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TECTONIC STRUCTURE OF ALASKA AS EVIDENCED BY ERTS IMAGERY AND ONGOING SEISMICITY

Progress Report

May 5, 1976

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Problems

None.

Accomplishments

As stated in the previous report, seismic instrumentation of the Brooks Range and the Alaskan north slope is being attempted to ascertain (among other things) if local earthquakes can be correlated with lineaments visible on LANDSAT imagery. Despite considerable logistical difficulties, this program has largely been a success, and telemetered signals from four stations have been recorded at the Geophysical Institute for a period of approximately four months. These stations are arranged in the Brooks Range within line-of-sight distance (100 miles or less) of Barter Island. Concurrently, the Geophysical Institute produced, under contract to the North Slope Borough, a LANDSAT mosaic of the entire north slope and northern Brooks Range. This mosaic is reproduced (in two parts) as Figs. 1 and 2. The original (at a scale of 1:1,000,000) is on permanent display in the North Slope Borough office at Barrow. The complex structural features of the Brooks Range, including faults and folds, is easily seen in Figs. 1 and 2. From the seismic data gathered to date, however, it appears that this area is relatively quiescent at present, and positive correlations between earthquakes and lineaments have yet to be made.

In November, a paper was presented to the 10th Michigan Conference on Remote Sensing of the Environment (reference in "Publications" section). This paper read, in part:

"LANDSAT images have been widely used to build regional mosaics for geologic applications. New linear features commonly have been recognized on nearly every image of land areas in the world. In south-central Alaska the Corps of Engineers is using these data... (by arrangement and contract through this project)...for siting and design refinements of a proposed hydroelectric project on the upper Susitna River. A LANDSAT regional mosaic was constructed from nine images obtained under very low sun-angle conditions. Such lighting conditions emphasize terrain relief and enhance the geologic interpretability of the image. A peaked shadow...is cast by Mt. McKinley, which constitutes part of the great Denali fault system which... transverses...the area. A...lineament...first noticed on ERTS-1 images, and which has since been confirmed to be a true geologic fault, now known as the Susitna fault, is apparent on the mosaic. Recent earthquake epicenters (magnitude 4 and greater) were correlated with...this and other geologic lineaments recognized from the satellite imagery. The preponderance of earthquakes in this study area occur beneath Mt. McKinley, but this seismicity is rather deep and poses no known hazards to any existing or planned structures. The area of seismic concern lies generally south and east of Mt. McKinley where the epicenters tend to be relatively shallow. In the upper Susitna River area the larger earthquakes seem to be associated with the Susitna fault...at least four moderate earthquakes have occurred on or near the Susitna fault in the last five years. In addition to the LANDSAT mosaic, this region was also studied in greater detail for the general tectonic grains by means of SLAR images mosaicked at an approximate scale of 1:250,000. In contrast to the technique used in mapping lineaments from LANDSAT imagery, the analysis of the SLAR data ignored the strongest lineaments and the lesser structural elements were emphasized. Only those lineaments less than 25 km in length were catalogued, with the intent to attenuate the statistical influence of the dominant structural features and provide an insight into the mode of deformation occurring in the surrounding areas...statistically, the concept which emerges is that the principal lineament orientations are to the northeast and northwest, with greatly lesser numbers of lineaments occurring at intermediate azimuths. A further evaluation indicates that the lineaments striking northeast (roughly parallel to the Susitna fault) are fewer in number but longer and stronger than those striking northwest. The latter tend to be shorter and abruptly truncated. This study strengthens the supposition that the Susitna fault represents the primary azimuth of lateral offset together with a strong set of shorter, secondary faults nearly orthogonal to the Susitna fault alignment. The geologic mapping of areas adjacent to the proposed damsite on the upper Susitna River is very incomplete, particularly for the central and northern portion, owing in part to the extreme inaccesibility and rugged terrain. In the absence of complete field knowledge of the geology of the region, the interpretation of remotely sensed data from satellite and SLAR images is playing an important role in the siting and design criteria for the hydroelectric project which would involve two or more dams."

This paper was delivered by John Miller of this Institute, and the cited portion was based on work performed under the auspices of this project, supplemented by support from the Corps of Engineers.

