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A multidisciplinary study of earth resources imagery of Australia, Antarctica and Papua New Guinea

Principal Investigator

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Bureau of Mineral Resources, Geology & Geophysics,

Department of Minerals and Energy,

Canberra, A.C.T. Australia

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Type III Report for Period 1972–January 1974

Department of Science,

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PREFACE

Overall objectives: to determine the usefulness of ERTS imagery in
i) studies of large scale features of the terrain, such as geological structures and their relationship to areas of mineralization
ii) forest type identification and stratification
iii) hydrological studies
iv) studies of offshore areas
v) inventories of crop and range lands, and in soil surveys
vi) land use, landform studies, thematic mapping and geographical studies
vii) studying atmospheric and surface variations affecting analysis of multispectral data.

Overall Scope of Work

Forestry: broadscale vegetation mapping; mapping of wildfire and insect damage; pine plantation detection; mapping controlled burn; detailed species typing; mapping diseased areas; land use mapping; mapping logged areas other than clear-cut.

Agriculture: inventory of soil erosion and sand drift; evaluation for soil and vegetation interpretability; study of irrigated agriculture; identification of crop and pasture diseases.

Geography: mapping of plant and landform patterns, and their change with time; effect of cyclonic storms; correlation of rainfall distribution and vegetation response.

Geology: mapping of geomorphology; terrain analysis; rock type identification, differentiation and correlation; mapping of structure; location of mineralized zones; monitoring of mining activity.

Hydrology: manual plotting of flood boundaries, mapping of surface indications of groundwater; mapping of landforms in relation to drainage.

Land use: mapping of rangeland vegetation and land use; determination of the relationship of management and weather events to the condition and trend in condition of vegetation communities.

Mapping & Cartography: positional accuracy tests; location of islands, reefs, shoals and estimation of water depths; suitability for Antarctic mapping; suitability for thematic mapping.

Interpretation Techniques: determination of the coefficient of variation in the spectral reflectance of targets on a small scale.

Overall Conclusions

Forestry: ERTS-1 imagery can be applied in the broadscale assessment of forest resources as a supplement to aerial photography and field survey.

Agriculture: No application to inventory of crop and pasture diseases mainly because of poor image quality and low resolution, and unreliability of image acquisition. No application for study of irrigation agriculture because of poor resolution and long durations between imaging passes.

Inventory of soil erosion was satisfactory in humid eastern New South Wales, but not in semi-arid areas. Detection of soil types beyond broad scale patterns had only limited success.

Geography: patterns of snow cover, areas of water in natural and artificial water bodies, extent of bushfires, and location of coastal mobile sand bodies were readily apparent. Lack of sequential ERTS imagery prevented studies of changes in observed patterns over time. ERTS did not add significantly to knowledge of South Australian coastal or gulf surface currents.

Geology: ERTS-1 imagery was judged to be a valuable addition to conventional techniques of regional small-scale geological mapping. Because of the synoptic ERTS view, known geological features have been extended, previously unknown features recognized, and new geological theories propounded.

Hydrology: ERTS-1 imagery was successfully used to map flooding and flood progression. The imagery was considered a useful aid in the search for ground water in arid terrain. Areas of surface water could be readily mapped and certain water quality parameters determined. Zones having common hydrological behaviour in terms of topography and groundwater conditions were recognized.

Land Use: ERTS-1 imagery was found valuable in many aspects of land use study if used in conjunction with established methods and larger scale imagery.

Mapping & Cartography: the imagery was found suitable for mapping at 1:1 000 000 scale both on the mainland and in Antarctica, but did not meet accuracy specifications for 1:250 000 mapping. It was found valuable in identifying islands, reefs and shoals, but considered to have only limited application for thematic mapping.

Interpretation Techniques: The coefficient of variation in scene from a small target seen by ERTS would be between 0.16 and 0.17.

Overall Recommendations

Forestry: stereoscopic summer imagery, or imagery with a relatively constant sun angle would be most efficient. Further investigation should be made of the usefulness of repetitive coverage, and of techniques such as density slicing; the application of imagery to forest resource management should be considered. Further work with repetitive imagery is required to evaluate the effects of seasonal changes both for interpretation and mapping of vegetation types and for studies of fire hazard prediction.

Agriculture and Land Use: the main requirements include better quality imagery, more rapid acquisition, stereoscopic cover and greater certainty of cover of areas under study.

Geography, Mapping and Cartography: provision of better quality imagery and better facilities for supply of scene-corrected imagery; provision of an additional working roll of 2nd generation imagery to Principal Investigators so that investigators can be supplied with timely information about availability of imagery without waiting for distribution of standard catalogues; provision of imagery with varying sun angles including high and low sun angles.

