E7.4-10574
CR-138679

EVALUATION OF FEASIBILITY OF MAPPING SEISMICALLY ACTIVE FAULTS IN ALASKA

Larry D. Gedney and James D. VanWormer
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

April 30, 1974
Final Report, Contract NAS5-21833, Task 10
ERTS Project 110-12

(E74-10574) EVALUATION OF FEASIBILITY OF MAPPING SEISMICALLY ACTIVE FAULTS IN ALASKA Final Report, Jul. 1972 - Jan. 1974 (Alaska Univ., Fairbanks.) 41 p HC $5.25 CSCL 08B G3/13

N74-28818

Unclas
00574

Prepared for:
NATIONAL AERONATUICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 9	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of feasibility of mapping seismically active faults in Alaska		5. Report Date 30 April 1974 6. Performing Organization Code
7. Author(s) Larry D. Gedney and James D. VanWormer		8. Performing Organization Report No.
9. Performing Organization Name and Address Geophysical Institute University of Alaska Fairbanks, Alaska 99701		10. Work Unit No. 11. Contract or Grant No. NAS5-21833 Task 10 13. Type of Report and Period Covered Type III-Final Report July 1972-January 1974
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Goddard Space Flight Center Greenbelt, Maryland 20771		14. Sponsoring Agency Code

15. Supplementary Notes
ERTS-1 Project, GSFC No. 110-1
Principal Investigator, Larry D. Gedney, GSFC ID No. UN601
One of 12 ERTS-1 projects conducted by the University of Alaska

16. Abstract
It is immediately apparent, when comparing ERTS-1 imagery with epicenter maps of earthquakes which have occurred within recent years, that most larger earthquakes within the state of Alaska occur on, or near lineaments which are visible on the imagery. North of the Alaska Range, in the central interior, earthquakes tend to occur at intersections of lineaments, particularly on a previously unmapped set of conjugate fractures which appear to be the result of outwardly directed compressive stress from around the great bend in the Alaska Range. In south-central Alaska, although much of the seismicity is of deep origin and associated with underthrusting of the north Pacific lithospheric plate, the shallow (and therefore potentially more hazardous) earthquakes also fall along recognizable lineaments. The implication is, of course, that these lineaments are actually seismically active faults which have gone unrecognized prior to the availability of ERTS-1 imagery. It therefore appears that ERTS imagery, in the next few years, will prove to be a most important tool in assessing earthquake hazards in areas where existing seismic and geologic data are minimal. This is an especially important matter in Alaska, which will soon be experiencing an unprecedented rate of growth and expansion.

17. Key Words (Selected by Author(s))		18. Distribution Statement
ERTS Alaska Earthquake Seismicity	Tectonics Fault	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	35	

PRECEDING PAGE BLANK NOT FILMED

PREFACE

It was the aim of the present project to utilize ERTS-1 imagery to obtain a fundamental grasp of the basic tectonic elements of Alaska and, in particular, to ascertain if the imagery could be used as a tool to delineate seismically active faults.

To this end, mosaics of the seismically active areas of central and south-central Alaska were drawn up and compared with seismic data recently obtained by the University of Alaska.

There is a striking correlation between the location of recent large earthquakes and lineaments visible on the imagery. In south-central Alaska, there is a zone of intermediate depth earthquakes associated with a subduction zone which do not necessarily follow this rule, but in the main, most shallow earthquakes can be associated with at least one prominent lineament. The role of remote sensing as an aid to seismic risk evaluation seems to be firmly established.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EVALUATION OF FEASIBILITY OF MAPPING SEISMICALLY ACTIVE FAULTS IN ALASKA

1.0 INTRODUCTION

This report summarizes the goals of, and the results obtained from the ERTS-1 investigation 110-12 entitled "Evaluation of feasibility of mapping seismically active faults in Alaska" (one of 12 University of Alaska projects sponsored under NASA Contract NAS5-21833). The research described was performed during the years 1972 and 1973, commencing shortly after the launch of ERTS-1 in July, 1972.

The test area selected for the study was the highly seismically active portion of interior and south-central Alaska bounded roughly by latitudes 60° and 67°N and longitudes 145° and 151°W. Repetitive coverage was obtained from shortly after launch until mid 1973, and the frames selected for closest scrutiny were those exhibiting the sharpest detail by virtue of sun angle, cloud cover, spectral band, seasonal vegetation, snow cover, and other factors.

The initial objective was to test the feasibility of using ERTS imagery to find and delineate seismically active faults in the area which were unmapped on the ground, but which were suspected on the basis of ongoing seismicity. A secondary goal was to deduce the tectonic framework of central and south central Alaska.

In the course of the study, many new features were found. Largely (as in other ERTS-1 investigations), these took the form of structural lineaments, many of which are seismically active and are thus assumed to be true faults. As a result of this investigation, previously unknown areas of seismic risk have been identified, and the principal investigators, in cooperation with co-workers from the University of Alaska and other State and Federal agencies, have been given the opportunity to view the tectonic structure of Alaska in new perspective.

2.0 DATA ANAYLSIS AND RESULTS OF INVESTIGATION

2.1 Approach

From past experience, it is known that earthquakes occur throughout a large area of central and south-central Alaska. In general, these events do not occur randomly, but tend to cluster in groups or spread out in elongate zones -- the latter suggesting the presence of faults or fault zones. Since geologic and tectonic mapping of much of Alaska is in a very preliminary stage, it was decided to utilize ERTS imagery in an attempt to identify structural features which had been unmapped on the ground, and, in particular, to relate seismically active areas to lineaments (possible faults) which might be visible on the imagery. To do this, the investigators chose to obtain a certain amount of airborne data along known seismically active lineaments.

to compare with the satellite imagery. The purpose of this was to evaluate the relative merits of the two methods, and the extent to which each might interlock with, and complement the other.

The method of data analysis was straightforward, employed essentially no specialized treatment of the data, and in essence, was merely the application of standard aerial photo interpretation techniques. As the experiment progressed, several things became apparent which made it easier for the investigators to select the particular band and scene which would yield the maximum amount of information for the purposes of this project. For instance, during the late summer passes, it was found that band 5 produced superior results, but as the year progressed, band 7 was found to yield the images with the greatest amount of clarity and detail. In addition, the later passes at very low sun angle (about 9°) showed far greater resolution of topographic detail, but ended to accentuate lineaments trending at right angles to sun azimuth.

At first, the scenes were treated individually, but it quickly became apparent that many of the structural relationships which were being sought were of such a scale that they could not be included on any individual frame, and mosaics were produced. These eventually proved to be of the greatest value to the investigation in defining regional structural relationships, and in pointing out many large scale features which would have been otherwise overlooked.

Predictably, it was found that the aircraft data were useful in discerning small scale features not visible on the imagery, while the imagery was superior in defining regional relationships. The two methods supplemented each other somewhat, but not to the extent which we had hoped (see next section).

2.2 Results

2.2.1 Airborne observations

Four lines were flown in central interior Alaska by NASA's NP3A aircraft in July of 1972 (Test site 314 - the 148th Meridian transect, Alaska (Fairbanks fault lines)). Conventional black and white, color, and color IR photography was obtained, as was thermal IR and SLAR imagery. Two of these lines were along mapped, seismically active faults, while the other two were along seismically active linears not mapped as faults in the field. All four lineaments (as it later developed) are clearly visible on the satellite imagery.

The longest line extended from the town of Nenana, on the Tanana River, to the ENE past Fairbanks and into the headwaters of the Chena River (Fig. 1). We have long suspected this feature to be a fault on the basis of earthquake activity along nearly its entire length. Notably, in June of 1967, a series of earthquakes ranging up to magnitude 6 occurred in the immediate Fairbanks area (Gedney and Berg, 1969), and aftershock activity continues to the present (Fig. 2). Earthquakes have also tended to cluster in the vicinity of Nenana and along the Chena River (coincidentally, we discovered during the course of the investigation that the upper Chena had finally been geologically mapped as a fault (Davies, 1972)). Even under careful scrutiny, however, the aircraft data failed to yield conclusive evidence of the fault nature of this lineament. This is very likely due to the thick deposits of alluvial fill along most of its length and the fact that it is largely overlain by the Tanana and Chena Rivers. One fascinating development, however, did turn up. Just south of Fairbanks, exactly in the aftershock zone of the 1967 earthquakes, are what appear to be a series of steeply plunging folds in the alluvium of the Tanana Valley. The remarkable thing about these features is that they appear only on the thermal IR scanner. Figure 3 is a reproduction of the original imagery (mission 209, roll 48, site 314, frame 134) with overlay, and Fig. 4 locates the scene geographically. We offer no explanation as to the possible nature of these features, other than to comment that we have not seen anything like them elsewhere, and it seems a remarkable coincidence that they precisely occupy a vigorously active seismic zone.

The other unmapped linear which was flown was the Minook Creek Valley northwest of Fairbanks (flight line 23 on Fig. 1). Since the occurrence of a magnitude 6.5 earthquake here in 1968 (Gedney et al., 1969), a remarkable aftershock sequence underlying the valley has developed (Fig. 5) and we have maintained since that time that the valley is actually the surficial expression of a seismically active fault. However, as before, escarpments, offset streams, or other evidence of recent faulting did not appear on the aircraft data. The thermal IR scanner (mission 209, roll 55B, site 314, frame 37) did show some evidence of hot springs along the trace, further attesting to the fault nature of this lineament (the Minook Creek fault will be dealt with in greater detail in a following section).

Both of the mapped faults (the Blair Lakes fault -- line 17 on Fig. 1, and the Minto fault -- line 21) were clearly visible on both the photography and side looking radar. It was possible to discern the trace of the Blair Lakes fault considerably to the northwest of its presently mapped extent, although further definition of the Minto fault was not possible.

In summary, it can probably be stated that the amount of new information gleaned from the aircraft data, spectacular as it is, probably does not justify the expense involved in its collection. This, of course, applies to <u>this investigation only</u> and in all likelihood, to this area alone (or others like it because of deep alluvial fill, etc.). The satellite imagery is far exceeding our expectations in fault scarp resolution under favorable lighting conditions. As an example of this, note that the Blair Lakes fault -- a minor feature with 10-15 feet of vertical offset at most -- is clearly visible in Fig. 13 of a later section.

As partial compensation, and without apology, it should be stated that the aircraft data are finding use in a variety of related matters, such as decision making in where to emplace remote seismic stations or field sites. It is extremely useful as a teaching aid (most people here have never had the opportunity to work with thermal IR or SLAR) and is valuable in geologic mapping (example: a graduate student has been using the data for his study area). It will be useful for many years to come.

2.2.2 Satellite (ERTS-1) observations

It is not possible, with the hundreds of images received, to go over each one in detail, although doubtless each one has something on it of interest. Because of this, only the superior scenes have been selected for discussion. Even so, the volume is still so great that we are presenting our results in two sections. The first will employ individual images which point out items of special interest which are not necessarily related to the major seismic zones of the state. The second (which is itself subdivided into two sections) will employ mosaics constructed from 35 individual scenes which cover the primary seismically active areas of central and south-central Alaska.

