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THE 1978 McARTHUR BASIN MAGNETO-TELLURIC SURVEY

by

J.P. Cull, A.G. Spence, J.A. Major,
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SUMMARY

In 1978 seventeen magneto-telluric (MT) sites were occupied along a 350 km traverse across the Wearyan Shelf and the eastern Batten Fault Zone of the McArthur Basin. The data from this survey are presented in this Record as individual graphic representations of rotated-tensor apparent resistivities and phase curves for each orthogonal component, together with tensor rotation angle versus frequency; these data are then used as the basis of subsequent interpretations.

A preliminary examination of the resistivity plots at each site revealed marked differences across the Emu Fault, with diverging components of apparent resistivity. The differences were emphasised further when data were presented as 2D pseudo-sections constructed from the individual plots. Causative mechanisms deep within the crust are suggested to explain these differences. However, the actual resistivities for each stratigraphic unit are not readily resolved because of anisotropy related to the structure near the fault.

Isotropic data for the eastern sites were inverted in a 1D analysis revealing a well-defined basement with resistivity of about 95 kilohm-metres. This is covered by a layer 800 m thick with consistent low resistivity values of 70 ohm-m. Above this is a more resistive layer, with values in the range 600-900 ohm-m. In addition there is a highly conductive overburden about 10 m thick, with a resistivity of about 2.5 ohm-m.

The results indicate a depth to basement of about 2.8 km near Calvert Hills, increasing to about 3.5 km near Robinson River. Towards the Emu Fault, a value of about 6.7 km has been calculated for the depth to basement, but 1D models are probably inadequate in this region, and detailed structural trends cannot be resolved.

The 1D analysis demonstrates that MT signals respond to basement trends in the McArthur Basin east of the Emu Fault; at shallow depth there are relatively conductive strata with characteristics similar to the Tawallah Group rocks, but there is no distinct conductivity anomaly which can be attributed to the very thin, discontinuous outcrops of McArthur Group rocks.

The remaining non-isotropic data at the western end of the traverse have been analysed by means of inversion techniques to generate a 2D model which clearly shows a major discordance at the Emu Fault. Furthermore, this discordance persists at depth, reflecting the concept that major faulting in the Batten Fault Zone occurred before the formation of the McArthur Basin.

In the area to the east of the Emu Fault, the statistical parameters of the 2D program generate resistivities different from the 1D results, but the principal features of the 1D interpretation remain: a clearly defined resistive basement overlain by a fairly simple conductive sequence. Once again, there are no conductivity anomalies which may be correlated with the carbonate rocks of the McArthur Group.

To the west of the Fault there is an entirely new block of highly resistive rocks which may be directly correlated with the McArthur Group outcrop in this area. Carbonate rocks typically have high resistivities, and the calculated thickness of this block (about 4.45 km) is very close to the thickness of McArthur Group interpreted from surface geology. The underlying conductive layer has a thickness equivalent to the Tawallah Group measured on the Wearyan Shelf, and is consistent with the proposed geological model.

There is little doubt that the 2D model can be used to identify the McArthur Group to the west of the Emu Fault and the Tawallah Group both east and west of the Emu Fault. The distinctive resistivity of the McArthur Group west of the Fault seemingly makes it impossible that any appreciable thickness of McArthur Group can be present east of the Fault.

The results of the MT modelling across the Wearyan Shelf and eastern Batten Fault Zone, and its geological interpretation, clearly support the currently preferred geological model, which assumes that the Batten Trough is a syndepositional graben with rapid changes in depositional thickness at the boundary faults (Plumb & Derrick, 1975; Plumb & others, 1980).

1. INTRODUCTION

The McArthur Basin occupies an area of about 170 000 km^2, mainly within the Northern Territory but extending into Queensland near the Gulf of Carpentaria (Fig. 1). Unmetamorphosed and relatively undeformed sedimentary rocks with a thickness up to 12 km are extensively exposed in the Basin; they comprise the type section for the Carpentarian (Dunn & others, 1966) and constitute a classic example of North Australian Platform Cover (GSA, 1971).

The thick sequence, widespread exposure, and unmetamorphosed nature of the Carpentarian sedimentary rocks and mineral deposits can be used to provide valuable models in studies of Proterozoic basin evolution and the genesis of stratiform ore deposits. These models may subsequently be used in the search for further mineral deposits in other areas of the McArthur Basin, in adjacent areas of the Northwest Queensland Province, and in other epicratonic basins.

The huge unmetamorphosed McArthur River lead-zinc deposits can be readily related to the stratigraphy of the Basin, and the associated extensive carbonate rocks have potential for Mississippi Valley-type deposits. Many facies provide attractive prospects for large low-grade sedimentary copper deposits. The Kombolgie Formation, Yiyintyi and Mattamurta Sandstones, and Westmoreland Conglomerate are all derived from a uraniferous Lower Proterozoic basement and must therefore have potential for sedimentary uranium deposits. However, detailed stratigraphic and structural studies are required to determine in more detail the criteria for identifying mineral prospects within the Basin.

A fundamental concept in the evolution of the McArthur Basin and the location of major mineral deposits is the hypothesis that the Batten Fault Zone was originally a syndepositional graben, with sudden changes in the depositional thickness at the bounding faults.
This concept is critical to models for the genesis of the H.Y.C. orebody, because it is situated immediately adjacent to the bounding Emu Fault. The concept is derived from the observation that the exposed sequences

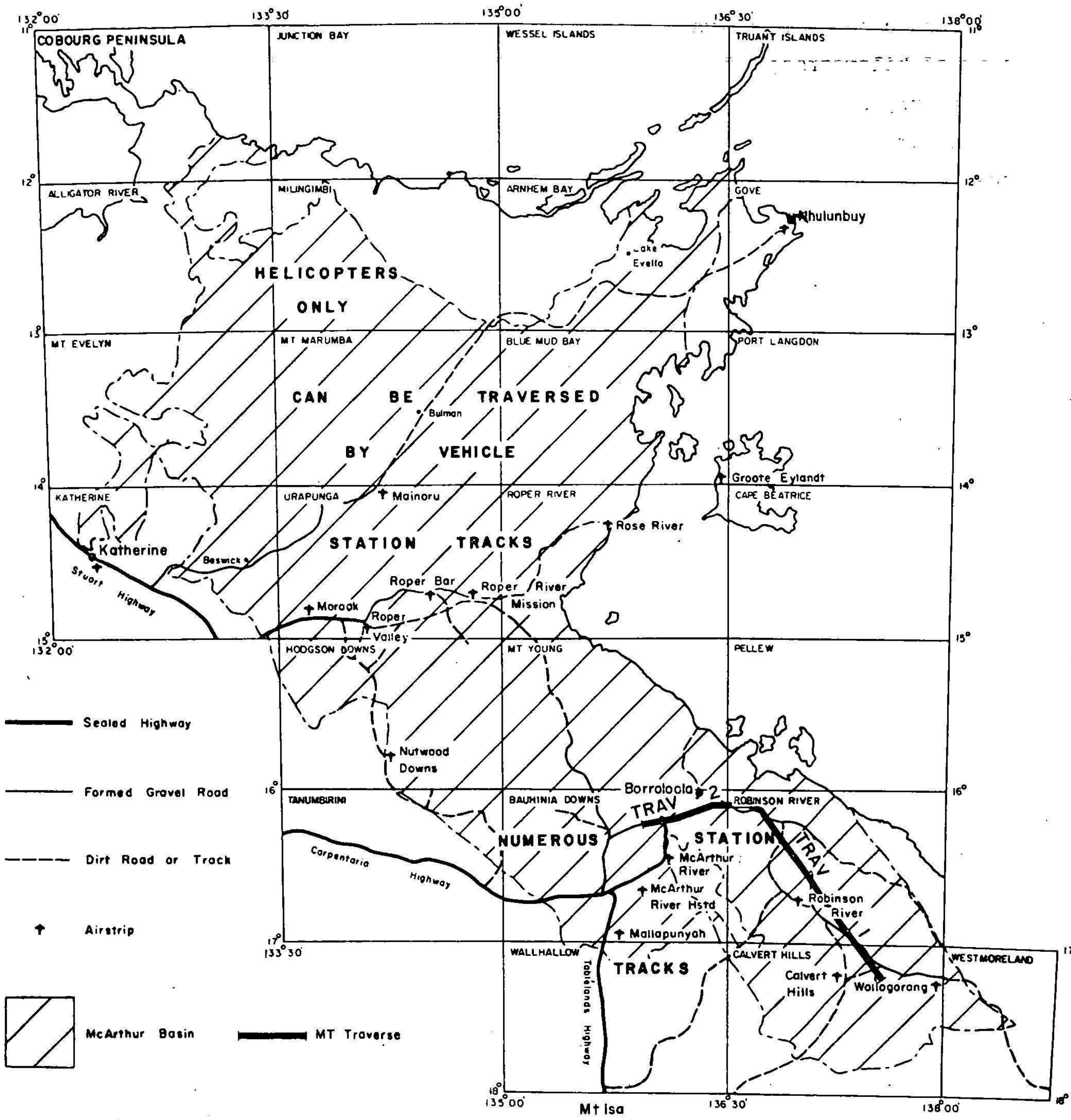

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Fig 1. Geographical setting of McArthur basin with index to 1:250 000 sheet areas and principal access.

on the bounding shelves are much thinner than in the Batten Fault Zone. However, exposures of the initial sequences on the shelves are separated from equivalent exposures in the Batten Fault by tens of kilometres; the critical exposures near the bounding faults are nearly always concealed by younger cover. Therefore, it is not known for certain whether the changes in thickness occur suddenly at the bounding faults, or change gradually over tens of kilometres. Subsurface information - from drilling or geophysics - is required to prove or disprove this concept. A magneto-telluric (MT) survey was therefore recommended for the McArthur Basin Project (Plumb, 1977), in an attempt to resolve the principal structural features in terms of electrical response.

The initial survey was designed across the southern part of the Basin because (1) the regional geology is well known; (2) detailed geological studies were in progress; (3) the H.Y.C. lead-zinc orebody, and other mineralisation, provide constraints immediately applicable to ore genesis studies; and (4) access and logistics are far easier than farther north, in Arnhem Land.

In 1978 seventeen MT sites were occupied in a 350 km traverse across the Wearyan Shelf and eastern Batten Fault Zone (Fig. 1) to resolve the structure across the Emu Fault (Fig. 2); 15 additional sites, extending the traverse 250 km to the west across the Bauhinia Shelf, were completed in 1979. Detailed gravity measurements have been made along the same traverse. Although interpretation of the 1979 data is not complete, the initial two-dimensional modelling of the 1978 data shows the major features of the structure across the Emu Fault and the thickness of basin sediments on the eastern shelf. Further interpretation will take place in 1980-81 when the results of gravity and refraction and reflection seismic surveys carried out in 1979 will be used in a composite geophysical interpretation.

2. GEOLOGY OF THE McARTHUR BASIN

The McArthur Basin is the relatively undeformed structure within which the Carpentarian Tawallah, McArthur, and Roper Group sediments and their stratigraphic equivalents 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 (Fig. 2). 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; no subsurface information is yet available 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.

Nature of the basement

The basement to the McArthur Basin comprises elements of the North Australian Orogenic Province. Exposures of the basement within the Basin are rare, so the probable nature of the unexposed basement must be extrapolated from inliers around its margins, particularly in the Pine Creek Inlier (Fig. 3).

The rocks of the Pine Creek Inlier comprise mainly low-grade metasediments, which are locally metamorphosed to amphibolite and low-granulite facies. Volcanic rocks are not abundant, but gabbroic sills are abundant in places. After deformation, extensive acid volcanics were extruded and associated large batholiths of granite were emplaced.

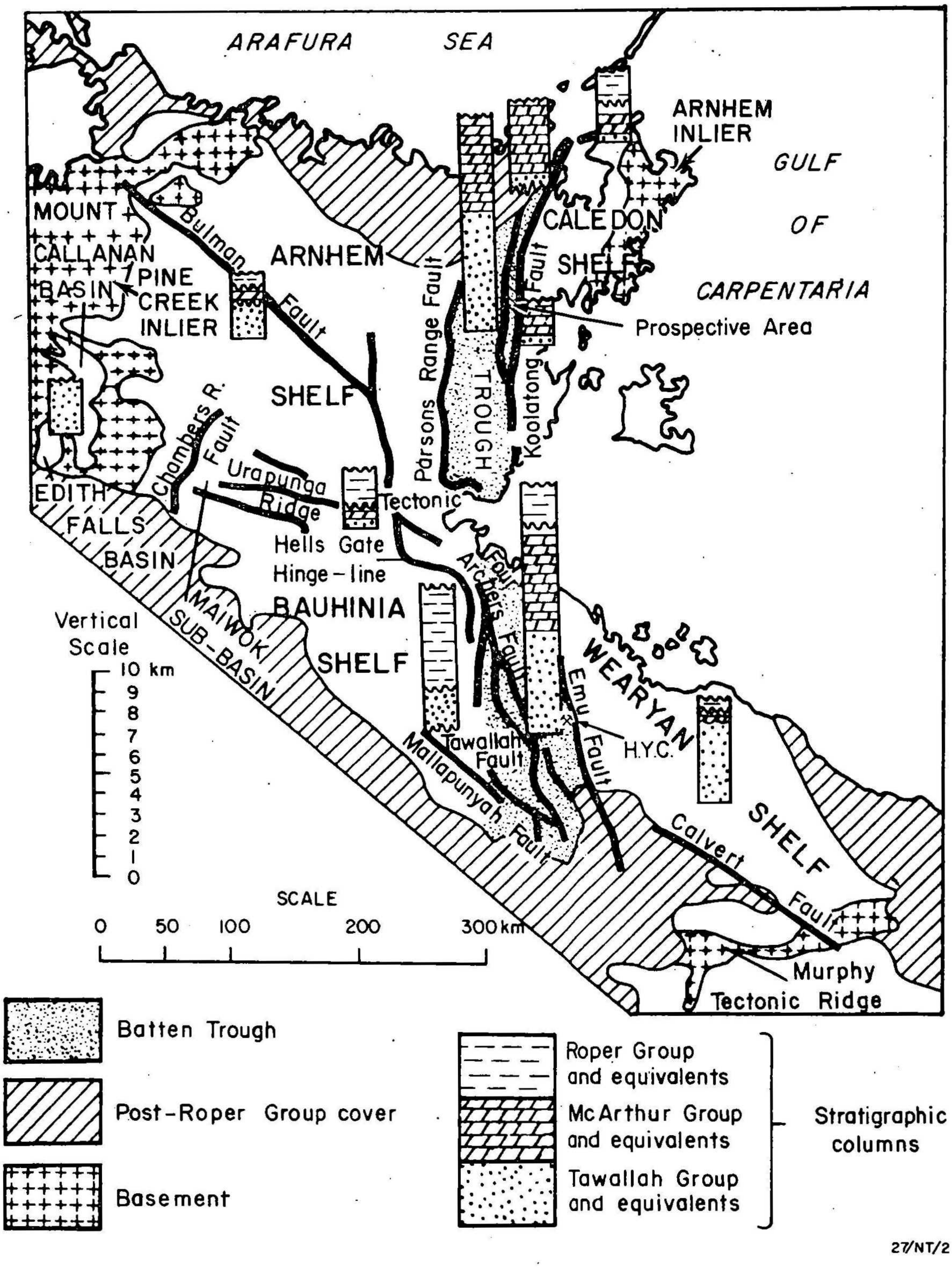

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Figure 2 Major tectonic elements, McArthur Basin (after Plumb & Derrick, 1975)

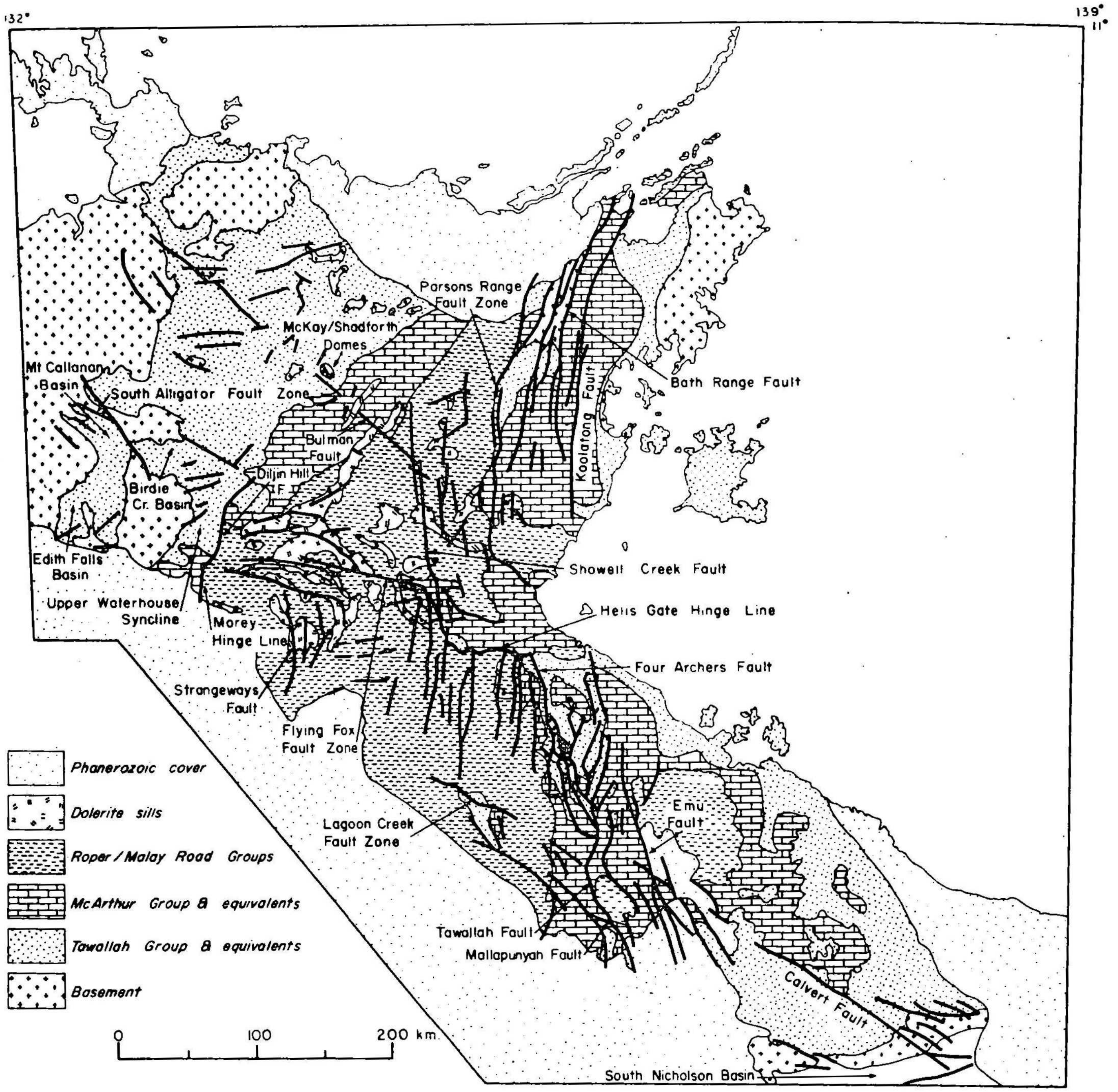

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Fig 3 Geological sketch map - McArthur Basin.

The limited outcrops of basement rocks exposed elsewhere indicate that all of these rock types can be expected to underlie the McArthur Basin, but data are insufficient for estimating the distribution or relative abundance. For practical purposes a mixture of low-grade metasediments and granites may be assumed.

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 (Fig. 3). The McArthur Basin lies near the eastern edge of the craton, adjacent to the penecontemporaneous mobile belt of the Mount Isa Orogen. After 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.

Tectonic units - statement of the problem

A number of distinct tectonic elements are recognised within the McArthur Basin. A 50-60 km wide meridional zone of relatively intense deformation, the Batten Fault Zone, contains a much thicker Carpentarian succession than that exposed on the adjoining Arnhem, Caledon, Bauhinia, and Wearyan Shelves. It is proposed, from geological evidence, that the Batten Fault Zone is the site of an earlier syn-depositional graben feature, the Batten Trough (Fig. 2). An exceptionally thin succession within the Urapunga Fault Zone indicates an earlier syndepositional feature, the Urapunga Tectonic Ridge.

