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APPLICATION OF ERTS IMAGERY IN GEOLOGICAL MAPPING AND OTHER FIELD OPERATIONS IN ANTARCTICA.

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SUMMARY

Imagery of parts of the Prince Charles Mountains in MacRobertson Land, Antarctica was taken by the Multi Spectral Scanner (MSS) system on board the orbiting ERTS (Earth Resources Technology Satellite) satellite. This satellite was launched in 1972 by the United States Aeronautics and Space Administration (NASA). Two overlapping scenes were selected and images taken in energy bands 4, 5, 6, and 7 and colour composites made by superimposing bands 4, 5, and 7 were examined in a 1:1 000 000 scale format. The main conclusions drawn from the investigation are that low sun elevation increases the detail displayed on the ERTS imagery because of shadow effects and that low sun elevation is more important than choice of Energy Band. Other possible application of ERTS imagery in Antarctica are also described. Most of the results reported here were presented to the ERTS investigators symposium held at the BMR, Canberra in December 1973.

INTRODUCTION

Positives of bands 4, 5, 6, and 7 and colour composites of bands 4, 5, and 7 of ERTS scenes E1148-03261 and E1219-03210 were obtained by BMR in October 1973. Scene E1148-03261 is dated 18 December 1972, and shows most of the Prince Charles Mountains north of latitude 72°S (Fig. 1). Sun elevation on this image is 31°. Scene E1219-03210 was imaged on 27 February 1973, with sun elevation 15°; it shows the ice plateau southwest of Fisher Massif and west of Mount Johns, and overlaps with scene E1148-03261.

Associated investigations

The Australian 'official investigator' for ERTS imagery of Antarctica is the Director, Antarctic Division, Department of Science, Melbourne. Possible applications of ERTS imagery in topographic mapping in Antarctica are being investigated by the Antarctic Mapping Section, Division of National Mapping, Department of Minerals & Energy, Melbourne.

Existing photography and maps

Systematic vertical aerial photography of the area displayed on the images is not complete. Unsystematic reconnaissance trimetrogon photography was flown by the RAAF ANARE Flight in the 1950s and 1960s, but coverage is incomplete. The trimetrogon photography has proved to be of limited use for geological mapping. Base maps prepared from the reconnaissance photography have been found to have shortcomings for systematic 1:250 000-scale geological mapping.

THE AREA SHOWN ON THE IMAGES (Fig. 1)

Geology

The Prince Charles Mountains are exposed in a great trough in the Antarctic Ice Sheet that was apparently caused by ice drainage into the Lambert Glacier/Amery Ice Shelf system. Geological mapping has shown that most mountains were formerly covered by the plateau ice, and that the regional ice level has been lowered recently and rapidly. Large flat-topped rock masses bounded by vertical cliffs are common near the major glaciers: the summits of some of these mountains are almost 1000 m above the ice level. Isolated jagged peaks are more common away from the main glaciers, and are particularly common in the north-western quadrant of the Prince Charles Mountains.

Glaciated erosion surfaces in the Prince Charles Mountains have not been greatly affected by weathering, and differential weathering of bedrock units is not well developed. Similarly, weathering patterns characteristic of particular rock types are rarely developed.

Most exposures displayed on the images consist of high-grade metamorphic rocks, but coal-bearing Permian sediments are exposed near Beaver Lake. The basement rocks are intersected by orthoamphibolite dykes, and unaltered basic sills and dykes of Cretaceous age intrude the sediments. A lava flow caps part of the southwest end of Manning Massif.

The main metamorphic rock types are charnockite, granulite, banded gneiss, metasediment, amphibolite, and metamorphosed granite. Sub-conformable granite dykes are common where anatexis accompanied the metamorphism.

Many exposures consist of light and dark banded gneiss, but individual bands are rarely more than 50m thick. Large homogeneous rock masses have been mapped at Fisher Massif (metabasalt), Loewe Massif (charnockite), and Beaver Lake (sediment).

Bedrock is best exposed in cliff faces, but more gentle slopes are commonly mantled with loose rock debris. In places the debris is locally derived and almost in situ: elsewhere it is of glacial origin. Bedrock trends are clearly visible on many slopes largely covered by locally derived debris.

Glaciology

Both scenes show large areas of the plateau ice and parts of the Lambert Glacier System. Glaciers are distinguished from plateau ice by prominent longitudinal 'flow lines' that are caused by intraglacier shearing. Glaciers that flow direct from the Northern Prince Charles Mountains to the Amery Ice Shelf are displayed on scene E1148-03261. The stagnant glacier that floats on Beaver Lake is also visible.

