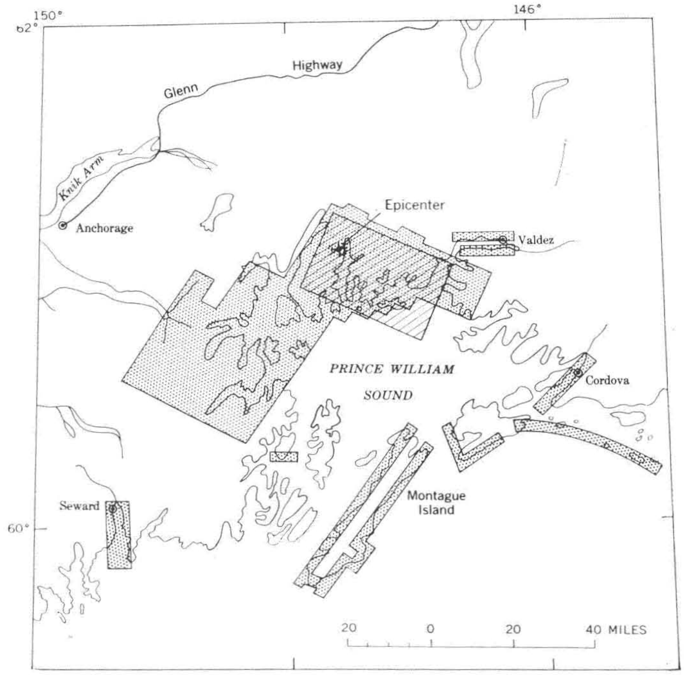
FIG. 1. Area covered by post-earthquake photography (stippled). Diagonal lines designate area of post-earth slides and avalanches around epicenter of earthquake (Figure 9).



ROBERT J. HACKMAN
U. S. Geological Survey
Washington, D. C.

Interpretation of Alaskan Post-Earthquake Photographs*

Uplifted shorelines were recognized where landslides overlapped the former beach lines.

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INTRODUCTION

AERIAL photographs taken after the March 27, 1964, Good Friday, Alaskan earthquake were examined stereoscopically to determine effects of the earthquake in areas remote from the towns, highways, and the railroad. The two thousand black and white photographs used in this study were taken in April, after the earthquake, by the U. S. Coast & Geodetic Survey and were generously supplied to the U. S. Geological Survey. Part of the photographs, at a scale of 1/24,000, provide blanket coverage of approximately 2,000 square miles of land area north and west of Prince William Sound, including parts of the mainland and some of the adjacent islands. The epicenter of the earthquake, near the head of Unakwik Inlet, is located in this area. The rest of the photographs, at scales ranging from 1/17,000 to 1/40,000, cover isolated strips of the coastline of the mainland and nearby islands in the general area of Prince William Sound.

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Figure 1 shows the area of new photo coverage used in this study. The objective of the study was to determine quickly whether geologic features resulting from the earthquake, such as faults, changes in shoreline, cracks in surficial material, pressure ridges in lake ice, fractures in glaciers and lake ice, and rock slides and avalanches, might be identifiable by photointerpretation. The study was made without benefit of comparisons with older, or pre-earthquake photography, which was not readily available for immediate use.

Faults

So far as known, all faults affected by the earthquake are old faults that were reactivated. Several such faults were identified in the field by George Plafker, U. S. Geological Survey, in June 1964 (written communication) and were also identified on the photographs. Figure 2 shows one of these faults where it crosses Hanning Bay on the west side of Montague Island.

The linear trace of this fault and the relative displacement of rocks on one side of the fault with respect to the other are apparent on the photograph. Obvious emergent features, near the intersection of the fault with the coastline, demonstrate major movement in which the west side (toward bottom of photograph) moved up. The plane of the fault appears to be nearly vertical on the aerial photograph. As known older faults in this same general area have similar displacements, classification of this fault as "new" or "reactivated" is uncertain. It is possible that with the addition of tidal data and a knowledge of vegetation conditions in the beach area, classification could be made from the new photographs alone, but a surer method would be to contrast the new photographs with pre-earthquake photographs. Even by this method, however, it would be necessary to know the height of the tide at the times the two sets of photographs were taken.

