COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1968/70

PAPERS PREPARED FOR THE SEVENTH SESSION,
WORKING PARTY OF SENIOR GEOLOGISTS

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
Tehran, Iran, 22-27 July, 1968

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PROGRESS IN GEOLOGICAL MAPPING IN AUSTRALIA
1966-68

by

N.H. Fisher

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
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PROGRESS IN GEOLOGICAL MAPPING IN AUSTRALIA 1966-1968

by

N.H. Fisher

After World War II it was decided at a conference between the Bureau of Mineral Resources and the Geological Surveys of the six Australian States to inaugurate the production of a series of geological maps to uniform scale and colour scheme and standards of compilation. The major effort was to be concentrated on maps at the scale of 4 miles to the inch each comprising 1½ degrees of longitude and 1 degree of latitude, in accordance with the Australian National grid. The scale was subsequently altered to 1:250,000, when the metric basis was adopted by Australian mapping authorities.

Accordingly a programme of geological mapping was commenced, in the first instance mainly by the Bureau of Mineral Resources, either in joint projects with the Geological Surveys of Queensland and Western Australia or alone, and by the Geological Survey of South Australia. Other State Surveys joined in later, as staff became available for mapping. The standard of mapping involved complete photo-geological interpretation, numerous field reconnaissances, plotting of the geology at photo scale and compilation on standard bases prepared by topographic mapping authorities, reproduction in colour with a standard format and surround, and accompanied by explanatory notes. In areas of good exposure and fairly complicated geology a party of three or four geologists maps a sheet area - about 7000 square miles - in a field season of five months, with the remainder of the year devoted to map and report compilation, photo-interpretation and laboratory work. In areas where the geology is much simpler and exposures are scarce, such as the Great Artesian Basin, the rate of mapping is greatly increased. In such areas surface mapping is supplemented by shallow stratigraphic drilling. This programme constituted the first systematic mapping on a sheet basis that had been undertaken in Australia. More recently the re-constituted Western Australian Geological Survey has undertaken a very active mapping programme to similar standards of field work and compilation as those of the Bureau of Mineral Resources and the South Australian Geological Survey. According to an early agreement most of their maps are being printed for the Western Australian Geological Survey by the Bureau of Mineral Resources.

In recent years the Geological Survey of N.S.W. has undertaken a very vigorous programme of compilation of maps at 1:250,000 scale and the rapid progress in the publication of these maps can be seen on Figure 3 which shows the progress in mapping during 1967 and 1968. The N.S.W. maps are based on somewhat less extensive field work than the maps of the other States and rely rather more on compilation of existing geological information, but otherwise are produced to the same format and colour scheme.

In addition to the 1:250,000 maps a considerable amount of map reproduction has been done at the scale of 1" to 1 mile (1:63,360) especially by the Geological Survey of Tasmania, the Geological Survey of South Australia and by the Bureau of Mineral Resources in the Northern Territory and jointly with the Queensland Geological Survey in North Queensland. It is probable that maps at this scale will be gradually phased out and the larger scale maps will be reproduced either at a scale of 1:50,000 or at 1:100,000. At this latter scale the mapping authorities are initiating a series of contoured maps which will eventually cover the whole of Australia.

During 1967 the Bureau of Mineral Resources began a long term programme of geological mapping of the Australian Continental Shelf. This investigation is designed primarily to examine areas around Australia and New Guinea for possible deposits of submarine phosphorite but will be continued and combined with surveys of other organisations interested in marine geology to cover the whole of the shelf areas around Australia, which amount in all to approximately 1 million square miles. The Geological Branch of the Bureau is carrying out bottom sampling, coring and dredging, and profiling, underwater photography, and sparker surveys to determine structure and thickness of the more recent sediments. The Geophysical Branch is concurrently undertaking systematic coverage by gravity (shipboard, with occasional bottom readings), magnetic survey (towed magnetometer) and seismic profiling with the use of a more powerful Spark array, with a 21000 joule power source.

Accompanying Plans:

Figure 1: Post-War Regional Geological Mapping showing maps published at scales smaller than 1:250,000.

Figure 2: Geological Mapping up to and including 1968, showing maps published at 1:250,000 (or 4 miles = 1 inch) and 1:63,360; and areas in which field work is completed and maps in course of preparation for publication.

Figure 3: Progress in Geological Mapping and map publication since 17.10.66, projected to the end of 1968.

Figure 4: Seismic surveys to 31.12.67.

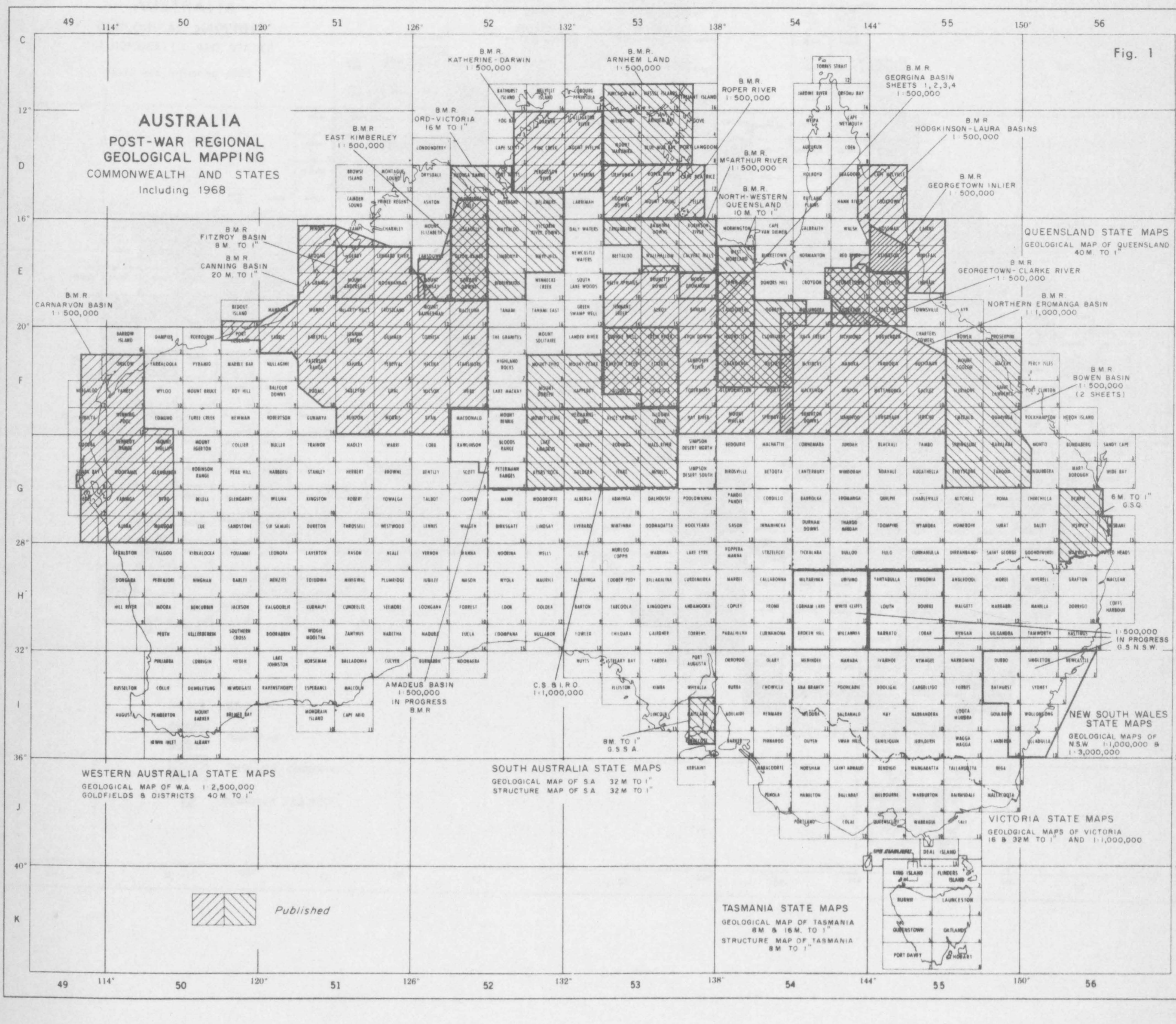


Fig. 1
AUSTRALIA
POST-WAR REGIONAL
GEOLOGICAL MAPPING
COMMONWEALTH AND STATES
Including 1968
B.M.R. KATHERINE-DARWIN 1:500,000
B.M.R. ARNHEM LAND 1:500,000
B.M.R. ROPER RIVER 1:500,000
B.M.R. GEORGINA BASIN SHEETS 1, 2, 3, 4 1:500,000
B.M.R. ORD-VICTORIA 16 M. TO 1"
B.M.R. EAST KIMBERLEY 1:500,000
B.M.R. McARTHUR RIVER 1:500,000
B.M.R. HODGKINSON-LAURA BASINS 1:500,000
B.M.R. NORTH-WESTERN QUEENSLAND 10 M. TO 1"
B.M.R. GEORGETOWN INLIER 1:500,000
B.M.R. FITZROY BASIN 8 M. TO 1"
B.M.R. CANNING BASIN 20 M. TO 1"
QUEENSLAND STATE MAPS
GEOLOGICAL MAP OF QUEENSLAND 40 M. TO 1"
B.M.R. GEORGETOWN-CLARKE RIVER 1:500,000
B.M.R. CARNARVON BASIN 1:500,000
B.M.R. NORTHERN EROMANGA BASIN 1:1,000,000
B.M.R. BOWEN BASIN 1:500,000 (2 SHEETS)
8 M. TO 1" G.S.Q.
1:500,000 IN PROGRESS G.S.N.S.W.
AMADEUS BASIN 1:500,000 IN PROGRESS B.M.R.
C.S.I.R.O. 1:1,000,000
8 M. TO 1" G.S.S.A.
NEW SOUTH WALES STATE MAPS
GEOLOGICAL MAPS OF N.S.W. 1:1,000,000 & 1:3,000,000
WESTERN AUSTRALIA STATE MAPS
GEOLOGICAL MAP OF W.A. 1:2,500,000
GOLDFIELDS & DISTRICTS 40 M. TO 1"
SOUTH AUSTRALIA STATE MAPS
GEOLOGICAL MAP OF S.A. 32 M. TO 1"
STRUCTURE MAP OF S.A. 32 M. TO 1"
VICTORIA STATE MAPS
GEOLOGICAL MAPS OF VICTORIA 16 & 32 M. TO 1" AND 1:1,000,000
Published
TASMANIA STATE MAPS
GEOLOGICAL MAP OF TASMANIA 8 M. & 16 M. TO 1"
STRUCTURE MAP OF TASMANIA 8 M. TO 1"
49 114° 50 120° 51 126° 52 132° 53 138° 54 144° 55 150° 56
C D E F G H I J K
12° 16° 20° 24° 28° 32° 36° 40°

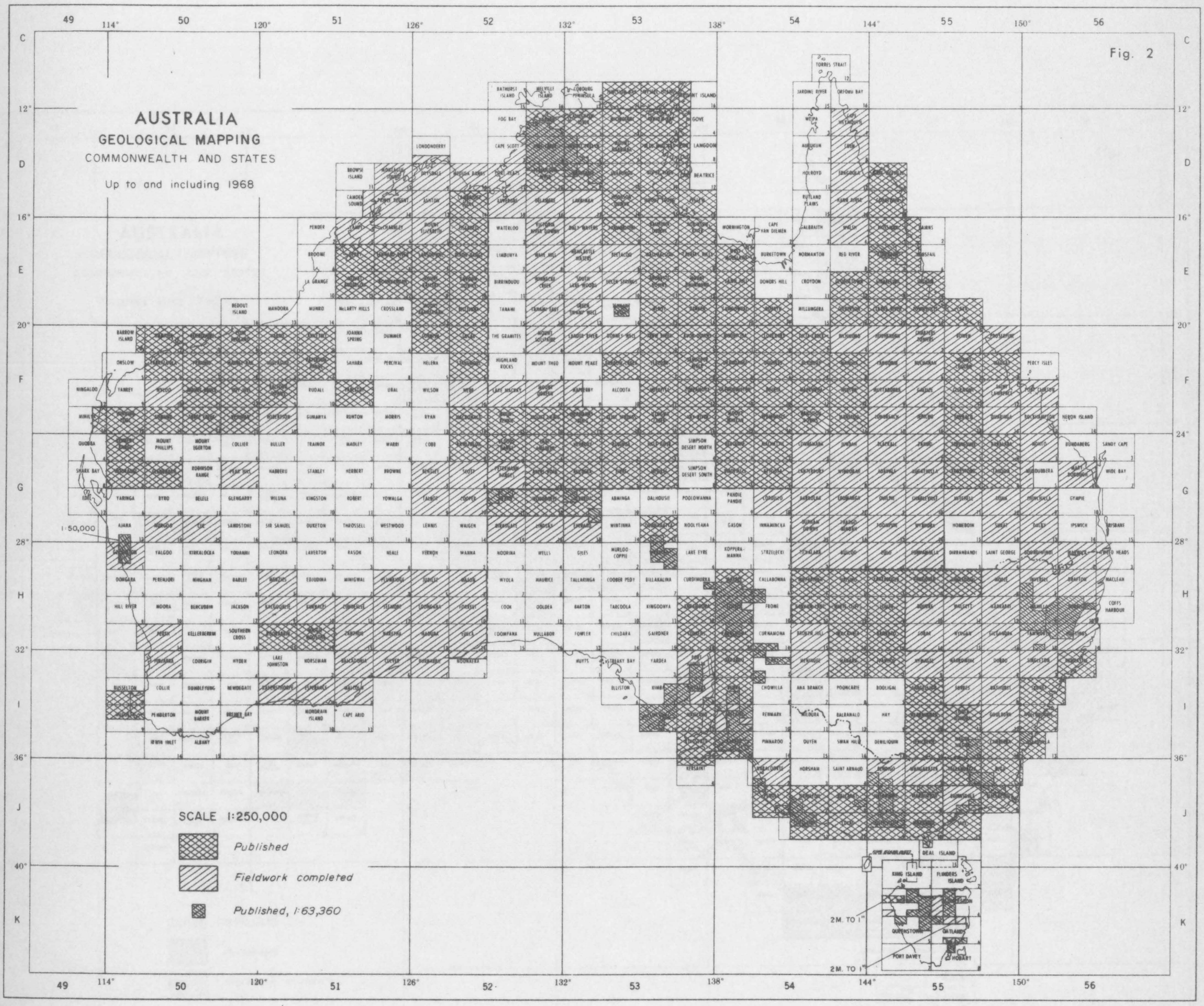


Fig. 2
AUSTRALIA
GEOLOGICAL MAPPING
COMMONWEALTH AND STATES
Up to and including 1968
SCALE 1:250,000
Published
Fieldwork completed
Published, 1:63,360
1:50,000
2M. TO 1"
2M. TO 1"