Most of the glaciers and the plateau ice are covered with snow. Blue (bare) ice is exposed near rock outcrops and positive relief features on the ice surface because local wind turbulence has prevented snow accumulation. Wind-scours up to 60m deep, 100m wide, and of various lengths are formed in the plateau ice on the windward side and along the edges of jagged rock features, but are less well developed near the larger flat-topped rock masses. Large snow drifts develop in the lee of rock exposures.

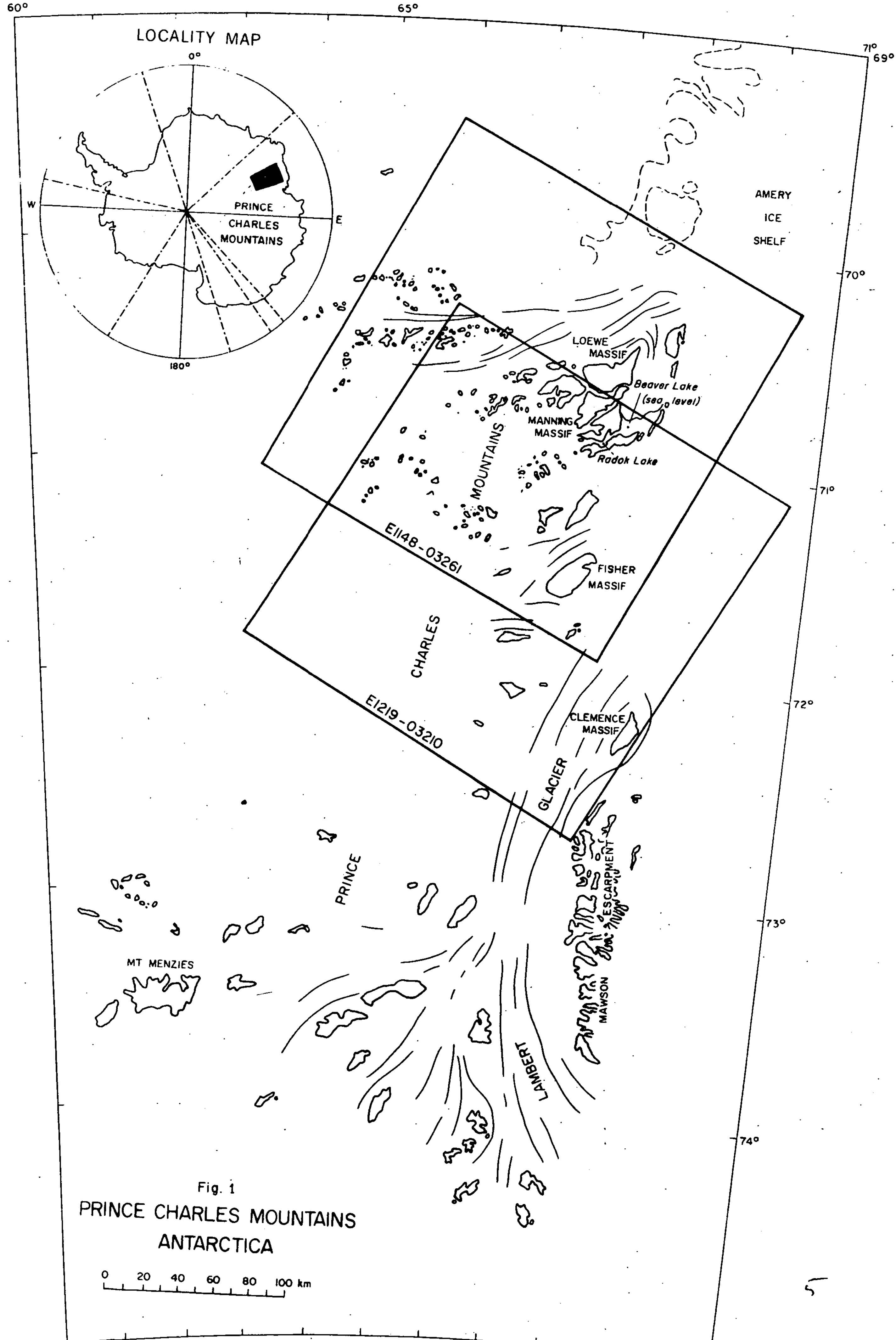

Fig. 1
PRINCE CHARLES MOUNTAINS
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Other Features

Beaver Lake, a brackish lake that occupies the lowest exposed area of the Prince Charles Mountains (Fig. 1), is thought to be tidal. Radok Lake is freshwater, and is drained by a seasonal stream that flows to Beaver Lake through a gorge eroded in Permian sedimentary rocks. A deeply weathered stagnant glacier that floats on Beaver Lake and a small glacier tongue on Radok Lake are visible on the ERTS scenes. Beaver Lake and Radok Lake are probably never free of ice but during the summer their ice covers become thin and patchy and dangerous to walk upon. The sea water in Beaver Lake is made brackish by freshwater from Radok Lake, from local meltwaters, and from the melting of the glacier on Beaver Lake.

