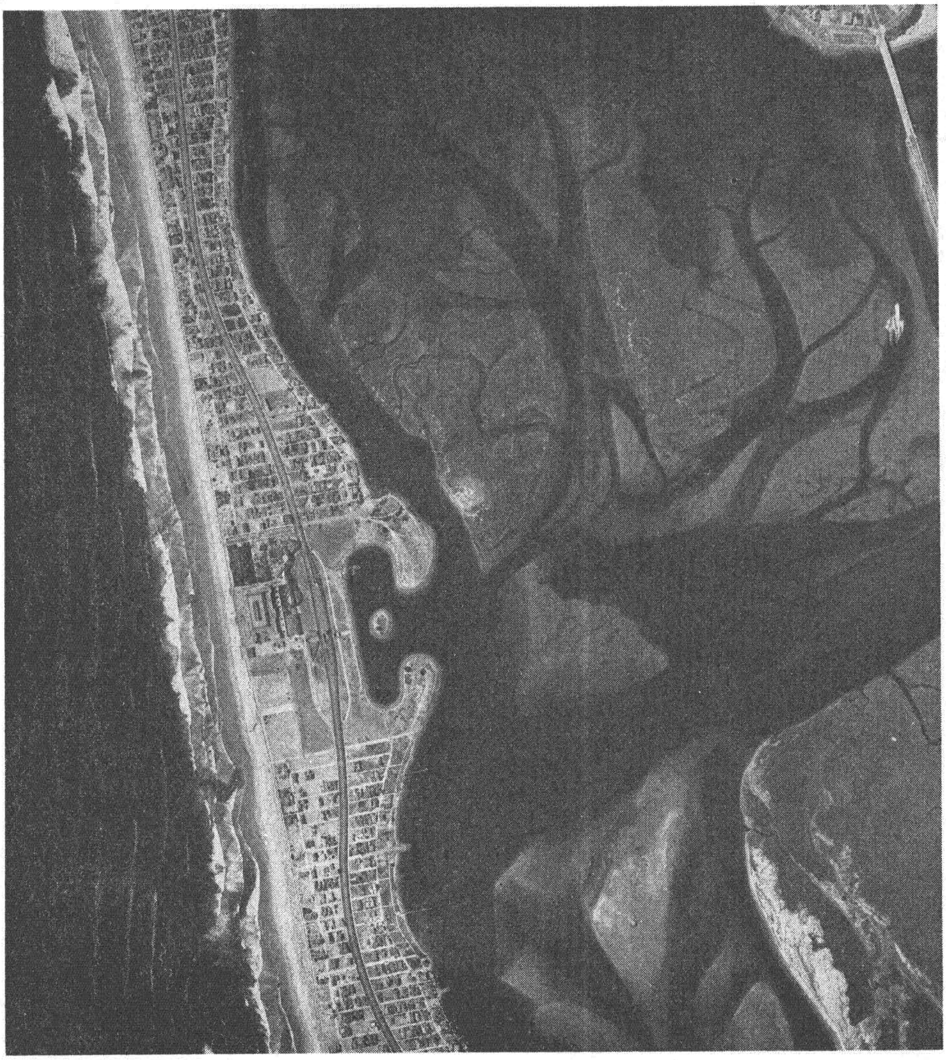

FIG. 1. A portion of Mission Bay, California, shows a tidal distributary system and a variety of other underwater features revealed by an air photo. Only the lightest areas are above water. U. S. Navy photo.

water work because such wave lengths are absorbed in the upper few centimeters of water.

Submerged features in shallow water bays and lagoons show up especially well from the air (Fig. 1). The coral reefs and the lagoon bottoms of Pacific atolls are also striking from the air. The Great Bahama Bank shoal often has the appearance of dry land, and the giant bottom ripples with the wave length and amplitude of sand dunes that it displays would excite the interest of any geomorphologist or sedimentologist. Along the coast of Florida on the Gulf side, bottom features can be seen many miles from land, and, near Miami, large saucer-shaped depressions are present which, above water, would have the appearance of the "hammocks" of the Everglades or of the "bays" of South Carolina. The aerial photographic coverage of such areas has great scientific value.