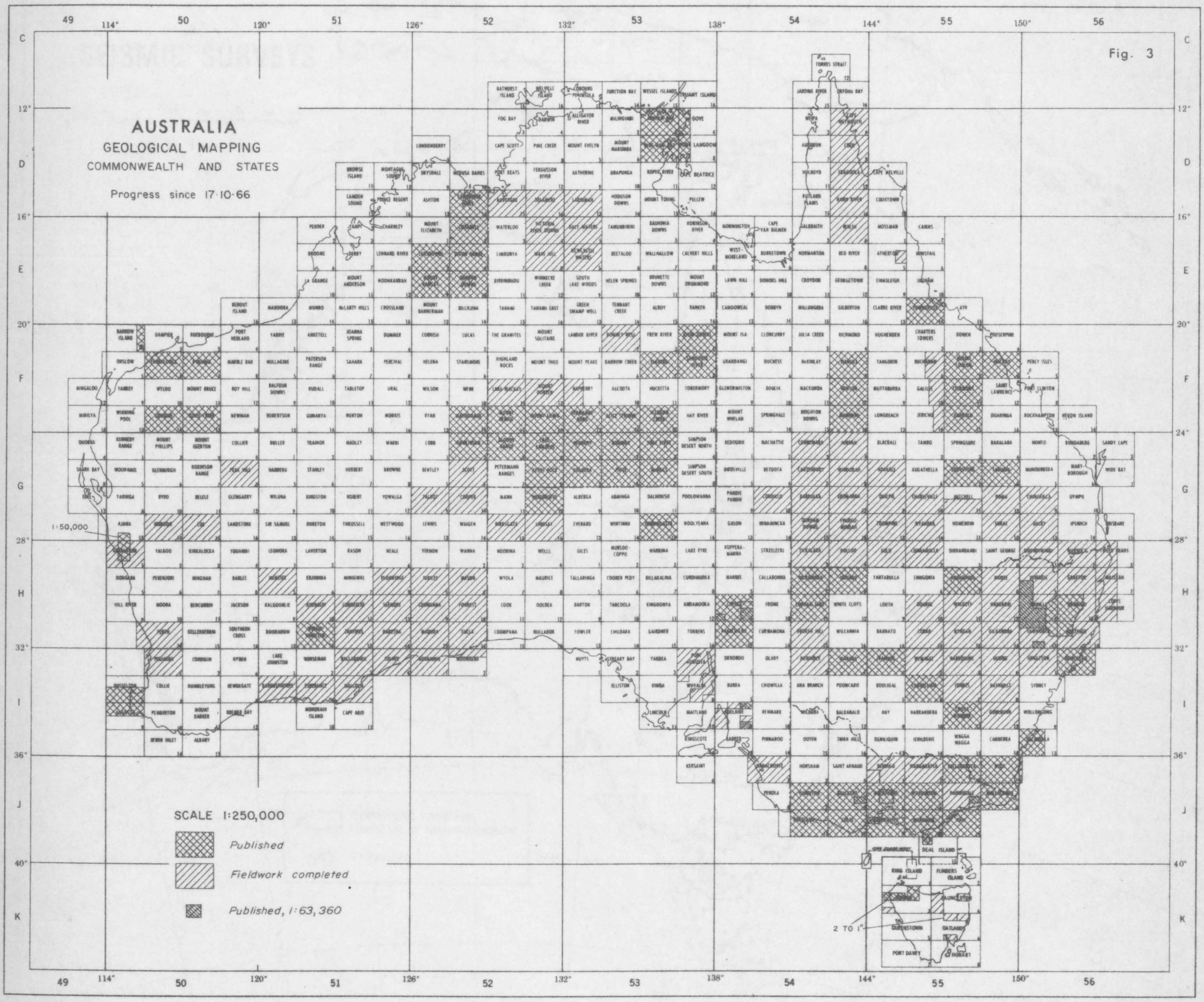

AUSTRALIA
GEOLOGICAL MAPPING
COMMONWEALTH AND STATES
Progress since 17·10·66
SCALE 1:250,000
Published
Fieldwork completed
Published, 1:63,360
1:50,000
2 TO 1"

Fig. 3

FIG.4
SEISMIC SURVEYS
100 0 100 200 300 400 500 MILES
TO 31·12·67
WEST IRIAN
PORT MORESBY
DARWIN
BRISBANE
PERTH
ADELAIDE
SYDNEY
MELBOURNE
HOBART
Systematic coverage (Detailed or reconnaissance)
Traverses
AUS2/60

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

PROGRESS REPORT ON GEOLOGICAL MAPS OF OCEANIA

by

B. Graham

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

PROGRESS REPORT ON GEOLOGICAL MAPS OF OCEANIA

By B. Graham

In 1955, the Bureau of Mineral Resources, Department of National Development, Australia, agreed to a request from the President of the Commission for the Geological Map of the World, that it should act as regional coordinating and compiling authority for a map of Australia and Oceania at 1:5,000,000 scale. At that time, other maps of the series, either published or in progress, included those of Europe, Africa, North and South America, Asia and the Far East.

In 1956 a conference of interested countries was held in Canberra to discuss the project, the following being represented - the South Pacific Commission, New Zealand, British Solomon Islands Protectorate, Fiji, New Caledonia and other French territories in the Pacific. Promises of assistance were also received from the Netherlands and the United States. At this meeting and in ensuing correspondence, decisions were made on the format of the map, arrangements for financing the project and its distribution on completion.

1. Format (See Index to Sheet Assembly)

The map consists of thirteen sheets, of which Sheet No. 1 (since it covers an area already included in the Geological Map of Asia and the Far East) is to be published as the general reference sheet for the whole series. Each sheet covers twenty four degrees of latitude and twenty four degrees of longitude, although in the case of sheets 7, 10 and 13, these have been extended slightly to include adjacent islands. The map projection is Lambert Conformal Conic with two standard parallels 10°S and 30°S; the colour scheme and general time and rock sub-divisions are based on those of the International Geological Legend, supplied by the Commission for the Geological Map of the World. The official language for the map is English, although geographical names have been retained in their national languages.

2. Financial Arrangements.

It was decided that the degree of financial participation of the countries with territories in the region, should depend upon the area of those territories. After publication expenses had been assessed, the following contributions were decided upon -

	Australia	N.Z.	Great Britain	United States	Netherlands	France
	$A	$A	$A	$A	$A	$A
Own land areas	8000	1700*				
Shared land areas			850			850
Mainly ocean islands	1120	1400*	1120	1120	1120	1120
TOTAL	9120	3100	1970	1120	1120	1970

* New Zealand preferred, rather than to make a financial contribution, to produce and bear the cost of publication of Sheet 13 (New Zealand) and Sheet 9 (Samoa, eastern Fiji, Tonga, Phoenix and Cook Islands groups).

3. Distribution of Maps

Of the two thousand copies of each map sheet to be printed, fifty complimentary copies were to go to each participating country, the distribution of the remaining seventeen hundred being based on financial contributions and areas of interest, as follows -

Sheet	Australia	N.Z.	U.K.	France	U.S.A.	Netherlands	Total
1	1,000	400	200	200	100	100	2,000
2	450	330	330	330	330	230	2,000
3	450	330	330	330	330	230	2,000
4	350	330	330	330	330	330	2,000
5	350	330	330	330	330	330	2,000
6	1,600	100	100	100	50	50	2,000
7	1,400	100	100	100	50	250	2,000
8	250	50	800	800	50	50	2,000
9	350	330	330	330	330	330	2,000
10(15)	350	330	330	330	330	330	2,000
11	1,600	100	100	100	50	50	2,000
12	1,600	100	100	100	50	50	2,000
13(14)	200	1,600	50	50	50	50	2,000
TOTALS	9,950 38.3%	4,430 17%	3,430 13.2%	3,430 13.2%	2,380 9.15%	2,380 9.15%	26,000 100%
FINANCIAL CONTRIB-UTION	49.6%	16.8%	10.7%	10.7%	6.1%	6.1%	100%

In addition, although financial and geological contributions for West Irian were supplied by the Netherlands (which had the responsibility for West Irian at that time), fifty complimentary copies of Sheet 7 have been forwarded to Indonesia from Australia's own stocks. Complimentary copies have also been supplied to the Commission for the Geological Map of the World.

Australia's sale copies are held by the Bureau of Mineral Resources, Canberra, and priced at $A.1-00 per sheet. Other authorities holding stocks are -

Geological Survey of the Netherlands, Harlem
Geological Survey of New Zealand, Wellington
Institute of Geological Sciences, London
Ministiere de la France D'Outre Mer, Paris
United States Geological Survey, Washington.

4. Progress of compilation.

Some years have elapsed since the first discussions on the project were held, but it is now nearing completion. Those years have been marked throughout by the willing and friendly co-operation of a large number of authorities and individuals in various countries, without whose help the project could never have been brought to fruition. The geological surveys of the British Solomon Islands Protectorate, the Condominium of the New Hebrides, Fiji, New Caledonia, New Zealand and the United States have all readily supplied data on request, but special thanks is due to Professor F. Faber and Dr. W. Visser (Netherlands), Professor P. Routhier (France), Dr. G. Corwin, Professors H. Hess and H. Menard (U.S.A.), Dr. T. Matsuzaki (G.E.B.C.O. Sub-committee for Submarine Toponymy) and to the officers of the Commission for the Geological Map of the World.

It was originally proposed that Australia should produce the maps to fair drawing stage, but that the actual publication should take place in France. Later, for reasons of convenience and economy it was decided that the maps should be wholly produced in Australia.

Topographic base maps were prepared by the Division of National Mapping, Department of National Development, Canberra, and participating countries checked the areas with which each was concerned. Compilation proceeded at 1:4,000,000 scale, close contact being maintained with the other countries, and their approval obtained of the format and scientific content of the maps.

The present state of progress of the Australia and Oceania map (see attached Index to Sheet Assembly) is as follows -

Sheets 2, 3, 4, 5, 6, 7, 11, and 12 have all been published and copies distributed to participating countries and the Commission for the Geological Map of the World.

Sheets 8, 10 and 15 (in part only, as an extension of Sheet 10) have reached proof stage and will soon be published.

Sheets 9, 13 and 14 (in part only as an extension of Sheet 13) are being compiled currently by the Geological Survey of New Zealand, and as soon as these are completed, preparation of Sheet 1, the general reference sheet for the whole series, will commence.

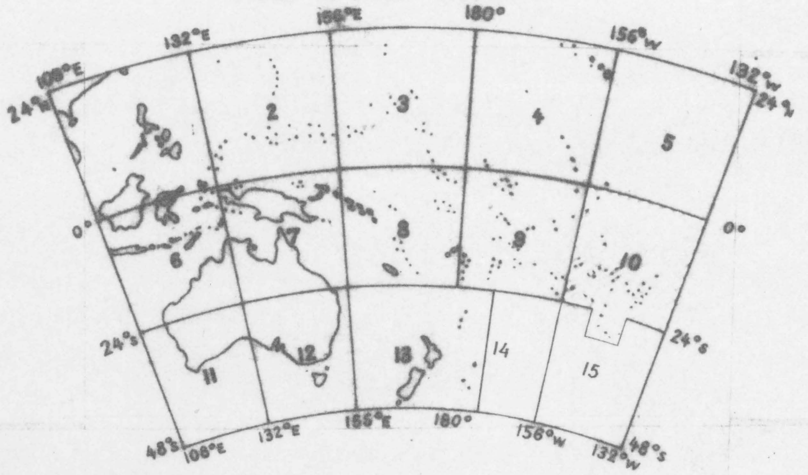
Geological World Atlas 1:10,000,000: Sheet 15 (Australia-New Guinea)

As in the case of the Australia and Oceania 1:5,000,000 map series, the Bureau of Mineral Resources, Department of National Development, Australia, has agreed to the request of the Commission for the Geological Map of the World, that it should prepare a geological compilation at 1:10,000,000 scale of Sheet 15(Australia-New Guinea) of the Geological World Atlas.

Toponymy for the map sheet has been supplied to the Geographical Society of America, which is currently engaged in preparation of the topographic base map.

A preliminary compilation, at 1:6,000,000 scale, of the geology of the Australian mainland is well advanced. On completion and reduction to 1:10,000,000 scale, this will be forwarded to the Commission for the Geological Map of the World, where it will be transferred to the topographic base. Time and rock subdivisions used in the compilation are similar (where scale permits) to those of the Australia and Oceania map (based on the International Geological Legend) but a considerable amount of new data will be incorporated in it. It is envisaged that the map will show pre-Quaternary geology, with the presence of superficial deposits indicated by an overprint.

INDEX TO SHEET ASSEMBLY



PROGRESS OF PUBLICATION

Sheet 1 (reference) – not yet prepared

Sheet 2 – printed in October 1967

Sheet 3 – printed in October 1967

Sheet 4 – printed in October 1967

Sheet 5 – printed in October 1967

Sheet 6 – printed in February 1966

Sheet 7 – printed in February 1966

Sheet 8 – machine proof received in May 1968

Sheet 9 – fair drawing in progress by Geol. Survey, N.Z.

Sheet 10 – machine proof received in May 1968

Sheet 11 – printed in February 1966

Sheet 12 – printed in February 1966

Sheet 13 – fair drawing in progress by Geol. Survey, N.Z.

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

PROGRESS REPORT ON THE TECTONIC MAP OF AUSTRALIA

by

H.F. Doutch and K.A. Plumb

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

PROGRESS REPORT ON THE TECTONIC MAP OF AUSTRALIA

(by H.F. Doutch, and K.A. Plumb, B.M.R.)

INTRODUCTION

A new Tectonic Map of Australia including New Guinea is being compiled as a Geological Society of Australia project by K.A. Plumb, H.F. Doutch and G. Cifali of the Bureau of Mineral Resources, and Dr. M. Rickard of the Australian National University, from State Tectonic Map Committee contributions. The new map is essentially Australia's contribution to the 1:15,000,000 Scale Tectonic Map of the World, although the Society intends to publish a more detailed map at 1:5,000,000 scale early next year. A hand coloured draft at 1:6,000,000 will be exhibited at the International Geological Congress in Prague in August, 1968.

BACKGROUND

A decision in principle to begin compilation of the Tectonic Map of the World was approved at a session of the Commission for the Geological Map of the World in December, 1962. A legend for the map was distributed at the International Geological Congress in India in 1964. Professor E.S. Hills of Melbourne University was appointed Convenor for Australia, New Zealand and Oceania of the Sub-Commission of the Tectonic Map of the World. State Tectonic Map Committees of the Geological Society of Australia have been engaged in compilation and discussion since 1965; the Commonwealth Territories Division has undertaken drawing and editing of the compilation, in which it has received valuable assistance from the Bureau of Mineral Resources and the Australian National University.

CONCEPT

The new maps show tectonics in much the same way as various recent tectonic maps produced in the U.S.S.R. For the 1:15,000,000 map Australia may be confined to a legend better suited to the European scene, although we have made a number of representations to the Sub-Commission for changes; some of our suggestions have been agreed to. A major difficulty remaining for us in the International Legend is the requirement that platform cover on cratons should indicate the age of basement, largely unknown for Precambrian platform cover in Australia, and that too few Precambrian platform cover episodes have been allowed for to permit a well balanced presentation of Australian tectonic history.

The compilers of the Australian map are attempting to show tectonic evolution in terms of progression from the geosynclinal regime through orogenesis and stabilization to the cratonic regime. (It is recognized that the original presence of geosynclines in some Precambrian shield areas is debatable, and that only terms such as crystalline or folded basement can be applied.) The kind of symbolization proposed in the 1:15,000,000 World Map legend is being used with extensive adaptations to accommodate the greater amount of detail at the larger compilation scale; the World Map colour scheme has been abandoned for compilation purposes and a new scheme has been designed to cover Australian orogenic and platform cover episodes. This independent approach is encouraged in principle by the Sub-Commission for the Tectonic Map of the World.

PRESENT PROGRESS

A penultimate draft has been compiled at 1:6,000,000 scale, which was chosen because of the readily available one sheet base; copies of it and a final legend will be circulated to State Committees to guide them in their accurate compilations at 1:5,000,000 for the final draft. Fair drawing for publication will be started at the end of this year.

The Tectonic Map Committee is co-operating with the compilers of the Metallogenic Map of Australia, who are considering tectonics in terms of tectonic facies. The Tectonic and Metallogenic maps will show similar basic tectonic subdivisions, and will differ only in emphasis on particular detail. The Metallogenic Map will also be published at a scale of 1:5,000,000.

In due course explanatory notes will be produced for both the Australia and World Tectonic Maps, but these projects are only in a preliminary discussion stage.

June, 1968

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

METALLOGENIC MAP OF AUSTRALIA - PROGRESS REPORT

by

R.G. Warren

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22-27 July, 1968.

METALLOGENIC MAP OF AUSTRALIA

PROGRESS REPORT

by

R.G. Warren

The Metallogenic Map of Australia (including the Territory of Papua and New Guinea) is being compiled by the Bureau of Mineral Resources in conjunction with the Geological Surveys of the States. Compilation of a first draft is well advanced. The map will be published at a scale of 1:5,000,000; it will include inserts at a scale of 1:2,500,000 of complex regions.

A metallogenic map is an attempt to show the relationships between mineral deposits and their tectonic or geological setting. As the extent of information available increases, the facts to be shown by the map also increase in complexity. The problem is to create a suitable legend for the geological and tectonic background.

Many legends at varying degress of complexity have been devised to cope with the problem. For showing the ore deposit, the usual approach is to use a symbol made up of central nucleus and surrounding devices (rings, open squares, arrows, ticks, and the like). Permutations of colours offer a large number of available symbols. Such a symbol can be very complex, and the final test is interpretation by the user of the map - a legend should make the map easy to read.

The proposed legend for the Metallogenic Map of Australia at 1:5,000,000 has been adapted from that proposed for the Metallogenic Map of Europe at 1:2,500,000.

This legend contains two parts: the first concerns the tectonic and geological setting of the deposits and the second concerns the deposits themselves. As the original legend was designed to meet European conditions it has required some modifications to meet Australian needs. The compilation so far has been centred on the deposits and only this part of the Australian legend has been set up. A copy is attached.