Geology: provision of better quality imagery (including 1:1 million scale early generation diapositives), varying sun angles including low sun angle, stereo coverage; expanded contrast range and better resolution; earth resources satellites should be non sun-synchronous, sensors should have narrower spectral bands, plus a thermal infrared band; installation in Australia of direct ERTS receiving and processing facilities; institution of a program of high altitude, high resolution, false colour, super wide angle aerial photography to support and complement the ERTS data.

Hydrology: continue mapping flood areas from ERTS data; continue to use the data for the search for hydrological resources in arid terrains; investigate repetitive imagery to find out whether changes in regional evapo-transpiration and soil moisture can be interpreted.

Interpretation Techniques: more solar irradiance measurements in ERTS band-passes should be made at many latitudes, seasons and in many atmospheric environments, and the coefficient of variation in spectral reflectance using ERTS bandpasses should be measured for various targets of different albedo using different integration areas.

Forestry Summary

Three State Forestry Commissions and the Commonwealth Forestry and Timber Bureau submitted reports on their studies of ERTS I imagery (see attached reports). The following abbreviations will be used for the various agencies in this summary:

Forestry & Timber Bureau	– F. & T.B.
South Australian Woods & Forests Dept.	– S.A.
N.S.W. Forestry Commission	– N.S.W.
Forests Commission, Victoria	– VIC.

All four agencies reported that the prime use for ERTS imagery in forestry was for the first stage of a broadscale multi-stage national forest inventory. Each agency was able to map with accuracy forested and non-forested land and some breakdown of the forest on the basis of broad areas of forest structure. The actual structures identified varied depending on the nature of the vegetation in the study areas. N.S.W. distinguished productive vs non productive forest, F. & T.B. separated 2 levels of stand density, S.A. and VIC both distinguished forest structures which were altitude or moisture related.

Although in some cases species occurrence could be inferred from structure and location none of the agencies were able to determine actual species composition or delineate forest cover types.

Three of the agencies found the imagery useful for mapping boundaries of areas damaged by wildfires and N.S.W. mapped areas of insect defoliation.

Three of the agencies studied the usefulness of the imagery for pine plantation management and found that 3 year age classes could be determined for plantations over 8–10 years of age and larger than 6 ha in area but none reported finding a practical use for the imagery in this area.

All four agencies used solely conventional photo interpretation techniques on paper prints or diapositives. Each agency used black and white prints of the individual bands while VIC used colour composites of bands 4, 5and 7 as well. All found band 5 most useful for vegetation mapping and band 7 most useful for mapping areas of wildfire damage. Three agencies felt that interpretation skill was needed for best results, while one found that equal results could be obtained by untrained interpreters.

Each agency found the images useful for illustrative purposes.

In conclusion, each agency felt that ERTS I - type imagery would have application in the broadscale assessment of forest resources as a supplement to aerial photography and field survey but reported no other continuing practical uses in forestry. Table I summarises this aggregate report in tabular form by State.

TABLE F.1 SUMMARY OF FORESTRY RESULTS

	Results			
	F. & T.B.	S.A.	N.S.W.	VIC.
A. USES STUDIED (Blank indicates the use was not studied or reported)				
i Broad Vegetation Mapping	YES	YES	YES	YES
ii Detailed Species Typing	NO	NO	NO	NO
iii Mapping Damage by Wildfire	YES		YES	YES
iv Mapping Controlled Burn				NO
v Mapping Insect Defoliation	NO		YES	
vi Mapping Logged Areas Other Than Clear cut			NO	
vii Mapping Diseased Areas	NO			NO
viii Land Use Mapping	YES		YES	YES
ix Pine Plantation Detection (age and Area)	YES		YES	YES
B. MATERIALS AND TECHNIQUES USED				
i Conventional P.I. Techniques	YES	YES	YES	YES
ii B & W Single Band Images	YES	YES	YES	YES
iii Colour Composites (Bands 4, 5 & 7)				YES
iv Print Scale 1:1 000 000	YES	YES	YES	YES
C. CONTINUING PRACTICAL USES REPORTED				
i Pine Plantation Management	NO	NO	NO	NO
ii Broad Forest Resource Survey	YES	YES	YES	YES
iii Other Production Uses	NO	NO	NO	

AGRICULTURE AND RANGE RESOURCE LAND USE

Abstract: ERTS I imagery is valuable in many aspects of land use study if used in conjunction with established methodology and larger scale imagery. The lack of detail and absence of steroscopic cover, together with inferior image quality and long delays in image acquisition, reduced the value of ERTS for most investigators; and eliminated it for others.

The satisfactory results were obtained where soil and vegetation features could be correlated with landform and/or land use features which generally were easier to interpret. Bands 5 and 7 were regarded as most suitable. False colour composite transparencies, while generally easier to interpret, did not always provide more information. Interpretation in all cases was by pattern recognition by eye, mostly by experienced interpreters.

