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COLD REGIONS ENVIRONMENTAL ANALYSIS BASED ON ERTS-1 IMAGERY

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ABSTRACT

An overriding problem in arctic and subarctic environmental research has been the absence of long-term observational data and the sparseness of geographical coverage of existing data. Studies of synoptic environmental events over regional-sized areas have been either impossible or prohibitively expensive. The launching of ERTS-A during the summer of 1972 will provide for the first time a means of accomplishing many types of investigations that were not feasible previously.

This paper will present a "first look" report on the use of ERTS-A imagery as a major tool in two large-area environmental studies: An investigation of sedimentation and other nearshore marine processes in Cook Inlet, Alaska, and a regional study of permafrost regimes in the discontinuous permafrost zone of Alaska. These studies incorporate ground truth acquisition techniques that are probably similar to most ERTS investigations. Underflight photography of one or two progressively larger scales will be obtained for diagnostic test areas within a larger regional area, and limited field checks will be made throughout the regional area when the first ERTS imagery becomes available.

Whereas prior studies of oceanographic processes in Cook Inlet have been restricted to local investigations by conventional shipboard techniques together with some aerial photography, ERTS-A imagery provides an opportunity to examine the entire Inlet on a synoptic basis. The analysis of ERTS imagery will be focused on seasonal changes in nearshore bathymetry, tidal and major current circulation patterns and coastal sedimentation processes applicable to navigation, construction and maintenance of harbors and to solving some of the siltation problems of the Inlet.

The distribution of permafrost in central Alaska, where its occurrence is discontinuous, is not well known. Small area studies of permafrost distribution and seasonal thaw regime based on large scale air photo interpretation have been done, but this method requires extensive ground examination and cannot readily be applied to large area surveys. The most important environmental variables for the analysis of discontinuous permafrost distribution are topographic position, soil type, vegetation cover, and micro climate. These parameters can be mapped with ERTS-A imagery within limitations imposed by resolution and cloud cover, but with the added advantage of synoptic coverage of seasonal changes over large areas. In this study the patterns of these changes will be used to define meso-scale similarities and differences in the environment. The primary seasonal indicators used will be snow cover ablation patterns and vegetative phenological events, particularly the development and abcission of leaves. The variance of these phenomena with area and elevation during the spring and fall seasons as viewed through ERTS-A imagery will provide more detailed environmental information on large areas than has previously been available. When considered together with the other environmental variables, the analysis of seasonal patterns should permit a more accurate delineation of boundaries in the discontinuous permafrost zone of Alaska.

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INTRODUCTION

An overriding problem in arctic and subarctic environmental research has been the absence of long-term observational data and sparseness of geographical coverage of existing data. Studies of synoptic environmental events over regional-sized areas have been either impossible or prohibitively expensive. The launching of ERTS-1 on July 23, 1972 provides for the first time a means of accomplishing many types of investigations that were not feasible previously.

The distribution of permafrost in central Alaska, where its occurrence is discontinuous, is not well known. Small area studies of permafrost distribution and seasonal thaw regime based on large scale air photo interpretation have been done, but this method requires extensive ground examination and cannot readily be applied to large area surveys. The most important environmental variables for the analysis of discontinuous permafrost distribution are surficial geology, vegetation cover, soil type, topographic position, and microclimate. Except for climate, these parameters can be mapped with ERTS-1 imagery within limitations imposed by resolution and cloud cover, but with the added advantage of regional scale coverage.

Presented here is an analysis of the Upper Koyukuk-Kobuk River area located in NW Alaska (Fig. 1). The image analyzed (1003-21355-457) is a color composite made from data acquired in the green, red and infrared bands of the multispectral scanner (Fig. 1). The area is devoid of cultural features except for several small villages and bush airstrips near the rivers. Documented information on the environment of the area is limited, consisting largely of statewide coverage of geology, vegetation, permafrost and climate. Therefore, a substantial challenge is provided in the interpretation of regional permafrost distribution and regimes in Alaska.

Resolution on the image varies with the shape and tone contrast of a feature. Rounded features such as lakes or ponds as small as 80 m. in diameter can be seen. Linear features such as streams or landing strips about 50 m. across are visible. Even though the three images comprising this color composite were classified as "poor" by NASA, the resolution of the composite is remarkably good and a thorough interpretation of the regional features can be made.

SURFICIAL GEOLOGY

The Kobuk and Koyukuk River Valleys are covered with surficial deposits that are principally of glacial, eolian, fluvial, and lacustrine origin. These deposits are easily discernable on the ERTS image based on differences in texture, tone and patterns.

Initial mapping of the surficial geology was accomplished without the aid of stereo pairs, reference to published maps or other available ground truth. Eight recognizable units are delineated on Figure 2. Bedrock-Colluvium (b) consists of coarse and fine grained deposits associated with moderate to steep-sloped mountains and hills; bedrock exposures are largely restricted to upper slopes and crestlines. Outwash deposits (Q_o) are fine and coarse grained alluvial deposits associated with lower highly dissected mountainous terrain. Solifluction appears to be an important process on this landscape. Undifferentiated alluvial-glaciofluvial deposits (Qag) are dominantly fine-to-coarse grained deposits associated with gentle to moderate sloping backslope positions; there are few bedrock outcrops. Fluvial-lacustrine deposits (Q_{fl}) are generally fine grained sands and silts associated with low-lying swampy areas. Undifferentiated alluvium-lacustrine deposits (Q_{a1}) are fine grained and associated with gently sloping footslope and terrace positions. Eolian deposits (Qe) are sand and loess present as active dunes. Fluvial deposits (Qf) are modern floodplains and low-lying terrace deposits; sediments would be fine-grained and generally well-rounded, an indication of significant particle movement. Undifferentiated deposits (Q_u) are coarse to fine grained deposits occurring on rolling uplands and consist primarily of colluvium mixed with some loess from the sand dune area to the northwest.