LEGEND FOR METALLIC DEPOSITS

A metal deposit is shown by a central nucleus, whose shape symbolises the shape of the deposit. Arrows are added to indicate genesis, the colours of the nucleus indicate groups of metals, and the broad chemistry of the deposit is shown by the form of lettering of the chemical symbols placed near the deposit.

Shape of ore body

The rectangular symbol for vein deposits implies the trend of the vein. Often old Australian reports do not include this information, or suggest that the deposit is several veins without a single trend. In a province, a large number of trends may exist without one dominant trend. To separate out these cases, a square will be used. Pipe deposits will be represented by a triangle. Important deposits within a province will be shown by a 2mm dot of the appropriate colour. This avoids clutter in presentation. To show isolated sub-economic deposits a one millimetre dot of the appropriate colour will be used. On extensive stratiform deposits the symbol for stratiform deposits may be omitted and the full extent of the deposit blocked in in the appropriate colour with the appropriate arrow for genesis added.

Genesis

The system of arrows created for the European legend has proved quite satisfactory. It is graphical in so far as the direction and position of the arrow indicates the direction from which the metal(s) arrived at their present site.

Size of deposits

Large These should have contained before exploitation at least 0.05% of total world reserves plus production.

Small Essentially economic deposits are included in this class.

Sub-economic Use of this class allows the map to show deposits that are not economically important, but are metallogenically interesting.

Province

This is a concept that is not well defined. It is at present the subject of intensive discussion among metallogenetists who are evolving a hierarchy of terms to describe various groupings of mineral deposits. The application of such terms requires a degree of information more suited to European conditions than to Australian, and 'province' as used at present in the legend covers a number of suggested terms in detailed classifications.

For the Australian compilation, 'province' is used in a rather loose sense as a spatial grouping of deposits arising from a particular set of geological conditions. In this sense it will be both space and time bounded - cf. petrographic province. It should be characterized by a principal metal or group of metals. All the deposits within a province may be expected to have a number of common features i.e. all might be epithermal, or have a similar gangue, or be in tension joints of similar age. Areal extent has been avoided as a criterion, but the amount of barren country that may intervene between deposits that could be linked into a province is a moot point, particularly where the information on the deposits is slight.

Many Australian mineralized areas are not yet defined or are not fully explored. Many areas contain mineralization which is sub-economic under present conditions, and many areas are masked by soil cover or laterite. To deal with these problems, different methods of showing province boundaries have been adopted. Where the province is well known, a solid boundary line will be used; where the limits are uncertain, dashed lines will be used, and province boundaries will be left open where the province may extend beyond the known area. Within the provinces, areas with a concentration of deposits of economic importance will be shown by hatching in the appropriate colour.

Isotopic ages

These symbols will be used sparingly to supplement the tectonofacies background and for important mineral deposits.

LEGEND FOR TECTONOFACIES BACKGROUND

This background shows a mixture of structure (e.g. major faults), tectonics (e.g. age of folding, phase of orogenic cycle), and geology (e.g. granites, metamorphic zones, limestones).

The legend proposed for this part of the Metallogenic Map of Europe must be modified for the Metallogenic Map of Australia because of the difference in scales of the two maps and the different tectonic history of the two continents. Close liaison is being kept with the compilers of the Tectonic Map of Australia.

Orogenic cycles

The tectonic history of Australia involves more cycles than allowed for in the European legend, and the Australian legend will be expanded to include those.

Facies and rock type

Because Australian geology is less well known, and the scale of the Australian map is smaller, the Australian legend will not be as detailed as that for the map of Europe. Our legend has broader categories, and much of the break-down into facies has to be confined to the enlarged inserts.

INSERTS

Seven areas have been enlarged to 1:2,500,000; these are so complex that representation at 1:5,000,000 would not be adequate. They may be areas of intense mineralization of unrelated types, or of complex tectonic history, or where 1:5,000,000 scale does not give an accurate picture of the relationship between deposits and tectonic history.

PART LEGEND: METALLOGENIC MAP OF AUSTRALIA

DRAFT

SCALE 1:5,000,000

FORM OF DEPOSIT

Shape

Vein, trend given by orientation of symbol.

Vein, trend unknown
Veins without one preferred trend

Pipe

Conformable, Stratiform

Without definite shape

Size

Large (0·05% of total world production plus reserves)

Small

Subeconomic (in colour of metal)

Deposit within province (in colour)

GENESIS OF DEPOSIT
(Shown by arrows added to deposit symbol)

Exogene

e.g *Superficial alteration*

Sedimentary

Alluvial

Unknown or under discussion — *Arrow omitted*

Endogene

Undifferentiated

Hydrothermal or Pneumatolytic

Telethermal or Epithermal

Mesothermal

Hypothermal or Pneumatolytic

subdivided

hypothermal (45°)

hypothermal or pneumatolytic (90°)

pneumatolytic (135°)

Magmatic

Pegmatitic

Metamorphic

METALLOGENIC "PROVINCES"
(in appropriate colours for metals present)

Fe — *Limits of "provinces"*

Zn Ag Pb — *An essentially lead "province" containing minor silver and zinc*

Sn — *A "province" whose western boundary is well defined, whose eastern boundary is not well defined, and which may extend further north*

Au — *Areas of economic deposits within "province" of more diffused mineralization*

AGE OF DEPOSIT OR ASSOCIATED ROCKS

275 K/Ar, 289 Pb, 750 Rb/Sr — *Radiometric age of deposit*

275 K/Ar, 289 Pb, 750 Rb/Sr — *Radiometric age of associated rock*

in millions of years

277 — *Genetic link between deposit and associated intrusive rocks*

CHEMISTRY OF DEPOSIT
(Shown by lettering used)

Upright	Fe, Cu	*Chemistry unknown*
Upright and underlined by solid line	Fe, Cu	*Sulphides, arsenides, sulphosalts*
Upright and underlined by dots	Fe, Cu	*Silicate*
Italics	*Fe, Cu*	*Oxides and native metals*
Italics underlined by solid line	*Fe, Cu*	*Carbonates, phosphates*

METALS PRESENT
(Shown by colours)

- Sn, W, Mo, Bi
- Au
- Cu
- Fe, V
- Ti, Zr
- Be, Ta, Nb, Li, Th, Rare earths (re)
- Ag, Sb, As, Hg
- Ba, F, Sr
- Mn
- P, Magnesite (mg), K.
- U
- Pb, Zn
- Ni, Cr, Co, Platenoids (pt)
- Al
- Pyrite (py)

M (C) 19

PROGRESS

Mineral deposits

Trial compilations of several mineralized regions were prepared, using different approaches and methods of presentation. In the light these trials, a draft legend was set up and a compilation made at 1:5,000,000 scale for all Australia and the Territory of Papua and New Guinea, showing deposits and grouping into provinces. Compilations at 1:2,500,000 scale were made for complex areas, which will be shown at this scale as inserts on the map.

Tectonofacies background

Trial compilations were made for several regions; on the basis of these trials, compilation of the Tasman Geosyncline region of eastern Australia has begun. The division into orogenic cycles which has been used for compilation of the Tectonic Map of Australia is being followed. The two compilations are broadly similar, but the compilation for the metallogenic map puts more emphasis on rock types and the tectonic events which have affected them.

Fair drawing

It is hoped that the compilation will be ready for fair drawing by the end of 1968. The topographic base has been scribed.

Explanatory Notes

Draft commentaries, using different approaches, have been prepared for the mineralized regions. Most of these need extensive revision and recasting.

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

A SCHEME FOR THE PREPARATION OF GROUNDWATER MAPS OF AUSTRALIA

by

G.M. Burton and T.W. Plumb

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

A SCHEME FOR THE PREPARATION OF GROUNDWATER MAPS OF AUSTRALIA

by

G.M. Burton and T.W. Plumb*

At its 4th Meeting, in June 1967, the Technical Committee on Underground Water of the Australian Water Resources Council (AWRC), established, at the request of the Council, a Working Party to advise "on the type of map or maps to be produced showing groundwater resources (of Australia) and a programme for publication". This paper is based on the findings of the Working Party.*

The Working Party began by examining comments sought from the member organisations of the Technical Committee. These organisations are the government departments and statutory authorities responsible for the assessment and development of the groundwater resources of the six States and the Commonwealth Territories.

The Party anticipated that the map and the accompanying explanatory notes would have a wide readership, including planners and administrators in government and private industry and their technical advisers, various tertiary-level students and teachers, and professionally-trained workers in hydrology and related disciplines; some use by workers overseas and visiting Australia was also envisaged. The readers would wish to use the publication to obtain a general understanding of the groundwater resources of Australia, of the state of knowledge of these resources and of the main gaps in knowledge, and as an introduction to technical information about specific areas and aspects.

The AWRC published in 1965 the map "Australia: Underground Water" at a scale of 1:5,000,000 as part of its "Review of Australia's Water Resources....1963".☆ This map must be regarded as a preliminary edition because it has a number of shortcomings in data, concepts, presentation and printing. It was prepared mainly from data that were readily available within the organisations concerned and with a pressing deadline, using very limited compilation, editorial and drafting resources.

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* The Working Party consisted of both Commonwealth and State officers:
G.M. Burton (Convener): Bureau of Mineral Resources, Commonwealth Department of National Development.
M. Hind: Water Conservation and Irrigation Commission, New South Wales.
C.R. Lawrence: Department of Mines, Victoria.
T.W. Plumb: Geographic Section, Commonwealth Department of National Development.

☆ AUSTRALIAN WATER RESOURCES COUNCIL, 1965. Review of Australia's Water Resources....1963. (Canberra: Australia. Department of National Development for the Council.)

However, as the first relatively detailed groundwater map of Australia, it served a very useful purpose. It showed mainly the nature of the aquifers and the quality of the water they contained; possible yields of the different rock groups in selected locations were indicated briefly in the legend. In view of the absence of information on depth and thickness of the aquifers, it was more a general hydrogeological map than a quantitative map of water resources. Some of the quantitative data were contained in the text of the report it accompanied.

Any new national map produced now should be a considerable advance on the 1965 Review map. Considerable additional data on groundwater resources have been gathered since then under the expanded programme of water resources assessment introduced under the Commonwealth States Grants (Water Resources) Act 1964 and States Grants (Water Resources Measurement) Act 1967; as much of these new data as practicable should be included.

The main requirement is for a map or maps that, when folded, could form with the explanatory notes a single publication, probably of International B5 size (250 x 176 mm). The map or maps should also be suitable for display on the wall of a small office. A large wall map at a scale of say 1:2,500,000 (e.g. Tectonic Map of Australia, 1960) would permit considerable detail to be shown on a single map but would be much less convenient for folding and display; it would also emphasise too strongly the great difference in availability of hydrological data over Australia.

The Working Party recommended a scale of about 1:6,000,000 realizing however that more than one map would be required. It was later decided to adopt the International scale of 1:5,000,000 because a base with suitable detail at this scale already exists and related geological maps are being prepared in Australia at this scale.

The general approach of the 1965 map was sound in showing the distribution of aquifers according to three geological groups and further subdividing these into five salinity ranges. The main problem in reading the map is the number of combinations of aquifer types and salinity ranges. This problem of legibility can be largely overcome by using a separate map for each of the three types of aquifer. This will provide space on each sheet for more detail including columnar sections, etc. A fourth sheet however is desirable to show in summary form the best resources available.

There would be great difficulty in including information on water usage and/or potential because of lack of precise data for much of Australia and the complexity which such data would add to the maps. Accordingly it is believed that this information cannot be shown in detail except in so far as it can be indicated on the fourth map. However, a sketch map will be included in the notes showing towns drawing more than a defined proportion of their supply from groundwater and broadly indicating important areas irrigated largely from groundwater. The precise form of such a sketch map would need to be defined before the data were requested from the members of the AWRC.

The geological subdivisions used in the 1965 map were based on the choice of two main geological parameters, lithology and structure, which divided aquifers into three natural groups with suitably different and significant combinations of the following important economic and hydrological factors:

1. Permeability and porosity
2. Continuity and geometrical form (including dip) of aquifer
3. Depth
4. Thickness
5. Recharge
6. Geochemistry of groundwater
7. Cost of drilling.

The definitions used for the three groups of aquifers on the 1965 map led to some difficulties of demarcation in the compilation of the map. Hence these should now be slightly modified and explained in terms of the seven properties to avoid such problems of demarcation and to ensure consistency of concepts throughout the new maps. The rock types of the three groups of aquifers now proposed are -

1. Shallow unconsolidated sediments
2. Porous consolidated sediments
3. Fractured rocks

The three rock types are now defined and their aquifers described in terms of the previous seven properties. Considerable generalisation of the descriptions has been necessary in the interests of simplicity.

Shallow Unconsolidated Sediments. Alluvial, aeolian, coastal and lacustrine unconsolidated and semi-consolidated sediments, usually of Quaternary and Tertiary age, and lying, overall, within about 500 feet of the surface.

These aquifers owe their generally high permeability and porosity to the presence of interconnected intergranular voids. The permeability and porosity may vary markedly laterally and vertically. The individual aquifers are commonly small in area, elongate, thin and flat-lying. The depth is usually quite shallow; drilling is inexpensive but commonly requires special techniques. The aquifers are commonly readily accessible to sources of recharge water. Aquifers near the surface commonly show marked seasonal fluctuations of water level. Very good quality water occurs in many areas, but marked vertical and lateral variations are common.

Porous Consolidated Sediments. Porous consolidated sediments of the deep sedimentary basins, usually older than Quaternary.

The aquifers owe their permeability and porosity mainly to the small voids between the grains, which are usually well compacted and commonly cemented. Permeability and porosity may be partly due to fractures and solution cavities. These aquifers usually have medium to low permeability, but a number of major aquifers have high permeability; the aquifers are usually continuous, areally large and of appreciable thickness. The aquifers usually dip gently but, in many areas, because of their extent reach great depths; hence bores may be quite expensive. Water quality in individual aquifers can be quite good and relatively uniform over extensive areas. In a vertical sequence of aquifers, quality may vary markedly. Recharge areas are commonly small in relation to the extent of the aquifer and distant from much of the storage area.

Fractured Rocks. Igneous, metamorphic, and considerably deformed sedimentary rocks.

These rocks owe their permeability and porosity to fractures, joints, solution cavities, and weathered zones. The water-bearing zones are commonly discontinuous and heterogeneous; the zones may be thin, irregular and steeply dipping. Their permeability and porosity are generally low. The depth to the permeable zone varies considerably but is generally less than 1,000 feet and commonly less than 300 feet. Drilling is frequently very hard. The water commonly contains appreciable amounts of dissolved salts. Recharge usually occurs locally and seasonal fluctuations of water levels and yields are very common.

The five ranges of salinity (total dissolved solids) used on the 1965 map to define quality of water were:

0-1,000 p.p.m.
1,000-3,000 "
3,000-7,000 "
7,000-14,000 "
Greater than 14,000 p.p.m.

A further category "insufficient data", was found necessary. These ranges are still regarded as satisfactory and should be used on each of the proposed maps.

To summarise, the Working Party recommended the publication of four maps compiled in accordance with the preceding definitions and salinity ranges. The proposed titles of the four sheets are:

Map I	Groundwater Resources of Shallow Unconsolidated Sediments
Map II	Groundwater Resources of Porous Consolidated Rocks of the Principal Sedimentary Basins
Map III	Groundwater Resources of Fractured Rocks
Map IV	Principal Groundwater Resources.

An outline of the content of each sheet and some of the means of representation that may be used is given below:

Map I Groundwater Resources of Shallow Unconsolidated Sediments

Map I will show the resources of the alluvial, aeolian, coastal and lacustrine unconsolidated and semi-consolidated sediments of less than about 500 feet in thickness and mainly of Quaternary and Tertiary age.

The coastal aeolianites of southern and western Australia, though cemented, and the Tertiary limestones of Queensland will be included on this map because of their closer affinity with the characteristics of the aquifers of the shallow sediments than those of the porous consolidated sediments.

On the other hand the Upper Cretaceous to Lower Tertiary friable sandstone of the Otway Basin and Murray Basin in south-eastern Australia will be included on Map II because they are part of the deeper sequences and more closely resemble the characteristics of the aquifers of the porous consolidated sediments. Aquifers of detrital laterite will be shown on Map I whereas the laterites themselves, which only convey water in joints or weathered zones, will be shown on Map III.