Recent months have seen a dramatic upsurge in the level of seismic activity in the Fairbanks area. April, in particular, gave cause for concern to many of the local residents, and prompted the enclosed newspaper article shown as Figure 3. The "fault line" cited is a lineament which we have long maintained (on the basis of some of the original ERTS-1 imagery) to be a true geologic fault, and it appears on the basis of the recent earthquake activity that our assumptions based on the satellite imagery are being borne out, even though the feature is not distinguishable on the ground, being overlain by a river and thick alluvial deposits. It is interesting that the larger earthquakes in April (there were many smaller events that were not felt) progressed in orderly fashion along this feature from the southwest to the northeast.

Figures 4,5, and 6 are a reprint of a recent paper (which acknowledges this contract) relating to earthquakes in the Fairbanks area which we now attribute to this same fault. We are presently trying to delineate more accurately its limits, and it appears from the imagery to extend much further to the northeast than is suggested by Fig. 3.

Inspection and cataloguing of the imagery continues, and we anticipate ordering, in the near future, imagery which we may have "missed" of various portions of the study area.

Significant Results

None.

Publications

Gedney, Larry and James VanWormer, Tectonic lineaments and plate tectonics in south-central Alaska, First International Symposium on the New Basement Tectonics, University of Utah Press, Utah Geological Association, 1975.

Gedney, Larry and Lewis Shapiro, Structural lineaments, seismicity and geology of the Talkeetna Mountains area, Alaska, prepared for the U.S. Army Corps of Engineers, Alaska Division, Anchorage, Alaska, September, 1975.

Publications (continued)

VanWormer, James, Larry Gedney, John Davies, and Vicki Condal, Vp/Vs and b-values: a test of the dilatancy model for earthquake precursors, Geophysical Research Letters, V. 2, No. 11, 514-516, November, 1975.

Miller, J. M., A. E. Belon, L. D. Gedney, and L. H. Shapiro, A look at Alaskan resources with LANDSAT data, Proceedings of the 10th International Symposium on Report Sensing of Environment, University of Michigan, Ann Arbor, Michigan, November, 1975.

Recommendations

None.

Funds expended

$45,000

Data Use

Value of Data Allowed	Value of Data Ordered	Value of Data Received
$7,300	$7,300	$4,015

FIGURE CAPTIONS

Figure 1. Western portion of mosaic of northern Brooks Range and Alaskan north slope. Point Barrow is pointed portion near top of mosaic.

Figure 2. Eastern portion of mosaic of northern Brooks Range and Alaskan north slope.

Figure 3. Newspaper clipping from Fairbanks Daily News-Miner relating to earthquakes occurring along lineament picked from LANDSAT imagery.

Figures 4,5, and 6. Reprint of article appearing in Geophysical Research Letters dealing with earthquakes in Fairbanks area occurring on same structural lineament appearing in Fig. 3.