2.2.2.1 Items of special interest

In 1937, an earthquake of magnitude 7.3 occurred about 30 miles southeast of Fairbanks. Although some ground breakage was reported, a thorough investigation was never carried out by qualified personnel, and indisputable surface faulting connected with the earthquake was never found. About 20 miles to the southeast of the assumed epicenter (which was not instrumentally located) is the Shaw Creek Valley, which is held by some workers to be the surface expression of a buried fault although this is questioned by others (F. Weber, U.S.G.S., oral communication). This feature is seen on the imagery to be a major structural lineament of surprisingly large scale. It includes not only the drainage of Shaw Creek, but of Charley River to the north as well, and extends northward across the Yukon River. It appears to be double-branched in at least one place, and, most significantly, left-laterally offsets another major tectonic feature of the area, the Tintina trench (a fault zone of major offset since the Cretaceous). Figures 6 and 7 are two adjoining frames which show this feature.

Another major lateral fault in the Alaskan interior is the Kaltag. King (1969) shows this fault south of the Yukon River and west of the town of Tanana to be buried. On the imagery there is a double feature parallel to and just south of the Kaltag fault with the two branches being separated by about 25 km. The most striking thing about this feature is the "herringbone" drainage pattern achieved by the apparently offset streams in the block between the two branches. The relative right-lateral offset of the streams to either side of the block (if they have actually been offset) would be about 15 km. This feature is shown in Fig. 8.

Figure 9 shows a previously unmapped seismically active fault which we have taken the liberty of naming the Susitna fault after the river and the glacier with which it is associated. Surface expression of the fault is a lineal depression, along which streams flow and sag ponds form. It can be traced for at least 120 km, and end points at approximately 62°26'N, 149°23'W, and 63°14'N, 147°44'W. On October 1, 1972, an earthquake of magnitude 5.2 occurred on this fault near its southern end. The event was felt throughout the Susitna Valley. Inspection of seismicity records dating back to 1967 reveals that earthquakes in this area have tended to cluster along the fault, particularly near the end points. This feature is of interest from yet another viewpoint, stemming from the fact that it intersects the Denali fault at its northern end. The

Denali fault is probably the major tectonic feature of the state, being Alaska's counterpart of California's San Andreas fault. Offset along the Denali has long been a matter of conjecture. Recent cooperative studies involving radiometric dating, geologic mapping and use of the imagery have now provided the first firm quantitative evidence of this offset (Turner et al., 1974). The Susitna fault separates K-Ar dated metamorphics of mid- and latest-Cretaceous ages. In Yukon Territory near Kluane Lake, another strong lineament on the opposite (north) side of the Denali fault separates K-Ar dated metamorphics of mid-Cretaceous age from igneous and metamorphic rocks yielding 57 m.y. dates. This lineament is also truncated by the Denali fault. The Susitna fault and this lineament are very similar in appearance and both intersect the Denali at the same angle. If they were once contiguous, as it would appear, the total amount of right-lateral offset along the Denali fault since the early Cretaceous is slightly greater than 400 km.

Although the area shown in Fig. 10 is not particularly seismically active, the scene is of interest from at least two viewpoints. First, an unmapped strand of the Totschunda fault at its intersection with the Denali shows up clearly. This branch extends northwestward through Stone Creek, across the valley of the Nabesna River, and into the mountains to the northwest. The most detailed geologic map available of this area (Richter and Matson, 1971) does not show this feature, presumably because of alluvial fill along its trace, lack of rock differentiation cross it, and sheer inaccessibility in the mountainous areas. Also on this scene is a small, but clearly defined topographic break on the northwest flank of Mt. Sanford. This is particularly interesting because it is clear from the lighting and from stream incision into the downhill block that if it is a fault, it is a reverse fault. That is, the mountain has dropped with respect to the valley. Since Mt. Sanford is a dormant volcano, some speculation into the possibility of reservoir drainage being responsible for the feature is inevitable.

2.2.2.2. An overview of seismicity patterns in Alaska

The recent emergence of plate tectonic theory as a unifying doctrine for the earth sciences is probably the most significant breakthrough of this century in explaining the recent evolution of our planet. The manifestations of seafloor spreading -- magnetic and heat flow anomalies, oceanic ridges, arc and trench systems, volcanoes, earthquakes -- are explained with a simplicity which earlier workers would have envied. Yet, there are areas in the world which do not submit gracefully to various aspects of the theory. Central Alaska is one of those areas.

Ideally, the north Pacific plate "should" underthrust Alaska along the Aleutian trench east of Kodiak Island and the Kenai Peninsula. Indeed, this was one mechanism which was postulated for the great earthquake of 1964 (c.g., Plafker, 1972, p. 163). As a result of that earthquake, Alaska suddenly became a focal point of interest to seismologists, and the first seismographic nets in the state were established (the U.S.C.G.S. station COL near Fairbanks had been the only permanent installation in the state). With the enhanced seismographic coverage -- particularly from those stations operated by the University of Alaska -- it was possible to locate small earthquakes which had previously gone undetected, and the first clear picture of seismicity in Alaska began to emerge.

It is this data which now lead us to claim that the subduction zone at the NE end of the trench-arc system does not lie offshore in the Aleutian trench, but instead extends up Cook Inlet and along the base of the Alaska Range to a point north of Mt. McKinley. The dipping interface associated with the underthrusting is clearly delineated when one examines the seismic zone in profile (Fig. 11). However, all earthquakes within the state do not occur within the subduction zone. Transmittal of stresses from around the great bend in the Alaska Range (which appears to enclose a corner of the downgoing plate) is the agent most likely responsible for a broad area of shallow seismicity in the Alaskan interior. Thus, continental Alaska can be classified into two regions on the basis of seismicity. The first of these is the area enclosed by the bend of the Alaska Range, in which earthquakes of shallow and intermediate depth (to 250 km) occur. This is separated from the shallow seismic zone of central interior Alaska by the Alaska Range, and by the Denali fault (which trends generally along the mid-line of the range). The Denali fault is therefore a transform fault along which differential movement between continent and oceanic plate is occurring.*

With this knowledge as background, it is now natural to inquire into the question of where earthquakes are likely to occur. Little can be second-guessed on the basis of past experience, because such a short period of reliable data collection has elapsed. It has been our experience that large earthquakes (magnitude 6 or greater) can occur almost randomly in the interior, and insufficient data have been accumulated to even indicate that such seismic zones might exist. Geologic mapping of the state is in such a preliminary stage that it is a certainty that many seismically active faults have gone unmapped.

Therefore, it was with a great deal of anticipation with which we awaited the first ERTS imagery of this area. We were gratified, indeed, when a first look at the data showed that the larger earthquakes in the state, more often than not, fell on or near lineaments which were clearly visible on the imagery. In most cases these lineaments were not mapped as faults. It therefore appears that ERTS imagery, in the next few years, will prove to be a most important tool in assessing earthquake hazards in areas where existing seismic and geologic data are minimal. This is an especially important matter in Alaska, which will be experiencing an unprecedented rate of growth and expansion now that resource development is so vital an issue to the nation.

2.2.2.2.1. South-central Alaska

Figure 12 is a mosaic constructed from 19 ERTS-1 images produced on four consecutive passes of the satellite on Novemeber 2,3,4 and 5, 1972. It shows south-central Alaska with Anchorage at the head of Cook Inlet near the right center, the Kenai Peninsula at lower right center, and the Alaska Range curving across the scene from the upper right to the lower left. Several well-known structural elements are readily apparent. Two of these are large scale strike-slip faults which are among Alaska's most notable tectonic features. A portion of the Denali fault crosses the scene from upper right to upper left center, and it is roughly paralleled by the Lake Clark fault (which is somewhat less conspicuous) to the south. The solid circles on the key to Fig. 12 represent epicenters of earthquakes which occurred in this area during 1972. They are keyed by number to their respective parameters in Appendix I. Note that these are epicenters of earthquakes which were of magnitude 4 and larger.

*The actual situation is not quite this simple. There are some problems with treating the Denali fault as a simple transform, but the matter will not be dealt with in this report.

Thousands of smaller events were recorded during this time. Most of the earthquakes are seen to occur in the vicinity of Cook Inlet, but it should be noted that this is largely deep-seated seismic activity related to the subduction zone, and it probably does not bear a direct relationship to lineaments which can be seen at the surface. A few earthqukes appear to be associated with the Denali fault, particularly in the vicinity of Mt. McKinley (which is casting the triangular shadow in the upper left quadrant), and there is an obvious clustering of earthquakes along the Lake Clark fault. Of particular interest, however, are those lineaments which are not geologically mapped as faults, but which could probably be so classified on the basis of ongoing seismicity. Particularly noteworthy are the set of sub-parallel lineaments trending off the Denali fault to the southwest, and the peculiar graben-like structure outlined by the mountains around Anchorage. The 1964 epicenter was very close to earthquakes 34 and 50 on the lineament near the right margin, although it is not clear whether or not this fault could have played a role in that earthquake. Note the extremely sharp escarpment of the Kenai Mountains which passes very close to Anchorage and the association of at least three earthquakes with this apparent fault.

2.2.2.2.2. Central Interior Alaska

Figure 13 is a mosaic of 6 ERTS-1 images collected on 4 and 5 November, 1972. Fairbanks is at right center, the Yukon River enters the scene at the top, the Tanana River crosses from right to left, and the Alaska Range is at bottom right. The scene is to the north of Fig. 12 and the mosaics partially overlap (although they are of different scales). First, faults which have been previously mapped on the ground are shown as solid lines on the key. In general, these are members of the same large scale strike-slip fault system to which the Lake Clark and Denali faults belong. Although not always topographically well-defined, large offsets have occurred along most of these since the Cretaceous. Second, the lineaments indicated by dashed lines appear to be large scale faults which supplement the known set. Included in this category is the northern escarpment of the Alaska Range which appears from the imagery to be a normal fault with considerable vertical displacement, although some workers believe that this is a fold feature. Finally a very sharp set of conjugate lineaments is shown on the key as dotted lines. These intersect at an angle of about 55° and appear to be the result of compressive stress in an outward direction from around the bend of the Alaska Range (leading to the postulation that they may have actually resulted from bending of the range). The angle of 55° is roughly the dihedral angel at which most brittle substances would be expected to fracture under compressive stress, with left-lateral offset on one set of fractures, and right-lateral offset on the other. The persistence of these features over large areas implies that they are continuous beneath the alluvium of the Tanana River Valley.

The circles on the key relate to epicenters of the largest earthquakes to occur within the mapped area within recent years. The numbers correlate the earthquakes with their respective parameters which are given in Appendix II. It is significant that these have tended to occur at intersections of lineaments visible on the imagery. It thus appears that the seismicity of this part of the state may be conceptually regarded as being the product of the grinding together of (relatively) rigid blocks, with earthquakes occurring along their common boundaries, and at the intersections where three or more blocks come into contact. Focal mechanism studies have shown that the earthquake on the conjugate set of lineaments (number 2) was the result of left-lateral slippage on the prominent north-south trending fault, in agreement with the model proposed above. This fault, not recognized prior to the earthquake in 1968, forms the surface expression of Minook Creek Valley. It appears to nearly intersect the proposed site for the bridge and pipeline crossing of the Yukon River, and is only about 40 km east of the proposed Rampart dam site. The Fairbanks earthquake of 1967 (number 1) appears to have been the result of left-lateral slippage on the NE-SW trending lineament -- a perplexing situation and one which indicates that the stress trajectories must curve across the region.