It is important to obtain a uniform treatment for the shallow unconsolidated sediments throughout Australia; for the 1965 map shallow sediments in several areas were omitted because the underlying aquifers were the better prospects. On the proposed Map I all unconsolidated sediments containing beds with economically significant permeability should be shown unless they are considered to be, on hydrological grounds, too small, or too thin, or they are dry and have no foreseeable possibility of serving as aquifers. Areas of sediments of marginal thickness and doubtful water content such as some of the aeolian sands of inland Australia could be designated as doubtful aquifers by a suitable symbol.

The areas of unconsolidated sediments on the map will be coloured according to the quality of water in the most important aquifer or aquifers. Symbols will be used to indicate significant quantities of better or poorer water above and below the main aquifer system.

Columnar sections will be used to show the stratigraphic relationship of the most important aquifers in major areas. The columnar sections will have the aquifers coloured to show the salinity of their water and bar diagrams will be placed beside the aquifer to show the relative proportions of the major cations and anions.

<u>Map II Groundwater Resources of Porous Consolidated Rocks of the Principal Sedimentary Basins</u> (Fig. 1.)

Map II will show the resources of the porous consolidated rocks of the principal sedimentary basins. These sediments usually will be Tertiary, Mesozoic or Palaeozoic in age; they will however include areas of the weakly deformed Proterozoic Carpentarian System which still contain beds with considerable intergranular permeability. The thick carbonate sequences of the Daly-Georgina and Eucla Basins will also be shown on this map for although much of the permeability of these is in joints it is considered that the aquifers have a closer affinity to the characteristics set out for porous consolidated sediments in the preceding definitions and explanations. Thick carbonate sequences such as these could be indicated, if necessary, by a special symbol on the map.

Structure contours (interval probably 1,000 feet) will be used to define the surface of the basement of the more important basins. The contours will indicate the thickness and dip of the sedimentary rocks. Should it be found during compilation that clarity will be impaired by including the contours on Map II they will be transferred to Map III.

Structurally complex areas of basins where dips commonly exceed 15° or where faulting is very common should be shown by some form of stippling to indicate the likely hydrological complexity of the aquifers and the greater expense and technical difficulty required in exploiting them. Examples of such areas would be the Amadeus Basin and probably much of the Bowen Basin.

Multiple aquifers and wide salinity ranges should be shown much as they were on the 1965 map. Columnar sections with bar diagrams adjoining them should be shown as on Map I to indicate the stratigraphy and salinity of the aquifers in the basins. By carefully positioning these columns it will be possible to indicate the general dip of beds in major basins such as the Great Artesian.

Map III Groundwater Resources of Fractured Rocks

Map III will show the resources of the fractured rocks, as defined earlier, which either crop out or, if covered by other rocks, are still capable of providing useful supplies of groundwater. The fractured rocks should be subdivided lithologically into the three following groups which would be shown by symbols on the map.

1. Granite, granite-gneiss and other crystalline rocks of similar grain size and mineralogy.
2. Major areas of flat lying volcanic rocks such as the Tertiary basalts and major areas of hypabyssal rocks such as the Jurassic dolerite sills.
3. All other fractured rocks and undifferentiated areas of Groups 1 and 2.

Bar diagrams could be used in selected areas to indicate the general proportions of anions and cations present in the water.

Map IV Principal Groundwater Resources

Map IV will show the best groundwater resources available in any area. The proposed map will be more difficult to compile than a similar map prepared of New South Wales because of the wider range of conditions to be represented on a national map.

The criteria for "best" will be all seven economic and hydrological properties already discussed, but with emphasis placed on those more directly determining quantity and quality of water. The map will be more subjective than Maps I, II and III and will require considerable liaison between the compilers, particularly in the early stages, to achieve uniformity.

Areas wherein good groundwater is probably available for major exploitation for irrigation and town supplies should be emphasised, possibly by increased colour strength. Only those areas that meet the following specifications should be shown in this way; they should:

1. Generally contain or could contain bores yielding more than 50 imperial gallons per minute.
2. Lie in the salinity ranges of:
   (a) 0-1,000 p.p.m.
   (b) 1,000-3,000 p.p.m.
3. Have a residual alkalinity of less than 200 p.p.m.

The map will also show to which of the three rock types the aquifer belongs. The method for doing this requires further cartographic experimentation.

Fig. 1


SCALE
100 0 100 200 300 Miles
BONAPARTE -ORD
FITZROY
DALY-GEORGINA
LAURA
CANNING
NGALIA
DRUMMOND
BOWEN
AMADEUS
GREAT ARTESIAN
CARNARVON
MARYBOROUGH
ESK
OFFICER
MORETON-CLARENCE
PERTH
EUCLA
PIRIE-TORRENS
ROBINSON-POLDA
COLLIE-WILGA
ULEY-LINCOLN
VINCENT
MURRAY
SYDNEY
OTWAY
GIPPSLAND
TASMANIA
PRINCIPAL SEDIMENTARY BASINS
(post Precambrian only)

Specific capacity and available drawdown, as ranges representative of the bores of a region, could be shown on this map if desirable. However, the more satisfactory place for this information may be in the Explanatory Notes.

Nature of Explanatory Notes

The nature of the explanatory notes was not determined in great detail but the following recommendations are made:

(i) The notes should be brief but not skimpy; a handbook is not recommended, but the notes if carefully prepared would be a major step in the preparation of a handbook at a later stage.

(ii) There should be a short introductory section of 3 to 4 pages on the occurrence and assessment of groundwater and its place in the hydrological cycle.

(iii) One-half to 1 page should be devoted to the relation of groundwater resources to surface water resources including the interrelation of the gauging of both.

(iv) About 1 page should be devoted to explaining the system of subdivision of rock types used on the map and their general properties as aquifers. The system used for classifying the quality of water should also be discussed here, together with general notes on quality of groundwater and its suitability for various uses.

(v) Resources should be discussed in turn under headings for the three rock types and sub-headings for the areas or basins. These descriptions of the various basins etc., should be brief but, in view of the absence of quantitative data on the map, should contain considerable factual material, including where available:

(a) information on direction of groundwater movement
(b) specific capacities
(c) transmissivities
(d) information on recharge, possibly by diagrams of major basins indicating the intake areas (areas of overdraft could be shown on the same figure)
(e) number of bores and approximate pumpage
(f) cross-sections of the basins

(vi) In general, stratigraphic names should be kept to a minimum.

(vii) Line drawings should form an important part of the explanatory notes as far as cost will permit. These should not involve much extra drafting if illustrations are selected from the many excellent small drawings already used in water publications of the various organisations in Australia concerned with groundwater.

(viii) The bibliography should be extensive and up-to-date so as to guide the reader rapidly to the best references for more details on each aspect of Australia's groundwater resources. It cannot be emphasised too strongly that this is one of the most important sections of the Notes and should be prepared very thoroughly.

(ix) The extensive tables used in the 1965 Review should be omitted. Tables, however, should be used for the brief presentation of data or for comparison of suitable facts.

Plan for Production

The bulk of the data for the maps would be compiled in preliminary form in the States and Territories. The data would be drawn on stable overlays to either the State geological map or the appropriate sheet of the Geological Map of Oceania which has been printed on the selected base at 1:5,000,000 scale. These preliminary compilations would be consolidated into the final compilation and edited by the Department of National Development in Canberra.

The explanatory notes would be compiled with similar co-operation between the State and Commonwealth organisations. A bound volume of 80-100 pages comprising 60,000 words, some tables and about 40 line drawings is envisaged.

Preliminary estimates were made of printing costs, but definite figures cannot be provided until nearer the time of printing when prevailing rates and the size of edition are known. The latter has an important effect on the cost per set, which for an edition of 5,000 is approximately half that if only 2,000 are printed.

The Working Party recommended that production should be handled by a working party comprising a convener, a map officer, a notes officer, and a representative from each State and the Northern Territory. The Technical Committee on Underground Water recently (May 1968) adopted this proposal and agreed to a programme covering the main stages of production, with publication scheduled for late 1970.

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

COMPILATION OF MAP OF POST-MIOCENE VOLCANIC CENTRES OF AUSTRALIA AND MELANESIA

by

G.A.M. Taylor

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

COMPILATION OF MAP OF POST-MIOCENE VOLCANIC CENTRES OF AUSTRALIA AND MELANESIA

G.A.M. TAYLOR

The International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) initiated a project involving the compilation of a world map of post-Miocene volcanoes. This project forms part of the Association's contribution to the Upper Mantle Project and will also provide a supplement to the "Catalogue of the Active Volcanoes of the World".

Some of the fields in which this map will be of value are in:-

(1) Correlating the locations of volcanic activity in the geologically young areas with the tectonic patterns and also with gravity, magnetic, heat flow and seismic phenomena.

(2) Prediction of sites of future volcanic eruptions

(3) Exploration of possible sites of geothermal fields.

The compilation was undertaken by a World Volcanological Map Working Group of the IAVCEI which consisted of sixteen members headed by Professor Hisashi Kuno of the University of Tokyo. Dr. N.H. Fisher, as the Australian member of the Group, undertook the collection of basic information on Australia and Melanesia centres.

The following authorities collaborated in providing relevant information:- the Geological Survey, British Residency, New Hebrides; the Geological Survey, British Solomon Islands Protectorate; the University of Queensland; the University of Melbourne; the South Australian Department of Mines; the Tasmanian Museum; the Bureau of Mineral Resources.

The volcanoes shown on the world maps will be classified according to condition of activity, volcano type and petrological composition. The details of this classification, which were decided after wide discussion among the Working Group, are as follows:-

Condition

A - Active volcanoes according to the definition adopted in the "Catalogue of the Active Volcanoes etc.", namely, volcanoes having historic records of eruption or active solfataras (shown in red)

B - Volcanoes which are known as post-Miocene in age and still retain the essential forms characteristic of volcanoes (shown in black)

Volcano Type (shown by symbols)

(a) Lava volcanoes (central type) including shield volcanoes and lava domes.

(b) Lava volcano (fissure type)

(c) Air-fall pyroclastic volcanoes

(d) Flow pyroclastic volcanoes

(e) Compound volcanoes (mixture of two or more of a, b, c & d)

(f) Unclassified volcanoes

(g) Active solfataric areas not connected with a volcanic edifice

Lava Type (shown by letters)

(a) Basalt undefined

(b) Alkali basalt plus or minus differentiates

(c) Tholeiite (including high-alumina basalt) plus or minus differentiates

(d) Trachyte and phonolite

(e) Andesite and dacite

(f) Rhyolite plus or minus dacite.

It was originally intended to produce two maps, one showing the world distribution of volcano types and the other lava types. Suggestions were made to the Map Working Group that it would be preferable to show all information on one map and a symbol system was designed at the BMR to display this combined information. After careful consideration the Working Group decided to combine the information on one map but our symbol system was not adopted because crowding of the volcanoes in some island areas affected legibility in the 1:10,000,000 scale world map. It was found that the diameter of the basic symbol must not exceed 1 millimetre. It was therefore decided to use mainly solid symbols for the volcano type and letters for the lava type.

The Australian contribution consisted of maps and information sheets covering coordinates, heights, condition of activity and lava type for 839 post-Miocene volcanic centres in Australia and Melanesia. The pattern revealed by this study indicates that the Australian centres are confined to the eastern half of the continent where they reach their greatest density in western Victoria and northern Queensland. From late Pliocene to Recent time in these two areas basaltic lava fields covering thousands of square miles were built up by activity from numerous small volcanoes; 364 centres have been recorded in Victoria and 243 in northern Queensland. The Victorian volcanic province overlaps into south Australia where an ash shower from Mount Gambier has been dated as 1400 years old by the C^{14} method. Likewise some of the North Queensland centres appear to have been active in quite recent times, although no C^{14} dates are yet available.

The A category volcanic centres are confined to Melanesia where 67 are recorded: 13 of these are in the New Hebrides, 6 in the British Solomon Islands and 48 in the Territory of Papua and New Guinea. Melanesia also contains 141 post-Miocene centres most of which probably had beginnings near the end of Pliocene. Although many of these centres are located in the currently active volcanic lines a considerable number are situated in the highlands of New Guinea where no eruptions have occurred within historic time. Recent studies suggest, however, that two of these volcanoes may have been active in the 19th century.

Drafts of the world map will be displayed at the 23rd Session of the International Geological Congress held at Prague in August, 1968.

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECONNAISSANCE GRAVITY SURVEY OF AUSTRALIA, 1965-1968.

by

A.J. Flavelle

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,

Tehran, Iran, 22 - 27 July, 1968.

RECONNAISSANCE GRAVITY SURVEY OF AUSTRALIA, 1965-1968.

by

A.J. Flavelle

The attached map (Plate 1) illustrates the extent of reconnaissance gravity coverage carried out by the Bureau of Mineral Resources, Geology and Geophysics (B.M.R.) since 1959. A description of the coverage prior to 1965 has been given by Vale (1965).

Since 1965 the two major developments have been the introduction of surface marine surveys with east-west lines spaced at ten miles and a substantial increase in land coverage to a yearly rate of over 200,000 square miles.

Marine surveys were carried out in 1965 and 1967, the total coverage being 180,000 square miles. The 1967 project included 16,000 miles of traverse with combined gravity, magnetic and sparker seismic. It was a 24-hour per day operation with combined very low frequency (VLF), radio and sonar doppler navigation aids. Cost was approximately $30.00 per line mile. VLF is a phase comparison method using transmissions from a world wide system called the Omega network plus other VLF transmitters. The wavelength of the transmission varies from 10 to 15 miles. By using this method alone positional accuracies of 0.5 to 1.0 mile can be achieved. Sonar doppler, a technique which accurately measures the ship's speed, utilises the doppler shift of an accoustic pulse transmitted from the ship reflected from the sea bottom and back to a receiver on the same ship. Satellite doppler as a further navigation aid is being considered for future surveys at sea.

The land reconnaissance coverage from 1965 to 1968 totals 1,000,000 square miles. The technique of obtaining reconnaissance coverage by using helicopters has been continued. There have been no fundamental changes in the technique, first described by Vale (1963). Nominal station density is one per fifty square miles. Costs have stabilised at about 75 cents per square mile. During the latter part of 1968 systematic reconnaissance coverage will be commenced in New Guinea. A nominal station density of one per fifteen square miles will be attempted and stations in otherwise inaccessible areas will be read using a remote reading gravity meter lowered from a hovering helicopter. For this project turbine-powered helicopters will be used (e.g. Bell "Jet Ranger") which cost more to operate than conventional helicopters but are in fact more economical because of their greater speed and payload. For helicopter-based reconnaissance surveys the cost of the helicopter has, in the past, been approximately 50% of the overall cost. By using turbine helicopters it is hoped to cut the cost of the helicopter component by 20% and the overall cost by 8%.

The effort has in general been concentrated in the northern part of Australia and by the end of 1968 virtually all the land part north of latitude 20°S will be covered except that part of North West Australia west of longitude 118°30'E.