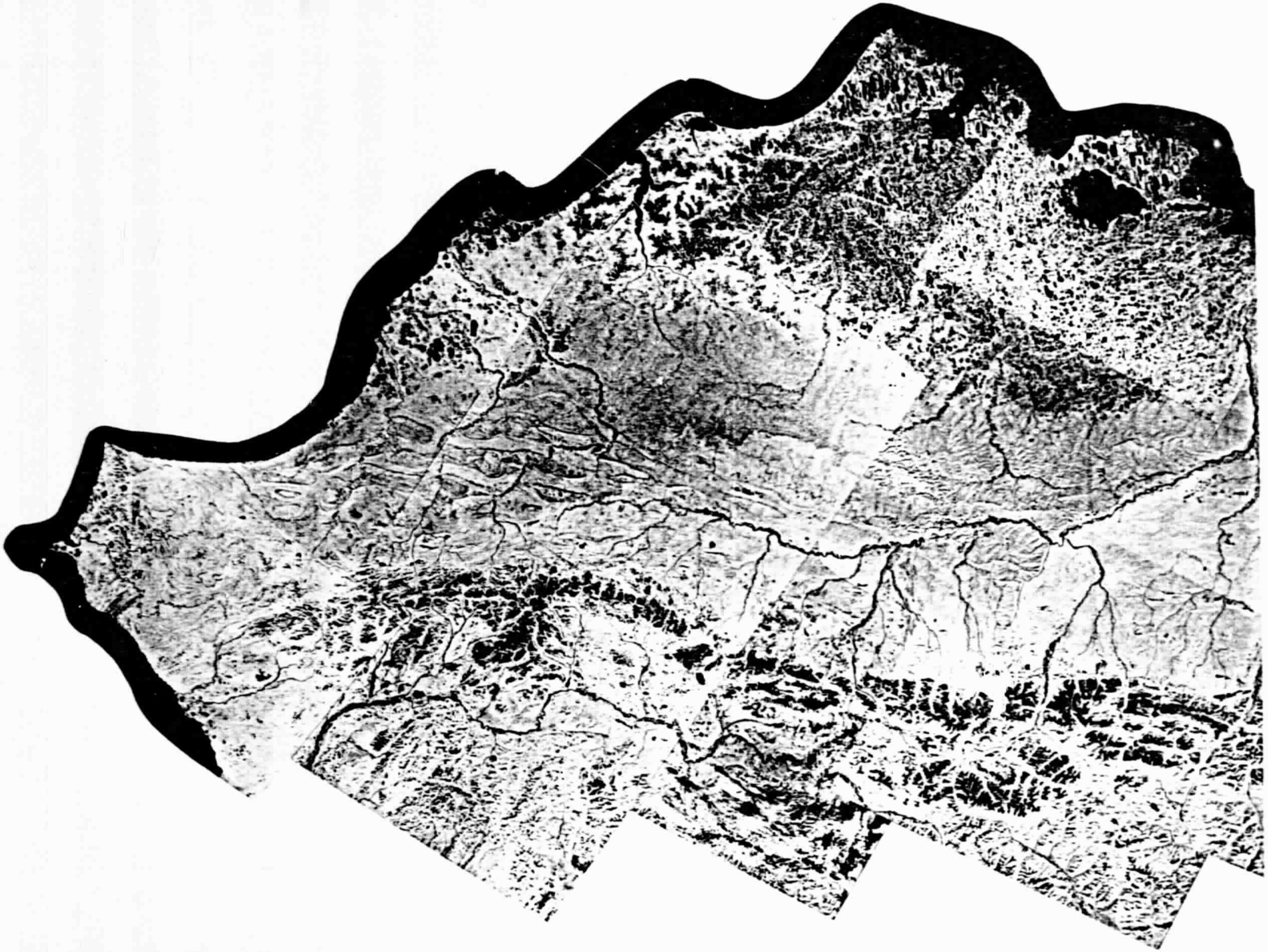


Figure 1

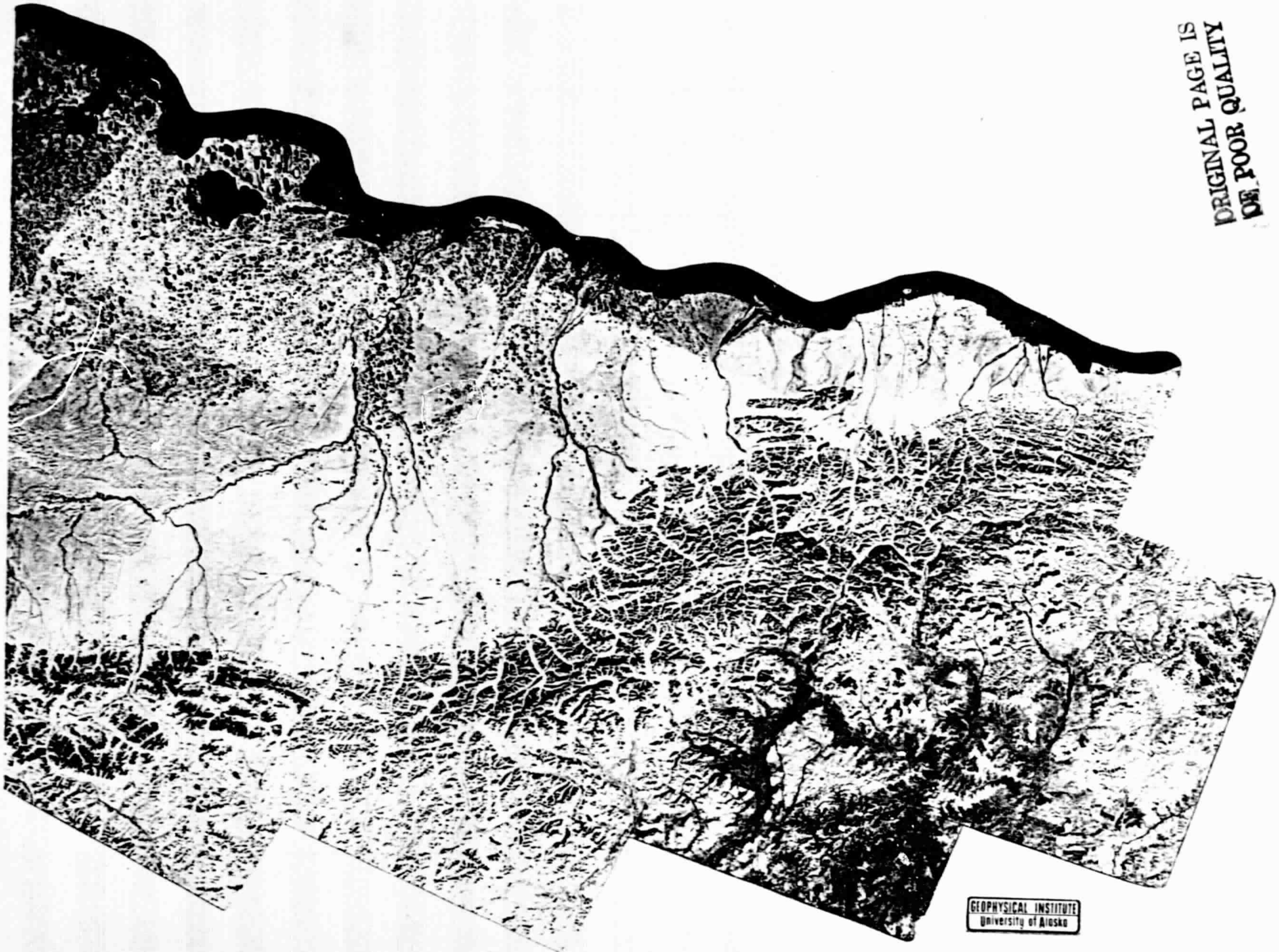


Figure 2

Figure 3

Quakes rumble through city

By ERIN VAN BRONKHORST
Staff Writer

Three earthquakes felt in the Fairbanks area early this morning may be part of a pattern of foreshocks before a larger quake, University of Alaska geophysicists indicated today.

"The Interior has had a history of having a fairly large earthquake every ten years, and it's about time again," said Larry Gedney, an associate geophysicist with the Geophysical Institute of the University of Alaska, Fairbanks.

The 1967 earthquake of magnitude 6 caused some damage, Gedney said, largely in stores when things fell off shelves. Some chimneys and foundations were damaged, he said, but there were no injuries.

The three earthquakes early this morning were centered in the Badger Road area, exactly the same place as the 1967 quake, Gedney said. The quakes were: at 1:32 a.m. magnitude 3, at 2:27 a.m. magnitude 4.2, and at 2:34 a.m. magnitude 3.8. No damage was reported, according to Civil Defense Director Jack Murphy.

There were two other tremors earlier this month. On April 16 a quake registered 4.2, centered about 10 miles southwest of Fairbanks, according to Neil Davis of the Institute. On April 25 at 1:12 a.m. a quake registered 3.6, centered about 10 miles southeast of Fairbanks, Davis reported.