The Batten Fault Zone is defined as being bounded by the Emu, Koolatong, and Parsons Range Faults (Fig. 2), but the southwestern boundary, with the Bauhinia Shelf, is gradational. There is clear geological evidence that the Emu Fault, and to a lesser extent the Koolatong and Parsons Range Faults, were active during deposition of at least parts of the succession, so the regional variations in stratigraphy may be readily explained by postulating that the boundary faults also defined the limits of the syndepositional graben. However, the critical sequences are not exposed in the areas immediately east of the Emu and Koolatong Faults and west of the Parsons Range Fault, so the possibility still exists that the changes in stratigraphic thickness could take place either suddenly or gradually, anywhere over distances of some 30-40 km. It is principally this problem for which a geophysical solution is required.

Stratigraphy

In the northern part of the Batten Fault Zone, the McArthur Basin succession has a maximum composite thickness of about 12 km, but in the present survey area (southern Batten Fault Zone) 10.5-11 km is more typical (Fig. 2). The sequences on the adjacent shelves are much thinner: in the survey area equivalent thicknesses are about 4 km on the Wearyan Shelf and 7 km farther west on the Bauhinia Shelf; in the north they are even less, 2-3 km on the Arnhem and Caledon Shelves.

The basin succession comprises three major subdivisions, each with its own distinctive association of rock types and regional variations in thickness.

The lowermost subdivision, the Tawallah Group, consists of quartz-rich arenites and subordinate basic volcanics, carbonates, and lutite. Its thickness in the survey area is relatively uniform: about 4.5 km in both the Batten Fault Zone and on the Wearyan Shelf, whilst the base is not exposed on the Bauhinia Shelf. Farther north, in Arnhem Land, the stratigraphic equivalents vary from 6 km thick in the Batten Fault Zone to 3 km and less on the Arnhem and Caledon Shelves (Fig. 2).

The overlying McArthur Group is a dominantly carbonate sequence: dolomite, dolomitic siltstone, and shale, and dolomitic sandstone. Within the survey area it varies from a maximum of 5.5 km in the Batten Fault Zone down to 100 m on the Wearyan Shelf and zero in the extreme western outcrops of the Bauhinia Shelf. Thickness variations in Arnhem Land are similar. Unconformities separate the McArthur and Tawallah Groups, and also various subgroups within the McArthur Group.

Overlying the McArthur Group with regional unconformity is the Roper Group, which displays a distinctly different facies association and pattern of thickness variation. It consists of extensive friable quartz-rich sands alternating with micaceous or carbonaceous shale and siltstone and, in the survey area, increases progressively in thickness from less than 1 km on the Wearyan Shelf to 5 km on the western Bauhinia Shelf.

A feature of the stratigraphy is the lateral uniformity of many units over wide areas and this, combined with the vertical variations in rock types, should provide a suitable succession for investigation by geophysical techniques.

Structure and tectonics

Structurally, the McArthur Basin contains stable shelves of shallowly dipping strata in the east and west, progressively younging towards a meridional zone of intense and complex block faulting, the Batten Fault Zone (Fig. 3); stratigraphic displacements of up to 7.5 km occur across these meridional faults, even exposing the basement in small inliers. A prominent zone of west-trending faults, the Urapunga Fault Zone, bisects the western stable block. Bedding dips rarely exceed 5° on the stable blocks, and even in the meridional deformed belt rarely exceed 20° - 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.

The major faults of the McArthur Basin are interpreted as long-lived structures which existed before the basin developed, were active during sedimentation in the basin, and then deformed it after deposition ceased (Plumb & others, 1980; in press). A major effect of the post-depositional deformation has been to uplift the rocks of the original Batten Trough, in many cases converting the original graben structure into a horst: basement is locally exposed in small inliers within the Batten Fault Zone. This reversal of movement can complicate the geophysical solution of the original form of the Batten Trough because, locally, the original subsidence or the syndepositional faults may be cancelled out or even reversed. The geophysical solution requires information on variations in stratigraphic thickness within the sequence, as well as simple identification of the basement configuration.

Although the two-dimensional geometry of the fault pattern is well known and the stratigraphic displacement of individual faults may be readily estimated, the attitude of the faults at depth is generally unknown and the true directions of movement are largely interpretative. Most of the faults are thought to dip steeply, and it has been postulated that the fault system is largely the result of horizontal strike-slip movements (Plumb & others, 1980).

3. GEOPHYSICAL CONSTRAINTS

Regional gravity data have been obtained in the McArthur Basin and are included in the Gravity Map of Australia at 1:5 million scale. At this scale there is little variation in gravity across the McArthur Basin; there is no obvious relation to structure in the sedimentary cover and most anomalies are tentatively ascribed to variations in the basement (Anfiloff, 1979). The data suggest a very low density contrast between the sediments and the underlying basement (2.5-2.6 t/m^3), which is consistent with the probable prevalence of low-grade metamorphic rocks and granite in the basement and the degree of lithification of the basin sediments. However, one of the major density contrasts may originate from the dolomites of the McArthur Group; values may exceed 2.7 t/m^3, causing anomalies diagnostic of structures critical to the evolutionary concept. An early reconnaissance gravity traverse from Normanton to Daly Waters (Neumann, 1964) showed marked anomalies which are not apparent in data on the regional grid. Further BMR data at intervals of 500-1000 m are now being reduced (Anfiloff, 1980) to allow more detailed interpretations.

An aeromagnetic survey was carried out by BMR during 1963-64 over about 7500 km^2, to the north and west of McArthur River (Young, 1964). Many of the major geological structures were recognised, but basic volcanics within the basin succession complicate calculations of depth to the lower Proterozoic basement. All of the intense anomalies overlie outcrop of the volcanics. The method has potential for extrapolating regional structures into areas of no outcrop, but calculations of depth to basement will require close geological-geophysical liaison to filter out the effects of the volcanics, etc. from the sequence.

In most circumstances seismic reflection techniques can be used to define structural features with great precision. However, in the McArthur Basin, the data must be obtained along profiles over rough terrain extending to distances of tens of kilometres. Access to many critical areas is very poor and logistical problems are considerable. In addition any seismic response would probably be reduced by the thick carbonates of the McArthur Group and consequently a large shot pattern would be required as a matter of routine. The cost of any such survey would then be excessive. Long-range seismic refraction profiles can be used as a compromise; these give poorer structural resolution but fewer shots are required. A major survey of this type was conducted by BMR in 1979, to investigate the velocity structure in the crust and upper mantle (Collins, in prep.), but there was no attempt to resolve the detailed structure within the sedimentary sequence of the basin.

A magneto-telluric (MT) survey can be used to complement the more common geophysical reconnaissance techniques described above. It is the only method currently available which can be used routinely to map electrical conductivities at depths from 1-20 km. A range of frequencies can be recorded to give a more definitive solution than can be obtained from gravity and magnetics alone. However, the usefulness of MT depends on the existence of adequate conductivity contrasts. While in some cases MT will provide information where other methods will not, it is also possible that some structures will not be detected by their electrical response.

4. BASIC PRINCIPLES OF THE MAGNETO-TELLURIC METHOD

The MT method is a geophysical tool for mapping subsurface electrical conductivity. Observations are made of the natural transient magnetic field together with the induced electric field. A detailed description of the method is given by Vozoff (1972) and only the basic principles will be repeated here.

The MT technique depends on electromagnetic energy reaching the earth's surface from two major sources. Signals with a frequency less than about 1 Hz are usually due to ionspheric currents at heights of 75 km or greater. Frequencies about 1 Hz and greater are usually produced by electrical or thunderstorm activity in the atmosphere. It is assumed in the MT method that these sources are remote; calculations are based on the assumption of plane waves but adequate results can be obtained using curved waves with a radius of curvature greater than several times the "skin depth" of penetration of the earth at that frequency. These conditions occur most of the time in most sedimentary basins in Australia, but it has been found on some occasions that plane wave conditions do not occur and this complicates the processing of the data.

When plane electromagnetic waves strike the earth's surface they may do so at any angle; they are then partially reflected [at an angle equal to the angle of incidence] and partially refracted at the air/ground interface. The angle of refraction depends on the angle of incidence of the wave and the relative velocity of the wave in the air and earth; typically this velocity ratio will be many orders of magnitude, so the refracted wave will always be propagated nearly vertical downwards into the earth. At the point of reflection on the earth's surface, the reflected magnetic component of the wave is inphase with the incident component, while the electric field undergoes cancellation due to phase reversal. The magnetic field at the air/earth interface is therefore nearly twice its value in free space, but the electric field component is reduced by many orders of magnitude over its free space value, and may be ignored.

The MT technique relies on this vertically-propagated alternating magnetic field, and the measurement of currents induced in a conducting medium (the earth) by that field. Penetration of the wave is determined by its frequency of oscillation and the conductivity of the medium, which together cause energy loss due to eddy currents. The ratio of induced electric to magnetic field at various frequencies is used to calculate apparent resistivity (i.e. the resistivity of a uniform earth which gives the measured E/H ratio) as a function of frequency. Apparent resistivity curves are then used to produce one-dimensional (1D) layered models and, finally in some cases, two-dimensional (2D) resistivity models.

In the MT technique the horizontal magnetic field is usually measured with the corresponding induced electric field in two orthogonal directions on the Earth's surface. If 3D structure is present the vertical magnetic field may also be measured, but for present purposes it can be assumed that measurement of both horizontal components in the E and H field ensures a complete knowledge of the Earth's electrical response; this is essential for the interpretation of two-dimensional structures. The induced electric field will lead the magnetic field in phase by 45 degrees in a uniform Earth. However E and H are generally complex and can be represented by amplitudes and phases of fields which are sinusoidal functions of time (t).

i.e. the actual field is $\varepsilon_x = E_x \; e^{-iwt}$

where $w = 2\pi/T$, and T = period(s)

The apparent resistivity P_{ij} of the ground can be calculated from the ratio of the orthogonal electric and magnetic fields from the formulae

$$P_{xy} = \frac{T}{5} \left| \frac{Ex}{Hy} \right|^2 = \frac{T}{5} \left| Z_{xy} \right|^2$$

$$P_{yx} = \frac{T}{5} \left| \frac{Ey}{Hx} \right|^2 = \frac{T}{5} \left| Z_{yx} \right|^2$$

where P_{ij} is the resistivity in ohm-metres (ij = xy or yz)

E is in millivolt km^{-1}

H is in nanoteslas

and Z_{ij}

is defined as the wave impedance of the medium (a complex number reflecting the phase difference in E and H).

Over a uniform earth the E/H ratio is constant at all periods and $P_{xy} = P_{yx}$ = ground resistivity. Over a non-uniform earth P_{xy} and P_{yx} vary with period (T), and a plot of P_{ij} as a function of T yields information on the sub-surface resistivity. At short periods P_{ij} tends to the resistivity of the shallow layers, and at long periods P_{ij} tends to the resistivity of the deeper layers. A measure of penetration is given by what is known as "skin depth". This is the depth at which field amplitude has dropped to 1/e of its surface amplitude at a particular frequency; it is defined by the expression $d = \frac{1}{2}\sqrt{PT}$ km.

Where there are lateral changes in resistivity (giving 2D or 3D structure) the following relations apply for the horizontal fields:

$$E_x = Z_{xx} H_x + Z_{xy} H_y$$

$$E_y = Z_{yx} H_x + Z_{yy} H_y$$

In a horizontally layered or uniform earth $Z_{xx} = Z_{yy} = 0$ and $Z_{xy} = Z_{yx}$ hence P_{xy} and P_{yx} are identical. For 2D structures with a coordinate system lined up along strike, $Z_{xx} = Z_{yy} = 0$ and one of Z_{ij} is a maximum and the other is a minimum. In practice, the strike is unknown or varies with frequency so that neither Z_{xx} nor Z_{yy} is small. The Z_{ij} can be rotated (mathematically) into a new reference frame to minimise $|Z_{xx}|^2 + |Z_{yy}|^2$ and maximise $|Z_{xy}|^2 + |Z_{yx}|^2$. The rotation angle enables strike to be determined but with an ambiguity of 90^o.

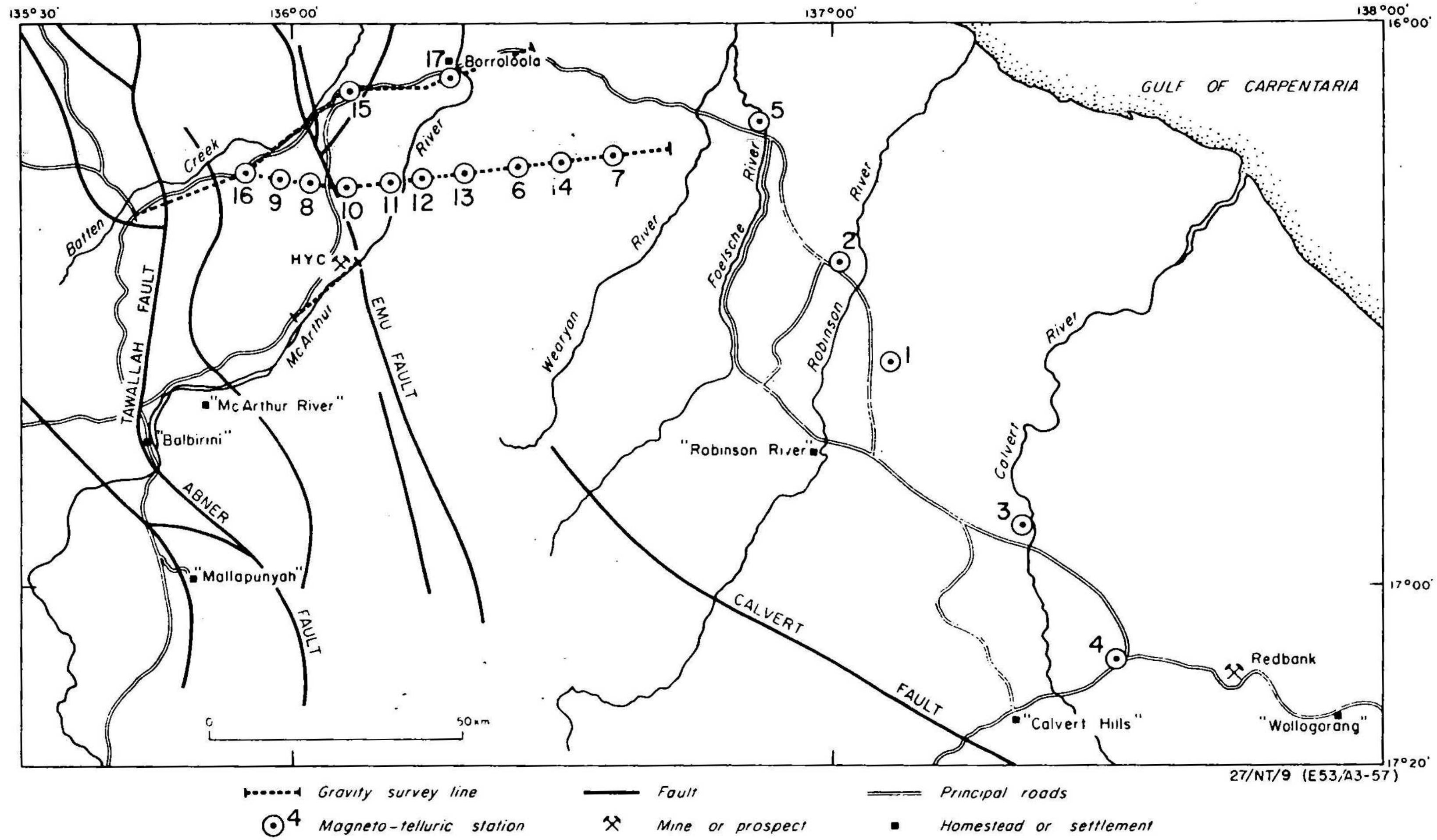
For a layered or uniform earth the vertical magnetic field H_Z is zero. Two- and three-dimensional structures produce vertical magnetic fields which may be used in conjunction with the horizontal fields to determine strike direction.

5. SURVEY DESIGN

The location of the survey was dictated by access. A more geologically desirable line passing through the H.Y.C. deposit, 15 km to the south, was totally inaccessible to the survey vehicles. The area of known, simple structure east of the Wearyan River was included as a control to test the effectiveness of the method in defining both basement and surface layer boundaries within the Tawallah Group. West from the Wearyan River the survey sites were located on a cleared line prepared specially for a gravity survey across the basin.

The location of the 1978 MT survey is shown in Figures 1 and 4, and two alternative but extreme geological cross-sections, which were constructed from surface geological data as a basis for the pre-survey modelling, are shown in Figure 5.

It was considered that geological control was adequate to define reasonably reliable sections west of the Emu Fault and at the eastern end of the survey, east of the Wearyan River. The critical, unknown area lay between the Wearyan River and the Emu Fault. The first section in Figure 5 assumes that the succession, particularly the McArthur Group, thickens suddenly across the Emu Fault.



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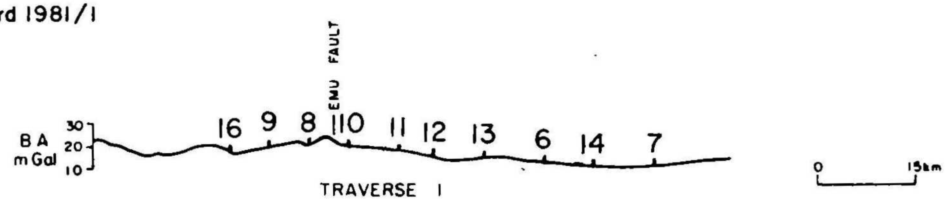

Fig. 4 Locality map and preliminary Bouguer anomaly profiles — McArthur Basin magneto-telluric and gravity survey, 1978.
(From Record 1979/15)

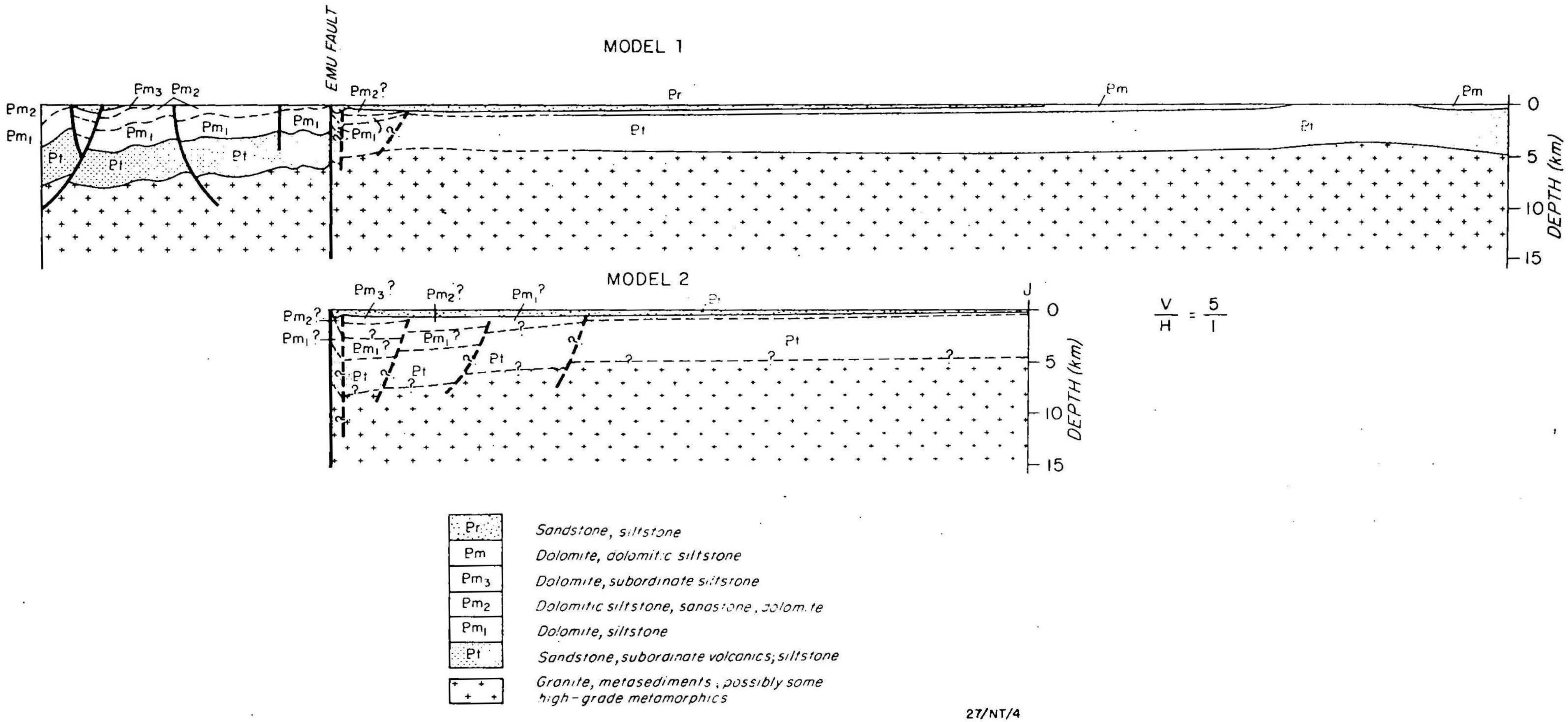

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Fig. 5 Alternative cross-sections

The alternative section is based on a gradual thickening of the sequence between the Wearyan River and Emu Fault. Other models can be formulated but the structural problem based on the existence of a graben can be solved if one extreme can be eliminated.