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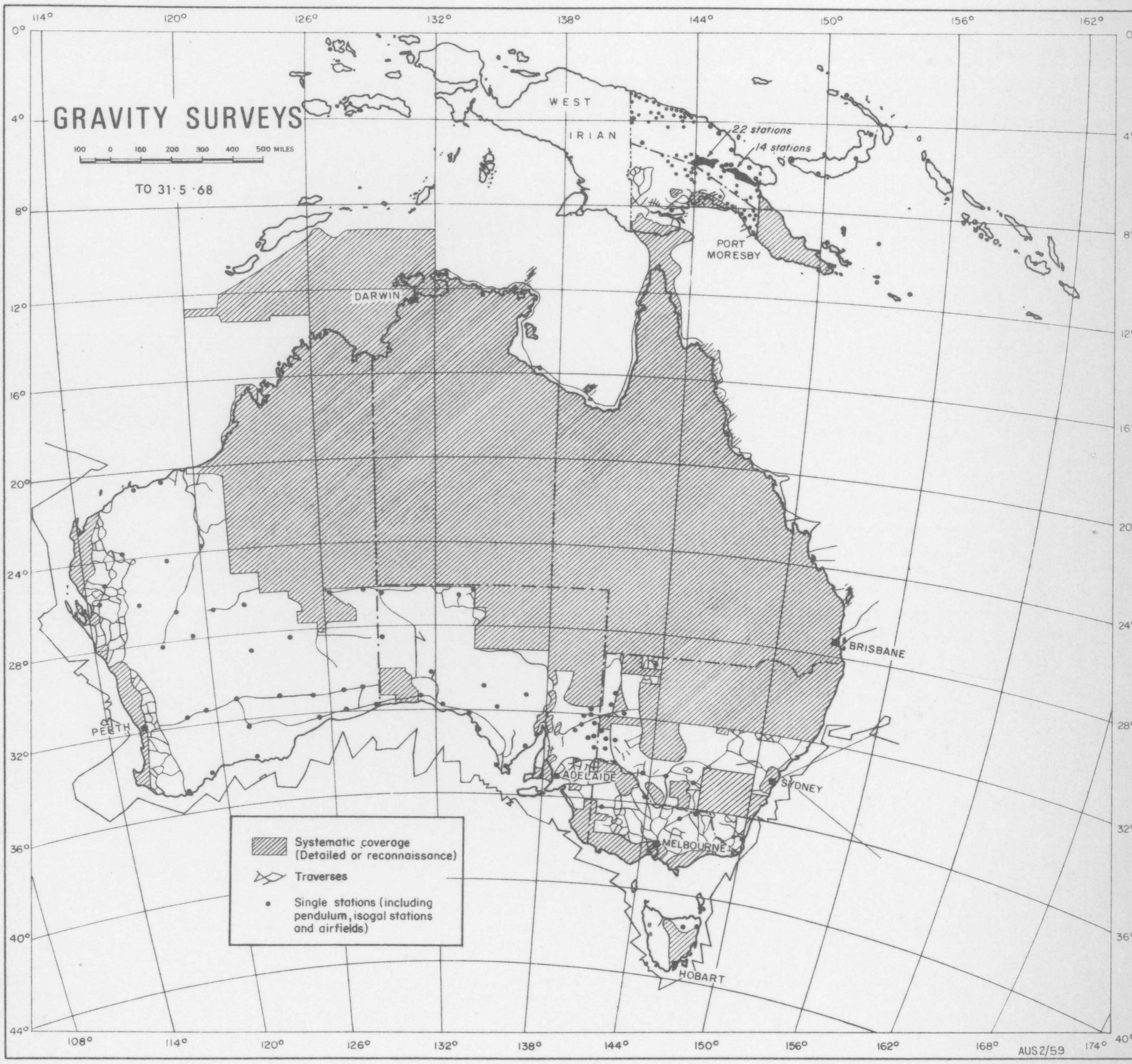


GRAVITY SURVEYS
100 0 100 200 300 400 500 MILES
TO 31·5·68
WEST
IRIAN
22 stations
14 stations
PORT
MORESBY
DARWIN
BRISBANE
PERTH
ADELAIDE
SYDNEY
MELBOURNE
HOBART
Systematic coverage
(Detailed or reconnaissance)
Traverses
Single stations (including
pendulum, isogal stations
and airfields)
AUS2/59

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

PROGRESS OF AEROMAGNETIC SURVEYING IN AUSTRALIA

by

N.G. Chamberlain

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

PROGRESS OF AEROMAGNETIC SURVEYING IN AUSTRALIA

by

N.G. Chamberlain

The extent of the aeromagnetic surveys completed in Australia and New Guinea since the introduction of the aeromagnetic method in 1950 to the end of 1967 is shown in the accompanying map.

The largest contribution by a single organisation is that of the Commonwealth Bureau of Mineral Resources, Geology and Geophysics, which has a continuing aeromagnetic programme to provide basic information to assist exploration for petroleum and metalliferous deposits. Oil exploration companies have been responsible for a large proportion of the surveys over the sedimentary basins. Most of this work has been carried out with financial assistance provided by the Commonwealth Government under the Petroleum Search Subsidy Act.

The aeromagnetic surveys carried out for oil exploration range from widely spaced reconnaissance lines for the purpose of differentiating broadly between areas of shallow and deep basement to systematic coverage by regularly spaced parallel lines to provide more complete delineation of the magnetic anomalies and from analysis of the anomalies to determine the generalised basement contours, main structural features of the basin and thickness of the sediments. In general, the aeromagnetic surveys of sedimentary basins in Australia have succeeded in providing such information, although the method is of limited application where the magnetic basement is not the effective basement for oil exploration or where igneous rocks intrude the sediments and cause anomalies tending to mask those due to the basement. The suitability of the method for large scale reconnaissance surveys makes it most useful in the early stages of a basin exploration as a guide to the planning of more detailed investigation by the more costly seismic method.

Aeromagnetic surveys have been carried out over practically all of the oil prospective areas on land but the type of coverage, having been determined by the objectives of each survey, varies considerably both in spacing of lines and height above sea level. In recent years there has been an increase in off-shore surveys and it is expected that future activity for oil exploration will be mainly directed towards investigation of the continental shelf.

The surveys of the 'hard rock' areas have generally been on a more systematic basis, consisting usually of lines flown at one mile spacing and at 500 feet above terrain. Surveys of this type have been completed over fairly extensive blocks in Western Australia, Northern Territory, South Australia and New South Wales. The results have assisted the regional geological mapping and the exploration for mineral deposits. Examples of the application of the method are provided by the Tennant Creek field where the aeromagnetic surveys conducted in 1956 and 1960 have remained the basic guide in the search for the ironstone bodies with which copper and gold deposits are associated, and the Kalgoorlie region of the Western Australian Precambrian shield where the aeromagnetic results are being used by mining companies to assist the mapping of the areas of basic and ultrabasic rocks favourable for the occurrence of nickel.

The airborne magnetometers commonly in use in Australia are the fluxgate and proton precession types. A high resolution caesium vapour magnetometer has been used in two major off-shore surveys, in the Timor Sea and Gulf of Papua. The ability of this magnetometer to resolve low-amplitude anomalies appears to give it certain advantages over other types for off-shore work.

For most surveys over land, aerial photography has been used for navigation during flying operations and for subsequent plotting of flight line positions. The Doppler navigation system has been used in a few surveys and is likely to come into more general use. It is used in conjunction with aerial photography. It provides accurate control of position during flight and effects a considerable saving in time required for flight line recovery. For adequate positioning control in off-shore surveys radio navigation aids are essential and various systems such as Toran, Raydist and Shoran, frequently supplemented by Doppler, have been used in surveys over the continental shelf.

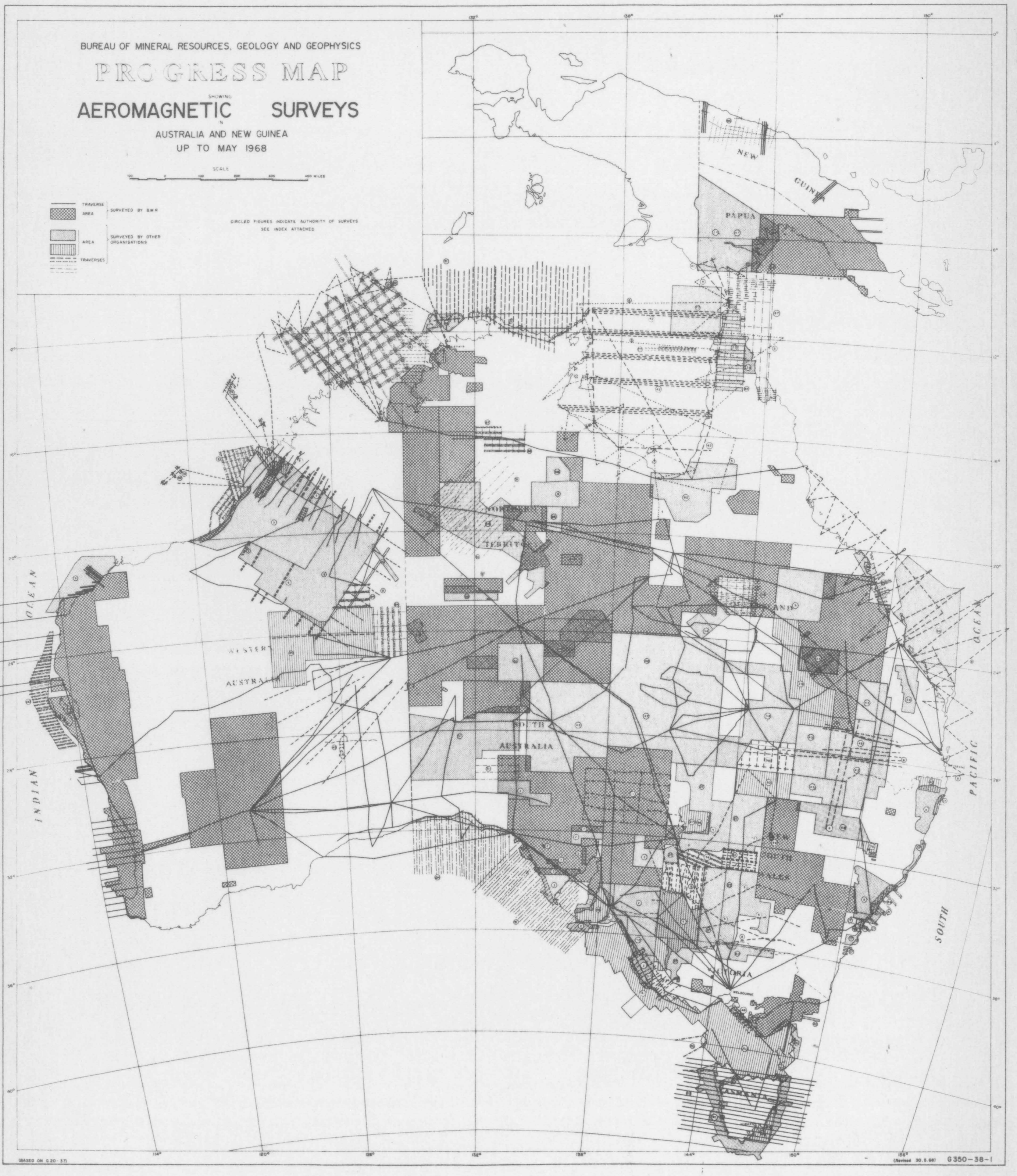
An important advance in the aeromagnetic technique now coming into use in Australia is the digital recording of the magnetic data during the survey. An electronic computer can then be used for the reduction of the data to a form suitable for presentation as magnetic contours or for analysis of the data to aid interpretation.

The scale of the accompanying map allows only the regional or reconnaissance type surveys to be shown. In addition to these, many detailed aeromagnetic surveys of small areas have been carried out in Australia since 1963, mainly to assist metalliferous exploration. Such surveys are usually flown at 1/10 mile spacing and at 250 feet above terrain and aim to investigate in detail areas of interest indicated by geological mapping or by the results of regional magnetic surveys. The detailed low-level surveys have been found to reduce substantially, although not entirely eliminate, the need for ground magnetic surveys in metalliferous prospecting.

The organisations which conduct aeromagnetic surveys are the Bureau of Mineral Resources and several contract geophysical companies. Competition between the contractors has maintained the cost of surveys at a reasonable level. The cost per line-mile for surveys using photo-navigation, including flying operations, reduction of data and contour presentation is usually about $A4 to $A6. Much higher costs, of the order of $A15 per line-mile, apply to off-shore surveys because of increased positioning costs and the requirement for more elaborate navigation systems.

The results of the Bureau's regional aeromagnetic surveys are published in the form of printed maps, at a scale of 1:125,000 or 1:250,000, showing contours of total magnetic intensity and planimetric detail. To overcome the delays which arise in completing the final presentation of the results and printing of the maps, an earlier release, within a few months of completion of the field operations, is made in the form of reduced scale magnetic profiles accompanied by an interpretative report. The data from the detailed low-level surveys can be processed more quickly and the final contour maps accompany the interpretative report issued shortly after the completion of the survey.

The results of the aeromagnetic surveys carried out for oil exploration under the subsidy scheme are released by the Bureau six months after the field operations by making the operating companies' reports and maps available for inspection and copying.



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
PROGRESS MAP
SHOWING
AEROMAGNETIC SURVEYS
IN
AUSTRALIA AND NEW GUINEA
UP TO MAY 1968
SCALE
100 0 100 200 300 400 MILES
TRAVERSE
AREA
SURVEYED BY B.M.R.
AREA
SURVEYED BY OTHER ORGANISATIONS
TRAVERSES
CIRCLED FIGURES INDICATE AUTHORITY OF SURVEYS
SEE INDEX ATTACHED
NEW
GUINEA
PAPUA
WESTERN
AUSTRALIA
SOUTH
AUSTRALIA
NEW
SOUTH
WALES
INDIAN
OCEAN
SOUTH
PACIFIC
OCEAN
(BASED ON G.20-37)
G350-38-1

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

SOME RECENT DEVELOPMENTS IN GEOLOGICAL SURVEY PRACTICES

ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST
WORKING PARTY OF SENIOR GEOLOGISTS, SEVENTH SESSION,
Tehran, Iran, 22 - 27 July, 1968

COLD-EXTRACTABLE METAL (CxMe) IN GEOCHEMICAL PROSPECTING

by

A. D. Haldane

Because of ease of field operation and analytical simplicity the determination of cold-extractable metal (CxMe) in stream sediments and soils has become a popular method of geochemical prospecting.

It has been suggested that there are other advantages in the use of CxMe, namely that in areas of low total metal content anomalous areas may be better defined by the use of CxMe methods which do not extract the lattice-held trace metals. This latter source of metal tends to swamp the smaller quantities of trace metals held in more readily displaced forms. It is the readily displaced metals, and not the lattice trace elements, which are related to mineralisation. By eliminating the lattice component better resolution is claimed in detecting weak anomalies.

The Bureau of Mineral Resources undertook to investigate various extractants, the effects of drying stream sediment samples, the contribution of dispersed primary and secondary minerals to the CxMe value, and the relation between CxMe value and total metal content.

The results obtained have shown that CxMe values for stream sediments are not more useful than total metal content in geochemical prospecting for the areas examined. It is possible that they could be less significant, because of variability in percentage extraction.

Particle size of the sample affects both CxMe and total values, but not overwhelmingly. Of far greater importance is whether the extractant can form complexes with the metals concerned. Non-complexing reagents other than acids did not extract any appreciable amount of metal.

Previous work had shown that drying of stream sediments resulted in lower CxMe values, so possibly the results of a geochemical stream sediment survey could depend on the season when sampling was carried out. This investigation has demonstrated that drying retards the rate of extraction, but not the ultimate equilibrium value. For oven-dried sediments equilibrium may not be reached for up to 3 weeks. It was therefore apparent that much of the discrepancy in CxMe methods was due to insufficient time for extraction, which should be at least overnight. Some procedures give extraction times as low as 1 minute.

Dispersed primary and secondary minerals contribute substantially to the CxMe value. The primary sulphides are the most resistant to attack, and secondary carbonates and sulphates are the most readily soluble; e.g., azurite and anglesite are completely soluble in ammonium citrate extractant.

There is no simple relation between total metal and CxMe. The relationship varies from sample to sample, and is mostly a complex one dependent on the forms the metal takes in the sediment, and the rate of extraction for each of these forms.

BUREAU OF MINERAL RESOURCES X-RAY LABORATORY

by

C.D. Branch

The X-ray laboratory in the Bureau of Mineral Resources, Geology Branch, is equipped with the following analytical instruments.

Philips automatic X-ray fluorescence spectrometer (PW 1212) Philips manual X-ray fluorescence spectrometer (PW 1540)	used for major and trace element analyses of rocks.
Philips X-ray diffractometer (PW 1010) Philips table model X-ray diffractometer (PW 1008) with powder cameras.	used for mineral identification.

The automatic X-ray spectrograph is used mainly for obtaining silicate analyses of rocks (elements Na, Mg, Al, Si, P, K, Ca, Ti, Mn, Fe). Sample preparation involves grinding the rock to minus 200 mesh size, then pressing about 2 gm of the sample into a powder button backed with boric acid (used for determining Na and trace elements), and fusing 0.28 gm of the sample into a lithium glass disc containing lanthanum as an absorber (for Mg to Fe). The elements Na to P are excited with a Ag-anode tube, K to Ti are excited with a Cr-anode tube, and Mn and Fe are excited with a W-anode tube. The absolute-ratio method of analysis is used: three unknowns held in the sample changer are in turn irradiated with primary X-rays for the time taken to accumulate a fixed number of X-ray photons on an artificial standard held in position 1. The calibration accuracy of the composition of the standard is better than 1% relative.

Four runs under different instrumental conditions are required to accumulate the analytical data for the 10 elements in each sample, and each run is automatically made in duplicate. All X-ray data are recorded directly on an IBM output writer and on a Friden paper tape punch. A C.D.C. 3600 computer is used to sort the data on the paper tape, correct for matrix effects subtract background corrections, and type out the analyses. About 40 silicate analyses are completed each week.