All five tremors now appear to be on the same fault, Davis and Gedney said today. In addition, they all probably are on the same fault as the 1967 quake, the scientists added.

The recent quakes cannot definitely be identified as foreshocks, Gedney explained, because foreshocks are not defined until the major earthquake occurs. He said the present series could even be aftershocks from the 1967 quake.

The fault causing the current series runs on a line from Nenana to about three to four miles south of Fairbanks, to Badger Road, to the headwaters of the Chena River, the two men said today.

The Interior does not have huge earthquakes causing great damage as on the southern coast, Davis said earlier, because the rocks on the southern coast are able to accumulate strains in the earth better, and when they crack, the results are greater.

The Good Friday earthquake in Anchorage in 1964 caused extensive damage and took 130 lives. It was registered at 8.4 on the Richter scale. In the series of quakes recorded in the Fairbanks area, none has been above 7.75, and that was in 1904.

In 1937, there was a 7.3 magnitude quake centered between Fairbanks and Mt. McKinley. In 1947, a quake of 7 magnitude was centered north of Mt. McKinley. In 1958 a quake of 6.5 magnitude was centered near Huslia, west of Fairbanks. The 1967 quake, one of a series, registered at 6 and was centered at Badger Road. Another tremor in 1968 registered at 6.8 and was centered near Rampart.