The units defined for mapping surficial geology from the ERTS image were subsequently compared to the Surficial Geologic Map of the Central Kobuk River Valley (Bull. 1181K)and the 1:1.5 million State of Alaska map. The following similarities and differences were found:

1) Five drift and three outwash units were defined on the USGS map based on glaciation periods. The drift units are composed primarily of till and outwash sands and gravels, whereas the outwash units contain chiefly gravels and sand. On this ERTS image it was not possible to differentiate between glaciation periods. Therefore, previously mapped drift areas were found to occur in our unit Qag (undifferentiated alluvial-glaciofluvial deposits) and the outwash area in Q_o (outwash deposits).

2) The water bodies in the image are primarily, but not exclusively, thaw lakes. Lacustrine sediments, not defined in this area on the 1:1.5 million scale surficial geology maps, are included in units Q_{a1} and Q_{f1} (Fig. 2).

3) Eolian deposits include sand dunes and loess which can not be easily discriminated on ERTS imagery. On the MSS color image active sand dunes show as light blue irregularly shaped features north of the Waring Mts. and are the only deposits mapped as Qe. Vegetated sandy areas were not included in this unit because on the basis of the imagery alone, they do not appear as distinct eolian sediments. These deposits are included in Qag, east of the Waring Mts. Subsequent ground truth verified that this area is a sparsely vegetated, stable dune field with relatively small, locally active dunes. However, Q_{ag} is defined in our legend as undifferentiated alluvial-glaciofluvial deposits.

In summary, the amount of detail available from the 1:1.3 million scale ERTS-1 image compared faborably in most respects to the available 1:250, 000 map and was superior to the 1:1.5 million State of Alaska map.

VEGETATION

Vegetation is one of the most important indicators of permafrost characteristics of an area, but the relationship is complex and must be examined in detail (Hopkins and others, 1955). Vegetation type and density in a permafrost region are most directly related to soil type and drainage conditions. As an indicator of permafrost, its most reliable value lies in its indication of the depth of seasonal thaw (Tyrtikov, 1959).

This ERTS scene is predominantly within the interior Alaska white spruce forest, a vegetative association confined to the well drained upland areas (Vierick, 1972). Poorly drained lowland areas are largely of treeless bogs with sedges, grasses, and small willows, alders and birches. Better drained lowland areas grade from moist tundra to open black spruce forest to birch and aspen on low ridges. Alpine tundra exists above the local timberline at about 600 m.

Vegetation differences are apparent on the MSS color composite primarily by tonal rather than textural patterns. This results from the approximately 80 m. limit of resolution. The tonal differences would appear to be primarily related to vegetation density, and species composition. Four density levels have been identified and mapped in this scene. The highest density tone is a dark red identified as a closed spruce-hardwood forest, labeled "F" in Figure 3. It is believed to consist of tall to moderately tall white and black spruce, together with paper birch, aspen, and balsam poplar and occurs on moderate to well drained sites such as active flood plains, mountain slopes, and highland areas. It is seen in a galaria forest pattern along several streams, including the Selawik and the Kobuk Rivers. The next lightest tone is a bright red associated with a low to hilly area, and is representative of moist tundra grading to low black spruce and well developed birch-aspen growth on the best drained slopes. This unit, labeled "M" in Figure 3, also contains most of the burn scars, labeled "B". The wet lowlands appear as a reddish gray, punctuated by the many thaw lakes typical of poorly drained permafrost alluvial areas. These areas are essentially treeless bogs ("W" in Figure 3) and have a cover of sedges and grasses, with an abundance of willows, alders, and resin birch, locally with widely spaced spruce and tamaracks. Two small areas, identified from geological mapping as formerly active sand dune areas, exhibit a unique gray tone with a faint red coloration, suggesting revegetation with shrubs or other open vegetation, with the bluish cast of sand still apparent. "A" is alpine tundra, predominantly barren, locally dominated by low heath shrubs, prostrate willow, and dwarf herbs.

Recently burned areas, one still burning, appear black and lie in the upland spruce-hardwood forest or in the less well drained black spruce - birch and aspen associations. The active burn is identified as the Pah River fire. The Bureau of Land Management estimated the area of this burn at 60,000 acres on July 8, 1972. At the time of this ERTS image, July 26, 1972, the burned area was measured by color densitometer planimetry to be 81,000 acres. This measured increase of 21,000 acres in 18 days compares favorably with the other methods used in calculating the size of burned areas.

The main influence of vegetation on permafrost terrain is that it affects the thermal exchange between the atmosphere and the lithosphere, and the moisture regime in the soil (Tyrtikov, 1959). Vegetation has the effect of retarding soil warming in the summer and cooling in the winter, but the depth of the active layer also depends on other variables, such as the depth of winter snow and drainage conditions during summer. A vegetation association-depth of thaw relationship where permafrost is present in the discontinuous permafrost zone has been given by Hopkins and others (1955); it is shown in Table 1.

