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VISIT TO BASE METAL PROSPECTING OPERATIONS, ARNHEM LAND - 20-24 AUGUST, 1974

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SUMMARY

The Vaughton Siltstone in eastern Arnhem Land has been recommended as being prospective for lead and zinc, based on stratigraphic and structural analogies between eastern Arnhem Land and McArthur River which were recognized by BMR after mapping in 1962. In August, 1974, Plumb visited the area to assess the exploration activities by BHP Co. Ltd, which have been based on his geological model.

The geological model is outlined, BHP's results are summarized, and the prospecting problems of the area are discussed. BHP's results have added support to the geological model, but no indications of major mineralization have been found so far.

The major prospecting problem is deep soil cover and poor outcrop. Exploration must be based on indirect methods, and will be very expensive. Results to date are inconclusive.

The principal need is more stratigraphic data from the prospective sequence. A regional IP survey, followed by stratigraphic diamond drilling, is recommended as the next stage in exploration of the area.

INTRODUCTION

After BMR mapped Arnhem Land in 1962 close stratigraphic and structural analogies were recognized between the McArthur Group at McArthur River and in eastern Arnhem Land. Despite the lack of known mineralization, the Vaughton Siltstone was specifically recommended as being prospective (Plumb & Roberts, 1965). Revision of the stratigraphy at McArthur River (Plumb & Brown, 1973) strengthened the analogy, and the Vaughton Siltstone has been pointed out as prospective during discussions with visitors to BMR, in lectures, and in publications (Plumb, 1974; Plumb & Derrick, 1975).

Before 1962, the only geological work on the mainland of eastern Arnhem Land comprised a reconnaissance survey by the Broken Hill Proprietary Co. Ltd in 1954, which outlined the main geological features, and a couple of government-sponsored prospecting expeditions between 1875 and 1912. Following the discovery of the Groote Eylandt manganese deposits during 1960-62, BHP took out an A to P over most of eastern Arnhem Land, and prospected for manganese, bauxite, and base metals.

In August, 1974, I had an opportunity to visit Arnhem Land, and see the work carried out. At that stage field work had come to a standstill, because of the new government policies on exploration within aboriginal reserves, and the company was undecided about the future.

Prospecting Problems

Outcrop is poor, and no surface mineralization is known. Prospectivity is based entirely on geological similarities to McArthur River.

Much of the area is masked by a thick cover of sand, alluvium, laterite, and Mesozoic rocks, and most of the carbonate rocks of the McArthur Group are deeply leached or extensively silicified by weathering. Outcrop of the prospective Vaughton Siltstone is almost non-existent. The depth of soil cover is not at all well known. Breccias (?silicified dolomite) have been noted at depths of 135 m, though 100 m away fresh pyrite was encountered below 23 m, and partly oxidized pyrite above.

The chances are that an orebody will have no surface expression. The thick cover of transported soil will mask any geochemical anomalies. Geophysical techniques able to detect mineralization at depths greater than 100 m would have to be used. Most geological information will have to be obtained by drilling.

In short, prospecting in the area is of the "grass-roots" type, and must depend on expensive indirect methods to find concealed deposits.

THE GEOLOGICAL MODEL

The major tectonic elements of the McArthur Basin are shown in Figure 1 (from Plumb & Derrick, 1975). Lateral changes between successions in widely separated areas prevent the mapping of the same rock units throughout the basin, but the consistency of the broad features of the stratigraphy allow the framework shown in Figure 2 (from Plumb & Derrick, 1975) to be confidently constructed.

The McArthur Group successions in the Batten Trough at McArthur River and Blue Mud Bay are very similar. Although the formations defined from McArthur River cannot be recognized in Blue Mud Bay, and the formation boundaries do not correspond exactly, the general rock associations in the two areas allow the general correlations shown in Table 1 to be made.