"I'd just tell people not to worry about it. We're going to get earthquakes here in the Interior, we always have, but they're not that bad," Gedney said.

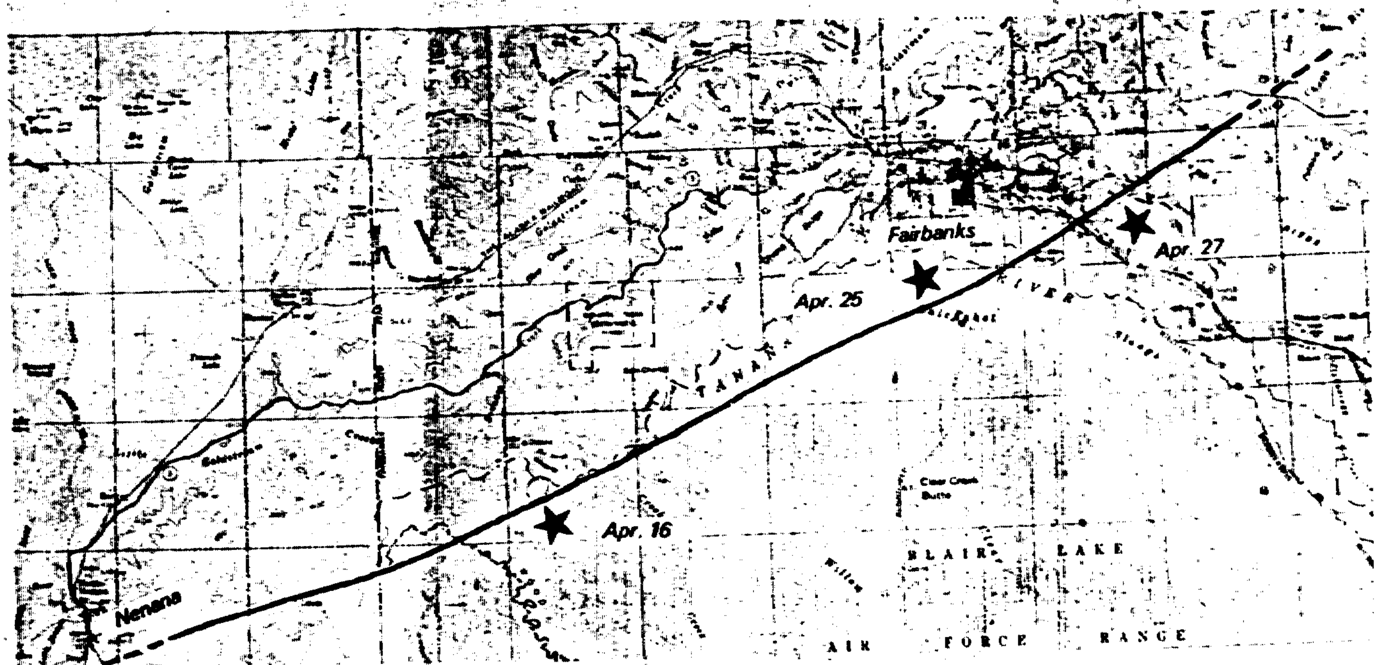
Davis indicated the "only rational sorts of warnings" are about procedures to be followed if an earthquake occurs. The Civil Defense office advises that people inside buildings should stand in a corner, in an interior doorway, or get under a sturdy desk or table. Generally speaking, people are better off staying inside rather than running outside because parts of buildings may fall into the street. However, inside it is a good idea to watch for falling plaster, light fixtures, or items on shelves.

Those who are driving cars during a quake should stop in an open area away from tall buildings and stay in the car until the quake is over.

The most important thing is to remain calm and keep thinking.

The only precaution people could take, Davis said, would be to consider the positions of crockery or other breakable items which may be stored on shelves. It would be a good idea to place these somewhere so that they could not fall off and break, he said.

"Even if we think there is going to be a quake, the question is whether it does more harm to tell people about it," he said.



FAULT LINE—The black line shows the location of the line University of Alaska geologists believe is the fault along which the earthquakes of the past week have occurred. It stretches from Nenana to the Badger Road area, the location of Monday night's tremors.

