COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1971/101

Geological Potential of Imagery from the BENDIX TM/LN-2 Thermal Infra-red Line Scanner

by

C.J. Simpson

Record 1971/101

GEOLOGICAL POTENTIAL OF IMAGERY FROM THE BENDIX TM/LN-2 THERMAL INFRA-RED LINE SCANNER

by

C.J. Simpson

CONTENTS

SUMMARY

Thermal imagery recording infrared radiation of wavelengths between either 1.0 to 5.5 microns or 3.7 to 5.5 microns were produced on film over test sites at Captain's Flat, Lake George, Googong Damsite, New South Wales, and Orroral Valley, A.C.T., in March, 1971.

With the exception of some alluvial deposits, and the Captain's Flat Mine dumps, the thermal imagery provided less geological data than conventional air photographs.

Pre-dawn imagery was not obtained. Study of the early morning imagery indicates that pre-dawn imagery would probably contain more useful geological data than imagery obtained during daylight hours.

INTRODUCTION

At the beginning of 1971 Canadian Aero Service Ltd positioned a Bendix Thermal Mapper Type TM/LN-2 in Sydney as part of their aerial survey equipment.

The company offered to obtain (at their expense) imagery over selected test sites in NSW and the ACT to allow interested parties to evaluate the Bendix equipment, and to demonstrate the potential of thermal imagery. Three Government agencies BMR, FTB, and CSIRO participated in the selection of test areas and the collection of ground information in the test areas. The following notes discuss interpretation and evaluation of the imagery obtained during March 1971 over test areas of interest to BMR.

Four test areas were imaged, Lake George, Googong damsite, Orroral Valley, and Captain's Flat mine dumps.

THERMAL IMAGERY

General

Infrared-sensitive photographic films can record radiation with wavelengths of 0.7 to 0.9 microns. Infrared wavelengths longer than these can be detected by suitable photodectors. Video tube displays of the photodetector electrical signal output - which corresponds to infrared radiation intensity - can be photographed to produce thermal imagery. The thermal imagery that results appears similar to a panchromatic film print; however, instead of the grey tones representing intensity of reflected light they represent relative heat. The warmer the material the lighter it will image.

During periods of sunlight incidence on the earth's surface two types of thermal infrared (IR) radiation are present. Radiation with wavelengths shorter than approximately 3.5 microns is reflected from surface objects. Radiation with wavelengths longer than approximately 3.5 microns is emitted from surface objects.

The Bendix Thermal Mapper

The Bendix Thermal Mapper type TM/LN-2 test flown by Canadian Aero Service Ltd contained a photodetector sensitive to IR radiation wavelengths between 1.0 and 5.5 microns. It had two interchangeable filters so that differentiation of the emitted IR from the reflected IR could be achieved.

Filter A transmitted wavelengths from 1.0 to 5.5 microns (i.e. reflected and emitted IR).

Filter D transmitted wavelengths from 3.7 to 5.5 microns (i.e. emitted IR only). (The Bendix company also supplies a detector sensitive to radiation with wavelengths between 8-14 microns. It is preferable to use this band for general geological work because at ordinary temperatures -around 300°K- the blackbody radiant emittance in the 8-14 micron band is greater than in the 3-5 micron band. At the time of the test flights this detector was not available from Canadian Aero Service Ltd).

The instrument has an instantaneous field of view of 2.5 milliradians, i.e. from 305m (1000 ft) altitude the detector looks at an area 0.76m (2.5 ft) square on the ground. The temperature sensitivity is claimed to be 0.1°C.

IMAGE EVALUATION

Conventional air photographs were used to interpret and evaluate the thermal IR imagery.

The image positive prints accompanying this report are not of high tonal quality, and the evaluation of the IR image strips has been mostly carried out on the original negatives. Where successive imaging flights were made over a target area the strips have been numbered so that increasing numbers indicate increased exposure to incident sunlight.

LAKE GEORGE

Seven imaging flights were made over Lake George. These have been designated A1, A2, B1, B2, C1, C2, D (FIGURE 1).

Image Lines A1, A2.

Airphotograph Coverage

Colour	BMR 104, 105, 106,
	ACT (CAC/19) Run 1/8533, 8534
Panchromatic	BMR Run 1/12, 13,

Image Flight Data

Both strips of imagery were obtained on 18-3-71 at 457m (1500 ft) AMGL.

Image time 0759 - 0802 hours. Filter used D - strip A1

" " 1337 - 1340 " " " " - strip A2.

Discussion

Strip A2 is centred slightly north of A1. Common points at each end of the strips are indicated by A (PLATE 1) strip A1 shows less contrast than A2, but despite this, recent lake deposits on line B-B can be readily differentiated, and more subdivisions can be detected on the IR imagery than on conventional photographs. The print of A2 shows more contrast within the near-shore water areas than print A1 and this allows the land-water boundary to be more accurately delineated. (The negative of A1 shows more detail than the print and would permit print enhancement).

Distortion effects are displayed by the image of the fences (C) which are actually straight and parallel.

Dark areas at D are cloud effects.

Problems of incorrect film speed/aircraft speed synchronization can be seen by comparing the shore to shore distance, for the image strips. Image strip A1 is 'stretched' relative to A2. Planimetric Sheet 8727-1 at 1:50,000 scale was used to compare map distance/image distance ratios (A1 ratio 335, A2 ratio 305). On the western end of the strips the bitumen surface road E shows well on both images. Tracks similar to F do not image on A2 (tracks are present leading up to and continuing through the vegetation clearings G).