Much of the area of the mosaic will be under development in the years ahead. In particular, the trans-Alaska pipeline will cut across nearly every one of the major lineaments in the northeast quadrant. Since so little is presently known of the seismicity of these areas over long periods of time, we are compelled to regard each of these lineaments (and those in Fig. 12) as being potential sites for future earthquakes, particularly in view of the fact that some of them have produced sizeable events in only the brief period since 1967.

2.2.3 Applications

There are two distinct, but interrelated study areas to which the present project applies. One is the tectonic mapping of the state of Alaska -- a task which has proceeded only slowly in the pre-ERTS era primarily because of the difficulties involved in performing field investigations across such a broad and remote area. The other is the evaluation of seismic risk, a factor which, as pointed out in the preceding section, is becoming more important in future planning as the state is being developed. Little hard knowledge was available on which to base estimates of seismic risk in most of Alaska. The 1964 earthquake taught us that earthquake hazard was a factor which would have to be dealt with in the future expansion of the state, but until that disastrous event, little actual research into the problem had been done. The satellite imagery is vastly speeding up the accumulation and consolidation of the needed information. It bears pointing out that people who have consulted us on this aspect of our investigation include both public and private organizations. Notably there has been the U. S. Army Corps of Engineers (contact: Glen Greeley, Alaska branch), which was (and is) interested in developing an improved seismic risk map along the proposed trans-Alaska pipeline route, and Woodward, Lundgren and Associates (contacts: D. B. Slemmons and L. Cluff, consultants to Alyeska, the pipeline consortium) who were interested in the same problem.

Investigators with whom we have had dealings on the tectonics of Alaska include D. Turner and R. Forbes of the University of Alaska, and T. Smith of the State of Alaska Department of Natural Resources who used the imagery to substantiate the 400 km offset on the Denali fault which was mentioned in section 2.2.2.1. F. Weber of the U. S. Geological Survey is interested in the problem of mapping the Shaw Creek fault, also mentioned in that section, and the imagery proved to be of considerable value. Other users have been too numerous to name, but include the Atlantic Richfield Company which has sent representatives (Leo Fay, Les Brockett) to visit on several occasions for the purpose of using

ERTS imagery in compiling information with which to upgrade the geologic and tectonic mapping of the state, and numerous other scientists, students, engineers, or merely interested citizens*

Clearly, the potential applications of the imagery for the purposes of geologic and tectonic mapping are practically unlimited.

3.0 NEW TECHNOLOGY

None.

4.0 CONCLUSIONS

Briefly stated, it appears that most earthquakes in Alaska can be associated with lineaments (suspected faults) which are visible on the imagery. The potential significance of this in terms of future construction planning, zoning, and seismic risk evaluation in the state is obvious.

A great deal of insight has been gained into the earthquake-producing forces at play in central Alaska. Apparently, there are two distinct seismic regimes, separated generally by the Alaska Range. The southern segment, enclosed by the great bend of the range, derives most of its seismicity either directly or indirectly from underthrusting of the north Pacific plate beneath the Alaska mainland. Consequently, many of the earthquakes are of intermediate depth and cannot be associated with features visible on the imagery. In most cases, however, the shallower (and therefore potentially more hazardous) earthquakes fall on or near well defined lineaments. In central interior Alaska north of the Alaska Range, earthquakes are all of shallow origin, and association with lineaments seen for the first time on the imagery is even more striking. The disclosure of a large scale conjugate fracture system is the first solid evidence that earthquakes here result from compressive stress directed outwardly from around the great bend in the Alaska Range near Mt. McKinley. The tectonic implication to this is that the range is being further deformed, probably in response to the processes of sea-floor spreading.

5.0 RECOMMENDATIONS

One disappointing aspect of the ERTS-1 imagery has been that the stereoscopic effect obtained by viewing side-lapping pairs in a stereoscope is negligible. As an example, the mosaic of Fig. 13, when viewed stereoscopically with Fig. 14 (another mosaic of 6 images collected on different passes), yields very little relief. The effect would probably be enhanced considerably if the spacecraft were equipped with obliquely mounted sensors, and it is our recommendation that a pair of these be considered for mounting in ERTS-B. Those investigations dealing with geology, geomorphology, tectonics etc. would probably be the ones to most directly benefit from this innovation.

---

*As this report went to press, the Principal Investigator was requested by the firm of Harding-Lawson Associates to utilize the imagery and seismicity records to prepare a statement of seismic risk along the Kenai Mountain escarpment (mentioned at the end of section 2.2.2.2.1.) where a new hospital is being planned.

6.0 APPENDICES

6.1 Appendix I

The following table lists, by number, all the epicenters which are plotted on Fig. 12. All data in the table were produced by the University of Alaska seismology program, except those accompanied by an asterisk (*), for which the National Oceanographic and Atmospheric Administration (NOAA) was the source.

Date (1972)	Latitude (N)	Longitude (W)	Magnitude
1. Jan 2	59.3	153.6	4.4
2. Jan 9	59.5	156.6	4.0
3. Jan 19	59.4	156.9	4.3
4. Jan 24 *	59.6	151.4	4.0
5. Feb 5 *	60.3	153.8	4.6
6. Feb 13 *	59.9	154.2	4.9
7. Feb 16	59.5	152.9	4.3
8. Feb 25	61.3	149.4	4.0
9. Feb 27	59.2	151.6	4.4
10. Feb 29	63.2	150.5	4.0
11. Mar 1 *	59.6	152.8	4.6
12. Mar 7	60.0	155.3	4.0
13. Mar 12 *	64.1	148.4	4.2
14. Mar 12	61.6	147.7	4.0
15. Mar 14	60.8	152.3	4.0
16. Mar 21	60.1	150.3	4.0
17. Mar 23	59.7	153.2	4.3
18. Mar 25	59.8	155.6	4.0
19. Mar 25	59.3	155.3	4.1
20. Mar 28 *	59.8	153.4	4.3
21. Mar 29 *	59.9	153.1	5.1
22. Apr 2 *	59.9	153.6	4.9
23. Apr 5	61.4	151.9	4.0
24. Apr 7 *	60.1	152.8	5.1
25. Apr 9	64.0	150.9	4.5
26. Apr 9	61.6	151.0	4.1
27. Apr 11 *	62.0	150.4	4.2
28. Apr 15	60.8	153.6	4.1
29. Apr 16	63.4	147.6	4.6
30. Apr 16	63.5	147.6	4.1
31. Apr 19	58.7	155.6	4.1
32. Apr 20 *	60.2	152.1	4.7
33. Apr 20 *	59.9	153.6	4.5
34. Apr 25	61.1	147.1	4.0
35. Apr 25 *	62.0	147.8	4.6
36. Apr 28 *	63.6	149.9	4.7
37. May 7	61.1	152.1	4.1
38. May 8	59.6	155.7	4.1
39. May 8	58.8	153.0	4.1
40. May 14	62.4	151.1	4.0
41. May 14	61.8	150.3	4.1
42. May 19	59.6	152.9	4.1

Date (1972)	Latitude (N)	Longitude (W)	Magnitude
43. May 20	59.6	152.9	5.2
44. Jun 1	59.6	155.1	4.0
45. Jun 10	59.1	155.6	4.1
46. Jun 14	61.0	152.5	5.2
47. Jun 16	59.3	152.3	4.2
48. Jun 18	62.6	152.7	4.7
49. Jun 20	59.5	152.7	5.1
50. Jun 22	61.4	147.5	4.6
51. Aug 6	60.0	149.2	4.0
52. Aug 9	58.7	154.5	4.1
53. Aug 12	61.4	149.8	4.0
54. Aug 17	59.4	152.6	4.2
55. Aug 19	59.1	153.3	4.2
56. Aug 22	59.8	152.2	4.1
57. Aug 23	58.4	153.2	5.5
58. Sep 3 *	59.7	149.1	4.7
59. Sep 11 *	59.6	148.9	5.1
60. Oct 1	62.7	149.1	5.2
61. Oct 1	59.8	153.3	4.7
62. Oct 20	60.0	152.4	4.2
63. Oct 21	63.2	151.1	5.4
64. Nov 19	60.9	153.1	4.6
65. Nov 21	62.2	149.7	4.1
66. Nov 22	59.6	152.4	4.1
67. Nov 25	58.6	152.2	4.3
68. Nov 28	59.7	153.5	5.1
69. Dec 3	59.8	154.7	4.0
70. Dec 3	58.6	155.2	4.4
71. Dec 4	59.8	154.8	4.2
72. Dec 15	60.3	151.2	5.0
73. Dec 18	60.8	153.1	5.6
74. Dec 29	61.6	151.3	4.5

6.2 Appendix II

Listing of earthquakes plotted on Figure13.

Date	Latitude (N)	Longitude (W)	Magnitude
1. 21 Jun 67	64.8°	147.4°	6.0
2. 29 Oct 68	65.4°	150.0°	6.5
3. 21 Jun 69	65.2°	147.6°	4.6
4. 9 Jun 70	64.9°	148.7°	4.2
5. 15 Aug 72	65.2°	148.7°	5.1

7.0 ACKNOWLEDGEMENTS

The seismic data collected during the course of this investigation was obtained with support from the U. S. Air Force under Contract F44620-71-C-0105.

8.0 LIST OF PUBLICATIONS

The following list includes papers, reports, presentations and publications dealing partly or in whole with the present ERST-1 investigation, for which NASA was the primary or ancillary funding agency.

Gedney, L., "Finding faults" with ERTS-1 imagery, The Northern Engineer, 5(1), pp. 3-5, Spring, 1973.

Gedney, L. and J. VanWormer, Some aspects of regional tectonics in Alaska as seen in ERTS-1 imagery, Symposium on Significant Results obtained from ERTS-1, Abstracts, Paper G-23, p. 49, New Carollton, Maryland, March 1973.

Gedney, L. and J. VanWormer, Some aspects of active tectonism in Alaska as seen on ERTS-1 imagery, Symposium on Significant Results obtained from ERTS-1, Vol. I: Technical Presentations, Section A, pp. 451-457, March 1973.

Gedney, Larry and James VanWormer, Tectonic mapping in Alaska with ERTS-1 imagery, interim scientific report, NASA Contract NAS5-21833, May 1973.

VanWormer, J., L. Gedney, J. Davies, and L. Shapiro, Central Alaska seismicity, 1972, Program with Abstracts, 68th Annual National Meeting of the Seismological Society of America, p. 49, Golden Colorado, May, 1973.

VanWormer, J., J. Davies and L. Gedney, Central Alaska earthquakes during 1972, Scientific Report UAG R-224, Geophysical Institute, University of Alaska, August, 1973.

Gedney, L. and J. VanWormer, Earthquake probabilities in selected areas of Alaska based on B-slope monitoring, Proceedings, U.S.-Japan Conference on Earthquake Prediction and Control, p. 38, Boulder, Colorado, August, 1973.

Gedney, L. and J. VanWormer, Seismically active structural lineaments in south-central Alaska as seen on ERTS-1 imagery, interim scientific report, NASA Contract NAS5-21833, November 1973.

Gedney, L. and J. VanWormer, ERTS-1, earthquakes, and tectonic evolution in Alaska, Proceedings of the third ERTS Symposium, Washington D.C., December 1973 (in press).

