N73- 2 54

Paper G 23

SOME ASPECTS OF ACTIVE TECTONISM IN ALASKA AS SEEN ON ERTS-1 IMAGERY

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ABSTRACT

ERTS-1 imagery is proving to be exceptionally useful in delineating structural features in Alaska which have never been recognized on the ground. Previously unmapped features such as seismically active faults and major structural lineaments are especially evident. Among the more significant results of this investigation is the discovery of an active strand of the Denali fault. The new fault has a history of scattered seismicity and was the scene of a magnitude 4.8 earthquake on October 1, 1972. Perhaps of greater significance is the disclosure of a large scale conjugate fracture system north of the Alaska Range. This fracture system appears to result from compressive stress radiating outward from around the outside of the great bend of the Alaska Range at Mt. McKinley. NASA aircraft data also support this assumption. One member of the fracture system was the scene of a magnitude 6.5 earthquake in 1968. The potential value of ERTS imagery to land use planning is reflected in the fact that the site of the proposed bridge and oil pipeline crossing of the Yukon River lies very near this fault.

1. INTRODUCTION

In an area as remote and inaccessible as most of Alaska, geologic mapping is, at best, hit-and-miss. Mapping in the state (if it has been done at all) is often, of necessity, the result of a few "point investigations" carried out by helicopter, with a lot of interpolation in between. For this reason, the application of ERTS imagery to a study of various aspects of the Alaskan environment takes on an importance found in few other areas.

As an example of features which may be missed by geologic field mapping in Alaska, consider that the Denali fault (which is a tectonic feature on the scale of, and perhaps more striking than the San Andreas fault) was not even named prior to 1957 (St. Amand, 1957). Since that time, it has been found to comprise an important element of the Pacific transform fault system of which the San Andreas is a member (e.g. Tobin and Sykes, 1968). More recent studies (Richter and Matson, 1971) have revealed that much of the motion between the north Pacific plate and the continent is now probably being taken up along the Totschunda fault system connecting the active segments of the Denali and Fairweather faults. All these features are clearly visible on ERTS-1 imagery, and for some purposes, the imagery is clearly superior to even detailed ground mapping. Consider, for instance, a scene containing the intersection of the Denali and Totschunda faults (image ID No. E-1081-20275). It appears obvious that a strand of the Totschunda fault extends northwestward through Stone Creek, across the valley of the Nabesna River and into the mountains to the northwest. However, the most detailed geologic map available of this area (Richter, 1971) does not show this feature, presumably because of alluvial fill along its trace, lack of rock differentiation across it, and sheer inacessibility in the mountainous areas. This scene also shows a small unmapped fault on the northwest flank of Mt. Sanford. While this is a minor feature, it is of interest because it appears from the lighting and stream incision that it is a reverse fault. That is, the mountain has dropped with respect to the valley. The value of obtaining imagery at low sun angles is illustrated by the fact that this feature is not seen (without enhancement) on two earlier, cloud-free passes during August and September. The present scene was made on October 12 when the sun angle was 18°. Equivalent sun angles during the earlier passes were 43° and 25° (Image ID Nos. E-1010-20331 and E-1063-20273).

2. OTHER FINDINGS RELATING TO TECTONICS IN ALASKA

One of the primary objectives of this investigation was to identify seismically active faults which had been postulated on the grounds of ongoing seismicity. After several years of data accumulation, we are finding that earthquakes in central and south-central Alaska very often occur in elongated clusters where no faults are mapped. ERTS-1 imagery is being found to be extremely valuable in identifying faults in these areas. A particularly good example is found in image ID No. E-1066-20444. A seismically active strand of the Denali fault can be easily traced for at least 120 km, with end points at approximately 62°26'N, 149°23'W, and 63°14'N, 147°44'W. It forms a lineal depression along which streams flow and sag ponds form. Seismicity records dating back to 1967 reveal that earthquakes have tended to cluster along the fault in this area, particularly near the end points, and the southern end was the scene of a magnitude 4.8 earthquake on October 1, 1972. This earthquake was felt throughout the Susitna River Valley. Although it appears from the image that the Susitna River has been left-laterally offset by this feature, the fault plane solution obtained of the event of October 1 indicates right-lateral displacement, which suggests that it is a strand of the Denali fault, and not a conjugate, or tear fault. Lathram (1972) identified a linear in this approximate area on the basis of Nimbus IV imagery, although it appears offset in the Nimbus imagery in a manner which is not apparent in the higher resolution ERTS-1 imagery.