In the following section, vegetation associations delineated in Figure 3 are considered in combination with surficial geology units (Figure 2) to provide the basis for an estimate of thaw depths within each permafrost mapping unit.

PERMAFROST

Permafrost is defined solely on a temperature basis. It is rock or soil material, with or without moisture or organic matter, that has remained continuously below 0°C for two or more years (Ferrians,1969). It occurs where the depth of winter freeze exceeds the depth of summer thaw, and is classified into two broad categories: continuous and discontinuous. In the continuous permafrost zone, permafrost lies beneath all land areas, but it is absent directly beneath large water bodies, which provide a sufficient heat reservoir to keep underlying materials unfrozen (Williams,1970). The thickness of permafrost in this zone ranges from several hundred feet in the south to an extreme of 600 m. in northern Alaska. The boundary that separates these two zones is theoretically distinct but imperfectly known. Climatically, it approximates the mean southern position of arctic air in summer (Bryson,1966); it is close to the southern limit of the tundra (MacKay,1972), and is the effective limit of active ice-wedges and pingos (Pewe, 1966). The discontinuous permafrost zone is a complex mosaic of frozen and unfrozen ground with permafrost thickness decreasing in a southerly direction.

The geographical distribution of permafrost in a particular area is dependent upon its past and present environmental regimes. The depth of the active layer is dependent on present relationships of soil type, drainage, moisture content, vegetative cover, topographic setting and climatic regimes. Figures 4 and 5 illustrate typical permafrost settings and the nomenclature in current use.

Standard, well-established, photogeologic methods and procedures for delineations of interpretation were used. Permafrost areas have been defined based on the patterns of vegetation, surficial geology, and drainage. Results were compared with documented information on vegetation, climate, climatic history and existing permafrost maps.

The Upper Koyukuk-Kobuk River area lies at the northern edge of the discontinuous permafrost zone (Hopkins and others, 1955) and is predominantly underlain by perennially frozen ground. Extrapolations from the nearest climatic stations suggest a mean annual temperature of about -4°C, and a mean annual precipitation of about 50 cm. Because of the proximity of the ocean, summers are cooler and the winters somewhat warmer than at equal latitudes further to the interior. This smaller seasonal amplitude is conducive to permafrost development (Saltykov, 1959).

Areas without permafrost within this scene are localized, and generally occur in coarse gravels along streams, near lakes and ponds, and on steep slopes with coarse, permeable, talus deposits. Areas mantled with a dense vegetative mat such as mosses, grasses or sedges have a shallow thaw depth (< 0.5 m).

Five permafrost regions were mapped based on the interpretation of surficial geology and the probable depth of thaw estimated on the basis of the vegetative cover (Fig. 6). Bedrock and colluvium (m_1) is characterized by scattered taliks, a thaw depth of 0.5 m. - 2.0 m. and alpine vegetation that grades into white spruce forest below timberline. Dissected alluvial deposits (u_1) contain numerous taliks, have indications of active solifluction, are characterized by alpine vegetation and a 0.5 m. - 2.0 m. thaw depth. Active floodplains (l_1) have numerous taliks, dense tree and shrub vegetation and a thaw depth of more that 2.0 m. Abandoned floodplains (l_2) with many small lakes and fine grained soils have grass, sedge, small shrubs and open spruce vegetation and a thaw depth less than 0.5 m. Alluvial-colluvial deposits (u_2) are characterized by continuous permafrost, birch-aspen forest on well-drained slopes grading to moist tundra in less well drained sites and a thaw depth less than 0.5 m. in areas of poor drainage and 0.5 m. - 2.0 m. on south facing, well drained slopes.

Although vegetation association boundaries usually conform to surficial geology units, there are many cases where this is not true. For instance, the u_2 unit may have alpine or forest vegetation depending upon elevation and/or exposure.

Using the criteria of surficial geology and vegetation, a permafrost distribution map has been prepared with considerably greater detail than was previously available. The accuracy of this interpretation of MSS scene 1003-21355-457 is being field checked. To the extent that it is found to be possible to utilize ERTS-1 imagery and extrapolate from existing maps of vegetation and surficial geology and from earlier observations, an improved and more detailed permafrost map of the area can be quickly produced. On the basis of this hasty and preliminary analysis we are optimistic.

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TABLE I

Vegetation	Depth of Thaw (m.)
Tall willows on flood plains	2.4
Mixed alder, willow, white birch	1.2
Mixed stands of white spruce and white birch	0.6-0.9
Black spruce in tundra or muskeg	0.3