Pre-survey modelling

Before any geophysical survey it is necessary to select techniques and procedures which are capable of providing an adequate solution to the geological problem. Mathematical modelling may be used to estimate the MT responses of the anticipated basin structure and so indicate the sensitivity of the model parameters and provide limits to resolution.

The objectives of pre-survey modelling of the McArthur Basin were to see whether MT could be used to:

(a) define the depth to basement;
(b) define marker horizons or boundaries in the McArthur Basin succession; and
(c) define structure near the Emu Fault to determine whether there is an abrupt or gradual change in the thickness of the McArthur Basin rocks from the thin sequence on the Wearyan Shelf to the thick sequence exposed within the Batten Fault Zone.

MT modelling provides a quantitative relation between the natural electromagnetic (EM) fields at the earth's surface and the resistivity distribution beneath the surface. The natural EM fields are the quantities measured in an MT survey; relating the subsurface resistivity changes to these measurements is a fundamental step in the interpretation of the data.

Forward modelling involves the calculation of the EM fields from the postulated resistivity distribution, whereas inverse modelling involves the calculation of the resistivity distribution from the actual measured EM fields.

In 1D modelling, the EM fields are related to the resistivity and thickness of horizontal layers. In 2D modelling, the EM fields are related to resistivity changes in two directions, the vertical direction and one horizontal direction. It is assumed that there is no variation in the other horizontal direction, the strike direction.

The EM fields over 1D structures can be expressed as closed analytical functions of the resistivity and thickness of each layer; the solution of these functions is described elsewhere (Vozoff, 1972). However, these simple solutions are rarely applicable in nature. Consequently, the pre-survey modelling for the McArthur Basin was based mainly on 2D forward modelling, using the computer program EMCAL developed by T.R. Madden in 1970 at Massachusetts Institute of Technology; this program relies on a transmission surface analogy, and numerical techniques are used to solve Maxwell's equations described elsewhere (Ward, 1967).

The 2D modelling program EMCAL calculates the theoretical EM fields for only two polarisations, either E perpendicular (E_I) to strike or E parallel (E_{II}) to strike, with the Y axis as the strike direction. At first this may seem unnecessarily restrictive; however, after rotating the observed data, ρ_{xy} is effectively the resistivity with E perpendicular to strike and ρ_{yx} is the resistivity with E parallel to strike.

Model resistivities

No resistivity information was available from pre-survey measurements on rock types in the survey area. Therefore, resistivity values were estimated from a table of 'typical' rock resistivities (Fig. 6). The resistivities chosen were consistent with two possible sections:

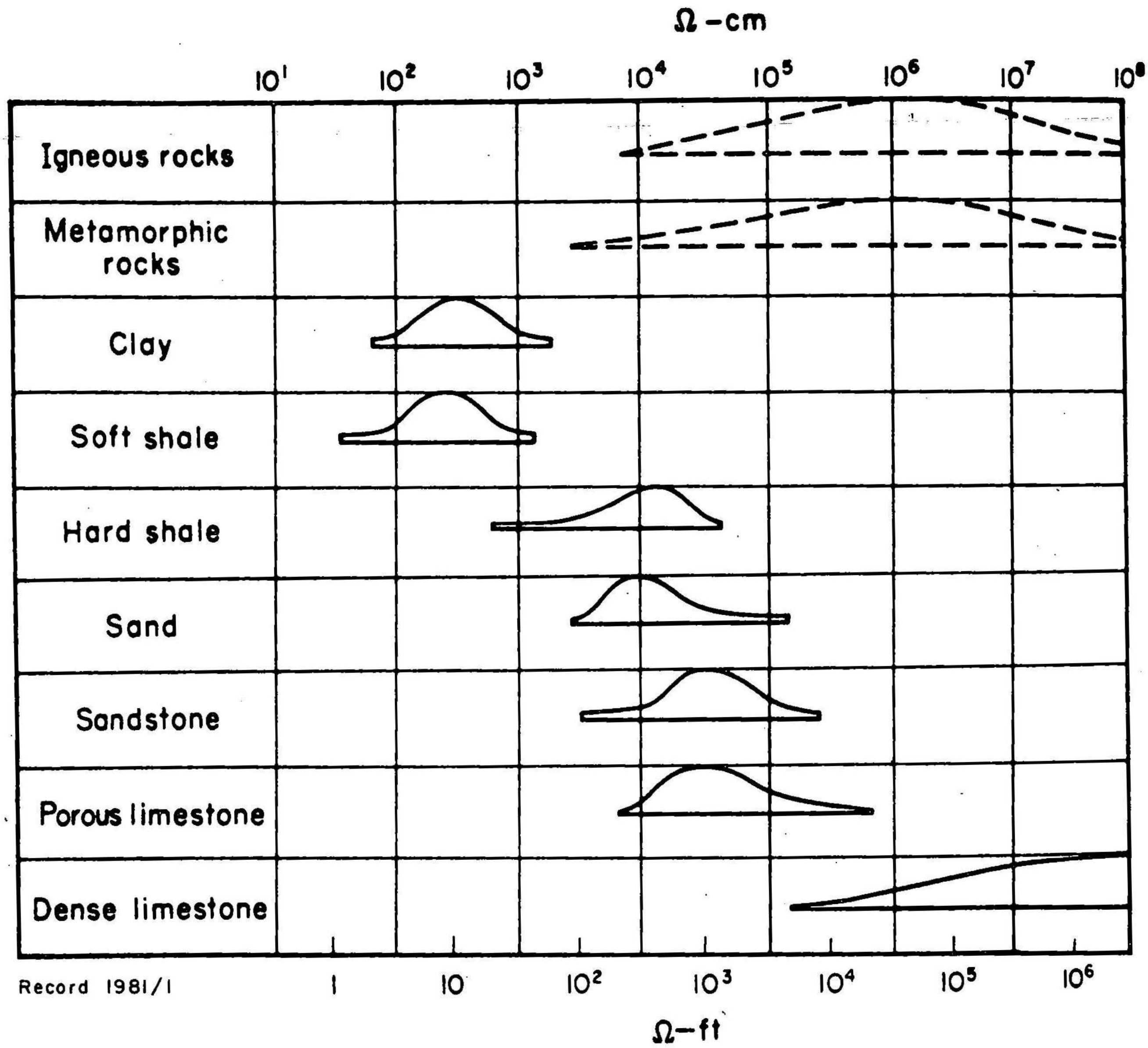


Fig. 6 *The Electrical Resistivities of Rocks*

Type A resistivities: McArthur Basin succession with moderate resistivity (100-500 ohm-m) together with a highly resistive basement (2000 ohm-m), providing a good resistivity contrast (20:1) at the basement. For this case, the main objective was to see whether the basement configuration could be defined by MT.

Type B resistivities: McArthur Group dolomite and Tawallah Group sandstone, both with a high resistivity (2000 ohm-m), and a slightly more resistive basement (5000 ohm-m), i.e. a small resistivity contrast (2.5:1) at the basement. Within the Tawallah Group the basalts and tuffs were assigned a moderate resistivity (200 ohm-m), and hence a contrast of 10:1 with the Tawallah Group sandstones. The main objective in this case was to see whether the basalt flows would form marker horizons within the Tawallah Group, which could be traced by MT. If successful, it would be necessary to assume that they were approximately parallel to the basement, in order to obtain the basement configuration near the Emu Fault.

Both types A and B have in common a large drop in resistivity at depths of 100 km within the mantle, together with a surface cover of moderate to low resistivity (100 ohm-m) of Roper Group sandstones and siltstones east of the Emu Fault. Any such conductive cover may result in rapid attenuation of the EM waves and partial screening of the effects from material beneath. Both type A and type B resistivities were applied to test the geological models 1 and 2 of Figure 5.

General comments

Before describing the details of each model some general comments are in order concerning the presentation of results.

(1) A pseudo-section is a contoured plot of a parameter. The parameter value is written at a point with the horizontal position representing the spatial position of the measuring site along the traverse. However, the vertical position is determined by the wave period,

plotted on a logarithmic scale increasing down the page. At longer periods the EM wave penetrates more deeply so that, in a crude way, the pseudo-section represents a plot of the parameter as a function of horizontal position and depth. But it must be stressed that the pseudo-section is not a plot of resistivity as a function of depth. Firstly the parameter plotted is usually the apparent resistivity and, secondly, the vertical scale is the log of period and not depth. The purpose of the pseudo-section is to indicate how the physical parameter changes in space (horizontal axis) and period (vertical axis). Comparison can then be made between pseudo-sections, indicating the sensitivity of the MT response when there is any change in the section structure or resistivity.

(2) Because the normal component of the E field is discontinuous across an interface where the conductivity changes, the ρ_{xy} apparent resistivity shows a more abrupt change than the ρ_{yx} component; consequently only examples of ρ_{xy} are presented here.

(3) The ratio of the vertical/horizontal component of the magnetic field is largest near the lateral discontinuities and close to zero over layered structures.

(4) Because of computer storage limitations, only part of the pseudo-sections can be modelled at any one time. For the present study the frequency range was therefore split into high, medium, and low bands, covering the periods 0.01 s to 3000 s. This splitting represents a vertical subdivision within the pseudo-section. A horizontal subdivision was also introduced by modelling only certain intervals of the geological section at a time. These horizontal subdivisions were overlapped, and this accounts for two values of a parameter occurring at some plotting points. The letter P along the top of the profiles in Figures 7 to 10 represents a surface point at which the EM fields were calculated.

(5) The BMR MT system has an upper limit of about 25-30 Hz to its frequency response. Consequently it is not possible to confirm the values predicted on the first level of each pseudo-section (100 Hz), and the values on the second level (30 Hz) can be obtained only at the limit of resolution of the measuring system.

Details of calculated pseudo-sections

In the following discussion surface locations will be referenced to the scale running from 0 km, west of the Tawallah Fault, to 400 km at the Murphy Inlier.

Type A resistivities: Good resistivity contrast between basement and the overlying McArthur Basin rocks

Comparison of P_{xy} in geological model 1 with P_{xy} in geological model 2 (Figs 7, 8), at 100 km, shows no significant change in the contours associated with the basement boundary (T = 6-30 s). This suggests that MT cannot be used to distinguish between models 1 and 2 (Fig. 5) by the response from this boundary alone. However, from 0.03 s to 6 s there is a significant difference in the predicted MT responses, caused by the thick moderately-resistive McArthur Group dolomite in structure II. Thus MT should detect the difference between models 1 and 2 (Fig. 5) due to the dolomite, but it may be unsuccessful at providing a reliable depth to basement.

A similar conclusion is reached by comparing computed values of P_{yx} for both structures. There is a significant difference in the responses from 0.03 to 6 seconds, but beyond that (6-3000 s) the pseudo-sections are almost identical.

The most significant changes in apparent resistivity are associated with structures at the Emu Fault (Fig. 7 at 85 km). Similar perturbations are indicated for both structures. This feature is caused by the contrast between the Roper Group (100 ohm-m) east of the Fault and the McArthur Group (500 ohm-m) west of the Fault. In the period range 0.3-10 s, the orthogonal field ratios for model 1 are significantly higher than those for model 2. Again, this is due to the abrupt change in the thickness of the McArthur Group across the fault in model 1, compared to the gradual change in model 2. In the range 30-3000 s, the values of the ratios decrease for both structures, indicating one-dimensional structure at depths in the range 30-100 km.

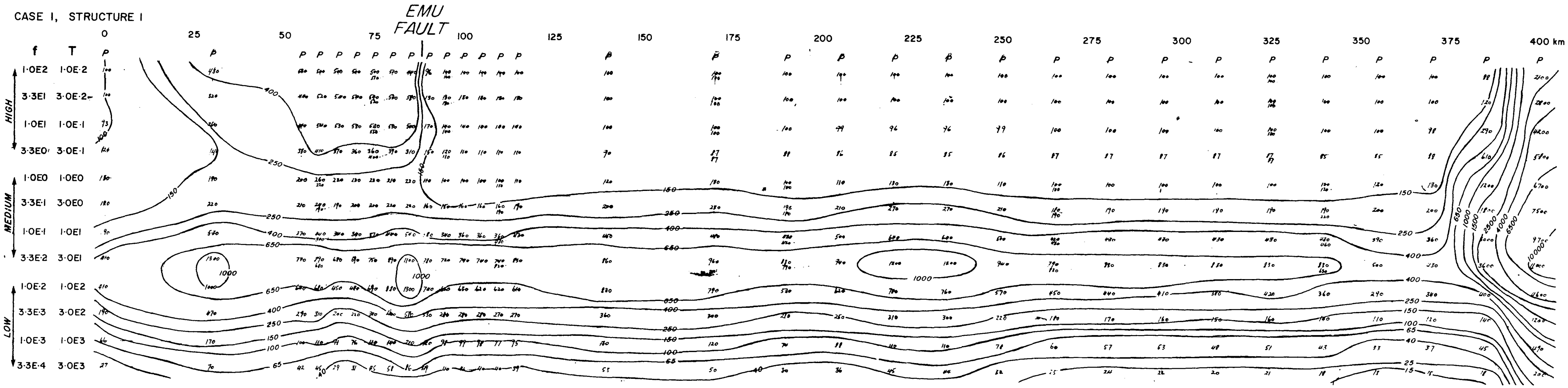
Another interesting feature in the P_{xy} contours is the response of the inferred basement high, located at the Murphy Inlier 225 km from the Emu fault (Fig. 7). A 25% change in the basement depth produces a similar (28%) change in P_{xy}, which implies that the depth to basement should be well defined. This result seems contradictory to the earlier conclusion that the basement depth would be poorly defined near the Emu fault (at 100 km). But in that case, the picture is complicated by the thick sequence of dolomite, which has a 5:1 resistivity contrast with the overlying Roper Group and with the underlying Tawallah group; the response of this configuration dominates the weaker response of the basement boundary.

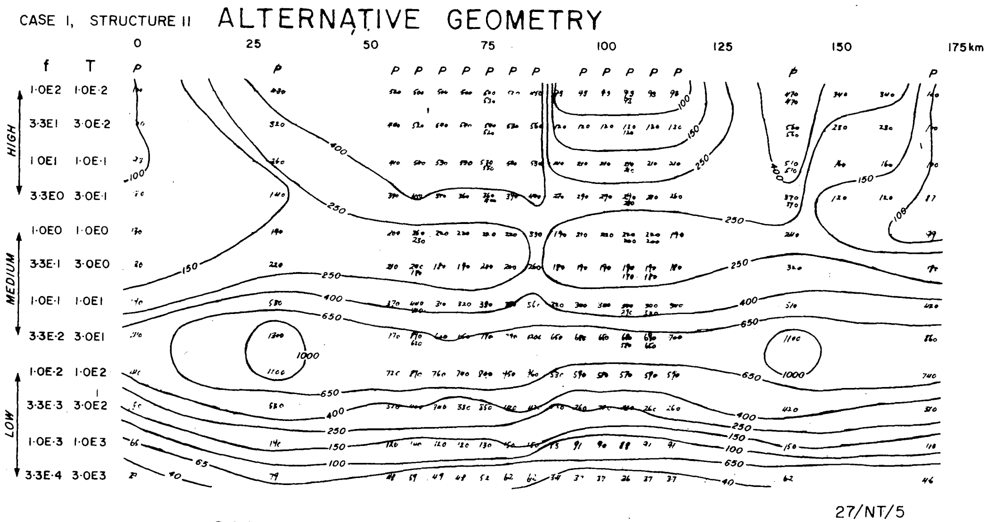
The rise of the highly resistive basement to the surface at the Murphy Inlier (Fig. 1) is evident from the contours in the region from 375-400 km (Fig. 7), but the effect appears more suddenly in the P_{xy} component than the P_{yx} component.

Type B resistivities: Poor contrast between the McArthur Basin succession and the underlying basement, with a low-resistivity basalt horizon in the Tawallah Group

Between the distances 170 km and 375 km (Fig. 9) the basalt horizon is evident in the P_{xy} and P_{yx} contours, where it appears as a low-resistivity trough for period 0.03-0.1 s (Fig. 9). At 225 km the trough rises, reflecting the upwarp of the basalt over the basement rise. Hence, at first sight, it would appear that MT should be successful at following the basalt flow, provided that good high-frequency data is available. However, the trough is much weaker, between 305 and 330 km, because of masking of the main basalt flow by the low-resistivity near-surface basalt. This near-surface flow was not included in the modelling, except for a surface block 500 m thick between 310 and 325 km.

The response of the main basalt flow is also masked by the low-resistivity Roper Group (100 ohm-m), which was modelled as a surface layer 500 m thick extending from the Emu Fault to a distance of 140 km.





PXY CONTOURS MODEL 2A

PXY CONTOURS MODEL 1A

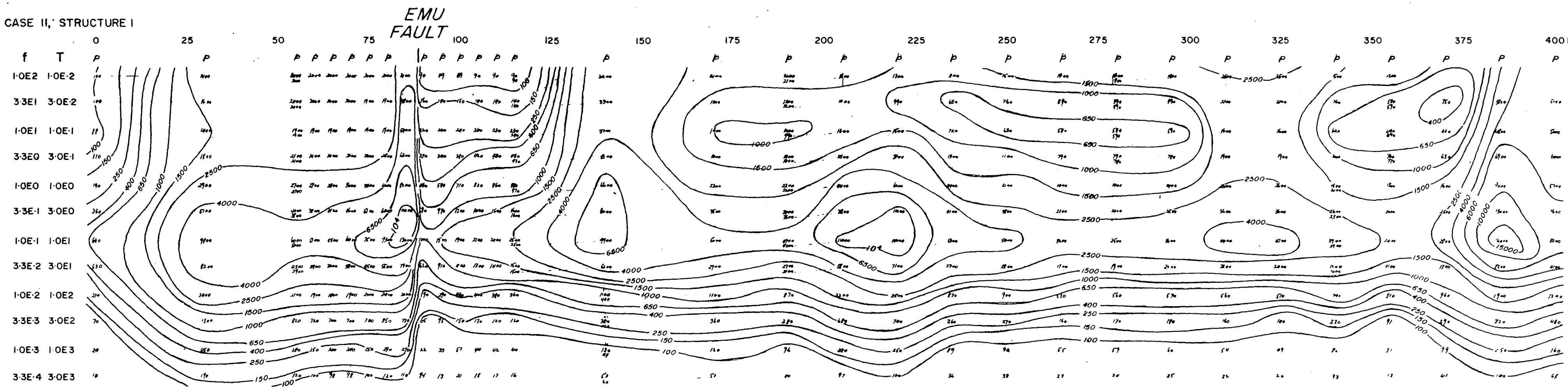
APPARENT RESISTIVITY E ⊥ TO STRIKE

$$PXY = \left| \frac{j}{\omega\mu_0} \left(\frac{EX}{HY} \right)^2 \right|$$

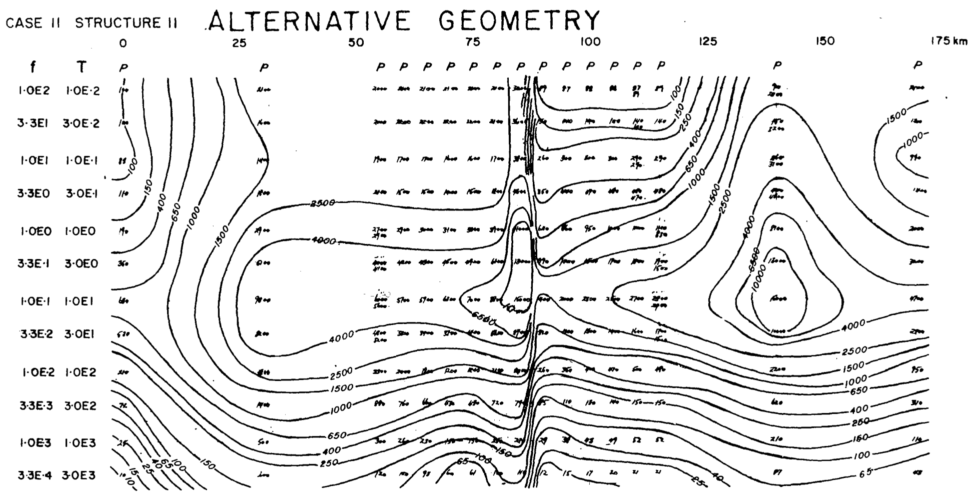
FIRST RESISTIVITY DISTRIBUTION

Figures: 7 and 8

3



PXY CONTOURS MODEL 1B



PXY CONTOURS MODEL 2B

27/NT/6

APPARENT RESISTIVITY E ⊥ TO STRIKE

$$\rho_{XY} = \left| \frac{j}{\omega \mu_0} \left(\frac{E_X}{H_y} \right)^2 \right|$$

SECOND RESISTIVITY DISTRIBUTION

Figures: 9 and 10

Record 1981/1

Because of this masking, the P_{xy} contours show only slightly lower values in the range 0.1-3000 s for model 1 than for model 2. The difference in values is caused by the main basalt flow, which is nearer the surface in model 1 than in model 2. The small difference in response of the two structures implies that MT may not give an accurate depth to the basalt horizon.