Road E marks the base of the topographic scarp along the western side of Lake George. Light toned area H corresponds to the scarp face and results from early morning heating of the east-facing scarp. The thermal difference is not apparent on A2. Thermal differences within the lake water appear to be negligible except in near shore areas.

Image Lines B1, B2.

Air Photograph Coverage

Colour BMR 131, 132, 133

Panchromatic Gunning Fault Zone Run 1/1674.

Image Flight Data

Both strips of imagery were obtained on 18-3-71 at 457m (1500 ft) AMGL.

Image time 0754 to 0756 hours. Filter Used D - strip B1

" " 1332 to 1335 " " " D - strip B2

Discussion

Strip B2 has a greater range of tonal contrasts over both land and water than B1. The land-water contact is difficult to identify on both images. The water temperature of Collector Creek (A) is different from the lake water temperature.

Strip B2 shows more variation of the lake water temperature than B1 and this indicates the main discharge direction from Collector Creek.

An earth dam is indicated at B.

A dark toned area C (on strip B2only) may be a groundwater spring.

A fenceline is shown at D. If it had been parallel to the scan lines it would not be detectable.

Tonal changes on the southern end of B1 are due to cloud.

Both the colour and panchromatic photographs contain more data about the Collector Creek discharge pattern than the thermal imagery.

Image Lines C1, C2.

Air Photograph Coverage

Colour	ACT (CAC/C3) Run 4/9466 - 9468
	BMR 068 - 070
Panchromatic	BMR Run 5/74 and Run 1/3, 4.

Image Flight Data

Both strips of imagery were obtained on 18-3-71 at 457m(1500 ft) AMGL.

Image time 0810 to 0813. Filter used D - strip C1.

" " 1345 to 1347. " " D - strip C2.

Discussion

Common image points are shown by A and B. The morning imagery C1 shows better differentiation of the Butmaroo Creek water temperatures than the afternoon imagery C2. The relatively cooler water shown on C2 does allow more definite delineation of the soil-water boundary to be made.

Details on the eastern end of the image strips.

A ridge of sand C is more clearly defined on strip C2.

D represents a swampy area and E a comparatively recent alluvial deposit.

Light-toned areas F are probably clean sand deposits (compared to sand, silt etc.). Dark toned areas G on C1 correspond to standing water. Dark toned area H appears to be due to vegetation.

Fenceline I can be distinguished by the alignment of dark strips (probably vegetation).

Details on the western end of the image strips

Both image strips are visibly distorted on the western end.

Strip C1 shows more detail within the zone of alluvium around the lake edge. Tones within this area are noticeably lighter than within the similar zone (E) on the eastern edge. This difference is difficult to explain. The strip was flown from west to east and no in-flight instrument adjustments are noticeable.

The road J shows as a light tone.

Dark toned vegetation indicates a fence, (K).

The region between J and K is a cultivated paddock and the tonal

variation may be due to vegetation cover. The crescentic lighter toned area near J corresponds to a steeper part of the hill slope which is poorly vegetated on 1968 air photographs. Over the lake water area dark strips perpendicular to the film edges (L-L') show irregularities in film travel speed. A series of unexplained light and dark bands parallels M-M'. Variations of gray scale over the water surface appear to be controlled by instrument "noise" rather than actual water temperature differences.

The early imagery (0810 - 0813 hours) shows better differentiation of the water temperatures, whereas the afternoon imagery (1345 - 1347 hours) shows more distinct differences between the various unconsolidated deposits.

The C1 and C2 IR imagery does not provide any more data than do conventional air photographs.

Image Line D

Air Photograph Coverage

Colour ACT (CAC/C9) Run 2/8548-8545

BMR 115, 116, 117.

Image Flight Data

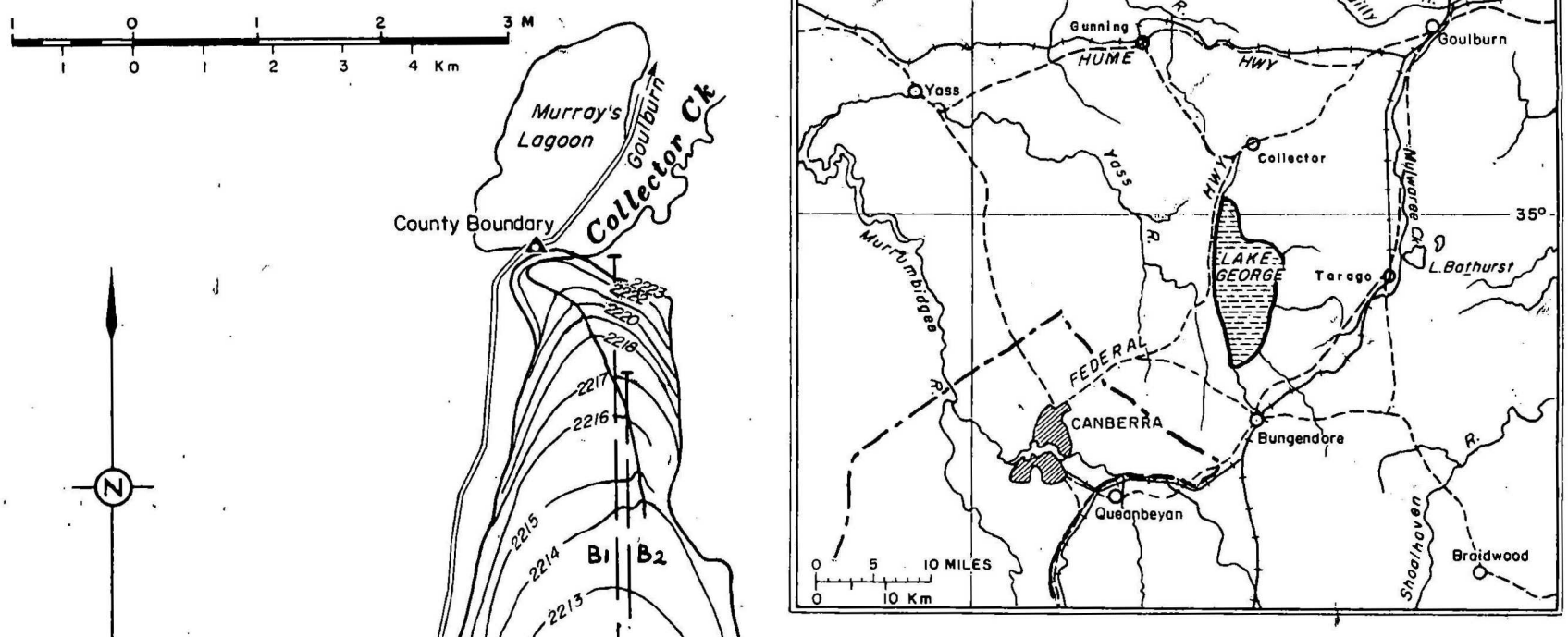
This image strip was flow on 18-3-71 at 457m (1500 ft) AMGL.