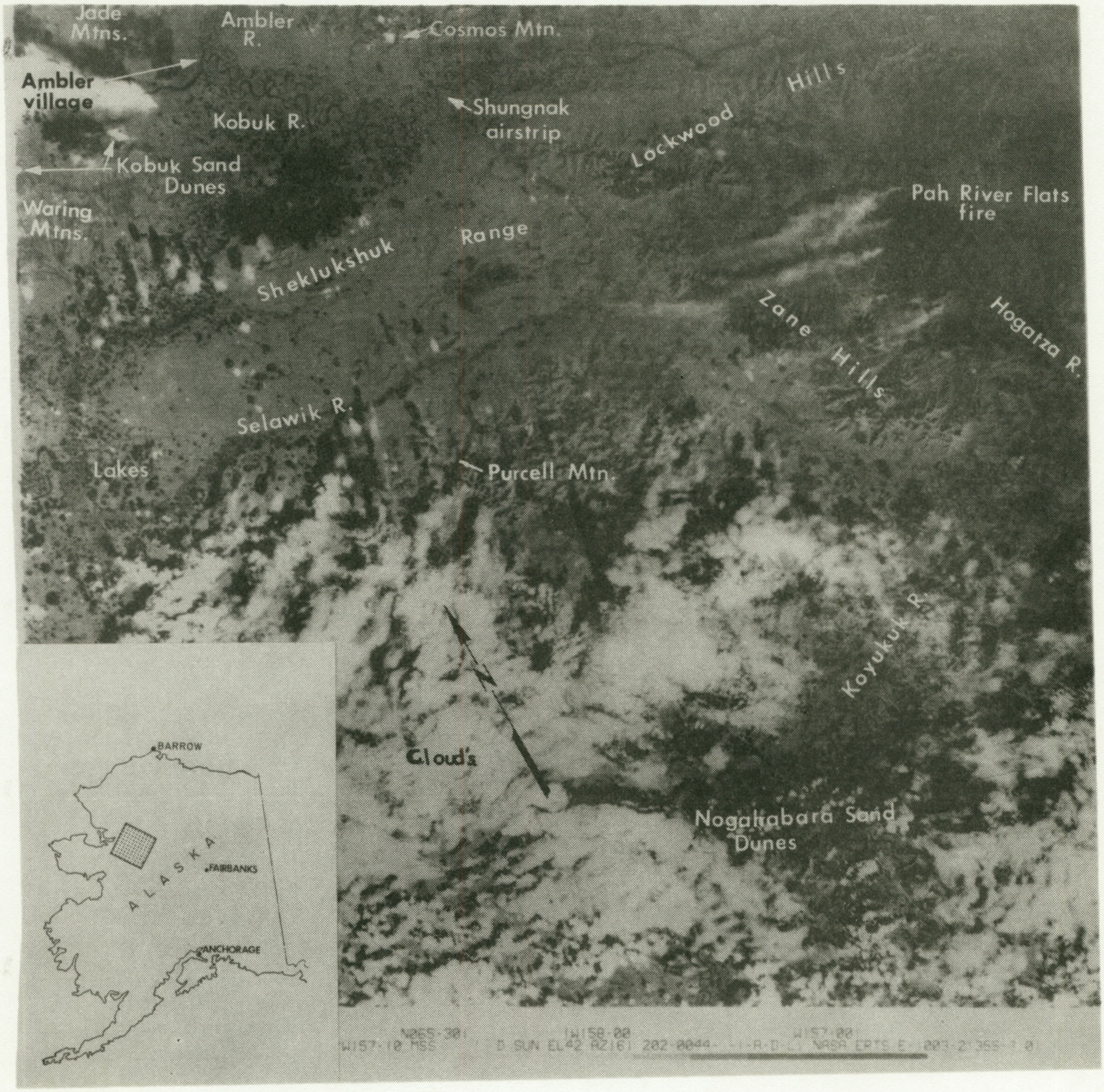

FIGURE 1. Image Area, 240 miles NW of Fairbanks, with major features and locations.