Limitations of modelling

(1) The biggest limitation in the modelling is caused by poorly specified rock resistivities within the section; if these values are not approximately correct, then much of the modelling is inapplicable.

(2) A further limitation is the solely qualitative comparison of the contours. For inversion modelling, a sensitivity analysis is available which enables the effect on the MT response to be assessed for variations of the model parameters. However, 2D modelling is very costly and was not justified for survey planning in view of the uncertainties in resistivity.

Conclusions from pre-survey modelling

In the absence of a conductive surface layer, the MT method should detect and give fairly accurate depths to the basement, assuming Type A resistivities, or to the basalt layer, assuming Type B resistivities. However, where there is partial masking by a conductive surface layer, the results could be much less reliable.

For Type A resistivities, data could be obtained to distinguish between models 1 and 2 in Figure 5 mainly as a result of the resistive dolomite included between the more conductive Roper Group and Tawallah Group rocks. Furthermore, even if there is little contrast within the McArthur Basin succession, the good response over the basement rise at 225 km implies that the basement surface could be mapped as far west as the Emu fault.

For Type B resistivities, there is little hope of determining the position of the basalt horizon, or of determining basement configurations, if there are conductive surface layers in the section.

6. ACQUISITION AND PROCESSING OF MAGNETO-TELLURIC DATA

Field techniques and equipment

The methods used for recording MT data depend to a large extent on the spectra of the signals being measured. Field strengths decrease rapidly at high frequencies, to levels approaching 1 picotesla (pT). However, a dynamic range of 100 dB is accommodated by the use of induction coil magnetometers, which become increasingly sensitive at higher frequencies. These low signal levels determine the critical design parameters for the analogue portion of the equipment. The magnetometer coils are buried underground to reduce noise interference and to provide greater thermal stability. This requires two trenchs 50 cm deep for the X and Y components and a vertical auger hole 2 m deep in the case of the Z component. The preamplifiers are of a type with extremely low noise levels (typically 0.03 μV) with guarded differential inputs and chopper stabilisation to eliminate DC drift.

The E field is measured with electrodes which consist of cadmium rods inserted in supersaturated cadmium chloride solution in porous pots. The porous pots are placed in contact with moist earth, usually in a hole with a covering to protect against wind and wildlife. Wire similar to seismic cable is used to connect the electrodes to the amplifiers. Shielding is not necessary because of the low source impedances involved. The particular arrangement described for the electrodes is necessary to protect against polarisation noise. The wire to the electrodes must be covered with sand or soil every few metres, to prevent induced EMFs caused by wind moving the wires.

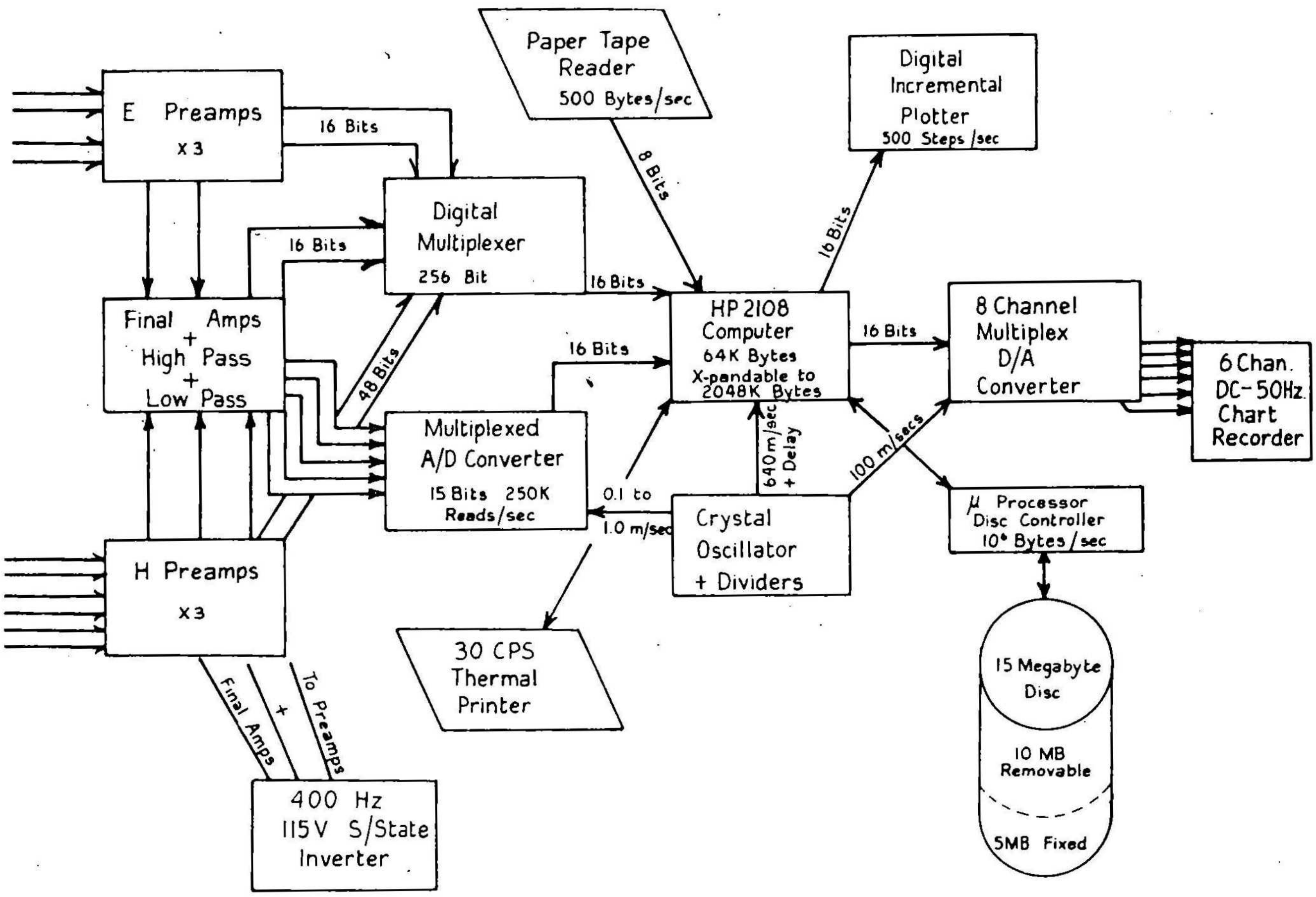


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Fig. 11 Schematic diagram of MT system

The digital portion of the equipment is a standard computer-based data acquisition system. The data are recorded in files on a 10 million bytes capacity disc memory, and transferred to a 9-track magnetic incremental recorder after field recording at each site. The analogue-to-digital converter has a resolution of 0.003%. A block diagram of the MT system is shown in Figure 11.

Recording at an MT site demands a digital sampling rate of 0.03 to 350 samples per second designed to cover specific frequency bands selected for reasons of dynamic range and economy in the number of data points. These bands are usually as follows:

0.002	-	0.025	Hz
0.01	-	0.125	Hz
0.1	-	2	Hz
1	-	25	Hz
10	-	25	Hz

The sampling rate and number of points recorded determine the maximum bandwidth which may be recorded. One site is usually occupied for a period of 2 days, during which time up to 150 bands would be recorded on tape. It is normal to process at least some of the recorded data, on site, before moving electrodes and magnetometers.

Full use of the digital equipment permits a very large amount of data to be acquired and processed. Field processing can be carried out simultaneously with data acquisition, if so desired. Processing of MT data to the stage where tensor impedance versus frequency plots are obtained is the only satisfactory and economic method of deciding whether or not the sites are being located correctly, and whether sufficient data have been acquired from a site. It is also possible to compute one-dimensional layered inversion models in the field as the survey progresses, providing useful information on the probable value of the data in meeting survey objectives.

Data obtained in the McArthur Basin

The two traverses (1 and 2) shown in Figure 4, extending a total distance of 330 km, were designed according to the objectives discussed in the section on Modelling. As described previously, the MT sites were located with the following aims:

(1) To determine the structure near the Emu Fault;
(2) To provide a depth to basement and/or to delineate horizons within the sediments in an area of simple geology; and
(3) To provide deep crustal information for the McArthur Basin area.

Consistent with the first objective, sites were occupied along Traverse 1 from about 75 km east of the Emu Fault to 25 km west of the Fault, with a station spacing of 7-10 km near the fault (Fig. 4). For the second objective, it was considered adequate to occupy only five stations along 230 km of traverse (Traverse 2). Furthermore, it was proposed to work only as close to the Murphy Inlier as was necessary to define basement. The deep crustal information would be obtained as a by-product, from observations on both these traverses.

During the course of the survey the traverse plan was modified progressively according to the results obtained. In particular, stations on Traverse 2 were occupied only as far south as station 4. The traverse was terminated there after consistent depths to basement had been observed from stations 1-4, with predictable trends to the surface at the Murphy Inlier. On Traverse 1 two slight bends were introduced near the Emu Fault (one between stations 11 and 12 and the other between stations 8 and 10), to accommodate stations 6 to 14 which were located on cleared lines used for a gravity traverse.

As a result of these operational modifications, the survey duration was reduced by 3-4 weeks. However, the MT stations did not comprise a linear profile, and the survey line did not intersect the Emu Fault normal to the strike. These are considered to be minor defects.

The stations occupied are listed in Table 1 together with grid coordinates and the magnetic azimuth of the x direction selected at each site.

Deep resistivity soundings using Schlumberger and equatorial dipole configurations were made on stations 6 and 7, to determine the resistivity to a depth of about 200 m. The methods used and the results of these soundings are presented in Appendix 1.

Data presentation

MT data are recorded in the time domain as a matter of convenience. However, it has been noted that impedance is a function of frequency. Therefore, the data records are transformed to the frequency domain, by means of a fast Fourier transform algorithm.

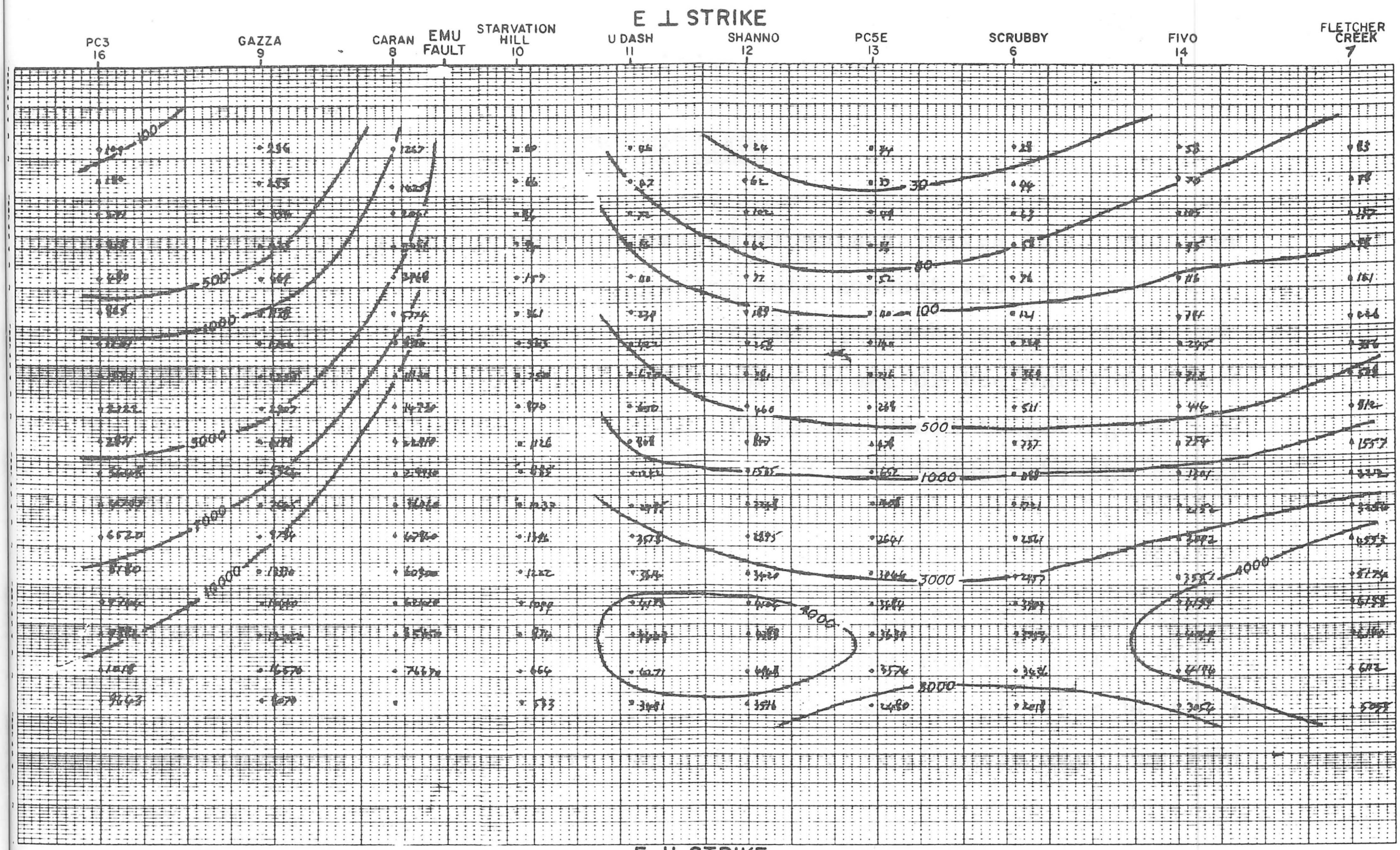
The Cooley-Tukey method is used to transform the demultiplexed data bands, which normally comprise a total of 2048 or fewer points (the primary limitation being the computer core memory size). The transformed data points are corrected for the frequency response and gain characteristics of the input amplifiers and filters; for this purpose, the transfer function of the amplifiers and the filters are calculated by the computer, and stored with the data at the time of data acquisition. The corrected transformed data points are stored at the end of the MT data tape, along with sets of averaged cross-power spectra and averaged autopower spectra. Spectra are averaged over ten points per decade of frequency, to allow statistical analysis of the transformed data.

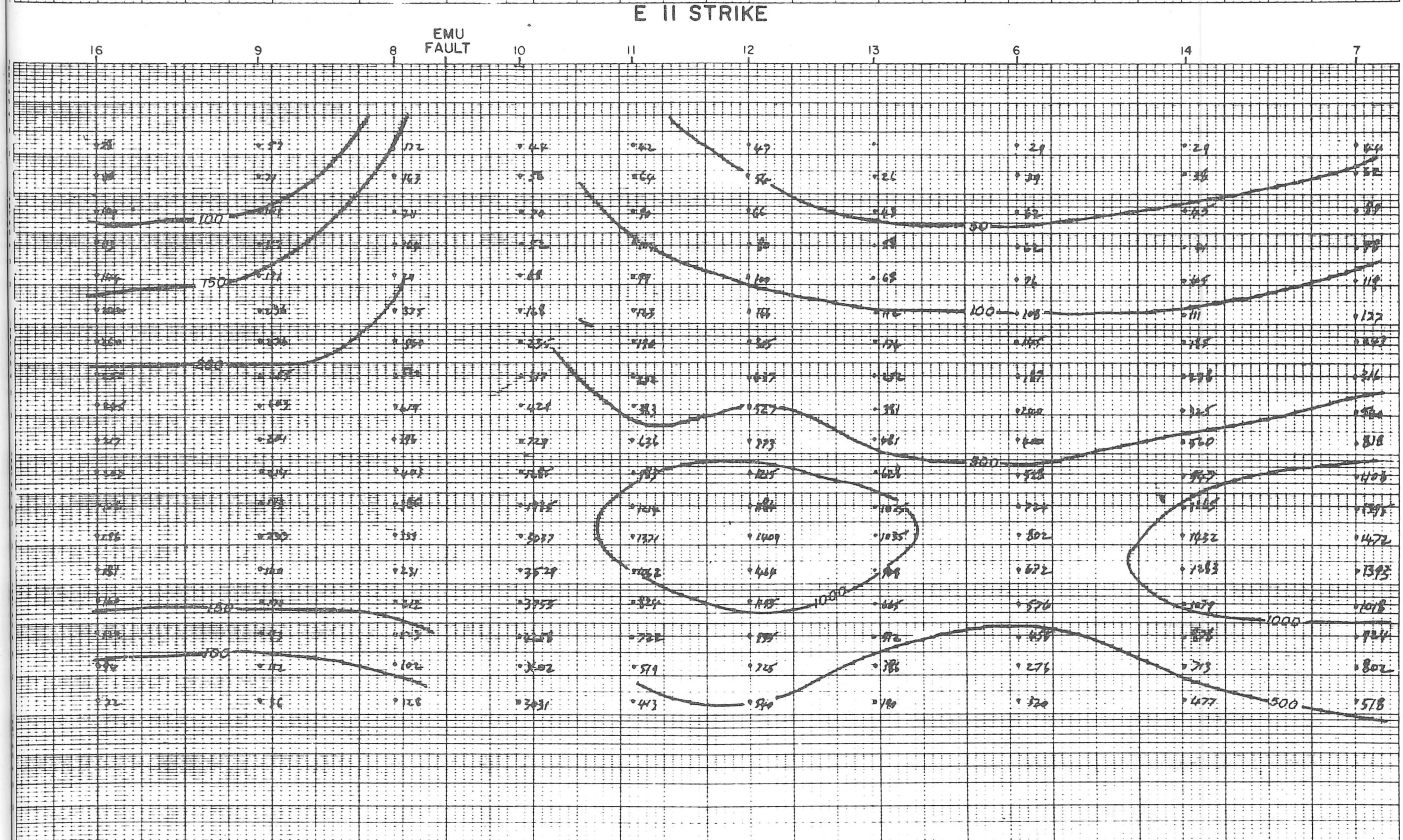
Initial output for the 17 sites occupied during the 1978 survey consisted of individual graphic representations of rotated tensor apparent resistivities, and phase curves for each orthogonal component plotted as a function of period; these data (Appendix 2) form the basis of subsequent interpretations.

A preliminary examination of the resistivity plots at each site can indicate whether the data result from one- or two-dimensional effects. If the curves diverge, as indicated for site 8 (Appendix 2), the structure is almost certainly two- or three-dimensional. With 1D data (e.g. for site No. 3), the orthogonal components almost coincide for most frequency bands and the magnitude of the diagonal impedance tensor is close to zero; in this case tensor rotation and tipper angles are undefined. However, it would be most unusual to find a completely 1D situation, since modern MT techniques in sedimentary basins can sound depths to 200 km (the tipper may then resolve deep lateral conductivity changes over an area of 100 000 km^2). If the resistivity curves diverge from one another, a definite strike direction should be evident from the tensor rotation angle; this can be confirmed from the 2D and 3D tipper rotation angles. Large relative values for the diagonal tensor impedance components and divergence of the two tipper rotation angles indicate 3D structure which can only be approximated by 2D techniques.