The Koolatong Siltstone contains the same shelf carbonate associations as the lower Umbolooga Sub-Group, and the Strawbridge Breccia consists of silicified dolomite reminiscent of a consistently silicified unit in the lower Emmerugga Dolomite. The sparse exposures of Vaughton Siltstone comprise mainly leached dolomitic siltstone and minor sandstone, passing up into black carbonaceous shale and dolomitic siltstone; some of the rocks may be tuffaceous. This assemblage resembles the Barney Creek Formation at McArthur River. Present data do not allow identification of the Teena Dolomite or upper Emmerugga Dolomite; they may well be represented by some of the beds in the lower Vaughton Siltstone. Conglomerate at the base of the Yarrawirrie

Table 1. Correlation of McArthur Group successions

Sub-Group	McArthur River	Blue Mud Bay
	Dungaminnie Formation Balbirini Dolomite Amos Formation	Kookaburra Creek Formation
	Smythe Sandstone	- ?— ? - - ? - - ? -
	---------- Unconformity ----------	
Batten Sub-Group	Looking Glass Formation Stretton Sandstone Yalco Formation Lynott Formation	Bath Range Formation Baiguridji Formation Yarrawirrie Formation
----------	---------- Unconformity ----------	----------
Umbolooga Sub-Group	Reward Dolomite	Zamia Creek Siltstone Conway Formation
	----------	----------
	Barney Creek Formation Teena Dolomite	Vaughton Siltstone
	- ? - - ? - - ? —	----------
	Emmerugga Dolomite	Strawbridge Breccia
	----------	----------
	Tooganinie Formation Tatoola Sandstone Amelia Dolomite Mallapunyah Formation	Koolatong Siltstone
	----------	----------

Formation can be equated with an unconformity at the base of the Lynott Formation, and the Yarrawirrie, Baiguridji, and lower Bath Range Formations contain the same detrital carbonate and terrigenous rocks as the Batten Sub-Group at McArthur River. The upper Bath Range Formation is less well known, and its relationship to the Kookaburra Creek Formation is uncertain (they could be partly equivalent). The Kookaburra Creek Formation is equivalent to the Amos Formation and Balbirini Dolomite, but some of the rock types of the upper Bath Range Formation may also correlate with these units. The overall thickness of units in the successions is consistent with these correlations.

The important point is that, despite uncertainties of detail, the total correlation strongly supports correlation of the Vaughton Siltstone with the Barney Creek Formation, which is the host of the H.Y.C. lead-zinc deposit at McArthur River.

At McArthur River the H.Y.C. deposit was deposited in the Bulburra Depression, immediately adjacent to the Emu Fault (Fig. 1). This locality and the Coxco Valley 15 km to the south are the only places where the Barney Creek Formation crops out near the fault. Away from the Bulburra Depression, the Barney Creek Formation is very thin, and lacks significant mineralization.

The only other area where a Barney Creek Formation equivalent crops out adjacent to the Emu Fault is the Blue Mud Bay area of eastern Arnhem Land. The Koolatong Fault is equivalent to the Emu Fault (Fig. 1). The Vaughton Siltstone crops out adjacent to, and parallel to, the Koolatong Fault over a strike length of about 30 km, making it the next prime prospect area after McArthur River.

In summary, the Vaughton Siltstone possesses the following favourable features:-

(1) Correct stratigraphic position in a total sequence which reflects a history similar to that of McArthur River.

(2) Favourable rock types - black carbonaceous and dolomitic shale; probable tuff; evaporites lower in the succession.

(3) Favourable structural setting adjacent to the Koolatong (Emu) Fault.

(4) Deposition in a trough adjacent to a shelf where little or no sedimentation was taking place at the time of deposition of the Vaughton Siltstone.

BHP INVESTIGATIONS

Before 1972. Base metal prospecting consisted of a number of stream sediment geochemical surveys, spot Pb and Zn tests of outcrops, and some geological mapping. The results were mostly negative.

1972. Surface geological mapping was carried out over the main areas of Koolatong Siltstone and Vaughton Siltstone, and IP and magnetic surveys were carried out along three traverses.

The mapping generally confirmed earlier BMR work, and one significant IP anomaly was found over Strawbridge Breccia.

1973. A program of drilling to bedrock along a series of traverse lines across the strike of the Vaughton Siltstone was only 25 percent (29 holes) completed because of a late start to the season and problems with the contractor. The principal results were some additional information about the rock types present, and the discovery of pyritic shale (5-10% pyrite) associated with the 1972 IP anomaly.

Surface mapping further confirmed the BMR work except that, in one area of problematical structure, it appears that two separate beds of chert breccia may have been mapped as Strawbridge Breccia by BMR.