Image time 0804 to 0808 hours, filter used D.

Discussion

Imagery over land on the eastern end of the strip shows good tonal contrast and limited distortion. In the alluvial material more information can be interpreted from the imagery than from conventional colour or panchromatic photographs. The region west of A-A consists of deltaic alluvial material in which different deposits can be seen e.g. B, C. The area of darker tone between A-A and C appears to correspond to a particular vegetation. Change in overall signal intensity along D-D (and M-M) is due to instrument adjustment during imaging

LAKE GEORGE, N.S.W.



LOCALITY MAP

TABLE OF CAPACITIES

APPROXIMATE

DEPTH OF WATER	R.L. OF CONTOUR	CAPACITY IN CUBIC FEET	SURFACE AREA
Bed	2208 ft.		1/3 Sq. Miles
1 ft	2209 "	158-000-000	14 1/2 " "
2	2210 "	712-000-000	25 3/4 " "
3	2211 "	1-554-000-000	34 3/4 " "
4	2212 "	2-623-000-000	42 " "
5	2213 "	3-888-000-000	48 3/4 " "
6	2214 "	5-288-000-000	51 1/2 " "
7	2215 "	6-765-000-000	54 1/2 " "
8	2216 "	8-300-000-000	55 3/4 " "
9	2217 "	9-861-000-000	56 1/4 " "
10	2218 "	11-440-000-000	57 " "
11	2219 "	13-038-000-000	57 1/2 " "
12	2220 "	14-653-000-000	58 1/4 " "
13	2221 "	16-284-000-000	58 3/4 " "
14	2222 "	17-933-000-000	59 1/2 " "
15	2223 "	19-611-000-000	61 Sq. Miles

Note: siltation, particularly at deltas of main tributaries, has slightly modified contours and changed volumes shown in table.
Approx. water depth on 18/3/1971 – 5·7 ft.

REFERENCE

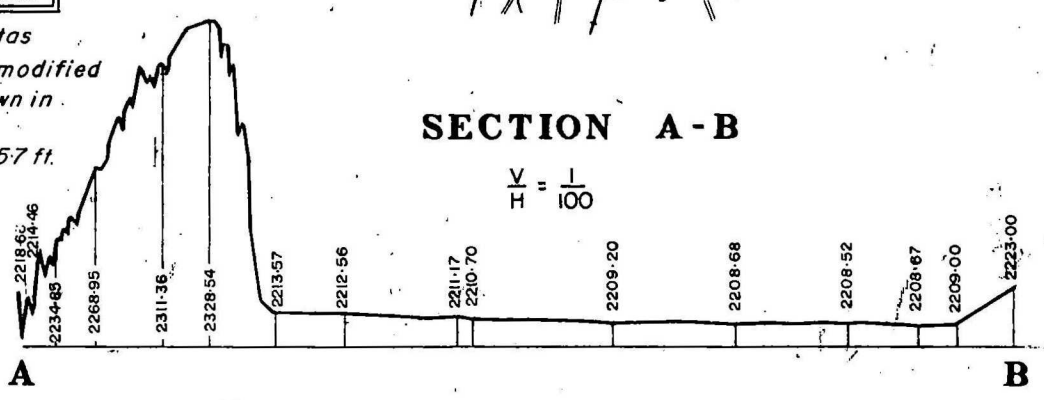
B.M.R. lake gauging station

2276.32 Trig. station with height

Thermal imaging flight lines

SECTION A-B

$\frac{V}{H} = \frac{1}{100}$



Modified, redrawn and reproduced with permission from N.S.W. Public Works Department Plan No B42 (3/2/1903).

FIGURE 1

I55/A16/455

Bureau of Mineral Resources, Geology and Geophysics.

(change in either gain control or D.C. level). The cultivated paddock bounded by fences (E) shows a fairly uniform tone. Some ancient drainage patterns F still image within the cultivated land.