Having obtained the values of apparent resistivity at each station, it is possible to construct a 2D pseudo-section for the traverse. The recording sites are first plotted horizontally on a linear scale, and the measured resistivities plotted vertically beneath the station positions, on a logarithmic frequency scale. The data are then contoured, producing sections such as are presented in Figures 12 and 13. Date formats of this type are useful, in that they tend to show the current flow and they can be used to identify lateral changes in conductivity.

As occurred in the pre-survey modelling, the 2D pseudo-sections (Figs. 12, 13) show a pronounced anomaly in the region of the Emu Fault, suggesting causative mechanisms deep within the crust. Actual resistivities for each stratigraphic unit are not readily resolved because of anisotropy related to the structure in the vicinity of the fault. However, the pseudo-sections in Figures 12 and 13 resemble most closely the form of Figure 9; this qualitatively supports abrupt change in sediment thickness.





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PSEUDOSECTIONS

Figures 12 and 13

7. INTERPRETATION

Interpretation of processed MT data involves the production of an electrical model, incorporating both conductivity and spatial parameters, in order to define the distance, depth, and thickness of the major structural units. A subsequent stage of the interpretative procedure consists of relating the electrical model to geological controls in a manner consistent with the limits imposed by the design criteria of the survey.

2D geological sections can be constructed from composite 1D MT inversion models only for isotropic situations. Usually the data are highly anisotropic, and 2D forward models must then be fitted by computer. Inversion programs for both situations are now available (Vozoff & Jupp, 1975), eliminating much of the labour in forward modelling, and also providing useful estimates of error.

1D Models

Principles: The first stage in the interpretation consists of 1D modelling for each component at each station; the apparent resistivity/phase data are used in a 1D computer inversion program, modified, to run on a small-scale minicomputer, from the program developed by Vozoff & Jupp (1975). This inversion technique produces a layered model for each site (representative examples of output appear in Appendix 3). (With 2D data, it is frequently necessary to invert on resistivity alone, since the phase data are not generally compatible with a layered model).

Results: The data at stations 1-4 were fairly isotropic, as indicated by similar E-parallel and E-perpendicular pseudo-sections; consequently, the inversion results have been drawn as a resistivity depth section. 1D modelling of these eastern sites reveals a well-defined basement of good contrast, with resistivity in the range 14-90 kilohm-m. This is covered by a layer 800-1250 m thick with consistently high conductivity values of 50-80 ohm-m. Above this is a more resistive layer, with values in the range 600-1200 ohm-m. In addition conventional deep resistivity soundings suggest that there is a highly conductive overburden, about 10 m thick, with a resistivity of about 2.5 ohm-m (Appendix 1).

The results (Fig. 14) indicate a depth to basement of about 2.8 km near Kangaroo Creek (station 1), increasing to about 3.5-3.6 km near Robinson River (station 2). Towards the Emu Fault, a value of about 6.7 km has been calculated for the depth to basement at station 6, but 1D models are probably inadequate in this region, and no data were obtained from adjoining sites to indicate the nature of the depth change.

The 1D inversions in the McArthur Basin region reveal the presence of well-defined electrical layers that are consistent with the major geological features. In particular the basement depths calculated from ρ_{xy} data at the eastern control sites support the geological predictions of a basement rise. A conflicting structure based on ρ_{yx} data probably results from spurious paths of conduction parallel to the geological strike. A more accurate analysis of both data sets is required for resolving 2D structure elsewhere in the McArthur Basin.

2D Models

Principles: The 2D inverse computer program allows more sophisticated interpretations than the 1D package; however, the CPU exceeds 4000 seconds in a 7600 computer, and costs are tolerated only using the lowest priority with operator booking. The constraints imposed by core storage space and central processor time therefore currently limit some of the interpretation capabilities; in particular, the only parameter allowed to vary is resistivity - it is necessary that all spatial dimensions in the model remain fixed. This restriction can be tolerated, because the 2D model is built of resistivity "blocks", with two spatial dimensions plus the parameter of resistivity. If computer inversion indicates that the resistivity of a block is the same as that of an adjacent block, the boundary between the blocks can be removed

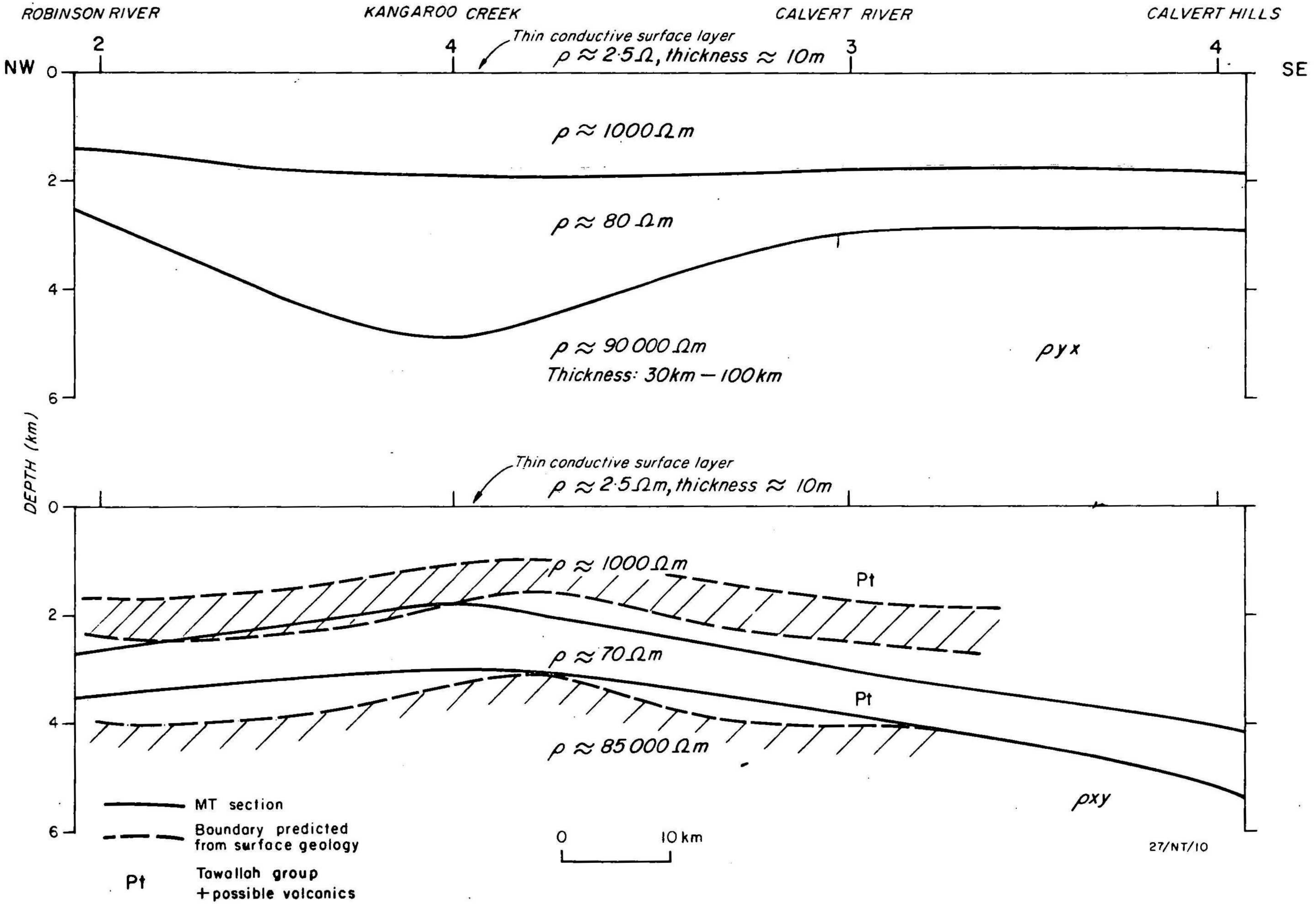

Fig. 14 Results of 1D inversion

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so that the two become one. Consequently, by judicious manipulation of the starting model and a number of re-inversions, a satisfactory 2D model can be obtained with a minimum root-mean-square error. Rates of convergence may subjectively indicate a correct solution but an equivalent statistical error may result from numerous starting models constituting the geological class.

For 2D inversion, both components of apparent resistivity and phase for all sites were provided as program input, together with a starting model based on the 1D results; a final resistivity model (Fig. 15) was then generated by computer analysis to ensure a best fit to the experimental data while providing estimates of parameter influence (Fig. 16, Appendix 4).

<u>1D Model - Traverse 2</u>

The 1D model of Traverse 2 (stations 1-4, Fig. 14) shows excellent agreement with the predicted geological section (model 1, Fig. 5a). There is a close correlation between the geologically predicted depth to basement and the depth to resistive basement defined by MT. Furthermore the cross-strike P_{xy} data have accurately depicted the anticline near Kangaroo Creek (station 1). There is little doubt that the MT method has clearly identified the actual basement to the McArthur Basin. The correlation between the predicted and measured depth to basement is remarkable when it is considered that the thickness of the deeper stratigraphic units has had to be extrapolated over distances of several tens of kilometres. These results give a further indication of the lateral uniformity of formations in the McArthur Basin succession.

The generally low resistivity values in the McArthur Basin succession (Fig. 14) are similar to those of the Tawallah Group rocks, which are known to comprise almost all of the section along Traverse 2. There is no distinct layer which can be attributed to the known very thin, discontinuous outcrops of McArthur Group. The major conductive layer (resistivity: 50-80 ohm-m) reflects the basal porous, probably water-saturated sandstone and conglomerate (Westmoreland Conglomerate) of the Tawallah Group, and the more resistive overlying layer (600-900 ohm-m) is readily interpretable in terms of the volcanic and carbonate rocks which alternate with sandstone in this part of the sequence. The deeper layer is thinner than the measured thickness of Westmoreland Conglomerate adjacent to the Murphy Inlier: this is geologically consistent with its distance from its source area, and may explain why the measured depth to basement (MT) is smaller than the predicted depth.

2D Model - Traverse 1

It is important to note that the 2D model (Fig. 15) has been derived substantially by mathematical modelling on the computer, with no significant geological constraints. However, within the error limitations of the model, it may be readily interpreted in terms of the geological parameters (Fig. 5).

The model clearly shows a major discordance at the Emu Fault, which was also indicated on the 1D pseudo-sections (Figs. 12 & 13). Furthermore, this discordance is of even greater apparent magnitude at depth, reflecting the concept that the major faults of the Batten Fault Zone were well established before sedimentation began in the McArthur Basin.

In the area to the east of the Emu Fault, the statistical parameters of the 2D program have produced resistivities which differ from the results of the 1D modelling of Traverse 2, but the major features remain: a clearly defined resistive basement overlain by a fairly simple conductive sequence. Once again, there is no layer which may be correlated with the carbonate rocks of the McArthur Group.

The average depth to basement east of the Emu Fault (ca. 4.45 km), defined by the 2D model (Fig. 15), is greater than the 3.6 km defined by the 1D model at the intersection of Traverses 1 and 2. This 1D estimate can be considered reliable for the isotropic eastern end of the traverse, and the depth to basement is interpreted as increasing progressively towards the Emu Fault, in accordance with surface geological structure. The increase in depth (ca. 0.8 km) is entirely explained by a shallow (less than 1 km) basin of Roper Group rocks which crops out to the west of the Wearyan River (see model 1, Fig. 5). It is reasonable that the sandstones and shales of the Roper Group should have similar resistivities to, and therefore will not be differentiated from, the Tawallah Group. There is no room in the succession for any appreciable thickness of McArthur Group.

The entirely separate block of highly resistive rocks which extends down from the surface west of the Emu Fault may be directly correlated with the McArthur Group outcrop in this area. Carbonate rocks typically have high resistivities, and the depth of this block (ca. 4.45 km) is very close to the preserved thickness of McArthur Group (Fig. 5a) estimated from measured stratigraphic sections in this part of the Batten Fault Zone. The model indicates a complex resistivity pattern in this block, but it is unrealistic at this stage to try to relate this to specific stratigraphic units within the McArthur Group. The underlying conductive layer (65 ohm-m) is identical in thickness (8.2 - 4.45 = ca. 3.7 km) to the Tawallah Group measured on the Wearyan Shelf, and consistent with the predicted geological model.

There is little doubt that the 2D model accurately depicts the McArthur Group to the west of the Emu Fault and the Tawallah Group both east and west of the Emu Fault. The distinctiveness of the McArthur Group, west of the fault, seemingly makes it impossible that any appreciable thickness of McArthur Group can be present east of the fault. A stratigraphic displacement of about 3.5 km is indicated across the Emu Fault, all of which is more than accommodated by syndepositional movement during deposition of the McArthur Group. (The predicted geological model actually requires some 7 km of syndepositional displacement during McArthur Group and Roper Group times, followed by later uplift of the previously downfaulted block).

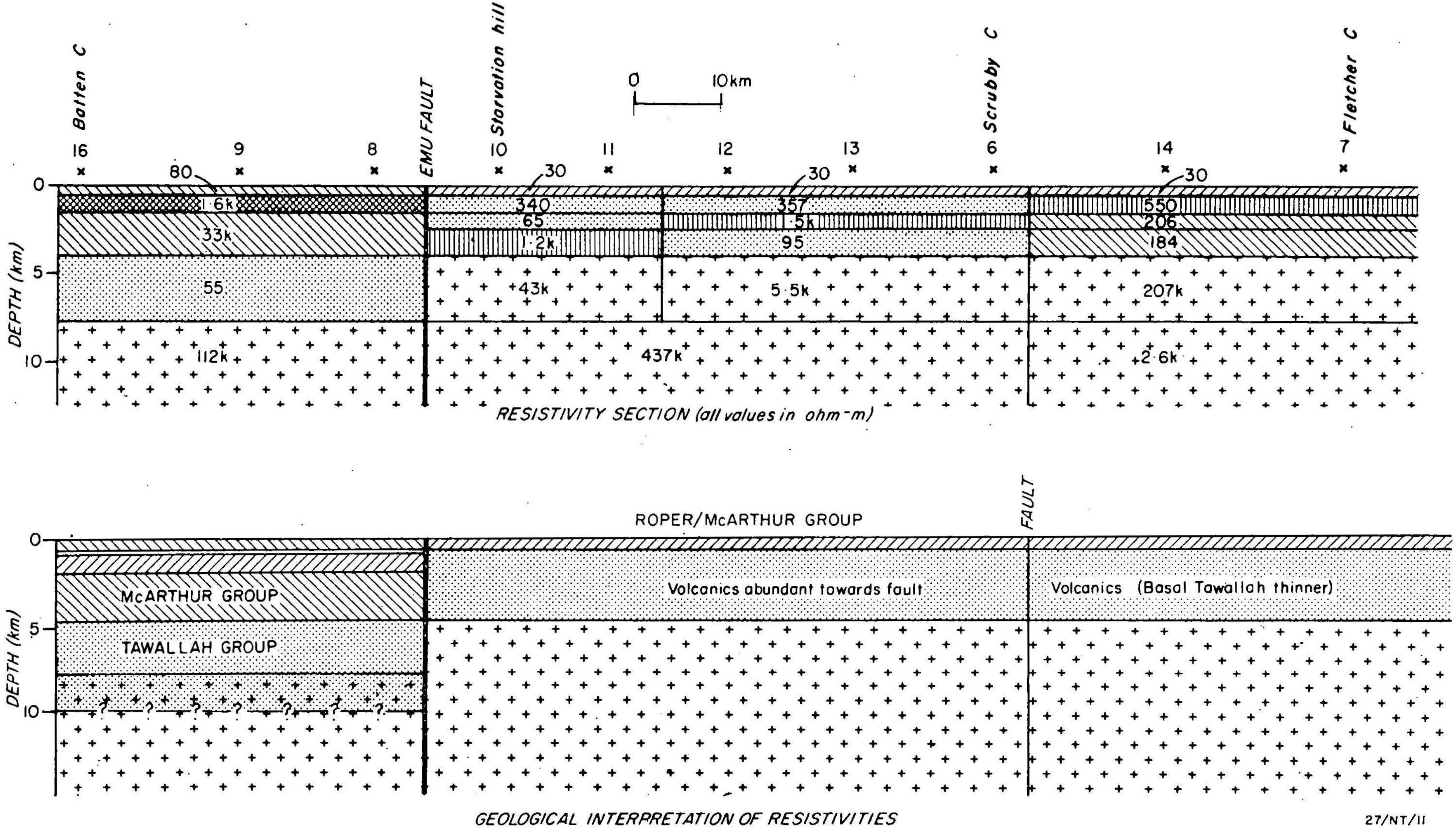

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Fig. 15 2D Profiles

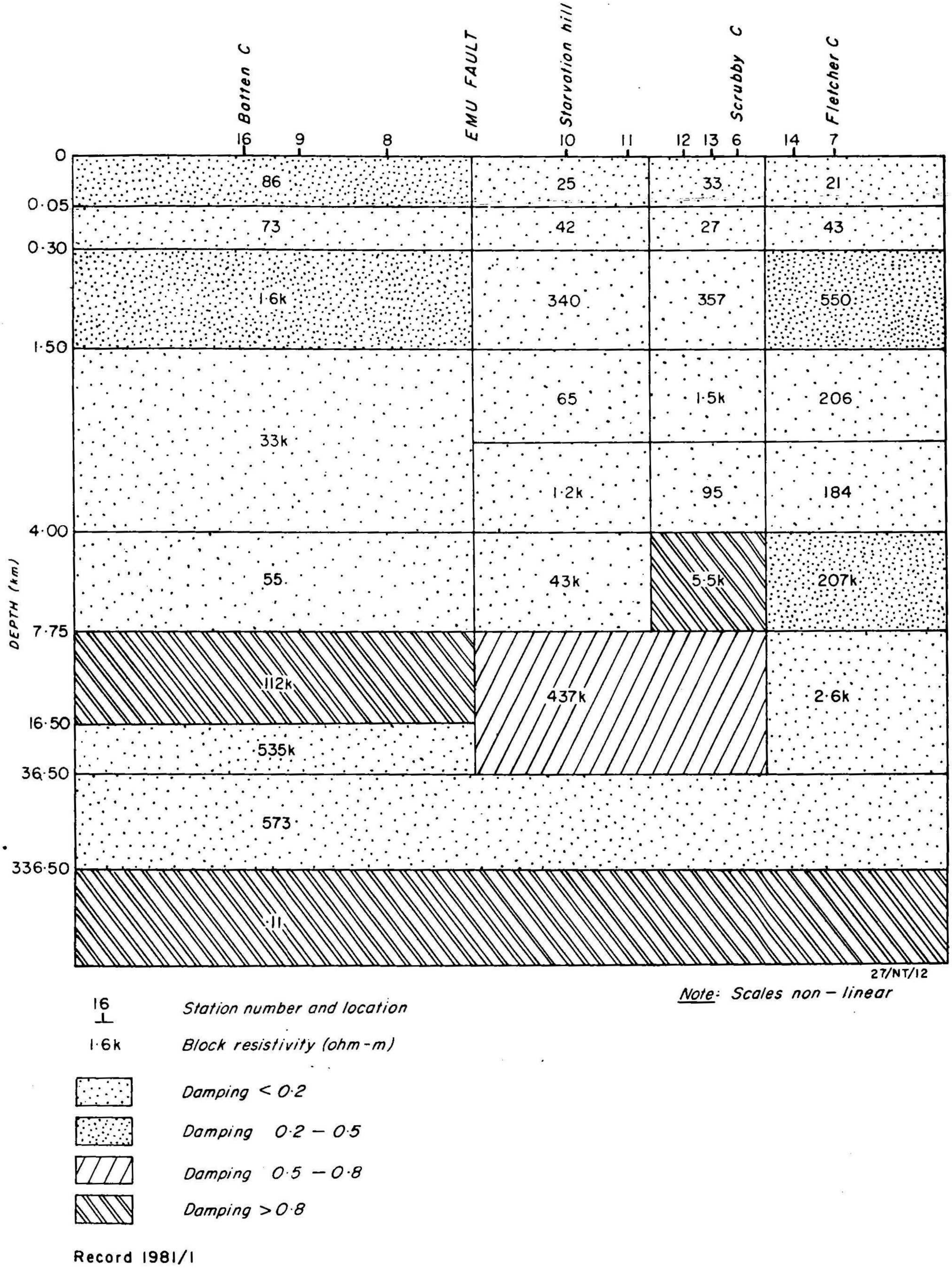

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Fig. 16 2D Inversion resistivity analysis

This preliminary modelling of the MT survey across the Wearyan Shelf and eastern Batten Fault Zone, and its geological interpretation, clearly support the currently preferred geological model (i.e. Fig. 5, model 1), which characterises the Batten Trough as a syndepositional graben with rapid changes in depositional thickness at the boundary faults (Plumb & Derrick, 1975; Plumb & others, 1980). However, this concept is in direct conflict with a preliminary model suggested by gravity along the same section (Anfiloff, 1979); further modelling and rationalisation of both sets of data is suggested, but in the absence of error estimates for the gravity data, particularly for parameter sensitivity, the MT results are considered superior in the present application.