For trace element analyses of rocks, artificial standards are used for calibration. The absorption coefficients for the standards and the unknown are measured directly on each sample using a special sample mount attached to the manual spectrograph.

The main project in the X-ray laboratory is a study of the geochemistry of northern Queensland granites: the aim is to test whether in different granites any correlation exists between the distribution of major and trace elements, the ore mineral suite, and the tectonic environment. The Queensland area is considered excellent for this study because it contains granites in close proximity which have different tectonic environments (synorogenic to post-orogenic), different ore mineral suites (Au, Ag-Pb, Zn, Sn-W-Bi-F, Cu), and different ages (Precambrian to Mesozoic).

PORTABLE ISOTOPE FLUORESCENCE ANALYSER

by

Geological Survey of South Australia

This apparatus contains a small quantity of beta-emitting radioactive material, which is mixed with suitable target material to produce X-rays.

Exposing rock material to these X-rays will cause secondary X-rays to be emitted, the wave lengths of which are characteristic of the elements contained in the exposed sample. The wave length from each element is inversely proportional to the square of the atomic number of the emitting element.

Most of the radiation from the lighter elements is absorbed by air or within the rock sample, but the shorter wave lengths from most of the metallic elements may be detected by use of a scintillation detector and ratemeter.

In addition to the radiation from the elements of the sample, part of the original radiation can reach the detector by scattering.

To identify the amount of radiation due to the element of interest, a suitable filter must be used between the sample and the detector. This filter depends on the fact that a thin layer of most elements can be prepared, which will effectively transmit wave lengths longer than a certain cut-off wave length, and will absorb heavily shorter wave lengths. By choosing suitable elements for the filters a pair of filters can be prepared, one of which will transmit the desired wave length, and the other absorb it. For all other wave lengths both filters have approximately the same characteristics.

The change in response brought about by substituting one filter for the other is due to the content of the characteristic wave length of the element it is desired to detect.

The apparatus may be assembled in either of two forms; one is for the assay of powdered material, where the sample is exposed to the energising radiation within a steel shield. In the other form the apparatus may be pressed against a flat rock surface. In either case there is a safety interlock on the apparatus which prevents the removal of the shutter covering the radioactive source until either the steel shield, or the rock surface, prevents the radiation from reaching the operator.

Since the particle size of the mineral particles containing the element may have considerable effect on the reading, powdered samples give the more accurate evaluation of the elemental concentration.

Even with powdered samples, the apparatus should be calibrated with assayed samples from the area investigated.

Since this method depends on the difference between readings with the two filters, the minimum detectable change in count is of the order of twice the standard deviation of the product of the count rate multiplied by the time constant of the ratemeter.

With this system the minimum concentration detected is an order lower than that obtainable with normal crystal analysing X-ray fluorescence methods.

For this reason this method of analysis is best applied only to elements difficult to detect by other means, tin being one example. Even for tin the minimum concentration detectable is of the order of 0.03% which is a high level for geochemical prospecting. For this type of work some form of concentration is desirable before analysis.

For lighter elements the minimum detectable concentration is higher, rendering the method unsuitable for trace quantity detection.

POLAROID CAMERAS

by

P.W. Crohn

A technique which is fairly widely used by the Geological Survey of Canada is the use of Polaroid cameras in the field. Photos are developed on the spot, and can be annotated to illustrate stratigraphic sections, record joint patterns, make boulder counts in unconsolidated sediments, etc. This can save quite a lot of sketching and measuring. Instability of the film in high temperatures could be a difficulty in some parts of south-east Asia.

USE OF EDGE-PUNCHED CARDS IN FIELD WORK

by

P.W. Crohn

Another technique employed by the Geological Survey of Canada is the use of edge-punched cards to record field observations. These may be punched right at the outcrop, or subsequently in camp, or even back in the office, and the spaces on the card can be allocated to emphasise petrological, mineralogical, or structural features according to the main interest of the survey. This system seems to be particularly useful when a uniform set of data is required from each of a large number of outcrops, e.g., in widely spaced helicopter touch-downs or in describing localities from which samples have been collected for age determination, chemical analysis, or other laboratory work. By a suitable selection of data categories, these cards could also be integrated with a data storage and retrieval system based on Hollerith 80-column punch cards, such as is currently used by the Bureau of Mineral Resources.

MOBILE ACID LABORATORY

by

E.C. Druce

The Bureau of Mineral Resources palaeontologists make extensive use of a mobile acid laboratory to search for conodonts in calcareous Palaeozoic rocks in the field.

The laboratory consists of a caravan (18'x8'), a canvas awning (20'x20'), a crushing plant, and an acid neutralizing plant. The caravan is fitted out as an office containing a fume-cupboard, microscope benches, and a library. The fume-cupboard consists of an enclosed metal cabinet with a vertically sliding glass door and is exhausted by a 24-volt Vent-axia fan situated in the wall of the caravan. The power for the fan, the neon strip lighting, and the microscope lamps is provided by a 240-volt generator driven by a 10 b.h.p. petrol engine.

The canvas awning is used as the acid laboratory to house 2 gallon polyethylene buckets placed on the ground; over 100 buckets are accommodated. A sieving bench fitted with a water source and a shower rose attachment is placed outside the awning. Movable water tanks on the caravan roof give sufficient "head" for sieving and bucket refill, and are conveniently heated by the sun to a water temperature of about 85° F.

The monochloracetic acid used in the process is transported, in crystal form, in 44 gallon drums and stored at the side of the awning to minimise handling; the acid is added to the buckets direct from the drums.

A 3 inch jaw crusher is mounted on the rear of a forward control four-wheel-drive vehicle and driven by a small power kerosene (T.V.O.) engine. The neutralizing plant consists of a 10-foot drainage trench terminating in a 5-foot-square sump. Both the trench and the sump are half filled with ¼ inch marble chips, which are replenished at intervals.

Samples of limestone weighing about 10 kilograms, are crushed into ¼" chips at each locality or as near the exposure as the terrain allows. They are then dry-sieved through an 8-mesh sieve to remove the "fines", bagged in plastic bags and labelled with masking tape.

The chemical disintegration process is carried out beneath the awning; about one pound of crushed rock chips is spread on the bottom of each bucket and crystals of monochloracetic acid added. In order to avoid the use of overstrength acid, tests are carried out to find the correct size of scoop to ensure an acid strength of 10-15% in a 2-gallon bucket. Water is added through ½" plastic hose, the buckets remaining "in situ".

The acid is changed every day, the spent liquor poured down the drainage channel into the neutralizing plant, and the samples either sieved or re-acidized depending on whether the sample had fully broken down. The residues are collected on a filter paper and dried in the fume-chamber. During this process the draftsman's tape bearing the sample number can be transferred at every step, from the sample bag to the bucket, from the bucket to the filter paper, and finally from the filter to the residue bottle.

During a 10-week period 130 samples were processed, totalling about 1,500 lb.; 35 samples contained conodonts, and about 600 identifiable specimens were recovered.

The processing of samples in the field has several advantages over the normal method of forwarding bulk rock samples to the headquarters laboratory. The operation of a field laboratory obviates unnecessary cartage of rock samples, and it enables fossiliferous localities to be re-sampled at once; rather than waiting for the next field season. Finally it makes available biostratigraphic data to the field party whilst mapping is proceeding; so that contentious sections can be re-examined and the mapping continued with expanding palaeontological results which are not normally available until the geologists have returned to headquarters.

HYDROGEOLOGIC ANALOGUE COMPUTER

by

Geological Survey of South Australia

Using the analogy between the flow of electric current in a resistive medium under the influence of voltage differences within the medium, and the flow of water in a confined aquifer under the influence of pressure differences, an electrical analogue model of a pressure aquifer can be constructed. A model of the Northern Adelaide Plains area has been constructed by this Department as part of the programme to evaluate the effect of continued large-scale water withdrawal in this area.

The model consists of a regular array of resistors and capacitors which simulate the aquifer. The resistors are chosen such that their conductivity, the reciprocal of resistance, is proportional to the transmissivity of the aquifer, and may be varied if the aquifer transmissivity is found to vary from one part of the aquifer to another. The capacitors supply the necessary storage coefficients to the model to enable transient phenomena to be simulated as well as steady state conditions.

Water withdrawal may be simulated by electrical pumping of current from the model. This withdrawal may be allowed to fluctuate seasonally with a higher rate in summer than in winter. The effect of this withdrawal may be demonstrated by measurement of voltage at points within the model by means of a suitable cathode ray oscillograph . The voltage changes measured represent the change in static water level expected at the corresponding point within the aquifer under the simulated withdrawal conditions.

By measurement at many points within the model area, information for drawing plans of equipotential contours may be obtained, and if values can be assigned to the permeability of the aquifer and its confining beds the volume of water which may be withdrawn for a particular withdrawal pattern may be estimated.

The model may thus be used to test the adequacy of hydrogeclogical information obtained from pump tests used in conjunction with hydrogeological hypothesis to explain draw-down patterns in the area.

NEUTRON MOISTURE MEASUREMENT

by

Geological Survey of South Australia

The measurement of moisture within test holes drilled in the soil may be made by the neutron backscatter method.

In this method, a radioactive source provides by interaction with beryllium incorporated in the source, high velocity neutrons, which travel outward from the source. These neutrons, by collision with hydrogen atoms,lose their velocity, since momentum is easily transferred between particles of equal mass. The low velocity or thermal neutrons diffuse in all directions, a proportion of them arriving at the slow neutron detection tube included with the radioactive source in the probe assembly. The number arriving depends on the distance the fast neutrons travelled from the probe before the loss of their velocity, and consequently on the number of hydrogen atoms in the probe vicinity.

By suitable calibration, the number of neutrons detected in unit time can be related to the moisture content of a particular soil. Calibration is necessary because of the presence of neutron absorbers chlorine, boron, rare earth elements etc. in the soils in varying amounts.

Calibration may be done in situ by taking suitable soil samples for moisture measurements, or the soil may be packed in suitable drums under controlled moisture conditions.

Soil moisture may be measured over the length of holes drilled in areas of interest by lowering the probe to the required depth, and taking a reading of the scattered neutrons, as counted by the scaling unit located at the ground surface.

To maintain access to the holes over a period of up to several years, soft walled polythene access tubing is used to line the hole,except in difficult conditions where more expensive stainless steel tubing may be employed.

To test for cavities near the hole a gamma backscatter density probe may be run in the same drill hole, cavities being indicated when the backscattered gamma radiation falls abnormally.

Variations in the soil moisture at depth indicate the penetration of surface waters and the possibility of their contribution to the intake of the underlying aquifers.

A reflecting shield is also available for use on the ground surface. With this the probes may be fitted in the shield so that the backscatter variations arise from one side only, so that the moisture and density of roadworks, earth wall dams etc. may be investigated using the same apparatus.

ELECTRIC LOGGING OF COAL SEAMS

by

Geological Survey of Queensland

Geophysical equipment utilised in oil search work today is often too large and too insensitive to be of value in coal exploration programmes. An interesting instrument developed by Schlumberger Seaco Pty. Ltd., has overcome both of these difficulties. The device is a micro-resistivity tool somewhat comparable to the micro-laterolog used in oil exploration. It is a compact unit which is easily transported and its sonde can be used in holes as small as three inches diameter. By adjusting carefully the voltage and current applied to the electrodes on the sonde, it is possible to focus a narrow pencil-like beam of surveying current on the wall of a borehole. The different resistivities of coal (high) and shale (low) make it possible to log coal seams down the hole, and as the beam will only scan a thin section of strata in front of it, the unit can quite easily detect shale bands of 1 inch thickness or less within a seam.

Detailed testing and adjustment of the instrument was carried out on a series of cored Mines Department boreholes on the Ipswich Coal Field. The electric logs produced from each hole were compared in detail with descriptive geological logs of the core which had been examined visually and radiographed under the Department's X-ray fluoroscope at Redbank. The results obtained by these various methods of logging compared very favourably with one another.

COMPUTER PROGRAMS IN GEOLOGY

by

T. Quinlan

The following computer programs to assist in the interpretation and analysis of geological data have been developed and/or adapted within the Bureau of Mineral Resources, Geological Branch.

Name	Purpose
FREQDIST	to derive the frequency distributions and histograms of variables.
FISHER K	to derive the mean, standard deviation, standard error, skewness and kurtosis of variables.
STDERROR	to determine the standard error of variables from duplicate observations.
DISCRIM	to perform a discriminant analysis on two groups of data.
REGRESS	for an analysis of multiple regression, accepting all variables.
STEPREG	for an analysis of multiple regression, selecting only those variables which make a significant contribution to the regression equation.
TREND	to define the 1st to the 8th order trend surface and to provide a contoured map of the surfaces.
THEIS	to fit the Theis non-equilibrium type curve to drawdown data about a pumping bore.
WLPLOT	to plot water level hydrographs.
MESONORM	to calculate the Barth Mesonorm of a rock from a silicate analysis.
CIPWNORM	to compute the CIPW Norm of a rock from its silicate analysis.
DIRECTN	to remove the component of tectonic dip from a series of current bedding readings and to compute the principal current direction.
XRAYF	to translate the paper tape output from the X-ray Fluorescence spectrograph and to calculate the percentage composition of oxides in a rock.

VOLCANO SURVEILLANCE IN THE TERRITORY OF PAPUA-NEW GUINEA

Installation of a telemetered Seismic Network at Rabaul

by

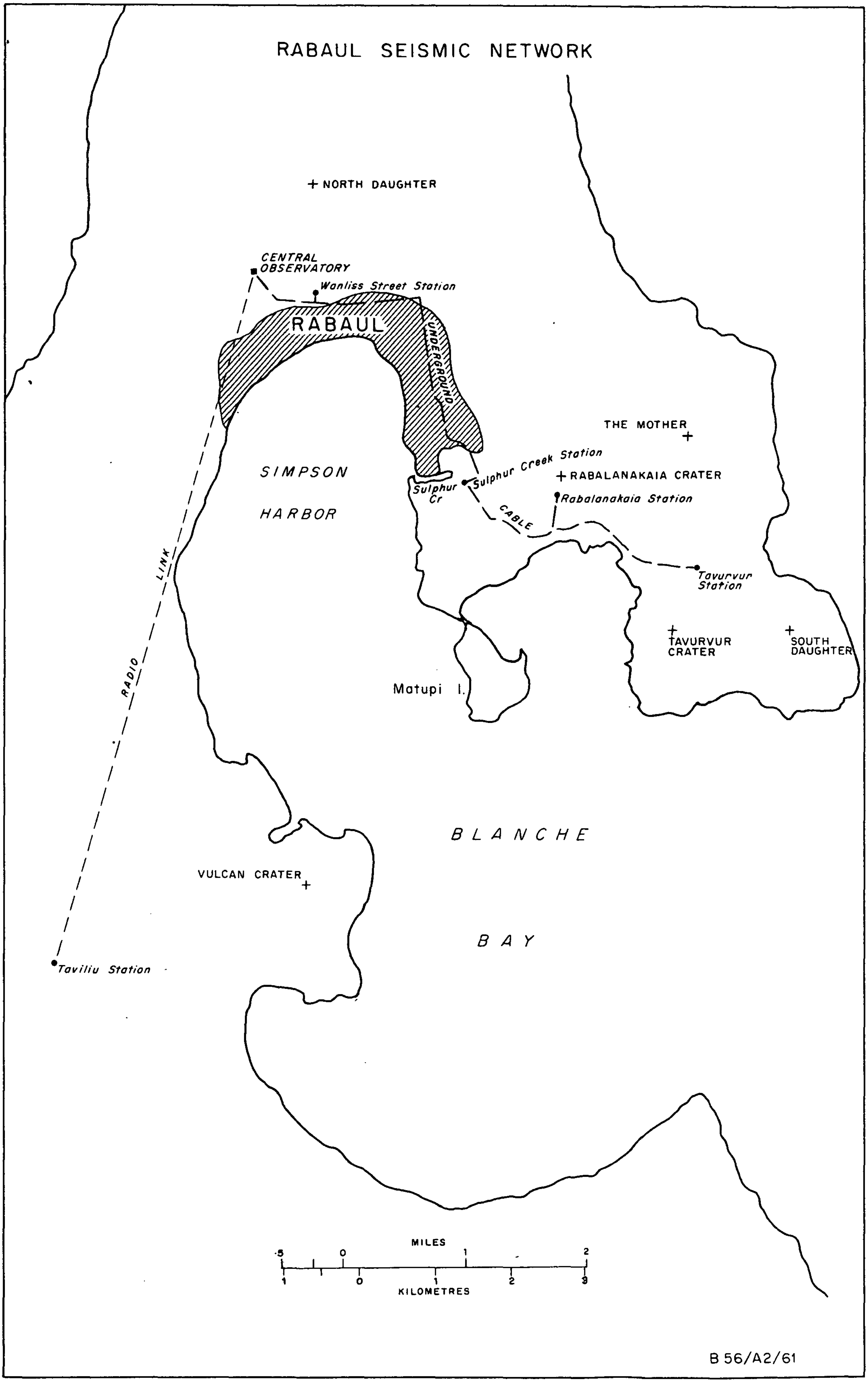
G.A.M. Taylor

The town of Rabaul in New Britain is one of the most important economic centres in the Territory of Papua - New Guinea. It acts as a shipping and supply centre for many of the islands of the Bismarck Archipelago and for the Solomon Islands. Its adjacent hinterland on the Gazelle Peninsula is one of the most extensive and highly developed agricultural areas in the Territory.