Even if aerial photos do not show the bottom, much information can be gleaned by indirect methods. Breaking waves usually indicate shallow reefs and banks; the deeper ones are indicated by refraction of the waves, by a decrease in wave length, or by a peaking of the waves. A reef may appear to be a source of circular waves. Some data regarding the depth of the bottom can be obtained by means of plunging breakers, the depth being equal approximately to 1.3 times the

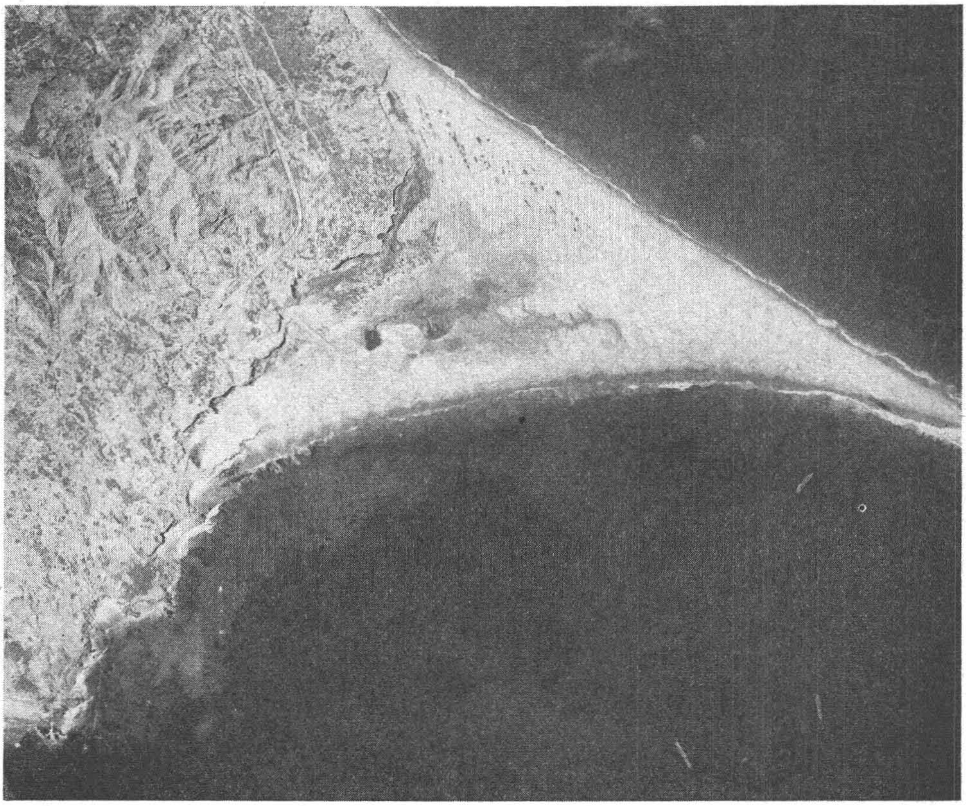

FIG. 2. This sand spit on San Nicolas Island off California is one type of feature formed by shore processes. Note the kelp bed (appearing as a black area) and the beach cusps on the concave beach. The cusps are ephemeral features produced by waves striking the beach at right angles and are destroyed by a change in wave direction. U. S. Navy photo.

height of the breaker. Information regarding the shore profile can be obtained by comparing aerial photographs taken at high tide with those taken at low tide. Along some coast lines depth of water and type of bottom is indicated by kelp; for instance, the large kelp Macrocystis usually grows on rock bottoms that vary in depth from about 25 to 100 feet (Fig. 2). Rea (1) states that kelp adhering to the off shore outcrops of Monterey shale delineates the Elwood anticline off the California coast at Santa Barbara and is clearly discernible on aerial photographs. For determining the suitability of beaches for landing operations during World War II, the Navy made extensive use of such indirect methods of obtaining bottom information from aerial photos.