Objectives: these included the inventory of erosion and sand drift; evaluation for vegetation, soil, land use, and geomorphological interpretability and for assistance in land resource and land system surveys; the broad scale mapping of vegetation types in rangelands area, and determination within these of the relationship of management and weather events to the condition and trend in condition of communities; the identification of crop and pasture diseases; the evaluation and monitoring of irrigated agriculture.

Techniques: no machine processing was used. Black and white prints and transparencies, false colour composite prints, and transparencies, and 'false colour' positive diazochrome transparencies were used with magnification by photographic and/or optical means. Most interpreters made comparisons with existing mapping and/or known ground truth and evaluated ERTS imagery on the basis of coincidence and variation.

Results and Conclusions: excessive density of image, cloud cover and lack of coverage of areas of interest precluded results in one program - the evaluation of soil and vegetation changes (Till). ERTS imagery had no application for the inventory of crop and pasture diseases, mainly due to poor image quality and low resolution, and to unreliability of image acquisition (Clare). The time lapse between, and poor resolution of, ERTS images reduced their value for study of irrigation agriculture. This shortcoming was accentuated by long delays in image acquisition and the comparatively simple acquisition of aircraft-flown imagery. However, the technology of ERTS image acquisition and processing may have value if utilised from airborne platforms. The density of the images was a limiting factor in this and other studies. Irrigation patterns are best distinguished on band 5. At ERTS scale confidence in interpretation was low unless other land use and landscape features could be correlated with the identification of open water bodies (Trickett). The inventory of soil erosion was satisfactory in humid eastern New South Wales, being particularly successful in identifying sources of siltation hazard. Band 5 and 7 were most useful, 5 for land use and erosion and 7 for topography, geology and soils. Inventory or erosion in semi-arid areas was not successful. The correlations between terrain, land use, and soil erosion which were the basis of the success in the east could not be so readily determined. Aeolian erosion and surface sheeting are less detectable than gully and stream erosion. Coastal sand drift could not be assessed, since this interpretation requires large scale images. Stereoscopic cover would assist in erosion inventory. An attempt is to be made to extrapolate from areas of known ground truth (Higginson and Emery).

Studies aimed at detected of soil types beyond the broad scale patterns discerned by Higginson and Emery, had limited success. ERTS imagery gave no direct guidance to soil features though there was weak correlation with ground truth in areas where landforms could be distinguished. However, the accuracy and detail of the landform interpretation was low and ERTS had no advantage over conventional techniques (Northcote). The incorporation of vegetation and land use as well as geomorphic features permitted more specific inferences but microfeatures such as gilgai were not identifiable. Good correlations were obtained for sandy soil in dune areas, clay substrata in plains with shallow lakes, saline soils in bare areas not attributable to land use, and shallow soils in outcrop areas. In humid areas soil type could not be inferred except in bare areas.

ERTS was therefore most suitable for eroded and salted soils. In arid areas land use identification provided a useful key for soil type. In semi-arid wheatlands the soil in fallow fields could be distinguished as sandy, salty, or clayey. Regional geomorphology and some land use and land condition could be detected. Features identified included burnt scrub, pine plantations, unirrigated pastures, areas of pasture with higher soil moisture content following rain such as should allow continuing hay-making, and cropland, rangelands, and irrigated lands (Blackburn).

Specific interpretation within rangelands was not highly successful with the techniques available. The identification of vegetation was comparative rather than absolute, depending on inference and complicated by the low density of plant cover and complexity of spatial patterns of vegetation.

The need for detection, location and identification, and assessment of the condition and trend in condition of communities was not adequately met. Management differences could be identified because of close association with fencelines and watering points but measurements were not possible. Biomass estimates may be possible eventually but their usefulness may be reduced by selective grazing behaviour (Graetz and Perry).

ERTS imagery was found to be superior to large scale photography and mosaics for overview and identification of general trends and patterns in regional resource surveys. Repeated ERTS coverage assisted in the confirmation of some boundaries. Band 4 is of limited use apart from confirmation of some vegetation patterns. Three common Great Soil Groups were most readily distinguished on bands 6 and 7, where land use and tone under fallow could be correlated, but not under crop stubble or pasture, and not on bands 4 or 5. Time of year was important in correlation of land system with land use in at least one instance. Vegetation communities were distinguished on tonal variation attributed to canopy density, leaf type variation and differential growth rates. Under enlargement some fine variations of vegetation associated with landforms and some additional cadastral data were distinguished. Projection of three bands in register with colour filtration made interpretation easier for Great Soil Groups, vegetation and land use. However, the scope of ERTS was limited due to the need for large scale and stereoscopic coverage for interpretation at the Land Unit level (Mullins).