Earthern dams show at G.

Buildings show shadow patterns indicative of early morning heating on their eastern sides.

Dark spots I are large crowned trees.

Light toned strip J is a recurved deltaic bar above water level, which deflects cooler water on its eastern side.

Light toned strip K corresponds to an unvegetated strip (sandy?).

Light area L may be standing water.

Fine detail within the land area on the western end of the image strip is masked out because of excessive warming of the east facing scarp.

(See similar effects on strip A1).

General Discussion of Lake George Imagery

Lake George was chosen as an imaging test area primarily to see what thermal variations existed between the water of streams discharging into the Lake and the Lake itself. The imagery shows that temperature differences occur between the stream waters and the Lake; however, the differences dissipate quickly after the stream waters enter the lake. Temperature differences within the Lake water are not detectable. If differences exist they may be masked by instrument 'noise'. The shallow depth of the lake (2 m at the time of imagery) compared to its large surface area may be a factor in maintaining uniform temperatures throughout the lake. Some imagery shows good differentiation between various alluvial deposits.

GOOGONG DAMSITE

Air Photograph Coverage

The area imaged is also covered by coloured air photographs A.C.T. Run 13/9743, 9744 and BMR panchromatic photos 25/105, 106.

Image Flight Data

Four imaging flights were made over the damsite at an altitude of 457 m (1500 ft) AMGL and at an aircraft speed of 110 knots.

19-3-71 Image time 0621 - 0624 hours. Filter used A-strip I.
19-3-71 " " 0937 - 0939 " " " D- " 2.
19-3-71 " " 0942 - 0944 " " " D- " 3.
18-3-71 " " 1526 - 1527 " " " D- " 4.

Annotation

Alphabetical annotation has been added to common features on all imagery as follows (PLATE 2A).

A - proposed site for Googong damsite retaining wall.

B - bedding traces (shales? in dacite).

C - joints.

D - granite.

E - moist soil.

F - water.

G - road.

H - limestone.

I - fenceline.

J - distorted region.

Joints (C) are more pronounced on strip 1 than on 2, 3, 4. Granite (D) can be detected on the negative of strip 1. On strip 2 positive print the light toned areas correspond to part of the granite intrusion, (FIGURE 2) but not all. Granite west of the proposed retaining wall site A (FIGURE 2) can not be distinguished on any strips.

Moist soil (E) shows better on 1 than on other strips. Such soil is not readily detected on the conventional air photographs.

Water boundaries (F) are more clearly defined on print 1 than on prints 2, 3, 4, but negatives of 2, 3, 4, show the boundaries just as clearly.