Gedney, L. and J. VanWormer, Tectonic mapping in Alaska with ERTS-1 imagery, Photo Interpretation, pp. 23-27, Jan.-Feb., 1974.

VanWormer J., J. Davies and L. Gedney, Some characteristics of the subduction zone in south-central Alaska, Program with abstracts p. 270, 69th Annual Meeting of the Seismological Society of America, Las Vegas, Nevada, March 1974.

Gedney, L. and J. VanWormer, Seismic Hazard evaluation in Alaska by remote sensing, GEOTIMES, pp. 15-17, Feb., 1974.

VanWormer, J., J. Davies and L. Gedney, Seismicity and plate tectonics in south-central Alaska, Bull. Seism. Soc. Am. (in press).

Gedney, Larry, James VanWormer and Lewis Shapiro, Tectonic lineaments and plate tectonics in south-central Alaska, Invited paper to appear in the Proceedings of the First International Symposium on the New Basement Tectonics, University of Utah Press, 1974.

9.0 LIST OF REFERENCES

Davies, W., The Tintina trench and its reflection in the structure of the Circle area, Yukon-Tanana upland, Alaska, 24th International Geological Congress, Sec. 3, 211-216, 1972.

Gedney, L. and E. Berg, The Fairbanks earthquakes of June 21, 1967; Aftershock distribution, focal mechanisms and crustal parameters, Bull. Seism. Soc. Am., 59, 73-100, 1969.

Gedney, L. E. Berg, H. Pulpan, J. Davies, and W. Feetham, A field report on the Rampart, Alaska earthquake of October 29, 1968, Bull. Seism. Soc. Am., 59, 1421-1423, 1969.

King. P., Tectonic map of North America, U. S. Geol. Survey, 1969.

Turner, D., T. Smith and R. Forbes, Geochronology of offset along the Denali fault system in Alaska, Geol. Soc. Am., Cordilleran Section Ann. Mtg., Program Abstracts, 1974 (in press).

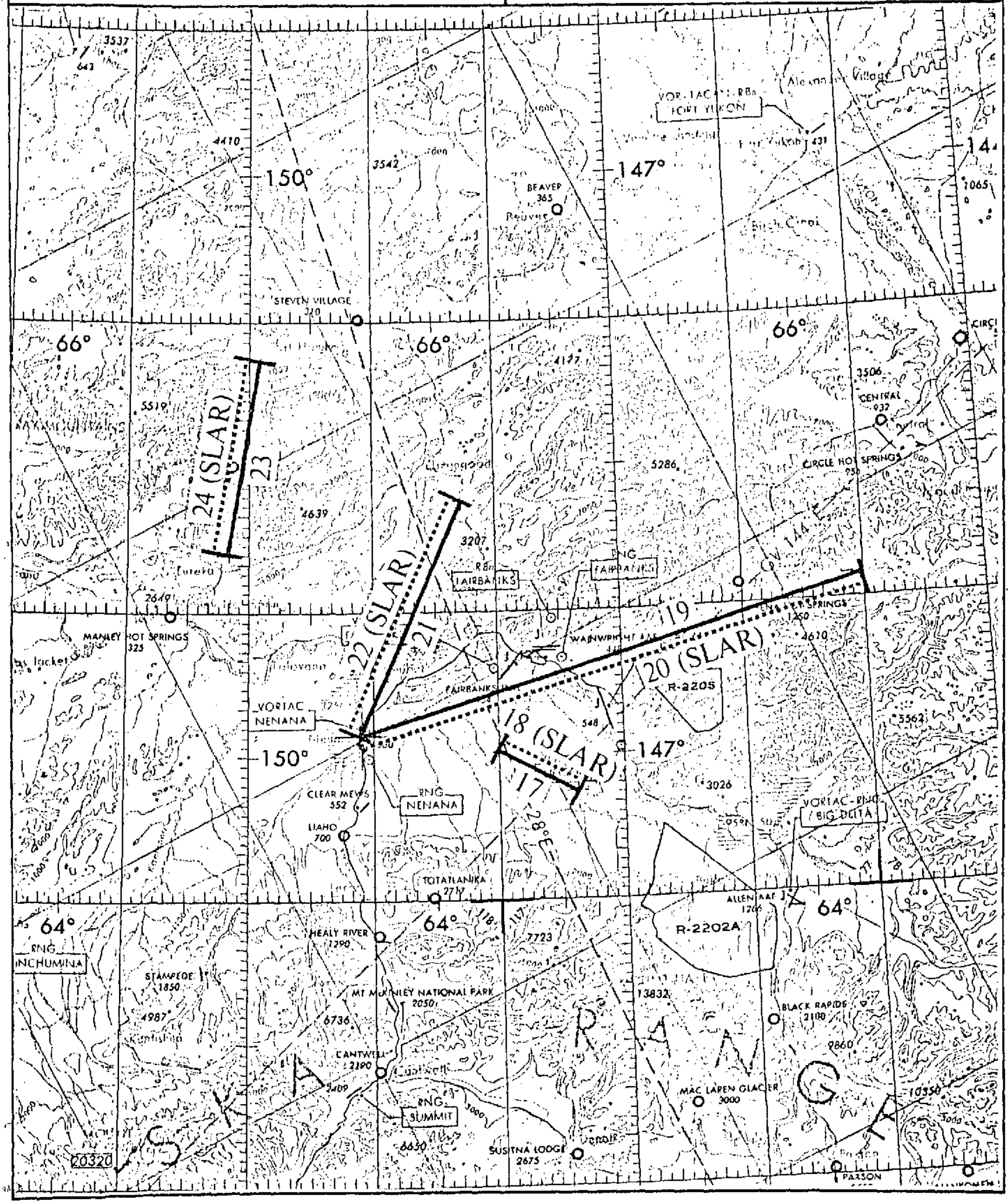
Plafker, G., Tectonics, The Great Alaska Earthquake of 1964, Seismology and Geoldesy, 113-174, Committee on the Alaska Earthquake of the Division of Earth Sciences, National Research Council, National Academy of Sciences 1972.

Richter, D. and N. Matson, Quaternary faulting in the eastern Alaska Range, Geol. Soc. Am. Bull., 82, 1529-1540, 1971.

Figure 1. Flight lines flown by NASA's NP3A aircraft for this project.

TEST SITE MAP

TEST SITE	PRINCIPAL INVESTIGATOR
314 - The 148th Meridian Transect, Alaska	Larry D. Gedney



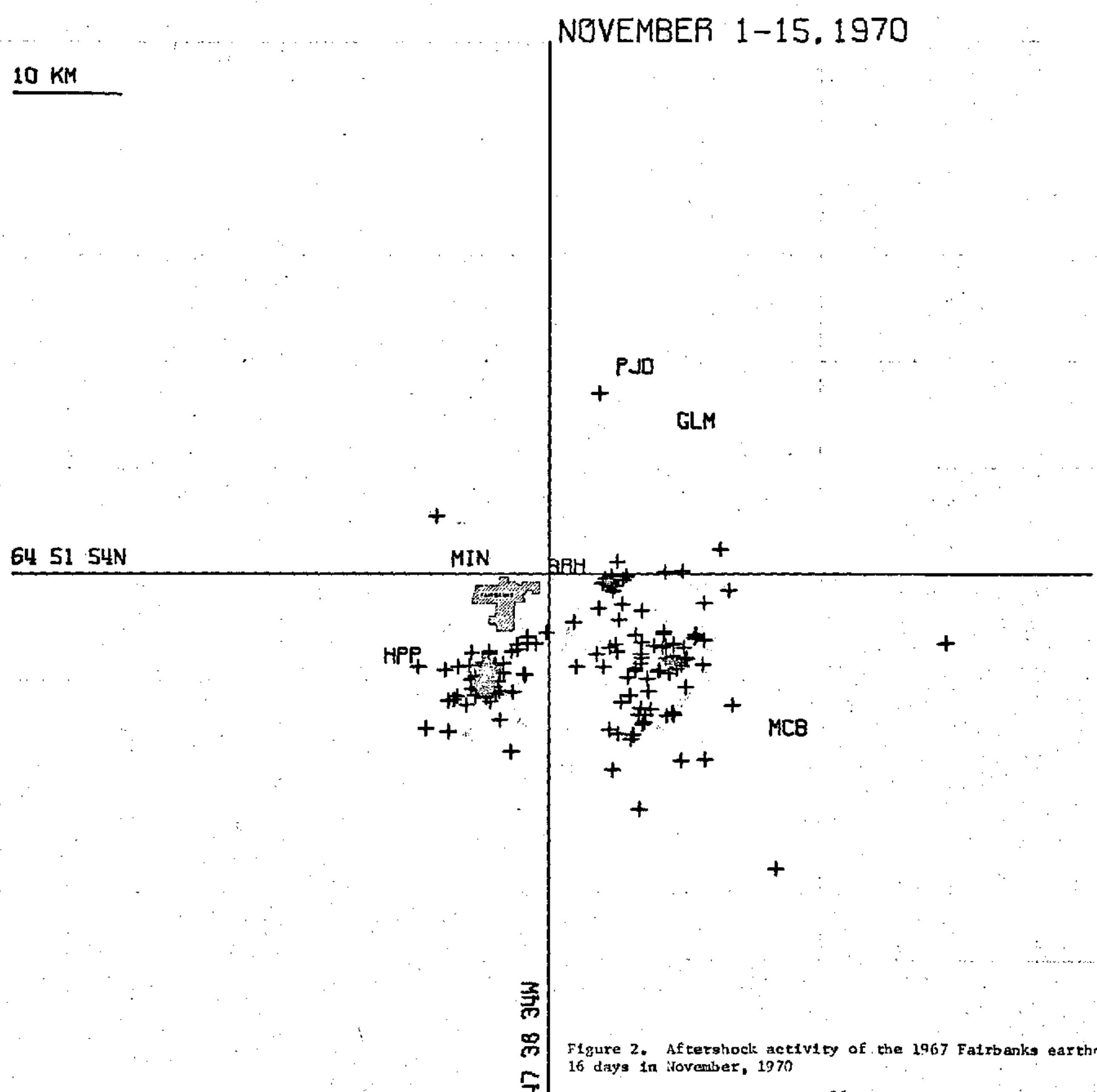


Figure 2. Aftershock activity of the 1967 Fairbanks earthquakes for 16 days in November, 1970

