DEPARTMENT OF NATIONAL RESOURCES

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McARTHUR BASIN PROJECT

by

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SUMMARY

BMR worked systematically in the Carpentarian McArthur Basin, N.T., during the period 1958-1962. Since then further information has come from company activity, and some special studies.

In 1977 BMR commenced a long-term plan to study the basin in detail, with the aim of applying the resulting data to a study of, and exploration for, ore deposits - most specifically stratabound sulphide mineralisation - in the region; and consideration of the geological evolution of the region.

This record outlines the present state of knowledge of the basin; discusses the major problems that require consideration: and present an integrated program to last about 12 years.

The proposed studies will lead to extensive revision of some 1:250 000 sheets, and 1:100 000 sheets will be produced of selected areas, but it is stressed that the project is primarily a multi-disciplinary study of selected specialist aspects.

INTRODUCTION

The McArthur Basin is a relatively undeformed structure containing up to 12 km of Carpentarian sediments, which are exposed over about 170 000 km^2 in the Northern Territory, and a small part of northwestern Queensland, around the western and southwestern side of the Gulf of Carpentaria. The basin covers all or parts of twenty-five 1:250 000 Sheet areas, although the main information comes from about 10 Sheets within the central meridional zone (Fig. 1).

The basin contains probably the thickest and most extensively exposed sequence of unmetamorphosed Carpentarian (1800-1300 m.y.) rocks in Australia, providing an excellent opportunity to study the evolution of a basin during this period of time, and was chosen as the type section for the Carpentarian by Dunn, Plumb & Roberts (1966). It is the classic example of North Australian Platform Cover on the Tectonic Map of Australia and New Guinea (GSA, 1971), and contains the large H.Y.C. zinc-lead deposit, which is achieving increasing prominence as a model for stratiform sulphide mineralisation.

It has been suggested that the McArthur Group contains a large barrier reef complex (e.g. Smith, 1964; Plumb & Paine, 1964), similar to the Permian El Capitan reef of the Delaware Basin in the United States of America. However, after suggestions of alternative correlations by Carpentaria Exploration Company Pty Ltd, this interpretation was shown to be in error, and the stratigraphy of the group was revised by Plumb & Brown (1973).

Little was known about the basin prior to the 1950's. Most of the presently available data came from the BMR's 1:250 000 mapping program from 1958-1962. This led to the establishment of a reasonably comprehensive stratigraphic and structural framework of the basin, sufficient for detailed assessment of future problems and studies.

Aims of this document

1. To recommend that a major program of detailed studies and re-mapping be carried out in the McArthur Basin;
2. To outline the present state of knowledge of the basin;
3. To outline previous work in the basin;
4. To outline the major problems in the basin;

5. To recommend projects for detailed study;
6. To outline a general plan for such projects.

AIMS AND OBJECTIVES OF PROJECT

The basic aim of the McArthur Basin Project is to study the evolution of the McArthur Basin in depth - stratigraphic, sedimentological, tectonic, etc. - and to apply these data to a study of the genesis of, and exploration for, ore deposits in the region, and to the geological evolution of Australia.

Within the context of the more detailed discussions which follow, the specific objectives can be summarised as follows:

(1) To develop criteria for detailed lithological and chronostratigraphic correlation, and apply these to the refinement or revision of the stratigraphic framework of the McArthur Basin;
(2) To study and identify the detailed sedimentary environments in which the units of the basin were deposited, with particular emphasis on the McArthur Group and its equivalents;
(3) To identify and describe the microfossil, stromatolite, and trace fossil assemblages of the McArthur Basin, determine their stratigraphic distribution and palaeoecology, and apply these studies to biostratigraphy, palaeoenvironmental analysis, and ore genesis;
(4) To determine the origin and history of the geological structures of the McArthur Basin;
(5) To study the distribution, the stratigraphic, sedimentological, and structural setting, and the mineralogy, geochemistry and fossil content of the mineral deposits of the McArthur Basin, with particular emphasis on lead-zinc and copper;
(6) To map selected areas geologically at 1:100 000 scale, and revise and correct, as necessary, existing 1:250 000 scale geological maps of the McArthur Basin;

These data will then be used to:

(7) Construct palaeogeographic maps of the McArthur Basin;
(8) Determine the palaeogeographic and tectonic evolution of the McArthur Basin;

(9) Determine the origin of mineral deposits in the McArthur Basin;

(10) Define criteria and methods to assist in the exploration for new ore deposits in northern Australia;

(11) Identify potential areas for exploration for new ore deposits in the McArthur Basin;

(12) Apply the data to the interpretation of the regional geology and tectonic evolution of northern Australia, and to the Precambrian chronostratigraphy of Australia;

(13) Publish the results, as appropriate, in Reports, Bulletins, papers in journals, and 1:100 000, 1:250 000, and special-scale geological maps and related thematic maps.

Reasons for proposed studies

(1) The Carpentarian is a period of widespread, strata-bound, sulphide mineralization in northern Australia;

(2) The unmetamorphosed McArthur River lead-zinc deposits, and several small strata-bound copper deposits, can be readily related to the stratigraphy of the basin and present a unique opportunity to study this type of mineralization within a total basin evolutionary framework.

(3) The thick sequence, widespread exposure, and unmetamorphosed sediments provide a unique opportunity to study the evolution of a major Carpentarian basin in Australia;

(4) A complete cross-section is available for study across the basin from edge to edge;

(5) The basin is a typical example of a Precambrian epicratonic basin;

(6) The basin possesses a wide range of palaeoenvironments for the study of Precambrian sedimentology;

(7) A particularly important carbonate complex (McArthur Group) appears to possess facies which can be readily related to modern environments, with important implications to the evolution of sedimentation, the atmosphere, etc., through time;

(8) Abundant stromatolites and microfossils, with wide lateral and vertical distributions, provide one of the best available areas for study of Precambrian palaeontology;

(9) The fault-controlled evolution of the basin provides an important tectonic model for epicratonic basin evolution;

(10) Detailed knowledge of the basin's evolution, sediment provenance, and mineralisation will be pertinent to the study and exploration of other areas, particularly in northern Australia.

Emphasis of proposed projects

The proposed studies will lead to extensive revision of some published 1:250 000 Sheets, and 1:100 000 Sheets will be produced or selected areas, but the project is primarily a specialist study project of aspects of the basin's evolution, and map production is only considered as a by-product of these studies.

ACCESS AND SUPPLY

The main access routes are summarised in Figure 1. The basin has been divided into two areas.

1) "McArthur River Region" from the Roper River southeast to the Queensland border.
2) Arnhem Land, to the north of the Roper River.

These areas differ, both with respect to geology and access.

The study region does not contain any towns of consequence. Borroloola consists principally of a hotel/post office/store, police station, and aboriginal settlement and hospital; it is not suitable as a supply centre. Nhulunbuy, on the northeast fringe of the study area, is now a major town, but because of its own supply difficulties it is unsuitable for bulk supplies.

Mail and passenger planes used to visit a number of station airstrips, generally once or more per week, but future services are unpredictable. Outpost radio bases operate from Mount Isa (FFDS) and Darwin (OTC). Either can be used, but traditionally areas north of Borroloola use Darwin and those south, Mount Isa.

"McArthur River Region"

Bauhinia Downs, Wallhallow, and Mount Young Sheets are the key to the

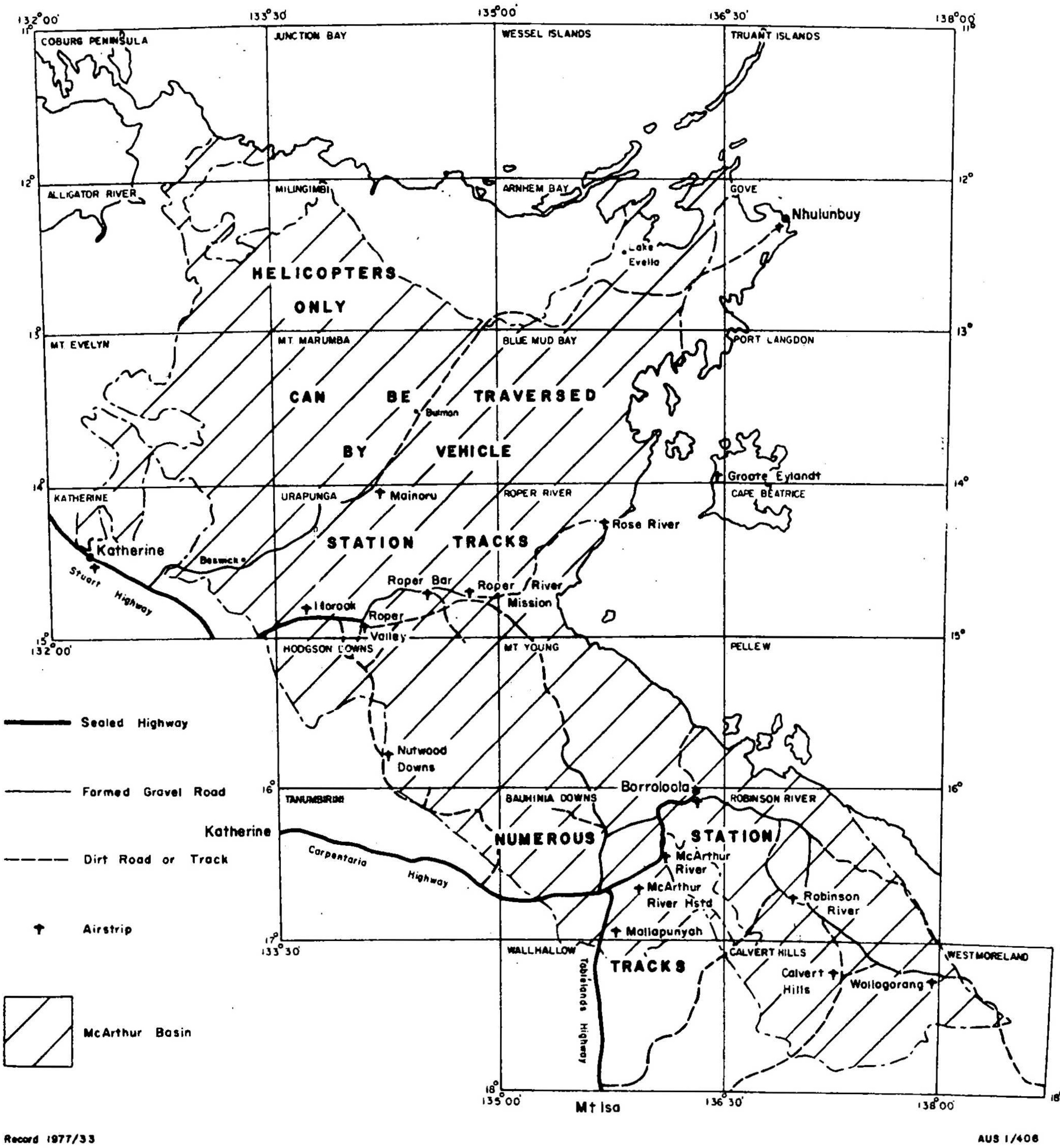

Fig I. Geographical setting of McArthur basin with index to I 250 000 sheet areas and principal access.

whole basin and should be the focus for the most detailed work. They have no access problems.

Sealed highways link Borroloola to Mount Isa via the Tablelands Highway (ca. 900 km, 12 hours driving time), and Katherine via the Carpentaria and Stuart Highways (ca. 580 km, 8 hours driving time). A network of formed gravel roads and station tracks give ready access to all the areas requiring detailed work, and base camp-sites are available near good roads.

A formed gravel road links Borroloola to Wollogorang (about 320 km, 5 hours drive) and, with available station tracks, provided access to most of the important sections in the Calvert Hills-Robinson River-Wollogorang area; helicopter access will be necessary locally. The Wollogorang road continues on to Burketown (a further 350 km) and Mount Isa (about 1000 km).

Northwards, a rough four-wheel-drive track now links Borroloola to Roper Bar (about 8 hours drive), via important areas in the Mount Young Sheet. A good, partly sealed partly formed, gravel road links Roper Bar to Katherine (about 250 km, 3½ hours driving time), and a network of station tracks provides access throughout the Roper River area.

Mount Isa was the supply point for McArthur River and Borroloola, because of historical connections with the Barkly Tableland cattle industry and the exploration activities of Mount Isa Mines; new roads now make Katherine closer. Bulk fuel is available at Borroloola (not necessarily by the Commonwealth contractor), but the price is extremely high.

For any base camps in the Roper River area Katherine is the obvious supply point. Base camps in the Calvert Hills area can probably obtain fuel from Burketown.

Mail to McArthur River and Calvert Hills is still routed via Mount Isa. A weekly truck carries refrigerated fruit, vegetables, etc. from Mount Isa to Borroloola, and to CEC at McArthur River. Market gardens in Katherine used to provide good fruit and vegetables. Meat is available from local stations.

Arnhem Land

Access to Arnhem Land is poor. When mapped by BMR in 1962 no roads existed within the reserve; a base camp was established near the centre of Arnhem Land, 200 km from the nearest road. Mail was collected from Mainoru, 250 km from camp. A network of bush tracks had to be established to give access to the main areas of work, which were commonly a day's drive from camp.

The situation has since improved: a dry-weather 4-wheel-drive track is in fairly regular use between Nhulunbuy and Katherine. The Arnhem Highway from Darwin is currently being extended eastwards from the Alligator Rivers region to Nhulunbuy. A new aboriginal mission has been established at Lake Evalla, with a network of tracks in the Flinders Peninsula area. BHP, during their exploration programs in eastern Arnhem Land, established a network of rough tracks which, although rapidly overgrown, could easily be reopened.

It is now a practical proposition to establish a full base camp in the Walker River-Koolatong River area of the Blue Mud Bay Sheet, the focus for the most detailed work in Arnhem Land. Supplies would come from Katherine or Darwin depending on future road developments. Mail could come from Lake Evalla or Nhulunbuy. Nhulunbuy has daily plane services from Darwin, Mount Isa, or Cairns.

The centre for work in western Arnhem Land is Bulman. This is linked by a fairly good road to Katherine (about 300 km) via Mainoru. Mail is available through Mainoru. The area required for detailed work is readily accessible by vehicle from Bulman. Other areas are situated around Beswick.

Farther west, on the Arnhem Plateau, access is only possible by helicopter. Most exposures are only of the flat-lying Kombolgie Formation and thus helicopter work is adequate. The western edge of the McArthur Basin - the Arnhem escarpment and the Edith Falls and Mount Callinan Basins - is accessible from the Katherine-Darwin Region to the west.

OUTLINE OF GEOLOGY OF THE McARTHUR BASIN

The geology of the whole McArthur Basin is summarised by Plumb & Derrick (1975); a more complete account of the basin's evolution, stratigraphic columns, palaeogeographic reconstructions, and tectonic synthesis, is being prepared, based on a lecture to the 1st Geological Society of Australia Convention (Plumb, 1975). This summary comes from these sources.

DEFINITION

The McArthur Basin is the relatively undeformed structure within which the Carpentarian Tawallah, McArthur, and Roper Groups, and their stratigraphic equivalents (Fig. 3), were deposited. The basin is bounded by and unconformably overlies the Lower Proterozoic Pine Creek Inlier in the northwest, the Murphy Inlier in the southeast, and the Arnhem Inlier in the northeast. In the north, south, and east the basin extends beneath the unconformably overlying covers of the Palaeozoic Arafura Basin, the early Palaeozoic Georgina and Daly River Basins, and the Mesozoic Carpentaria Basin respectively; there is no subsurface information available yet to indicate the full extent of the basin in these directions.

In its present form the basin is essentially a structural basin, but palaeogeographic reconstructions suggest that the depositional limits did not extend very far beyond the present northwestern and northeastern limits. The Murphy Inlier in the southeast is, by definition, the boundary between the McArthur Basin and the Northwest Queensland Province farther to the south.

REGIONAL SETTING

The McArthur Basin is the largest of the several mid-Proterozoic mildly deformed platform covers which compose the North Australian Platform Cover (GSA, 1971), and which unconformably overlie highly deformed basements forming the North Australian Orogenic Province. The McArthur Basin lies near the eastern edge of the craton, adjacent to the penecontemporaneous mobile belt of the Mount Isa Orogen. Following cratonisation of the Mount Isa Orogen, it and the North Australian Platform Cover were unconformably overlain by Adelaidean and Palaeozoic basins belonging to the Central Australian Platform Cover.

STRATIGRAPHY

The McArthur Basin succession has a maximum composite thickness of about 12 km (Fig. 4), although 10.5 to 11 km is more typical in the central belt of maximum thickness. The succession comprises three major subdivisions (Fig. 3): the Tawallah Group and equivalents consist of quartz-rich arenites, subordinate basic volcanics, carbonates, and lutites, and is up to 6 km thick; this is followed by a dominantly carbonate sequence, the McArthur Group and equivalents, which is up to 5.5 km thick; this is overlain with regional unconformity by the Roper and Malay Road Groups, which consist of alternating quartz arenites and micaceous lutites up to 5 km thick. Shallow-water sediments predominate, and a feature is the remarkable lateral uniformity of many of the units over wide areas. Extensive tholeiitic dolerite sills were emplaced into the northwestern part of the basin, after deposition of the Roper Group but before the main deformation.

The major outcrops of the groups are widely separated (Fig. 4) and this, combined with facies changes, prevents the mapping of the same formations throughout the basin, so that different stratigraphic nomenclatures have been applied in different areas (Fig. 3). However the general features of the successions are consistent and the groups may be correlated with confidence, while most of the finer correlations of Figure 3 are similarly valid.

The stratigraphy is summarised in Table 1.

STRUCTURE

Structurally, the McArthur Basin contains broad belts of shallowly dipping strata in the east and west, progressively younging towards a meridional zone of intense and complex block faulting (Fig. 2); stratigraphic displacements of up to 7.5 km occur across these meridional faults, even exposing the basement in small inliers. A prominent zone of westerly trending faults, the Flying Fox Fault Zone, bisects the western stable block. Bedding dips rarely exceed 5^{o} on the stable blocks, and even in the meridional deformed belt rarely exceed 20^{o} - except adjacent to faults. Virtually all folding can be related to faulting, and the rocks of the basin are unmetamorphosed. The principal fault trends, northwest, and north to north-northeast, reflect the major regional pattern of northern Australia.

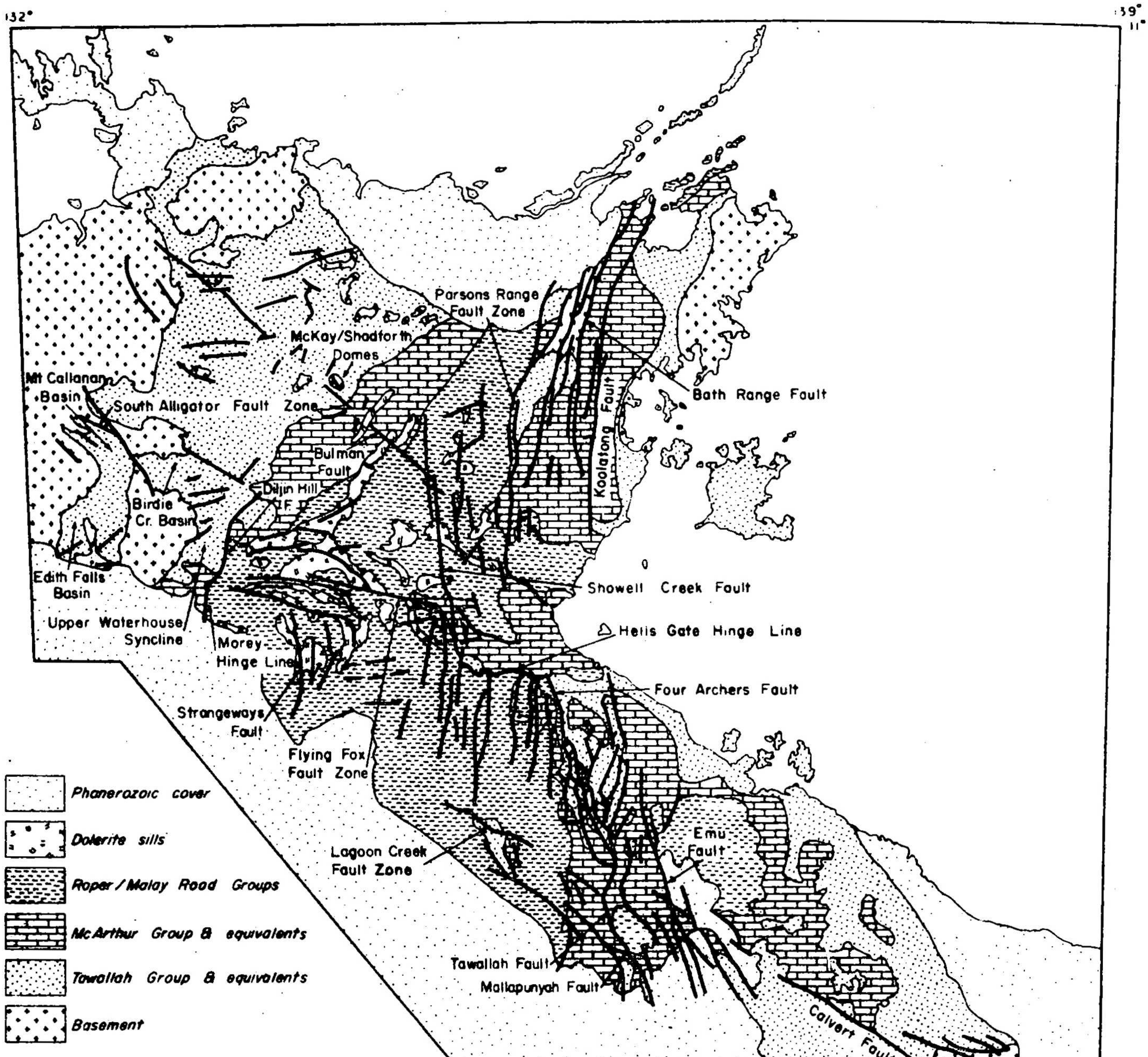

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Fig 2 Geological sketch map-McArthur Basin.