The two ERTS scenes examined are almost free of cloud, but drift snow streaming in the wind is clearly shown in the upper left hand corner of scene E1219-03210. A single cloud high above Fisher Massif on scene E1148-03261 casts a well defined shadow, and is probably about 10 000m above ground level.

IMAGERY

Examination of the imagery

The various features of the two scenes were examined with a mirror stereoscope. Magnifications of 1:1, 1.8:1 and 3:1 were used. Some features were examined by 10:1 hand lens. The main features of the examination are listed below. Rock features are dark grey on all the positive images and on the colour composites.

Sun elevation

Because of the high latitude sun elevation in the Prince Charles Mountains varies greatly with the time of year. For example at latitude 70°S sun elevation at midday on December 21 is 44° but it is only 4° at midday on May 7th. The ERTS satellite is programmed to pass over a particular point on the earth once every eighteen days at about 0930 hrs local time. The Prince Charles Mountains are illuminated at this time between about August 22nd and April 22nd the following year. Sun elevation at 0930 hrs ranges from about 4° on August 22nd and April 22nd to 38° on December 21st.

Shadow effects around relief features are exaggerated when the sun is low. The shadows do not obscure much detail on the imagery. Many features that cast shadows on the low-sun images are uniformly illunimated, and in many cases undetectable, on the high-sun images. The shadows cast by any particular object will be twice as long on the 15^{o} sun-elevation image as on the 31^{o} sun-elevation image.

The shadow effect of low sun elevation indirectly increases the amount of detail displayed on the imagery. Detail of ice relief is particularly enhanced: rock detail is perceptibly, but not greatly, improved. Although various features are emphasized in the various imagery bands, some detail is detected only by the shadow effect.

The Del shadow effects enhance linear features at right angles to the sun's azimuth at the time of imagery. Most scenes are imaged when the sun is in the northeast: therefore, northwest trending detail is particularly enhanced by the shadow effects of the low sun. Northeast-trending detail is not so enhanced. This differential enhancement must be borne in mind in the interpretation of low-sun-angle imagery.

Low sun elevation also appears to give less reflection of band 7 energy from blue ice areas. Slight tonal contrasts between blue ice and snow-covered areas are not visible in bands 4 and 5 of the high sun elevation imagery, but are visible in band 4 on the low.