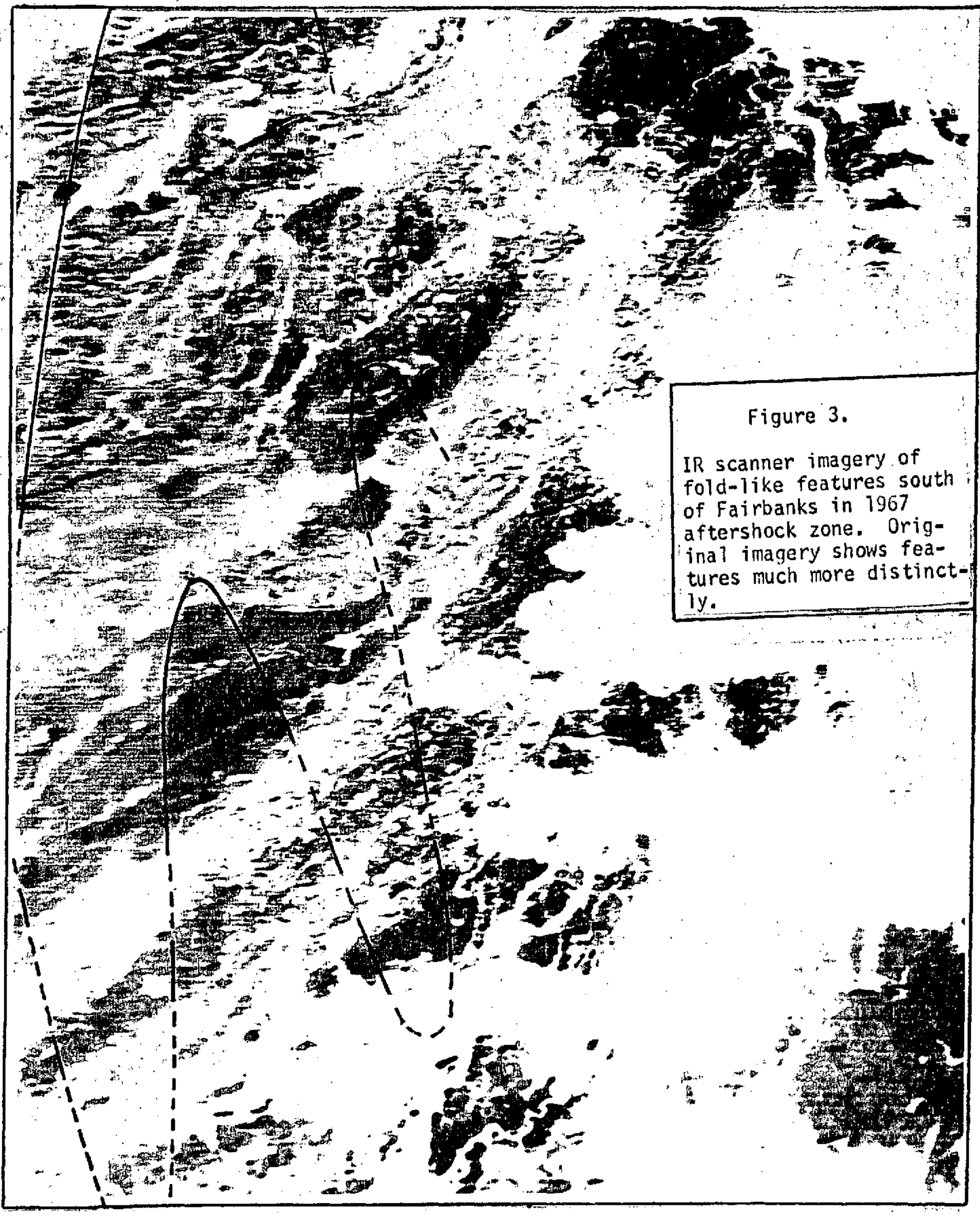


Figure 3.

IR scanner imagery of fold-like features south of Fairbanks in 1967 aftershock zone. Original imagery shows features much more distinctly.

Figure 3.

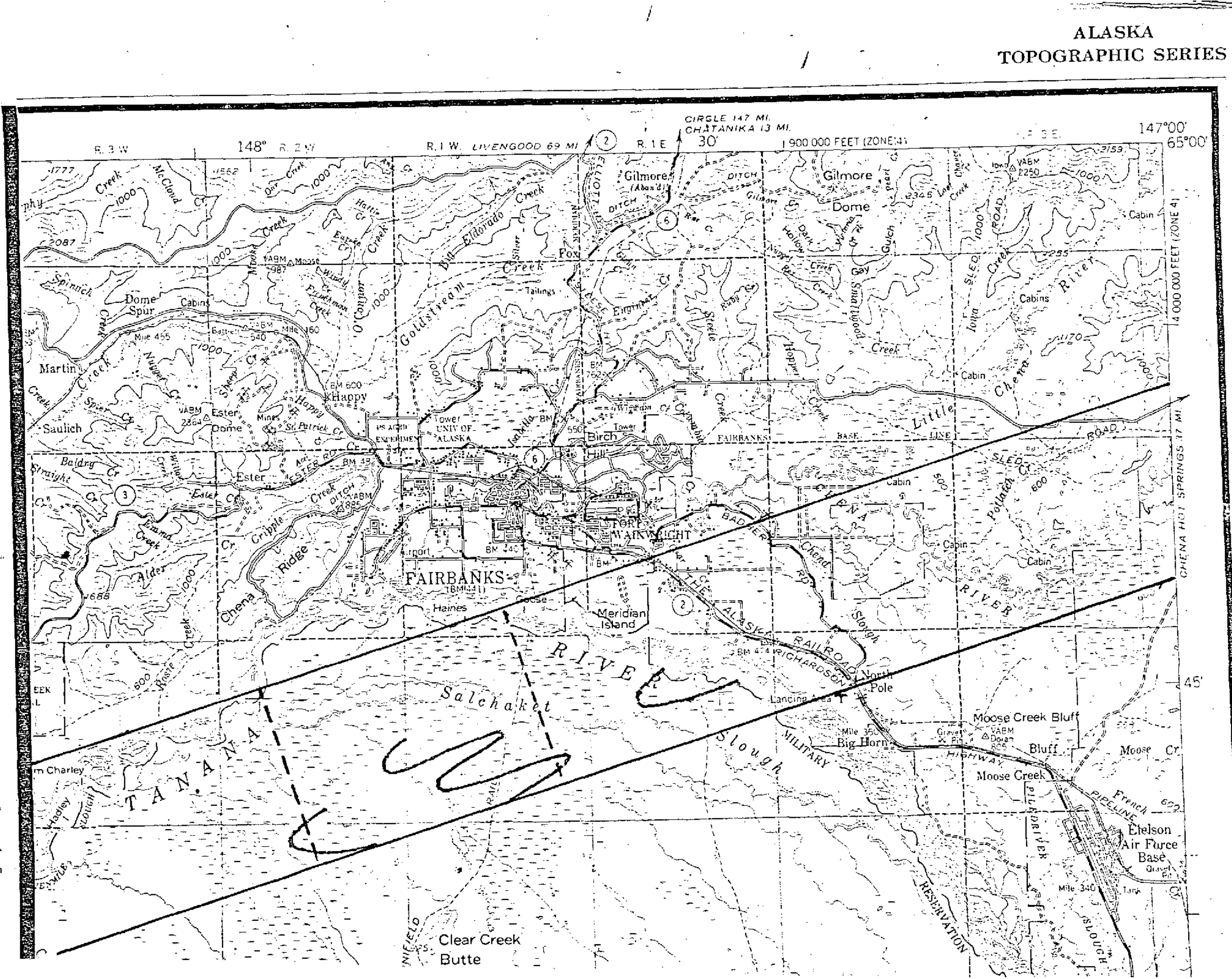


Figure 4. Geographical location of fold-like features reproduced from the infra-red imagery in Fig. 3. Solid lines indicate coverage by this flight line, while dotted lines indicate area included in previous figure.

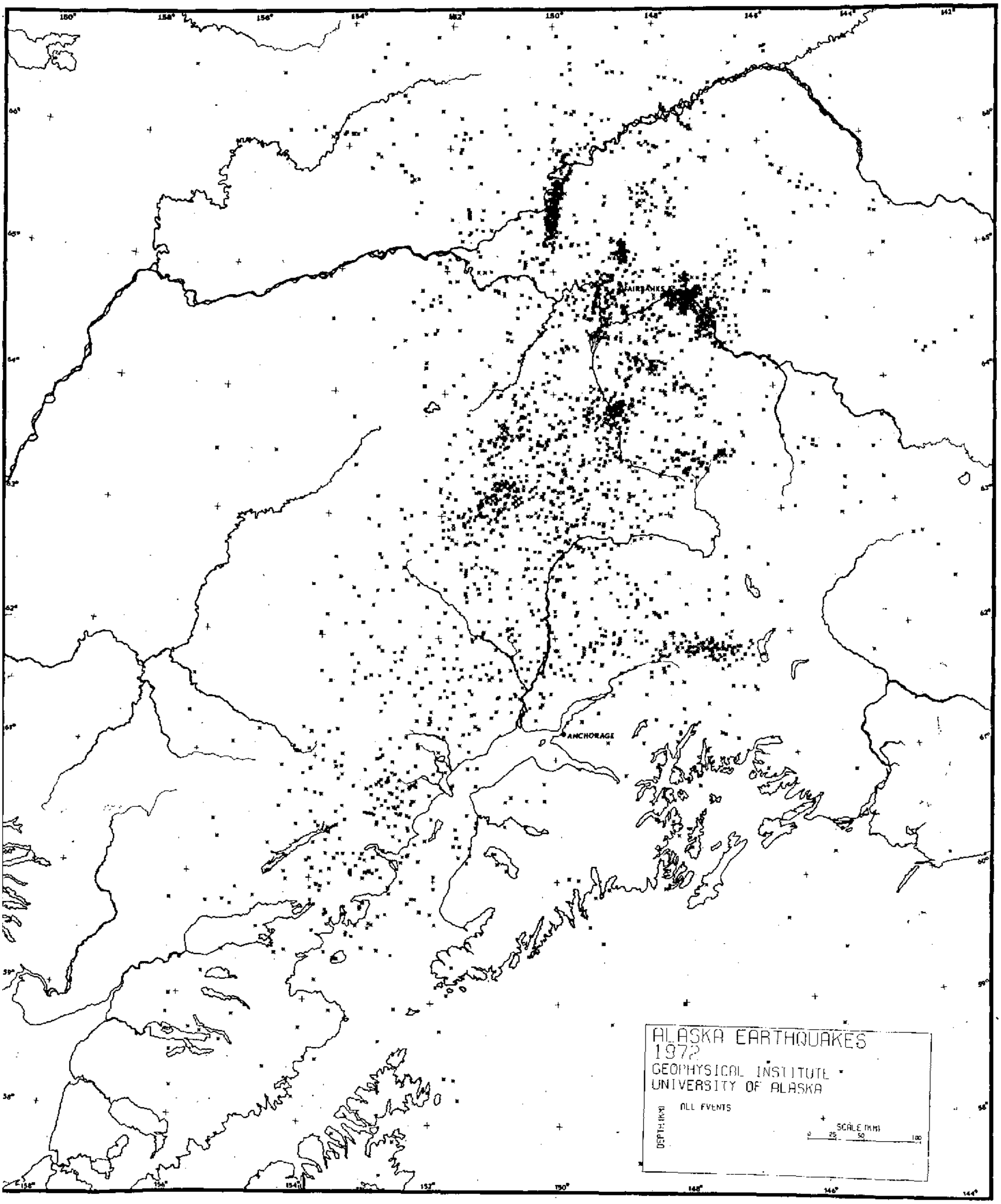


Figure 5. Epicenters of Alaskan earthquakes occurring during 1972 which were located by the University of Alaska. The Minook Creek aftershock swarm is the north-south trending group of epicenters near 65.5°N, 150.0°W.