Above water, shorelines display a wealth of both depositional features, such

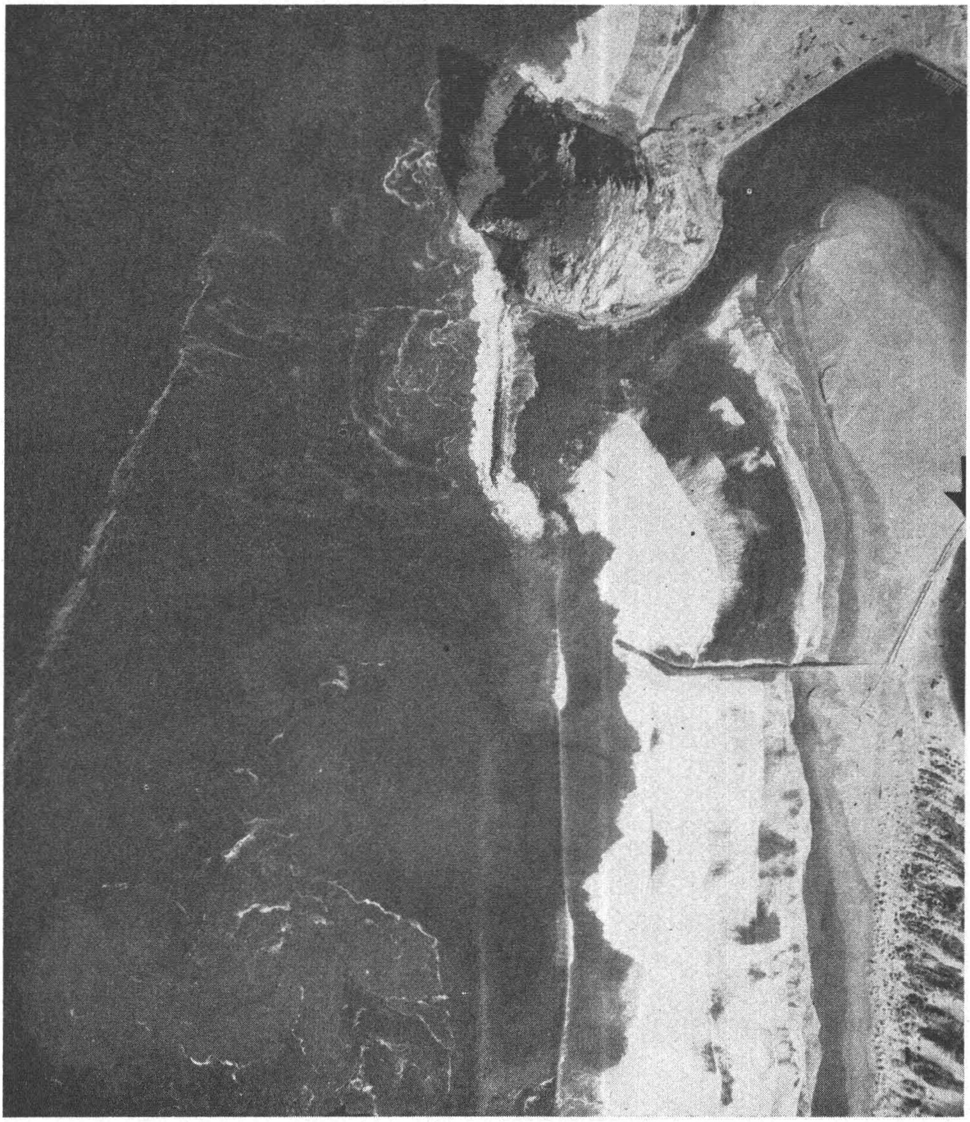

FIG. 3. Shoreline in the vicinity of Morro Bay, California, photographed from 12,000 feet during a period of large waves. Note large silty swirls of a rip current carrying sediment offshore. U. S. Navy photo.

as bars, beach ridges, tombolos, and spits, and erosional features, such as wave-cut terraces, sea cliffs, and stacks (Figs. 2 and 3). Such features are frequently found elevated well above sea level due to local earth movements or because sea level is at present lower than during previous interglacial times. Aerial photos are useful in determining the geographic distribution of these physiographic features. In this manner, much information can be obtained regarding the migrations of the wandering shoreline or the degree to which a shoreline has achieved equilibrium at its present position. From an aerial photo alone, one can usually classify a shoreline according to the system suggested by Shepard (2).