ORIGINAL PAGE IS OF POOR QUALITY

V_p/V_s AND b-VALUES: A TEST OF THE DILATANCY MODEL FOR EARTHQUAKE PRECURSORS

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Abstract. Three days prior to a magnitude 3.0 earthquake near Fairbanks, Alaska, the b-value began to decrease, reaching a statistically significant minimum one day before the event. This decrease in b-value is in accord with the dilatancy model for earthquake occurrence. Changes in V_p/V_s would have been only marginally detectable with the data available.

The dilatancy model recently offered as an explanation for observed precursors to earthquakes [Scholz et. al., 1973] may be tested in a number of ways - crustal deformation, seismic wave velocity changes and variations in seismicity to name a few. Numerous reports have appeared in which possible precursors have been examined, with mixed results. This report considers two possible precursory phenomena of a magnitude 3.0 earthquake which occurred near Fairbanks, Alaska, on 12 November 1970. A portion of the data has been reported as supportive evidence for the dilatancy model [Scholz et. al., 1973].

Figure 1 shows the distribution of epicenters and stations in the Fairbanks area. The located events were shallow (10-20 km depth) crustal earthquakes and indicated strike-slip faulting in response to regional north-south compression [Gedney and VanWormer, 1973].

Seismic wave arrivals timed to 0.01 second were used to construct a Wadati diagram to fix the earthquake origin time. Hypocenters were then determined by finding the best fit in space while also allowing the P-wave velocity to vary. The V_p/V_s ratio was least-squared from the Wadati diagram and used with the "hypocenter-best-fit" P-wave velocity to calculate the S-wave velocity.

The values of V_p/V_s are shown in Figure 2 for the events in the southwest quadrant of Figure 1. There are no obvious changes in the ratio that can be associated with the two largest events (2 and 12 November) which occurred in the southwest cluster of activity. Addition of V_p/V_s values from events outside the southwest quadrant does not improve this situation. Although we did not see a change in V_p/V_s associated with the M=3.0 earthquake, we do not consider this to be conclusive because any changes associated with the event would have been only marginally detectable using the available data due to the small dilatant zone expected and the poor distribution of stations. It should be noted that changes in the velocity ratio have been difficult to detect in the well-studied strike-slip regime typified by the San Andreas Fault, and that the Fairbanks earthquakes are also strike-slip in nature.

Of the nearly 800 earthquakes detected in the Fairbanks area during the first 13 days of November 1970, less than 200 were large enough to per-

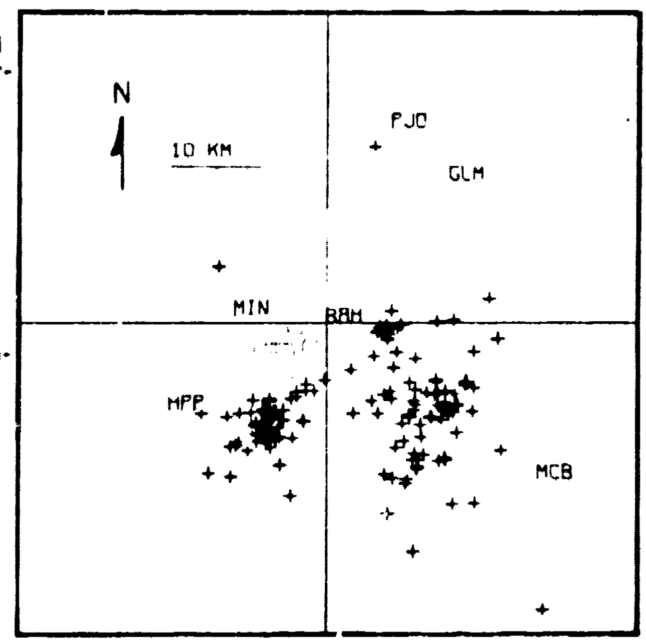

Figure 1. Earthquake epicenters and stations used for epicenter determinations in the immediate vicinity of Fairbanks, Alaska.

Figure 4

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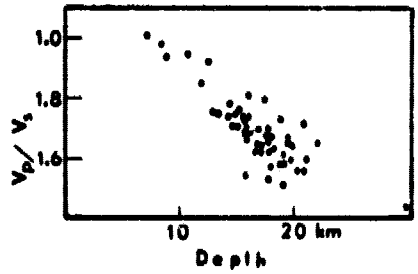

Figure 2. V_p/V_s values for events in the southwest quadrant of Figure 1.