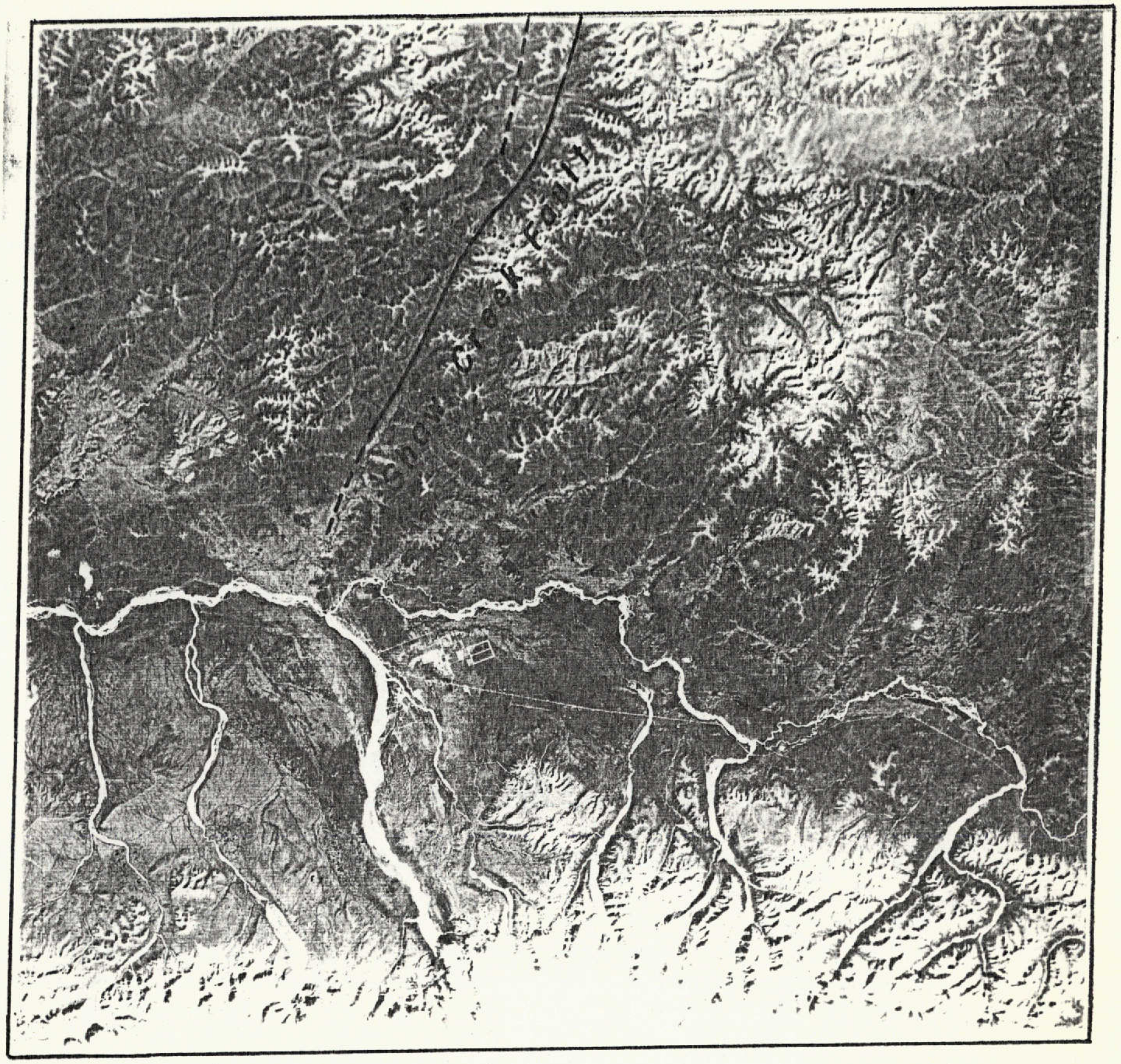


Figure 6. Southern portion of Shaw Creek fault southeast of Fairbanks. Northern portion is shown in Figure 7. Speculation exists as to whether this prominent feature is actually a fault. The Alaska highway crosses the lower half of the scene. The rectangular feature at lower center is a fire break constructed preparatory to clear-burning the area for farming.

Figure 7. Northern portion of the Shaw Creek fault showing area where it apparently offsets the Tintina fault zone (trench) south of the Yukon River. Unresolved structural lineaments are shown as dashed lines.

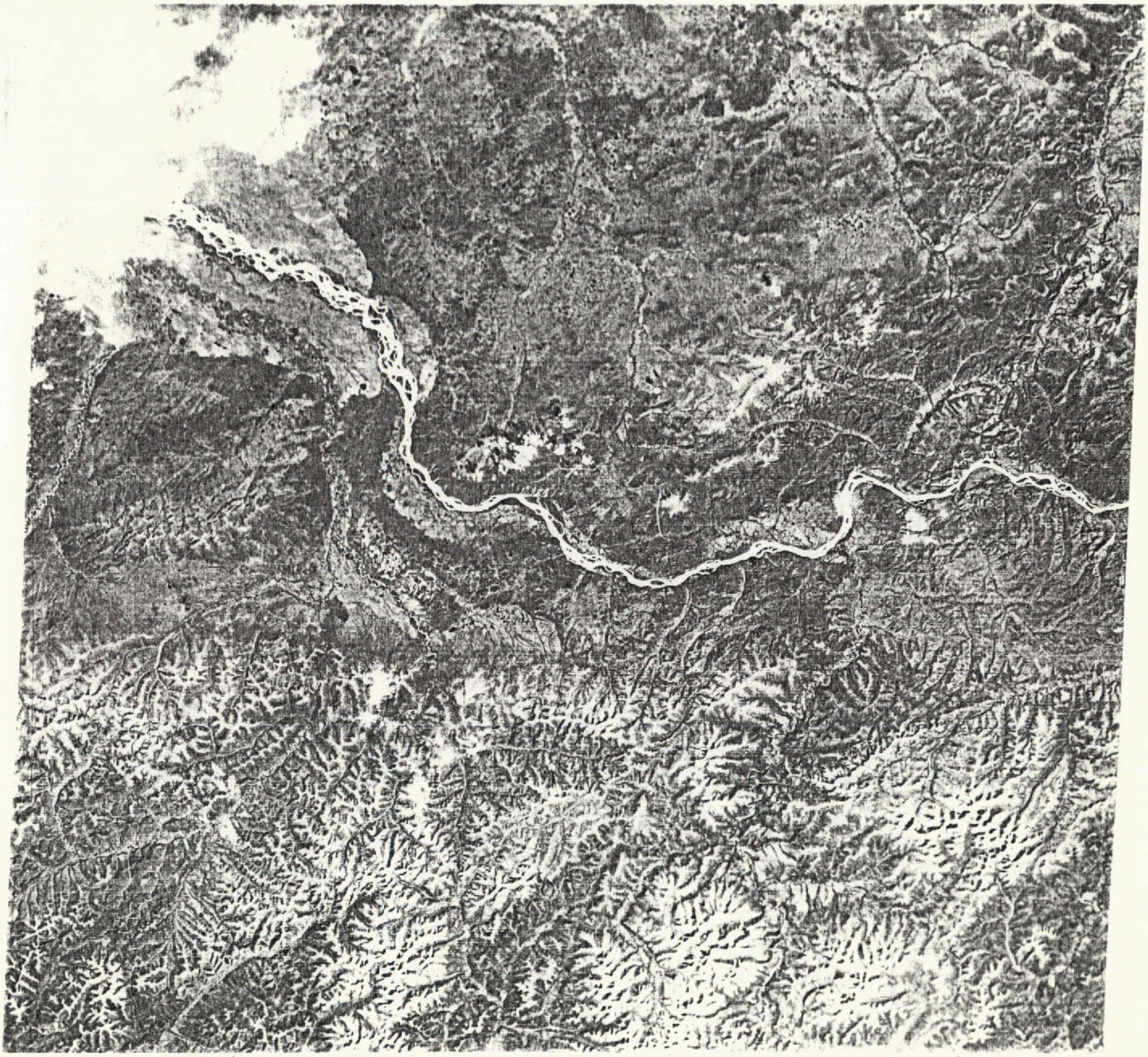


Figure 8. The Kaltag fault is thought to extend across the southeast corner of the scene just south of, and roughly parallel to the Yukon River. Note the unusual feature south of the Kaltag which appears to be a block undergoing right-lateral deformation with faults parallel to the Kaltag on its north and south boundaries.

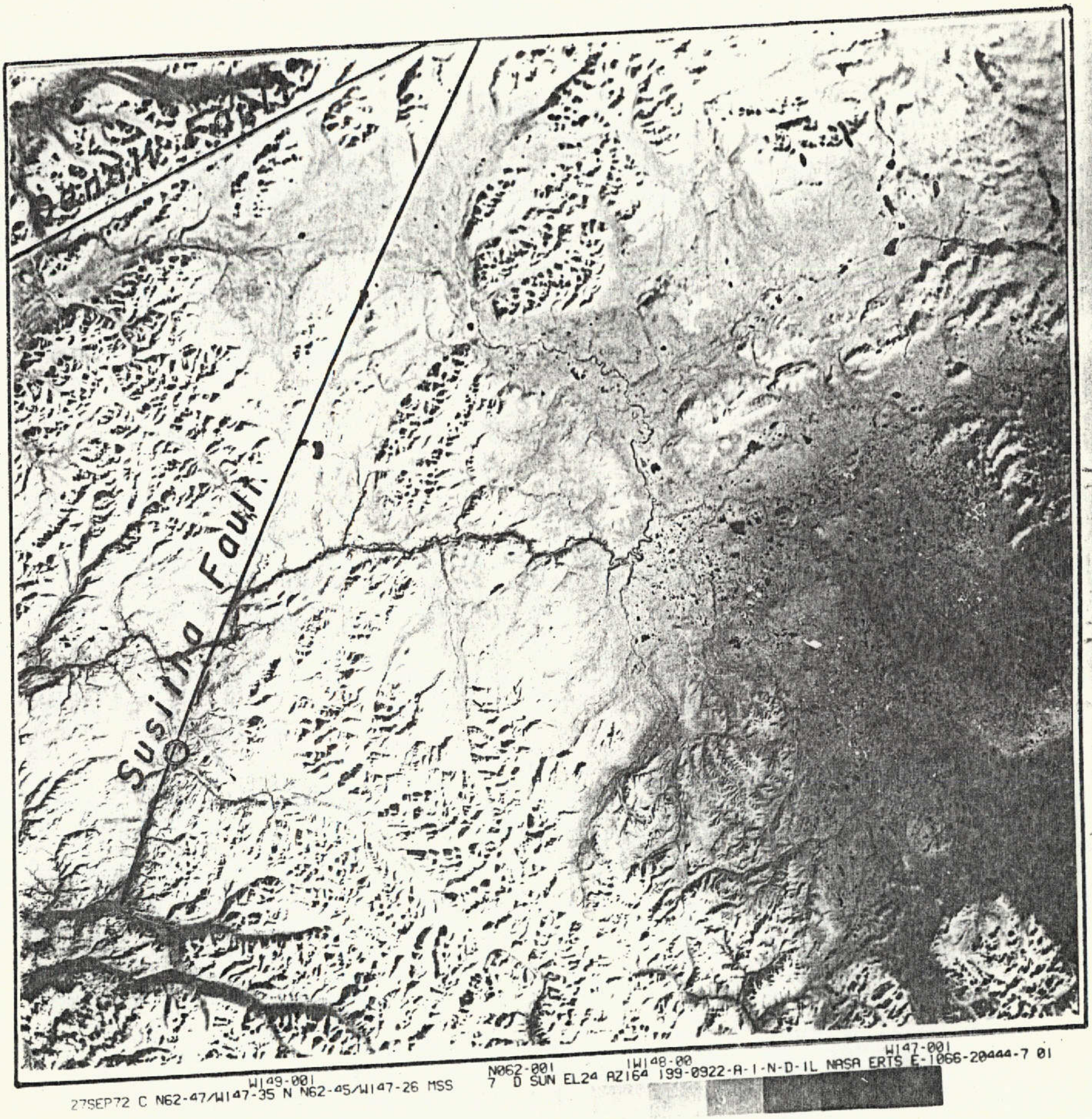


Figure 9. Previously unmapped seismically active fault with sag ponds, site of a magnitude 5.2 earthquake in 1972 (circle). It is truncated by the Denali fault which crosses the northwest corner of the scene.