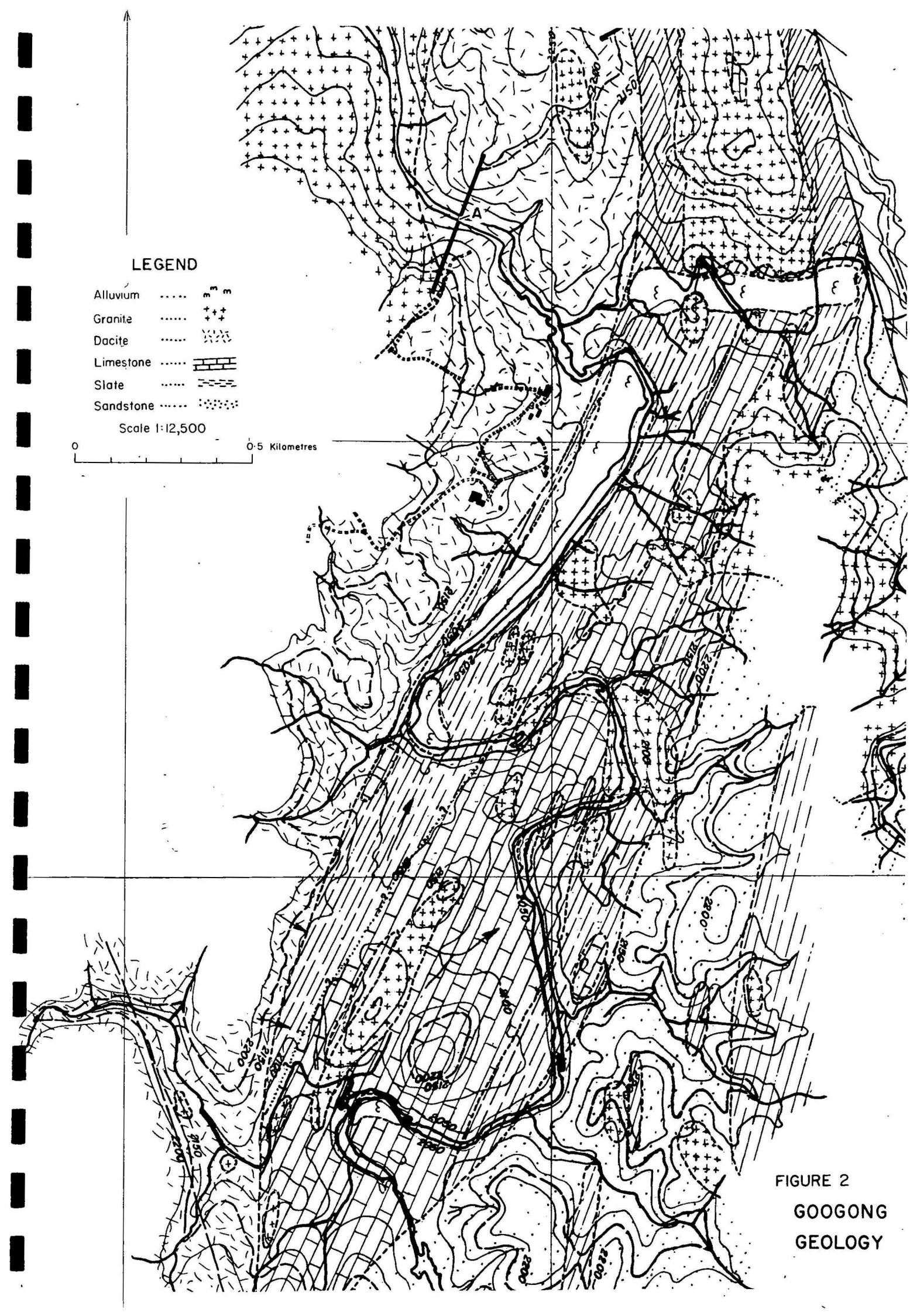


FIGURE 2

GOOGONG

GEOLOGY

Roads (G) show best on 1.

A mottled region (H) on strip 1 negative corresponds to limestone on the geological map. Prints of 2 and 3 show some darker tone in the same general region but the limits are not definite.

One fenceline (1) on strip 1 cannot be detected on 2, 3, 4, Fences can be inferred around a cultivated paddock detected on all strips.

A zone across strip 2 at J shows the effect of distortion. Such distortion prohibits structural interpretation. Note the displacement and 'stretching' of tree images.

The negative of strip I shows much more detail than the positive print. The positive print strip 2 shows more contrast than 1, 3, or 4. Strip 4 shows the most distortion of all strips and the least tonal contrast.

DISCUSSION

The Googong damsite was chosen as an imaging test site because the geology of the several different rock types is well known. A significant result of the early morning imagery is that there is a thermal differentiation between granite and limestone (D and H), but granite within dacite is undifferentiated, probably because granite and dacite have a similar thermal inertia.

The emitted radiation (dark area) image of the early morning strip 1 (0621 - 0624 hours) contains more detail than all subsequent strips. Detail from reflected light areas is poor.

With the exception of some moist soil areas, strip 1 does not show anything that cannot be detected on conventional vertical photography. Such imagery may provide useful data for near surface hydrological problems.

ORRORAL VALLEY

Air photograph Coverage

Colour	ACT	Run	19/7787 - 91
			20/7837 - 41
			21/7866 - 69
			22/9622 - 27

Image Flight Data

Three image strips were flown at 457 m (1500 ft) AMGL.

19-3-71	Image time	0656 to 0700 hours.	Filter used	A - strip 1.
19-3-71	" "	0701 to 0704 hours.	" "	D - strip 2.
18-3-71	" "	1609 to 1612 hours.	" "	D - strip 3.

Annotation

Geological Features

Strip 2 (emitted radiation) shows white toned granite outcrops A (PLATE 2B) in the cleared land and B within the natural forest. The overall distribution of granite outcrops can be readily seen.

The map of the hydrogeology (PLATE 7) after Palmer (1971) shows outcrops of metasediments in the vicinity of C (PLATE 3). The outcrops can not be detected on the imagery. Ordovician? sediments occur at D. The change in rock outcrop pattern imaged through the forest at D (compare B and D) on strip 2 may reflect the different rock types.

Both strips 2 and 1 show a tonal lineament E-E which corresponds to a suspected fault line. Lineament F-F may be a continuation of lineament E-E. A set of tonal lineaments can be seen at G-G on strip 3. These subparallel a fracture set observable on the air photographs. The density of lineaments at G-G is far greater than those detected on air photographs and it is suspencted that the lineaments on the imagery are due to mid afternoon shadow alignments from moderately spaced trees.

Lineament H-H on strip 3 corresponds to a straight gully.

Linear features I-I, J-J, K-K, correspond to fences.

Hydrological Features

All imagery shows the stream in good detail. Strip 2 is clearer than 1 or 3. Swampy areas L shows on all strips (relatively light toned on 1 and 2 and dark on 3). Moist soil areas M and alluvium along gullies show well on 1 and 2. On air photographs several groundwater springs are obvious along suspected fault line E-E. They cannot be detected on the imagery.

General Features

The cleared ground-natural forest boundary N is detectable on all strips. The masking effect of the forest is shown on strip 2. Dark toned moist soil M can be readily seen in the cleared areas. In the forest area this is represented by subtle scattered dark toned spots which would be detected as soil only by inference. Some dark spots O on strip 3 can not be identified.

The bright rectangles P on strip 2 are open sewerage tanks.

Builidings Q and R on strip 3 are constructed of the same material. The difference in signal is probably due to the effect of a cooling system in building Q.

Scan lines on strip 2 cross the film at about 2° off perpendicular to the film edges. This does not occur on strip 1 or 3 and is due to aircraft crab. When present it introduces another element of distortion into the imagery. Wave-like distortion can be clearly observed near J-J on strip 3.

Less obvious effects of scan distortion can be seen by examining road patterns around the tracking station on strips 2 and 3.

Discussion

Orroral Valley was chosen as an imaging test area because it is one of the 100 Australian representative drainage basins under investigation by the Australian Water Resources Council. The valley is considered to be fault controlled and the thermal imagery was flown primarily to see if it could provide data about the influence of the fault on the hydrology of the valley.