An Aerial Input EM survey was flown at 1 km line spacing over most of the permit area. Anomalies due to conductive overburden were identified in some areas, and some low-order bed-rock anomalies were identified within the Koolatong Siltstone, but no significant anomalies were detected within the Vaughton Siltstone. The contractor (Geoterrex) is confident that the method has worked in the area, and claims that it should be able to detect massive sulphides (10-20%) at depths up to 130 m. He doubts that any major sulphide body exists in the area surveyed.

1974. No work was carried out during 1974 because of difficulty of access due to the extreme 1973-74 "wet" season, and because of political uncertainties due to new government policies on exploration within aboriginal reserves.

1974 VISIT

A party consisting of Messrs John Arnold, Michael Diemar, a field hand from BHP, and I flew into Arnhem Land on 20 August. Various outcrops, traverse lines, and drill cuttings in the Koolatong River-Strawbridge Creek area, and reports of previous surveys, were studied between 20-22nd. Vehicle problems caused some loss of time on the 23rd, after which we flew to Groote Eylandt for an inspection of the manganese deposits, before returning to Darwin on the 24th.

COMMENTS

Because the drilling contract was not completed during 1973, the new stratigraphic information is not great, but it does add further support to the correlations with formations at McArthur River. BHP have recognized several informal units which I have correlated with those at McArthur River in Table 2.

The discovery of pyritic carbonaceous shale adjacent to the Koolatong Fault is important, because it occurs where the model predicts it should occur, and it shows that the IP method works in the area. The concentration of pyrite is about 5-10%, and associated Pb, Zn, and Cu values are low.

Table 2. Subdivisions of the McArthur Group.

BMR Unit	BHP Unit	Rock Types	McArthur River Equivalent
	Ɇmv$_3$	Black carbonaceous shale, green-grey tuffaceous (?) shale.	Barney Creek Formation
Vaughton Siltstone	Ɇmv$_2$	Buff to grey regularly bedded dolomitic siltstone and sandstone.	Barney Creek Formation (?) & Teena Dolomite (?)
	Ɇmv$_1$	Chert breccia, dolomitic siltstone.	Mitchell Yard Dolomite Member (of Emmerugga Dolomite) (?).
Strawbridge Breccia		Silicified dolomite, chert breccia.	Mara Dolomite Member (of Emmerugga Dolomite).
	Ɇmk$_c$	Red siltstone.	Myrtle Shale Member (of Tooganinie Formation)
Koolatong Siltstone	Ɇmk$_b$	Quartz-rich sandstone & conglomerate, resistive siltstone	Leila Sandstone Member (of Tooganinie Formation)
	Ɇmk$_a$	Siliceous & dolomitic siltstone, dolomite, stromatolites, some sandstone.	Tooganinie Formation etc.

A major problem is the interpretation of the ubiquitous weathered outcrops. Weathered and silicified carbonate rocks in northern Australia are almost impossible to interpret without prior experience in an area where the full range of rocks from fresh to weathered can be seen. The BHP party interpreted chert breccias as slump breccias rather than silicified dolomite; silicified dolomite as deep-water chert; and stromatolites as slump folds. Most geologists new to this terrain have made similar errors, and a familiarization period in the McArthur River district should be an essential prelude to work in Arnhem Land.

Shallow drilling data must be interpreted cautiously. Bedrock samples will be weathered. Outcropping mineralized shale at McArthur River has some lead remaining (less than 1%), fine pyrite is completely altered to iron oxide, and almost all zinc has been leached. There is no gossan directly over the orebody; the H.Y.C. gossan is a silicified dolomite breccia (enriched in secondary zinc, and with low lead values) 60 m stratigraphically above the ore beds. In the absence of a suitable secondary host, any geochemical anomaly may be relatively small.

The drilling grid interval must be less than the dimensions of the expected orebody, because there is no spread in the soil geochemical anomaly at H.Y.C. (Fricker, 1962). The H.Y.C. deposit is about 50 m thick, and has a strike length of 1500 m, but obviously this is an exceptionally large target.

In the alluvium at H.Y.C., Fricker obtained significant soil anomalies only from deep samples collected close to bedrock, where zinc values of 1000 p.p.m. to over 1%, but no anomalous lead values, were found. The anomaly did not overlie the orebody, but occurred in a zone parallel to, and of similar width to, the orebody, above barren dolomitic shale in the hanging wall. If conditions had been slightly different there may have been no anomaly at all.