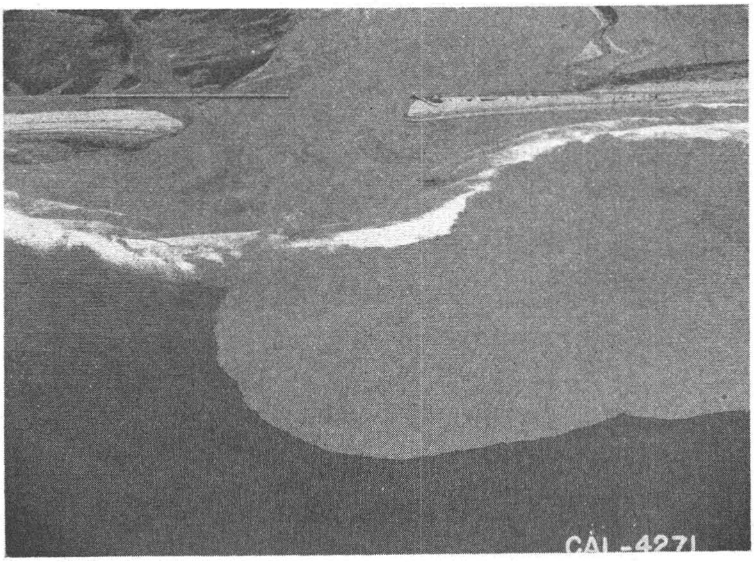

FIG. 4. Extent and direction of a movement of a water mass containing sediment transported in the ocean off the mouth of the Santa Clara River, California, is clearly outlined by an air photo. Photo by M. L. Natland.

FIG. 5. Turbid water mass off the mouth of the Fraser River, British Columbia. Three boats traversing the muddy water leave a clear wake which indicates that this silty layer is floating on denser (more saline and/or colder) sea water. Photo by R. E. McFarland.

SHORE PROCESSES

The study of shore processes is another phase of shoreline science in which aerial photographs are of importance. Waves constantly cut back the headlands and straighten the shoreline. Sediment carried out from the continents is sorted and transported. Aerial photos can be used for studying the transportation of this sediment along the shore, as areas of discolored water can be readily mapped especially if color-sensitive film is used. Also, it is possible to map the extent to which suspended sediment is transported out to sea by rivers (Figs. 4 and 5). In times of flood, discolored water has been reported hundreds of miles from land.