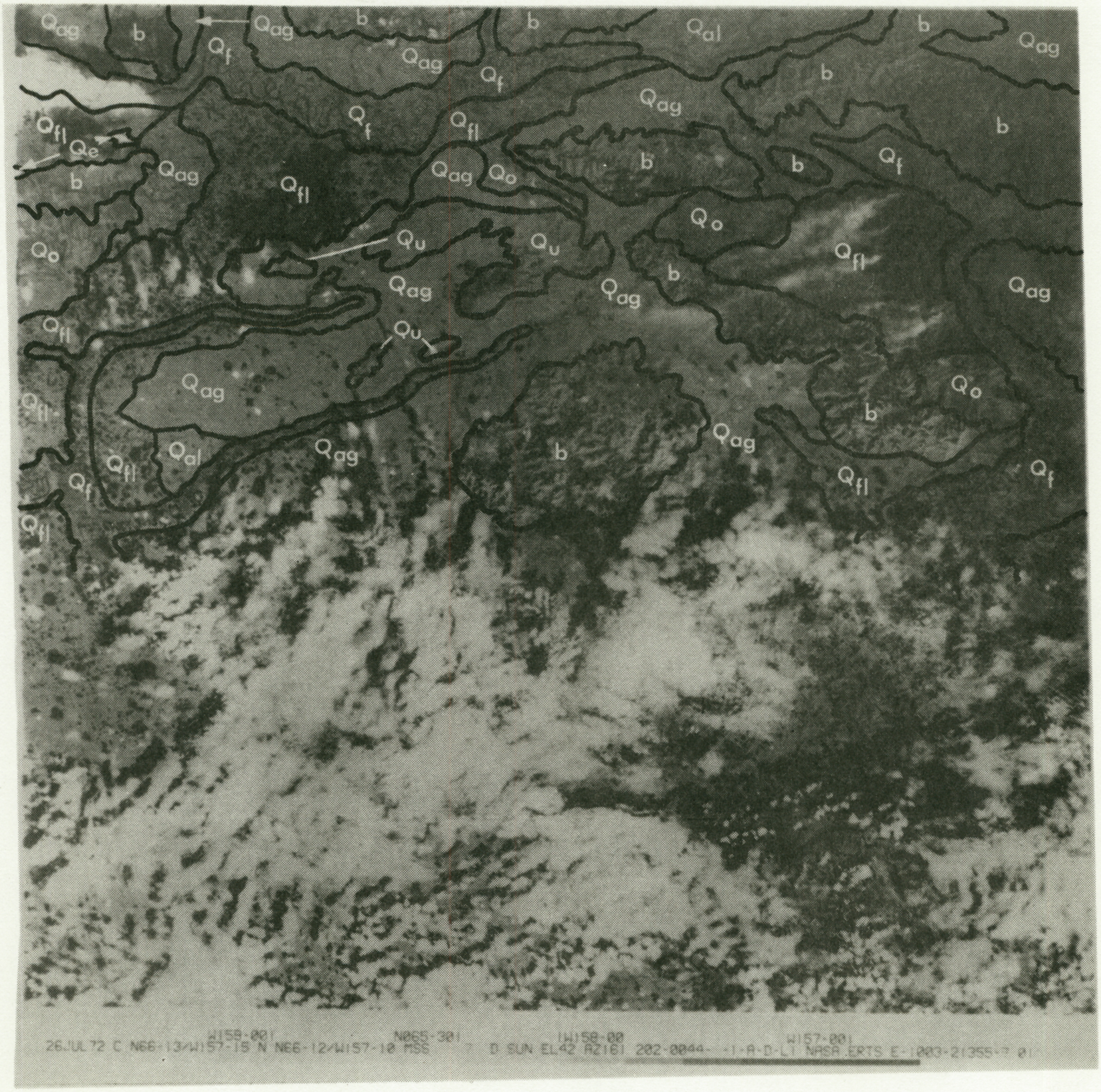

FIGURE 2. Distribution of surficial geologic units: b, bedrock-colluvium; Q_o, outwash deposits; Qag, undifferentiated alluvial-glaciofluvial deposits; Q_{fl}, fluvial-lacustrine deposits; Q_{al}, undifferentiated alluvium-lacustrine deposits; Q_e, eolian deposits; Q_f, fluvial deposits; and, Q_u, undifferentiated deposits.