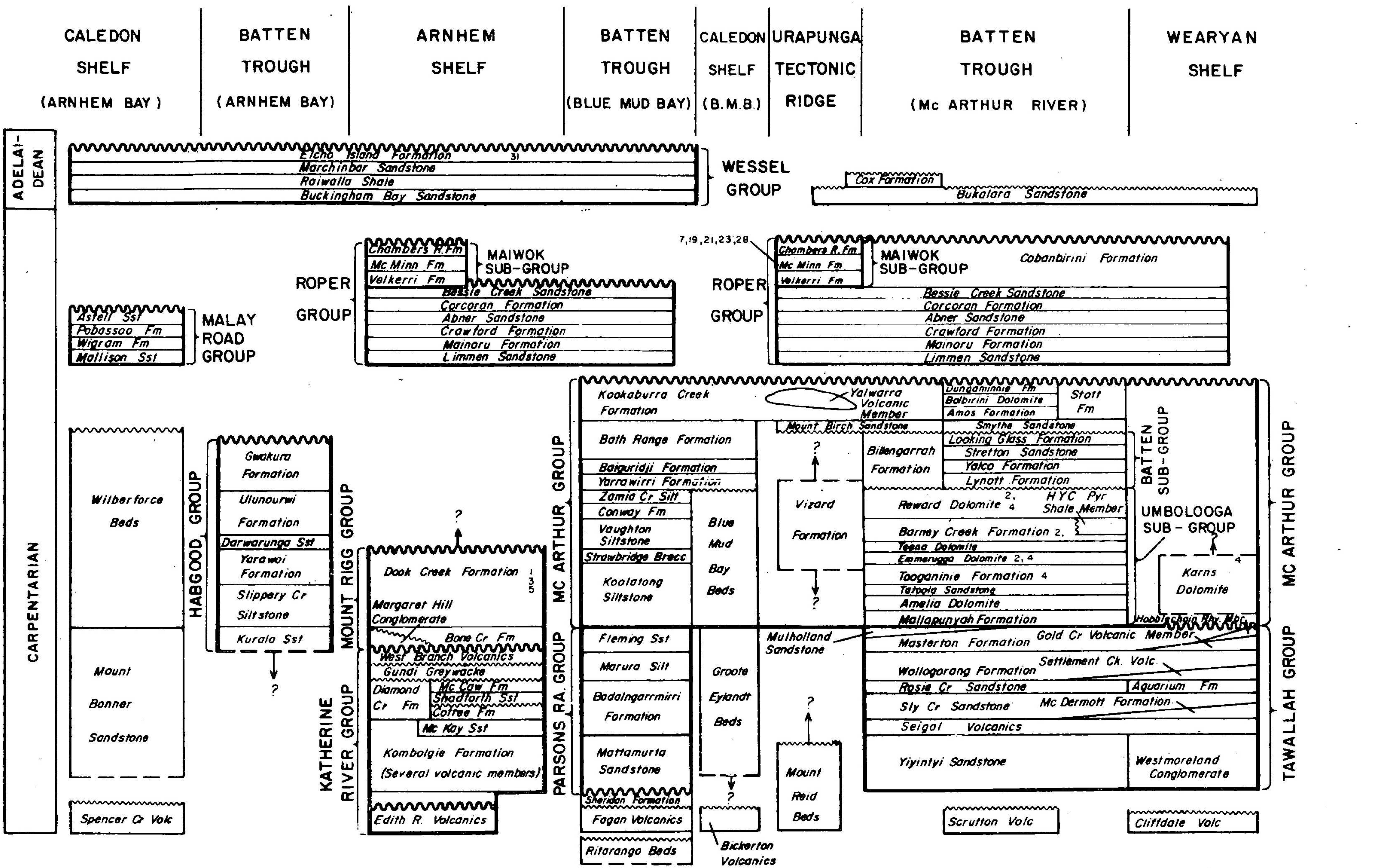

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Figure 3. Stratigraphic correlation chart, Mc Arthur Basin, with underlying acid volcanic complexes and overlying Adelaidean basins. (Modif. from Plumb & Derrick 1975)

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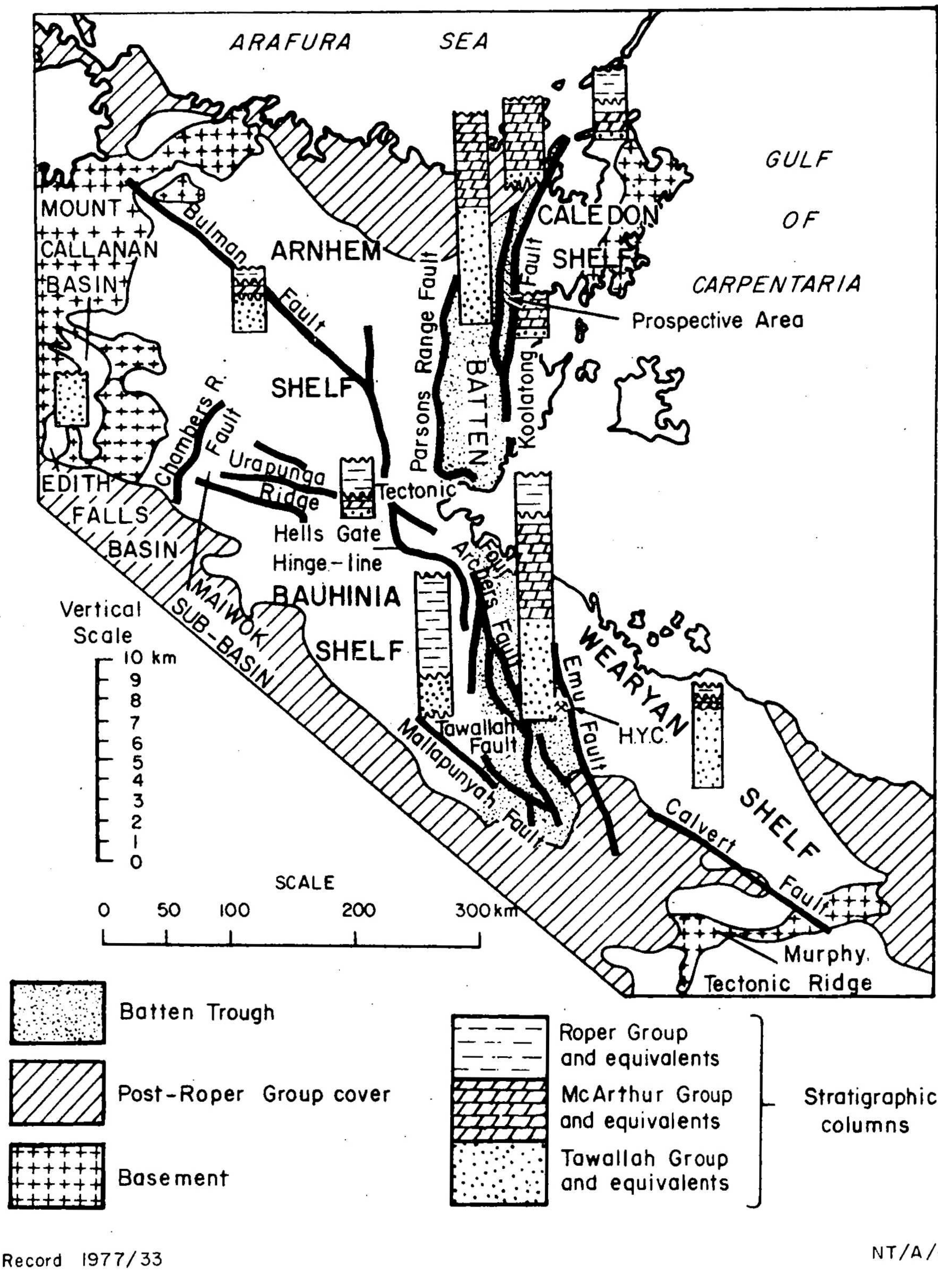

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Figure 4. Major tectonic elements, Mac Arthur Basin (after Plumb & Derrick, 1975).

TABLE 1: SUMMARY OF STRATIGRAPHY,

Unit and Locality	Thickness (m)
Dolerite sills	
ROPER GROUP (throughout basin)	500-5000
MALAY ROAD GROUP (Caledon Shelf)	1500+
McARTHUR GROUP	0 - 5500
Batten Trough - McArthur River area	1250
<u>Batten Sub-Group</u>	1000
<u>Billengarrah Formation</u>	1000
<u>Umbolooga Sub-Group</u>	Up to 3250
<u>Batten Trough - Blue Mud Bay area</u>	4500

McARTHUR BASIN (from Plumb & Derrick, 1975)

Main Rock Types	Remarks
	Intrude Roper, Mt Rigg, Katherine R, & Malay Road Gps.
Quartz sandstone, minor ferruginous sandstone, shale (Limmen, Abner, Bessie Cr Ssts); micaceous siltstone (Mainoru Fm); micaceous glauconitic sandstone (Crawford Fm); interbedded micaceous fine sandstone, siltstone, & shale (Corcoran, Cobanbirini Fms, Maiwok Sub-Gp).	Fe (Roper R) in Sherwin Ironstone Mbr of McMinn Fm. Overlies McArthur & Mt Rigg Gps with regional unconformity.
Quartz sandstone (Mallison, Astell Ssts); micaceous siltstone, quartz greywacke (Wigram, Pobassoo Fms); black shale (Wigram Fm); glauconitic sandstone (Pobassoo Fm).	Unconformably overlies Wilberforce Beds. Correlated with Roper Gp.
Dominantly carbonate rocks	
Chert-quartz sandstone, conglomerate (Smythe Sst.); dolomite, siltstone, shale, chert, oolitic chert (Amos, Dungaminnie, Stott Fms); dolomite, dololutite, some stromatolites (Balbirini Dol).	Locally unconformably on Batten Sub-Gp
Dolomitic siltstone, sandstone, shale (Lynott Fm); interlaminated siltstone-chert (Yalco Fm); quartz sandstone (Stretton Sst); chert, cherty siltstone (Looking Glass Fm).	Locally unconformable on Umbolooga Sub-Gp.
Chert, sandstone, dolomite, shale.	Correlated with Batten Sub-Gp.
Ferruginous & dolomitic sandstone & siltstone, dolomite (Mallapunyah Fm); dolomite, dololutite, abundant stromatolites (Amelia, Emmerugga, Teena, Reward Dols); flaggy sandstone (Tatoola Sst); alternating dolomite (stromatolites), dolomitic siltstone & sandstone (Tooganinie Fm); dolomitic, tuffaceous, bituminous, & pyritic shale (Barney Creek Fm), basic to intermediate volcanics (?Amelia Dol).	Pb-Zn (H.Y.C.) in H.Y.C. Pyritic Sh Mbr of Barney Cr Fm. Minor Pb in Emmerugga Dol & Cu in Amelia Dol & Tooganinie Fm.
Siltstone, shale, dolomite (Koolatong Sltst); chert breccia (Strawbridge Breccia); black shale, dolomitic siltstone & shale (?tuff) (Vaughton Sltst); siliceous siltstone, chert (Conway Fm, Zamia Cr, Sltst); dolomitic siltstone, chert-quartz sandstone, conglomerate	Succession broadly similar to that at McArthur River although detailed correlations not possible - Vaughton Sltst probably equivalent to Barney Cr Fm.

TABLE 1 (continued)

Unit and Locality		Thickness (m)
McARTHUR GROUP	Urapunga Tectonic Ridge	750+
	Wearyan Shelf	150
	Caledon Shelf - Blue Mud Bay area	1600
HABGOOD GROUP (Batten Trough - Arnhem Bay area)		4000
Wilberforce Beds (Caledon Shelf)		1500
MOUNT RIGG GROUP (Arnhem Shelf)		700
TAWALLAH GROUP (Wearyan Shelf, Batten Trough - McArthur River area)		4000-5000

Main Rock Types	Remarks
(Yarrawirrie Fm); interlaminated siltstone-claystone, feldspathic fine-grained sandstone (Baiguridii Fm); feldspathic tuffaceous siltstone, pelletal & oolitic chert, interlaminated siltstone-claystone, dolomitic siltstone (Bath Ra Fm).	
Dolomitic & cherty siltstone; dolomite, stromatolitic dolomite; dolomitic, feldspathic, & quartz sandstones (Vizard, Kookaburra Cr Fms); feldspathic chert-quartz sandstone, conglomerate (Mt Birch Sst); oolitic chert (Kookaburra Cr Fm); basic to intermediate volcanics (Yalwarra Volc Mbr of Kookaburra Cr Fm).	Minor Pb, Cu in Kookaburra Cr Fm.
Dolomite, stromatolites common; dolomitic siltstone, sandstone, chert (Karns Dol).	Minor Pb. Time equivalent of McArthur Gp. Unconformably on Tawallah Gp.
Dolomitic siltstone, chert, sandstone, dolomite, stromatolites (Blue Mud Bay Beds), plus Yarrawirrie, Buiguridgi & Bath Ra Fms.	Thickness includes Yarrawirrie, Baiguridgi, & Bath Ra Fms.
Dolomitic & cherty siltstone & sandstone, dolomite, stromatolites, conglomerate (Yarawoi, Ulunourwi, Gwakura Fms); micaceous siltstone, pyritic sandstone (Slippery Cr Sltst); quartz sandstone (Kurala, Darwarunga Ssts).	Base & top not exposed. Correlates with McArthur Gp & uppermost Parsons Ra Gp.
Micaceous dolomitic siltstone, shale, & fine sandstone.	Section imcompletely exposed. Lateral equivalent of McArthur Gp.
Quartz sandstone, conglomerate (Bone Cr Fm, Margaret Hill Cgl); dolomite, stromatolites, dolomitic siltstone & sandstone, chert, oolites (Dook Cr Fm).	Pb-Zn (Bulman). Correlated with McArthur Gp & uppermost Tawallah Gp.
Quartz and feldspathic sandstones, conglomerate (Yiyintyi, Sly Creek, Mulholland Ssts, Westmoreland Cgl, Masterton Fm). Subordinate basic to intermediate volcanics, (Peters Cr, Settlement Cr Volcs, Gold Cr Volc Mbr of Masterton Fm); acid volcanics (Hobblechain Rhyolite & Tanumbirini Volc. Mbrs of Masterton Fm); dolomite, dolomitic siltstone & sandstone (Wollogorang, McDermott Fms); glauconitic sandstone & siltstone (Aquarium Fm, Rosie Cr Sst).	U (Westmoreland) in dolerite dykes in Westmoreland Cg. Minor U in Peters Cr Volc. Cu (Redbank) in breccia pipes in Gold Cr Volc Mbr.

TABLE 1 (continued)

Unit and Locality	Thickness (m)
KATHERINE RIVER GROUP (Arnhem Shelf)	1800-2700
PARSONS RANGE GROUP (Batten Trough - Blue Mud Bay area)	6000
Groote Eylandt Beds (Caledon Shelf)	9-600
Mount Bonner Sandstone (Caledon Shelf)	150
Mount Reid Beds (Urapunga Tectonic Ridge)	60

Main Rock Types	Remarks
Quartz sandstone, minor feldspathic or ferruginous sandstone, conglomerate (Kombolgie Fm, McKay, Shadforth Ssts); basic volcanics (various mbrs of Kombolgie Fm & West Branch Volc, McKay Fm); (tuffaceous) quartz greywacke (Gundi Greywacke, West Branch Volc, Kolbolgie Fm (locally); dolomite, dolomitic siltstone & sandstone, siltstone, shale, glauconite (Cottee, McCaw, Diamond Cr Fms).	U (ABC) in McAddens Cr Volc Mbr of Kombolgie Fm. Correlated with Tawallah Gp. Several unconformities in succession. Group includes Edith R Volc (see Table 2).
Quartz sandstone (Mattamurta, Fleming Ssts); quartz sandstone, ferruginous and feldspathic sandstones, siltstone, dolomite (Badalngarrmirri Fm); siltstone, shale, dolomite (Marura Sltst).	Correlated with Tawallah Gp.
Quartz sandstone, argillaceous sandstone, quartz greywacke, shale, conglomerate	Lateral equivalent of all or part of Tawallah Gp in Blue Mud Bay.
Quartz sandstone, conglomerate	Lateral equivalent of all or part of Tawallah Gp near Arnhem Bay.
Porphyritic rhyolite overlain by sandstone & conglomerate	Possibly equivalent to Tawallah Gp & Cliffdale Volc; correlation uncertain.

TECTONIC UNITS

A number of distinct tectonic elements are recognised within the McArthur Basin (Fig. 4). A very much thicker Carpentarian succession was deposited in the 50-60 km wide northerly trending fault-bounded Batten Trough, than on the adjoining Arnhem, Caledon, Bauhinia, and Wearyan Shelves. The east-bounding Emu and Koolatong Faults were active during deposition, and the Parsons Range Fault on the northwestern side was, by analogy, also probably active. In the south however the western margin to the trough is gradational. South of the Mallapunyah Fault the similarity of the stratigraphy within the trough to that on the Wearyan and Bauhinia Shelves may indicate proximity to the southern limit of the Batten Trough. An exceptionally thin Carpentarian succession at Urapunga indicates a westerly trending ridge (Urapunga Tectonic Ridge) between the Arnhem and Bauhinia Shelves. Extrapolation of this ridge eastwards into the area of poor outcrop near the coast appears to offset the Batten Trough, and it may be that the trough developed as two separate structures, separated by the ridge. The Mount Callanan and Edith Falls Basins, in the extreme west, are marginal downwarps in which abruptly thickened sequences of Kombolgie Formation were deposited; in the southeast, the Tawallah Group thins abruptly onto the Murphy Tectonic Ridge.

Following deposition of the McArthur Group and equivalents, there was a period of non-deposition throughout the McArthur Basin, at about the same time as the deformation and metamorphism of the Northwest Queensland Province to the southeast. Subsequent sedimentation, the Roper and Malay Road Groups, developed a different pattern with a westward shift of the zone of thickest sedimentation to the area overlying the Bauhinia Shelf. The thickness decreases gradually to the north and east and it is unclear what influence, if any, the Batten Trough faults had on Roper Group sedimentation. The Chambers River Fault controlled the westerly limit of the Roper Group. The name Maiwok Sub-Basin is applied to the area where the Maiwok Sub-Group was deposited. The Malay Road Group in northeast Arnhem Land probably accumulated in a distinct basin, which was separated from the Roper Group by a ridge along the site of the earlier Batten Trough.

AGE OF THE BASIN

A regional assessment of the available isotopic age determinations from the McArthur Basin and surrounding areas was given by Plumb & Sweet (1974), and Plumb & Derrick (1975); these are summarised in Figure 5. Details have

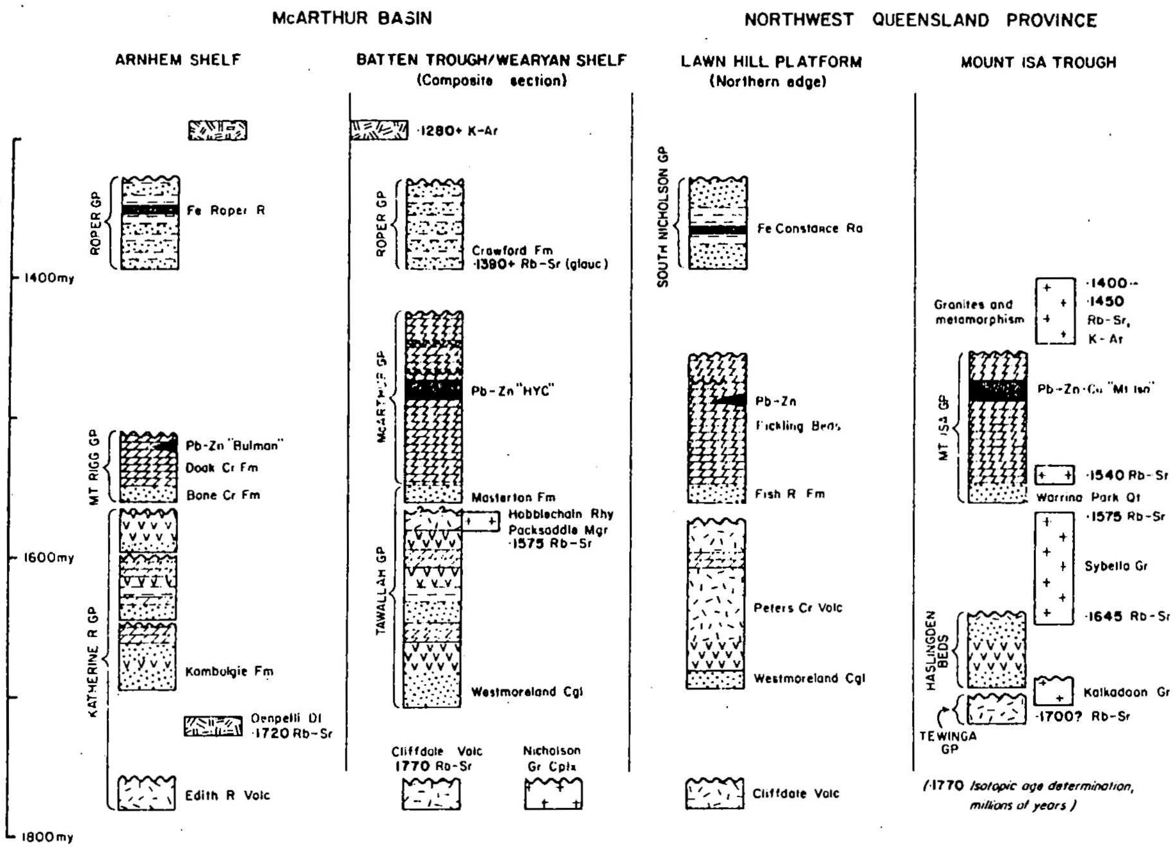


Fig. 5 - Postulated time relationships of principal rock units, McArthur Basin and Northwest Queensland Province (after Plumb & Sweet, 1974).

since been modified within the Mount Isa region (R.W. Page, pers. comm. 1977).

In summary, the Tawallah Group and equivalents now appear to have been deposited somewhere within the period 1750-1600 m.y. ago, the McArthur Group during the span 1600 m.y. to around 1500-1450 m.y. ago, and the Roper Group between 1450 and 1300 m.y. ago.

Rates of sedimentation

Assuming continuous sedimentation, these time ranges allow average rates of sedimentation for the thickest sections in the McArthur Basin of:

Tallawah Group (including volcanics) - 50 mm/1000 years

Parsons Range Group - 60 mm/1000 years

McArthur Group - 45 mm/1000 years

Roper Group - 50 mm/1000 yrs, as against normal average rates of around 100 cm/1000 yrs.

SUMMARY OF THE BASIN'S EVOLUTION

Tawallah Group (and equivalents)

Sedimentation in the McArthur Basin began with the deposition of up to 3000 m of cross-bedded quartz-rich sandstone (Yiyintyi Sandstone and equivalents). These sandstones are thickest, best sorted, and most uniform within the Batten Trough. The Westmoreland Conglomerate includes (?)fluviatile conglomerates and arkoses, derived from the adjacent (?)fault-bounded Murphy Tectonic Ridge, which was only transgressed intermittently. In the west, the (?)fluviatile Kombolgie Formation locally contains quartz greywackes in the marginal Mount Callanan and Edith Falls Basins.

The deposition of the basal arenites was followed by widespread flood basalt volcanism (Seigal Volcanics, etc.). The volcanics occur throughout the Tawallah and Katherine River Groups and are thickest on the Wearyan, Bauhinia, and Arnhem Shelves. They die out rapidly to the north in the Batten Trough, and are absent in the Parsons Range Group.

Early volcanics are succeeded by sandstone alternating with siltstone, carbonates, and later volcanics. The presence of glauconite in some units indicates shallow-marine conditions. Locally the carbonates contain stromatolites, and considerable terriginous material. Sandstones predominate in the Batten Trough, while carbonates are best developed on the Arnhem and Wearyan Shelves. Several periods of erosion interrupted sedimentation on the Arnhem Shelf, particularly around domes overlying basement ridges.

The Tawallah Group equivalent on the Urapunga Tectonic Ridge (Mount Reid Beds) is only 30 m thick. On the Caledon Shelf the Mount Bonner Sandstone and Groote Eylandt Beds (up to 600 m thick) represent the whole of the Tawallah Group, and progressively transgress onto a stable basement ridge centred around Gove Peninsula and Blue Mud Bay.

On the Arnhem and Wearyan Shelves erosion occurred at or near the top of the Tawallah Group. It has recently been postulated that a minor unconformity may be present throughout the Batten Trough as well.

McArthur Group (and equivalents)

The McArthur Group is best known from the McArthur River area. The Batten Trough successions of Blue Mud Bay, and Arnhem Bay (Habgood Group), are similar. The equivalents on the Arnhem and Wearyan Shelves (Dook Creek Formation and Karns Dolomite) are mainly shelf carbonates like the Umbolooga Sub-Group, although precise correlations are not possible. On the Bauhinia Shelf the Umbolooga Sub-group is directly overlain by the Roper Group or Mount Birch Sandstone. The Vizard Formation on the Urapunga Tectonic Ridge is equivalent to all or part of the Umbolooga or Batten Sub-Groups, or both; facies changes preclude precise correlations. The shelves may have been essentially areas of non-deposition during the period when the Batten Sub-Group was laid down, except on the Caledon Shelf where the younger units transgress, without significant changes in thickness, the thin Blue Mud Bay Beds.

The Umbolooga Sub-Group and equivalents were deposited in an arid hypersaline environment alternating between supratidal, intertidal, and shallow subtidal conditions. Dolomite alternates with siltstone and sandstone. The presence of stromatolites, evaporites, oolites, mud cracks, ripple marks, cross-beds, and red oxidised terriginous sediments attest to the environment. Similar conditions existed over most of the McArthur Basin. Thin potassium-rich tuffs are scattered through the sub-group, and basic lavas were extruded locally near the base of the sequence northwest of Borroloola. During a later transgression, muddy sediments containing considerable tuffaceous material (Barney Creek Formation) were confined to the Batten Trough area. At McArthur

River the Bulburra Depression developed locally adjacent to the active Emu Fault. Up to 530 m of shale is present in the depression, including the H.Y.C. Pyritic Shale Member, which contains the bedded sphalerite and galena of the H.Y.C. orebody. The Vaughton Siltstone of the Blue Mud Bay area may correlate with the Barney Creek Formation. A regression resulted in a return to shallow shelf conditions (Reward Dolomite) at the top of the sub-group.