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APPENDIX 1

Deep resistivity soundings, McArthur Basin 1978, stations 6 & 7.

Deep resistivity soundings using Schlumberger (S) and equatorial dipole (ED) configurations (Bhattacharya & Patra, 1968) were made at stations 6 and 7 to determine the resistivity to about 200 m depth.

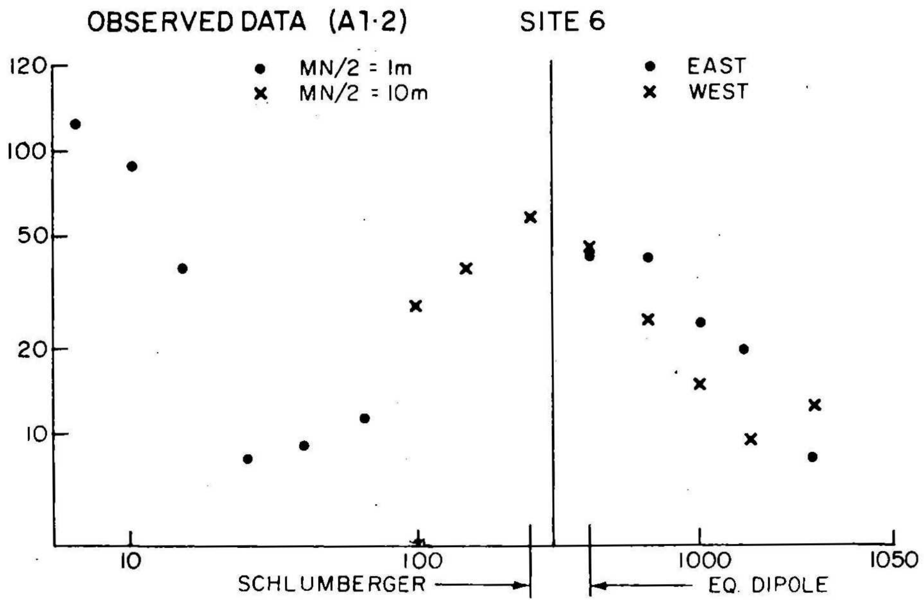
The electrode configurations are illustrated in Figure A1.1. For the S array apparent resistivity is plotted against AB/2 while for the ED array it is plotted against $\bar{r}$ = ARx. The sounding curves for the ED can be interpreted by treating $\bar{r}$ as AB/2 for an S sounding.

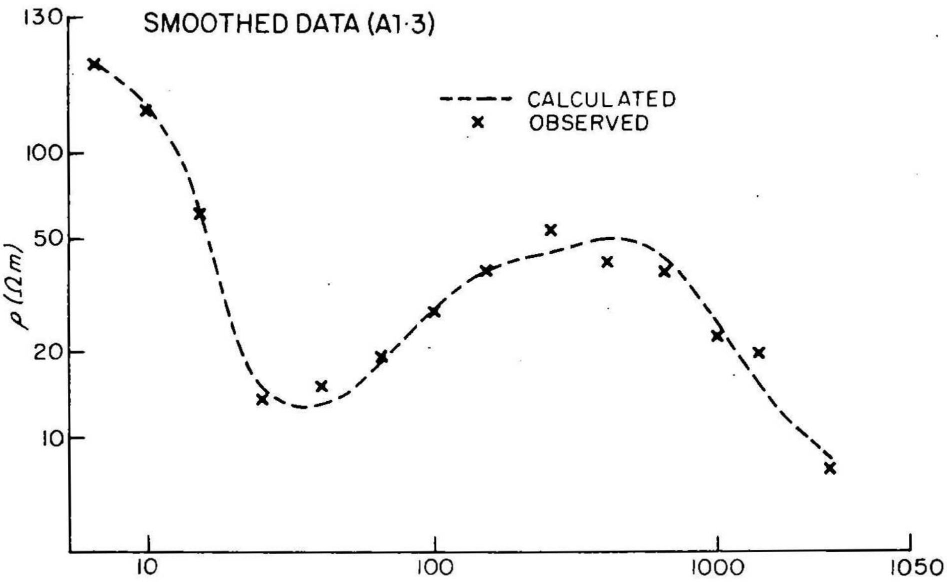
The transmitter was a 10 kW Geotronics model FT-10 which was used to transmit a square wave of 10 seconds period. The receiver was a Fluke 845 AB high-impedance voltmeter preceded by an Sp cancellation box and followed by a Mosely 7100B chart recorder.

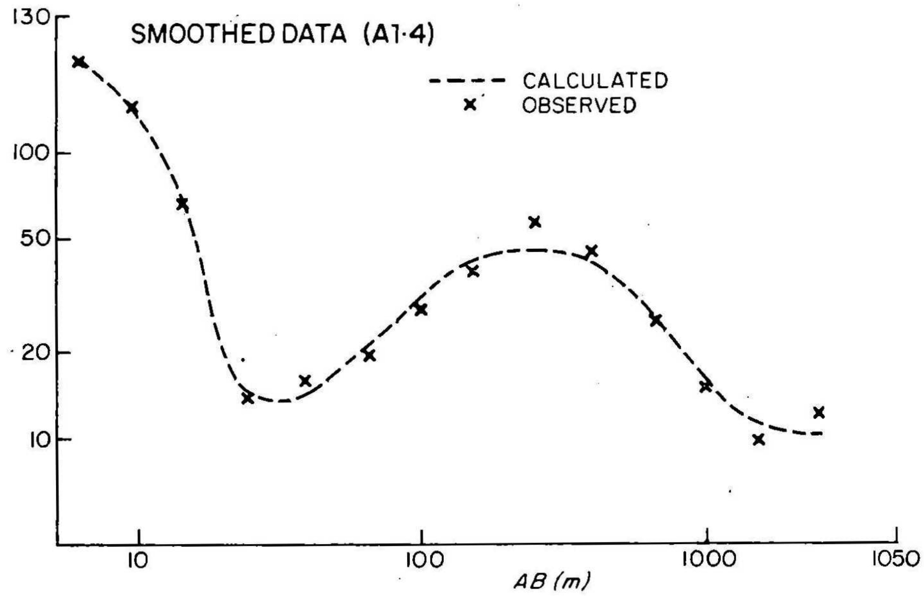
Field procedure

At both sites 6 and 7 the electrodes were expanded at five points per decade in the S configuration with MN/2 = 1 m and AB/2 running from 6.5 to 65 m inclusive. The potential electrodes were then expanded to MN/2 = 10 m and a second reading for AB/2 = 65 m was taken. The current electrodes were then expanded from AB/2 = 65 m to AB/2 = 250 m.

With the current electrodes at a separation of 500 m (AB/2 = 250 m) the potential electrodes were separated to MN/2 = 50 m and then moved in the ED array so that successive values of $\bar{r}$ were 400 m, 650 m, 1000 m, 1500 m, 2500 m, 4000 m. The receiver was then moved onto the opposite side of the transmitting dipole and again moved in the ED configuration through the same sequence of r values.







INITIAL MODEL

Ωm	m
250	5·5
6·2	22
320	36
9	

FINAL MODEL 070° MAG (EAST)

Ωm	m
293	4·9
9·5	30
418	48
8·1	

83m

FINAL MODEL 250° MAG (WEST)

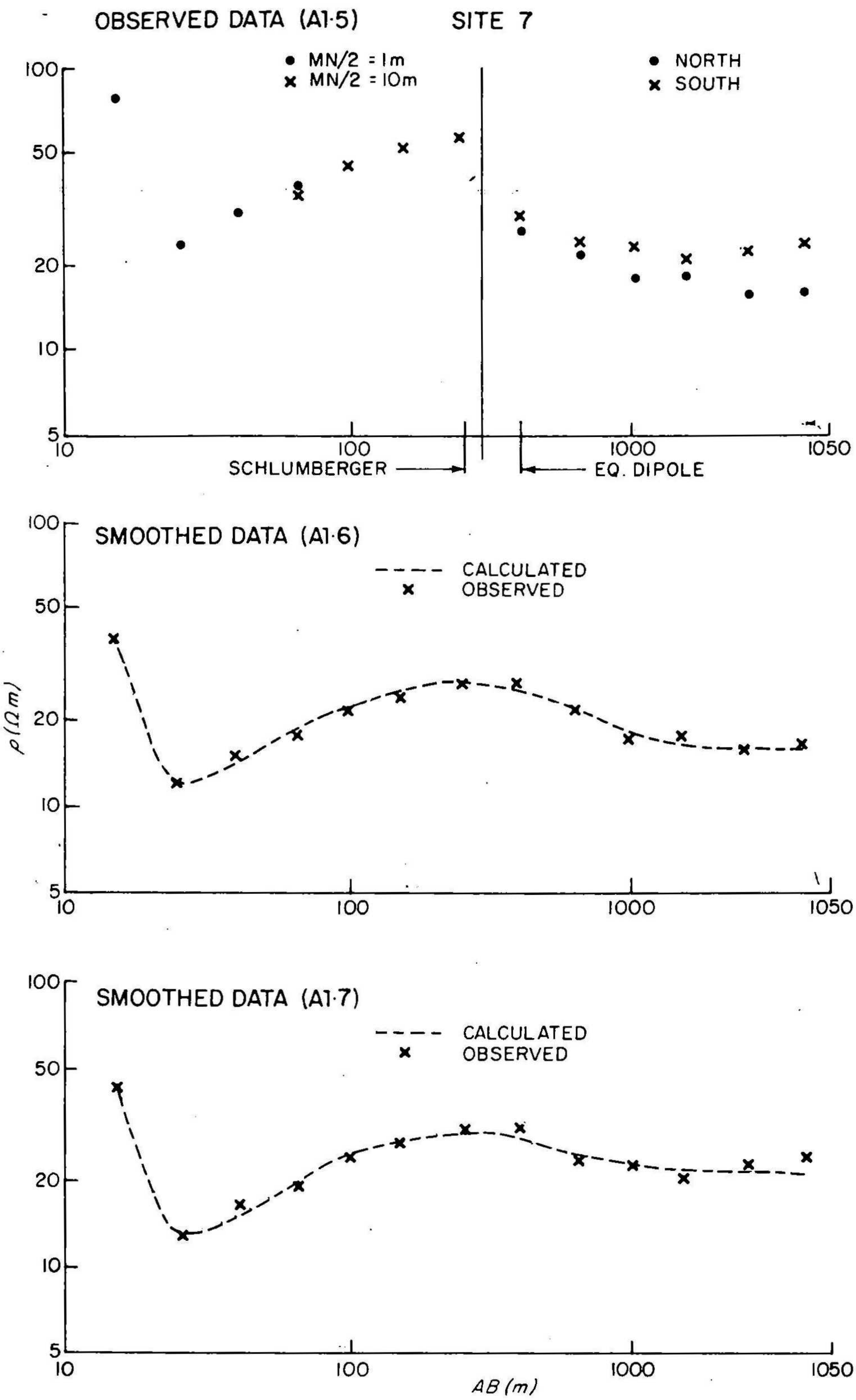
Ωm	m
276	5·3
3·9	9·9
341	35
9·7	

50m

27/NT/18

Record 1981/1

Figures: A1·2,3,4 D–C Resistivity, site 6



INITIAL MODEL

Ωm	m
315	4·4
8·5	20
50	100
25	

FINAL MODEL 309° MAG. (NORTH)

Ωm	m
621	2·9
9·1	18
34	183
16	204m

FINAL MODEL 129° MAG. (SOUTH)

Ωm	m
473	3·2
8·3	14
37	131
22	148m

27/NT/19

Record 1981/1

Figures: A1·5,6,7 D-C Resistivity, site 7

Processing results

The results from sites 6 and 7 are shown in Figures A1.2 to A1.5 and A1.6 to A1.9 respectively.

Figure A1.2 shows the observed resistivity at site 6. There is a discontinuity at 65 m when changing from MN/2 = 1 m to MN/2 = 10 m which is due to near-surface effects. For the ED array, the apparent resistivity for the receiver east of the transmitting dipole differs from that for the receiver to the west. This could be due to either lateral changes or a dip in the beds.

Figures A1.3 and A1.4 show the "smoothed" curves for the east and west ED expansions respectively. (The S expansion is common to both figures). The discontinuity at AB/2 = 65 m was removed from the "smoothed" curves by translating the shallow part of the observed curve parallel to the y axis. This would introduce errors into the interpretation of the near-surface layers while leaving the deep layers and half-space relatively unchanged.

The smoothed curves were interpreted by means of Orrelana & Mooney (1966) master curves to obtain a preliminary model for input to a resistivity inversion program. Figure A1.5 shows the results of inverse modelling.

A similar procedure was used to interpret the soundings at site 7 (Figs. A1.6-1.9).

APPENDIX 2

Apparent resistivities
McArthur Basin 1978

MCARTHUR 1978 SITE 1

1

NØISE TØ SIGNAL RATIØ = .129E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.980

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES

1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	136.0829	134.9061	137.2699	.0000
2	1907.8010	1805.2461	2016.1821	.0046
3	16626.9530	16260.1460	17002.0350	.7578
4	1165.3206	1074.1555	1264.2229	.0128
5	414.2992	379.1875	452.6622	.0176

LAYER DEPTHS (TØ BASE)

1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	3529.5464	3460.5166	3599.9531	.0062
2	34380.4140	32543.0390	36321.5310	.0224
3	138687.4100	133550.2800	144022.1200	.0039
4	296592.1900	283345.0000	310458.7500	.0051

FINISHED NØW

/MTINV : STØP 00000

MCARTHUR 1978 SITE 2

1

NØISE TØ SIGNAL RATIØ = .756E-02 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.733

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES

1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	268.8650	266.8584	270.8867	.0000
2	4305.1152	4116.9072	4501.9268	.0017
3	32277.8790	31869.2230	32691.7730	.8336
4	1488.7222	1425.3083	1554.9573	.0016
5	22.8097	20.4720	25.4148	.2646

LAYER DEPTHS (TØ BASE)

1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	5081.3926	4997.1846	5167.0205	.0001
2	61145.9840	58491.1720	63921.2890	.0141
3	197349.9700	192451.7800	202372.8100	.0008
4	522694.0600	513216.1900	532347.0000	.0005

FINISHED NØW

/MTINV : STØP 00000

MCARTHUR 1978 SITE 3 Z

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	250.90	-31.67	513.50	-56.85	.0199
.0501	260.40	-37.14	191.50	-37.11	.0501
.0794	333.80	-46.26	218.30	-46.81	.0794
.1259	389.70	-49.71	242.20	-53.12	.1259
.1995	297.20	-49.52	169.20	-50.26	.1995
.3162	363.20	-44.26	224.20	-42.30	.3162
.5012	387.10	-39.54	163.70	-48.73	.5012
.7943	532.70	-33.60	224.60	-39.55	.7943
1.2590	690.30	-30.63	255.20	-38.12	1.2590
1.9950	826.50	-32.68	256.10	-32.66	1.9950
3.1620	826.20	-34.85	272.90	-31.46	3.1620
5.0120	1086.00	-35.20	424.40	-32.16	5.0120
7.9430	1730.00	-23.43	633.20	-23.01	7.9430
12.5900	2806.00	-28.17	1031.00	-27.49	12.5900
19.9500	3499.00	-30.96	1472.00	-30.10	19.9500
31.6200	4171.00	-36.22	1801.00	-36.77	31.6200
50.1200	5442.00	-39.02	2178.00	-46.73	50.1200
79.4300	5521.00	-39.44	1635.00	-47.12	79.4300
125.9000	5631.00	-43.79	1620.00	-48.39	125.9000
199.5000	5380.00	-48.00	1473.00	-56.65	199.5000
316.2000	5567.00	-49.83	1133.00	-57.19	316.2000
501.2000	5009.00	-54.92	975.10	-61.34	501.2000
794.3000	3679.00	-63.67	796.10	-59.30	794.3000
1259.0000	2465.00	-60.56	922.10	-59.16	1259.000
1995.0000	1131.00	-80.50	458.70	-67.18	1995.000

MCARTHUR 1978 SITE 4 Z

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0316	150.44	-41.00	220.00	-32.40	.0316
.0501	166.50	-41.05	173.00	-39.97	.0501
.0794	197.70	-44.95	222.60	-45.92	.0794
.1259	235.60	-48.17	259.90	-48.30	.1259
.1995	141.60	-45.35	186.10	-46.55	.1995
.3162	151.30	-38.11	183.60	-40.90	.3162
.5012	228.60	-37.93	235.80	-42.50	.5012
.7943	279.40	-35.13	312.80	-34.42	.7943
1.2590	482.90	-31.03	554.10	-33.52	1.2590
1.9950	516.30	-21.31	621.90	-29.74	1.9950
3.1620	610.80	-34.47	725.00	-29.98	3.1620
5.0120	540.10	-33.52	852.60	-39.61	5.0120
7.9430	1069.00	-22.89	1295.00	-30.21	7.9430
12.5900	1617.00	-27.26	1744.00	-34.56	12.5900
19.9500	1910.00	-35.56	1973.00	-36.66	19.9500
31.6200	2034.00	-40.48	2456.00	-41.35	31.6200
50.1200	2166.00	-45.97	3207.00	-46.35	50.1200
79.4300	1972.00	-49.96	2791.00	-47.39	79.4300
125.9000	1865.00	-51.86	2983.00	-52.37	125.9000
199.5000	1664.00	-51.71	2371.00	-53.66	199.5000
316.2000	1832.00	-53.00	3889.00	-56.08	316.2000
501.2000	1951.00	-59.00	2215.00	-54.97	501.2000
794.3000	1369.00	-67.50	1747.00	-59.48	794.3000
1259.0000	1035.00	-69.00	1060.00	-53.45	1259.000
1995.0000	749.00	-73.50	243.00	-29.18	1995.000

MCARTHUR 1978 SITE 5 Z

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	120.40	-35.00	306.00	-79.00	.0199
.0501	121.70	-35.80	305.60	-37.81	.0501
.0794	154.00	-42.98	367.70	-43.14	.0794
.1259	187.70	-46.23	407.80	-51.52	.1259
.1995	147.80	-46.70	259.70	-49.33	.1995
.3162	179.20	-40.91	247.70	-49.37	.3162
.5012	189.80	-38.07	272.40	-43.74	.5012
.7943	298.30	-32.40	337.10	-36.90	.7943
1.2590	452.00	-29.65	427.40	-33.55	1.2590
1.9950	603.50	-23.00	463.40	-36.47	1.9950
3.1620	723.20	-29.15	563.00	-30.60	3.1620
5.0120	726.60	-27.63	637.50	-34.26	5.0120
7.9430	1123.00	-19.36	1173.00	-20.25	7.9430
12.5900	1611.00	-28.09	1760.00	-25.12	12.5900
19.9500	2398.00	-28.24	2342.00	-29.19	19.9500
31.6200	2921.00	-25.98	2881.00	-32.55	31.6200
50.1200	3877.00	-34.39	3613.00	-35.30	50.1200
79.4300	4458.00	-36.05	3580.00	-41.60	79.4300
125.9000	4228.00	-43.28	4060.00	-46.15	125.9000
199.5000	4677.00	-45.15	3853.00	-51.72	199.5000
316.2000	4976.00	-53.25	2841.00	-47.93	316.2000
501.2000	3781.00	-68.00	3316.00	-45.73	501.2000
794.3000	2957.00	-50.00	3435.00	-60.83	794.3000
1259.0000	2210.00	-71.75	2556.00	-59.20	1259.000
1995.0000	2232.00	-61.75	1512.00	-82.00	1995.000