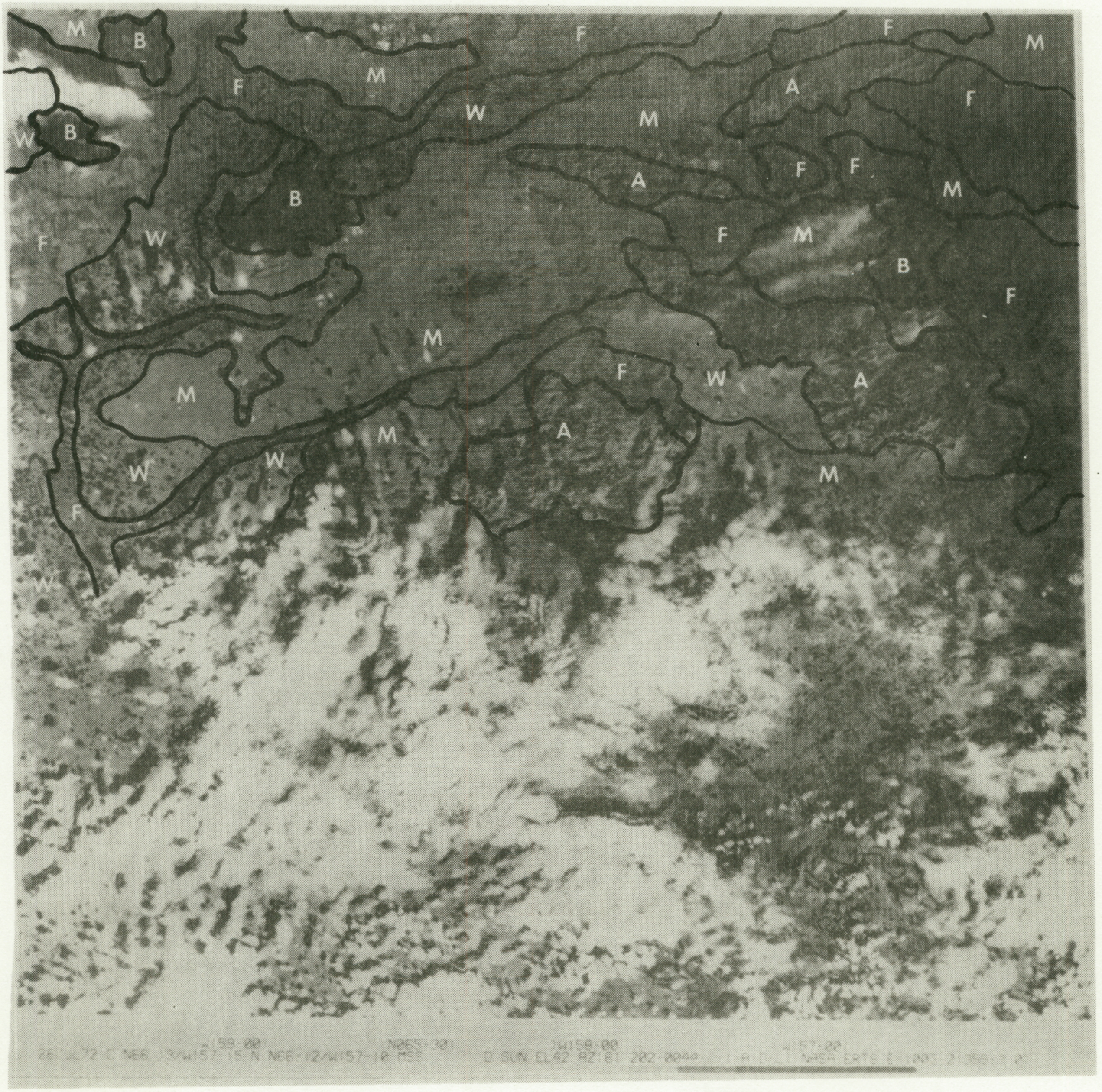

FIGURE 3. Vegetation associations. W, treeless bogs, M, moist tundra, B, burn scars, F, upland hardwood and spruce forest, A, alpine tundra.

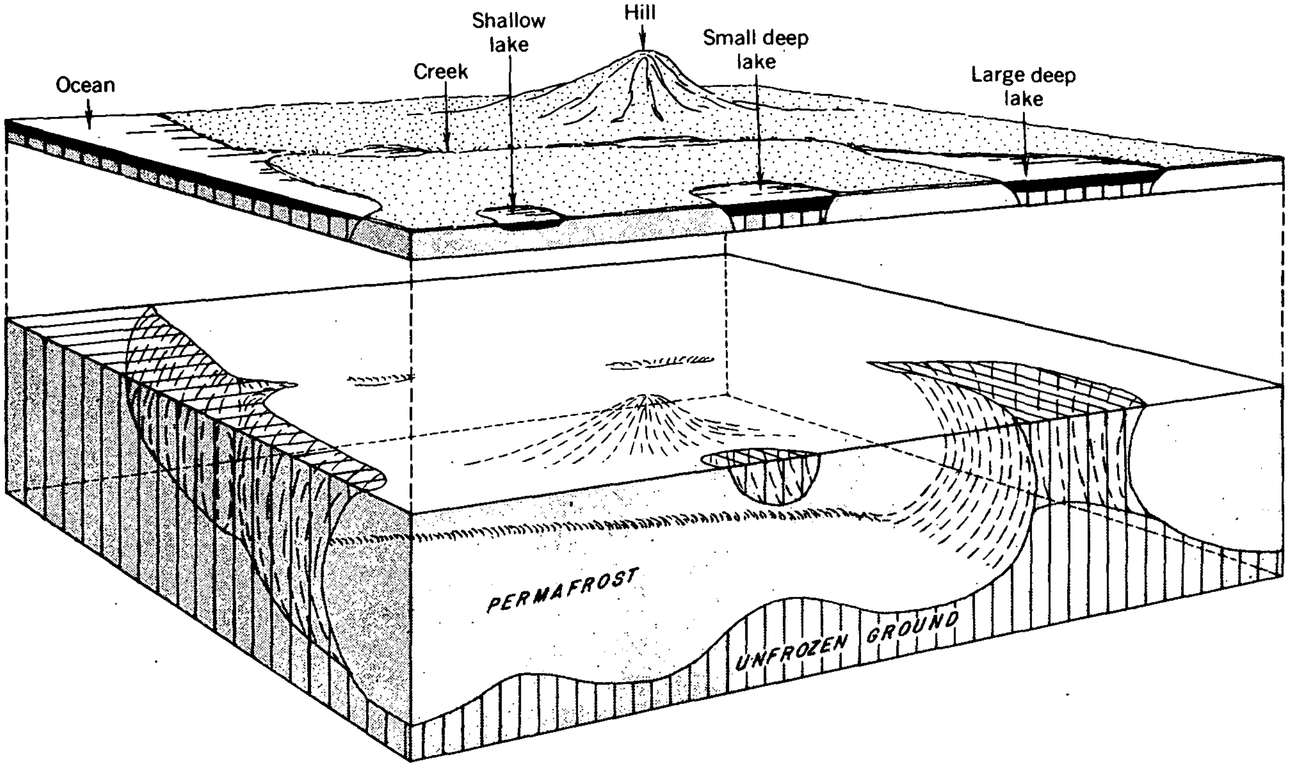

FIGURE 4. The effect of surface features on the distribution of permafrost in the continuous permafrost zone. After Lachenbruch (1968).