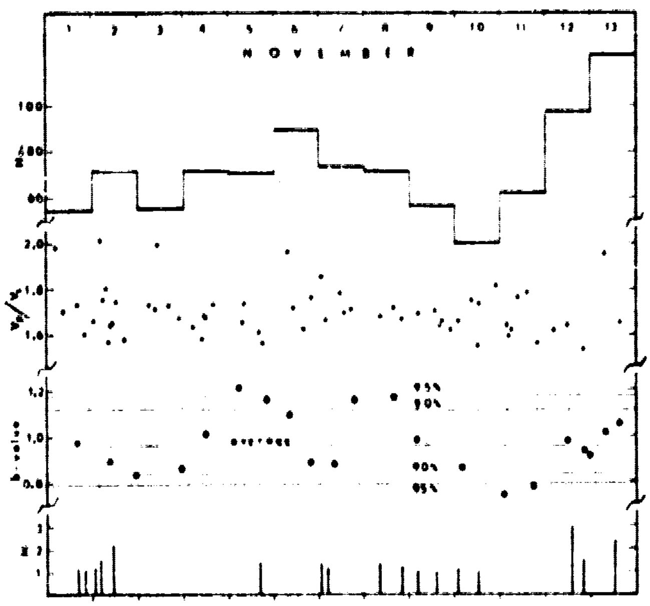

Figure 3. Top curve: number of earthquakes per day in area covered by Figure 1. Middle curve: V_p/V_s for events in the southwest quadrant of Figure 1. Bottom curve: b-values for all events in the area of Figure 1 (see text). Bars at the bottom of the figure indicate time and magnitude of larger events located in the SW portion of Figure 1.

mit location. With the assumption that the small unlocated events and the located events originated in the same focal areas, "b-values" were calculated for all events using Utsu's [1966] relationship

$$b = \frac{S \log(e)}{\Sigma M_i - SM_s} \qquad (1)$$

Where S is the total number of earthquakes with magnitude greater than or equal to M_s and ΣM_i is the sum of magnitudes of all the S earthquakes. Rather than calculate a magnitude for all the events of the sequence, we chose to use the value log(A) where A is the maximum trace amplitude. We feel that this substitution is justifiable because local magnitude is defined [Richter, 1958] as $\log(A)-\log(A_o)$ where A_o is the amplitude of a standard earthquake. This approach was used for all events within approximately 40 km (5 second S-P time) of station GLM (Figure 1). Most of these events were in the distance range 15 to 35 km, over which $-\log(A_o)$ varies from 1.6 to 2.3. This variation of $\pm.35$ due to distance was ignored and no corrections for distance or attenuation were applied.

The b-values were determined by Equation (1) for consecutive windows of 70 events each with overlaps of 35 events. Although it may be argued [Ryall et. al., 1968] that the windows should have been larger, it would appear that 70 is a sufficient sample when following Utsu's method which accounts for sample size when comparing two values to determine if they are significantly different. Results of our b-value calculations are shown in Figure 2, along with confidence limits which indicate that some of the individual 70-event samples are significantly different from the average b-value.

We interpret the below-average values for 9-12 November to be in accord with the dilatancy model and to be a possible precursor to the M=3.0 earthquake on 12 November. The data in Figure 2 also show a pronounced low in daily activity two days prior to the 12 November event. There is no ready explanation of why the below-average b-values for 3 and 7 November were not followed by larger events. However, neither of these periods exceeded the 95% confidence level as did the values of 11 November. Since these periods were not followed by larger events, it could be argued that they do not represent dilatancy or that for some reason fracture failed to occur.

It is not clear why events from the two main areas of activity (Figure 1) should, when combined, show a marked decrease in b-value for a small dilatant zone in one of the areas. The change may be due to only the events from the southwest quadrant and would be even more pronounced if the events from other areas could be separated from the samples.

In summary, while other investigators have found changes in V_p/V_s to be a useful prediction technique, we have not in this particular case. We assume this to be due to our approach and no fault of the concept of dilatancy and V_p/V_s changes. However, continuous monitoring of b-values shows promise in the search for successful earthquake prediction. In the case cited above, a statistically significant decrease in b-value preceded a moderate earthquake.

Acknowledgments

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Figure 6