North of the Alaska Range, in the central interior, there is a broad zone of shallow seismicity which extends at least as far north as the southern Brooks Range (Gedney et al., 1972). Since 1904, eight earthquakes of magnitude greater than 6.0 (up to 7.8) have occurred in this area. Although considerable seismic data has been accumulated for this region, primarily in recent years, geologic and tectonic mapping is minimal or nonexistent. In October, 1968, an earthquake of magnitude 6.5 occurred in the Minook Creek Valley northwest of Fairbanks. Figure 1 is a mosaic composed of portions of six ERTS-1 images (Image ID Nos. E-1104-20554, E-1104-20560, E-1104-20563, E-1105-21012, E-1105-21015, and E-1105-21021). Minook Creek appears in the upper left center at approximately 65.4°N., 150.1°W. Prior to the 1968 earthquake, this feature was not recognized as a fault. Since that time, aftershock studies, fault plane solutions, and geologic field mapping have revealed that it is, indeed, a left-lateral fault. Had ERTS imagery been previously available, this conclusion would undoubtably have been reached long ago. The extreme sharpness of stream incision, the textural and tonal differences across the valley, and the series of parallel fractures in the surrounding mountains would have left little doubt. Although the left-lateral nature is not obvious on the Minook Creek fault, the fourth parallel feature to the east shows it quite well, with truncation of mountain lobes on both the north and south sides of the ridge line.

On closer inspection, one sees that the Minook Creek fault is only part of a large scale fracture system involving many other linears. Parallel features can be seen in the mountains across the Yukon River to the northwest, they can be identified on the southeast banks of the Yukon, where they affect tributary drainage, and two long lineaments are seen in the Kuskokwim Mountains to the southwest. Textural changes occur across the latter two, although they become lost in the alluvium of the Tanana River at their northern ends. Figure 2 is a key to the mosaic, pointing out these features and others mentioned in the following discussion.

An almost equally impressive set of conjugate fractures intersects the Minook Creek complex at an angle of 55°, and strikes southeast to the Alaska Range. This is roughly the dihedral angle at which most brittle substances would be expected to fail if compressive stress had been applied at an azimuth bisecting the acute angle between the two sets. In this case the direction is at an azimuth of about 345°, roughly perpendicular to the trend of the Alaska Range. The conjugate set is most apparent in the Ray Mountains, across the Yukon River from Minook Creek; but it is also visible in the mountains around Minook Creek, south of the Tanana River, and near the bottom center of Fig. 1. The latter lineament appears to truncate the small mountain near its center.

There is a strong implication that earthquakes in this area are the product of compressive stress radiating outward from around the great bend in the Alaska Range, and that this stress system has resulted in the formation of a conjugate shear system with earthquakes occurring along the individual fractures. A mechanism of this sort agrees well with the fault plane solution obtained for the 1968 earthquake, and with one obtained for a magnitude 6.0 earthquake near Fairbanks in 1967. For the latter event, a nearly north-south azimuth of compressive stress was obtained, nearly perpendicular to the Alaska Range at this point, as was true with the Minook Creek event. The 1967 earthquake occurred on a prominent lineament extending from the town of Nenana, past Fairbanks, and into the headwaters of the Chena River to the northeast. As a suspected fault, this line was flown with a NASA aircraft (NP3A) during the summer of 1972. While conventional and reflective infrared photography failed to reveal conclusive evidence of faulting (as did side-looking radar), the IR scanner produced some unusual and unexpected results. Just south of Fairbanks, on the Chena lineament in the aftershock zone of the 1967 earthquake, there are what appear to be a series of steeply dipping folds. Their appearance virtually rules out the possibility that they are old river meanders. They are in an area which is normally regarded as being overlain by thick flood plain deposits, which makes it seem unlikely that they are a reflection of the underlying bedrock. The fold axes trend generally along the line of the Chena lineament, with an amplitude of about 7 km and a period of about 3 km. It is conceivable that they are a result of deformation of the Quaternary sediments by compressive stress in a north-south direction, although this is admittedly "reaching".

If the concept of outwardly-directed compressive stress to the north and northwest of the bend in the Alaska Range is to be taken seriously, the logical question which now arises is, "What causes the compression?". A possible explanation is that the forces which caused the Alaska Range to "buckle", forming the great 90° bight in the range at Mt. McKinley, have not yet subsided and further deformation is occurring. The primary cause is probably related to underthrusting of the north Pacific plate beneath the continental margin along Cook Inlet and the western Alaska Range (Davies, 1973). But whatever the basic energy source, it would seem plausible that further buckling of the range would result in outwardly directed compressive stress around the outside of the bend, with a resulting pattern of conjugate fractures of the type we have been discussing.