Other deposits at Teena, W-fold, and Reward, which are overlain by mainly residual soils, gave good anomalies from shallow (0.3 m) samples, and W-Fold was clearly detected from stream sediment samples (Fricker, 1962).

Much more stratigraphic information is needed to establish the prospects of the area and the viability of the geological model. Shallow drilling to bedrock is of little value because, apart from the weathered samples obtained, critical beds may be straddled by the sampling grid. At McArthur River the Barney Creek Formation thins rapidly to only about 100 m within a kilometre or so of the orebody. The pyritic or mineralized beds may be only a couple of metres, or less, thick. Diamond drilling by C.E.C. and BMR (Fricker, 1962; Lambert & Scott, 1973) showed that equivalents of the H.Y.C. Pyritic Shale Member can be recognized, by rock type and by anomalous zinc and lead, at least 20 km from the orebody. However, at one of Lambert & Scott's sites, careful sampling of surface exposure by M.C. Brown (unpublished data) missed a significant zinc-rich bed, either because of leaching or lack of outcrop.

Stratigraphic drilling of continuous cores through the Conway Formation, Barney Creek Formation, and Strawbridge Breccia would be of immense value in assessing the viability of the geological model, and in determining whether prospective beds are present. Apart from detailed comparison of the section with that at McArthur River, indicators which would be significant include carbonaceous pyritic shale, vitric tuff, potash-rich rocks, ferroan dolomite, and anomalous Zn, Pb, As, and Hg contents (Brown, Claxton & Plumb, unpublished data; Lambert & Scott, 1973). The total section requiring study is about one kilometre thick, so a major program of inclined overlapping holes would be best to intersect the steeply dipping section adjacent to the Koolatong Fault.

Even without the problem of exploration within aboriginal reserves, some BHP personnel favour abandoning the area because of the negative results obtained by the input EM survey. Although the results of this survey are disappointing, it is doubtful whether one can be as conclusive about negative geophysical results as the contractor has been.

The depth penetration claimed by the contractor is not much greater than the expected depths of weathering. G.A. Young (BMR, pers. comm., 1974) points out that, because of the number of unknown variables, depth penetration claims must be treated with caution. M. Raetz (BHP, pers. comm.) has described areas in the Mount Isa-Cloncurry region where the method penetrated much less than 130 m. IP work at McArthur River (Sedmik, 1967) outlined the shallow parts of the orebody well, but failed to produce an anomaly below about 200 m.

D.C. Stuart (BMR pers. comm.) studied the results of the input survey, when a member of the BHP staff, and concurred with the contractor's conclusions. However, subsequent study of the McArthur River IP results indicated higher resistivities (of the mineralization) than he had assumed, and he now considers that the results of the input survey are less conclusive than previously supposed.

I consider that the Vaughton Siltstone still represents the best prospect for a major lead-zinc deposit in the McArthur Basin, outside the areas immediately surrounding the H.Y.C. deposit at McArthur River itself.

ALTERNATIVE PROSPECTING TECHNIQUES

The greatest single need in assessing the prospectivity of the area is a detailed stratigraphic section, which can be obtained only by drilling. Excluding overheads, a single section through the prospective section would cost around $50 000, plus the cost of petrographic study and chemical analysis. More than one section would be desirable.

Direct prospecting for mineralization can be carried out by IP surveys, or geochemical surveys based on drilling to bedrock. Either method would probably produce anomalies if significant mineralization is present.

To ensure detection of possible targets, traverse lines would need to be about 0.5 km apart. The prospective area is about 40 km long (i.e., 80 traverse lines) and 1-1.5 km wide.

Excluding surveying and line clearing, 80 IP lines could be surveyed for around $25 000. The potential target ideally requires geochemical sampling at 50 m intervals along the traverse lines. 1600 holes could cost more than $500 000, and an additional $150 000-$200 000 for chemical analyses. IP is the obvious regional tool.

As well as possibly detecting an orebody directly, a systematic IP survey would be a useful guide to choosing the most effective section line(s) for stratigraphic diamond-drilling.

CONCLUSIONS

Despite the disappointing results of the Aerial Input EM survey, the Vaughton Siltstone is still considered to be the best prospect for a major lead-zinc deposit in the McArthur Basin, outside the McArthur River area itself. Any exploration will be very expensive and based on indirect, highly subjective methods. Results to date are inconclusive.