W149-001
27SEP72 C N62-47/W147-35 N N62-45/W147-26 MSS
N062-001
7 D SUN EL24 AZ164 199-0922-A-1-N-D-1L NASA ERTS E-1066-20444-7 01
1W148-00
W147-001

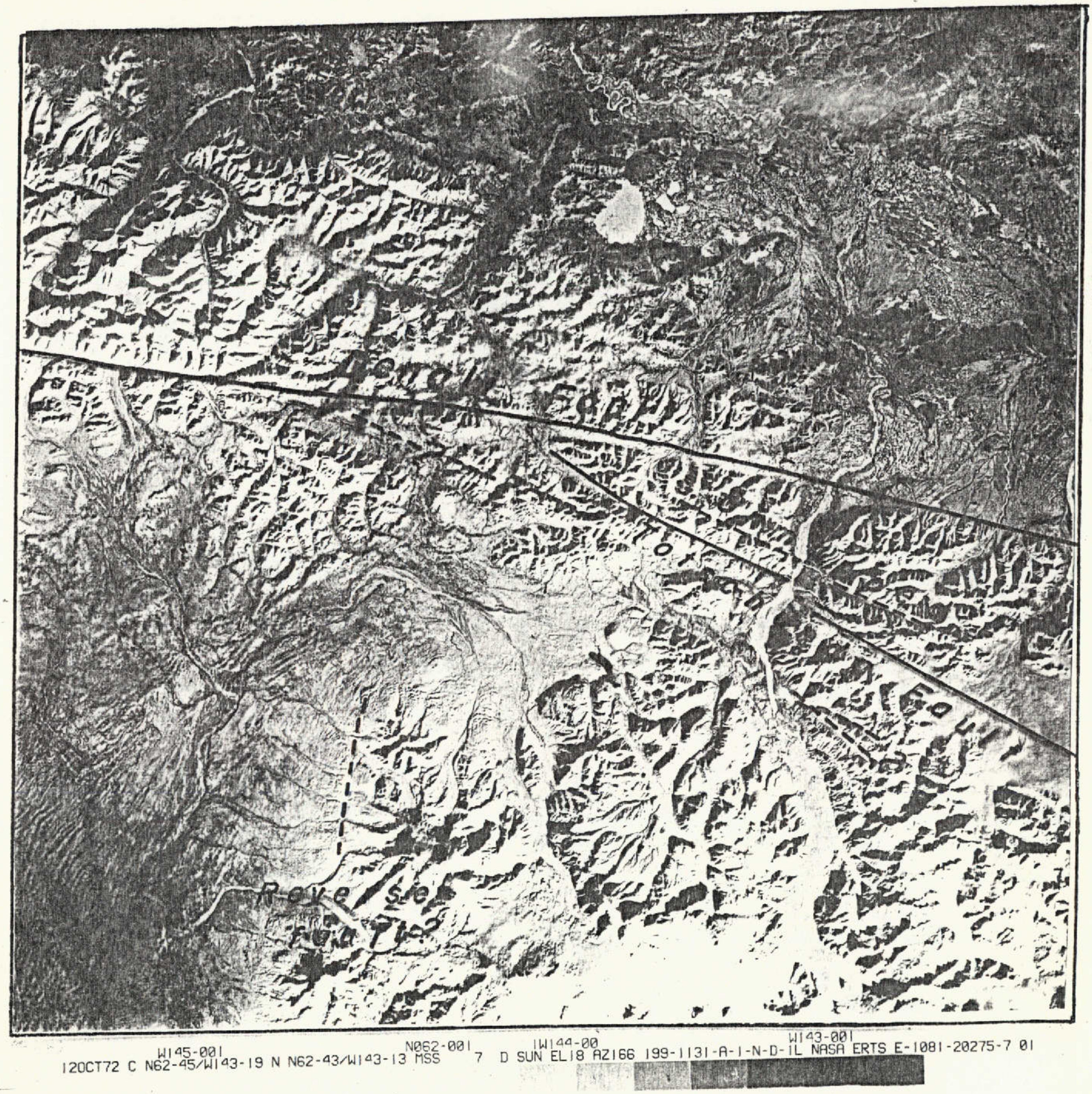
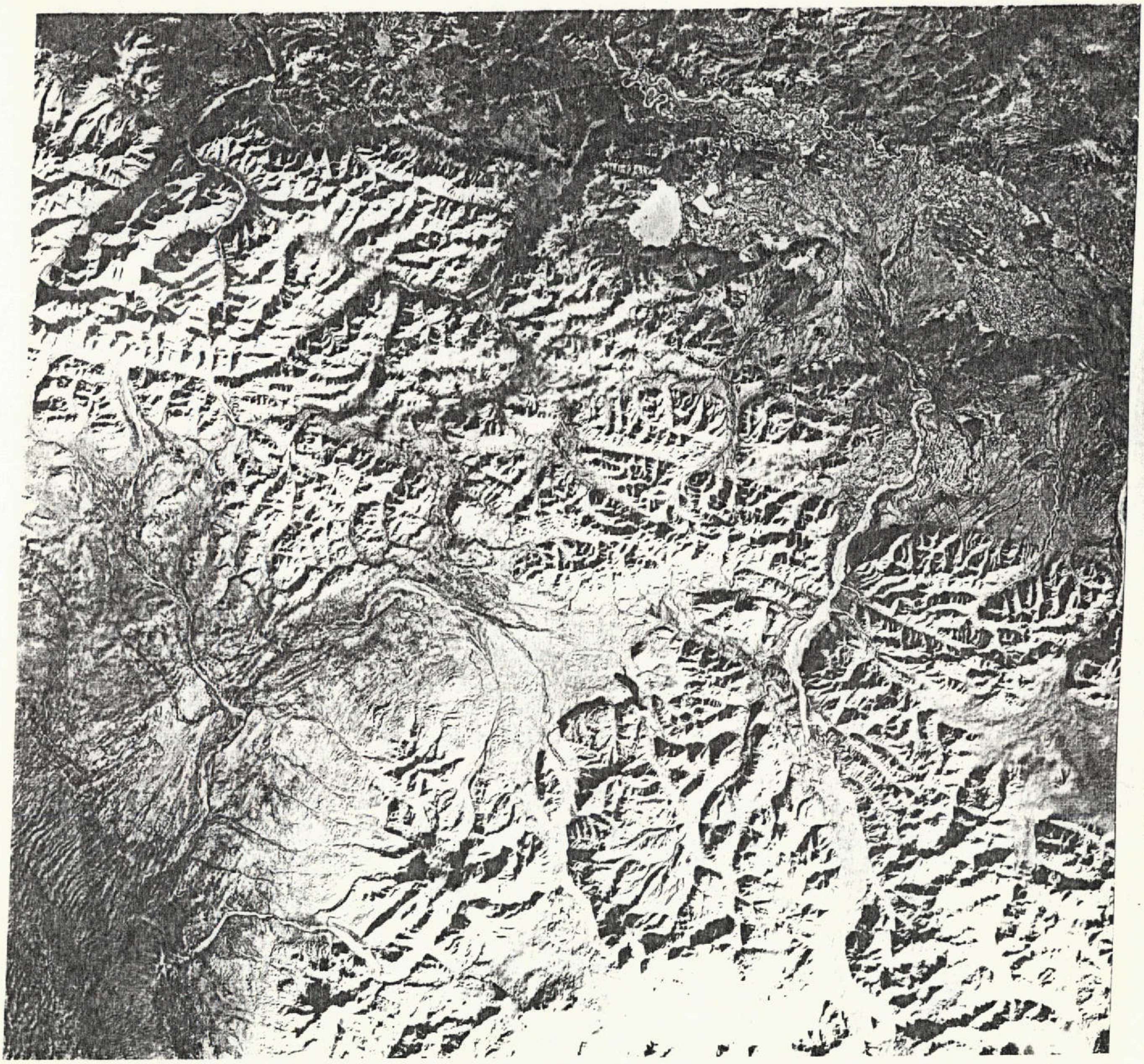
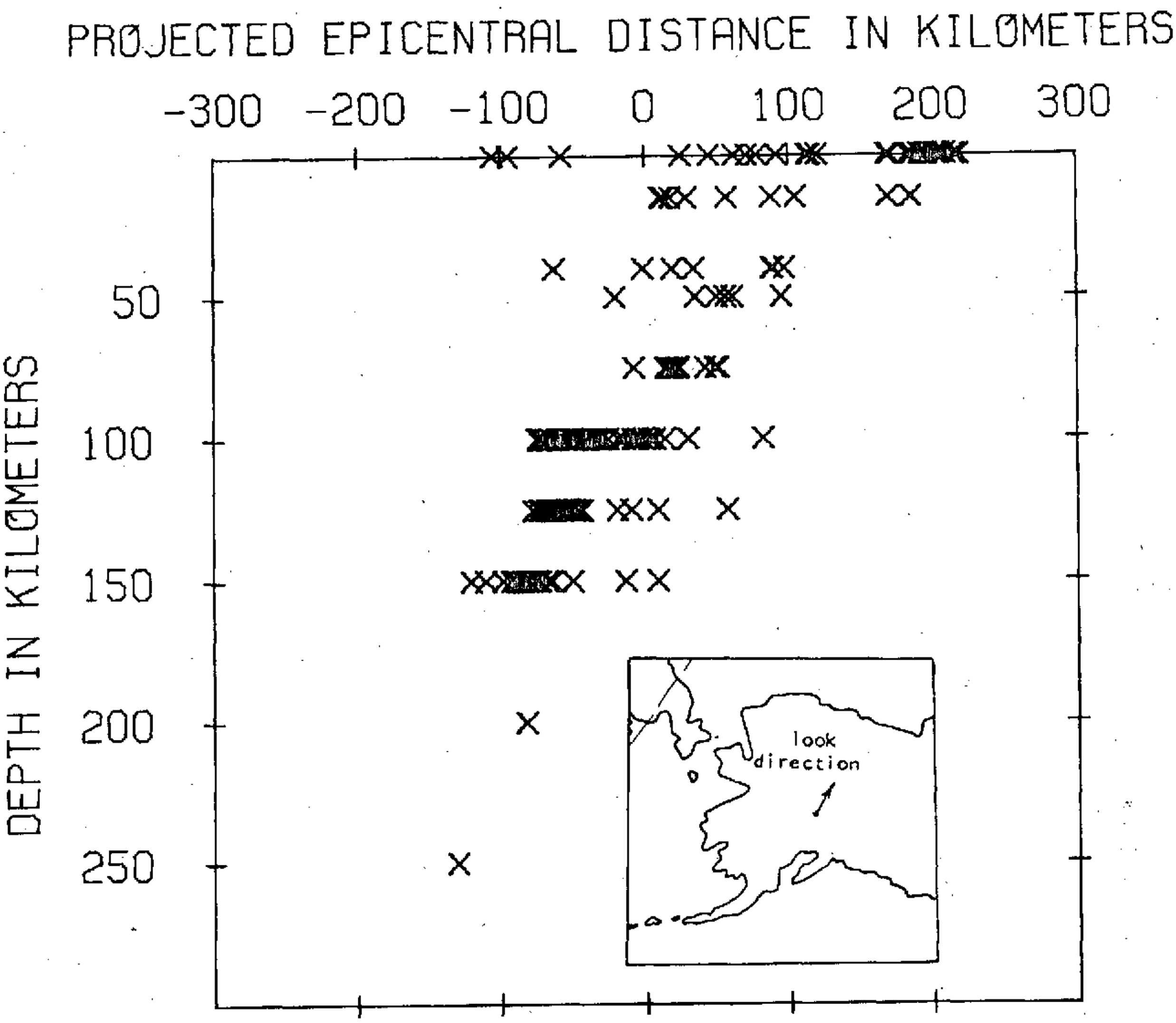