The town is situated on the floor of a youthful volcanic caldera one side of which is breached to allow entry of the sea. The resultant inlet with its extensive area, deep water and protective walls is one of the finest harbours in the Pacific. The caldera contains, however, four dormant volcanic centres whose potential reactivation constitutes a threat to smooth operation of the community. Within the last 100 years eruptions have occurred in 1878, 1937 and 1941-2. The eruption of Vulcan in 1937 was the most severe of these events. It caused some loss of life, and the port was closed and the town evacuated for a few days.

To safeguard the community against the occurrence of such events without warning and to mitigate their effects the Administration established a vulcanological observatory at Rabaul soon after this eruption. This institution was destroyed during the war and was subsequently rebuilt in the early 50's. In recent years steps have been taken to improve the instrumentation of the Rabaul Observatory by installing a telemetered seismic network of advanced design.

A normal precursor to large scale eruption is the occurrence of local earthquakes. The shocks are caused by sudden movements in the conduits and magma chamber beneath the volcano as the highly pressurised lava and hot gases disrupt the confining rock and begin working their way towards the surface. If the focal movements of these disturbances can be determined accurately it is possible to trace the upward advance of the magma and it becomes practicable to predict the time and place of an eruption with some precision. The essential requirements for such determinations is a network of at least four well-spaced seismic stations with extremely good time control. Focal determinations are based on differences in the arrival times at the network stations of shock waves which are travelling at velocities of several kilometres per second. Hence arrivals must be timed with an accuracy of a small fraction of a second if focal origins are to be fixed precisely.


RABAUL SEISMIC NETWORK
NORTH DAUGHTER
CENTRAL OBSERVATORY
Wanliss Street Station
RABAUL
UNDERGROUND
THE MOTHER
Sulphur Creek Station
RABALANAKAIA CRATER
SIMPSON
Sulphur Cr
Rabalanakaia Station
HARBOR
CABLE
LINK
Tavurvur Station
TAVURVUR CRATER
SOUTH DAUGHTER
RADIO
Matupi I.
BLANCHE
VULCAN CRATER
BAY
Taviliu Station
MILES
·5
0
1
2
1
1
0
1
2
3
KILOMETRES
B 56/A2/61

The network stations can be laid out either as self-contained units or as a telemetered array with a common recording point. The telemetered system has advantages that more than compensate for the slightly greater capital cost. By centralizing the recording equipment at one point, timing errors, which arise from checking several clocks in the self-contained stations, are eliminated; the data are immediately available for analysis; power requirements can be reduced to a minimum and a single emergency plant can cope with mains failure in the event of eruption; the bulk of the equipment used in the system can be housed in an air-conditioned environment - an important consideration for reliability of electronic equipment in the tropics; maintenance and operations staff are reduced to a minimum.

Basic plans for installation of a telemetered seismic network were drawn up in 1963 and the proposal was submitted to the Administration with the suggestion that Professor C. Newstead, then of the University of Tasmania, should examine it. Professor Newstead had been carrying out, for several years in Tasmania, advanced research in the telemetering of seismic signals. He reported favourably on the proposals for Rabaul and provided specifications for manufacture of the telemetering equipment. He subsequently arranged testing of the equipment with assistance of Mr. P. Watt of the University of Tasmania and Mr. K. Muirhead of the Australian National University.

Installation of the first phase of the Rabaul network is now completed. It consists of five "pick-up" stations within the caldera and provision for recording on a common time base at a central observatory (layout illustrated in attached sketch map). Four of these stations, Tavurvur, Rabalanakaia, Sulphur Creek and Wanliss Street are connected to the observatory by underground cable. Taviliu station on the southern side of the caldera is connected by high frequency radio.

Each station contains a Benioff model 4681A seismometer whose signals are amplified by a Texas Instruments RA2 amplifier before being frequency-modulated for transmission. On reception at the observatory the signal is demodulated and amplified before it is visually recorded on a hot-pen instrument of the Helicorder type. Provision is made for remote control of gain by appropriate attenuator adjustments. Power is supplied to four of the stations by the underground cable. The radio link at Taviliu is powered by an automatic diesel plant and alkali storage batteries. All equipment and installations are designed to operate under conditions of actual eruption to ensure that continuity of observations is maintained.

The noise level in the caldera from both natural and cultural sources is very high in some parts of the caldera. With the installation of suitable filtering the normal operating gain of the network ranges from six to thirty thousand.

The second phase of the network development will be to commission three additional stations located at points up to 70 kilometres from the observatory. This will increase the depth range of the system and make it possible to trace earthquakes associated with initial magma movements from a source in the mantle.

It is also envisaged that in the near future interpretation of the data from the network will be largely automated by installing magnetic tape facilities which can be played directly into a computer.

This development will be assisted by a series of crustal study projects which began last year. These investigations will yield fundamental data on crustal thickness, local seismic wave velocities and other details of local structure. Preliminary results from last years' work suggest the presence in most adjacent areas of a 3-layered crust ranging in thickness from 12 to 42 kilometres. The seismic wave velocities in the layers are 2.8, 5.8, and 6.9 kilometres per second. Mantle velocity ranges from 7.7 to 8.9 kilometres per second.

VILLAGE WATER SUPPLY SURVEYS, PAPUA - NEW GUINEA

by

E.K. Carter

Most villages and other small settlements in the Territory of Papua - New Guinea draw their domestic water supplies from streams or shallow wells that are subject to pollution and drought. In order to improve the standard of village water supplies the Territory Administration has set up a survey team to examine the present position District by District and to advise what action is needed in each village visited to improve the quality, permanence and quantity of water available.

At the present stage of development, any scheme recommended must be cheap to install and maintain, and must be so designed as to reduce to a minimum the risk of bacterial pollution; deep drilling is generally too expensive. Most villages can be supplied by shallow wells, so equipped that water is drawn off at a point some distance from the well to prevent pollution; or by spears into sandy aquifers. Quality of water is a problem in many coastal areas. In favourable locations water from uncontaminated surface streams may be gravitated to the settlement. In a few instances it has been necessary to recommend an artificial catchment and storage, or relocation of the settlement.

The survey team generally consists of a geohydrologist, an engineer, and an officer of the Department of Public Health; it is usually accompanied by an officer of the Department of District Administration. Not all settlements in a District can be visited in the course of a survey, therefore population, present water supply and climate of each settlement is determined before the survey starts and a selection is made, based on needs, access and special features, to cover as wide a range of conditions as possible. In a 4 - 8 week survey from 40 to more than 150 settlements may be visited. At each village the quality and adequacy of the existing water supply is checked and a written report, giving recommendations and including cost, is prepared immediately and handed or sent to local and District authorities. A photograph, which includes a leading villager, is taken of any well-site selected, for later identification of the spot. A comprehensive report is compiled on the completion of each survey.

A further account of the methods of operation of the survey team, including specifications for a standard sanitary well, will appear in a forthcoming issue of "Engineering Geology", published by Elsevier Publishing Company, Amsterdam. The paper is based on experience in the Milne Bay and Sepik Districts-the first two surveys carried out.

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

CURRENT PRACTICES IN AUSTRALIA FOR ANALYSING GEOCHEMICAL PROSPECTING SAMPLES

by

A.D. Haldane

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SUMMARY

At present in Australia the emphasis in the analysis of geochemical prospecting samples is on laboratory-based instrumental techniques. Atomic absorption spectrophotometry and semi-quantitive emission spectrography are the two techniques by which most analyses of this type are carried out. The cost of analysis by either method does not differ greatly, being 25 ¢ per sample plus 25 ¢ per determination for atomic absorption spectrophotometry, and 40 ¢ per sample plus 10 ¢ per determination for semi-quantitative emission spectrography.

Colorimetric and X-ray fluorescence methods are restricted to special analyses and cost an average of $1.00 per determination. The direct reading emission spectrograph has not been applied to routine analysis of geochemical prospecting samples.

Current development in atomic absorption instrumentation make the appearance of rugged multi-element field instruments only a matter of time.

INTRODUCTION

Initially the particular scheme adopted for the analysis of geochemical prospecting samples is determined by the desire for either field or laboratory operation. Often an important factor in selecting either one of the two modes is the availability of suitable instrumentation for repetetive quantitative analyses. During recent years the trend in geochemical prospecting has been towards analysis in the laboratory rather than the field. Better control of accuracy is possible and advanced instrumentation is available. About five years ago it was thought that the direct reading emission spectrograph could be used for rapid multi-element analyses of geochemical samples. This system had the potential of complete automation up to the final product of a complete geochemical map. Apart from the substantial cost involved in establishing such facilities, the expected performance as a rapid multi-element instrument has not been fully achieved.

The recent development of atomic absorption spectrophotometry has had considerable impact on analytical methods for geochemical prospecting samples. At the present time atomic absorption methods are confined to laboratory operations but it is only a matter of time before the rapidly developing instrumentation of this technique will provide an automated multi-element analysis system suitable for either laboratory or field use. Irrespective of whether field or laboratory analysis is chosen, the criteria for the selection of any analytical method for geochemical prospecting are: high sensitivity, high selectivity, simplicity and reliability of operation, and high productivity. For field operations some loss in the accuracy attainable under laboratory conditions is accepted.

The analytical techniques that have been applied or considered for geochemical prospecting according to the criteria given above are:

Colorimetry (spectrophotometry)

Optical Spectrography

X-ray fluorescence spectrography (X.R.F.)

Atomic absorption spectrophotometry (A.A.S.)

These techniques are all currently in use in Australia and a summary of their application and operational costs follows. The figures for operational costs are based on commercial analysts specialising in geochemical prospecting and are for minimum batches of 10-20 samples not requiring sample preparation. For soils and rocks requiring grinding and sieving there is a charge of an average 60 ¢ per sample under 200 gm, rising to $1.00 for samples up to 1 kgm; stream sediments generally do not require any sample preparation. In some cases an additional handling fee up to $5.00 may be charged for each batch of samples irrespective of the number of samples or analyses required.

Where the number of samples per annum from any one customer is large (5000-30,000) reductions in total cost up to 60% are offered or may be negotiated by contract. Many of the prospecting companies operating in Australia consider it more efficient to use the services of these analysts rather than set up and maintain their own facilities.

COLORIMETRY

The range of elements that can be determined by colorimetric methods suitable for geochemical prospecting application is limited by the availability of specific reagents and the complexity of preliminary separations. Research into new organic reagents for metals continues to improve selectivity and sensitivity but any substantial improvement in colorimetric methods is unlikely. In the laboratory colorimetric methods have been replaced wherever possible by more advanced instrumental methods, particularly atomic absorption spectrophotometry, and in time this should extend to field operations as well.

At present colorimetric methods are not prominent in any of the analytical schemes offered commercially in Australia and are restricted to the determination of a few elements such as phosphorus, arsenic, selenium, tungsten and molybdenum. Charges range from 90 ¢ to $1.50 per determination.

The auto-analyser has been applied to colorimetric analysis of geochemical prospecting samples by J.S. Webb at Imperial College, London. This approach has not been developed in Australia so that no comparison of costs can be made between the normal and automated techniques. It would be expected, however, that the use of the auto-analyser would result in a substantial reduction in the charges quoted above.

OPTICAL SPECTROGRAPHY

Advances in instrumentation in optical spectrography have developed the sophisticated direct reading spectrograph from the simple photographic instrument so widely used for trace element analysis. Both are currently in use in geochemical investigations.

The direct reading spectrograph as a geochemical tool has been discussed by Cruft and Giles (1967) who used it for a study of the minor and trace element distribution in ash flows. A similar instrument is operated by the B.M.R. but so far it has been applied to geochemical investigations rather than routine geochemical prospecting. The only commercially operated direct reading spectrograph is programmed mainly for ferrous alloy and rapid silicate analyses; no geochemical prospecting service is offered. From the information available it is not possible to arrive at any meaningful estimate of the operating costs for this instrument if applied to the analysis of geochemical prospecting samples. There is nothing to suggest that such costs would be lower than established alternative techniques.

The simple photographic spectrograph has been applied successfully to the "semi-quantitative" type of analysis for many years both in the laboratory and in mobile field units. The latter usage has been restricted by the difficulties of transporting a large delicate optical instrument.

In the laboratory, however, the photographic spectrograph is a very versatile and informative tool when in the hands of an adequately trained operator. A wide range of elements is covered and the speed of analysis is high. An accuracy varying from ± 20% to ± 50% is obtainable at rates of 800-1000 element determinations per day over an indefinite period. Higher rates are possible over short periods where "clean-up" operations can be allowed to accumulate. Sample preparation is minimal, involving only grinding and mixing. The mode of occurrence of the elements sought is in most cases of no consequence, an advantage over chemical methods where the first step is to bring into solution those elements of interest. Elements such as tin, beryllium, vanadium, chromium, barium, titanium, etc. commonly occur in forms which do not yield readily to simple acid digestion, consequently samples must be fused with a suitable flux thereby reducing speed and simplicity of operation. The spectrographic method does not suffer from difficulties of this type.

For semi-quantitative spectrographic analysis the range of elements covered includes: Cu(1), Pb(5), Zn(20), Co(1), Ni(1), Sn(5), Cd(5), Ag(1), Au(5), Cr(3), V(3), W(20), Mo(2), Mn(5), Be(1), Ga(1), Ge(1), Pd(2), Os(5), Ir(2), Rh(2), Ru(5), Bi(1), Te(20), Tl(3). The figures in brachets show detection limits in parts per million. The common rock forming elements and rare earths can also be detected spectrographically. For the elements listed the charges are 40 ¢ per sample, plus 10 ¢ for each element determined.

X-RAY FLUORESCENCE SPECTROGRAPHY

X-ray fluorescence spectrography is used only to a limited extend in Australia for the analysis of geochemical prospecting samples. The technique satisfies most of the criteria for the selection of an analytical scheme; it is completely specific for any element, can achieve low detection limits, for trace analyses requires no sample treatment other than grinding and has high reliability. However, productivity is too low for normal geochemical prospecting applications and its use is restricted to the determination of elements such as tungsten, niobium, tantalum, tin and selenium which can present problems by other methods. For this type of analysis the charges are equivalent to 40 ¢ per sample, and 60 ¢ for each element determined.

ATOMIC ABSORPTION SPECTROPHOTOMETRY

Undoubtedly the most significant recent achievement in the field of chemical analysis is the rapid development over the last ten years of methods employing atomic absorption. This technique, first prosposed by Walsh (1955), has practically replaced all other chemical methods for the analysis of geochemical prospecting samples.

As atomic absorption is almost completely free from interferences from other elements present, it is necessary only to select a suitable reagent to dissolve or extract the sample and the resultant solution can then be analysed without further treatment. Analytical methods based on atomic absorption have no difficulty in satisfying the criteria previously given for geochemical prospecting needs. In addition the one basic technique will cover a range of more than sixty elements, which includes all of those of importance in geochemical prospecting. The following list is typical of the range of elements and corresponding limits of detection in the sample: Cu(2), Pb(5), Zn(1), Co(5), Ni(5), Cd(1), Ag(1), Au(1), Cr(10), Mo(3), Mn(5), Be(1), Fe(5), Bi(5), Sb(20), Te(5).