3. CONCLUSIONS

Although our discussion has dealt primarily with tectonic aspects of Alaska which can be seen on ERTS imagery, the most salient point is this: It is possible, with ERTS data, to delineate seismically active faults which may go otherwise unnoticed. Certainly the Minook Creek fault (site of the magnitude 6.5 earthquake of 1968) would have been recognized long ago, had ERTS imagery been available, and its freshness of appearance would have labeled it as being recently active. It bears pointing out that the site for the proposed Rampart bridge and oil pipeline crossing of the Yukon River is very near the Minook Creek fault if it extends to the north, and that the proposed route also crosses the two strong lineaments at the top center of Figs. 1 and 2. Particularly in Alaska, where these areas are remote and accessible only at great time and expense, ERTS imagery shows great promise as an aid in construction planning, zoning, and seismic risk evaluation.

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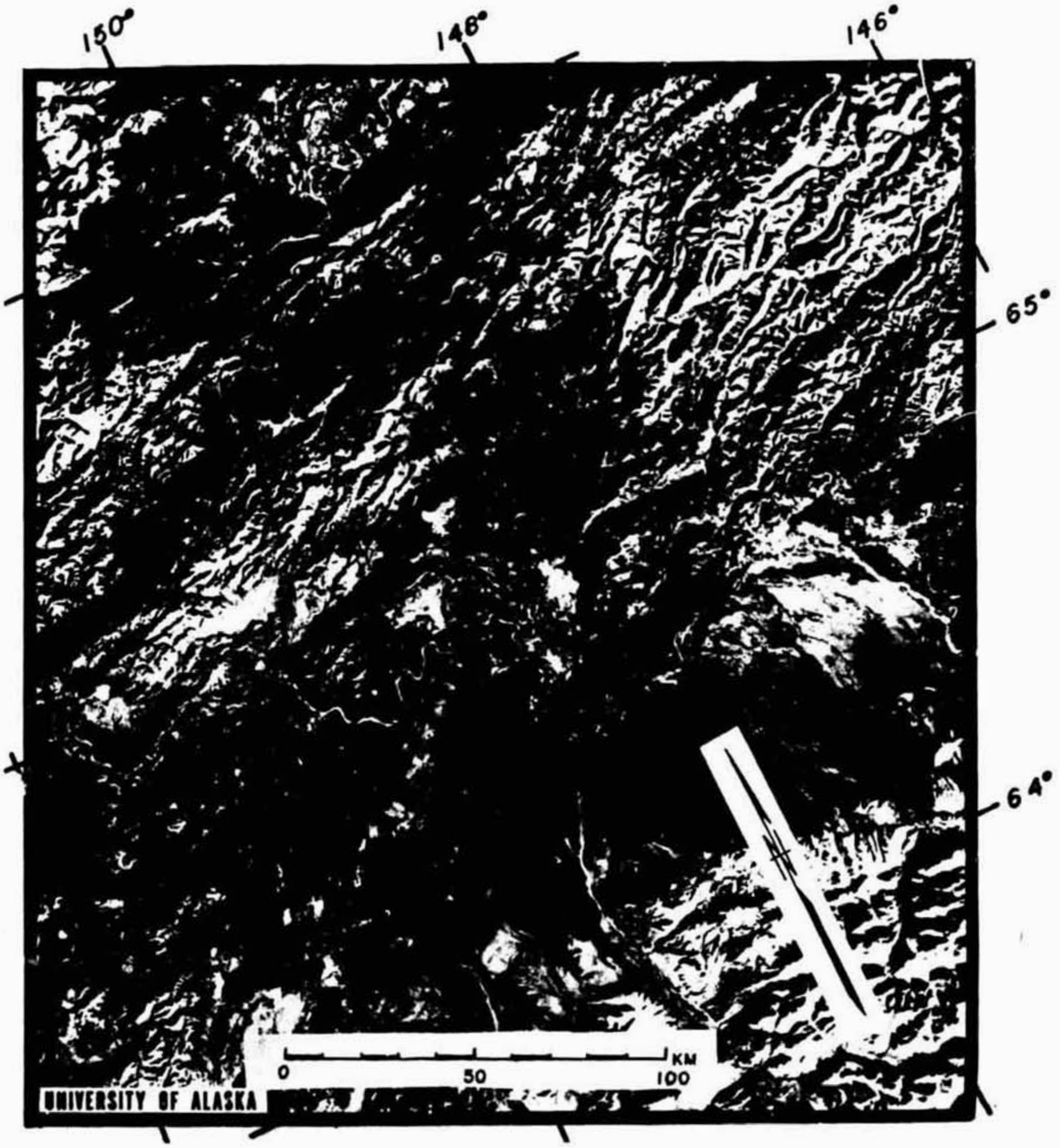

Figure 1. Mosaic of six ERTS-1 MSS images of central interior Alaska. See text for image ID Nos. and Figure 2 for key to mosaic.