A detail comparison of ERTS interpretation with a previous Land System survey confirmed the value of ERTS for regional overview. ERTS interpretation preliminary to large scale photo interpretation and field work should allow elimination of unwanted detail. The interpretation of land systems is in any event subjective so the comparative evaluation of ERTS and conventional methods in land system survey is limited in scope. Areas of coincidence with conventional interpretation included rugged terrain, lakes, alluvial plains, outwash plains, dunes, and red earths with mulga. More subdivision was achieved for alluvial and outwash plains with ERTS and less achieved for dunes. Lithological distinctions were not detected in rugged terrain at the intensity of interpretation adopted. Correlation was best with major land systems distinguished by topography, least satisfactory with those distinguished by vegetation lithology. In some cases ERTS imagery enabled better interpretability of vegetation e.g. on outwash and alluvial plains readily detectable variation in both soil and vegetation was not mapped by the original survey team (Story, Yapp and Dunn).

The major requirements for future research by Agriculture and Rangeland Land Use investigators include better quality imagery, more rapid acquisition, stereoscopic cover and greater certainty of cover of areas under study.

GEOGRAPHY

This section comprises four reports only, two of which were inconclusive. Most other geographic reports have been included under other headings, such as land use and mapping. This therefore cannot be an overview of the whole discipline.

One group of investigators (B.G. Thom, R.F. McLean, N. Wace, J.M. Bowler and J.N. Jennings) were concerned with identifying plant and landform patterns in various parts of Australia. They found patterns of snow cover, areas of water in natural and artificial water bodies, extent of bushfires, and location of coastal mobile sand bodies were all readily apparent on ERTS-1 imagery. Some general differentiation of landforms on the riverine plain (Murray-River basin) could be made and also general vegetation types. Lack of sequential series of ERTS and other imagery prevented experiments on changes in observed patterns over time.

Two investigators were interested in weather and climatic effects in north-east Australia. D. Hopley had planned to study the effects of cyclonic storms on coastal areas of north Queensland. Only two storms affected the region in the 1972/73 season and both were relatively small so that no major effects could be expected. Also, only imagery taken before the storms was available.

J. Oliver's interest was in rainfall distribution and vegetation response in the 'channel country' of inland Queensland. However, evaluation of imagery was not completed due to the investigator's absence from Australia.

One investigator (S.A. Shepherd) was interested in mapping shoreline and shallow sublittoral features in South Australia, including mangrove communities. In Spencer Gulf gross surface currents were deduced from movement of turbid water, but in general ERTS did not add significantly to knowledge of coastal or Gulf surface currents.

GEOLOGY

A total of 35 co-investigators representing 21 different organizations reported on geological aspects of ERTS imagery. The organizations comprised 5 Universities, 4 Australian Government Department, 6 State Government Departments and 6 mineral exploration companies.

All investigators worked on photographic products, and there was a general preference for imagery at 1:1 000 000 scale. Approximately half the investigators experimented with larger photographic scale up to 1:100 000. The specific scales of enlargements examined strongly reflect the standard topographic and thematic map scales available in Australia. One investigator (Burns) compared the resolution of various scales of ERTS enlargements, maps and air photographs.

Most investigators worked on panchromatic products although many have evaluated false colour composite prints. Marshall, and Langron and Walker reported on the usefulness of colour composites formed by superimposition of three diazochrome film prints of separate bands.

Investigator reports varied from appraisals for regional mapping purposes (e.g. Woods and Wilson) to specific applications such as monitoring of mining operations (e.g. Whitmore). The reports have been grouped into 5 categories:

Geomorphology/Terrain analysis
Rock type identification, differentiation and correlation
Structure
Application to mineralization location
Monitoring of mining activities

Table G.1 shows which categories are discussed in individual investigator reports.

Geomorphology/Terrain Analysis

A study of selected ERTS images of south eastern Australia by Joyce has demonstrated that ERTS imagery could be used to produce a geomorphic map. The test region examined includes an inland riverine plain with a semi-arid climate, a dividing range over 700 m above sea level and a temperate coastal plain. Within this area it was possible to produce an incomplete map of most of the current main streams as well as many former stream courses. Lakes, irrigation canals, swamp boundaries, lowlying areas, high terrain, fault scarps and young lava flows could be identified and annotated. A series of geomorphic regions could also be delineated. When compared against existing relief and landform maps the ERTS interpreation showed good agreement except in those regions where subdivisions are based on a detailed appreciation of relief. Although it was possible to produce a geomorphic map from ERTS Joyce stressed that the regions delineated need much checking against available information before their accuracy and meaning can be determined. It was concluded that the main value of ERTS imagery in geomorphic mapping will be in the initial stages of studying an area.

Investigations by Grant tend to support this. His studies aimed at using the ERTS for terrain evaluation in urban and rural planning projects. Currently this requires mapping on air photographs at progressively larger scales from 1:250 000 up to 1:5 000. Although macro-geological features showed well on ERTS imagery the monoscopic nature and the overall small scale of the imagery meant that it had only limited use for the interpretation of the terrain attributes necessary for successful terrain evaluation.