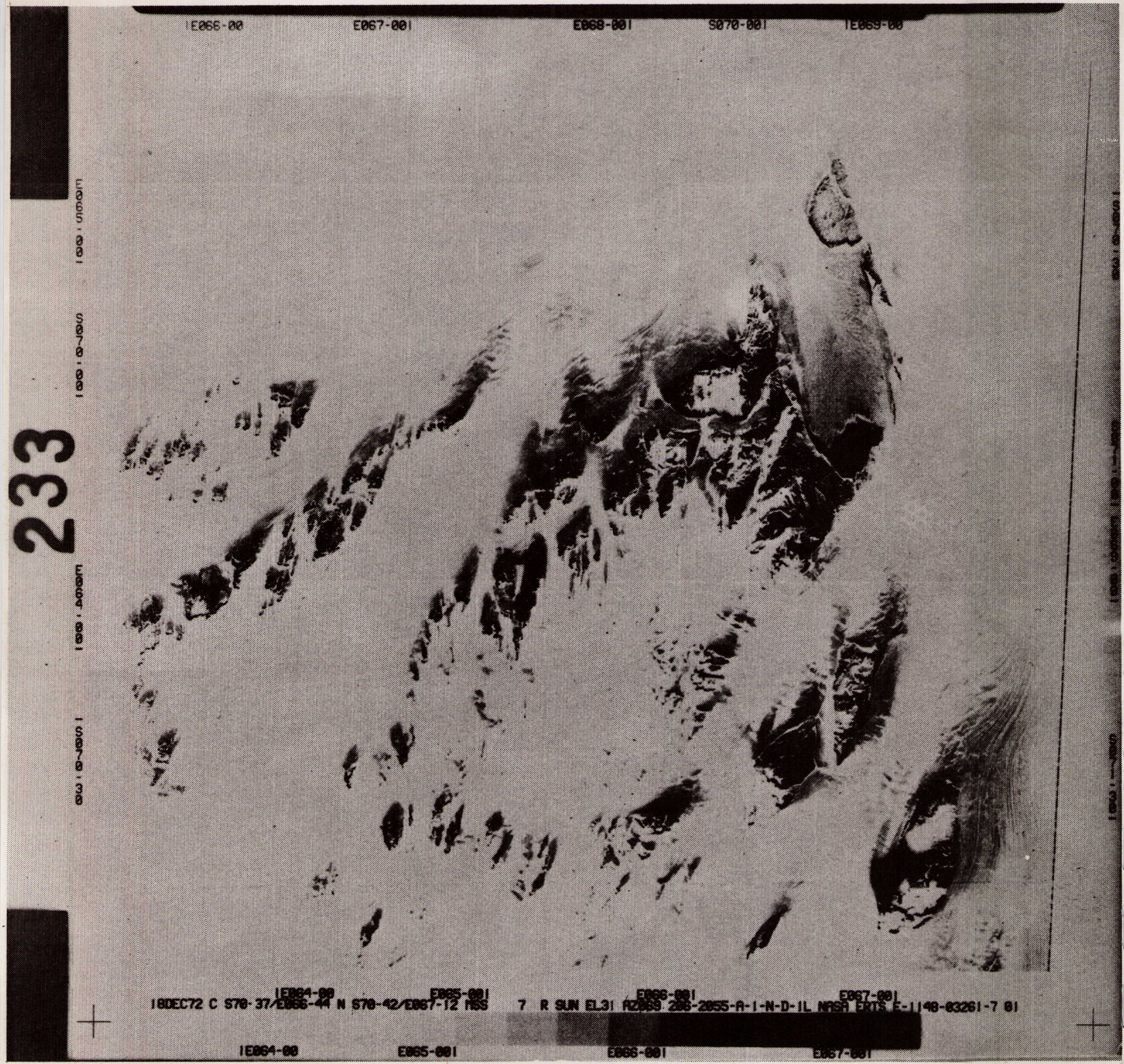
Band 4 images

Tonal contrasts between snow cover, exposed blue ice, glacier ice, and (frozen) lakes are barely perceptible on the high sun imagery, but are perceptible on the low sun images. Contrast between rock on the one hand, and snow and ice on the other is very distinct in Band 4 images, and tonal differences within the rock masses can be detected. Band 4 is probably best suited to mapping rock, particularly if shadow effects reveal the morphology of ice-covered areas.

Band 6 images

Blue ice shows up clearly on Band 6 images of both scenes. Contrasts between frozen lakes and glacier ice and other ice features are more marked than in Band 5 imagery. Rock outcrop shows up as dark grey, and is easily distinguished from the blue ice areas, which are displayed in light grey shades. Shadow effects on the low-sun image reveal much detail on the surface of the ice: shadows along the edges of mountains are much the same in Bands 4, 5, and 6, and in general, the edges of the mountains can be discerned. Because of the clear distinction between exposed rock and blue ice, Band 6 imagery is regarded as the most suitable and economical for geological interpretation.

Low Sun Angle Image E1219-03210.



High Sun Angle Image E1140-03261.

Band 7 images

Blue ice, lakes, and some topographic detail of the ice are displayed in grey tones on the Band 7 images. In places the boundary between rock and ice is ill defined on this imagery, as the grey tones of the ice resemble the grey tones of the rock features. Blue ice areas are duller grey on the high sun than on the low sun images. This is probably due to greater incident Band 7 energy at higher sun elevation, reflection of a greater proportion of incident energy at higher angles of incidence, and, possibly, the effect of slightly greater snow cover on the low sun elevation scene. On Band 7 rock and blue ice contrast better on low than on high sun elevation image. The rock-ice contact is therefore more easily distinguished on the low sun angle Band 7 image: however, it is even better defined on the Band 4, 5, and 6 images.

Rock features appear on the Band 7 image much as they appear on the other band images. Band 7 thus enhances the display of ice features, but is not especially good for the display of rock detail.

Colour Composites

The colour composites show rock as grey and ice features in blue tints. The rock-ice interface is well defined, and confusion between rock and ice features - which can occur in some Band 7 imagery - is avoided. Colour-composite images do not appear to show any more geological detail than can be detected on the images of individual energy bands: they are therefore not thought to be especially useful for geological interpretation of Antarctic scenes.