Subsequent tectonic adjustments are indicated by local unconformities at the base of the Batten Sub-Group, and by conglomerates at the base of the Yarrawirrie and Gwakura Formations in Arnhem Land. The carbonate basinal facies of the Batten Sub-Group appears to have been largely restricted to the Batten Trough area. The carbonate detritus was probably derived from erosion of the shelves, and much of the abundant fine terriginous material may have been transported by wind. Potassium-rich tuffs are locally abundant in the Bath Range Formation in Arnhem Land.

Further tectonic adjustments are indicated by the presence of conglomerates, and by transgression of the Mount Birch and Smythe Sandstones across older units. The presence of stromatolitic dolomites and oolites in the overlying units indicate a return to a shallow-shelf environment. Local basic volcanics are interbedded with feldspathic sandstone in the Yalwarra Volcanic Member on the Urapunga Tectonic Ridge.

Roper and Malay Road Groups

The widespread erosional unconformity below the Roper and Malay Road Groups is believed to be of the same age as the folding and metamorphism in the Mount Isa Orogen. The groups are characterised by mica-rich siltstone and quartz greywacke alternating with clean quartz sandstone, typical of an unstable shelf association. Cycles involving shallow marine, transitional, and perhaps fluviatile environments are indicated. Oolitic sideritic and hematitic iron ores (Sherwin Ironstone Member) were deposited in the Roper River area.

Tholeiitic dolerite sills intrude the Roper, Mount Rigg, and Katherine River Groups on the Arnhem Shelf and Urapunga Tectonic Ridge, and the Malay Road Group on the Caledon Shelf. They antedate the main deformation.

Deformation has been mainly in response to complex block faulting on pre-existing basement faults. It is most intense on northerly trending faults along the Batten Trough. Although movements in the McArthur Basin are dominated by vertical displacements of up to 7.5 km, it has been postulated that the primary control is a major system of northerly trending right-lateral strike-slip movements.

MINERAL DEPOSITS

Four main types of mineral deposits occur in the McArthur Basin - Pb-Zn, Cu, Fe, and U. Pb-Zn and Cu have the most economic potential, but the Fe deposits are of considerable scientific interest. Some potential exists for sedimentary U deposits.

Distributions of mineral deposits are summarised in Figure 6 and Table 2.

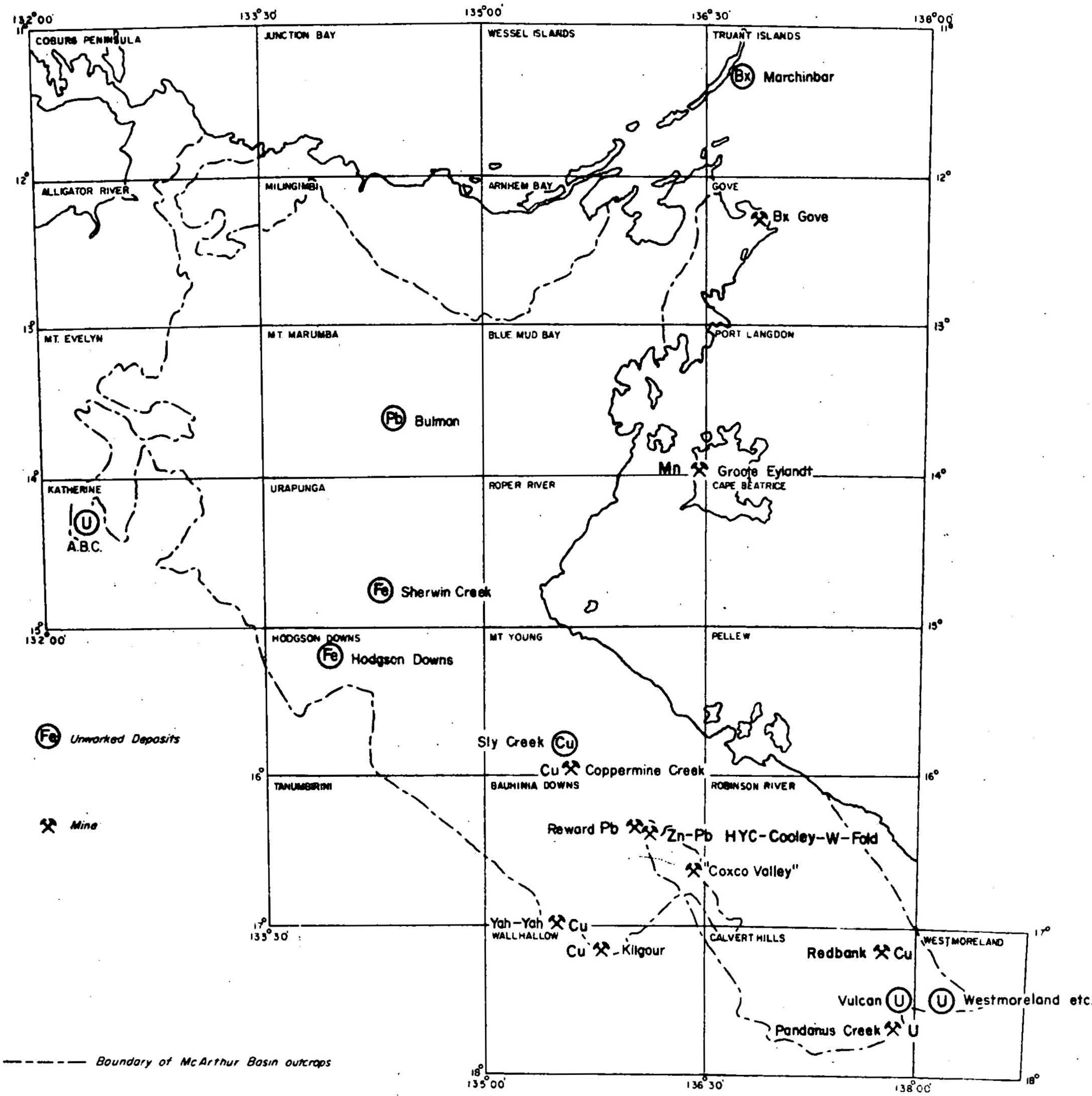
Lead-Zinc

All Pb-Zn deposits are stratabound and occur in the McArthur Group rocks or their equivalents. The McArthur Group, and its equivalents in the McArthur Basin and the Northwest Queensland Province, probably constitute the major Pb-Zn province of Australia. All the important deposits seem to be of syngenetic origin. Minor remobilisation by faults has influenced some deposits, such as Cooks.

The principal interest lies in the bedded-sulphide deposits of the H.Y.C., with proven reserves of 190 000 000 tonnes of 9½ percent Zn and 4 percent Pb ore, and the nearby W-Fold and Teena areas. The host rocks are carbonaceous dolomitic shales deposited in the restricted Bulburra Depression, lying adjacent to the syndepositional Emu Fault. Mineralisation dies off rapidly away from the depression. The ore-bodies are unmetamorphosed and are of interest as models for this type of mineralization. Several studies have been carried out (Croxford, 1968; Croxford & Jephcott, 1972; Lambert & Scott, 1973; Murray, 1975; Lambert, 1976).

Other deposits consist of strata-bound disseminated galena in massive dolomite units. Their economic potential is limited at this stage, but does indicate a potential for Mississippi Valley-type deposits.

Bulman comprises coarse galena in dolomite, at the contact with a dolerite sill; it is probably a remobilisation of original syngenetic lead.



Record 1977/33 Fig.6 Principal mineral deposits, McArthur Basin. AUS 1/407

TABLE 2: PRINCIPAL MINERAL DEPOSITS IN McARTHUR BASIN

	Deposit	Host Formation	Sheet Area
LEAD-ZINC			
McARTHUR RIVER DEPOSITS	H.Y.C.	H.Y.C. Pyritic Shale Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	W-Fold	H.Y.C. Pyritic Shale Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	Wickens Hill	H.Y.C. Pyritic Shale Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	Teena	H.Y.C. Pyritic Shale Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	Ridge 1	Cooley Dolomite Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	Ridge II	Cooley Dolomite Member	Bauhinia Downs
McARTHUR RIVER DEPOSITS	Cooley I	Cooley Dolomite Member	Bauhinia Downs
	Reward	Reward Dolomite	Bauhinia Downs
	Coxs	(?) Reward Dolomite	Bauhinia Downs
	Cooks	(?) Reward Dolomite	Bauhinia Downs
	Barneys	Mitchell Yard Dolomite Member	Bauhinia Downs
	Bald Hills	Mitchell Yard Dolomite Member	Bauhinia Downs
	Bulman	Dook Creek Formation	Mount Marumba
	Minor disseminated galena	Kookaburra Creek Formation Karns Dolomite	Urapunga Calvert Hills
COPPER			
	Ridge II	Cooley Dolomite Member	Bauhinia Downs
	Cooley II	Cooley Dolomite Member	Bauhinia Downs
	Turnbull	Mara Dolomite Member	Bauhinia Downs
	Squib	Mara Dolomite Member	Bauhinia Downs
	Yah-Yah	Myrtle Shale Member	Wallhallow
	Kilgour	Amelia Dolomite	Mount Young
	Coppermine Creek	Amelia Dolomite	Mount Young
	Sly Creek	Amelia Dolomite	Mount Young
	Darcys	(?) Reward Dolomite	Bauhinia Downs
REDBANK DEPOSITS	Azurite	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Redbank	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Quartzite	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Bluff	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Seven Mile	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Black Charlie	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Masterton	Gold Creek Volcanic Member	Calvert Hills
REDBANK DEPOSITS	Yellow Girl	Gold Creek Volcanic Member	Calvert Hills

TABLE 2 (continued)

	Deposit	Host Formation	Sheet Area
COPPER (continued)			
REDBANK DEPOSITS	Prince		
	Vulcan	Seigal Volcanics	Calvert Hills
		Kookaburra Creek Formation	Urapunga
		Karns Dolomite	
		McDermott Formation	Calvert Hills
		Settlement Creek Volcanics	
	Minor disseminated copper	Wollogorang Formation	Calvert Hills, Bauhinia Downs
		Tooganinie Formation	
		Amelia Dolomite	Bauhinia Downs
IRON			
	Sherwin Creek (Gum Ck.)		Urapunga
	Maiwok Creek	Sherwin Ironstone Member	
	Hodgson Downs		Hodgson Downs
WESTMORELAND DEPOSITS	Redtree		
	Huarbagoo	Seigal Volcanics dykes in Westmoreland Conglomerate	
	Namalangi		Westmoreland
	Moongooma		
	Tjuambi		
	Cobar 2		
	Old Parr	Seigal Volcanics	Calvert Hills
	El Hussen		
	Kings Ransom		
	A.B.C.	McCaddens Creek Volcanic Member	Katherine

Copper

Cu deposits fall into two types: those associated with volcanic rocks (e.g. Redbank); and those associated with very shallow-water dolomitic or terrigenous deposits.

Most production has come from Redbank, where the sulphides are concentrated into breccia pipes. Considerable tonnage has been proved - 4 000 000 tonnes of 2½ percent Cu - but mining is prevented by cost, isolation, mining difficulties, and infrastructure requirements. Other deposits associated with volcanic rocks are concentrated along faults.

The deposits so far known in sedimentary rocks are all small and usually show some structural control. However, all occur in similar facies (Table 2), and probably represent remobilised strata-bound deposits. The host rocks are very shallow-water or red-bed carbonate and terrigenous sediments; a preliminary investigation tends to suggest that they occur in the dolomitic silts rather than the nearby carbonates. Recent detailed work by M.D. Muir has revealed very fine-grained disseminated copper in thin sections of otherwise apparently unmineralised rocks. Most deposits at the surface comprise secondary carbonates and oxides. Workings are collapsed and inaccessible. The nature of the deposits at depth is unknown.

There appears to be potential for the discovery of large low-grade bedded copper deposits.

Iron

Although currently uneconomic, the sedimentary iron deposits in the Roper Group are of considerable scientific interest. The four classic facies of iron-formation - sulphide, carbonate, silicate, and oxide (James, 1954) all occur, closely interbedded and intermixed, and the simple structure and unmetamorphosed nature of the rocks provide an excellent opportunity to study their palaeogeography and environment of deposition. The deposits are virtually identical to those at Constance Range.

Uranium

The known deposits within the McArthur Basin all show a structural control and are associated with basic volcanic rocks in the lower part of the sequence. The Westmoreland deposits are related to dykes of trachyandesite, intruding the Westmoreland Conglomerate. The dykes were probably feeders for the Seigal Volcanics.

The basal arenite sequence - Kombolgie Formation and Westmoreland Conglomerate - would appear to be favourable hosts for South African-type sedimentary uranium deposits - they appear to be fluviatile and to be derived from uraniferous basement. More knowledge of their sedimentology and palaeogeography should allow their potential to be better assessed.

PREVIOUS INVESTIGATIONS

Prior to 1950 little was known about the regional geology of the region. Some observations were made by the early explorers (Flinders, 1814; Fitton, 1826; King, 1826; Leichhardt, 1847; Gregory, 1861; Cadell, 1868; Lindsay, 1884, 1887), and Government sponsored prospecting expeditions (Love, 1911; Murphy, 1912). The first Government geologist visited the area around the turn of the century (Parkes, 1891; Brown, 1908; Woolnough, 1912; Jensen, 1914). In 1939-40 the Aerial Geological and Geophysical Survey of North Australia carried out some mapping along the Queensland border (AGGSNA, 1939; 1940a, 1940b), and some observations were made of the Redbank copper deposit (Blanchard, 1940; Jensen, 1940). Noakes & Traves (1954) briefly investigated the basin during the CSIRO survey of the Barkly Region in 1947-48, as did Hossfeld (1954) during his study of the geology of the Northern Territory.

REGIONAL GEOLOGICAL MAPPING

In 1950 BMR commenced systematic regional mapping of the Katherine-Darwin (Walpole, Crohn, Dunn & Randal, 1968) and northwest Queensland (Carter, Brooks & Walker, 1961) regions, during which they touched on the edges of the McArthur Basin (Alligator River, Mount Evelyn, Katherine, Calvert Hills, Westmoreland Sheets).

In 1952 Opik & Walpole observed important regional relationships in the Mount Marumba area (Opik, 1952). With interest in mineral exploration in the mid-50's, companies carried out regional reconnaissance mapping as part of their exploration programs in the central McArthur Basin (Fig. 7) (Crohn, 1956; Cochrane, 1956; Kriewaldt, 1957; and Paterson, 1958). These studies provided

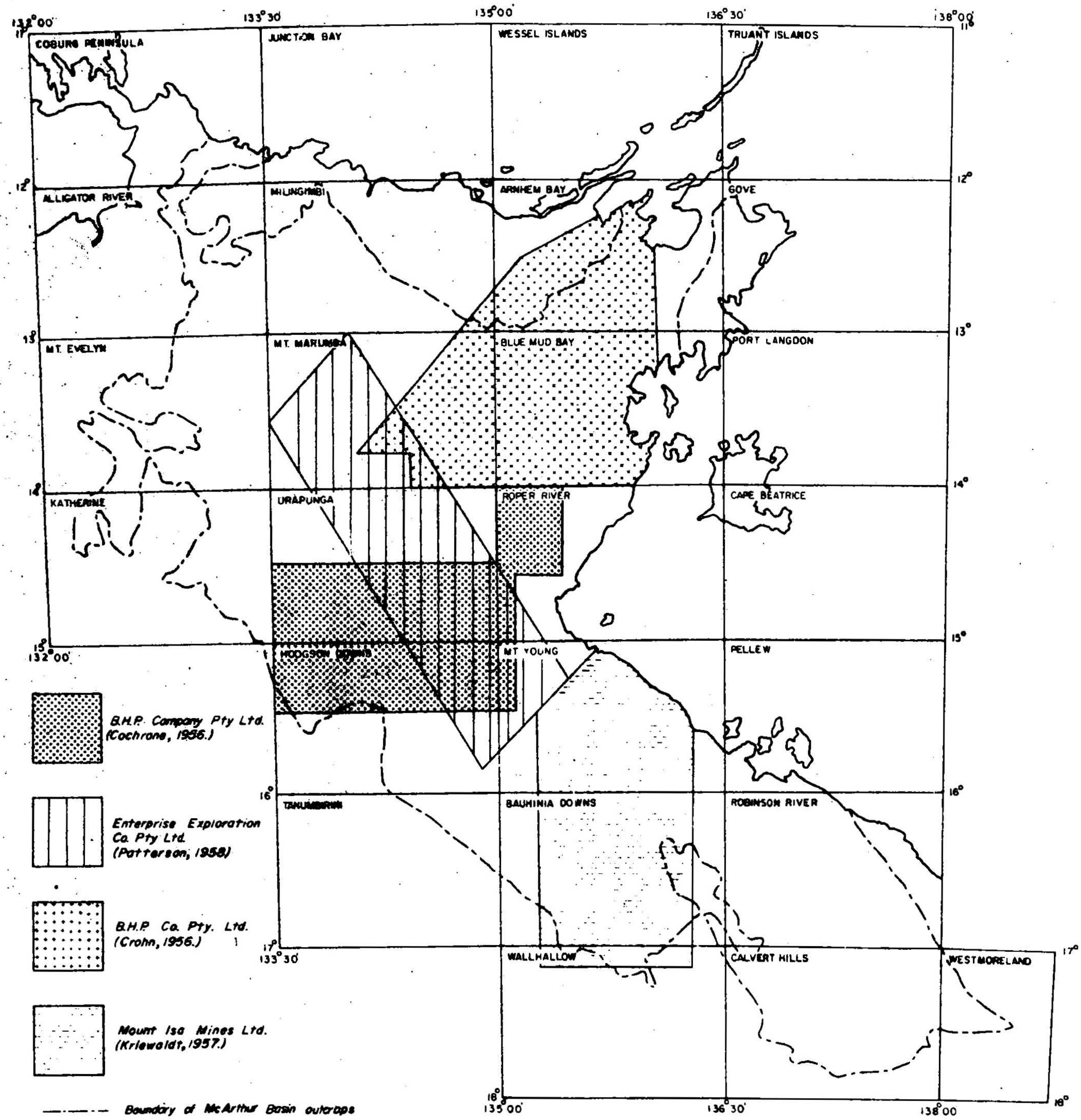


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Fig 7. Regional reconnaissance mapping by companies, 1954-58.

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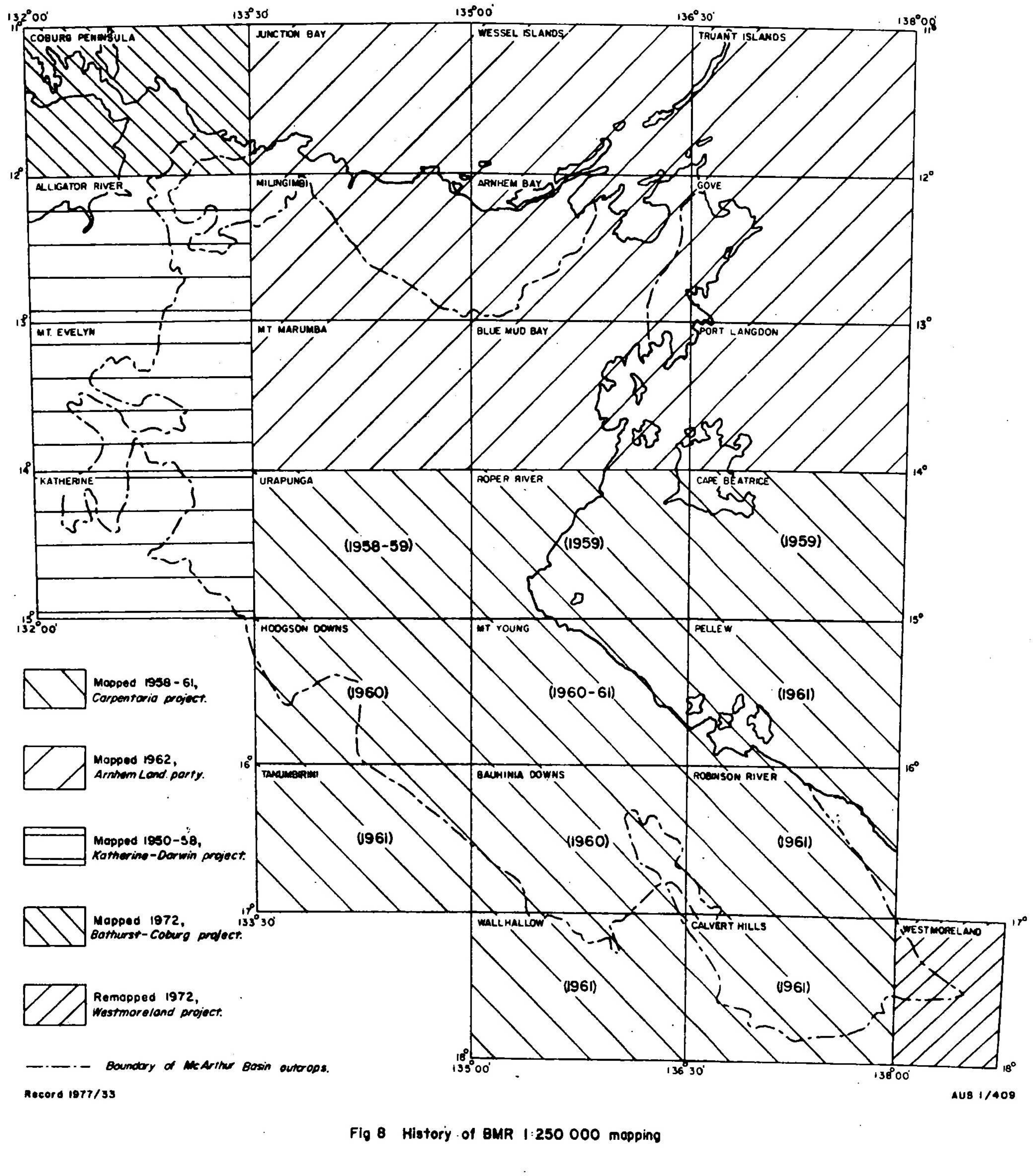

Fig 8 History of BMR 1:250 000 mapping

the framework for the systematic 1:250 000 mapping of the McArthur Basin.

Systematic mapping by BMR commenced in the Urapunga and Katherine Sheets in 1958 and was completed, in Arnhem Land, in 1962 (Fig. 8). Twenty Sheets were mapped, and all were published by 1965.

Comprehensive Bulletins have still not been published: Arnhem Land (Roberts & Plumb, in prep.) is well advanced and should be completed. Roper River-Queensland Border (Dunn, Smith, Roberts & Plumb) has been abandoned. A summary bulletin synthesising the evolution of the whole basin, based on Plumb (1975) should replace it to some degree.

Mapping by CEC Pty Ltd during the mid-60's led to a major revision of the stratigraphy of the McArthur Group (Plumb & Brown, 1973) and invalidated much of the earlier Bulletin drafts. I have extended the new concepts throughout the basin and anticipated where changes to published maps are likely. Detailed descriptions of the Tawallah Group (by Roberts) are available in preliminary draft form; later concepts have invalidated much of the original data from the McArthur Group; the data from the Roper Group were never fully compiled.

Despite these deficiencies, the regional mapping has provided a stratigraphic and structural framework upon which further detailed work can be based. It is expected that detailed work will not radically alter the existing framework, but simply add detail.

REGIONAL GEOPHYSICAL INVESTIGATIONS

Gravity

The only full geophysical coverage of the McArthur Basin is that of the Gravity Map of Australia at 1:2 500 000 scale. At this scale there is little variation in gravity across the McArthur Basin, and no obvious relationship to structures in the sedimentary cover; most anomalies are tentatively ascribed to variations in the basement.

An earlier reconnaissance gravity traverse from Normanton to Daly Waters (Neumann, 1964) shows marked anomalies which are not apparent on the regional grid. Further data are required before any useful interpretation can be made of the gravity of the region.

Aeromagnetics

An aeromagnetic survey was carried out over about 7 500 km^2, to the north and west of McArthur River, in 1963-64 (Young, 1964). Many of the major geological structures can be recognised, but basic volcanics within the successions complicate calculations of depth to true basement. All the intense anomalies overlie outcrop of the volcanics. The method has potential for extrapolating regional structures into areas of no outcrop, but depth to basement calculations will require close geological-geophysical liaison to filter out the effects of the volcanics, etc. from the sequence.

DETAILED GEOLOGICAL MAPPING

In 1972 BMR commenced 1:100 000 mapping programs around the edges of the McArthur Basin (Fig. 9); these programs are continuing.