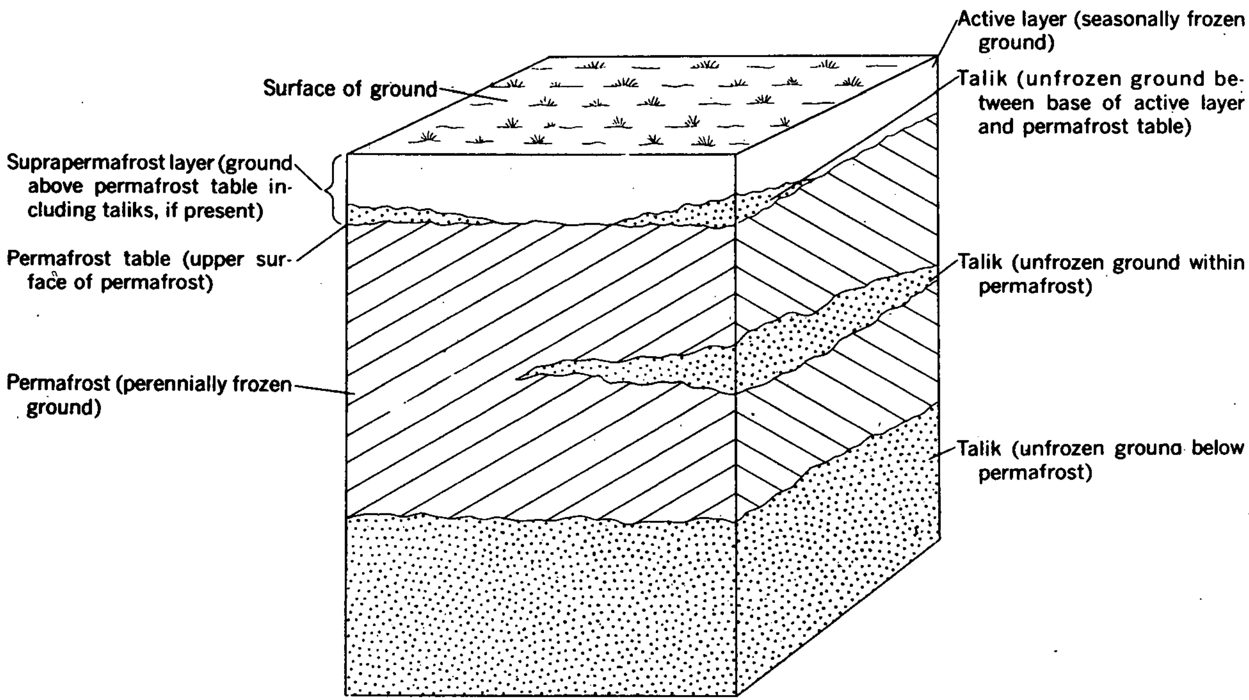

FIGURE 5. Occurrence of taliks in relation to the active layer, suprapermafrost zone, permafrost table and permafrost. From Ferrians (1969).

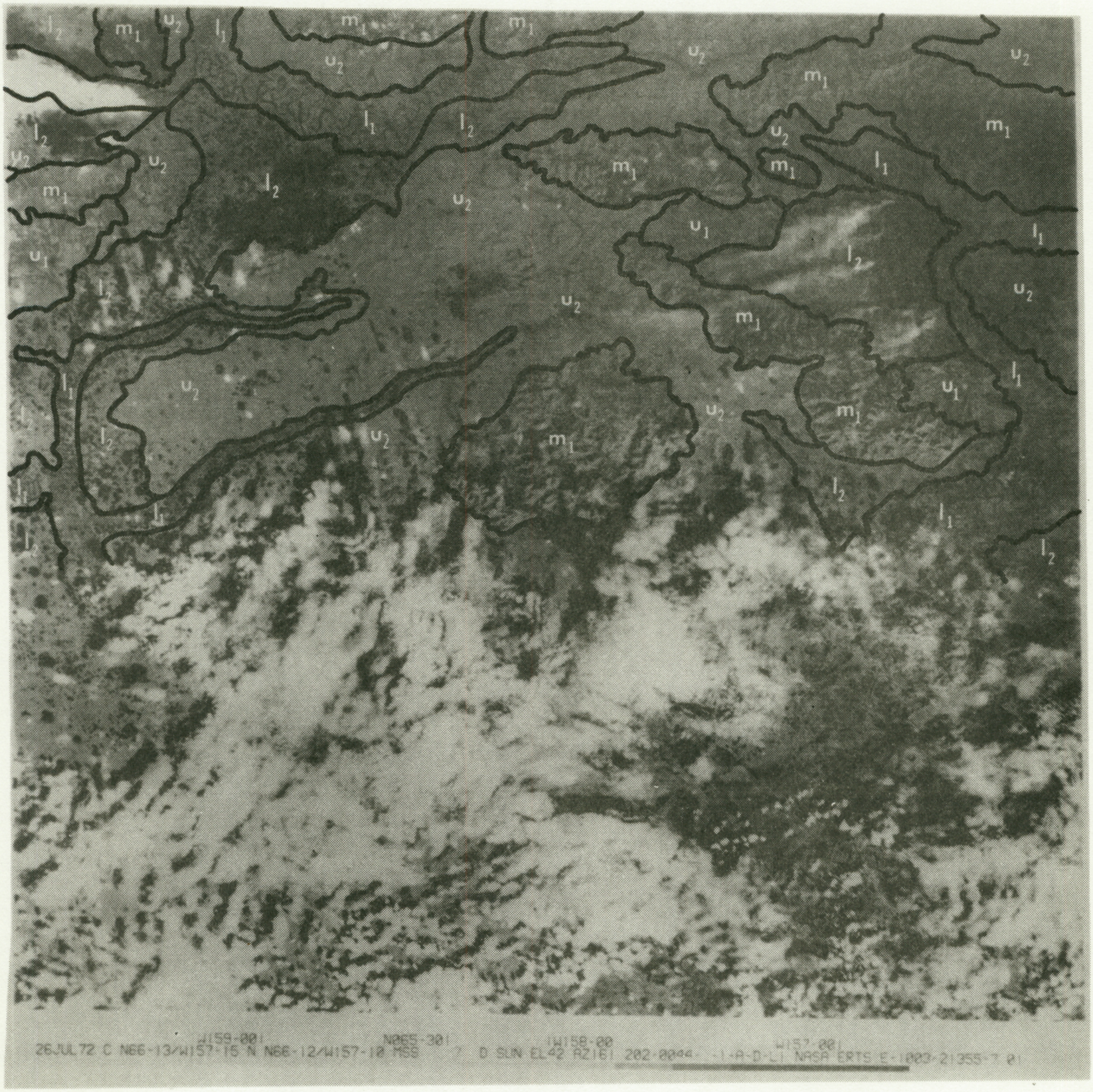

FIGURE 6. Permafrost units and distribution.