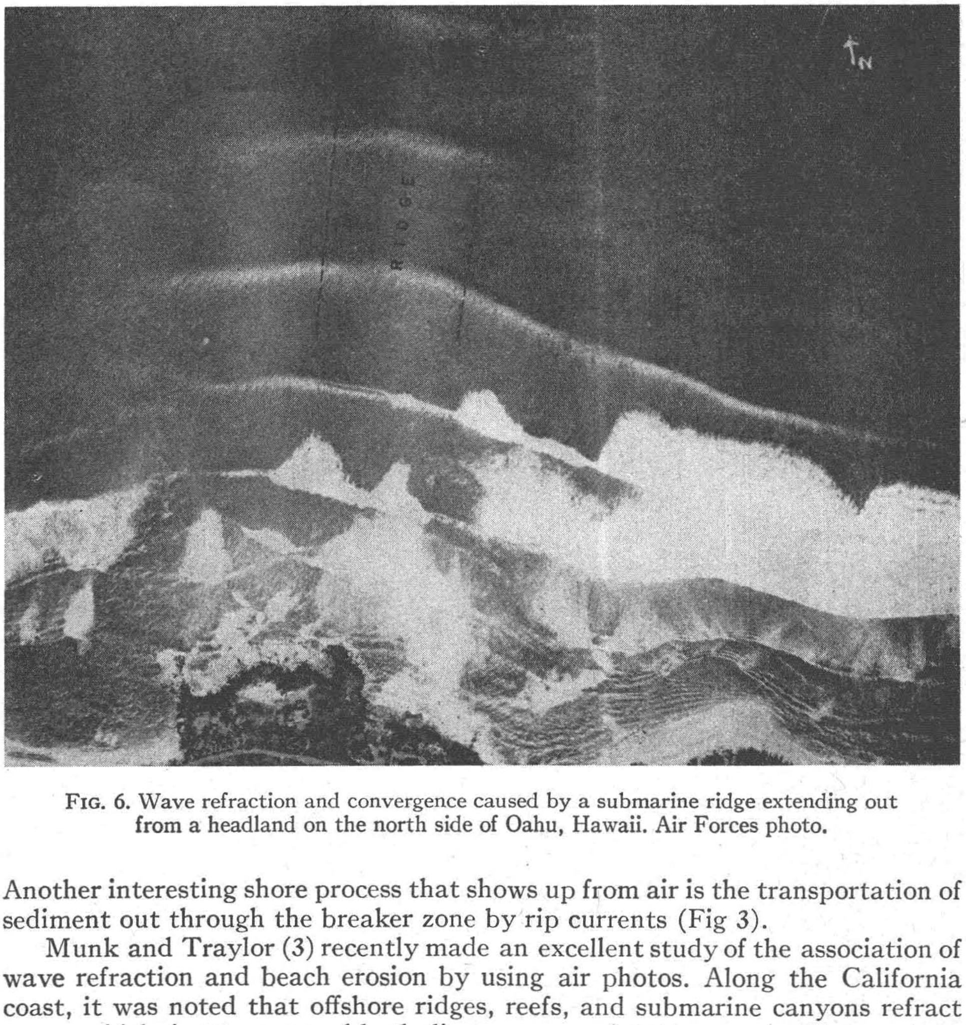

FIG. 6. Wave refraction and convergence caused by a submarine ridge extending out from a headland on the north side of Oahu, Hawaii. Air Forces photo.

Another interesting shore process that shows up from air is the transportation of sediment out through the breaker zone by rip currents (Fig 3).

Munk and Traylor (3) recently made an excellent study of the association of wave refraction and beach erosion by using air photos. Along the California coast, it was noted that offshore ridges, reefs, and submarine canyons refract waves which, in turn, caused both divergences and convergences. These writers showed that variation in wave height along the shore is controlled, in part, by sea-floor topography. Figure 6 shows that a submarine ridge extending out from a headland causes a convergence or a focusing of the waves, which results in rapid erosion of the headland. Figure 7 shows the effect of a submarine canyon on wave refraction.

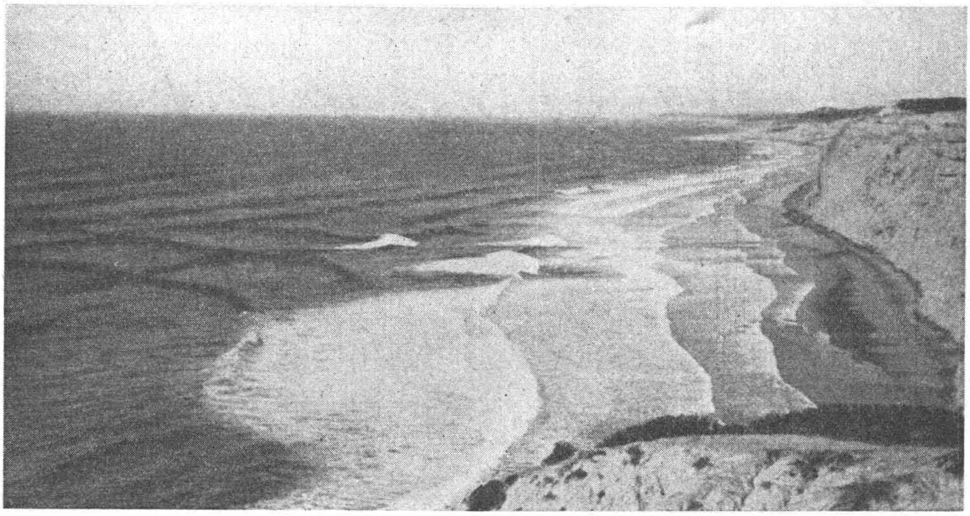

FIG. 7. Waves forming a cross pattern north of La Jolla, California. A highly refracted group of waves deflected by a shoal are crossing unrefracted waves moving into shore in the deep water over a submarine canyon. Photo by W. H. Munk.

SHORE CHANGES

An especially fruitful field for aerial photos is in the study of shoreline changes. A photograph is a permanent and detailed record which can be readily compared with other photographs of the same area taken at a different time.