CEC have mapped about 1 800 km^2 around McArthur River at a scale of 1 800 = 1".

CRA (Polkinghome & Rudd, 1974) mapped the strip between southwest Mount Young and southeast Urapunga in 1973. BHP have mapped selected areas in the Blue Mud Bay Sheet, but we do not have copies of their maps. Triako, Amdex and others have carried out detailed mapping around the Redbank deposits but again we do not have copies of their maps. Western Nuclear, presumably, mapped the area around Bulman. Kenneth McMahon & Partners (1967, 1968) have produced useful detailed maps of areas near Mallapunyah and Kilgour River on the northern Wallhallow Sheet, and areas around Calvert Hills. Various other maps held on Open File in Darwin are generally based on the BMR 1:250 000 Sheets.

DETAILED GEOPHYSICAL SURVEYS

Several detailed surveys have been conducted at and around the H.Y.C. orebody using various electrical methods by M.I.M. or C.E.C. (Newton, 1960; Stubbs, 1961), and BMR (Horvath, 1959; BMR, 1964; Sedmik, 1967); and using gravity (Seston, 1960). BHP have used IP and Aerial Input EM in Arnhem Land, but the results were still confidential in 1975. The surveys have shown that methods such as IP, which have sufficient penetration to operate below the deep weathering and soil covers of the area, when used as a detailed or semi-

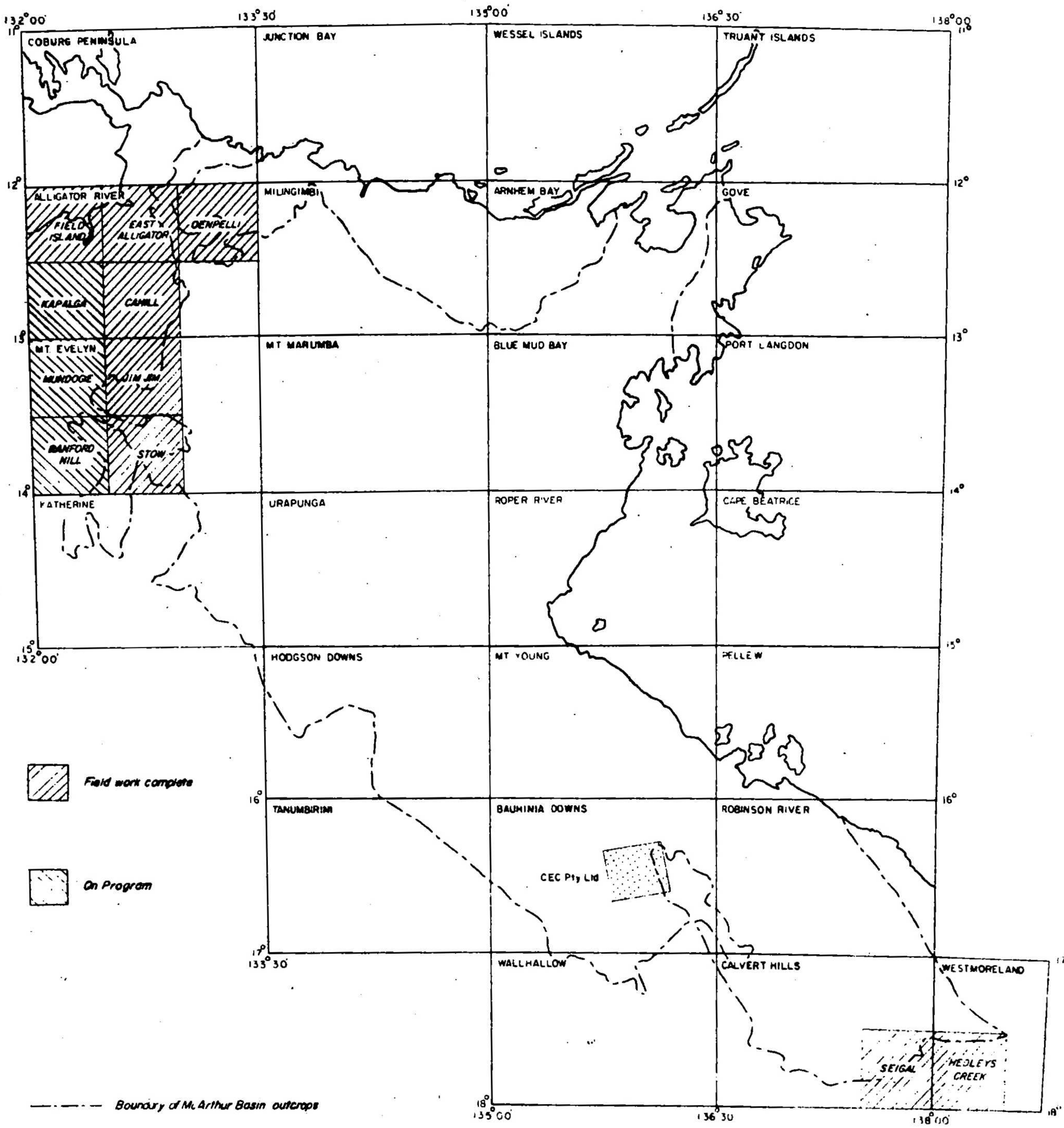

Fig. 9 BMR 1:100000 mapping and other detailed mapping (1975)

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reconnaissance tool, can be successful in revealing conductive rocks such as sulphides and carbonaceous shales.

GEOCHEMICAL SURVEYS

Soil sampling

Several soil sample surveys carried out at and around the H.Y.C. (Crabb, 1957; Fricker, 1962; Haldane, 1965) have confirmed the critical relationship between soil type and sample depth in detecting mineralization. Deep auger samples from near bedrock are needed in alluvium, but shallow samples are adequate in residual soils. Some deposits have been detected by stream-sediment sampling (Fricker, 1962). Various stream sediment sampling programs are described in Open File reports in Darwin.

Regional rock sampling

Semi-regional rock geochemical surveys of a selected part of the McArthur Group sequence at and around the H.Y.C. has indicated relationships between stratigraphy and element distribution, provided some data on ore genesis and depositional environments, and also some regional geochemical guides to base-metal sulphide exploration (Brown, Claxton & Plumb, 1969; Lambert & Scott, 1973). Care in interpreting the results is critical because of the failure of surface samples (Brown and others, 1969) to reflect zinc anomalies found in drill core of identical sectiona (Lambert & Scott, 1973).

Detailed rock sampling

Croxford & Jephcott (1970, 1972), and Williams (1974), have carried out detailed studies of element distribution within the H.Y.C., Cooley and Ridge orebodies, with relevance to ore genesis. Williams' complete work is not published yet.

SEDIMENTOLOGICAL STUDIES

Brown (in Brown et al., 1969) studied the depositional environments of the units from the upper Tooganinie Formation to the Reward Dolomite around

McArthur River, as a guide to the depositional setting of the H.Y.C. mineralisation. Several detailed sections were measured and constraints were placed on the depositional environments of the units studied.

CEC geologists have made numerous detailed observations around McArthur River over many years, and detailed petrographic studies have been made of the orebody (e.g. Croxford, 1968; Croxford & Jephcott, 1970, 1972) but, to my knowledge, these have not yet been supported by sedimentological work.

Recent recognition of gypsum and anhydrite beds in the McArthur Group have added new impetus to the studies in the Basin (Plumb & Muir, 1976; Walker and others 1977).

PALAEONTOLOGICAL STUDIES

Stromatolites. Stromatolites are abundant in the McArthur Group, and also occur in the Tawallah Group. Walter (1972) made some preliminary laboratory studies without fieldwork on stromatolites from the McArthur River area provided by BMR. He is now extending these studies with field and laboratory studies, initially concentrating on studying *Conophyton*.

Microfossils. Abundant microfossils have recently been discovered in the McArthur and Roper Groups (Croxford, Janecek, Muir, & Plumb, 1973; Hamilton & Muir, 1974; Muir, 1974; Muir & Plumb, 1976; Oehler, 1976; Oehler & Croxford, 1976). Microfossils are now known from the Amelia Dolomite, Tooganinie Formation, H.Y.C. Pyritic Shale Member, Cooley Dolomite Member, and Balbirini Dolomite of the McArthur Group, and the McMinn Formation of the Roper Group. The McArthur Basin studies are valuable because of the range of facies represented, the wide lateral and vertical range of material available, the fact that they represent an age which has been little studied elsewhere, and that the microfossils are associated with sulphide mineralisation.

MINING AND EXPLORATION ACTIVITY

The distribution of all known mineral deposits is summarised in Figure 6 and Table 2. Significant references are listed in the bibliography.

Historical

Lead was discovered in dolomites at McArthur River in 1887 by Mr Tom Lynott, soon after he took up the first pastoral lease in the area. Spasmodic interest over the ensuing twenty years resulted in the discovery of most of the minor deposits near McArthur River homestead (Barneys, Bald Hills) and in the Coxco Valley (Pb- Cooks, Cox's; Cu- Turnbulls, Squib). There was no production. Activity by a Melbourne-based company resulted in some drilling and shaft sinking at Cooks in 1909.

About this time copper deposits were discovered in dolomites at Yah Yah (1900), Kilbour (1912) and Copper Mine creek (1918). Spasmodic mining of these deposits, generally only amounting to a few tens of tonnes of ore, took place over the next forty years. Bulman lead, in southern Arnhem Land, was discovered in 1910, and some minor mining was carried out there in 1911 and 1925.

A new area emerged with the discovery in 1899 of copper in volcanic rocks in the Settlement Creek Valley, near Wollogorang homestead. In 1912 some mining took place in the Seigal Volcanics in the headwaters of Branch Creek, and in 1916 Mr Masterton discovered copper at Redbank. Masterton mined Redbank alone until his death in 1961, and discovered most of the deposits in this area. His is the only production of note from the McArthur Basin to date - about 1 000 tonnes of ore averaging 25-52 percent Cu.

A revival of interest in the basin occurred after the Second World War. Consolidated Zinc investigated Redbank and McArthur River in 1948 and 1953. Enterprise Exploration investigated the Bulman deposits and carried out a regional reconnaissance in 1952-1958. BHP carried out a reconnaissance of eastern Arnhem Land in 1954. In 1955, BHP recognised the potential of iron ore deposits around Roper River and they mapped the area and tested the deposits between 1955-58. In 1955 Mount Isa Mines commenced a widespread regional reconnaissance of the McArthur Basin, from the Roper River southeast to the Queensland Border and investigated several deposits; they have worked continuously in the area ever since.

Uranium was discovered at Pandanus Creek, just below the McArthur Basin succession, in 1955 and then at Cobar II, in the Seigal Volcanics, in 1956; Pandanus Creek produced about 215 tonnes of 8-9 percent U_3O_8 ore before 1961; Cobar II produced 795 lbs of U concentrate between 1957-59. However, the most significant development in the basin resulted from the activities of

Mount Isa Mines (later operating as Carpentaria Exploration - CEC). In 1955 siliceous gossanous outcrops containing lead and zinc were discovered at Reward and H.Y.C. Initial work was concentrated at the Reward, which proved to be a supergene enrichment containing only about 100 000 tonnes of 13 percent Pb ore. It was not until 1959 that drilling revealed the potential of the H.Y.C. deposit, and by 1965 190 million tonnes of ore averaging 9½ percent Zn and 4 percent Pb was indicated. The adjoining Cooley deposits were found by drilling about this time, and further reserves were found at W-Fold during 1973-74, but mining to date has been prevented by metallurgical problems.

Several companies carried out exploration programs during the late 1960's and early 1970's, but most were unsuccessful and only a few produced any significant new data. Western Nuclear slightly increased the reserves at Bulman. New uranium deposits were discovered and outlined at Westmoreland by Queensland Mines and BHP Co. Ltd. Ore reserves totalling about 4 million tonnes of 2.5 percent Cu have been outlined at Redbank. Australian Geophysical Pty Ltd carried out an extensive stream-sediment sampling program and outlined several anomalous areas, which were subsequently mapped in detail, in the Mallapunyah, Kilgour, Robinson River, and Calvert Hills areas.

Selected company activity

CEC Pty Ltd have been continuously active in the area since 1955. They have done detailed mapping over a wide area around the H.Y.C., and are currently concentrating on detailed drilling and mapping programs around the H.Y.C.-W-Fold-Emu Fault area. The H.Y.C. orebody has been opened by an adit, and small-scale mining is proceeding for a pilot plant to test the economics of ore treatment. They possess a wealth of unpublished data, in addition to their published and open file reports. During 1975 they outlined new copper occurrences in the Mallapunyah area in the Tooganinie, Amelia, and Mallapunyah Formations, following earlier work by Australian Geophysical.

Triako Minerals-Amdex Mining are the current operators at Redbank; a succession of other companies preceded them. They have carried out extensive detailed mapping, section measuring, drilling, and geophysics in the area, but all of the data remain unpublished. The deposits have recently been the subject of a study by the Baas Becking Geobiological Laboratory and BMR.

BHP Co. Ltd have carried out some exploration for lead-zinc in eastern Arnhem Land, summarised by Plumb (1975); they are not active at present. Uranium deposits at Westmoreland were drilled in the early 1970's. BMR holds copies of company reports of their activities before 1960, in Arnhem Land and Roper River.

Australian Geophysical Pty Ltd analysed 13 000 stream-sediment samples from the Calvert Hills-Robinson River-Mallapunyah areas during the mid and late 1960's. Anomalous areas were then geologically mapped in detail, gridded with IP and magnetic surveys, and geochemical soil samples collected on a grid basis. A few holes were drilled. Stratabound copper mineralisation was found in the Karns Dolomite, Settlement Creek Volcanics, Wollogorang Formation, Amelia Dolomite, and McDermott Formation. Very extensive reports are available on Open File in Darwin, including very useful detailed geological maps.

CRA Exploration Pty Ltd mapped areas between Bauhinia Downs homestead and Eastern Creek, and around Urapunga, during 1973. They determined thicknesses of several units and recognised an unconformity with a regolith at the top of the Reward Dolomite. Their Open File Reports in Darwin includes a good geological map of both areas, and lithologic correlation charts of the McArthur Group at Urapunga.

Western Nuclear drilled several holes and outlined some new mineralisation at Bulman during the late 1960's. Their work added little to the stratigraphy of the deposits or their geological setting, but the core is still available.

Queensland Mines Limited drilled the Westmoreland uranium deposits extensively in the early 1970's.

Enterprise Exploration Co. Ltd are no longer active, but BMR still hold copies of reports on their work in the Bulman region during the 1950's, including both regional reconnaissance and investigations of the Bulman deposits.

Australian Aquitaine investigated the oil potential of the McArthur Group during the early 1960's, and measured several sections. BMR holds copies of their reports, both in the original French, and English translations. In 1970 they carried out reconnaissance exploration in western Arnhem Land, around Mainoru and Bulman, during which they determined background metal contents for most stratigraphic units.

AGIP Nucleare Australia Pty Ltd carried out airborne radiometric and magnetometer surveys of the Tawallah Range area, and ground checked and assayed anomalies, during the early 1970's. Anomalies were due to lithological variations and superficial effects, and to a small placer of Th-U minerals in the Yiyintyi Sandstone. High backgrounds were obtained over the Scruthon and Seigal Volcanics. Palaeocurrent directions from the north and northwest were interpreted from structures in the Yiyintyi and Sly Creek Sandstones.

Kratos Uranium N.L. carried out a large airborne radiometric and magnetometer survey and ground follow-up program over the Roper Group, between O.T. Downs and Roper Bar. Their magnetic surveys successfully delineated several major structures and basic intrusives. They drilled, cored, and logged at number of holes through the Corcoran Formation, up to 400 m deep.

DRILLING

McArthur River - CEC Pty Ltd

Many thousands of metres of diamond-drill core have been drilled at and around the region of the H.Y.C. deposit, W-Fold, Cooleys, Coxco Valley. All the core is located at the McArthur River camp, except Amelia No. 1, which was donated to BMR and is held in the Cores and Cuttings Laboratory.

Redbank - Triako Minerals, and others

Considerable footage of diamond-drill core has been drilled both within and adjacent to the deposits. The core is stored at Redbank.

Bulman - Enterprise Exploration Co. Pty Ltd; Western Nuclear

The diamond-drill core drilled by Western Nuclear in the late 1960's is held by Mines Branch in Darwin. The location of the original core by Enterprise Exploration is unknown.

Westmoreland - Queensland Mines and BHP Co. Ltd

Considerable footage of diamond-drill core was drilled in the Westmoreland Conglomerate. The core was still at Westmoreland in 1972, but the present location is unknown.

McArthur River Area/CSIRO

Four stratigraphic holes near McArthur River were drilled in 1972 by BMR for CSIRO. The core is now in the BMR Cores and Cutting Laboratory.

Roper River - BHP Co. Ltd

A number of diamond-drill holes were drilled in the late 1950's to investigate the iron ore deposits. The core is now the property of Mines Branch, Darwin but is still stored at Sherwin Creek, near Roper River. The core is in good condition and has been a source of valuable material for microfossil studies.

The location of core drilled by Australian Geophysical, Kratos Uranium, and others is unknown.

OUTSTANDING PROBLEMS

The original 1:250 000 mapping of the McArthur Basin provided a geological framework, but entirely lacked any specialist studies. Many have only been revealed by subsequent analysis of the data.

New insights have come from detailed mapping by CEC and from the BMR studies, by Brown, Muir and others. It is possible to predict where major changes are likely to occur, and the general trend of future studies.

REGIONAL MAPPING

Major revision is required to the published Bauhinia Downs, Mount Young, and Wallhallow 1:250 000 Sheets, but the areas where major errors occur are already known and their revision should be a relatively straightforward. Plumb & Brown (1973) resolved the original misinterpretation of stratigraphic relationships, and CEC have already mapped in detail those areas where the corrections would have been hardest and most extensive. Other areas, already known, are mainly local mismapping, rather than major misinterpretations.

The geology of all other sheets can be readily resolved into the new stratigraphic framework, without actual changes to outcrop patterns on the face of the map - changes will mainly involve letter symbols and legends (e.g. dolerites in Milingimbi which were interpreted as sills have been shown to be basement inliers by the Alligator River Party, but outcrops remain the same).

Although major changes are not expected, new detail and corrections of odd outcrops will probably warrant second editions of all the 1:250 000 Sheets in the basin.

STRATIGRAPHIC CORRELATIONS

Lithostratigraphy

Current correlations (Fig. 3) are all lithostratigraphic. The broad groupings are consistent throughout the basin and the general correlation framework is considered to be reliable, but reassessments have revealed potential for improved correlations. Correlations requiring more detail are:

(1) Maiwok Sub-group with Cobanbirini Formation

(2) Habgood Group with McArthur Group

(3) McArthur Group of Arnhem Land with McArthur Group of McArthur River area. (Specifically subdivision of the Bath Range Formation, Vaughton Siltstone and Koolatong Siltstone, and the detailed recognition of possible equivalents from the McArthur River area. The Bath Range Formation might contain an unconformity corresponding to the Smythe Sandstone).

(4) Detailed correlation of Kookaburra Creek Formation with Amos Formation - Balbirini Dolomite-Dungaminnie Formation. (Kookaburra Creek Formation on Mount Young Sheet may be replaced by Amos-Balbirini-Dungaminnie nomenclature).

(5) Similarly, correlation of the Stott Formation with Amos Formation Balbirini Dolomite-Dungaminnie Formation (very poor outcrop of the Stott Formation is a major problem).

(6) Subdivision of Billengarrah Formation, and correlation with Batten Sub-Group.

(7) Correlation of Vizard Formation and Karns Dolomite with specific parts of the main McArthur Group sequence.

(8) The Mulholland Sandstone has been mapped inconsistently through Bauhinia Downs Sheet, and must be tied into the type section properly.
(9) A possible unconformity within Masterton Formation (Plumb & Sweet, 1974) must be checked; one may also exist at the base of the Sly Creek Sandstone).

Chronostratigraphy

Accurate reconstructions of palaeogeography and facies changes depend on a framework of isochronous reference planes through the successions. Many major rock-unit boundaries may represent catastrophic events and approximate to time lines, but all possible methods must be investigated. Isotopic age determinations provide absolute ages, and can assist confirmation of regional correlations, but are probably not precise enough for the requirements of detailed palaeogeographic and facies interpretations.

Possible criteria for establishing isochronous reference planes are:

(1) Magnetostratigraphy: Mapping polar reversal patterns probably has the best potential for establishing isochronous reference planes through the sequences at this stage. Full testing of the method is essential.
(2) Volcanics: K-rich tuffs occur abundantly in the McArthur Group in thin beds and are easily mapped. They approximate to isochronous beds and provide, at least, local time lines.
(3) Fossils: Probably only gross correlations are possible; they may be more indicative of environments.
(4) The application of Walther's Law to the interpretation of vertical and horizontal successions of facies.
(5) Significant depositional events, e.g. sudden transgressions; influxes of terrigenous detritus related to uplifts, may be traced through different facies.
(6) Regional unconformities, provided that they can be clearly related to some penecontemporaneous rather than diachronous event.
(7) Other regional tectonic events (e.g. uplift producing influx of terrigenous detritus which may be traced through several facies.

Isotopic age determinations

All possible rock types - shales, glauconites, igneous rocks - within the McArthur Basin have been tried, using standard Rb-Sr and K-Ar methods, but only a few have provided even approximate results (Fig. 5).

Two new avenues exist for possible improvement in absolute time control of the age of the basin.

(1) Zircon dating: Suitable zircons should be readily available from

(a) acid volcanics immediately underlying the basin - Cliffdale, Scrutton, Fagan, Bickerton, Spencer Creek, Edith River Volcanics - and their associated granites - Nicholson, Caledon, Kimbu, Grace Creek, Malone, Jim Jim, etc. As many as possible should be dated to give age control of the base of the basin.

(b) acid volcanics and intrusives near top of Tawallah Group - Hobblechain Rhyolite Member, Tanumbirini Volcanic Member, Packsaddle Microgranite, intrusives near McArthur River.

(c) porphyritic volcanics in lower McArthur Group of southeast Mount Young Sheet area may be sufficiently acid to provide zircons.

(d) K-rich tuffs in McArthur Group, suitable results from similar tuffs are obtained from Mount Isa (R.W. Page, pers. comm.).

(e) Yalwarra Volcanic Member contains mixed acid and basic fractions in agglomerates.

(f) A concerted attempt should be made to obtain zircons from the dolerite sills intruding the Roper Group. It may be possible to find sufficiently acid granophyric phases to increase the yield.

(2) Shale dating: Shale dating from the McArthur Basin may be suitable - if combined with careful mineralogical studies and separation of the suitable clay fractions, as described by N. Clauer and others from the Centre de Sedimentologie at Geochimie de la Surface, in France. If the method can be made to work, a wide range of formations should be available through the sequence.

PALAEOGEOGRAPHY AND SEDIMENTOLOGY

Detailed interpretation by sedimentologists, palaeontologists, geochemists, and other specialists, of the palaeonenvironments and palaeogeography of the basin, is the prime need in the analysis of the McArthur Basin. The 1:250 000 mapping was carried out without any specialist knowledge of sedimentology and without benefit of detailed mapping and observations. No palaeocurrent analyses were made. Most interpretations of environments are therefore fairly superficial, although the gross features of some units place obvious constraints on their palaeoenvironments. More detailed data have become available from the recent work of Brown on the McArthur Group, Muir & Diver during 1975 on the Amelia Dolomite, and from Walker and others (1977) on the McArthur Group.

The potential studies fall into three major groups.

McArthur Group and equivalents: This is the key unit of the basin. It is the most important economically. It comprises a wide variety of carbonate rocks, readily amenable to detailed environmental analysis. A variety of facies can be readily recognized, mapped, and related to modern environments. The abundant carbonates place constraints on interpretations of regional tectonics and climates.

The whole succession must be investigated, not just those parts associated with mineralisation. A feature of the present palaeogeographic interpretation is that initial sedimentation was widespread, and then became restricted to areas within the Batten Trough; it is postulated that during the deposition of the H.Y.C. orebody the surrounding areas were being subaerially eroded. This may be critical to concepts of the origin of the ore deposits and must be evaluated by study of the whole basin.

Tawallah Group and equivalents: This essentially comprises clastic terrigenous sediments, with some carbonates. Study of the succession is important to establish the basin's evolution prior to the McArthur Group. Data on palaeoenvironment, provenance, and directions of sediment transport may be of broad significance to the tectonic histories of surrounding regions, such as the Pine Creek Inlier and Mount Isa Orogen.