Thompson found that major geomorphic features are readily apparent in areas of both low and high relief. Brief landform evaluation in central southern Australia by Thomson supported the findings of Joyce in that ERTS imagery was useful for tracing fossil river channels. Strand lines, surface water and sink hole areas could also be detected.

In northern Australia Woods and Wilson noted that with sun elevations of 49°–58° in low terrain (less than 300 m relief) shadows affected landform appraisal, north-trending ridges being more evident than east-trending ridges. Several investigators reported that landforms can be better interpreted from low sun angle than from high sun angle imagery. In arid Western Australian terrain Emerson noted that Tertiary drainage and weathering features were dominant on bands 6 and 7.

Among the investigators listed above, there was a general preference for bands 5 and 7 or 6 for landform evaluation.

Hopley attempted mapping of macro features of the coastal geomorphology of North Queensland,however insufficient ERTS coastal coverage was received to make any meaningful consistent study. Sugden encountered the same problem although on available ERTS scenes the differences in water penetration between Bands 4 and 5 yielded information as to submarine topography and depth of shallow sediment formation and transport.

Rock type identification, differentiation and correlation.

The degree of success in differentiating rock type and specifically identifying rock types from ERTS imagery was affected primarily by the environmental setting of the areas examined. This was to be expected since the constraints of rock composition, soil and/or vegetation cover, erosional history etc., which affect the appearance of rocks on conventional aerial photographs apply equally well to ERTS imagery.

The environments studied can be broadly classified into arid and temperate.

Arid

In well exposed arid terrain of the Pilbara region (Western Australia) Huntington found that where tonal contrasts between different rock types are high and the units are sufficiently large excellent lithological discrimination may be evident (as on 1130-01275). However it is rare to find unique criteria for the consistent identification of specific lithological units other than over quite small distances.

Work in the Mt Isa (Queensland) and Alice Springs (Northern Territory) regions by Perry et al. agrees with the findings of Huntington. They concluded that because of gradational tonal changes along strike attempted differentiation and correlation of rock types on tonal/textural criteria is not reliable and only general rock distribution can be interpreted.

In northwest Queensland Dunnett found that in general interpretation of rock types or formations is more difficult than from conventional photography. Stephenson noted that band 4 emphasizes flat lying Cretaceous sandstones and bands 6 and 7 emphasize Tertiary basalt flows.

Where topography reflects different rock types ERTS has proven useful. Langron and Walker found that in the Cloncurry Region where quartzites form topographic highs they are readily distinguishable from less resistant argillite horizons. The use in the field of 1:1 million scale diazochrome film colour transparencies facilitated interpretation.

In the poorly exposed and weathered terrain of Western Australia Hudson and Ewers note "moderate" success in discriminating lithologic types by tonal variations. Such findings were supported by Lord who concluded that in the Kalgoorlie and Kurnalpie areas the imagery gives only a broad guide to first order rock distribution at the reconnaissance stage. Marshall reported similar results and concluded that tonal discrimination of rock types must be used with great caution in this environment, and with pre-knowledge of the geology.

Temperate

Investigations in temperate regions involved terrain containing various proportions of natural and cultivated vegetation cover. This factor was an added complication to lithological differentiation. Scheibner found that in natural forest areas some intrusives could be mapped and/or further subdivided on the basis of different tones that are believed to be due to natural vegetation differences. Perry et al. reported that while this was also the case in some parts of the Canberra region they concluded that because many lithological boundaries do not follow tone, vegetation, landform or texture boundaries on ERTS, rock type differentiation and correlation on these criteria are not reliable. Although recognition criteria are not specified Williams and McClenaghan's investigations in Tasmania suggest similar problems by concluding that different rock types could be distinguished only over small areas.

Structure

Geological structures on ERTS were extensively investigated.

In attempting to identify and extropolate Cambrian formations Henderson noted that structural trends could be recognized.

Perry et al. attempted to identify trends, folds, joints and dykes and differentiate them from man made structures. Linear man-made structures could not always be distinguished from natural features.

In arid regions with well developed cuesta morphology it was normally possible to divide dipping beds into two categories - high and low dipping. Without such morphology it was generally not possible to determine the attitude of steeply dipping beds. Thus although folds could be readily recognized they generally could not be further identified as synform or antiform. Scheibner reported that in many instances it was possible to improve on the previously mapped position of fold axes, and to detect unmapped ones.

The main effort of structural investigations on ERTS was directed at the detection and analysis of known major fault structures and the study of new linear features.

Several investigators reported that many known faults could be detected and often further extended on ERTS and there was general agreement that such ERTS studies would lead to a better understanding of the regional structure.

Structural features could generally be best detected on low sun angle imagery. Huntington studied this phenomenon and provided data for calculating the approximate optimum imaging seasons for structural enchancement in Australia.