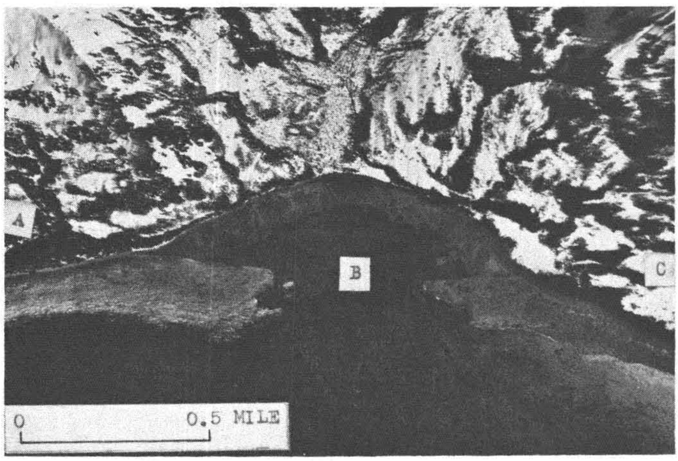

Fig. 2. Vertical aerial photograph showing location (*ABC* of reactivated fault on Montague Island). (Photograph courtesy U. S. Department of Commerce.)

Figure 3 is a photograph of the fault which occurs in a cove just south of Hanning Bay. The vertical displacement along the fault is 13.5 feet in the foreground and 16.3 feet at

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the beach ridge in the background. The nearly vertical rock ledge can be seen in places along the escarpment.

Many well-defined lineations existing in the area prior to the earthquake (Condon and Cass, 1958) were examined for evidence of recent fault movement, but no evidence was apparent; for example, trees growing on the floors of linear grooves were undisturbed.

Changes in Shoreline

Shorelines have been uplifted and downwarped in the earthquake area (Grantz, et al., 1964; U. S. Coast and Geodetic Survey, 1964; and Christensen and Bolt, 1964). Changes in shoreline could be recognized in only a few places from the photographs alone, however, because of a lack of tide record at the time of photography. Figure 4 shows a portion of the eastern shore of Montague Island where photointerpretation criteria suggest an uplifted shoreline. Here, numerous landslides overlap the strand line. As the slides were probably triggered by the earthquake, and wave action had not altered them in the three weeks between the earthquake and the time of photography, the beach has probably been uplifted. The uplift of this coastline has been substantiated by Plafker's field investigations.

Cracks in Surficial Material

Cracks in surficial material were recognized in some isolated places, although none were as conspicuous as those in the Anchorage area (Grantz, et al., 1964). Cracks in surficial material at the head of Blue Fiord on the west side of Prince William Sound (Figure 5) were identified on the photographs and subsequently verified by field investigations (Plafker, oral communication). Because of the resolution of the 1/24,000-scale photographs and the masking of the surface by snow after the earthquake, cracks generally could be recognized only with great difficulty, and then only by use of high magnification (5×) in the stereoscopic model. Most of the cracks known to be present on the ground in the Valdez area (Henry W. Coulter, U. S. Geological Survey, oral communication) were beyond the resolution of the 1/24,000-scale photography.

Pressure Ridges in Lake Ice

Numerous pressure ridges on certain frozen lakes were recognized on the photographs. These pressure ridges are a result of the earthquake and generally are oriented in a direction perpendicular to the direction of the shock wave (Grantz, et al., 1964). The pressure ridges recognized in the area of study generally have a predominant northeast trend west of Prince William Sound, and a west trend north of Prince William Sound. Figure 6 shows the location of some pressure ridges produced by the earthquake on an unnamed lake on the mainland just north of Esther Island.