Air photos taken of the same area of shoreline many years apart can be used to determine the rate of prograding or retrograding of a shoreline, or to determine the sand fill behind a breakwater or in a harbor. Diastrophic uplifting or sinking of the land can also be detected. The advent of aerial photography is so recent that there has not been a sufficient lapse of time to make such observations in most places so that comparative studies have had to make use of maps or ground photographs. Yet the comparative photos of Figures 8 and 9 display a

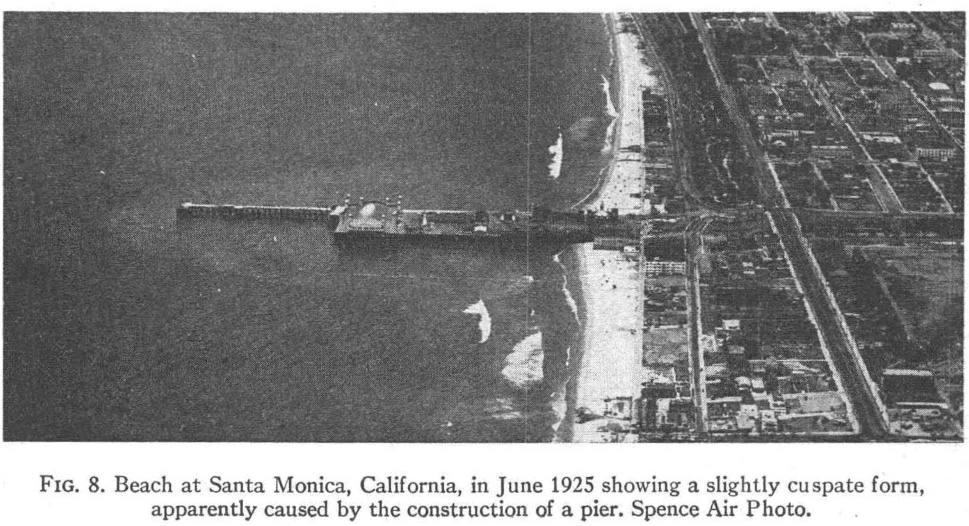

FIG. 8. Beach at Santa Monica, California, in June 1925 showing a slightly cuspate form, apparently caused by the construction of a pier. Spence Air Photo.

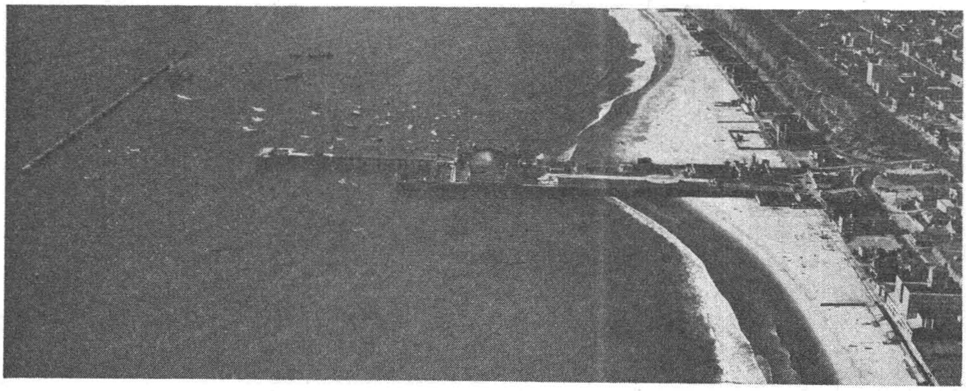

FIG. 9. Beach at Santa Monica, California, in October 1934 showing an extensive building out of the beach caused by the construction of a breakwater. Spence Air Photo.

marked change in the shoreline that has occurred in nine years at Santa Monica, California, due to the construction of a breakwater. Aerial photographs taken of the present shoreline will obviously be valuable in the future if properly filed and made available to the general public.

Important changes in the shoreline take place in a period as short as one year. Along the California coast many beaches undergo a cyclic building up during the summer and a cutting down in the winter; other beaches appear to have a seasonal shift in position. There is also a monthly cycle of slight building up and destruction of beaches related, to the periods of spring tides. Aerial photos taken at proper intervals would yield much information on these cyclic sand movements.