FEATURES DISPLAYED ON THE IMAGERY

As the glaciated surfaces of rock features in the Prince Charles Mountains have not been greatly modified by weathering, details within the rock masses are distinguished mainly on the basis of colour. These colour contrasts are portrayed as grey tones on the ERTS images.

Tonal contrasts within rock masses displayed on the images are not common, but the Permian sediments near Beaver Lake have a characteristic light grey tone. Granite and metabasalt mapped at Fisher Massif cannot be differentiated on the imagery, but the lava flow on Manning Massif is clearly visible because it cuts across the grain of the underlying gneiss, and has a characteristic surface morphology. Compositional banding in gneiss is just visible in places.

Linear features that cut across rock exposures are visible in some outcrops, particularly near Beaver Lake and at Fisher Massif. Some of these lineaments represent orthoamphibolite dykes; others may be faults. Larger-scale lineaments seen on the images may be the expression of major structures. Some of the detail of ice morphology that appears on the low sun elevation images is useful for detecting subglacial relief features and the possible subglacial extent of lineaments.

Geomorphological features such as cirques, moraines, and glaciated pavements are well displayed in the imagery, and can be more accurately assessed than on the existing trimetrogon photography.

The modern glaciers are best diaplayed on the low sun elevation Band 7 images. Crevasse zones and flow-lines are easily visible. The contact between glacier ice and plateau ice can be easily defined on the images. Details of ice topography are best displayed on low sun elevation imagery.

APPLICATION FOR ERTS IMAGERY IN OTHER ANTARCTIC FIELD STUDIES

The applications of ERTS imagery in topographic mapping of Antarctica were reported by the Division of National Mapping, Department of Minerals and Energy, to the ERTS Investigators Symposium held at BMR in December, 1973.

Glaciology

The excellent display of ice-surface detail shown on the low sun elevation imagery should be useful for planning glaciological fieldwork, and particularly projects intended to estimate the ice economy of an area. Planning of programs to measure ice thickness by airborne radar profiling might also benefit from the use of ERTS, particularly where subglacial relief is expressed at the glacier surface.

At the coast ERTS imagery would provide an accurate means of monitoring the quantity of ice that leaves Antarctica as icebergs, and thus of measuring the ice economy of particular areas, or, ultimately, of Antarctica as a whole. Studies of ERTS imagery may also reveal local patterns in the accumulation and the break-up of sea ice, and provide valuable information for logistic purposes.

Logistics

ERTS imagery, unlike that of weather satellites such as ESSA, is not available in real time. Nonetheless it could have the following applications for logistics.

(a) ERTS imagery, particularly low sun elevation imagery, should have some application in planning oversnow tractor train routes.

(b) Flying in Antarctica is under visual flight rules. ERTS imagery, which provides a convenient and objective display of ice and rock features, would probably be less subjective than standard maps.

Imagery could also be used in planning aerial photography programs, ice-thickness radar profiling programs and, possibly, airborne geophysical programs. The cost of flying in Antarctica is so great that any planning aid that can lead to efficient use of aircraft deserves close examination.

(c) The best season for aircraft-supported fieldwork in Antarctica is from mid-November to mid-January. Australian field activities are restricted to January and February, because, it is thought, ships cannot approach within reasonable flying distance of the Antarctic Coast before mid-December. Study of ERTS imagery should reveal any pattern there might be in the break-up of sea ice, and may lead to fieldwork at the best time. This would be more efficient and economical than at present.

In other areas ERTS imagery has been used for plotting reefs and other underwater obstacles. Many such obstacles are clearly visible on Band 4 imagery, but Band 7 energy is totally absorbed by water. Comparison of the four images of a particular scene allows the depth of underwater obstacles to be estimated. ERTS imagery may prove to be an economic method of detecting and mapping underwater obstacles in Antarctic waters.

CONCLUSIONS

The clear, convenient, and objective overview that 1:1 000 000-scale ERTS imagery provides is a useful aid to geological mapping in Antarctica. It is particularly useful for the detection of major lineaments and structures that

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are not apparent on larger-scale aerial photographs. Distinction between rock units is possible, but is hampered by the lack of differential weathering patterns. ERTS imagery also has uses for cartography, glaciology, and geomorphological studies. As an aid to planning fieldwork and logistics ERTS may result in increased efficiency and certain economies.

ERTS imagery of Antarctica is partially enhanced by low sun elevation, a factor that is more important than the choice of energy band. However, the shadows thrown by a low sun do tend to exaggerate northwest at the expense of northeast trending detail. In general Band 6 is thought to be the most suitable for geological interpretation of ERTS imagery of Antarctica.