Mountainous areas: m_1, bedrock and colluvium

Upland areas: u_1, dissected alluvial deposits

u_2, alluvial-colluvial deposits

Lowland areas: l_1, active floodplains

l_2, abandoned floodplains

Objectives (Reference NASA Contract S-70253-AG dated 14 June 1972):

* Analyze and map the sediment deposition in harbors, inlets, and docking facilities in the Cook Inlet.

* Map the permafrost areas of Alaska as inferred by vegetative patterns. Compare major tonal and textural permafrost patterns with Mariner imagery.

* Correlate the snowpack cover of Caribou-Poker Creek with stream runoff.

* Map and inventory the icing on the Chena River.

* Items 2 and 4 above are to be correlated with the University of Alaska studies in the same area.

Accomplishments:

The first shipment of ERTS-1 imagery was received on 31 August 1972. The first two months of ERTS imagery and related ground truth data have been processed and evaluated. The data reduction and analysis plan outlined in our proposal (No. MMC-298, revision 1, dated 21 January 1972, sections 4.2: Objectives, 4.3: Approach, 4.4: Results and 4.5: Investigator's Data Handling Plan) has been evaluated. The data processing and analysis procedures are compatible with spacecraft data received and the proposed objectives have been reassessed. No revision or modification is required.

A paper entitled, "Cold Regions Environmental Analysis Based on ERTS-1 Imagery" by R. K. Haugen, H. L. McKim, L. W. Gatto and D. M. Anderson was presented at the Eighth International Symposium on Remote Sensing of Environment, 2-6 October, 1972. (reference NTIS Weekly Abstracts 9 October 1972, copy of the paper inclosed).

Mapping of permafrost areas in Alaska has been expanded to selected sites within: the northeastern region, 64°-71° north latitude and 141°-150° west longitude; the southeastern region, 59°-64° north latitude and 141°-150° west longitude; and, the west-central region, 64°-68° north latitude and 150°-160° west longitude.

Activities planned for the next reporting period (23 October 1972 - 23 December 1972) include: the preparation of photo-mosaics of selected portions of Alaska at a scale of 1:1,000,000, mapping and analysis of currents and sedimentation patterns in Cook Inlet, continued thematic mapping of surficial geology, vegetation and permafrost; initiation of an analysis of the snowpack in the Caribou-Poker Creek watershed.

<u>Published Articles, Papers, Preprints, Abstracts</u> (NTIS Weekly Abstracts 9 October 1972):

Abstract: "Cold Regions Environmental Analysis Based on ERTS-A Imagery" by R. K. Haugen, L. W. Gatto and D. M. Anderson

Preprint: "Cold Regions Environmental Analysis Based on ERTS-1 Imagery" by R. K. Haugen, H. L. McKim, L. W. Gatto and D. M. Anderson

Problems: None

Changes in Standing Order Forms:

31 August 1972: include all of Alaska, 0-100% cloud cover acceptable, only fair and good images acceptable, 9.5 in. positive transparencies and prints of MSS bands.

2 October 1972: (by telephone) include only mainland Alaska with coordinates 69N, 169W; 72N, 158W; 71N, 141W; 59N, 141W; 56N, 154W; and, 60N, 169W

6 November 1972 (by telephone): only 0-60% cloud cover acceptable.

ERTS Image Descriptor Forms:

Descriptor forms have been submitted for 52 RBV and MSS scenes received from 31 August 1972 to 23 October 1972.

Data Request Forms Submitted:

6 September 1972	Precision B/W 9.5 in. print	(pending)
13 September 1972	Precision color 9.5 in. transparency and print	(pending)
15 September 1972	Bulk and precision digital, 7-track tapes	(pending)
25 September 1972	Bulk B/W, 9.5 in transparencies and prints	(pending)
28 September 1972	Bulk B/W, 9.5 in transparencies and prints	(pending)

RESULTS

(23 August 1972-23 October 1972)

ERTS-1 Project No. MMC-298

ARCTIC AND SUBARCTIC ENVIRONMENTAL ANALYSES UTILIZING ERTS-1 IMAGERY

Principal Investigator
Dr. Duwayne M. Anderson - DE 329

Discipline 8: Interpretation Techniques Development

Subdiscipline C: Classification and Pattern Recognition

Resolution of MSS images varies with the shape and tone contrast of a feature. Rounded features such as lakes and ponds as small as 100 m in diameter and linear features such as streams, landing strips and roads about 50 m across are visible. Sediment distribution, surface, circulation patterns and tidal flat morphology in Cook Inlet, Alaska are most apparent on MSS bands 4 and 5. Mapping of surficial geology and permafrost in Alaska can best be accomplished using MSS bands 5 and 7. Color composites made on a color additive viewer with green filters over MSS bands 6 and 7 and no filter over band 5 are especially useful in making interpretations of vegetation patterns.