The basic requirement is a complete detailed stratigraphic section through the Conway Formation, Vaughton Siltstone, and Strawbridge Breccia for comparison with McArthur River, and to confirm whether or not prospective beds are present.

A regional IP survey should be carried out, followed by stratigraphic diamond drilling of the critical units along one or more section lines. Detailed petrographic and chemical studies should be made of the core. Subsequent geochemical surveys could be confined to any prospective zones discovered.

If publicly available, the fundamental data derived from stratigraphic drilling would be of great value throughout the McArthur Basin. Such a drilling program may therefore be considered to be more a function of a government survey (BMR or GSNT) than private enterprise, particularly if no companies are actively prospecting in the area.

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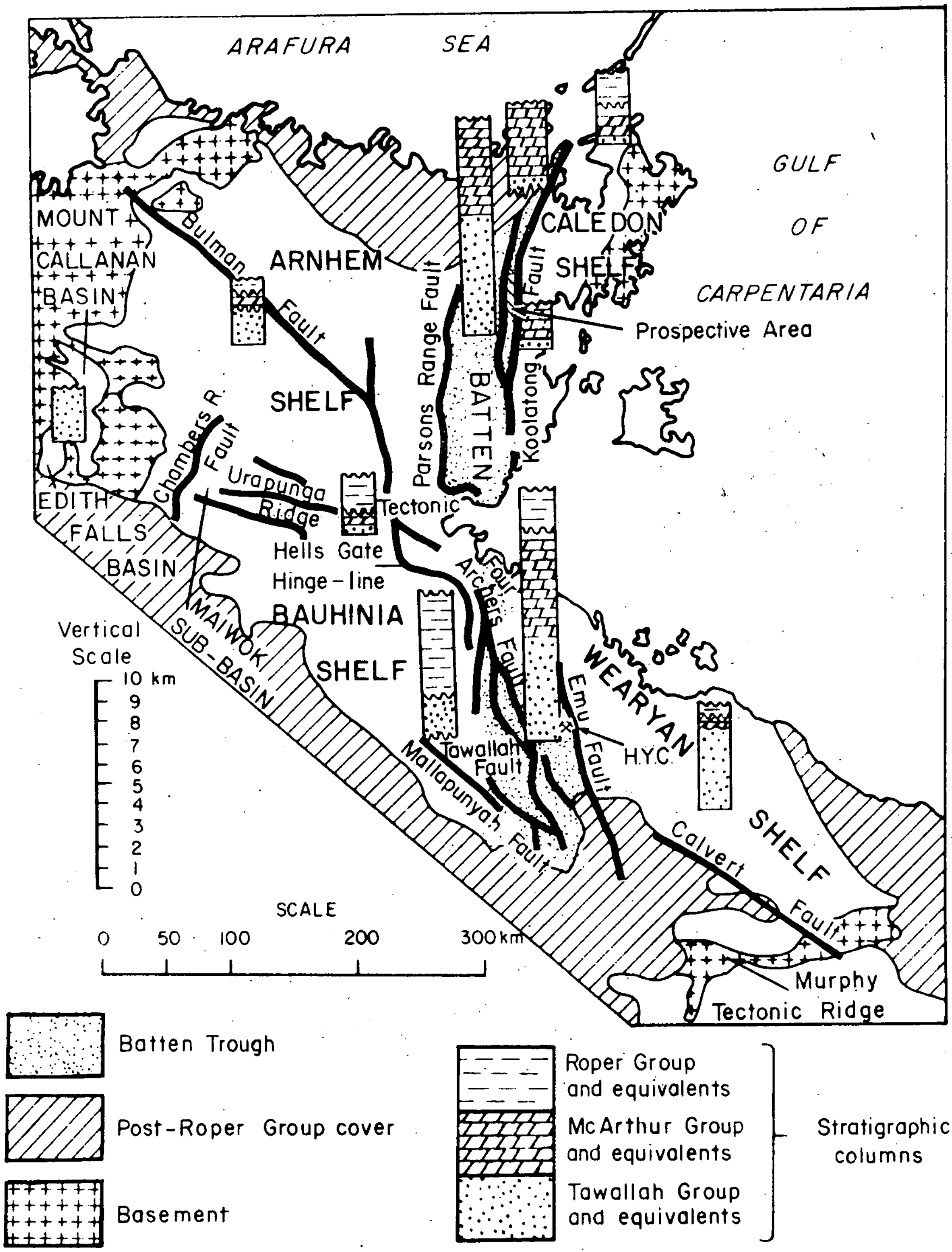

Figure 1. Major tectonic elements, Mac Arthur Basin (after Plumb & Derrick, 1975).