MCARTHUR 1978 SITE 6 Z

PERIØD	XY AP.RES	XY PHASE	YX AP.RES	YX PHASE	PERIØD
.0199	48.59	-42.25	44.71	-52.60	.0199
.0316	18.80	-8.50	24.95	-17.95	.0316
.0501	24.34	-16.19	25.64	-22.85	.0501
.0794	35.87	-20.32	36.27	-28.05	.0794
.1259	58.93	-27.08	57.32	-32.98	.1259
.1995	61.19	-31.33	47.62	-36.71	.1995
.3162	66.21	-30.83	55.33	-34.58	.3162
.5012	89.99	-29.73	77.94	-34.97	.5012
.7943	179.40	-28.04	116.40	-33.43	.7943
1.2590	237.10	-27.24	162.80	-32.56	1.2590
1.9950	320.70	-27.67	183.50	-31.34	1.9950
3.1620	422.30	-28.73	217.60	-31.10	3.1620
5.0120	411.00	-33.12	157.60	-43.49	5.0120
7.9430	764.70	-23.90	402.80	-26.58	7.9430
12.5900	913.70	-24.23	508.80	-31.29	12.5900
19.9500	1266.00	-29.08	587.10	-36.32	19.9500
31.6200	1746.00	-27.61	1067.00	-41.99	31.6200
50.1200	2656.00	-27.57	1619.00	-51.08	50.1200
79.4300	2541.00	-33.44	953.70	-54.02	79.4300
125.9000	2938.00	-36.38	1142.00	-53.66	125.9000
199.5000	3159.00	-45.44	1586.00	-60.70	199.5000
316.2000	3837.00	-49.00	2985.00	-62.47	316.2000
501.2000	3165.00	-57.81	2447.00	-63.87	501.2000
794.3000	2126.00	-59.56	2289.00	-63.31	794.3000
1259.0000	1553.00	-77.45	1247.00	-58.39	1259.000
1995.0000	992.30	-54.67	2258.00	-44.10	1995.000

1

NØISE TØ SIGNAL RATIØ = .120E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS   7.958

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	61.8853	58.5628	65.3963	.0047
2	409.4626	394.5764	424.9106	.0019
3	3492.7466	3171.9847	3845.9448	.0176
4	4376.1982	4304.8184	4448.7617	.0001
5	702.8729	674.6470	732.2776	.0007

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	410.7435	378.8583	445.3123	.0132
2	6199.2246	5959.4561	6448.6406	.0036
3	21199.2190	21172.2190	21226.2540	.9373
4	337304.2500	330533.6900	344213.5000	.0020

FINISHED NØW
/MTINV : STØP   00000

MCARTHUR 1978 SITE 8

NØISE TØ SIGNAL RATIØ = .701E+01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 4.004

1

"ERRØR BØUNDS" USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	445.3826	438.5460	452.3257	.1974
2	7008.4922	7001.6416	7015.3496	.9658
3	714.8522	714.7043	714.9999	.9920
4	48.2612	48.1926	48.3299	.9195
5	243.8966	240.6463	247.1888	.1987

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	7864.3779	7731.9141	7999.1104	.0389
2	17074.3280	17002.1520	17146.8090	.8752
3	18501.8050	18302.9770	18702.7890	.0763
4	20341.5630	20098.3480	20587.7190	.0442

FINISHED NØW
/MTINV : STØP 00000

1

NØISE TØ SIGNAL RATIØ = .111E+00 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 5.241

1

"ERRØR BØUNDS" USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	234.3997	233.0855	235.7213	.0000
3	2181.3076	2180.9888	2181.6265	.9986
4	139.3210	136.2064	142.5068	.0022
5	89.9037	87.5083	92.3646	.0016

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	71.3327	70.6089	72.0640	.0000
2	9137.3203	8533.8340	9783.4824	.4347
3	9334.3086	8886.4102	9804.7832	.1361
4	29334.3200	29334.3200	29334.3200	1.0000

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 10

1

NØISE TØ SIGNAL RATIØ = .221E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 5.024

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	107.8967	107.0975	108.7019	.0011
3	1859.7471	1846.7551	1872.6303	.0000
4	568.2727	566.7343	569.8153	.8624
5	227.3718	223.0446	231.7830	.0007

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	4.9673	4.9294	5.0055	.9354
2	1306.0886	1295.7883	1316.4709	.0007
3	78563.7810	77785.0620	79350.2970	.0093
4	98563.7970	98563.7970	98563.7970	1.0000

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 11

1

NØISE TØ SIGNAL RATIØ = .131E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.939

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	287.8158	277.5121	298.5021	.0001
3	4073.0801	3908.1304	4244.9912	.0004
4	5456.5859	5117.4609	5818.1846	.0021
5	159.4627	149.0987	170.5471	.0010

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	149.0598	145.2333	152.9871	.0000
2	3853.3306	3711.0557	4001.0601	.0002
3	86606.5470	74147.2970	101159.3800	.0566
4	417018.6200	410043.3700	424112.5000	.0000

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 12

1

NØISE TØ SIGNAL RATIØ = .212E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 5.986

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES

1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	286.7117	282.4338	291.0544	.0001
3	2025.7151	1927.3982	2129.0469	.0058
4	4279.1553	4048.7959	4522.6211	.0177
5	4046.0576	3978.6221	4114.6357	.0001

LAYER DEPTHS (TØ BASE)

1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	138.3994	136.8646	139.9311	.0000
2	4601.7871	4483.9814	4722.6875	.0006
3	19601.7810	19528.0160	19675.8280	.9387
4	40324.3050	40012.7340	40638.2970	.8739

FINISHED NØW

/MTINV : STØP 00000

MCARTHUR 1978   SITE 13

NØISE TØ SIGNAL RATIØ = .322E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS   6.956

ERRØR BØUNDS USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	22.2556	21.3885	23.1579	.0018
2	166.2395	159.8164	172.9208	.0020
3	979.5562	934.1035	1027.2183	.0070
4	5298.8809	5239.1299	5359.3135	.8600
5	2476.8882	2429.9507	2524.7324	.0001

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	270.7699	255.6082	286.8310	.0058
2	3668.5469	3506.2905	3838.3120	.0038
3	18668.5430	17768.6250	19614.0390	.4128
4	24419.2810	22891.0980	26049.4840	.2319

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 14

1

NØISE TØ SIGNAL RATIØ = .173E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 6.999

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES

1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	200.4564	197.2232	203.7426	.0000
3	1246.4248	1215.8352	1277.7839	.0001
4	5308.3496	5200.4473	5418.4902	.0000
5	943.9258	915.0059	973.7596	.0006

LAYER DEPTHS (TØ BASE)

1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	122.9167	120.9192	124.9471	.0000
2	3678.0972	3608.1924	3749.3564	.0001
3	18678.0900	18648.6990	18707.5270	.9210
4	235740.2800	231100.9700	240472.7200	.0032

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978   SITE 15

1

NØISE TØ SIGNAL RATIØ = .269E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS   6.000

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	335.6731	325.5182	346.1448	.0002
3	2145.7070	2092.7671	2199.9863	.0003
4	2561.8164	2525.8398	2598.3052	.7546
5	3789.7432	3712.0010	3869.1133	.0001

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	175.7895	172.9794	178.6451	.0000
2	3915.0352	3781.2573	4053.5459	.0004
3	44224.1170	43000.2660	45482.7970	.5405
4	48777.1250	46440.5860	51231.2270	.1488

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 16

1

NØISE TØ SIGNAL RATIØ = .437E-02 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 6.998

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES

1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	20.0000	20.0000	20.0000	1.0000
2	375.7985	360.9083	391.3030	.0126
3	3939.9424	3857.8078	4023.8257	.0005
4	12041.7500	11838.1890	12248.8110	.0000
5	10.1795	10.0280	10.3334	.9502

LAYER DEPTHS (TØ BASE)

1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	32.1026	30.2365	34.0839	.0250
2	2399.9146	2305.0264	2498.7090	.0093
3	41744.2190	40636.1950	42882.4610	.0008
4	939655.8700	927059.0000	952423.8700	.0001

FINISHED NØW

/MTINV : STØP 00000

MCARTHUR 1978 SITE 17

1

NØISE TØ SIGNAL RATIØ = .893E-02 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 8.704

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	63.2080	60.8724	65.6332	.0009
2	905.4310	834.2338	982.7046	.0159
3	4861.0586	4413.2607	5354.2930	.0778
4	10031.2930	9703.6055	10370.0450	.0005
5	1061.5933	1010.1436	1115.6636	.0013

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	659.2228	622.9368	697.6224	.0040
2	8128.3809	7391.5400	8938.6758	.0411
3	43401.8360	38286.5310	49200.5780	.1233
4	517655.0000	505958.3700	529622.0000	.0001

FINISHED NØW
/MTINV : STØP 00000

APPENDIX 3

1D Inversions,
1978 McArthur Basin magneto-telluric data

MCARTHUR 1978 SITE 01

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0501	44.33	-38.25	165.00	-43.60	.0501
.0794	87.92	-44.68	185.60	-50.00	.0794
.1259	144.60	-48.83	259.40	-57.19	.1259
.1995	71.99	-48.81	128.40	-51.64	.1995
.3162	63.75	-42.65	113.50	-41.51	.3162
.5012	88.80	-42.23	102.80	-41.27	.5012
.7943	144.10	-31.27	158.70	-36.52	.7943
1.2590	198.70	-31.41	182.90	-36.83	1.2590
1.9950	248.20	-28.54	319.80	-38.31	1.9950
3.1620	268.30	-31.41	393.50	-31.92	3.1620
5.0120	521.20	-21.98	360.60	-25.39	5.0120
7.9430	614.10	-17.04	720.10	-26.52	7.9430
12.5900	1376.00	-21.73	696.40	-24.98	12.5900
19.9500	1779.00	-23.18	747.20	-31.79	19.9500
31.6200	1750.00	-31.77	945.40	-40.03	31.6200
50.1200	2033.00	-37.12	1298.00	-47.85	50.1200
79.4300	1510.00	-39.06	1076.00	-54.43	79.4300
125.9000	3239.00	-42.85	941.30	-58.48	125.9000
199.5000	3186.00	-46.68	781.50	-61.58	199.5000
316.2000	3043.00	-53.50	814.20	-58.13	316.2000
501.2000	2208.00	-59.00	456.70	-60.58	501.2000
794.3000	1134.00	-50.43	358.70	-47.29	794.3000
1259.0000	1138.00	-52.00	297.30	-74.63	1259.000
1995.0000	1550.00	-52.00	5.05	-35.00	1995.000

MCARTHUR 1978 SITE 2 Z

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0501	143.00	-43.00	181.40	-41.22	.0501
.0794	171.00	-49.88	200.90	-48.70	.0794
.1259	246.30	-52.21	234.00	-55.84	.1259
.1995	177.20	-53.09	125.10	-53.99	.1995
.3162	177.80	-42.52	182.30	-43.09	.3162
.5012	196.50	-38.09	181.80	-53.84	.5012
.7943	294.30	-39.32	214.40	-36.51	.7943
1.2590	461.70	-31.75	336.60	-34.37	1.2590
1.9950	633.10	-28.39	299.70	-35.64	1.9950
3.1620	545.80	-32.60	321.30	-29.74	3.1620
5.0120	778.40	-26.72	427.70	-27.26	5.0120
7.9430	1173.00	-15.33	611.50	-21.15	7.9430
12.5900	2081.00	-24.34	976.00	-23.62	12.5900
19.9500	2745.00	-25.90	1270.00	-24.42	19.9500
31.6200	3222.00	-27.76	1474.00	-29.93	31.6200
50.1200	3919.00	-32.62	2009.00	-40.69	50.1200
79.4300	3912.00	-39.45	1728.00	-43.23	79.4300
125.9000	3532.00	-43.15	1576.00	-48.21	125.9000
199.5000	3962.00	-50.29	1380.00	-49.13	199.5000
316.2000	3902.00	-51.67	1818.00	-53.83	316.2000
501.2000	3636.00	-58.83	1783.00	-55.92	501.2000
794.3000	2663.00	-67.50	1431.00	-62.40	794.3000
1259.0000	1873.00	-71.50	876.20	-68.43	1259.000
1995.0000	635.80	-76.50	585.80	-68.63	1995.000

MCARTHUR 1978 SITE 3

*

1

NØISE TØ SIGNAL RATIØ = .551E-02 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.856

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	425.5892	423.3156	427.8751	.0000
2	4605.4922	4464.9043	4750.5059	.0003
3	35316.0000	35082.4840	35551.0700	.8782
4	2601.4546	2506.0195	2700.5239	.0008
5	65.9741	59.6416	72.9790	.1426

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	5636.0693	5554.3584	5718.9824	.0000
2	71706.2190	69209.1870	74293.3440	.0066
3	191256.5300	186159.0600	196493.5900	.0011
4	637084.6200	626136.6200	648224.0000	.0004

MCARTHUR 1978 SITE 4

1

NØISE TØ SIGNAL RATIØ = .122E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.276

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	235.8233	234.5227	237.1311	.0000
2	2585.1099	2505.2754	2667.4883	.0004
3	10020.7750	9869.8203	10174.0390	.7929
4	612.2611	591.2007	634.0718	.0007
5	10.4333	9.7620	11.1508	.7259

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	4143.2939	4085.9883	4201.4033	.0000
2	51098.2890	49092.4770	53186.0550	.0215
3	120873.3600	118460.1200	123335.7500	.0007
4	404821.5000	397344.3100	412439.3700	.0010

MCARTHUR 1978 SITE 5

NØISE TØ SIGNAL RATIØ = .963E-02 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 6.989

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	218.6567	217.5146	219.8048	.0000
2	3181.7334	3049.5361	3319.6616	.0015
3	20802.6410	20661.4650	20944.7810	.8925
4	6793.4063	6629.5000	6961.3652	.0004
5	595.5884	560.0697	633.3596	.0060

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	3797.3984	3747.3223	3848.1436	.0001
2	42528.1090	40233.8280	44953.2190	.0095
3	62528.1250	62292.7660	62764.3670	.8288
4	359811.0000	352086.8700	367704.5600	.0151

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE 6

1

NØISE TØ SIGNAL RATIØ = .168E-01 PERCENT

THE NUMBER ØF EFFECTIVE PARAMETERS IS 7.961

1

'ERRØR BØUNDS' USING MULTIPLIERS FRØM STATS

LAYER RESISTIVITIES
1.0000 PERCENT ERRØR LEVEL

I	RØ(I)	BØUND(1)	BØUND(2)	DAMPING
1	25.3151	24.5714	26.0813	.0014
2	347.0711	337.1283	357.3071	.0018
3	1570.0452	1516.9177	1625.0332	.0010
4	4394.9434	4319.4287	4471.7783	.0000
5	84.9818	80.0397	90.2291	.0284

LAYER DEPTHS (TØ BASE)
1.0000 PERCENT ERRØR LEVEL

I	Z(I)	BØUND(1)	BØUND(2)	DAMPING
1	287.5444	276.7719	298.7363	.0032
2	5060.4961	4868.8867	5259.6465	.0029
3	25060.5080	25043.0900	25077.9370	.9407
4	421867.1200	416958.4400	426833.6200	.0019

FINISHED NØW
/MTINV : STØP 00000

MCARTHUR 1978 SITE / Z

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0501	53.41	-17.30	.15	-86.00	.0199
.0794	91.06	-25.17	56.60	-9.02	.0316
.1259	138.10	-31.72	49.96	-23.52	.0501
.1995	106.10	-34.44	73.60	-31.43	.0794
.3162	130.20	-35.39	94.49	-37.26	.1259
.5012	196.30	-33.73	82.59	-37.71	.1995
.7943	261.30	-35.75	101.80	-40.92	.3162
1.2590	640.90	-34.42	119.30	-40.07	.5012
1.9950	494.50	-26.47	153.40	-30.40	.7943
3.1620	638.30	-29.27	226.30	-30.93	1.2590
5.0120	796.90	-33.78	282.10	-28.78	1.9950
7.9430	926.40	-25.79	365.20	-28.48	3.1620
12.5900	1554.00	-24.16	488.50	-29.16	5.0120
19.9500	1912.00	-28.83	745.50	-21.40	7.9430
31.6200	2075.00	-30.68	1061.00	-25.19	12.5900
50.1200	2703.00	-34.63	1317.00	-30.07	19.9500
79.4300	3077.00	-36.91	1647.00	-36.55	31.6200
125.9000	3097.00	-38.44	2404.00	-40.95	50.1200
199.5000	2905.00	-46.37	2051.00	-42.08	79.4300
316.2000	3673.00	-47.93	2590.00	-48.71	125.9000
501.2000	2686.00	-51.75	2436.00	-51.54	199.5000
794.3000	2430.00	-58.40	2269.00	-59.54	316.2000
1259.0000	1904.00	-61.00	1765.00	-63.53	501.2000
1995.0000	954.20	-56.67	1673.00	-70.93	794.3000

MCARTHUR 1978 SITE 08

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	79.93	-38.70	121.30	-21.30	.0199
.0501	111.30	-44.17	1273.00	-13.90	.0501
.0794	152.30	-44.38	1425.00	-24.52	.0794
.1259	208.40	-49.15	2004.00	-25.85	.1259
.1995	184.00	-44.85	1736.00	-27.02	.1995
.3162	208.40	-43.03	2705.00	-31.00	.3162
.5012	239.50	-38.99	3869.00	-24.53	.5012
.7943	371.80	-36.93	5623.00	-24.62	.7943
1.2590	449.40	-41.47	8225.00	-24.74	1.2590
1.9950	519.00	-45.78	9623.00	-28.42	1.9950
3.1620	508.90	-52.00	11530.00	-27.81	3.1620
5.0120	427.20	-52.08	14330.00	-32.09	5.0120
7.9430	412.50	-53.93	23050.00	-24.89	7.9430
12.5900	439.50	-54.41	29100.00	-27.26	12.5900
19.9500	344.20	-52.81	34950.00	-29.12	19.9500
31.6200	386.80	-51.46	40740.00	-31.82	31.6200
50.1200	307.60	-55.60	59340.00	-37.80	50.1200
79.4300	355.30	-49.18	54030.00	-34.71	79.4300
125.9000	258.70	-55.80	46590.00	-30.85	125.9000
199.5000	208.70	-17.00	37560.00	-47.70	199.5000
316.2000	114.70	-56.25	81350.00	-49.30	316.2000
501.2000	104.60	-47.50	76670.00	-52.98	501.2000
794.3000	270.90	-62.33	61850.00	-62.80	794.3000
1259.0000	243.10	-36.75	49940.00	-62.70	1259.000
1995.0000	188.00	-70.00	18040.00	-56.55	1995.000

MCARTHUR 1978 SITE09

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	3.18	-81.25	20.30	-24.60	.0199
.0501	66.08	-38.23	244.50	-30.12	.0501
.0794	72.28	-41.01	292.10	-31.70	.0794
.1259	105.10	-42.29	362.90	-29.37	.1259
.1995	119.10	-41.04	375.20	-28.28	.1995
.3162	139.70	-41.31	519.90	-26.72	.3162
.5012	190.70	-40.69	787.00	-24.49	.5012
.7943	241.90	-42.08	1187.00	-23.64	.7943
1.2590	273.40	-46.13	1792.00	-23.53	1.2590
1.9950	287.70	-51.10	2120.00	-27.68	1.9950
3.1620	230.20	-55.23	2333.00	-29.09	3.1620
5.0120	233.30	-53.96	2861.00	-32.60	5.0120
7.9430	207.20	-48.54	4201.00	-25.67	7.9430
12.5900	231.10	-51.50	5722.00	-27.01	12.5900
19.9500	222.70	-48.52	6312.00	-28.03	19.9500
31.6200	212.10	-51.59	6705.00	-29.66	31.6200
50.1200	215.30	-48.88	10360.00	-34.78	50.1200
79.4300	157.60	-47.00	11680.00	-35.10	79.4300
125.9000	169.00	-49.40	13580.00	-41.93	125.9000
199.5000	144.90	-47.50	11430.00	-47.63	199.5000
501.2000	112.00	-58.75	4294.00	-31.45	1995.000
1995.0000	19.90	-22.00	0.00	0.00	0.0000