A particular problem is the origin and environment of the thick, widespread uniform quartz-sandstone sheets which are common throughout the McArthur Basin, and other mid-Precambrian basins of the world.

Roper Group: This group comprises clastic terrigenous sediments, but with more lateral variations than in the Tawallah Group. The overall sequence resembles a mollase-type facies, which is an enigma in its tectonic setting. The rocks are noted for their abundance and variety of sedimentary structures. A complex of fluvial, transitional, and shallow-marine facies is indicated at this stage.

The pure well-sorted Abner and Bessie Creek Sandstones are again widespread sand-sheets, but are almost certainly of different origin to those of the Tawallah Group.

Palaeocurrent and provenance studies will assist interpretation of the tectonics of surrounding areas, such as the Victoria River Basin: initial examination suggests source directions from the south and west, where little is known of the history during this time interval.

IGNEOUS PETROLOGY

Basic volcanic and intrusive rocks occur at several levels, but mostly in the Tawallah and Katherine River Groups. Exposures are usually very deeply weathered. The BMR Westmoreland Party has analysed some of the Seigal Volcanics from the southern Calvert Hills Sheet - the best outcrop of the unit. Elsewhere, drilling is necessary to obtain material suitable for study, and the areas are generally very inaccessible.

The volcanics form part of an extensive basic igneous province extending from the Mount Isa-Cloncurry to Katherine-Darwin regions. Present detailed data from the Mount Isa-Cloncurry region reveal geochemical trends which can be related to crustal types. Extension of the studies across the province may provide useful regional tectonic data.

A low priority is assigned to this study at this stage, within the aims of the McArthur Basin Project itself.

PALAEONTOLOGY

Precambrian palaeontology is rapidly expanding. Abundant stromatolites have long been known from the McArthur Basin, and abundant microfossils have recently been found (Croxford and others, 1973; Hamilton & Muir, 1973; Muir, 1974; Oehler, 1976; Oehler & Croxford, 1976). The thick sequence and wide areal extent of fossiliferous rocks provides an opportunity for the application of clastic biostratigraphic techniques to their study. The microfossils and stromatolites are closely associated, and their studies can be integrated to assess stromatolite morphology in terms of environmental factors or the species of organisms forming them. Potential applications are listed below.

Biostratigraphic correlation

The extent of fossiliferous beds allows at least local assessment of biostratigraphic correlations, using both stromatolites and microfossils. Integration of these methods allows considerations of which features of stromatolites are organically controlled, and therefore of evolutionary significance, and which features are environmentally controlled.

Palaeoenvironments

Comparison of modern-day and fossil stromatolites has long been used to indicate palaeoenvironments. Preliminary study by Muir and Diver (pers comm, 1975) is showing a correlation between microfossil assemblages and the palaeoenvironments in the Amelia Dolomite. Other facies, such as the H.Y.C. Pyritic Shale Member (Oehler & Croxford, 1976) and the Roper Group, have distinctive assemblages. Many features of the microfossil assemblages are found within modern assemblages.

Ore genesis

Most mineral deposits in the McArthur Basin have microfossils associated with them. The fossil assemblages are generally specific to a particular deposit. Some species are characterised by the presence of metals and sulphides within their cell structure. Stromatolites are also found near certain deposits.

It is still not known whether there is a genetic connection between the ore deposits and the fossils, or whether it is a coincidence of suitable depositional environments for both. Even if the organisms have not contributed to the formation of the ore-bodies, they still provide constraints to the depositional environments. Systematic study is required as an aid to theories of genesis of mineral deposits, and indicators for use in mineral exploration.

STRUCTURE AND TECTONICS

Structural analysis

Deformation of the McArthur Basin has been mainly by faulting. The faults can be easily traced on aerial photographs during regional mapping, and the two-dimensional geometry of the fault pattern is well known. Actual fault planes are rarely visible on the ground, and the attitude of the faults at depth is generally unknown. Although the stratigraphic displacement of individual faults is readily estimated, the true directions of movement are not conclusively known. It has been postulated that the fault system is largely the result of horizontal strike-slip movements. The pattern of movements may provide a model for the structural evolution of a typical Precambrian epi-cratonic basin. The nature of the faults and fractures and the stress field producing them may control whether the faults could provide channel-ways for ore solutions. The long-term movement pattern is of significance to palaeo-geographic reconstructions.

Form of major tectonic features

A fundamental concept in the evolution of the McArthur Basin is the hypothesis that the Batten Trough was a syndepositional graben, with sudden changes in the depositional thickness at the bounding faults. The concept is also critical to the genesis of the H.Y.C. orebody, which is situated immed-iately adjacent to the bounding Emu Fault. The concept is derived from the observation that sequences on the shelves are much thinner than in the trough, although the sequences are separated by tens of kilometres and the critical exposures near the bounding faults are nearly always concealed by younger cover. It is not known for certain whether the changes in thickness occur suddenly at the faults, or gradually over tens of kilometres. Subsurface data - drilling or geophysics - is required to prove or disprove this concept.

Structural effect of evaporites

Abundant halite casts have long been known from the McArthur Group. Recently abundant gypsum and anhydrite pseudomorphs, including bedded gypsum up to 30 m thick, have been identified (Walker and others, 1977); the original minerals have been replaced by dolomite and silica. Such evaporites present some potential for diapiric activity and investigation is required to determine whether some of the structures in the area (e.g. domes and restricted depress-ions such as the Bulburra Depression) could have been localised by diapirism of the evaporites.

Tectonic evolution of the basin

It is postulated that the major faults of the McArthur Basin are long-lived structures which existed before the basin developed, were active during sedimentation in the basin, and deformed it after deposition ceased. Differential movements produced major structures such as the Batten Trough and Urapunga Tectonic Ridge. Recent analysis suggests that local uplifts may also have been significant in areas such as the Tawallah Range. All possible evidence such as palaeoenvironments, provenance, palaeocurrents, must be used to test these theses, so as to develop a picture of the evolution of the McArthur Basin.

ORE GENESIS AND MINERAL EXPLORATION

The H.Y.C. deposit represents a classic model for studying the genesis of stratiform deposits, and thus provides exploration guides for the discovery of further deposits in areas such as Arnhem Land and the Northwest Queensland Province. The extensive carbonate rocks of the area also provide an opportunity for undiscovered Mississippi Valley-type deposits.

Many formations in the McArthur Group and upper Tawallah Group provide suitable facies for large low-grade sedimentary copper deposits, and detailed stratigraphic and sedimentological assessment is required to identify aereas of potential deposits.

The Kombolgie Formation, Yiyintyi and Mattamurta Sandstones, and Westmoreland Conglomerate, are all derived from uraniferous Lower Proterozoic basement and must have potential for sedimentary uranium deposits.

The specific problems associated with ore genesis and mineral exploration are:

Lead and zinc

(1) Detailed depositional environment of the H.Y.C. Pyritic Shale Member.
(2) Environment and origin of the Cooley Dolomite Member.
(3) The relationship between the H.Y.C. Pyritic Shale Member and the Cooley Dolomite Member.
(4) Identification of the source of the H.Y.C. metals.
(5) Further assessment of volcanic contribution to the H.Y.C. mineralisation.

(6) The genetic relationship between the H.Y.C, and disseminated sulphides in underlying dolomites.
(7) Relationships between the H.Y.C. and evaporites.
(8) Relationships between mineralisation and organisms.
(9) Roles of evaporites, sabkhas, dolomites, groundwater leaching of bedrock, in the genesis of mineralisation.
(10) Significance of the Emu Fault (structural control of the Bulburra Depression? Channey-way for mineralising solutions?) to the development of the H.Y.C.
(11) Structural controls responsible for the localisation of the Bulburra Depression (Emu Fault? Diapirism of evaporites? Intersection of regional structures?).
(12) Detailed geological setting and origin of the Bulman deposits.
(13) Recognition of formations and localities with potential for Mississippi Valley-type mineralisation.
(14) Identification of indicators (geochemical, structural, sedimentological, biologic, volcanic, geophysical) for the exploration of concealed deposits in other areas.

Copper

Most of the strata-bound copper mineralisation is associated with shallow-water carbonates and red-beds in the Umbolooga Sub-group and Tawallah Group. Terrigenous rocks are generally the hosts, but specific types of dolomite (e.g. "gypsum marbles") are often nearby. Detailed microscopic studies reveal very fine-grained disseminated chalcopyrite in rocks which are barren in hand specimen.

The principal problems are:

(1) Search for very fine-grained disseminated copper.
(2) Precise stratigraphic and structural setting of copper mineralisation.
(3) Depositional environment of strata-bound copper.
(4) Comparisons between deposits.
(5) Associations with vulcanism, evaporites, sabkhas, and organisms, and their roles in ore genesis.
(6) Mineralogical and geochemical comparisons between copper in sedimentary rocks, volcanic rocks, and breccia pipes (Redbank).

(7) Comparisons (depositional environments, structural setting, stable isotope compositions, etc.) between copper and lead-zinc mineralisation.
(8) Exploration guides to copper deposits.

Iron

Although uneconomic, the iron deposits of the Roper River region contain the classic four facies of iron formation - sulphide, carbonate, silicate, and oxide (James, 1954). Microfossils are also abundant. The simple structure and unmetamorphosed nature of the deposits provide an exceptional opportunity to study the palaeogeography and depositional environments of such mineralisation.

Uranium

Detailed sedimentology of the basal arenite units of the McArthur Basin sequence is necessary to assess their potential for bedded uranium deposits.

OUTLINE OF STUDIES

STUDY AREAS (See Fig. 10)

1. McArthur River area

This is the key area of the Basin, and corresponds to the southern part of the Batten Trough. The whole sequence is represented, and the area contains the best exposures in the McArthur Basin. The area contains the H.Y.C. deposit and most of the other known mineral deposits. It is the area where the basic model of the basin was evolved. It is the most rewarding area for detailed study. There are two main areas:

1A. The area of best exposures; these occur in the extreme south and they gradually deteriorate northwards.
1B. Poor to moderate exposures. The sandstones of the Tawallah and Roper Groups stand up as bold strike ridges. The carbonates of the McArthur Group are commonly deeply weathered and silicified, and occupy the valley areas

between the sandstone ranges. Lutites are rare in outcrop.

Initial studies should commence in the southern part of 1A, and progress northwards into the more weathered areas of 1B.

2. <u>Eastern Arnhem Land</u>

This is the northern extension of the Batten Trough. It contains similar sequences, and has a similar evolution, to the McArthur River area. The exposures of the McArthur Group are moderate to poor and are generally deeply weathered and silicified. The area has potential for an H.Y.C.-type ore-body. However, the area cannot be interpreted effectively without extensive experience in the McArthur River area first. Logistic problems occur, because the area lies within the Arnhem Land Aboriginal Reserve.

The main areas, as outlined on Figure 9, are:

2A. Mostly McArthur Group.
2B. Mostly Parson's Range Group.
2C. Mostly Habgood Group.

3. <u>Tanumbirini - Urapunga areas</u>

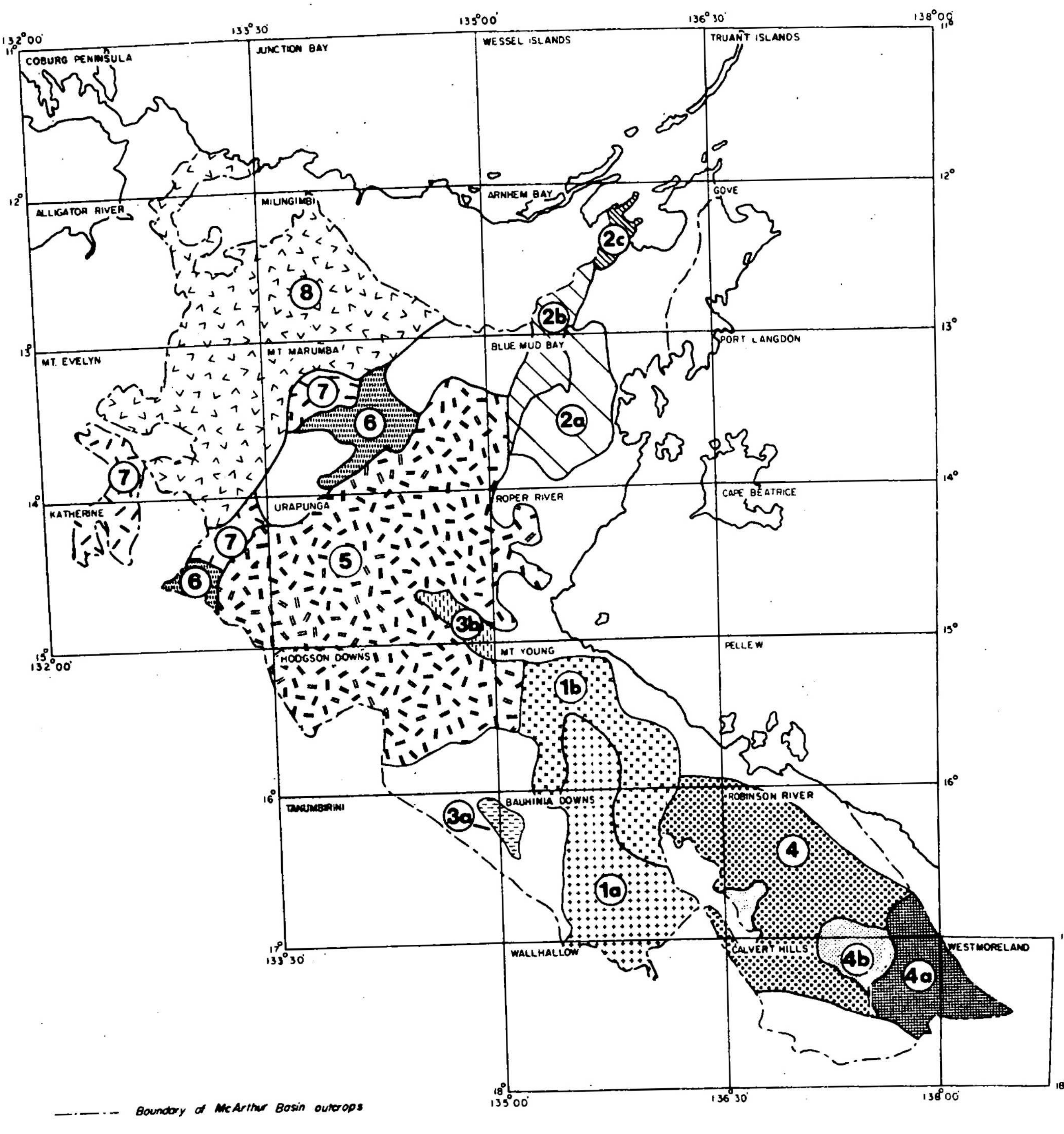
These are the only two areas in the south where inliers of the McArthur and Tawallah Groups are exposed west of the Batten Trough, so they are critical to the interpretation of the McArthur area palaeogeography.

3A. <u>Tanumbirini</u>: Outcrops are moderate to poor, but reliable correlations with the Batten Trough sequence is relatively simple. The McArthur Group lenses out in this area.

3B. <u>Urapunga</u>: The outcrops here are poor, except for key sections at Mount Vizard and Mount Reid. The sequence shows considerable facies changes from the McArthur area, and thus correlations are problematic. It is the key area for defining the Urapunga Tectonic Ridge, and thus is important to the regional palaeogeography.

4. <u>Wearyan Shelf</u>

Structure in this area is simple, with mostly subhorizontal strata. Large areas are covered by younger Cambrian and Mesozoic rocks. The mapping at 1:250 000 scale should be reliable, and 1:100 000 mapping is not warranted.



Record 1977/33 Fig 10. Nature of outcrops and proposed studies (see text for explanation). AUS 1/410

There are however important to the palaeogeography of the basin, and merits detailed study of selected sections and local detailed facies mapping of key areas. The two particular areas outlined on Figure 10 are:

4A. A complete section through the Tawallah Group. There are many differences to the McArthur River area. The units seem locally consistent, so the study will consist mainly of detailed study of specific sections. Important inliers of some units occur to the west and northwest.

4B. The principal outcrops of the Karns Dolomite, which is the only representative of the McArthur Group in this area. The unit is subhorizontal and very thin, and was deposited on a very uneven surface of the Tawallah Group. There are therefore considerable facies changes, which can only be resolved by detailed study of the available better sections.

5. <u>Bauhinia Shelf</u>

This is the principal outcrop of the Roper Group in the basin. The structure is relatively simple and the Roper Group is very easy to map. The 1:250 000 maps should be reliable and the geology may not warrant 1:100 000 mapping. The sedimentological study of the Roper Group should simply be carried out by detailed study and measuring of selected sections. These sections can be readily chosen from the existing maps and air photographs.

6. <u>Arnhem Shelf - Dook Creek Formation</u>

This is the thin Arnhem Shelf equivalent of the McArthur Group. The outcrops tend to be scattered, the bedding is subhorizontal, and facies changes seem to be common. The outcrop generally consists of different, disconnected sections through low-topped hills, and therefore it is difficult to determine a simple stratigraphic sequence. Detailed mapping will be required of key areas to determine the proper sequence and palaeogeography.

7. <u>Arnhem Shelf - Katherine River Group</u>

These are the main exposures of dipping Katherine River Group rocks around the edges of domes and basins. Access varies from reasonable to difficult, but the areas are rewarding for sedimentological study because of the compact sections available.

8. Arnhem Shelf - Arnhem Land Plateau

This area consists of flat-lying Kombolgie Sandstone. The structure is extremely simple and the area can be easily photo-interpreted. The topography is very rough and is only accessible by helicopter. The area must be attacked by sedimentological study of selected key sections, plus scattered observations of palaeocurrents.

REGIONAL AND DETAILED MAPPING

1:100 000 Mapping

The areas of potential 1:100 000 mapping are summarised in Figure 11.

1. McArthur River Region: As outlined previously, this is the key area of the McArthur Basin and all, or parts, of the fourteen sheets outlined require 1:100 000 mapping. The areas are summarised in more detail in Figure 12.

As shown on Figure 12 very few sheets require complete mapping at 1:100 000 scale; on some only very small portions need to be so mapped.

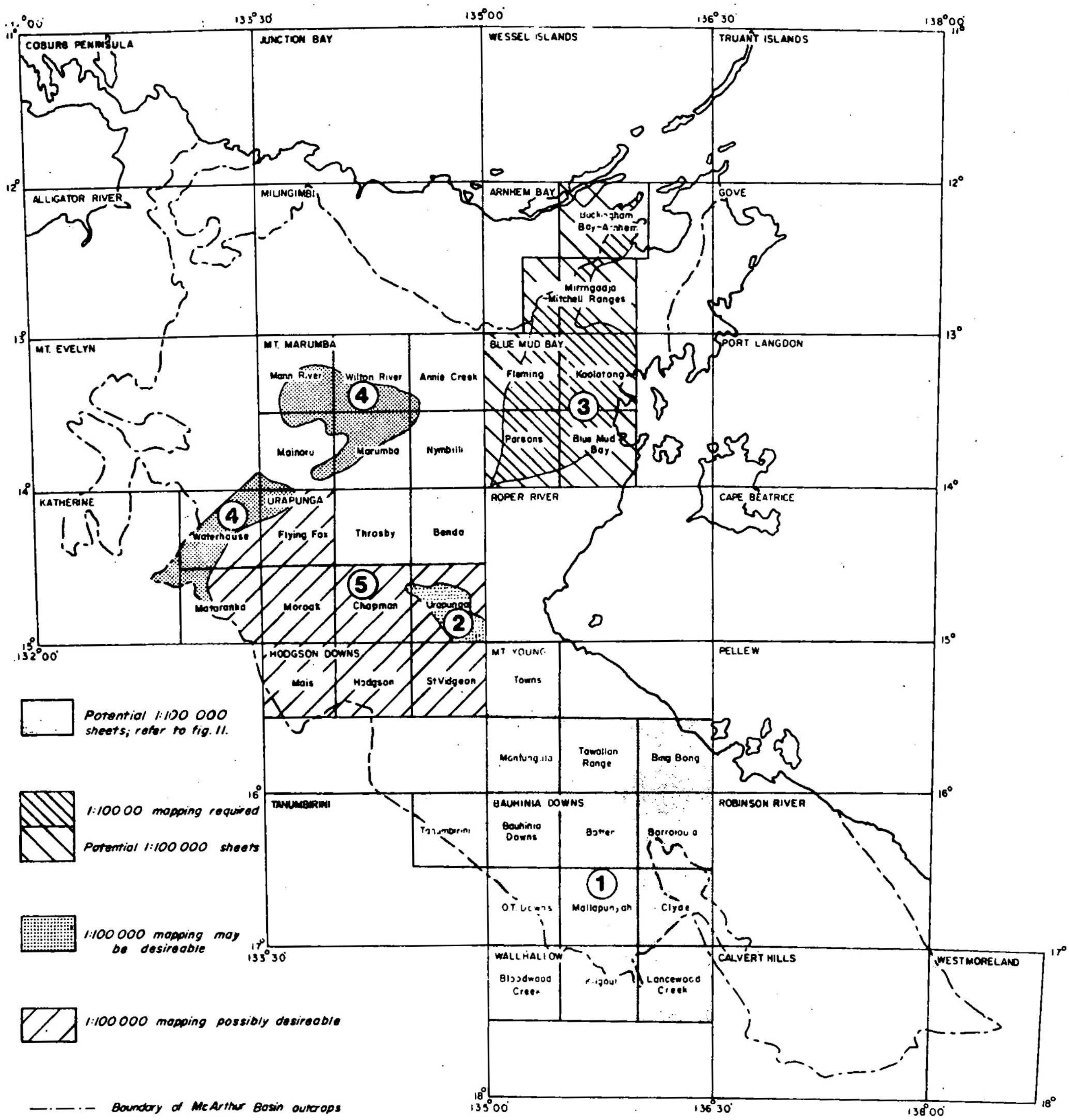
The number of sheets can be drastically reduced by combining whole or part sheet areas, as has commonly been done in the 1:250 000 series. Figure 13 shows an alternative in which the 14 sheets can be reduced to the following 6 - Mantungula-Towns, Tawallah Range-Bing Bong, Tanumbirini-Bauhinia Downs, Batten-Borroloola, Mallapunyah-Kilgour and Clyde-Lancewood. Other combinations are possible.

Apart from the obvious saving in publishing costs, many of the resulting sheets will be more meaningful, and unnecessary mapping will be reduced.

2. Urapunga: Although much of the outcrop is poor, the McArthur Group in this area is sufficiently important to warrant a 1:100 000 Sheet, encompassing part of the Chapman Sheet if necessary.

3. Eastern Arnhem Land: As the northern extension of the Batten Trough, and a prospective area for H.Y.C.-type mineralization, 1:100 000 mapping is warranted. The total area can be reduced by publication of four standard sheets - Fleming, Koolatong, Parsons, Blue Mud Bay, and two composite sheets - Mirrngadja-Mitchell Ranges, and Buckingham Bay-Arnhem.