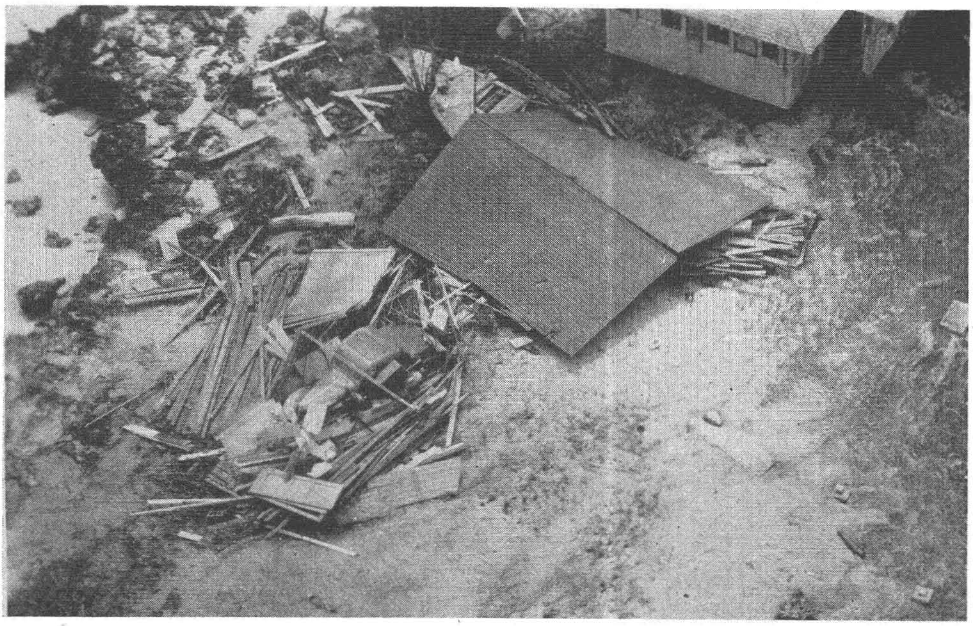

FIG. 10. Low altitude air photo of damage and sand transport inland by the Hawaiian tsunami (tidal-wave) of 1 April 1946. The sea lies to the left. U. S. Navy photo.

Photographs taken at intervals as short as a single day show interesting changes on the beach. For example, the beach cusps shown by Figure 2 are ephemeral features, developed by waves striking normal to the coast, and are destroyed by a change in wave direction. Excellent use can be made of aerial photos in studying shoreline changes caused by related tsunamis (so-called tidal waves) and by hurricanes or other storms (Fig 10).

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GEOLOGICAL MAPPING OF THE ROSS LAKE AREA, USING AIR PHOTOGRAPHS*

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THE Ross Lake area in the Northwest Territories was especially suitable for use of air photographs in geological mapping, because it showed a maximum amount of rock exposures, which were well glaciated and rendered bare by recent forest fires. The maximum relief is about 200 feet and generally less than 100 feet. The area had received a priority for geological mapping on a scale of 1 inch to 1 mile, because of its diverse mineral deposits.

No proper base map was available. The area was covered by oblique air photographs from which had been compiled a manuscript map of 2 miles to the inch, published at 4 miles to the inch. A geological map of the reconnaissance type, 4 miles to the inch, was available.

It was decided to photograph the area from the air, by a member of the Geological Survey with an ordinary camera to which a bull's eye level was attached. Individual air photographs were enlarged to an approximate scale of 1/6 mile or 880 feet to the inch. About 80 per cent of the area was thus covered by vertical air photographs which could be used as field maps, the geology of the remaining 20 per cent to be recorded on the foreground of oblique air photographs or recorded in notes along pace and compass traverses between points covered by vertical air photographs.

A photostat enlargement of the 2-mile manuscript map to 1 mile to the inch was made on which was traced the area covered by each 880-foot vertical air photograph. This was called an index map.

For the purpose of description the uses made of the vertical air photographs may be classified under three headings: Planning, Field Use, and Compilation.

PLANNING

Investigation of air photographs before actual field work permitted: A—to outline roughly the geology, B—to infer hypotheses later to be investigated in

* No base map available.