Of the three strips flown, the early morning imagery taken with a filter to eliminate reflected heat (i.e. strip 2) is the most useful.

The thermal IR allows moist soil patches and the distribution of granite outcrops to be readily determined. Apart from the concenience of these aspects the imagery does not provide as much hydrological or geological data as conventional colour photography.

CAPTAIN'S FLAT

Air Photograph Coverage

Captain's Flat CAC/C2 Run 3/7423, 7424, 7425 in both colour and panchromatic.

Image Flight Data.

Seven strips of imagery were obtained.

19-3-71	Image time	0630 - 0632	hours	FILTER	A	Altitude	305 m (1000')	STRIP	1
"	"	0633 - 0635	"	"	D	"	305 m (1000')	"	2
"	"	0642 - 0644	"	"	A	"	914 m (3000')	"	3
"	"	0950 - 0951	"	"	D	"	457 m (1500')	"	4
"	"	0956 - 0957	"	"	D	"	610 m (2000')	"	5
"	"	1001 - 1004	"	"	D	"	914 m (3000')	"	6
"	"	1535 - 1537	"	"	D	"	457 m (1500')	"	7

Ground Data

Numbered points on STRIP 2 (PLATE 2C) indicate ground temperatures measurements taken on 19-3-71 between 0630 - 0645 hours, i.e. at the time of the imaging flights for STRIPS 1, 2 and 3.

Point 1 Air temperature 1 m above ground: 9°C.

Water - near dam wall: 18.2°C.

Water - 45 m south of dam wall 0.6 m offshore: 18.0°C.

Point 2 Pool of water on slimes dump: 10°C.

Slime dump: 9½° - 10°C.

Point 3 Top of slimes dump in shade: 14½°C.

" " " " " sunlight for 10 minutes: 16°C.

Point 4 Ground measurement in shade: 13°-15°C.

Point 5 Stream water 9 m south of bridge: 15°C.

Point 6 Mine drainage water 30 m south of bridge: 11°C.
(Thermometer calibrated at ± 0.25°C. at 25°C.)

Annotation

The most useful strip in terms of ground surface differentiation is the early morning STRIP 2 (0633 hours) filtered to emitted radiation. Only this strip has been annotated (PLATE 2C).

A - bright toned areas correspond to large surface areas of massive rock outcrop. These contrast with areas B which also designates outcrop, although these outcrops are rubbly, commonly consisting of vertically oriented rock wedges (tombstone topography). The difference in tone is probably due to the difference in thermal inertia between rocks of similar composition but of different gross surface texture.

C - The small dark toned area corresponds to loosely packed, coarse, uniformly sized alluvial particles (presumably moist at the time of imaging).

D - dark toned area is suspected moist alluvium.

E - Mining waste slimes dump.

F - The large uniformly toned area is also a slimes dump but differs from E in that it contains a higher concentration of metallic sulphides (primarily pyrite). Dump F images warmer than dump E. The smaller patches of F consist of the same material spread (by erosion and slumping) as surficial coatings. The similarity in tone between the thin deposits and the dump suggests that the relatively higher radiant emittance is primarily due to composition rather than heat generated by sulphide oxidation.

G - A dump of stockpiled pyrite concentrate. This shows lighter tone corresponding to the dump face. The variation in temperature around the dump face may be due to pyrite oxidation. The dump face is extensively corrugated by erosion, and the resulting increase in surface area may be conducive to increased oxidation. This is in contrast to the relatively cooler temperature of the dump's upper surface. (Note the partial sun warming - image STRIP 1 - has no appreciable effect).

H - Circular warm spots correspond to concrete mill plant tanks containing slimes.

I - Water of the mine storage dam. On the early morning imagery STRIP 2, the water images warm (18° from ground data) relative to the surrounding land (13° - 15°C). On the afternoon imagery e.g. strip 7, it images relatively cool.

J - bright spots are water tanks (part of town supply). The tanks are separated by another tank which was apparently empty at the time of imagery - see other strips.

K - light toned area is water behind a retaining wall. The dark toned areas bordering the water on the west are moist water-laid dump material.

L - dark toned areas are covered with mine smelter slag.

M - asphalt surfaced road

N - earth formed road

O - lineament O - O which shows on the higher altitude imagery (strips 3, 4, 5, 6,) is emphasized because of thermal shadow effects. It corresponds to the Molonglo Fault mapped by Oldershaw (1965).

P - the dark area on strips 4, 5 is an open mine pit.

Discussion

The mine waste dumps at Captain's Flat were the main targets of the thermal imaging test flights. They were imaged to try to detect any heat that may be present from the exothermic reactions of sulphide oxidation. One dump of stockpiled pyrite (G) shows abnormal heat which is probably due to sulphide oxidation.

The difference in emitted heat of outcrops of similar rock type (A, B) shows a problem of thermal image interpretation which would be difficult to resolve without field data. Although most of the other features annotated on the imagery are man made, the majority of them could not be positively identified without the aid of conventional air photographs or field data.

The difference between water temperature at Point 1 and Point 5 was measured as 3°C. Considering the relative grey tones of the imagery at these points it is unlikely that temperature differences less than 1°C could be visually differentiated by their corresponding grey tones.

DISCUSSION OF THE BENDIX TM/LN-2 TEST IMAGERY

All post-midday imagery suffers from distortion other than inherent scan instrument distortion. In some cases e.g. Googong strip 4 and Orroral strip 3 distortion due to turbulant flying conditions is severe enough to prohibit any meaningful geological structural interpretation. Roll stabilization of the instrument could elimate most of this type of distortion.