Although pressure ridges could be seen on many of the lakes, other seemingly comparable lakes had none that could be recognized on the photographs. Differences in the depth, size, and shape of lakes, or thicknesses of ice, might account for absence of pressure ridges on some lakes, but smaller ridges may have been covered by late snows, or may be beyond

Abstract: *Two thousand aerial photographs taken after the March 27, 1963, Good Friday, Alaskan earthquake were examined stereoscopically. The objective was to determine quickly whether geologic features resulting from the earthquake might be identifiable by photointerpretation. Faults on Montague Island, reactivated by the earthquake and identified in the field, were recognizable on the aerial photographs only along the coast. Uplifted shorelines were recognized where landslides overlapped the former strand or beach line and were undisturbed by wave action. Cracks in surficial material that were not beyond the resolution of the photography were observed. Numerous pressure ridges associated with the earthquake were recognized on some frozen lakes. These ridges have a predominant northwest trend west of Prince William Sound and a west trend north of Prince William Sound. No recognizable changes were observed in the extensive snow and ice fields. The distribution, direction and type of slides and avalanches were readily discernible in the area. Two thousand and thirty-six such features were identified. The longest avalanche in the area of study was three miles long.*

FIG. 3. Ground photograph of Hanning Bay fault in a cove just south of Hanning Bay. (Photograph by George Plafker.)

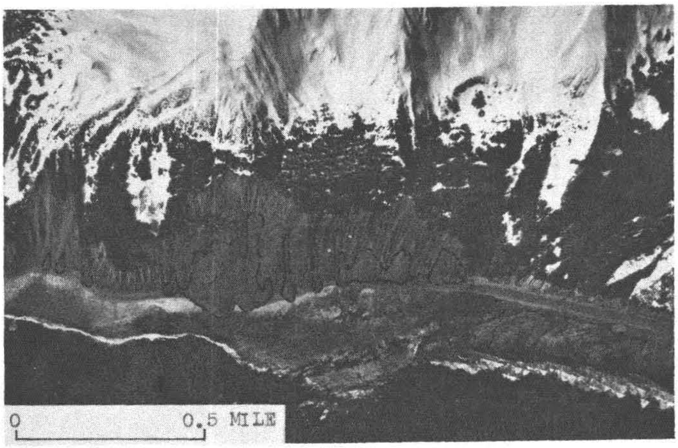

FIG. 4. Vertical aerial photograph showing evidence of recently uplifted coastline. Outlined areas are recent landslides partially covering former beach. (Photograph courtesy of U. S. Department of Commerce.)

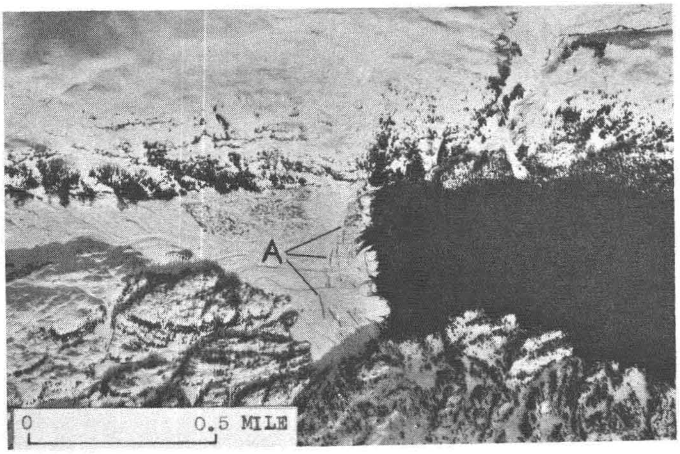

FIG. 5. Vertical aerial photograph showing location of cracks (A) in surficial material at the head of Blue Fiord. (Photograph courtesy of U. S. Department of Commerce.)

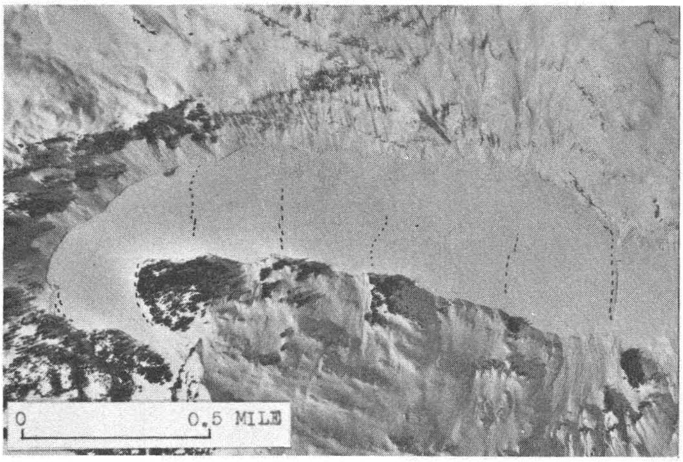

FIG. 6. Vertical aerial photograph showing location of pressure ridges (dotted lines) on ice covered lake. (Photograph courtesy of U. S. Department of Commerce.)

the resolution of the photography. Many such features identified in the area could only be seen under 5× magnification.