Figure 10. The Totschunda fault as mapped by Richter and Matson (1971) is shown as a solid line. It appears that there is another strand to the north. A small (apparently reverse) fault is seen on the flank of Mt. Sanford near the bottom of the image.



W145-001 N062-001 1W144-00 W143-001
12OCT72 C N62-45/W143-19 N N62-43/W143-13 MSS 7 D SUN EL18 AZ166 199-1131-A-1-N-D-1L NASA ERTS E-1081-20275-7 01



PROJECTION ORIGIN: 62.54N 150.08W

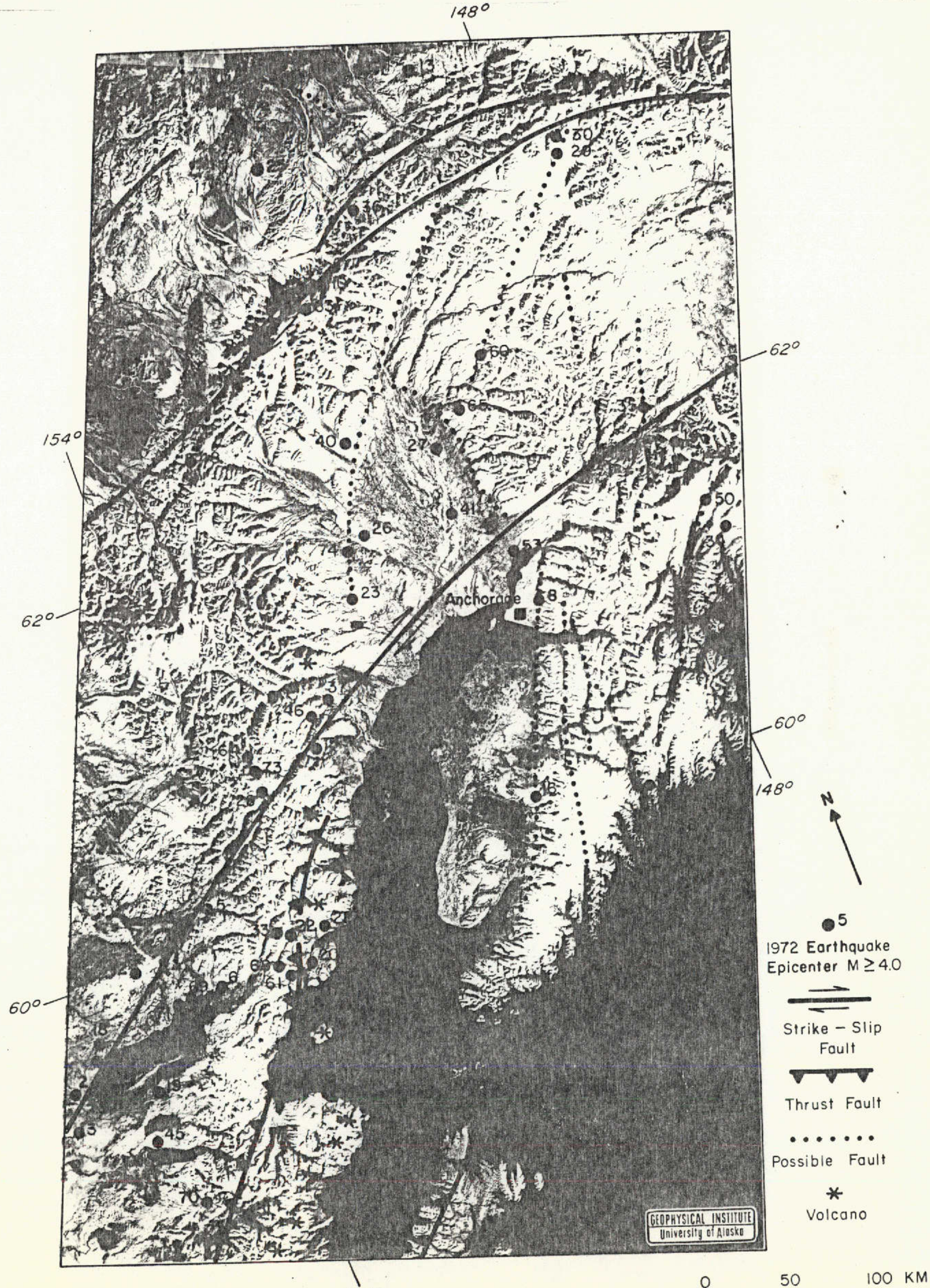
LIMITING ORIGIN: 62.96N 149.74W

AZIMUTH OF PROJ PLANE: 20 DEGREES

NUMBER OF EVENTS PLOTTED: 162 OF 1847

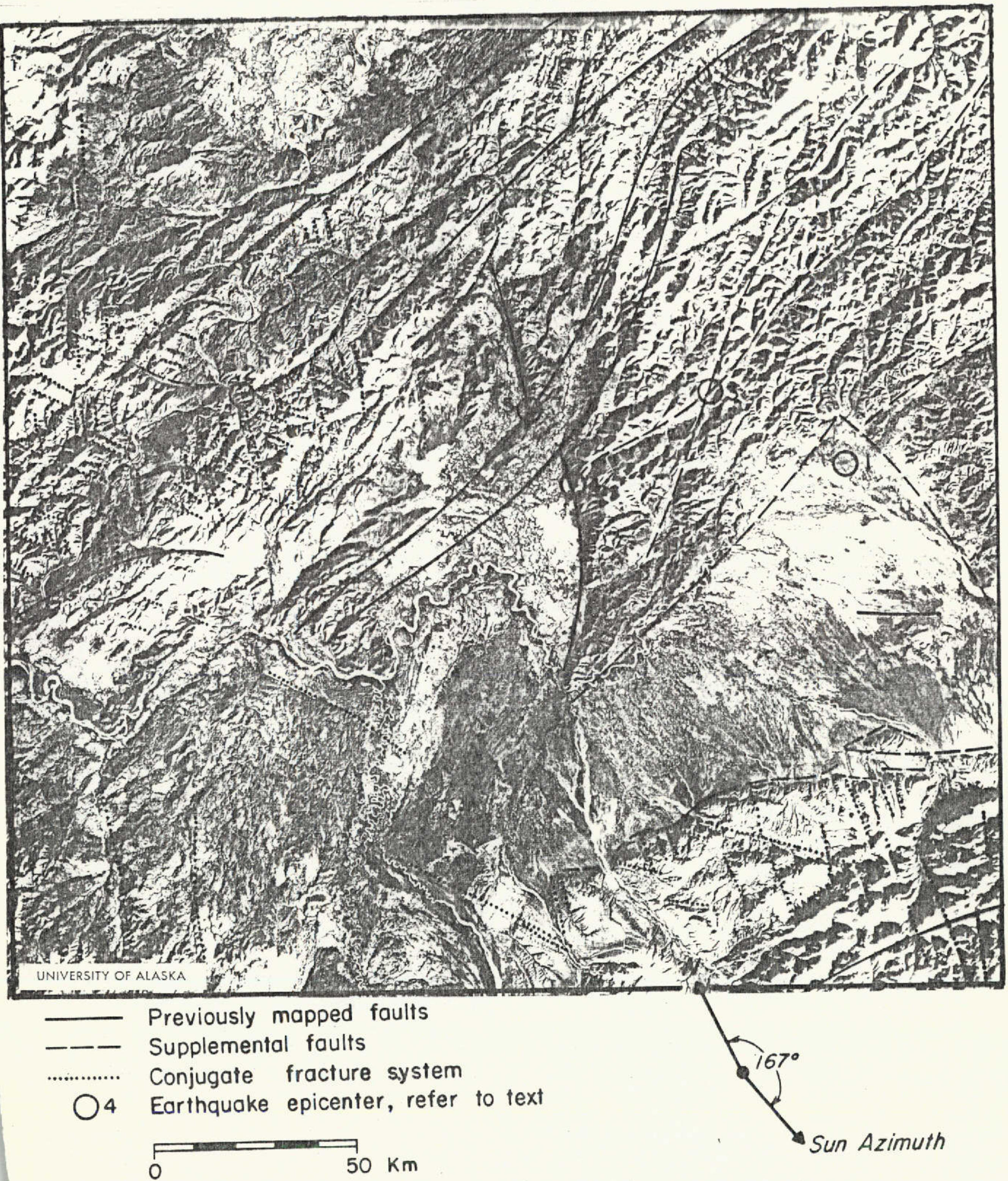
Figure 11. Sample cross section of 50 km thick slab looking to NE along plane of subduction zone in south-central Alaska. Hypocenters plotted are those occurring within this volume during 1972. Note that the vertical scale is twice the horizontal, so that the seismic zone actually dips at an angle of only about 45°.

Figure 12. Mosaic of 19 ERTS images showing seismic zone of south-central Alaska, with overlay showing linears and epicenters of earthquakes of magnitude 4 and greater occurring in the area during 1972.




GEOPHYSICAL INSTITUTE
University of Alaska

Figure 13. Mosaic of 6 ERTS images showing seismic zone of central interior Alaska. Scene is to the north of Fig. 12 and the mosaics partially overlap, although they are of different scales. Overlay shows linears and epicenters of largest earthquakes to occur in the area during recent years.




UNIVERSITY OF ALASKA

Figure 14. Mosaic of 6 ERTS images sidelapping previous mosaic to the east. For stereoscopic viewing with Fig. 13, there is a narrow strip down the (composite) scene for which both mosaics employ the same pass, and the sensation of relief would not be expected. However, even outside this area, the stereoscopic effect is minimal.