Scale discrepancies are present between most multiple imaging flights over the one target area at the same altitude. These can be corrected if thermal signals are recorded on magnetic tape rather than directly onto film.

Of the test strips flown, the early morning imagery recording the 3.7 to 5.5 micron wavelengths (i.e. emitted radiation) contains the most useful geological data. This is in agreement with the findings of experiments carried out by Rasmussen (1970) with a Bendix thermal imager, and Rowan et al. (1970) with a Singer thermal imager. The researchers concluded that pre-dawn thermal imagery is the most suitable for geological targets. Although one aim of the imaging flights over the BMR selected test sites - was the obtaining of pre-dawn imagery this was not achieved. The earliest imagery was obtained between 0621 and 0624 hours on the 19-3-71. Sunrise was at 0605 hours.

The Googong damsite imagery strip 1 (0621 hours) shows that different rocks (i.e. granite and limestone) can image separately. This is believed to be due to the differences in thermal inertia of either the two rock types or the weathering products derived from them. In the same imagery granite and dacite are not differentiated presumably because the thermal inertias of these rocks and/or their weathering products are not significantly different.

Positive image interpretation without ground data and/or conventional air photographs is very difficult.

With the exception of the imagery of the Captain's Flat Mine dump and that of some Lake George alluvial deposits, the Bendix thermal imagery provided less geological data than conventional air photographs.

CONCLUSIONS AND RECOMMENDATIONS

In areas of good exposure it is believed that the instrument has potential for lithological differentiation if the thermal properties of the rocks under investigation differ sufficiently.

Because of this it is recommended that before doing a thermal imaging survey, the thermal properties of the rocks in the area should be studied to establish whether significant differences are present. Pre-dawn imaging flights over the target areas would be necessary to better evaluate the potential geological applications of the Bendix TM/LN-2 thermal imager.

Study of the test imagery indicates that pre-dawn imagery should produce the most useful geological data. The effects of instrument image distortion and the nature of thermal imagery make interpretation and ground navigation directly from the early morning emitted radiation imagery very difficult. As much field data as possible (geological, cultural and geographical) should be collected at the time of imagery to assist interpretation. If necessary consideration should be given to obtaining simultaneous air photographs of the survey area at a scale similar to that of the daytime imagery.