4. Bulman-Beswick: Work in this area will require detailed observations and



Record 1977/33 — Fig 11. Potential 100 000 map sheets. (see text for explanation) — AUS 1/411

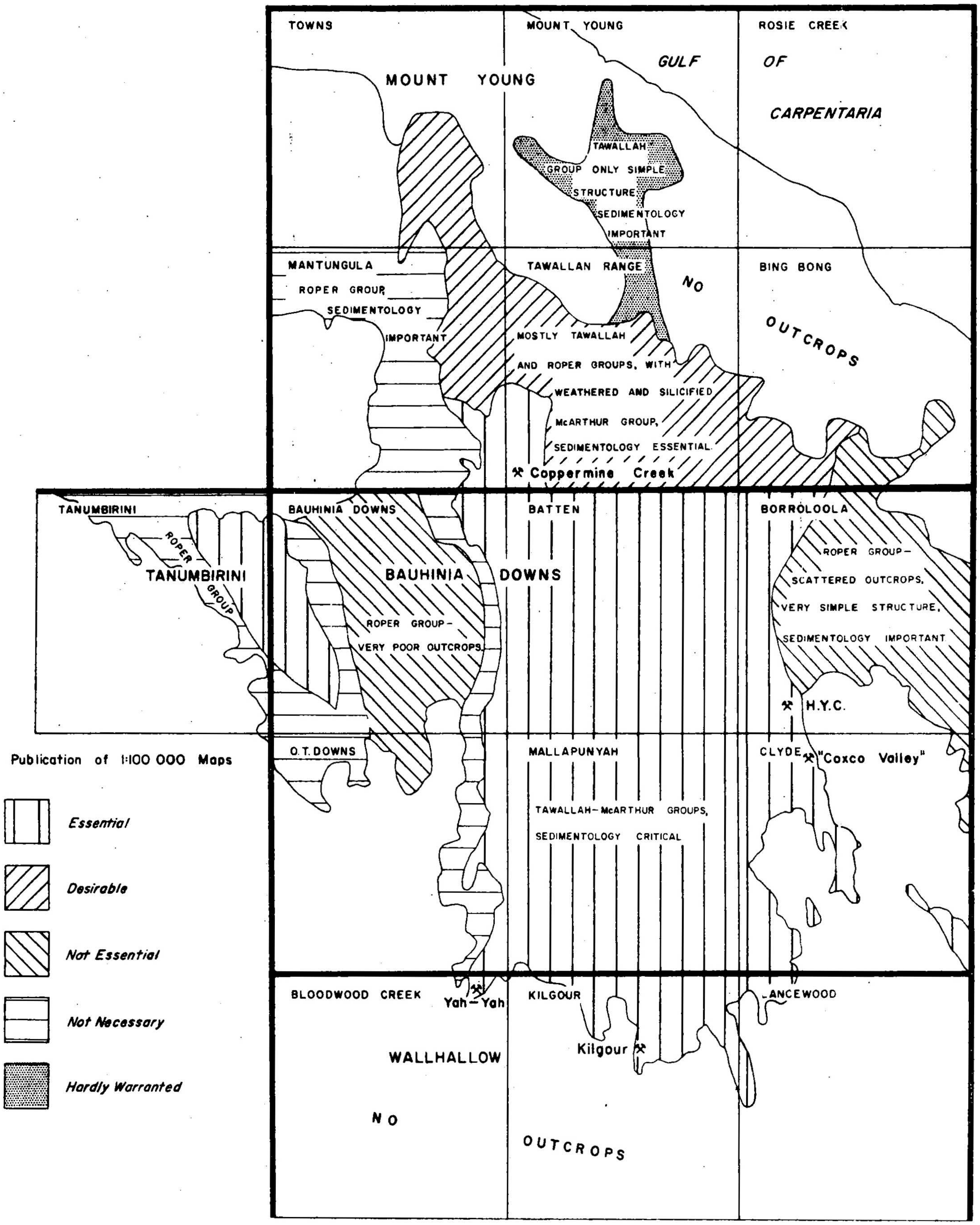


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Fig 12 Summary of 1:100 000 sheet areas — McArthur River region.

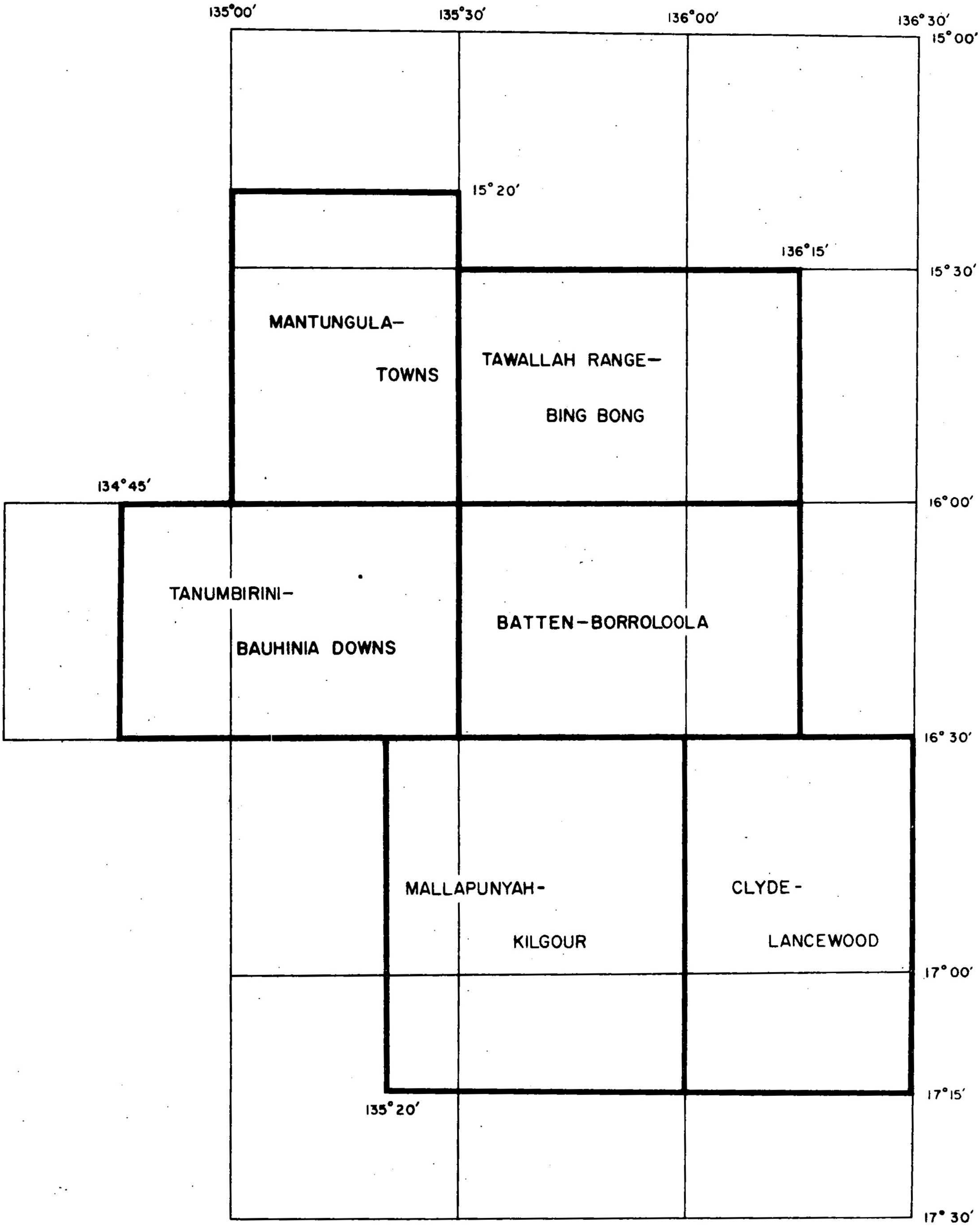

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Fig 13. Alternative 1:100 000 sheet layout - McArthur River region.

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sections. The structure is simple and the basic geology can be reasonably portrayed at 1:250 000 scale. 1:100 000 sheets may be necessary if sufficient facies subdivisions can be portrayed. Composites can reduce the number of sheets e.g., "Bulman" and "Beswick" Specials.

5. Roper River Area: Although this area will have several detailed sections measured and local areas may be mapped in detail, the type of data collected is not suitable for standard maps. The Roper Group is already rather finely subdivided and is readily portrayed at 1:250 000 scale. The cost and effort of 1:100 000 maps is probably not justified.

1:250 000 mapping

It is now known that major errors exist on parts of Bauhinia Downs, Mount Young, and Wallhallow Sheets. Much of the area in error has been re-mapped by CEC and the other changes can be readily anticipated. Second editions will definitely be needed.

Most of the other sheets are considered to be reasonably reliable. No doubt this project will reveal minor errors and second editions will be warranted. However, I do not think systematic 1:250 000 mapping of the whole basin is warranted.

SPECIALIST STUDIES

Field parties will comprise field geologists, primarily involved in systematic mapping, and specialists. In practice there will be considerable interchange. The field geologists will collect much of the basic data for the specialists. The specialists will concentrate on key areas and sections, and their detailed mapping will contribute to the systematic mapping. As the project progresses it would be desirable if some of the field geologists could become involved in special studies themselves, under appropriate direction and advice.

Sedimentology

This will comprise a major part of the project, involving the standard techniques of measured sections, petrography, facies mapping, palaeocurrent analysis, and so on. Two major branches are involved, requiring different

individuals.
Carbonates - McArthur Group and equivalents, and the Wollogorang and McDermott Formations of the Tawallah Group. This is the major study of the project. Much data will be contributed by the palaeontologists. Carbonate geochemical studies are also critical.
Terrigenous clastics - The Tawallah and Roper Groups and their equivalents. Of particular interest is the palaeocurrent analysis, and the interpretation of the widespread quartz-rich sandstone sheets.

Palaeontology

Two special studies are involved - stromatolites and microfossils. Both are intimately associated in the field and, since understanding of the stromatolites requires knowledge of their contained microfossils, the two studies must be carried out jointly. The palaeontological field work will involve considerations of stratigraphy and sedimentology, and will thus contribute to these studies, and will, itself in turn, depend on the detailed stratigraphic framework provided from the systematic mapping.

Geochemistry

Three main aspects are involved.
(a) Stratigraphic distribution of elements: rock samples will be collected from selected measured sections and drill holes, and analysed for appropriate major and minor elements which will give information on the depositional environments of the rocks, and provide exploration indicators.

Work will concentrate principally on the McArthur Group, with major effort in the Umbolooga Sub-Group. Some work has already been done, by Brown and others (1969), and Lambert & Scott (1973), but the stratigraphic coverage of those studies was limited. The results obtained were much as expected, although there has been some criticism about the choice of elements. The elements to be analysed will be selected by the appropriate specialists.
(b) Carbonate geochemistry: this is concerned with (a) above. It is now a very specific field, concerned with the relationships of element distributions and depositional environments. It requires extensive knowledge of modern environments, carbonate mineralogy, processes of carbonate sedimentation, diagenesis, recrystallisation, and dolomitisation, and the movements of ele-

ments which occur during these processes. The work will proceed in intimate association with the sedimentological studies. A knowledge of the movement of elements is crucial in assessing the possible roles of diagenesis, dolomitisation, brines, and leaching in the genesis of base-metal deposits.

(c) Base metals: this will study the stratigraphic and regional distribution of base-metal anomalies. The work by Lambert & Scott (1973) revealed some regional zinc anomalies in drill-core which has were not reported from surface outcrops by Brown and others (1969). Diamond drilling may be needed to obtain reliable results, perhaps as "calibration sections" to tie in with the more numerous surface sections. The study will be relevant to possible exploration indicators and palaeoenvironments, particularly if certain horizons are anomalous over wide areas.

The microchemistry and trace elements of the sulphides from as many environments as possible, including volcanic material such as Redbank and the Seigal Volcanics, might produce patterns which can be used as environmental signatures for the origin of the deposits.

Samples will come from both the known deposits and from any minor disseminated sulphide material found during the detailed studies. Formations so far known to include disseminated sulphides are: Amelia Dolomite, Toogan-inie Formation, Mitchell Yard Dolomite Member, Barney Creek Formation, Reward Dolomite, Karns Dolomite, Wollogorang Formation, McDermott Formation, and the basic volcanic units - Gold Creek Volcanic Member, Settlement Creek Volcanics and Seigal Volcanics.

Most of the known small copper deposits (Table 2) consist of secondary carbonates, oxides and sulphides at the surface; drilling may be needed to obtain fresh sulphides.

Stable Isotopes

Carbon and oxygen. Carbon and oxygen isotopes in carbonates can provide indications of (1) the compositions of the solutions from which they were deposited: (2) the diagenetic processes which have taken place and the compositions of the diagenetic solutions;

(3) the processes and timing of dolomitisation;

(4) the contribution of organically derived carbon to the formation of the carbonate;

(5) possibly, the evolution of the atmosphere.

Systematic measurements from carbonates throughout the sequence should be undertaken in close association with the sedimentology, carbonate geochemistry, and palaeontology studies.

Oxygen isotopes of sulphate minerals can provide data on the palaeotemperature of their formation, and possibly, palaeoclimates, they should be measured where available. Most evaporitic minerals are now replaced by dolomite, so material may be scarce.

Carbon isotopes, and hydrocarbon analysis of carbonaceous matter and kerogens, can indicate the thermal and metamorphic state of the kerogen, and the relative contributions from various organisms. The metamorphic state can be used to obtain qualitative comparisons of the maximum depth of burial of the kerogen. A regional spread of such measurements, compared with the postulated depths of burial based on stratigraphy, might indicate areas of anomalous burial depth, and therefore indicate areas of syndepositional uplift or downwarp, which were not immediately apparent from the stratigraphy. Preliminary estimates of carbonaceous matter from the H.Y.C. orebody (Taylor, pers comm) indicate depths of burial which are much less than those inferred from stratigraphic considerations. At the H.Y.C. carbonaceous shales in drill-core are available over some 500 m of section; systematic measurements through this section should be able to test the applicability of the method, generally applied to relatively young coal deposits), to the Proterozoic rocks of the area.

<u>Lead and sulphur</u>

Studies so far have been confined to the H.Y.C. and adjacent rocks. Similar results have been obtained from both lead and sulphur. Smith & Croxford (1973) obtain different sulphur isotopes from the pyrite to those in the lead and zinc, and Gulson (1975) noted similar deficiencies in the lead isotopes. From this it has been postulated that the pyrite has a different origin and source to the galena and sphalerite. However Williams & Rye (1974) pointed out that the sulphur isotopes can be explained by fractionation from a single source, while Richards (1975) noted that the lead isotopic compositions in the ore can be explained by leaching and mixing from a variety of sources in the thick sedimentary column. Small vein deposits near the H.Y.C. have a variety of compositions suggesting a different source, but Richards (pers. comm.) points out that the results are too variable and the sampling too sparse for conclusive results. An extensive, systematic studyis required to identify the sources of lead and sulphur in all the mineral deposits and country rocks.

A study of sulphur and lead isotopes could be carried out on the sulphides from the deposits listed in Table 2. Particular attention should be given to the obvious volcanic deposits, such as Redbank, and to the various disseminated bedded sulphides (lead and copper) which have not been affected by later mobilisation, in order to identify any systematic variations which may occur. Analysis of trace lead in country rocks, both sedimentary and volcanic, may also help identify sources. Selection of these samples should be left to an advanced stage of the project when specific targets can be identified.

Structural geology

This is basically a field study of small structures to support laboratory analysis of the mapped fracture patterns. Most data will come from the field geologists during mapping.

Since the major faults are rarely visible on the ground thic work must be directed at:

1. subsidiary structures associated with major faults, which give evidence of their three-dimensional form, movement direction, and stress field;
2. a study of smaller faults and joint systems, which can commonly be seen within major sandstone ranges such as Tawallah, Batten, and Yiyintyi Ranges, and which can provide data on the large-scale stress fields and movement patterns.

A statistical analysis of fracture patterns on air photographs from Arnhem Land (Roberts & Plumb, in prep.) has proved to be successful, and may be extended into several areas of the Roper River to Queensland border region.

Geophysics

Confirmation is required of the true form of the major tectonic features of the McArthur Basin - the Batten Trough and Urapunga Tectonic Ridge - and the nature of their boundaries. The use of techniques which produce inconclusive results is wasteful, so this would suggest that seismic geophysics is the only valid tool. However, seismic is undesirable for the following reasons:

(1) Penetration would be ruined by the thick carbonates of the McArthur Group;
(2) Penetration to depths of 10 km would be required over distances of tens of kilometres, making the cost extremely high;
(3) Access in the critical areas is difficult.

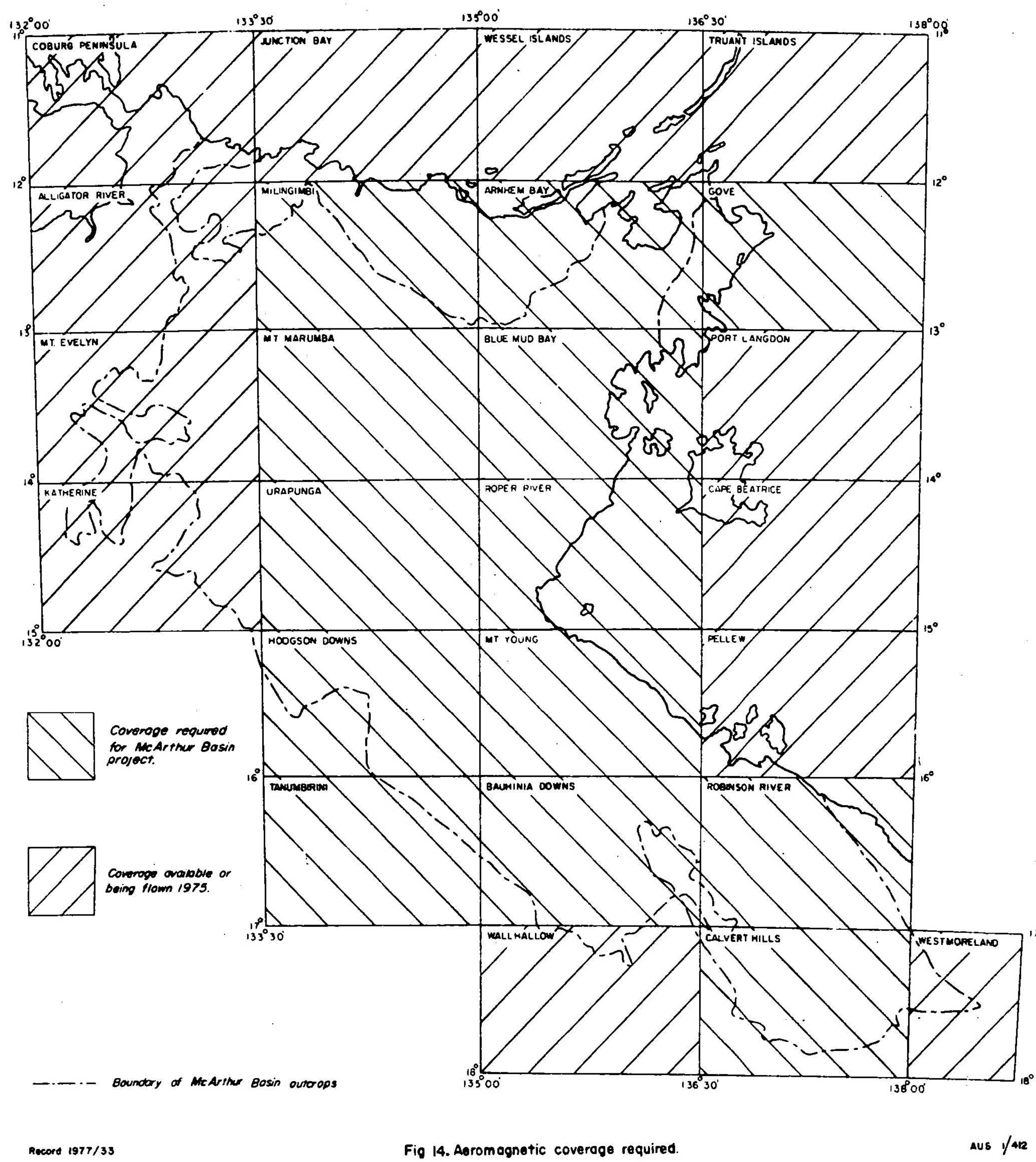
Other methods should therefore be attempted first.

<u>Aeromagnetic</u>: It is BMR policy to eventually obtain systematic regional coverage of the whole of Australia. A systematic coverage of total geological provinces is far more useful than ad hoc coverage of individual sheet areas, and makes interpretation more meaningful. The effort will be far more useful if applied to an area where BMR is currently working and interpretation will be enhanced by the opportunity for geophysicists and geologists to work in close liaison.

It is recommended that aeromagnetic coverage of the whole of the McArthur Basin should be obtained as early as practicable in the project. Figure 14 shows the coverage now available. Thirteen 1:250 000 Sheets are required to complete the basin. These can be flown more economically as a group and maximum benefit would accrue to the project by the availability of the full coverage. If a split is required the southern sheets - Bauhinia Downs, Robinson River, Tanumbirini, Calvert Hills, Mt Young, Hodgson Downs, Urapunga and Roper River - are required first, in that order.

The available data from Bauhinia Downs (Young, 1965) shows that the major structures can be readily obtained from aeromagnetics, so coverage of the basin will allow the major structures to be traced through many areas of no exposure, and allow better definition of the distribution of the Batten Trough, Urapunga Tectonic Ridge, and so on. The basalts in the sequence make calculations of depth to basement difficult but, with an overview of the whole Basin and close liaison with the geologists, it may be possible to filter out these effects and make meaningful calculations.

<u>Gravity</u>: The present regional gravity coverage of the McArthur Basin shows very little of the regional structure, probably due to the sparse data.



Record 1977/33

Fig 14. Aeromagnetic coverage required.

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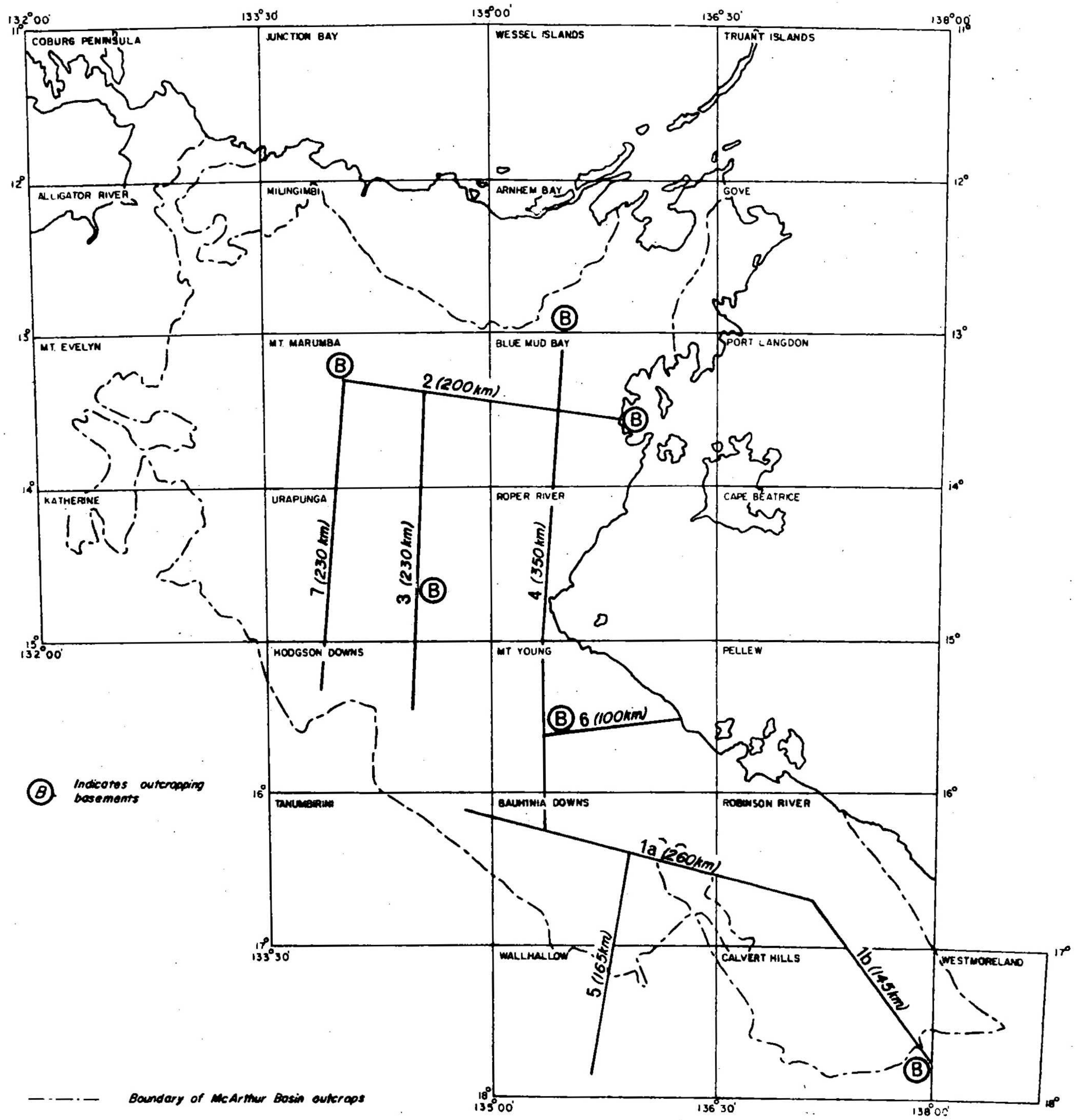


Record 1977/33

Fig.15. Proposed gravity traverses

AUS 1/413

Anfiloff (pers. comm.) considers that detailed single-line traverses should identify the major structures and, with adequate geological control, gravity modelling should indicate whether the current hypotheses of the form of the major structures are feasible.