Cracks in Glaciers and Lake Ice

Except for the presence of an unusual number of snow slides and avalanches on their borders, the vast snow and ice fields and the glaciers appear to have been undisturbed by the earthquake. Many crevasses were observed on the glaciers, but as crevasses are normally associated with glaciers and as we have no record of immediate pre-earthquake conditions, there is no justification for associating such features with the earthquake. However, near the terminal end of some glaciers, some very recent fracturing can be observed on the photographs.

Considerable broken ice resulting from the earth tremors was observed on many of the larger lakes. On some lakes breakage resulted from the accumulated weight of snow and rock slide material. A triangular unnamed lake, fed by an arm of the Columbia Glacier and located several miles northwest of Columbia Bay, appears to have partly drained as a result of the earthquake. Large contiguous blocks of ice along the shoreline seem to have dropped downward without rotation (Figure 7).

Slides

On aerial photographs the most conspicuous features associated with the earthquake are avalanches, snow slides, and rock slides. Although no information is available on the

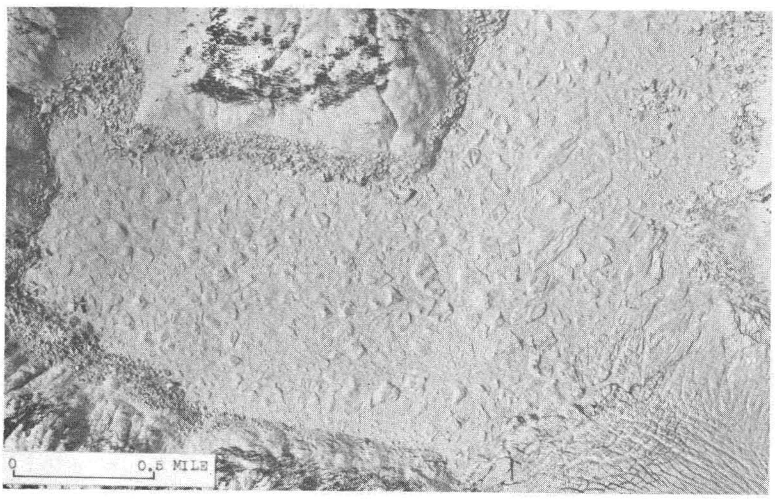

FIG. 7. Vertical aerial photograph showing evidence of recent lowering of water level on an unnamed lake. (Photograph courtesy of U. S. Department of Commerce.)

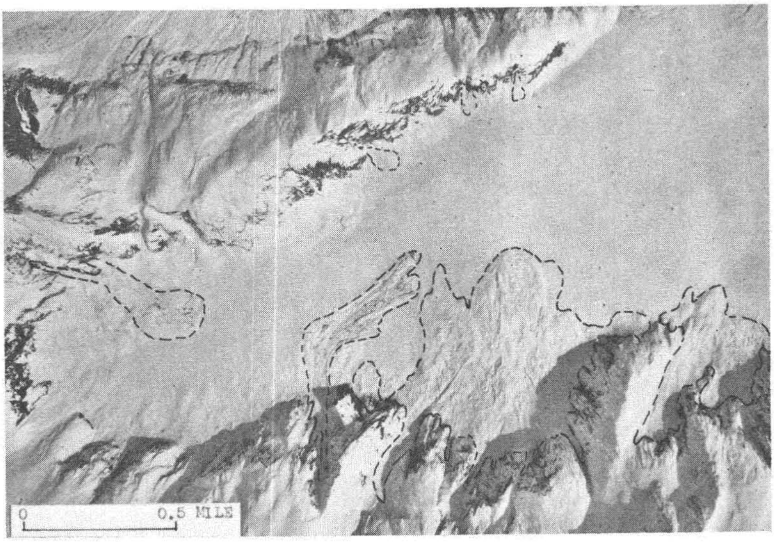

FIG. 8. Vertical aerial photograph showing location of recent avalanches and snow slides (dashed lines) on Contact Glacier. (Photograph courtesy of U. S. Department of Commerce.)