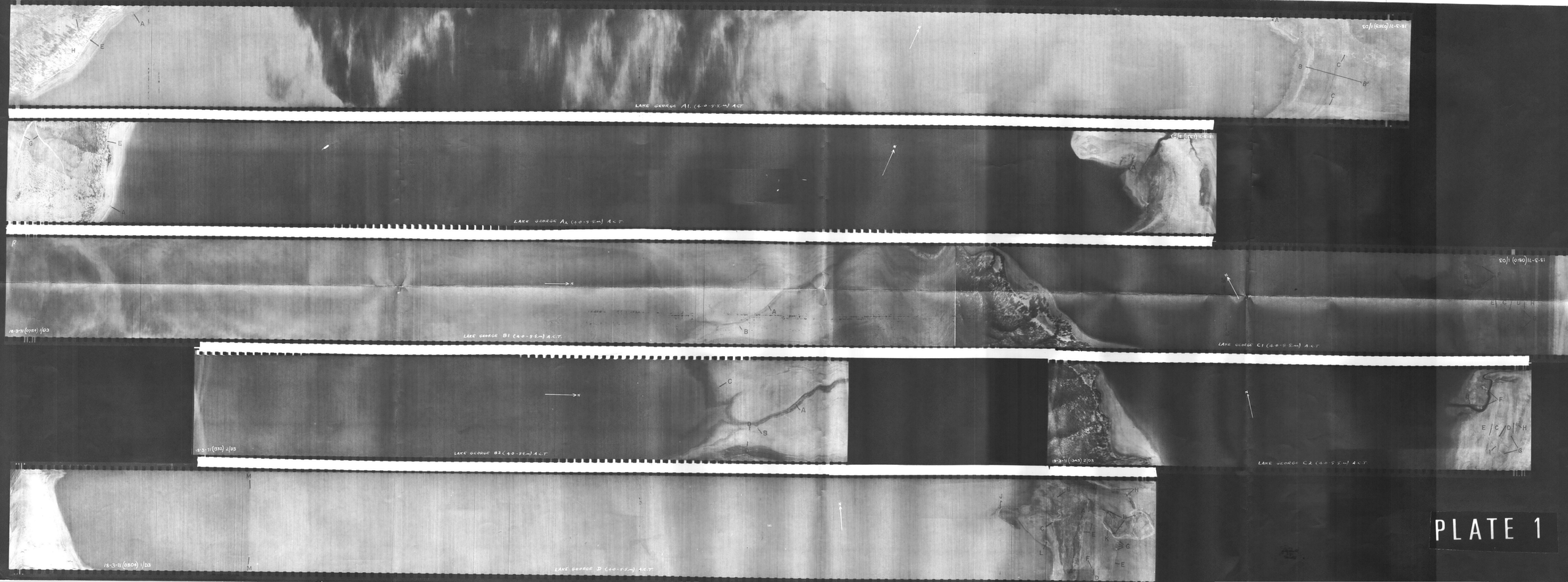
REFERENCES

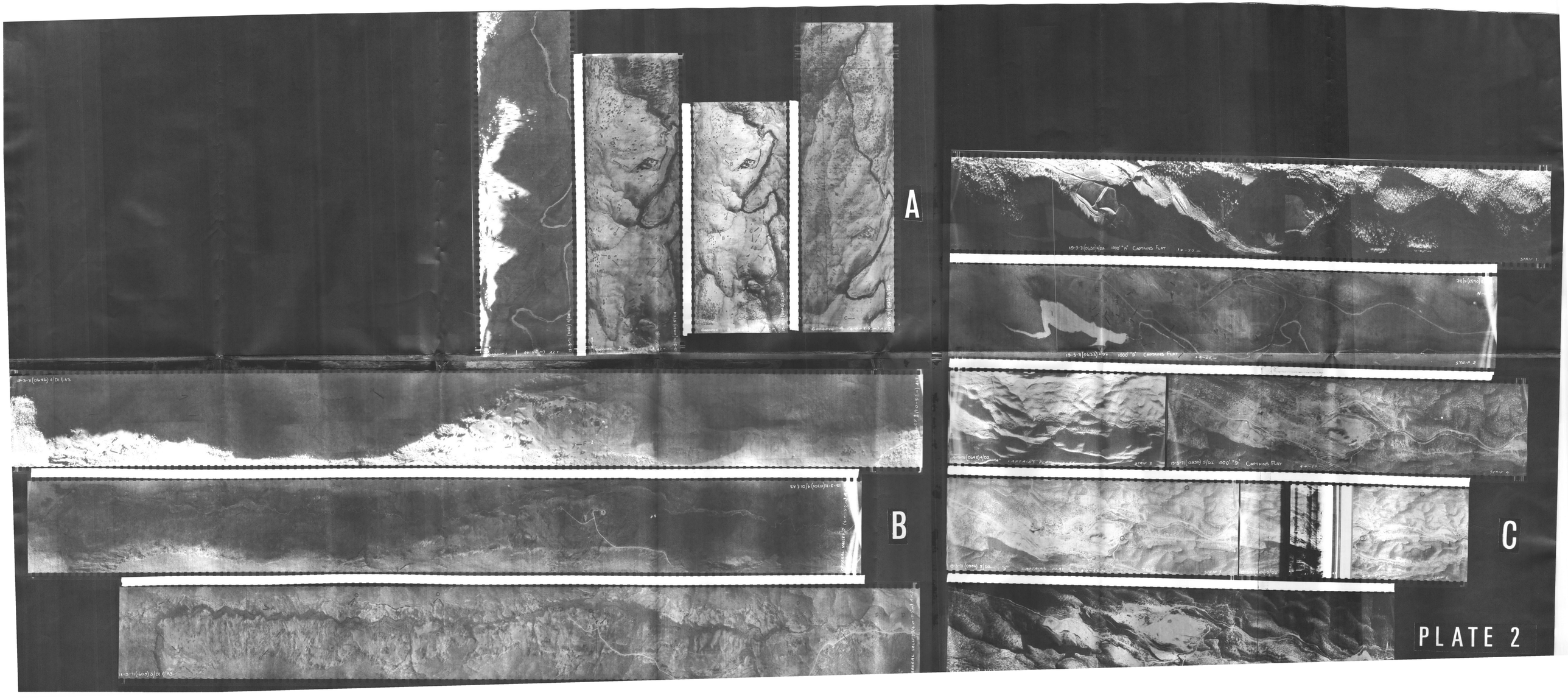
OLDERSHAW, W., 1965 - Geological and geochemical survey of the Captain's Flat area, New South Wales. Bur. Miner. Resour. Aust. Rep. 101.

PALMER. K., 1971 - Preliminary report on the geology and hydrogeology of the Orroral River representative Basin. Bur. Miner. Resour. Aust. Record manuscript (unpubl.).

RASMUSSEN, W., 1970 - Experimental applications of the Bendix Thermal Mapper to mining geophysics. Bendix Aerospace Systems Division Report BSR 3026.

ROWAN, L.C., OFFIELD, T.W., WATSON, K., CANNON, P.J., WATSON, R.D., 1970 - Thermal infrared investigations, Arbuckle Mountains, Oklahoma. Bull geol. Soc. Amer. 81, 3549-62.


LAKE GEORGE A1 (40-55 m) A.C.T.
LAKE GEORGE A2 (40-55 m) A.C.T.
LAKE GEORGE B1 (40-55 m) A.C.T.
LAKE GEORGE C1 (40-55 m) A.C.T.
LAKE GEORGE B2 (40-55 m) A.C.T.
LAKE GEORGE C2 (40-55 m) A.C.T.
LAKE GEORGE D (40-55 m) A.C.T.
PLATE 1


A
B
C
PLATE 2

THE HYDROGEOLOGY OF THE ORRORAL RIVER BASIN.

SCALE.

0 1 2 miles.

0 1 2 3 km.

N

PLATE 3

Granodiorite, 90-100% outcrop.

Granodiorite, undiff. outcrop.

Ordovician? sediments.

Metasediments.

Talus, colluvium.

Outwash.

Solifluction lobes.

Cobbles, gravels.

Alluvium, < 5' thick

Alluvium, > 5' thick

Granitic soil, >10' thick.

RECENT

veins

dykes

watershead

physiographic units.

springs

X7 water sample.

nickpoint.

marsh.

airphoto lineations.

foliation (dipping).

cleavage.

joints.

GS gauging station

water bore

q, ap, do quartz, aplite, dolerite