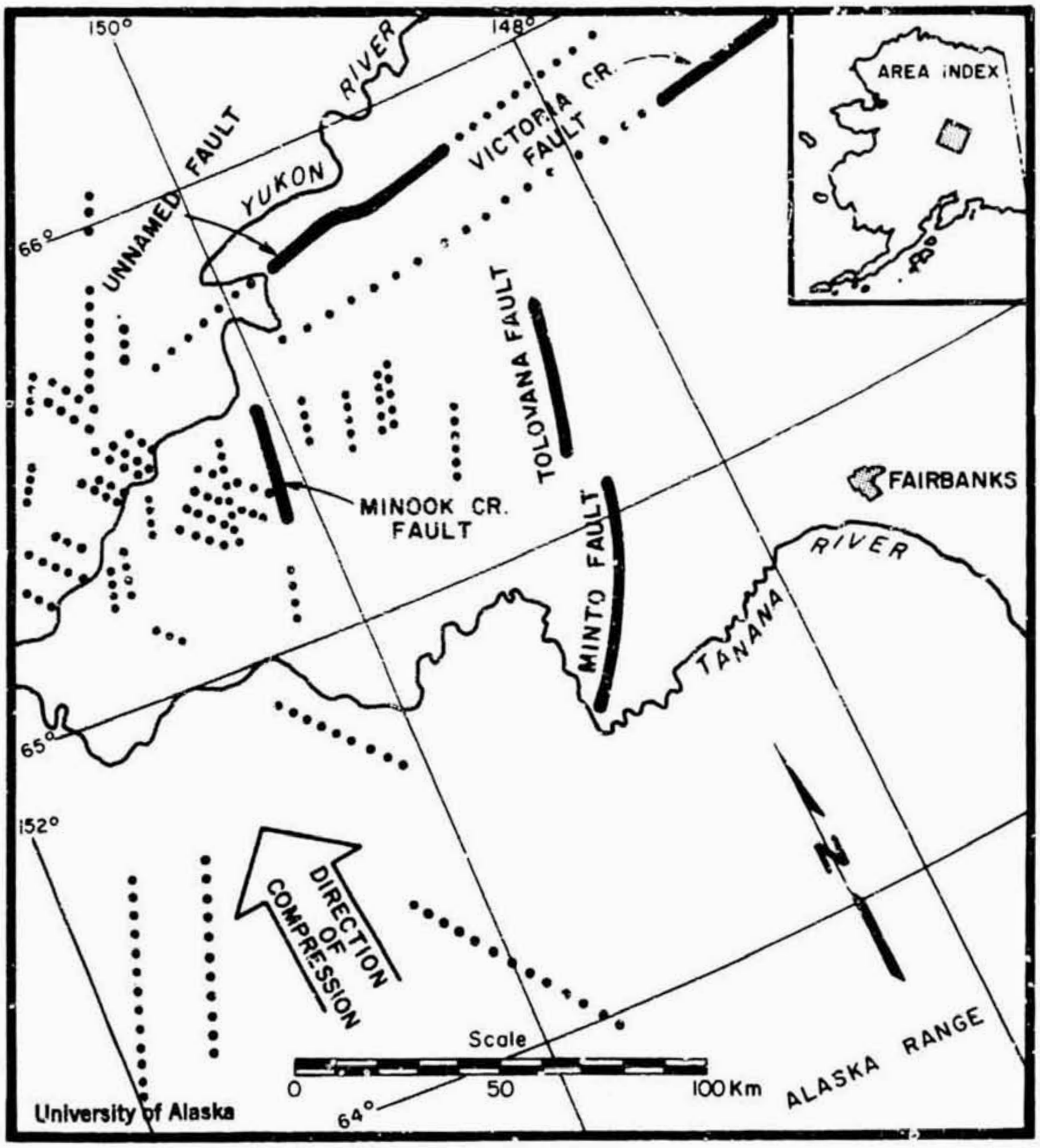

Figure 2. Key to Figure 1. Those linears shown by heavy solid lines are known faults which are identifiable in ERTS-1 imagery. Features shown in dotted lines are previously unmapped faults and lineaments recognized for the first time in the ERTS images.