The regional coverage suggests a very low density contrast between the sediments and the underlying basement. This is to be expected with the prevalence of low-grade metamorphics and granites in the basement. One of the major density contrasts appears to originate from the dolomites of the McArthur Group itself, and this might greatly assist the interpretation of critical features.

Because of these problems in gravity modelling, it is essential that extensive coverage be made over the areas where the geological section can be confidently predicted, to develop density values, for modelling over the unknown areas.

Suggested traverses, totalling 1675 km, are outlined on Figure 15. They are, in order of priority:

1A - 1B (400 km) - Murphy Tectonic Ridge (Basement) - Wearyan Shelf - Emu Fault - Batten Trough - Bauhinia Shelf, finishing over structural high at Tanumbirini. This section passes through the H.Y.C. and across the classic area of the Batten Trough. The section can be confidently predicted from the exposed basement along line 1B, and along the western part of 1A, to provide density data for modelling across the critical Emu Fault and the unknown area extending 50 km east of the fault. More than one line over the critical area would be a useful check.

2 (200 km) - Arnhem Shelf - Batten Trough - Caledon Shelf. A similar section across the northern Batten Trough, with control provided by exposed basement at each end.

3 (230 km) - Urapunga Tectonic Ridge. This section passes through the type area of the ridge, with exposed basement and is designed to determine its gravity expression.

4 (350 km) - Eastern Urapunga Tectonic Ridge. This will test whether Urapunga Tectonic Ridge extends eastwards into the area of no outcrop around the mouth of the Roper River. The section continues up the axis of

the Batten Trough, linking lines 1 and 2, and finishes in the basement high of Mirarrmina Complex, which is of high-grade metamorphics different to most of the area farther south.

5 / 165 km - South Batten Trough extension. This will test the possible extension of the Batten Trough southwards beneath the Georgina Basin and the westward extension of the Murphy Tectonic Ridge.

6 / 100 km - Central Batten Trough. This will test the extension of the Batten Trough into the zone of no outcrop in the northeast of Mount Young Sheet. The very sparse data suggests that it may die out in this area.

7 / 230 km - Western Urapunga Tectonic Ridge. This will test the western limit of the Urapunga Tectonic Ridge, where it is completely concealed by the Roper Group.

For reasons of interpretation the traverses have been laid out in straight lines. Poor access dictates the use of helicopters and barometer levelling. With careful design of the traverses almost no terrain correction will be necessary, and over some long distances almost no altitude correction will be required.

Ore genesis

The main problems of ore genesis in the McArthur Basin revolve around the detailed setting of the deposits within the framework of the basin. There will not be a specific single study of ore genesis but, rather, an integration of all studies to obtain an overall hypothesis of ore genesis in the basin. The outstanding problems have been listed previously. They can be summarised as follows:

Stratigraphy: The detailed stratigraphic setting of all mineral deposits and the identification of patterns and common features;

Sedimentology: The detailed depositional environments of all the stratabound deposits, and identification of any common features and patterns, including a specialist study of the H.Y.C. Pyritic

Shale Member and the Cooley Dolomite Member. The investigation of consistent associations of mineralisation with possible sources such as volcanics, evaporites, red-beds and organisms. The contribution of sedimentary processes such as diagenesis, dolomitisation, to mineral-forming processes;

Structure: The structural settings of the deposits:

Palaeontology: The significance of the association between fossils and mineral deposits;

Geochemistry: The anomalous geochemical features associated with ore-bearing strata. The macro and micro-geochemical features of mineralisation, and comparisons between the different types and environments. Specific comparisons between the definitely volcanic and the definitely sedimentary deposits;

Stable isotopes: The comparison of isotopes between the different deposits throughout the column, with particular reference to comparisons between definitely sedimentary and definitely volcanic deposits. Isotopic analysis of country rocks to identify sources of minerals.

COMPANY PARTICIPATION

Many of the types of investigations outlined here have been, or are being, carried out by companies in various areas. This involves not only direct studies of ore bodies, but detailed mapping and stratigraphic studies. Competition and duplication of effort should be avoided and co-operation between BMR and companies in the overall project is to be encouraged. This should go far beyond the supplying of company data to BMR. The appropriate companies should be invited to participate in the BMR program actively.

Any studies of specific ore bodies must be carried out and published jointly with company personnel. Companies may be invited to second geologists to the BMR field parties, to enable them to participate in the mapping and special studies where they have particular expertise, or knowledge of specific areas. Company personnel may also spend periods in Canberra to assist in laboratory studies, writing of publications, and map compilation, and BMR personnel might spend periods in company establishments. Such co-operation will be of joint benefit to all the organizations concerned.

Restrictions will probably be necessary in the access of company personnel to other properties, and the availability of confidential information; these problems can be dealt with as they arise. Since we will be dealing mainly with data for publication, confidentiality will not be a major problem, particularly if the main assessment is carried out by company personnel.

The most obvious possibility for such co-operation is CEC Pty Ltd, who have worked in the region now for some 20 years, at both detailed and regional scale. No useful assessment of the McArthur deposits is possible without their involvement, and they have also carried out detailed mapping of a significant portion of the McArthur River area.

Other possibilities are Triako Minerals and Amdex Mining - Redbank area; CRA - Mount Young to Urapunga area; BHP - eastern Arnhem Land. Full assessment of possible company contributions can only be made after consulting the files of Mines Branch, Darwin.

BAAS-BECKING LABORATORY

The project as outlined is basically a BMR regional study and, as such, depends principally on BMR personnel. However some co-operation with the Baas Becking Laboratory is planned particularly in the following fields.

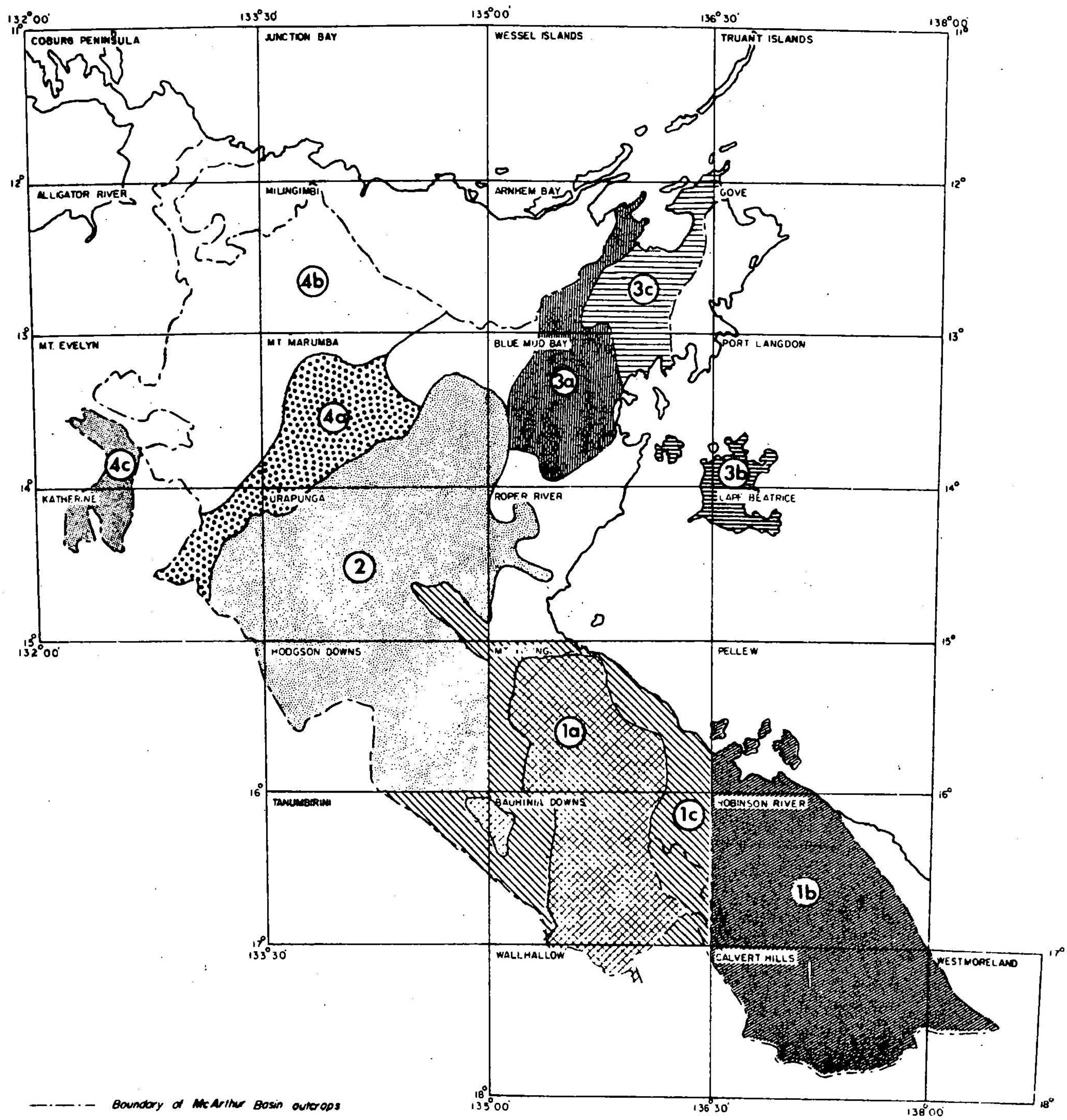
1. Studies of modern environments and comparison with the McArthur Basin palaeoenvironments;
2. The geochemistry of the base metals and associated elements, mineragraphy, and other laboratory studies of mineral deposits;
3. Stable isotope studies.

PROGRAM

SUMMARY PROGRAM

General Program (Figure 16)

Stage 1 - "McArthur River Region" - 10 years.
Detailed study, mapping and reporting of type area of McArthur Basin.



Record 1977/33

Fig 16. Proposed program (explanation in text).

AUS 1/414

Stage 2 - Roper Group - 3 years
Complete detailed study and reporting of Roper Group; overlap Stage 1.

Stage 3 - Eastern Arnhem Land - 5 years (Overlap stages 1-2)
Detailed study, mapping and reporting of northern Batten Trough.

Stage 4 - Western Arnhem Land - 3 years (Overlap stages 1, 2, 3)

Finale - 2 years. Prepare final Bulletin synthesising geological evolution and mineral deposits of whole McArthur Basin.

Total time (with overlaps - About 12 years).

Detailed Program - Stages 1-2

Year 1 Pilot studies and reconnaissance.

Year2-3 Field geological studies - Mallapunyah-Kilgour; Clyde-Lancewood, Batten-Borroloola Sheets. Aeromagnetic coverage of McArthur Basin. Basin-wide gravity and magneto-telluric traverses.

Year 4 Laboratory studies, map compilation, progress reports.

Years 5-6 Field geological studies - Tanumbirini-Bauhinia Downs, Tawallah Range-Bing Bong, Mantungula-Towns, Urapunga Sheets. Specialist studies on Wearyan Shelf (Stage 1b), and Roper Group (Stage 2).

Years 7-8 Complete all studies. Map compilation, progress reports.

Years 9-10 Finalise all studies. Prepare all maps and Stage 1-2 final reports for publication.

Years 11-12 Finale. Complete outstanding publications. Synthesise whole McArthur Basin.

GENERAL PROGRAM

The total project is immense, and detailed programming at this stage is only a general guide. Flexibility is essential, especially to allow for unforseen variations in staffing and finance.

The project may be divided into broad stages and time limits estimated, assuming full staffing. In practise these stages will overlap. Some field personnel should be transferred to Stages 3-4, probably about Years 4 or 5, only after gaining appropriate experience in the better exposed areas of Stage 1. This will require an overall increase in staff, if both areas are to be completed according to program.

The areas covered are shown in Figure 16. A detailed program has been worked out so far only for Stages 1-2.

1. "McArthur River Region" (10 years)

(a) Measure sections, map in detail, and carry out detailed studies of the sedimentary, palaeocurrents, palaeontology, geochemistry, stable isotopes, and palaeogeography of the Tawallah, McArthur, and Roper Groups within the Mount Young, Bauhinia Downs, Wallhallow, and Tanumbirini 1:250 000 Sheet areas (1A, Fig. 16).

(b) Measure sections and carry out detailed studies of the Tawallah, McArthur, and Roper Groups in selected areas of the Robinson River, Calvert Hills, and Westmoreland 1:250 000 Sheet areas (1B, Fig. 16).

(c) Map in detail, measure sections, and carry out detailed studies of the McArthur and Tawallah Groups in the Urapunga 1:100 000 area (1C, Fig. 16).

(d) Determine the stratigraphic and structural setting, palaeoenvironments, palaeontology, geochemistry, mineragraphy, and stable isotope compisitions of the mineral deposits of the "McArthur River Region" (all of area 1, Fig. 16), and identify factors relevant to their genesis and exploration for further deposits.

(e) Study the structural geology and tectonic evolution of the McArthur Basin in the "McArthur River Region".

(f) Complete aeromagnetic coverage of the whole McArthur Basin (Fig. 14) and interpret the results.

(g) Carry out detailed gravity and/or magnetotelluric measurements along seven profiles (Fig. 15) and interpret the subsurface structure of the McArthur Basin.

(h) Publish results, as appropriate, in Records, Reports, Bulletins, BMR Journal, and outside journals.

(i) Publish 1:100 000 geological sheets of Mallapunyah-Kilgour, Clyde-Lancewood, Batten-Borroloola, Tanumbirini-Bauhinia Downs, Tawallah Range-Bing Bong, Mantungula-Towns, (Fig. 13) and possibly Urapunga (Fig. 11).

(j) Revise and publish, as necessary, 2nd editions of Mount Young, Bauhinia Downs, Wallhallow, Tanumbirini, Robinson River, Calvert

Hills, and Westmoreland 1:250 000 Sheets.

2. Roper Group (3 years)

(a) Measure sections and complete detailed studies of the Roper Group. Integrate with Roper Group studies of the "McArthur River Region".

(b) Study the structural geology of the Roper River region.

(c) Determine the environment of deposition of the Roper River iron-ore deposits.

(d) Publish results, as appropriate, in Records, Reports, Bulletins, BMR Journal, and outside journals.

(e) Publish if necessary (considered unlikely), selected 1:100 000 Sheets (Fig. 11).

(f) Revise and publish, as necessary, 2nd editions of Urapunga and

3. Eastern Arnhem Land (5 years)

(a) Measure sections, map in detail, and carry out detailed studies of the moderately exposed Parsons Range, McArthur, and Habgood Groups in the Blue Mud Bay and Arnhem Bay 1:250 000 Sheet areas (3A, Fig. 16), using models derived from the "McArthur River Region".

(b) Measure sections and carry out studies of the sedimentology and palaeocurrents of the Groote Eylandt Beds around Blue Mud Bay, and on Groote Eylandt (3B, Fig. 16).

(c) Study selected scattered outcrops of McArthur Basin rocks to the south and east of Arnhem Bay (3C, Fig. 16).

(d) Investigate the prospectivity of the McArthur and Habgood Groups in Arnhem Land by use of drilling, geophysics, geochemistry, and stratigraphy, using the McArthur River deposits as a model.

(e) Study the structural geology and tectonic evolution of the McArthur Basin in eastern Arnhem Land.

(f) Publish results as appropriate, in Records, Reports, Bulletins, BMR Journal, and outside journals.

(g) Publish, if warranted, 1:100 000 geological sheets of Fleming, Koolatong, Parsons, Blue Mud Bay, Mirrngadja-Mitchell Ranges, and Buckingham Bay-Arnhem (Fig. 11).

(h) Revise and publish, as necessary, 2nd editions of Wessel Islands-Truant Island, Arnhem Bay-Gove, Blue Mud Bay-Port Langdon, and Roper River-Cape Beatrice 1:250 000 Sheets.

4. Western Arnhem Land (3 years)

(a) Measure sections, map in detail, and carry out detailed studies of the Katherine River and Mount Rigg Groups in selected areas of the Bulman-Beswick region (4A, Fig. 16).

(b) Measure sections and carry out sedimentological and palaeo-current studies of selected areas of the Kombolgie Formation of the Arnhem Land Plateau (4B, Fig. 16).

(c) Measure sections and carry out detailed studies of the Kombolgie Formation in the Edith River and Mount Callinan Synclines (4C, Fig. 16).

(d) Make observations of the structural geology of the McArthur Basin in western Arnhem Land.

(e) Investigte the base metal potential of the Dook Creek Formation and sedimentary uranium potential of the Kombolgie Formation.

(f) Publish results as appropriate, in Records, Reports, Bulletins, BMR Journal, and outside journals.

(g) Publish, if appropriate, "Bulman" and "Beswick" Special 1:100 000 Sheets.

(h) Revise and publish, as necessary, 2nd editions of Milingimbi, Mount Marumba, Urapunga, Katherine, and Mount Evelyn 1:250 000 Sheets.

Finale (2 years)

Prepare a Bulletin and other specialist publications summarising results from, and synthesising the geological evolution and mineral deposits of, the whole McArthur Basin.

STAGE 1-2 - DETAILED PROGRAM

Ideally, the project should only commence when the necessary personnel are fully available and completely free from outstanding commitments. A detailed program is suggested only for stage 1-2 sat present; similar programs can be devised for subsequent stages later.

Most stratigraphic units in the McArthur Basin are laterally uniform over wide areas. Detailed reports describing individual 1:100 000 Sheet areas will involve unnecessary repetition because the broader view is necessary for meaningful results. Early stages of the project should emphasise field work and areal coverage; initial progress reports should only be compendia of raw data, measured sections, and the like, with a minimum of synthesis.

Two approaches to the project are possible:

(1) Initially study critical areas in detail and then fill in remaining regions later by systematic mapping.

(2) Systematically work through the basin, both mapping and carrying out specialist studies, sheet area by sheet area.

The first alternative has the advantage of obtaining a rapid overview of the whole basin and achieving, with reasonable reliability, the main aim of the project in quite a short time; its disadvantage is a patchwork of data, and a flood of maps to compile at the end of the project. The second alternative achieves a steady flow of preliminary maps, all specialist studies are tied together on the ground, and logistics are simpler. its disadvantages ia a longer period of time before the total overview is available.

The basic approach of the second alternative - systematic map-sheet coverage - is proposed here. Work will commence in the south, expand towards the H.Y.C., and then northwards into Mount Young area. In practice, many specialist studies extend over a wider area than the concurrent systematic mapping; this may be backed up by mapping of selected key areas farther afield.

Mapping should be easier and proceed faster than in the Mount Isa region. Time estimates assume 20-week field seasons, for efficient use of field resources, and full staff complements. Time is allowed for reporting stages fully, before commencing later stages.

The idealised sequence of events is:

<u>Year 1</u>

(a) Guided introductory reconnaissance for whole party,

(b) Commence studies and mapping in the Mallapunyah-Kilgour and Glyde-Lancewood 1:100 000 Sheet areas.

(c) Pilot magnetostratigraphy measurements through type sections.

(d) Ore genesis studies, restricted to reconnaissance of known deposits and pilot geochemistry.

(e) Prepare brief progress report.

Years 1-2

(a) Complete aeromagnetic coverage of McArthur Basin (Fig. 14).

(b) Pilot gravity and magneto-telluric profiles of McArthur Basin.

Years 2-3

(a) Complete geological studies and mapping, with the aid of drilling and magnetostratigraphy (if method suitable), in the Mallapunyah-Kilgour, Glyde-Lancewood, and Batten-Borroloola Sheets.

(b) Identify potential beds and localities for detailed ore - genesis studies, from geochemistry and petrology of stratigraphic sections. Commence studies of selected deposits.

(c) Carry out detailed gravity and/or magneto-telluric profiling of McArthur Basin (Fig. 15).

(d) Interpret aeromagnetic data.

Year 4

(a) Continue laboratory studies.

(b) Minor field-work, if necessary. Possibly expand some studies into Wearyan Shelf (Stage 1B).

(c) Complete (if necessary) gravity and/or magneto-telluric profiles (Fig. 15). Interpret data.

(d) Compile preliminary Mallapunyah-Kilgour, Glyde-Lancewood, and Batten-Borroloola 1:100 000 Sheets.

(e) Prepare progress publications describing preliminary results and interpretations.

Years 5-6

(a) Geological studies and mapping, with magnetostratigraphy(?) and considerable drilling, in the Tanumbirini-Bauhinia Downs, Tawallah Range-Bing Bong, Manturgula-Towns, and Urapunga 1:100 000 Sheets. Study Tawallah

Group in the Yiyintyi Range (Mount Young Sheet), without systematic mapping.

(b) Specialist studies in the Wearyan Shelf (Stage 1b) and Roper Group (Stage 2).

(c) Intensive ore genesis studies of selected strata-bound mineralisation and selected deposits.

Years 7-8

(a) Complete all laboratory studies.

(b) Complete all outstanding field work.

(c) Compile preliminary Tanumbirini-Bauhinia Downs, Tawallah Range-Bing Bong, Manturgula-Towns, and Urapunga 1:100 000 Sheets. Commence 1st Editions.

(d) Revise Mount Young, Bauhinia Downs, Wallhallow, Tanumbirini, Robinson River, Calvert Hills, Westmoreland, Urapunga, and Hodgson Downs 1:250 000 Sheets for 2nd editions, as warranted. Write Explanatory Notes.

(e) Prepare reports for publication, synthesising all the various aspects of the total Stages 1-2 of Project.

Years 11-12 FINALE

In conjunction with Stages 3-4:

(a) Complete outstanding publications on specialist sections of Projects.

(b) Prepare a single final Bulletin synthesising the total geological evolution and mineral deposits of the whole McArthur Basin.

PROPOSED PUBLICATIONS

1:100 000 MAPS (Figs 11, 12, 13)

Probable

12 sheets: Mallapunyah-Kilgour, Clyde-Lancewood, Batten-Borroloola, Tanumbirini-Bauhinia Downs, Tawallah Range-Bing Bong, Mantungula-Towns, Fleming, Koolatong, Parsons, Blue Mud Bay, Mirrngadja-Mitchell Ranges, Buckingham Bay-Arnhem.

Possible

3 sheets, as follows: "Bulman" and "Beswick" Specials, Urapunga.

Possible, but unlikely

Up to 6 sheets, if required, in Urapunga-Hodgson Downs 1:250 090 Sheet areas.

1:250 000 MAPS

2nd editions of 3 sheets: Mount Young, Bauhinia Downs, Wallhallow.

Probable

2nd editions of up to 14 sheets as follows: Tanumbirini, Robinson River, Calvert Hills, Westmoreland, Urapunga, Hodgson Downs, Wessel Islands-Truant Island, Arnhem Bay-Gove, Blue Mud Bay-Port Langdon, Roper River-Cape Beatrice, Milingimbi, Mount Marumba, Katherine, Mount Evelyn.

BULLETINS

Definite

A comprehensive final synthesis entitled: "Geological evolution and mineral deposits of the McArthur Basin".

Probable

Various completion accounts, as required, of detailed results and conclusions of various specialist studies, such as:

"Origin of the Tawallah Group",
"Origin of the McArthur Group",
"Origin of the Roper Group",
"Palaeontology of the McArthur Basin",

"Origin of strata-bound mineral deposits in the McArthur Basin".

REPORTS

Completion reports of various stages of project.

RECORDS

Progress reports recording preliminary data, and interpretations of facets and stages of both general and specialist studies.

PAPERS IN BMR AND EXTERNAL JOURNALS

Short papers describing particular highlights and discoveries of urgent and significant scientific interest.

REQUIREMENTS - STAGES 1-2

PERSONNEL, PROFESSIONAL

These cover the idealised staff requirements for maximum results in a reasonable time.

Summary list

Project leader
Party leader
3 Field geologists

3 Sedimentologists specialising in (Carbonates (Carbonate sedimentologist/ geochemist (Terrigenous clastics

2 Palaeontologists (Stromatolites (Microfossils

1 Geochemist/Mineragrapher

2 Stable isotope chemists (Carbon, oxygen, sulphur (Lead

Hydrocarbon geochemist

2 Geophysicists (Aeromagnetics
(Magneto-tellurics
(Gravity

General

Project Leader

1. Supervise and co-ordinate scientific activities of project;
2. Participate in field and laboratory investigations where possible; and in structural analysis of the basin.
3. Participate in writing of the major, and selected specialist publications;
4. Edit reports and maps resulting from project.