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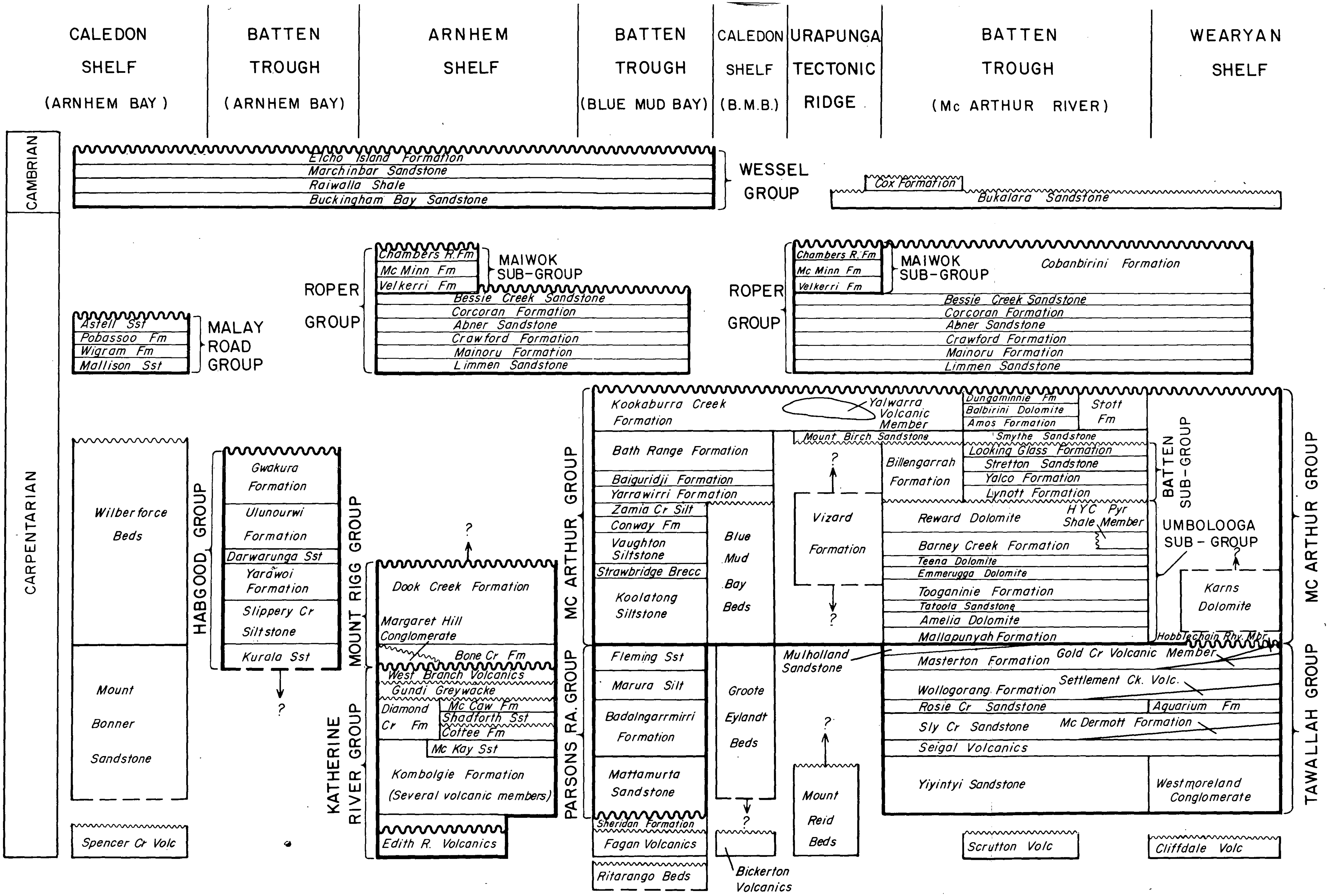

Figure 2 Stratigraphic correlation chart, Mc Arthur Basin, with underlying acid volcanic complexes and overlying Cambrian basin. (Modif. from L.Plumb & Derrick 1975)

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