Scheibner carried out an ERTS lineament study of the State of New South Wales and produced a large amount of new information which suggests that the major crustal blocks possess their own diagnostic rhegmatic patterns.

Investigations in the Broken Hill region of New South Wales by Johnson showed that blocks of Precambrian, Cambrian, Ordovician and Devonian rocks could be readily distinguished and the trends of faults and folds could be resolved in some places within the blocks. Thomson carried out a preliminary lineament study of South Australia and attempted to classify lineaments into sets based on possible relative age. It was assumed that lineaments are associated with steeply dipping fracture zones possibly related to basement block movement.

Studies in the Eastern Highlands of N.S.W. and Victoria by Burns demonstrated that the ERTS imagery now provides a means of investigating several hypotheses (dating from 1926) relating fractures and topography. The investigations by both Burns and Thompson tend to confirm the hypotheses.

Although most investigators studying structural aspects detected numerous lineaments many found difficulty in explaining their origins. Williams and McClenaghan found that virtually all the lineaments detected appear to correspond to faults or closely parallel faults. Scheibner concluded that lineaments may consist of faults shear zones, major joints, prevailing foliation in intrusives and metamorphics, lithological trends, drainage and morphological linears. He interpreted one set of circular features as possible astroblemes. Lacy and Taylor report that major linear and circular features closely reflect locations of basin hinge lines deduced from palaeogeographic studies. Investigations by Marshall, Huntington, and Langron and Walker found that even in areas of little or no outcrop ERTS lineaments coincide with magnetic lineaments interpreted from aeromagnetic maps. Hudson and Ewers propose that one of the fields of structural geology for the future is to evaluate the signfic ance of large linear features which have no aeromagnetic expression, and are not recognizable on the ground.

After comparing ERTS lineaments with lineaments postulated from a consideration of geological, geophysical and morphological discontinuities O'Driscoll and Duncan concluded that the ERTS imagery could be used successfully to obtain information on tectonically significant photolineament patterns in the Archaean of Western Australia. On the other hand Emerson reported that in an extensively weathered area of Western Australia no significant lineaments could be detected.

Perry et al. compared ERTS lineaments with data from detailed geological maps of the Mt Isa area. As with conventional photogeological interpretation the main transgressive faults were detected but strike or near strike faults could not be identified. They concluded that only about 10% of known faults and inferred faults (greater than 4 km length) could be detected and that the origin of approximately 70% of ERTS lineaments remained uncertain.

Heidecker noted surprisingly little torsional distortion or offset at lineament intersections. One possible explanation for this is offered by Huntington who suggests that some of the lineaments studied may be surface manifestations of major basement faults or hinge zones. Working in central northern Australia with ERTS Dunnett reported a previously unidentified lineament set which apparently does not displace Proterozoic rocks and may represent basement features. Partly within the same region Woods and Wilson detected a similar trending set of lineaments which they could not relate to known structures.

To explain seemingly uniform rhegmatic patterns Scheibner discusses a mechanism in which old fractures are laterally superposed into younger areas.

In the Alice Springs area Perry et al. suggest that some lineaments which have no evidence of movement are relatively young structural features. Lord also considers lineaments in the Kalgoorlie-Kurnalpie region to be mostly late fractures. Doyle however in attempting to detect evidence of seismic zones on ERTS reported no positive identification of fault zones.

Application to mineralization location

Three investigations concentrated on the potential use of ERTS for locating mineralization, and the studies of another three investigators involved this application to a lesser extent.

Lacy and Taylor studied copper and tin metallogenic provinces of north Queensland in an attempt to identify any significant patterns or spectral "fingerprints" that would indicate the presence or increased likelihood of mineral concentrations. They found that bulk low grade copper and/or tin deposits are not predictable on the basis of ERTS imagery. However major mineralized districts appear to occupy zones of intersections of major cross-linears which appear to correlate with basin hinge-lines intersecting the Tasman Orogenic Zone.

In the Mount Isa region of Queensland Woods and Wilson report that whereas certain rock types associated with base metal mineralization could be recognized in some places on ERTS, no specific zones, textures or patterns, could be identified with the known ore deposits.

In several test areas Langron and Walker compared information interpreted from ERTS with data compiled during mineral exploration activities. They found that the main value of ERTS was in mapping long structural features. Field work indicated that the location of such structures could assist in the broad definition of prospective areas for mineralization although it was emphasized that they had no evidence that ERTS has directly indicated a body of mineralization. Huntington expresses similar views and while his report concentrates on structural investigations he does note the possibility of ERTS being used to detect "large area mineral deposits". The Shay Gap iron ore deposit in Western Australia is evident on all bands as a very dark elongate (1 km x $\frac{3}{4}$ km) mass probably detectable because of natural rock colouring.