As with semi-quantitative emission spectrography high production rates can be maintained over prolonged periods. Instrumental speeds in excess of 200 analyses per hour are possible so that sample preparation and clean-up are the limiting factors. Atomic absorption spectrophotometers are simple to operate and their accuracy does not depend on the skill of the operator as is the case with visual comparison methods, either colorimetric or spectrographic. The average cost does not vary greatly and is 25 ¢ per sample plus 25 ¢ per element determination. Current research into atomic absorption instrumentation is aimed at the development of multi-element instruments, elimination of the necessity for a monochromator, and complete automation from sample feed to typed results. An instrument capable of the simultaneous determination of five elements without the use of a monochromator has already been constructed.

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

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RECENT DEVELOPMENTS IN GEOPHYSICAL PROSPECTING PRACTICES IN AUSTRALIA

by

N.G.Chamberlain, L.S.Prior and K.R.Vale

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In the exploration for metalliferous orebodies induced polarisation (I.P) continues to be the ground geophysical method most used by prospecting companies in Australia, even though the limitations of the method - principally the difficulty in applying it in the presence of highly conductive overburden and the high sensitivity to minor amounts of sulphides - are generally recognised.

Renewed activity in the search for uranium had led to proposals for the introduction of gamma - ray spectrometers for laboratory and airborne use. Aircraft are currently being equipped with spectrometers by geophysical contractors and the Bureau. The Bureau will operate a spectrometer in conjunction with a magnetometer in an Aerocommander 500U aircraft. This technique is expected to have application to the search for phosphate and to assist geologists in general mapping.

A portable metal analyser using a radioisotope source and operating on the principle of X-ray fluorescence has been developed in the United Kingdom and was recently demonstrated in Australia. The instrument has been designed for field assays of various elements and could have useful mining and industrial applications.

In oil search exploration there has been a decline in the intensity of land-based operations in the standard methods of geophysical surveys - gravity, magnetic and seismic-but a technique new to Australia, namely magneto-telluric surveying, has been introduced.

In the magneto - telluric method use is made of the earth's fluctuating magnetic field and the electric field it induces in the earth's crust. The electric field is measured by grounded electrodes spaced widely apart. With this method of survey it is presumed possible to define the depth to, and extent of, basement enclosing sedimentary basins.

Offshore exploration activity measured in terms of expenditure is relatively high. Seismic is the principal tool and the use of airgun and other non-explosive energy sources is growing. All commercial work is being done with multiple-coverage techniques and digital recording and processing with the aim of removing noise from reverberations within the water layers and removing multiples of shallow reflections that interfere with deeper reflection. Such techniques are expensive.

The Bureau recently did some 16,000 miles of experimental work in the Timor Sea using marine sparker, shipboard gravity meter and fish magnetometer. Problems of accurate navigation have presented a challenge and methods using very low frequency radio waves (VLF) and satellite - doppler techniques are currently being investigated both to position the ship and determine its velocity accurately.

There has been a steady increase in the use of digital computers for reduction, processing, filtering, plotting etc., of geophysical data, particularly from seismic and aeromagnetic surveys. Computer programming and automatic data processing are more and more becoming the common tools of the geophysicist both during the progress of a survey and the post-survey analysis and interpretation.

COMMONWEALTH OF AUSTRALIA
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BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

GEOSCIENCE FACILITIES IN AUSTRALIAN UNIVERSITIES, 1967.

by

K.A. Townley and I.R. McLeod

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GEOSCIENCE FACULTIES IN AUSTRALIAN UNIVERSITIES, 1967

by K. A. Townley and I. R. McLeod

In 1967 the Census Committee of the Geological Society of Australia sent to the Geology Departments of all Australian Tertiary Institutions a questionnaire on their activities. We are grateful to the recipients for the care and effort they put into their replies, from which this paper is compiled.

Students

Student enrolment in geology and geophysics in 1967 is shown in Table 1. The figures exclude enrolments in service courses such as those for engineering students; but of course the first-year enrolments include a large majority of students for whom geology is only an ancillary study.

Of the totals in Table 1, 161 third-year students (61%) and 134 graduate students (47%) are assisted by scholarships; 58 (unspecified) are already employed in geoscience.

The numbers and pattern of 1966 graduates are given in Table 2, and the fields of employment into which they passed in Table 3.

It is of interest that graduates entering the Government (mainly survey) field total 22, and those entering industry 69. A similar questionnaire distributed to employers of geoscientists has elicited the number of new positions filled during 1967: it is the difference between 'number engaged' and 'number lost' as reported by employers. The figures for Government employment are as yet incomplete, but 146 new positions were apparently established in industrial employment; the figure of 69 entering industry shows therefore, that there was a shortfall of 77 (53%) in the supply. The shortfall can be subdivided, again on the basis of employers' returns, into 12 (18%) in the mining industry, 37 (77%) in the petroleum industry, and 28 (85%) in the consultant and service firms.

These figures deal only with positions filled; to complete the picture we must add the vacancies (as at 30th September 1967) reported by employers. They are: 127 geologists, 43 geophysicists, and 8 geochemists. 86 vacancies were reported by mining companies, 40 by petroleum companies, and 52 by consultant and service firms.[1]

It is apparent, therefore, that Australian demand is very considerably greater than Australian output.

Another facet of interest is a comparison of the proportions of new entrants in each of the various grades of degree (Table 3) with the requirements and preferences indicated by employers (Table 4).

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[1] To these may be added the incomplete total of 36 geologists, 23 geophysicists, and 4 geochemists in Government employment.

Staff

Totals of University staff are shown in Table 5.

We made some inquiry into the mobility and breadth of experience of members of University staff, partly in view of the opinion voiced at, or implicit in, a symposium held in 1966 at the Australian National University,* that University thinking is somewhat remote from that of employers. Breakdowns of the careers of 145 staff members were compiled by Universities; we believe that this number includes most of the permanent staff.

No detailed analysis can be made of such a small and varied sample, but the numerical results do not bear out the implied criticism. Table 6 shows experience, in years, of University staff inside and outside Universities. The figures can also be broken down in the following categories:

(a) Members of staff with experience outside University

In research institutions, survey, and industry . . .	3
In research institutions and survey	7
In research institutions and industry	8
In survey and industry	15
In research institutions only	18
In survey only	31
In industry only	19
In unspecified category	6[a]
Total with 'outside' experience	107

(b) Members of staff with experience only in Universities

In oversea Universities	9[a]
In other Australian Universities	2
In both	4[a]
In present University only	23
Total	38

(c) Members of staff with experience both in other Universities and in other forms of employment[b]

'Outside' experience and oversea University	47
'Outside' experience and other Australian University	36

* Proceedings of the Symposium on Undergraduate Geological Training (24-25 February 1966). Geol. Dep. A.N.U., Canberra, June 1966.

a excluding sabbatical leave.

b these figures are not exclusive of preceding ones.

(d) Specific experience

With survey experience (average about 5½ years) 56

With industrial experience (average about 4½ years) 45

With other research experience (average about 3 years) . . . 35

For comparison, the average experience of all University staff is:

Present University . . . . 5½ years

Total University . . . . 7½ years

Total professional experience . . . . 11 years

We realize, of course, that these figures have little if any statistical value; but they are sufficient to show considerable mobility, and consequent experience and knowledge of the conditions and requirements of industrial and Governmental employment, in the present staff of Australian Universities.

Fields of Research

Universities have kindly enumerated the main fields of research in which they are engaged. Since they may influence the choice of University by intending graduate students, they are itemized below.

University College Townsville: Mineralogy and petrology; recent sedimentation; economic geology; palaeontology and stratigraphy.

University of Queensland: Petrology and geochemistry of volcanic, plutonic, and metamorphic rocks; isotope geology; palaeontology of corals, pelecypods, brachiopods, conodonts, Mesozoic ferns; general palynology; sedimentology and diagenesis of carbonate rocks; economic geology of copper and nickel; clay mineralogy; petroleum geology; seismology.

University of New England: Igneous and metamorphic mineralogy and petrology; origin of metalliferous ore deposits; regional stratigraphy, structure, and sedimentation; palaeontology (including micropalaeontology); biostratigraphy.

University of Newcastle: Mineralogy (secondary minerals, DTA determination of carbonates); petrology (Carboniferous volcanics); chromatography in geology; Permo-Triassic sedimentology; coal geology; structural geology.

University of Sydney: Coal; igneous and metamorphic petrology; economic geology; structural geology; stratigraphy and palaeontology; sedimentology and marine geology; geophysics.

University of New South Wales: Not specified.

Macquarie University: Petrology; structural geology; sedimentology; geomorphology; stratigraphy.

A.N.U. (Institute of Advanced Studies): Geochronology and isotopic geochemistry; radiocarbon dating; trace element geochemistry; descriptive and analytical petrology; experimental petrology; rock deformation and structural geology; seismology; palaeomagnetism; geothermy.

A.N.U. (School of General Studies): Igneous and metamorphic petrology; Lower and Middle Palaeozoic stratigraphic palaeontology and sedimentology.

University of Melbourne: "Virtually all fields are covered".

University of Tasmania: Tectonics, especially of New Guinea; Ordovician, Permian, and Tertiary stratigraphy, sedimentation, and palaeontology, mainly of Tasmania; chemistry and origin of base metal ores; geochemistry and mineralogy of diagenesis, especially of clays; systematic gravity surveys; systematic study of Tasmanian minerals; chemical studies on basaltic magmas; the deep structure of the earth as revealed by geophysical methods.

University of Adelaide: Precambrian-Cambrian stratigraphy and palaeontology; structural geology and tectonics; geochemistry of layered intrusions; metamorphic and granite petrology; ore deposits; X-ray crystallography.

University of Western Australia: Marine carbonate sedimentation; palynology; selenology and meteoritics; igneous, metamorphic, and sedimentary petrology; geology of Solomon Islands.

Royal Melbourne Institute of Technology: General geology of special areas; industrial research in engineering materials; palaeontology.

Bendigo Institute of Technology: Metamorphic petrology and structure.

TABLE 1

Student and staff numbers, geoscience departments at Australian Universities and colleges of advanced education, 1967

ENROLMENT

University	Undergraduate				Graduate				Staff	
	First year	Second Year	Third Year	Fourth Year	Honours	Master	Ph.D.	Others	Lecturer and higher grades	Other full time professional[f]
Townsville	23	11	b	-	-	-	1	-	3	3
Queensland	120	48	31	1	3	13	15	-	13	8
New England	31	16	16	-	5	3	13	-	7	8
Newcastle	91	29	16	-	2	-	2	-	7	2
Sydney	219	42	45	-	14	23[a]	19	-	16	12
New South Wales	140	65	30	1	5	14	10	7[d]	11	8
Macquarie	212	b	b	-	-	3	1	-	3	-
A.N.U. (I.A.S.)	-	-	-	-	-	-	24	-	15	9[e]
A.N.U. (S.G.S.)	45	23	13		5	3	11		9	6
Melbourne	138	23	19	-	2	5	5	-	10	5
Tasmania	67	22	22	-	3	2	12	-	6	4
Adelaide	417	34	31		12	2	17	-	10	6
Western Australia	115	23	15[c] 15		7	5	14	-	8	7
Total, University	1618	336	253	2	58	73	144		124	78
R.M.I.T.[g]	1	25	22	-				4[h]	4	
Ballarat	7	3	2	-					1	
Bendigo	4	7	1	-					1	
Total, colleges of advanced education	12	35	25	-				4	6	-
Total all	1630	317	278	-	58	73	144	11	130	78

a. Including 7 M.Sc. preliminary
b. Not offered in 1967
c. 15 in course 30 ('hard rock'), 15 in course 31 ('soft rock'); these courses are not mutually exclusive.
d. Diploma in Applied Geophysics.
e. Research Fellows and Research Assistants
f. Including demonstrators, teaching fellows, research fellows, research assistants.
g. Plus 32 part-time Associateship Diploma students
h. Fellowship Diploma

TABLE 2

Institution	Diploma	Bachelor	Bachelor (Honours)	Master	Ph.D.	Others
Queensland		23	6	1	2	
New England		14	3	1	2	
Newcastle		5	-	-	-	
Sydney		41	14	6	3	
New South Wales		-	5	2	2	1[a]
A.N.U. (I.A.S.)		-	-	-	5	
A.N.U. (S.G.S.)		5	2	1	2	
Melbourne		5	3	5	3	
Tasmania		8	4	2	1	
Adelaide		14	14	1	2	
Western Australia		6	7	-	-	
R.M.I.T.	4					
Ballarat	3					
Bendigo	2					
Total	9	121	58	19	22	1

[a]Post-graduate Diploma in Applied Geophysics

Table 2: Graduates in geoscience at Australian universities and colleges of advanced education.

TABLE 3

Employment field	Diplomatic	B.Sc.	B.Sc. (Hons)	M.Sc.	Ph.D.	Other	Total
University[a]	-	25	15	6	6	1	53
Survey		4	11	3	2	-	20
Mining Companies	8	27	13	3	2	-	53
Oil Companies	-	3	5	1	2	-	11
Consultants	-	3	-	2	-	-	5
Water Commissions	-	-	1	1	-	-	2
Teaching[b]		25	2	-	-	-	27
Overseas		-	5	-	8	-	13
Other	1	12	3	1	-	-	17
No known	-	22	3	2	2	-	29

[a]Includes further study and research

[b]Except Tertiary

Table 3: Employment of 1966 graduates

TABLE 4

	Dipl.	Bachelor	Honours	Master	Doctor	Other[a]
Requirement						
Companies	25	66	16	2	-	-
Total geoscientists employed	197	651	114	5	-	-
Preference						
Companies	3	25	55	11	6	1
Total geoscientists employed	6	121	582	142	35	8

[a] The meaning of this category was not specified by the company that included it.

Table 4: Requirements and Preferences of Companies in Recruitment.

TABLE 5

Professors	17
Associate Professors and Readers	18
Senior Lecturers and Senior Fellows	55
Lecturers and Fellows	34
Demonstrators, Tutors, Teaching Fellows	51
Research Fellows	7
Research Assistants	20
Total	202

Table 5: Totals of professional staff in geoscience departments of Australian universities, 1967.

TABLE 6

FIELD OF EXPERIENCE

Years experience	Present university	Other Aust. university	Total uni. in Aust.	Overseas university	Total universities	Other research inst., Aust.	Other research inst., overseas	Total, other research inst.	Government	Industry	Other	Total extra-university	Total professional
Less than 1	5		2		1				2	1			
1	16	4	10	11	6	2	8	9	5	8		13	1
2	15	5	15	10	10	5	4	7	8	10	5	15	4
3	7	5	4	5	1	2	6	10	12	6	2	19	3
4	9	2	7	6	8	1	2	3	7	4	1	9	7
5	11	2	11	-	13	2	2	4	4	4		6	5
6	8	6	9	2	8	1	1	2	2	3	2	5	8
7	13	2	14	-	12		-		2	2		7	5
8	6	1	6	3	7		1	1	2	3	1	6	6
9	10	1	11	1	12				3	-		3	5
10	7	1	9	1	8				-	1		2	7
11	4	-	5	1	10				3	-		1	4
12	3	1	2	-	3				-	2		2	9
13	6	2	5	-	5				-			-	7
14	3	-	3	-	6				1		1	4	5
15	4	2	6	1	7				-	2		1	4
16	6	-	6	-	7				1		1	1	11
17	1	-	2	-	2				2			3	7
18	1	-	1	-	-							3	4
19	1	-	3	-	3							1	4
20	3	-	3	-	3							1	7
21	1	-	3	-	2								3
22	1	-	1	-	1							1	2
23	1	-	1	-	1								5
24	-	-	-	-	-								1
25	-	-	-	-	-								1
26	1	-	1	-	1				1				3
27	-	1	-	-	-								1
28	-	-	1	-	1								1
29	1	-	1	-	1								2
30	-	-	1	-	2								1
31	-	-	1	-	1								
32	-	-	-	-	-								2
33				1									2
34	1		1	1									2
35													2
36													1
37													1
40													1
44													1

Table 6: Numbers of university staff with experience in various fields of employment

Explanation of Table: e.g. against '15 years', one can read that: 4 people have spent 15 years each at their present University; 2 have spent 15 years at other Universities; 6 have spent 15 years at

(Table 6, Explanation of Table cont.)

Australian Universities (the fact that this happens to be the numerical sum of 4 and 2 is purely coincidental: the 6 has no traceable relationship to the earlier figures); 1 has spent 15 years at oversea Universities; 7 have spent 15 years at Universities in general; 2 have spent 15 years in industry, and 1 has 15 years extra-University experience. Finally, 4 staff members of Australian Universities have 15 years' professional experience, in whatever field.