MCARTHUR 1978 SITE 10

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	11.48	-45.06	.52	-64.37	.0199
.0316	56.60	-31.00	26.10	-28.30	.0316
.0501	66.14	-28.13	32.74	-29.58	.0501
.0794	82.60	-31.46	47.45	-36.03	.0794
.1259	107.90	-33.87	57.86	-36.65	.1259
.1995	98.33	-34.14	46.99	-36.19	.1995
.3162	139.40	-26.56	63.54	-34.67	.3162
.5012	216.70	-23.13	100.60	-28.01	.5012
.7943	369.90	-22.53	147.90	-23.10	.7943
1.2590	595.30	-24.06	238.00	-25.52	1.2590
1.9950	664.70	-30.17	277.90	-26.02	1.9950
3.1620	816.80	-31.61	354.50	-28.46	3.1620
5.0120	929.60	-34.70	465.50	-25.63	5.0120
7.9430	1119.00	-35.12	728.90	-20.91	7.9430
12.5900	1320.00	-40.59	1072.00	-22.21	12.5900
19.9500	1323.00	-44.54	1603.00	-23.80	19.9500
31.6200	1302.00	-47.08	2074.00	-26.53	31.6200
50.1200	1396.00	-49.94	3066.00	-32.04	50.1200
79.4300	1187.00	-51.73	3111.00	-33.65	79.4300
125.9000	1152.00	-57.50	3602.00	-39.71	125.9000
199.5000	867.10	-61.92	3811.00	-46.21	199.5000
316.2000	794.40	-62.00	3829.00	-49.59	316.2000
501.2000	643.70	-64.50	3513.00	-54.43	501.2000
794.3000	536.40	-64.40	3052.00	-60.15	794.3000
1259.0000	338.90	-63.75	2132.00	-70.95	1259.000
1995.0000	208.00	-53.60	843.40	-69.84	1995.000

MCARTHUR 1978 SITE 11

	XY		YX		
PERIOD	AP.RES	PHASE	AP.RES	PHASE	PERIOD
.0199	2.02	-36.14	10.93	-51.87	.0199
.0501	51.15	-22.75	46.70	-27.60	.0316
.0794	39.83	-31.58	48.51	-26.10	.0501
.1259	67.82	-33.91	67.19	-35.36	.0794
.1995	82.75	-31.79	94.69	-38.66	.1259
.3162	100.50	-32.76	72.74	-37.27	.1995
.5012	130.00	-29.04	98.04	-42.48	.3162
.7943	227.50	-20.11	102.70	-32.59	.5012
1.2570	403.60	-19.17	128.40	-29.71	.7943
1.9950	565.70	-18.19	189.60	-28.52	1.2590
3.1620	610.50	-24.57	212.50	-31.40	1.9950
5.0120	643.20	-33.80	279.60	-27.71	3.1620
7.9430	840.90	-29.93	429.20	-26.44	5.0120
12.5900	1463.00	-25.29	600.70	-26.48	7.9430
19.9500	1750.00	-29.72	973.90	-36.87	12.5900
31.6200	2989.00	-32.17	907.20	-43.04	19.9500
50.1200	3426.00	-37.65	1425.00	-47.96	31.6200
79.4300	3678.00	-40.43	1241.00	-61.05	50.1200
125.9000	4192.00	-41.70	1128.00	-58.01	79.4300
199.5000	4452.00	-44.33	967.80	-57.14	125.9000
316.2000	4427.00	-47.33	708.50	-59.79	199.5000
501.2000	4404.00	-53.13	642.70	-61.01	316.2000
794.3000	4601.00	-57.10	478.80	-64.35	501.2000
1259.0000	246.00	-72.38	432.00	-67.41	794.3000
1995.0000	357.30	-58.00	249.60	-59.82	1259.000

MCARTHUR 1978 SITE 12

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	.64	-40.46	8.47	-32.79	.0199
.0316	62.90	-26.00	23.60	-20.90	.0316
.0501	57.08	-25.22	42.28	-29.01	.0501
.0794	72.34	-27.57	57.81	-31.71	.0794
.1259	112.30	-30.94	70.50	-34.05	.1259
.1995	92.99	-31.66	71.72	-35.96	.1995
.3162	121.30	-30.85	73.41	-38.97	.3162
.5012	134.60	-28.91	118.90	-30.05	.5012
.7943	203.60	-27.16	174.90	-24.50	.7943
1.2590	293.30	-25.73	325.30	-21.47	1.2590
1.9950	341.90	-24.07	396.40	-27.39	1.9950
3.1620	395.60	-25.93	498.80	-27.76	3.1620
5.0120	473.20	-23.40	593.60	-30.20	5.0120
7.9430	775.80	-22.49	771.20	-30.55	7.9430
12.5900	1472.00	-19.52	1271.00	-36.40	12.5900
19.9500	1921.00	-21.46	1239.00	-39.02	19.9500
31.6200	2266.00	-27.61	1256.00	-44.09	31.6200
50.1200	3039.00	-28.94	1462.00	-49.46	50.1200
79.4300	3461.00	-33.14	1359.00	-51.20	79.4300
125.9000	3655.00	-36.18	1286.00	-54.90	125.9000
199.5000	4939.00	-38.67	961.70	-64.28	199.5000
316.2000	4831.00	-44.91	936.70	-66.15	316.2000
501.2000	4331.00	-46.89	588.90	-64.18	501.2000
794.3000	2319.00	-50.13	439.90	-61.53	794.3000
1259.0000	244.50	-5.00	462.40	-53.85	1259.000
1995.0000	602.40	-85.00	269.10	-46.07	1995.000

MCARTHUR 1978 SITE 13

PERIØD	XY AP.RES	XY PHASE	YX AP.RES	YX PHASE	PERIØD
.0199	.15	-18.55	.78	-12.82	.0199
.0794	34.02	-26.65	18.54	-19.67	.0501
.1259	62.97	-30.74	39.83	-26.02	.0794
.1995	50.66	-34.48	42.02	-31.87	.1259
.3162	70.78	-32.46	52.56	-37.14	.1995
.5012	99.39	-33.24	58.77	-40.26	.3162
.7943	124.70	-30.71	78.86	-32.19	.5012
1.2590	173.10	-29.86	104.60	-27.04	.7943
1.9950	202.80	-24.86	200.10	-24.99	1.2590
3.1620	237.30	-29.75	242.90	-26.96	1.9950
5.0120	316.20	-27.45	299.60	-24.34	3.1620
7.9430	482.40	-18.83	357.30	-26.79	5.0120
12.5900	577.70	-22.25	396.80	-27.87	7.9430
19.9500	873.00	-28.14	425.60	-34.61	12.5900
31.6200	1767.00	-28.24	463.10	-36.42	19.9500
50.1200	2942.00	-32.13	846.60	-48.21	31.6200
79.4300	2622.00	-30.88	1082.00	-53.94	50.1200
125.9000	3511.00	-37.50	1045.00	-52.93	79.4300
199.5000	4371.00	-40.80	782.50	-55.94	125.9000
316.2000	3412.00	-46.08	680.50	-61.84	199.5000
501.2000	3220.00	-51.50	466.20	-63.40	316.2000
794.3000	2490.00	-55.91	406.00	-58.35	501.2000
1259.0000	184.00	-65.00	291.20	-59.96	794.3000
1995.0000	65.80	-65.00	39.95	-69.35	1259.000

MCARTHUR 1978 SITE 14

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	.08	-37.94	.25	-39.53	.0199
.0501	53.60	-21.50	25.13	-18.50	.0501
.0794	69.18	-25.60	28.57	-30.04	.0794
.1259	104.60	-31.56	41.39	-34.73	.1259
.1995	94.18	-33.16	35.13	-40.17	.1995
.3162	106.60	-34.93	62.09	-41.50	.3162
.5012	135.40	-30.32	92.10	-37.13	.5012
.7943	177.70	-28.92	123.00	-31.18	.7943
1.2590	253.50	-28.55	215.70	-27.46	1.2590
1.9950	293.90	-24.02	280.50	-28.16	1.9950
3.1620	352.90	-26.22	273.10	-25.26	3.1620
5.0120	443.70	-26.00	390.00	-27.94	5.0120
7.9430	763.70	-18.48	544.40	-27.28	7.9430
12.5900	1155.00	-19.04	896.40	-29.35	12.5900
19.9500	1801.00	-22.05	1167.00	-35.92	19.9500
31.6200	2244.00	-27.23	1345.00	-42.18	31.6200
50.1200	3231.00	-29.75	1373.00	-50.62	50.1200
79.4300	3585.00	-32.61	1106.00	-51.62	79.4300
125.9000	4574.00	-36.67	1014.00	-57.36	125.9000
199.5000	4340.00	-43.14	872.00	-54.79	199.5000
316.2000	4120.00	-48.00	861.80	-62.62	316.2000
501.2000	4256.00	-53.40	666.50	-63.10	501.2000
794.3000	3121.00	-60.42	484.80	-64.65	794.3000
1259.0000	1764.00	-62.27	338.70	-64.46	1259.000
1995.0000	1932.00	-62.75	90.10	-85.40	1995.000

MCARTHUR 1978 SITE 15

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0199	.12	-47.64	.09	-33.79	.0199
.0501	22.68	-17.50	15.80	-27.50	.0316
.0794	50.11	-25.88	12.14	-30.40	.0501
.1259	76.72	-29.84	10.54	-41.15	.0794
.1995	69.59	-29.61	16.72	-44.87	.1259
.3162	94.71	-26.56	15.63	-45.12	.1995
.5012	128.50	-24.51	23.41	-38.64	.3162
.7943	217.40	-21.42	34.64	-32.30	.5012
1.2590	349.40	-22.58	34.23	-33.81	.7943
1.9950	417.40	-24.86	47.83	-30.31	1.2590
3.1620	507.00	-30.27	57.47	-36.07	1.9950
5.0120	640.90	-29.53	61.90	-33.21	3.1620
7.9430	879.00	-27.93	82.34	-38.76	5.0120
12.5900	1005.00	-25.59	98.90	-35.04	7.9430
19.9500	1202.00	-24.94	132.20	-39.32	12.5900
31.6200	1575.00	-27.41	137.80	-42.65	19.9500
50.1200	2235.00	-32.15	149.80	-47.39	31.6200
79.4300	2934.00	-32.59	130.30	-53.94	50.1200
125.9000	2849.00	-38.27	127.00	-54.11	79.4300
199.5000	3294.00	-44.19	109.00	-56.20	125.9000
316.2000	3774.00	-46.33	101.40	-47.82	199.5000
501.2000	3447.00	-51.20	73.64	-51.85	316.2000
794.3000	2563.00	-56.08	61.23	-60.13	501.2000
1259.0000	2163.00	-57.86	54.95	-64.88	794.3000

MCARTHUR 1978 SITE 16

	XY		YX		
PERIOD	AP.RES	PHASE	AP.RES	PHASE	PERIOD
.0501	111.80	-24.69	71.17	-27.09	.0501
.0794	180.50	-22.11	90.13	-32.66	.0794
.1259	269.20	-23.98	109.60	-38.02	.1259
.1995	277.10	-27.65	104.50	-37.21	.1995
.3162	363.00	-26.27	118.00	-36.99	.3162
.5012	503.90	-25.80	153.10	-40.59	.5012
.7943	807.40	-25.26	210.50	-40.07	.7943
1.2590	1130.00	-25.94	257.10	-44.78	1.2590
1.9950	1361.00	-27.59	238.10	-52.12	1.9950
3.1620	1622.00	-27.76	234.50	-57.09	3.1620
5.0120	2064.00	-27.68	217.20	-56.25	5.0120
7.9430	2818.00	-25.82	215.80	-54.44	7.9430
12.5900	3590.00	-25.93	204.40	-55.90	12.5900
19.9500	4289.00	-27.69	187.30	-54.25	19.9500
31.6200	5202.00	-27.95	188.80	-52.54	31.6200
50.1200	7449.00	-32.14	193.20	-59.44	50.1200
79.4300	7834.00	-35.14	170.40	-58.74	79.4300
125.9000	9471.00	-38.64	166.20	-67.64	125.9000
199.5000	9516.00	-42.07	126.30	-60.91	199.5000
316.2000	10490.00	-49.02	116.30	-68.18	316.2000
501.2000	10150.00	-52.16	84.22	-70.25	501.2000
794.3000	9643.00	-61.90	72.36	-80.83	794.3000
1259.0000	5210.00	-74.30	68.42	-50.50	1259.0000
1995.0000	3874.00	-83.03	0.00	0.00	0.0000

MCARTHUR 1978 SITE 17

	XY		YX		
PERIØD	AP.RES	PHASE	AP.RES	PHASE	PERIØD
.0316	3.69	-42.67	715.70	-85.44	.0316
.0501	16.75	-15.33	79.00	-28.10	.0501
.0794	40.06	-29.83	105.50	-32.66	.0794
.1259	93.18	-31.48	136.00	-35.91	.1259
.1995	87.60	-33.54	147.60	31.57	.1995
.3162	195.40	-47.86	3806.00	-20.91	.3162
.5012	341.40	-54.67	2086.00	-54.86	.5012
.7943	330.20	-27.47	2757.00	-28.79	.7943
1.2590	485.80	-23.66	594.20	-37.20	1.2590
1.9950	659.80	-22.43	668.70	-35.45	1.9950
3.1620	757.90	-22.48	624.50	-36.96	3.1620
5.0120	976.60	-26.22	769.70	-43.03	5.0120
7.9430	1136.00	-19.45	794.80	-32.05	7.9430
12.5900	1777.00	-18.70	924.70	-35.96	12.5900
19.9500	2526.00	-26.50	967.30	-39.89	19.9500
31.6200	3496.00	-26.90	1237.00	-44.78	31.6200
50.1200	4823.00	-30.18	1272.00	-52.35	50.1200
79.4300	5418.00	-33.03	1062.00	-51.66	79.4300
125.9000	5996.00	38.15	1019.00	-58.39	125.9000
199.5000	6237.00	-44.16	840.00	-60.79	199.5000
316.2000	6932.00	-47.20	734.60	-62.84	316.2000
501.2000	6818.00	-54.67	570.20	-65.63	501.2000
794.3000	5295.00	-59.29	480.90	-67.25	794.3000
1259.0000	3230.00	-65.60	221.70	-45.65	1259.000
1995.0000	2208.00	-44.60	141.30	-44.35	1995.000

APPENDIX 4

2D Inversion and Parameter Sensitivity Analysis

Inversion of magneto-telluric data consists of comparing the response of a model with the actual survey data in an iterative fashion, such that at each iteration the relative root-mean-square error in resistivity between model and field data is minimised. The Jacobian or influence matrix (i.e. the matrix of partial derivatives of the model data with respect to model parameters) determines the effect that any particular model parameter will have upon model results. The inverse Jacobian is used with the survey and model results to generate a correction vector, which may be applied to the model parameters to bring the model results closer to the survey data. Numerical stability of the inverse problem is ensured by classifying model parameters as "important" (large effect on model results), "unimportant" (small effect on model results) and "irrelevant" (no effect on model results); this classification is obtained from the magnitude of the partial derivatives in the appropriate column of the Jacobian (i.e. large, small, and zero). Unimportant and irrelevant parameters could have a highly unstable effect on the inversion if not controlled, so irrelevant model parameters are not allowed to change during inversion, and unimportant parameters are only allowed to influence the inversion in the final stages, in order to reduce the final least-squares error. A form of "tapered damping" is applied during the process, so that only the major parameters of the model are altered in the early stages of inversion. Consequently, if the inversion converges to a solution with results close to the survey data, then the Jacobian may be used as a good guide to those parameters which are well defined.

Error statistics resulting from the inversion process can be obtained from the V matrix or parameter space eigenvector; this matrix defines the relation between the original and transformed parameter spaces, and is derived from the singular value decomposition of the Jacobian. It can be used to decide which of the parameter combinations are "important" (e.g. resistivity/thickness products etc.). Important variables are normally described as those whose normalised singular value is greater than 1% at the 1% damping level. As an example Jupp & Vozoff (1975) have considered the 1D model shown in Figure A4.1. The parameters defining this model must first be expressed in a logarithmic form to ensure stability and remove any constraint related to transformation of dimension within the Jacobian. The resulting normalised singular values (k_i) of the Jacobian appear with the parameter space eigenvectors in Table A4.1. Parameters with $k_i \geqslant 0.01$ are called important at the 1% level; consequently in Table A4.1 there are 6 important parameters. However, it must be noted that such descriptions refer to sensitivity rather than accuracy. Unimportant and irrelevant parameters may be significant to the solution since they may effectively mask any deeper layer. Consequently damping factors must be applied to these parameters to avoid instability in the solution; the original values persist simply because there is no good reason to change them.

To interpret the nature of the important and unimportant parameters they must be related to the original data defining the model.

The logarithmic structure is convenient because significant parameter combinations in resistivity are often products and ratios. The factors P_i, h_i, $P_i h_i$, h_i / P_i, and P_{i+1} / P_i may all appear as transformed parameters, and the V matrix can be interpreted in terms of these (familiar) combinations.

For example in Figure A4.1 the second transformed parameter, $\log q_2$, corresponds to the second column of V in Table A4.1, i.e.

$$\log q_2 = 0.392 \log P_1 - 0.730 \log P_2 - 0.039 \log P_3 - 0.035 \log P_4$$

$$+ 0.544 \log P_5 + 0.027 \log h_1 + 0.109 \log h_2 - 0.042 \log h_3;$$

For interpretation this can be stated as:

$$q_2 \approx P_2 / P_5 \text{ (with } P_2 \text{ predominant).}$$

In a similar way the six Important parameter combinations are, P_5, P_2/P_5, P_1, q_4, q_5, h_2/P_4, and the three Unimportant parameters are h_3/P_3, h_1, and h_4. The parameters q_4 and q_5 are more complicated. q_5 is roughly $h_2 P_4/P_3$, and q_4 is roughly $P_4 P_3 h_3$. q_5 is an important interactive parameter and is above the threshold at the 0.1, or 10 percent level.

The V matrix may also be used to assess how important a given layer parameter is. The rows of V represent the way the original parameters are spread among the transformed parameters. For example, P_3 corresponds to the third row of V, and has significant components in columns corresponding to q_4, q_5 and q_7 with most 'energy' in the q_4 and q_7 columns. As noted above q_4 corresponds roughly with the product ($P_3 h_3$) and q_7 corresponds with (h_3/P_3).

McArthur Basin Analysis

The starting model used in the 2D inversion of the 1978 data appears together with the corresponding output in Table A4.2. This model represents a synthesis of the principal spatial features identified in 14 separate inversions. However it must be emphasised that the scales for the tabulated values are highly non-linear, on both the vertical and horizontal axis. To allow structural features to be more readily identified, the final model has been redrawn in Figure 15 as a resistivity profile with linear scales.

For the 1978 data (Table A4.3) the transformed parameters are "important" up to column 14 of the Jacobian and are significant to column 25. The influence of the original resistivity parameters can then be readily assessed from the "power" distribution. For example most of the power in row 5 is concentrated in column 28; therefore the resistivity of block 5 cannot be well resolved. In contrast, most of the power in row 6 is distributed in columns 1-5, and this resistivity is therefore well determined. A similar process has been used to assess data in each row and the apparent quality of the result for each block is indicated in Figure 16.

TABLE 1: MAGNETO-TELLURIC STATION LOCATIONS

Station number	Name	1:100 000 Sheet	Position Longitude (E) Latitude (S)	Magnetic azimuth of X axis direction (E of N)
1	KANGAROO CREEK	PUNGALINA	137.132° 16.637°	020°
2	ROBINSON RIVER	WEARYAN	136.968° 16.390°	000°
3	CALVERT RIVER	PUNGALINA	137.347° 16.900°	022°
4	CALVERT HILLS	CALVERT HILLS	137.488° 17.170°	072°
5	FOELSCHE RIVER	WEARYAN	136.808° 16.155°	000°
6	SCRUBBY CREEK	BORROLOOLA	136.390° 16.255°	027°
7	FLETCHER CREEK	WEARYAN	136.573° 16.212°	083°
8	CARANBIRINI	BORROLOOLA	136.055° 16.295°	007°
9	GAZZA	BATTEN	135.978° 16.285°	003°
10	STARVATION HILL	BORROLOOLA	136.125° 16.297°	082°
11	U-DASH	BORROLOOLA	136.185° 16.288°	002°
12	SHANNO	BORROLOOLA	136.248° 16.285°	070°
13	PC5 EAST	BORROLOOLA	136.315° 16.270°	072°
14	FIVO	BORROLOOLA	136.432° 16.232°	070°
15	PC9	BORROLOOLA	136.125° 16.117°	009°
16	PC3	BATTEN	135.885° 16.275°	009°
17	BORROLOOLA	BORROLOOLA	136.292° 16.078°	007°