normal incidence of slides in the area, the fresh appearance of most of these features strongly suggests that they are of very recent origin and were probably triggered by the Good Friday Earthquake and/or subsequent after shocks. Figure 8 shows some very recent avalanches on Contact Glacier.

In the 2,000 square miles of land area adjoining Prince William Sound and including the epicenter of the earthquake, 2,036 slides were identified. They comprise 20 rock slides, 58 combined snow and rock slides, and 1,958 avalanches and snow slides. Avalanches were differentiated from slides by their linear pat-

FIG. 9. Map showing distribution and direction of post-earthquake slides and avalanches around epicenter of earthquake of March 27, 1964.

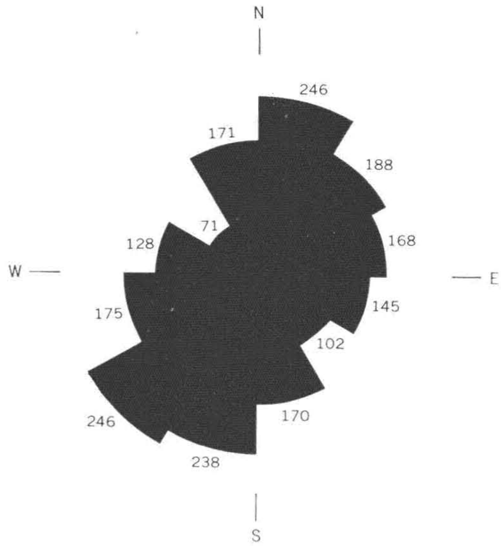

FIG. 10. Rosette graph of trends of 2,036 avalanches and slides in area of blanket photo coverage.

tern and generally greater extent—½ mile or more in length. Although the density of slides varies considerably within the area, the average is roughly one slide per square mile.

The longest avalanche scar is three miles long and extends from an elevation of 5,000 feet to sea level near the head of Unakwik Bay. Several miles to the south is another avalanche two miles long. Both are within several miles of the epicenter. Figure 9 shows the distribution of slides in the epicentral area.

A rosette graph (Figure 10) summarizes the directions of slides in the area of blanket photo coverage. In plotting the graph, only the direction of the tail or starting place of the slide was used. The graph shows preferred directions of slides to the southwest and to the northeast. There is a noticeably smaller number of slides trending to the southeast and northwest

Prevalence of northwest-southeast trending valleys with very steep sides facing northeast and southwest in the area west of Prince William Sound probably accounts for the directional distribution of the slides. Without a detailed analysis of the topography with respect to the direction of slides, it would be difficult to assume a preferred direction trend related to the earthquake.

Conclusions

In the area of study, faults affected by the earthquake and identified in the field were recognizable on the photographs only along the coast. In contrast, many unaffected faults, because of their greater initial displacement and/or topographic expression enhanced by erosion, could be seen on the photographs. It was possible to recognize some uplifted shorelines, and with additional knowledge of tide conditions at the time the photographs were taken, it would probably be possible to determine additional changes in shoreline. The extent and distribution of cracks in surficial material could be determined with a high degree of reliability. The orientation of pressure ridges on lake ice could be mapped over a large area, thus providing information on the direction of the shock waves. The distribution, direction, and types of slides and avalanches over a wide area were readily discernible. Excluding avalanches and slides and also some minor cracking near the snouts of some glaciers, no recognizable evidence of earthquake damage or changes was recognized in the extensive snow and ice fields.

In a future similar study, larger-scale photography would be more useful in recognizing fault movements resulting from the earthquake, as well as small pressure ridges on lake ice and small cracks in surficial materials.

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