Party Leader

1. Lead and manage the field and office operations of the party. Maintain schedules of map compilation, general report writing, etc.;
2. Take leading role in the fieldwork of field geologists.

Field geologists - 3 (to be selected) plus party leader

1. Systematically map selected areas;
2. Measure stratigraphic sections and record geological data, under advice of specialists;
3. Compile selected 1:100 000 and 1:250 000 geological maps;
4. Write reports synthesising the results of the combined specialist studies;
5. Carry out selected individual research projects, with assistance from specialists.

Specialists

If not a-ailable full time, some specialists may have to contribute part-time to the project on a consulting basis, but the program ideally envisages that most will be available full time.

Sedimentologists - 3 (to be selected)

1. Carry out detailed studies of the palaeoenvironments and origins of the sedimentary rocks of the McArthur Basin.
2. Measure detailed stratigraphic sections, carry out detailed mapping of selected areas, and contribute to the systematic mapping of the basin.
3. Advise and assist field geologists in their research projects.
4. Prepare reports on their studies and contribute to the general synthesis of the basin.

Three fields are involved:

(a) Carbonates Sedimentologist - experienced in the interpretation of the compositions, structures, and textures of carbonate rocks, for studies in the McArthur Group, and parts of the Tawallah Group.

(b) Carbonate Sedimentologist/Geochemist - with specific experience in the geochemistry of carbonate rocks, as related to depositional environments, diagenesis, dolomitisation, movement of elements, during recrystallisation, etc., to assist studies of the McArthur Group.

(c) Terrigenous Clastics Sedimentologist, to assist with the studies of terrigenous sediments, particularly in the Tawallah and Roper Groups.

Palaeontologists - 2 (see below)

1. Continue current studies of the taxonomy, stratigraphic distribution, and palaeoenvironments of the fossils of the McArthur, Tawallah, and Roper Groups, and apply these studies to biostratigraphy, environmental interpretation, and ore genesis;

2. Measure detailed stratigraphic sections, make sedimentological observations, and map selected areas in detail in association with other specialists. Contribute to the systematic mapping of the basin;

3. Prepare appropriate reports on the results of studies and contribute to the general synthesis of the basin.

Two fields are involved:

Microfossils

Stromatolites

Geochemist/Mineragrapher

1. Study and interpret the geochemistry and mineragraphy of known mineral deposits.

2. Study and interpret the stratigraphic and regional distribution of major, trace, and base-metal elements of significance to ore genesis.

Stable - Isotope Chemists - 2 (see below)

Analyse and interpret the stable-isotope compositions of selected rocks and minerals. Two specialists required:

1. Carbon, oxygen, sulphur
2. Lead

Hydrocarbon Geochemist

Analyse and interpret the metamorphic states and thermal history of kerogen and hydrocarbon material.

Geophysicists - at least 2 (to be selected)

1. Carry out regional geophysical surveys, with support staff, of the McArthur Basin.

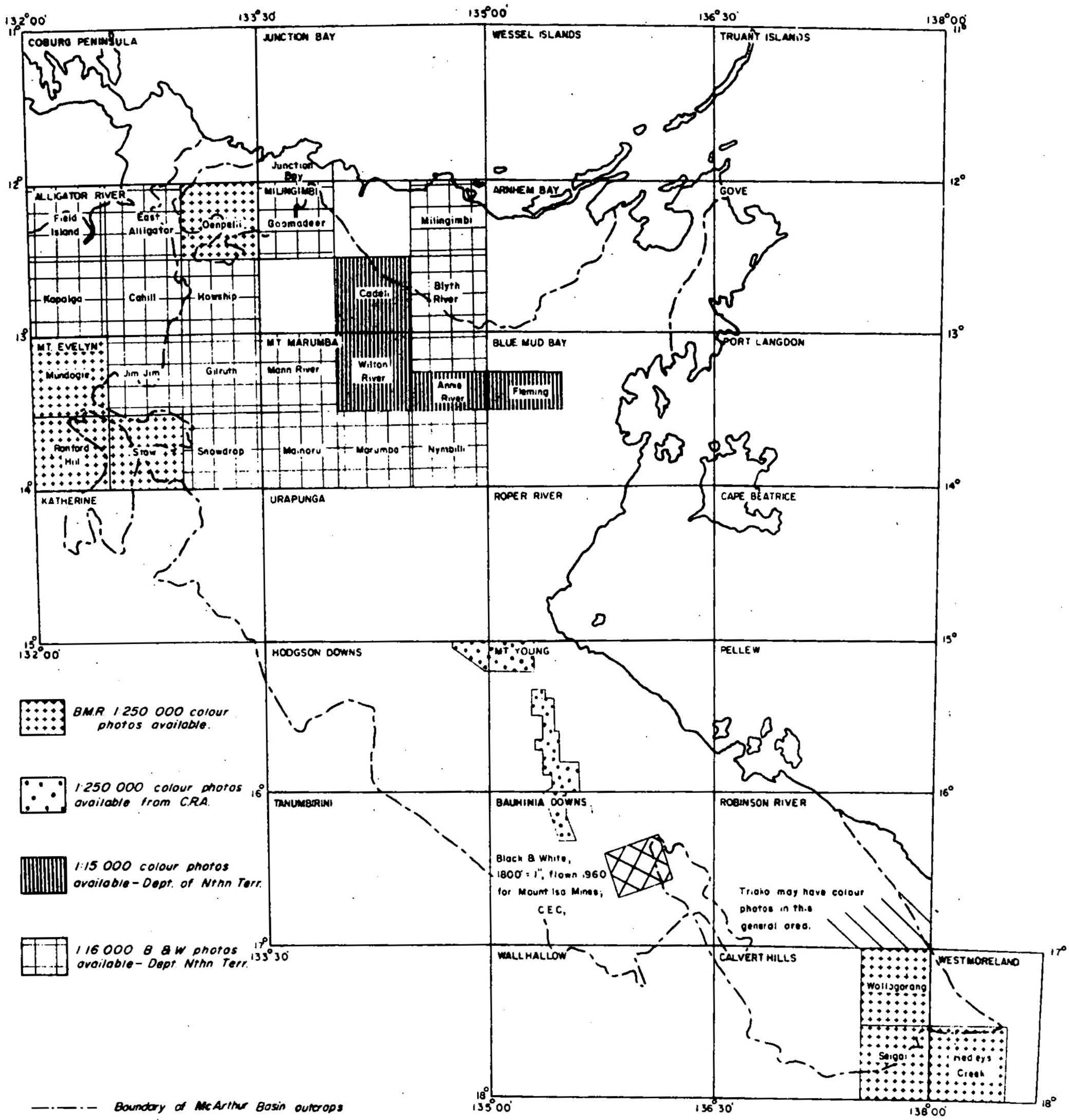
2. Interpret the subsurface structure of the McArthur Basin in collaboration with geologists.

Three fields involved:

1. Aeromagnetics
2. Magneto-tellurics
3. Gravity

COLOUR AERIAL PHOTOGRAPHS

The present availability is shown in Figure 17. Some areas at the margins of the basin have been flown in colour for BMR. A large area in western Arnhem Land has been flown in black and white at 1:16 000 scale,

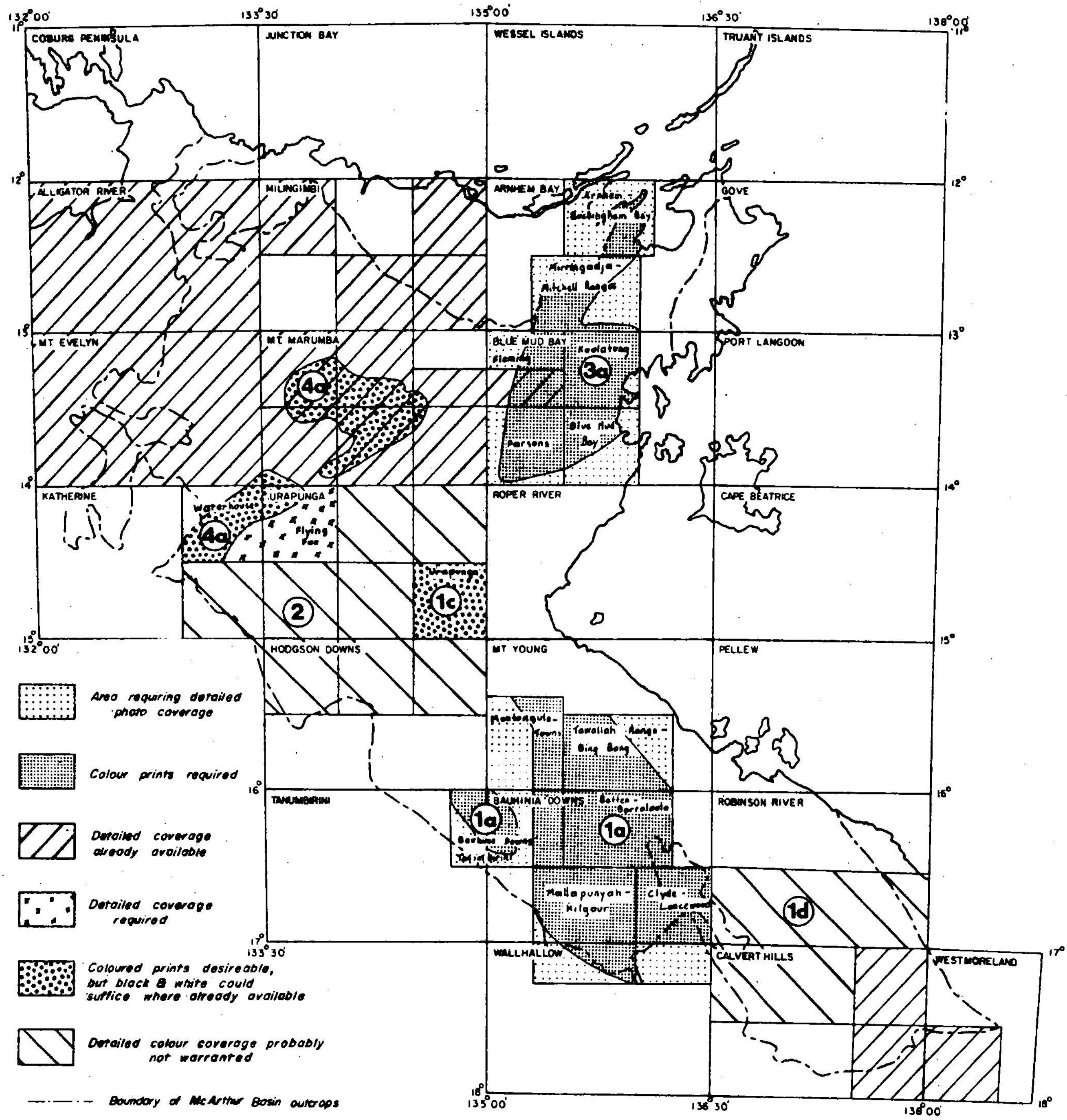


Record 1977/33

Fig 17. Availability of detailed air photographs

(There may be other company photography available, of which there is no knowledge at present.)

AUS 1/415



Record 1977/33

Fig 18. Colour air photograph requirements.

AUS 1/416

and some in colour at 1:15 000 scale, for the Department of the Northern Territory. In the McArthur River region, a small area of very detailed black and white photos - 1" = 1800' - were flown for MIM in 1960; these are only useful for very detailed mapping and are not suitable for photo-interpretation. CRA have detailed colour coverage of an area in the Mount Young and Urapunga Sheets; the precise area is unknown but it includes the main outcrop of the McArthur Group.

The areas where new colour photography is required are shown in Figure 18.

Stage 1 - McArthur River Region

The following 1:100 000 Sheets are required at the start of the project:

(a) Mallapunyah-Kilgour, Clyde-Lancewood, Batten-Borroloola.

(b) Tanumbirini-Bauhinia Downs, Batten-Borroloola, Mantungula-Towns, Tawallah Range-Bing Bong.

The CRA coverage of Mantungula-Towns is probably adequate for our requirements and prints can be obtained through CRA.

It is desirable that all the above sheets are available at the beginning of the project, because the specialised studies will advance ahead of the systematic mapping. If this is not possible, then the sheets should be flown in the two groups above, with (a) first.

It is not necessary to print the whole area in colour; the area for which colour prints will be required is shown in Figure 18 - Area 1A, but the small saving, if flying is restricted to the special sheets outlined, probably does not warrant the trouble.

For the Wearyan Shelf detailed colour photos of Area 1D would assist the detailed studies but, since the area will not be systematically mapped, flying of the area is probably not warranted. In any case, some of the most important areas (Wollogorang) are already available. Enlargements of RC9s will probably suffice in other areas.

Stage 2 - Roper River area

This is outlined on Figure 18 - Area 2.

It is probable that the area will not be systematically mapped at this stage. Key sections will be studied in detail. The Roper Group is very easy to photo-interpret. Colour photography is probably not warranted unless:

(1) It is subsequently decided to produce 1:100 000 Sheets,
(2) a general policy is adopted to obtain an extensive library of colour photos as a matter of course.

Stage 3 - Eastern Arnhem Land

Colour coverage will be eventually required of Parsons, Blue Mud Bay, Fleming, Koolatong, Mirrngadja, Mitchell Ranges, Buckingham Bay, and westernmost Arnhem Bay. The photos will not be required until the commencement of Stage 3, and colour prints will only be required of the area outlined on Figure 18 (3A). Current progress suggests that the Department of the Northern Territory may fly the area before we need photos.

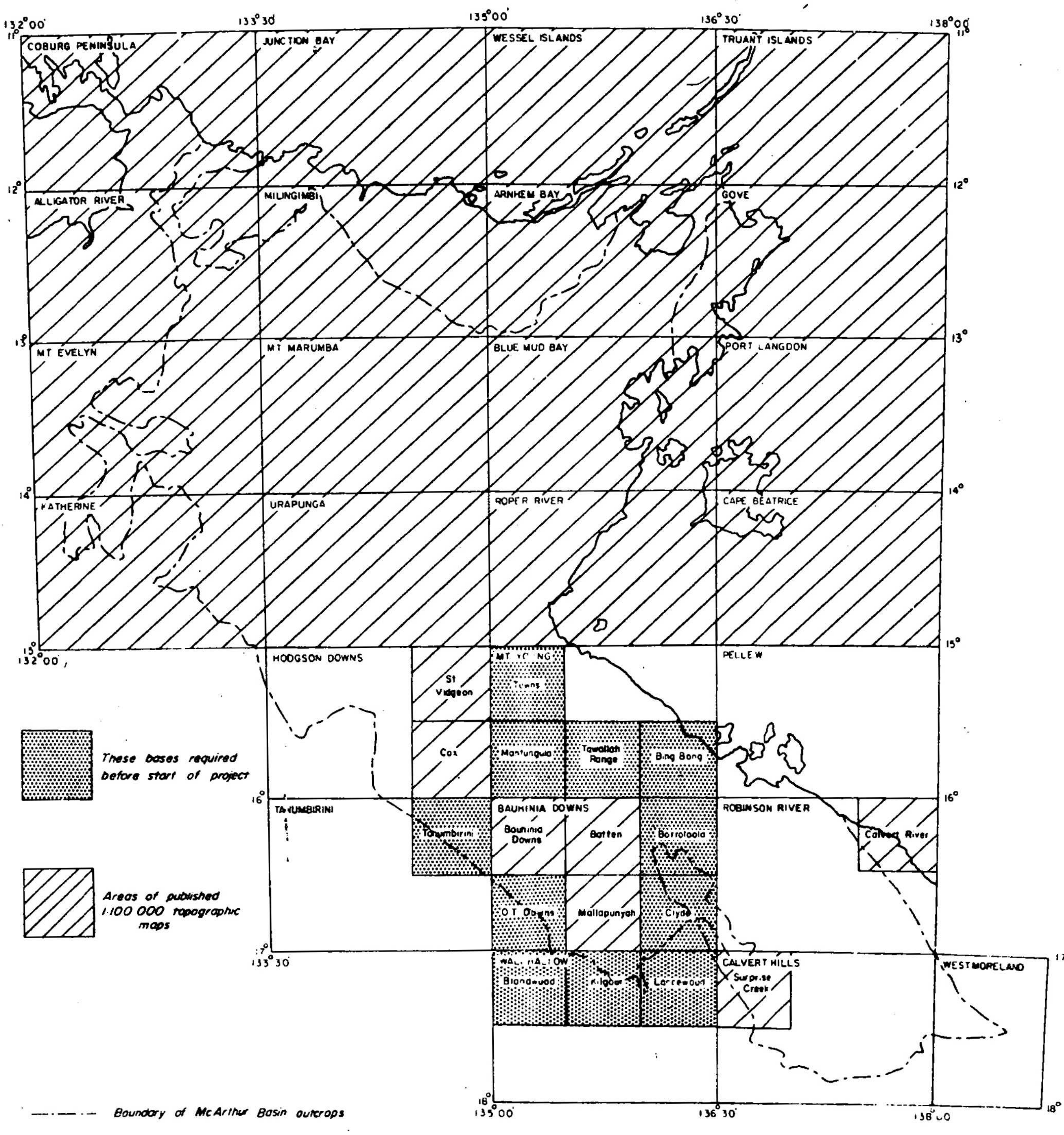
Stage 4 - Western Arnhem Land

A large area is already covered by detailed black and white photos, and some by colour. In the areas to be mapped in detail, coverage is still required at this stage for Waterhouse and the northwest corner of Flying Fox Sheets. Parts of Mann River, Mainoru, and Marumba will be mapped in detail (and colour would be desirable), but the available black and white coverage could suffice.

1:100 000 TOPOGRAPHIC BASES

The published 1:100 000 topographic maps currently available are shown on Figure 19. All the sheets to the north of Hodgson Downs and Mount Young 1:250 000 Sheets are now available. South of this line, the only sheets available are St Vidgeon, Cox, Bauhinia, Batten, Mallapunyah, Surprise Creek, and Calvert River. Therefore, before geological maps can be compiled for Stage 1 of the project, eleven 1:100 000 bases are required:

Bloodwood Creek
Kilgour
Lancewood
O.T. Downs



Record 1977/33 Fig 19 Availability of 1:100 000 topographic maps - July 1975. AUS 1/417

Clyde
Borroloola
Tanumbirini
Mantungula
Tawallah Range
Bing Bong
Towns

GEOPHYSICAL STUDIES

The principal contribution to the project by the Geophysical Branch has already been discussed. They comprise:

(1) Aeromagnetic coverage and interpretation of the basin - Figure 14.

(2) Detailed gravity traverses and modelling - Figure 15.

Ideally this should take place at a very early stage of the project. Although the gravity traverses will extend far beyond the limits of Stage 1, sufficient access is available in Arnhem Land for adequate helicopter fuel dumps and fly-camps.

No IP or similar coverage, is envisaged during Stage 1 of the project. Some may be required during Stage 3 - Eastern Arnhem Land - as an aid in defining conductive beds in the Vaughton Siltstone, and identifying useful areas for stratigraphic drilling.

This area could provide a very useful testing ground for the development of techniques in the search for blind ore-bodies.

Magnetotellurics. Magnetotellurics have been discussed with M.G. Allen as a guide to subsurface structures. It seems unlikely that it will give better data than gravity without an extremely detailed, expensive program. In any case the method is ruled out by the lack of access for the heavy truckloads of equipment which are necessary for this work.

DRILLING

Stage 1 - "McArthur River Region"

Most McArthur Group rocks crop out poorly or are deeply leached and silicified in the Mount Young and northern Bauhinia Downs Sheets. Farther south, dolomites crop out well, but lutites do so poorly and are rarely seen fresh. Stratigraphically, the surface expression of the units can be summed up as follows:

Umbolooga Sub-Group: Generally good sections are available in the south except for the lutites. Outcrops are scattered and extensively silicified in the north. Outcrop of the Mallapunyah Formation is particularly poor throughout the area.

Barney Creek Formation: Crops out very poorly throughout the region. It is particularly bad in the H.Y.C. area, where it has been extensively drilled by CEC.

Batten Sub-Group: This is deeply leached throughout the area, except in some deeply dissected areas around the Clyde and Kilgour Rivers.

Balbirini Dolomite and equivalents: This is essentially the same as the Umbolooga Sub-Group. The Kookaburra Creek Formation is very extensively silicified in the north.

Drilling, to obtain fresh samples or complete stratigraphic sections in key areas, will be required for:

(1) Stratigraphic control: principally in the northern area to obtain complete sections of critical sequences;

(2) Petrographic study: drilling is the only way to obtain fresh samples of lutites over much of the area and to obtain fresh samples of most units in the north;

(3) Regional and stratigraphic geochemistry: many base metals are leached at the surface. Present experiences indicates variations in the results obtained from surface sections and drill-core, due either to leaching or incomplete outcrop at the surface. Wide-spread drilling may be required for valid results. A useful subsidiary line of research, with wider application, will be a comparison of the results from subsurface and outcrop samples of the same sections.

(4) Microfossils: experience with the Amelia Dolomite shows that microfossils are much better preserved in drill-core than in outcrop samples.

(5) Mineral deposits: most mineral deposits are altered at the surface

to oxides, carbonates, and silicates. Drilling will be required to obtain primary sulphides. The subsurface form of most of the small deposits is poorly known and so it will be difficult to anticipate the results of such drilling. This is approaching more the proving of deposits which should probably be avoided if possible, and only undertaken when other avenues have been exhausted.

Most of these requirements are really variations of stratigraphic drilling and can be co-ordinated so that most requirements are satisfied by the same holes. The detailed requirements cannot be assessed at this stage. Drilling should only be undertaken after surface studies have been carried out, so as to select key sites and avoid unnecessary drilling.

Some exceptions may be possible in the north where the stratigraphic deficiencies are obvious and the drilling-sites will be dictated to some degree by access. A limited program could commence in the second or third years and a more extensive program will be desirable later; specific programming can be deferred.

Stage 2 - Roper Group

Most lutites crop out very poorly and are rarely seen. Although not as economically important as the McArthur Group, selective stratigraphic drilling of poorly exposed units will assist the total interpretation of the Group.

Stage 3 - Eastern Arnhem Land

Outcrop in this area is poor and all McArthur Group rocks are deeply leached. Considerable stratigraphic drilling will be desirable for complete assessment of the area.

The area is prospective for lead-zinc deposits, although exploration is at a very early stage. Subject to company programs in the meantime, detailed stratigraphic drilling of the Vaughton Siltstone, supported by IP work, is needed to properly assess the ore potential of the area.

Detailed programming can be deferred for several years.

Stage 4 - Western Arnhem Land

Some stratigraphic drilling may be desirable, but it can be deferred until at least the initial surface mapping has been carried out in several years' time.

HELICOPTER CONTRACTS

Extensive use of helicopters will be needed in Arnhem Land during Stages 3-4.

Most of the McArthur River region has adequate vehicle access and, since the work will be detailed and best suited to vehicle traverses, helicopters will only be required in selected inaccessible areas. These can be detailed as follows:

Years 1-2

(1) Basinwide gravity traverses;

(2) detailed geology of inaccessible areas of:

Clyde-Lancewood Sheet - inliers within Bukalara Plateau.

Mallapunyah-Kilgour Sheet - Roper Group sections in the central Abner Range. Possibly some sections in the upper Kilgour River.

Batten-Borroloola - some sections in the central Tawallah Ranges.

These geological requirements are fairly limited and will not involve much work, probably only a couple of weeks. The most efficient use of the helicopter may be possible if the work could be co-ordinated with the gravity contract.

Years 4-5;

Selected inaccessible geological sections are as follows:

Tanumbirini-Bauhinia Downs Sheet - some isolated Roper Group sections.

Tawallah Range-Bing Bong and Mt Young - inaccessible sections in the central Tawallah Range. Some widely scattered isolated outcrops on the coastal plain. Sedimentological studies within the central Yiyintyi Range.

Mantungula-Towns Sheet - some key Roper Group sections in the isolated western area.

The total contract would involve less than one month - probably only about two weeks - with utilization of the whole field party.

Years 4-6:

Helicopter access will be needed for specialised studies in some critical isolated areas of the Wearyan Shelf. This probably only involves about two weeks' work.

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