Investigations of lineaments by Thomson over areas of South Australia has furnished evidence for broad exploration guidelines. There are some indications that the density of lineament swarms may increase in the vicinity of the Moomba-Gidgealpa gas field. A lineament has been identified which correlates with a hinge zone associated with Cainozoic sedimentary uranium mineralization.

In the Alice Springs area of the Northern Territory Perry et al. found that apart from one lineament (which may be associated with four separate mineral occurrences) the remainder of lineaments detected do not appear to have any obvious relationship to the locations of metalliferous mineral deposits.

Several investigators (e.g. Hudson and Ewers) discuss the potential for indirect use of ERTS in mineral exploration through the better appreciation of regional geology that may result from studies involving ERTS.

Monitoring of mining activities

Whitmore evaluated ERTS for the monitoring of strip mining operations over Weipa bauxite mine and the Stradbroke Island beach sand mine (Queensland). Only panchromatic photographic products were examined and although strip mining operations could be identified quite satisfactorily the ERTS imagery was of little use in distinguishing between various stages of extraction or rehabilitation of the disturbed areas.

Woods and Wilson noted that the large open-pit mines at Mount Isa and Mary Kathleen (northwest Queensland) could be recognized.

TABLE G.1

MAIN TOPICS DISCUSSED IN GEOLOGICAL REPORTS

Report Number	Geomorphology Terrain Analysis	Rock Type Identification Differentiation Correlation	Structure	Mineralization Location	Monitoring Mining Activities
	A	B	C	D	E
G.1			1		
G.2			1		
G.3			1		
G.4		1	1		
G.5	1				
G.6			1		
G.7			1		
G.8	1				
G.9			1		
G.10		1	1	1	
G.11		1	1		
G.12	1				
G.13			1	1	
G.14			1	1	
G.15		1	1		
G.16		1	1		
G.17			1		
G.18		1	1	1	
G.19	1	1	1		
G.20		1			
G.21	1				
G.22	1		1		
G.23	1		1	1	
G.24					1
G.25		1	1		
G.26	1	1	1	1	

HYDROLOGY

1. Victorian Floods (See Appendix H.1)

Corop Lakes.

Colour aerial photography from an altitude of 15 000 feet recorded the flooded Corop Lakes area on 23 February 1973. An ERTS-1 image, 1216-23324, recorded the area on the 24th February 1973. The image has been colour enhanced at a scale of 1:250 000. The imagery shows the inundated area and displays a variety of colours in the water which can be used to trace flood water back to the source of entry into the flooded system.

The colour photography has been used to map the details of the flooded area on 1:30 000 contour plans with 1 ft contour intervals. The differences between the colours in the water indicate sediments from a particular geological source and these colours as in the ERTS image have allowed the determination of the source of the various sediment laden waters which have entered the flooded area.

The cost of the small format 70 mm aerial photography of the flooded area was $300, the cost of the colour enhanced satellite imagery was $20. Interpretation costs for both types of remote sensing and draughting the base plans are the same in both cases. The same area was covered by mapping photography, 230 mm, during a regional aerial survey at a later date and the cost of the larger scale photography was $1000.

Northern Plains Flooding

The Commission requested that the winter flooding of the Northern plains of Victoria be recorded by ERTS through ACERTS. This was completed on the 24th August 1973 and the results were sent to the Commission on the 4th September 1973. The image used was 1397-23363 and the flooded land in Northern Victoria was determined from black and white enlargements of Band 7 to a scale of 1:60 000 and from a colour enhanced transparency of scale 1:1 000 000.

Maps of the flooded area were produced to scales of 1:250 000 and 1:60 000 and these maps were subsequently used by a Cabinet Sub-committee for establishing guidelines in the event of future floods in the north of Victoria. The cost of conventional photography of this area was $10,000 as against $120 for the Band 7 enlargements from ERTS.

2. Eastern Goldfields, western Australia Hydrology (See Appendix H.2)

The chief features noted from the images were the surface water bodies and the areas of possible "wetness" or valley areas. Features with distinguishing lineations were marked as possible mountain or hill ranges or faults, which are often the source of rivers and streams in this area.

After the interpretations were completed without recourse to any maps, the image tracings were photographed and then compared with the topographical maps by projecting the interpretation slide over the map and adjusting to the same scale. Considering that the equipment used was simple and that there were a number of transference procedures from the original images to the completed overlay, the alignment was remarkable.

Saline lakes could be distinguished easily but not so rivers as there had been very little rain in these areas and the streams are intermittent. Areas of wetness were found to have an accumulation of wells, bores and soaks in at least part of their areas.

Lineaments are most often found to be hill ranges which are well drained.

The large coverage of the images allowed a reduction in the amount of field work necessary before a search for water deposits was undertaken. Sufficient evidence is provided to select target areas, which is an advantage in the large tractless areas of Australia.

3. Regional Water Resources. South East of South Australia (Appendix E.3)

The ERTS data available are for 29th November 1972 which is in the late spring/early summer. Pattern recognition of the area is assisted if frames 4, 5, and 7 are inverse false coloured by the primary colours yellow, red and blue. The image shows a strong pattern resemblance to the ground truth derived hydrologic zones.

The land features evident are parallel dunes, ranges, lakes, land areas with reflections indicating upward moving ground-water replenishing moisture demand of plants, and karstic features due to the more efficient underground drainage. The ERTS data corroborate the hydrologic zones map and may with further investigation lead to important modifications of the map.

Excluding small areas of irrigation and larger areas of exotic and natural forest, the remainder of the region is used for stock grazing and the pasture grasses may not differ in composition to any marked degree over the region. If this fact could be established, then the reflections recorded in MSS bands 4 and 5 may be an indicator of greenness and dryness of the pasture which is at least an index of a transpiration. The infrared bands appear to be showing relatively higher ground water areas, therefore this may be providing an index of direct soil evaporation independent of transpiration.

It is possible that the ERTS imagery may be used to determine a soil moisture deficit and evapotranspiration over a wide area. Results could be checked against recorded rainfall/catchment runoff data.

Lake Cadnite and other areas were found to have a changed regime to that expected. Licences which would lead to these changes have not been issued.

The border between the states of South Australia and Victoria is on Longitude 140°-59'E. This line can clearly be seen and it would seem that there is a perceptible tendency for farmers on the western side of the border to adopt a practice which leads to a dryer land surface by early summer.

MAPPING AND CARTOGRAPHY

1. Investigations

Investigations into these aspects of the program were made by the Division of National Mapping. A dearth of suitable imagery in the nominated parts of the Great Barrier Reef and Queensland necessitated changes and moficiations to the original proposals.

The investigations made were:

- Positional accuracy tests.
- Location of islands, reefs, shoals and estimation of water depths.
- Suitability for Antarctic mapping.
- Suitability for thematic mapping

2. Positional Accuracy Tests

Black and white as well as false colour system corrected MSS imagery was tested against Australian 1:250 000 map accuracy specifications and was found to be unsuitable for mapping at that scale but suitable for mapping at 1:1 000 000 scale. Investigations with scene corrected imagery were planned and coordinates and identifications as specified were provided for the test area but advice was received from NDPF that this type of imagery was not available.

3. Location of Reefs, Islands, Shoals and Estimation of Depths

Although imagery for this investigation was not available for the nominated area, suitable ground truth was available in Torres Strait and near Perth to allow assessment of two good MSS scenes of these areas.

In both cases bottom features could be identified to a depth of ten metres.

Islands, reefs and shoals could be readily identified but all MSS bands as well as colour composites were required to:-

- Identify vegetation patterns
- Differentiate between exposed and submerged features.
- Differentiate between light cloud and shoal areas.

The value of the imagery for identifying marine hazards has been recognised and imagery is being used in this regard for the planning of bathymetric surveys.

4. Antarctic Mapping

Mosaics at 1:250 000 scale of nine map areas in the Prince Charles Mountains region were prepared and line base maps for recording survey data and planning were made from them. In the past line compilation sheets were prepared from oblique aerial photography and upon comparing that series with the ERTS mosaics significant errors in position were found of some features shown on the compilation series.

The large sidelap between orbits allowed useful stereoscopic examination of the imagery. MSS Band 4 was found to be of little use but the other bands and false colour composites were all required for interpretation.

Tests have shown that MSS system corrected imagery will satisfy requirements of 1:1 000 000 mapping of Antarctica. It is proposed to produce a series of mosaics and line overlays at 1:500 000 scale of all areas of significant interest for which imagery is available in order to provide an interim series until standard 1:250 000 maps can be compiled from vertical aerial photography.

5. Thematic Mapping

Imagery was not available for the area of prime interest so investigations were confined to visual examination of colour composites of part of the Fitzroy Region of Queensland. The imagery showed broad structure, drainage and vegetation boundaries. Some additional features could be distinguished with the aid of maps. From this limited test the imagery appears to have only limited practical application for thematic mapping.

INTERPRETATION TECHNIQUES DEVELOPMENT

One investigator studied atmospheric and surface variations affecting analysis of multispectral data from ERTS.

Experiments were performed to determine the coefficient of variation in the spectral reflectance of targets on a small scale; a typical value for sandstone outcrops for a 30 cm integration area was 0.16. The coefficient of variation in scene radiance from such a target seen by ERTS would be between 0.16 and 0.17, but lay between 0.16 and 0.20 for 25 nm and 50 nm band passes. The report recommends that more solar irradiance measurements in ERTS band-passes be made at many latitudes, seasons and in many atmospheric environments to order to predict more completely the atmospheric contribution to spectral scene radiance variation; and that the coefficient of variation in spectral reflectance using ERTS bandpasses be measured for various targets of different albedo using different integration areas.