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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

COMPILATION AND REVIEW OF THE GEOPHYSICS OF THE BONAPARTE GULF BASIN, 1962.

VOLUME 1. PARTS I to IV. (TEXT).

PART 1 of 11

by

A.L. Bigg-Wither.

5928/65

COMPILATION AND REVIEW

OF THE GEOPHYSICS

OF THE BONAPARTE GULF BASIN

by A. L. Bigg-Wither

Record No. 1963/165

ABSTRACT

During the collation of data on the geophysical surveys conducted in the Bonaparte Gulf Basin, the common use of arbitrary datums and the lack of ties between the various surveys became apparent. An examination of available reports also showed that very little data had been presented with the reports.

To enable an assessment to be made of the geophysical reports, most of the available data was collected (and is now available from the Bureau of Mineral Resources, Canberra). The reviews of the various surveys were conducted when the data became available; these were finally assembled as follows:

(1) Volume I deals with the various gravity surveys. The datums used, (level, horizontal, and gravity), methods of survey (topographic and gravity), togographic and gravity ties to other surveys, the data available, and principal observations for each survey are given. For convenience of description and assembling of data, the section is divided into four parts.

(2) Volume II contains extracts and summaries from each of the seismic surveys conducted up to 1963. Descriptions cover objects of the surveys, survey details, discussion of results, identification of reflectors and refractors, results, and conclusions.

(3) Volume III is a discussion of the relationship between gravity profiles and known surface geology, and subsurface structure suggested by the seismic surveys. Some results of aeromagnetic surveys in the region are also briefly described.

Volumes I to III form the text of the report; Volume IV contains the Plates. For convenience, Volume IV is also broken up into four parts:

Parts 2 to 3 to accompany Volumes I to III

Part 4 is a set of miscellaneous plates.

Because of the large number of plates, only a limited number have been printed. The originals, however, will be stored by the Bureau, and further sets may be printed on request. Likewise, only a limited number of the appendices (which list the actual data) will be distributed, but additional sets could be made available on request.

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INTRODUCTION

Several gravity surveys, by the Bureau of Mineral Resources and private companies have been carried out in the Bonaparte Gulf Basin since 1955. Most of these surveys were carried out as independent projects using arbitrary values as datums for the level and gravity surveys. As most of the Bonaparte Gulf Basin will eventually be surveyed it is essential, if the various surveys are to be integrated, that all observed gravity values and altitude values be as accurate as possible in the absolute as well as the relative sense. This requires that each survey be tied to one of the Pendulum stations in the area or to stations of earlier surveys which have been reliably tied to the Pendulum stations. For ~~for~~ The topographic survey, ties should be made to bench marks for level control and to astronomical, Laplace or triangulation stations for horizontal control either directly or to stations of earlier surveys which have reliable ties to these stations.

The reports which have been put out on the various gravity surveys in the Bonaparte Gulf Basin do not give sufficient information to enable a recompilation to be made, without further research into the files of the B.M.R. and of private companies and into the field sheets of the level and gravity surveys.

One of the most important omissions has been the recording of precisely how each compilation was carried out. Where two or more surveys have been integrated, loop closure errors have been distributed around loops, and the Bouguer Anomaly Map, and/or table of principal facts, give only the adjusted Bouguer Anomaly values; the actual adjustments are rarely shown.

In this compilation, the data presented for the various surveys have been taken directly from field sheets whenever these could be obtained; otherwise the computation sheets or table of principal facts are given. The data for each survey are given in appendices following brief summaries of the surveys which include:

Datums used
Methods of Survey
Topographic and gravity ties to earlier surveys.
Topographic and gravity ties to later surveys.
Survey data available.
Principal observations.
Other important survey details.

Other data, in the form of surface control maps, which may be useful for a gravity compilation are given in Part 4 of Volume 4 (Plates).

GEOPHYSICAL HISTORY (GRAVITY)

1. BUREAU OF MINERAL RESOURCES SURVEY 1950

The first gravity readings taken in the area were the observations made by the Bureau of Mineral Resources in October 1950 using invar pendulums on loan from the Department of Geodesy of Cambridge University in the course of establishing a basic gravity network for Australia during 1950-51 (Dooley et al 1961). The mean period and gravity values obtained at Footscray and at pendulum stations around the area are given below:-

Number	Station	Date	Mean Period 2(X10-7 sec)	Observed Gravity (Milligals)	- Z (gauss)	Magnetic Correction	Corrected Gravity (Milligals)	Standard Error
1 (BASE)	Melbourne (Footscray)	1950-51	5,057,763.9	979,979.0	.57	0	979,979.0	..
29	Hall's Creek	4.10.50	5,061,683.2	462.0	.38	-0.6	461.4	0.6
30	Wyndham	9.10.50	5,061,800.4	416.7	.34	-0.8	415.9	0.7
31	Victoria River Downs	16.10.50	5,061,777.2	425.6	.35	-0.7	424.9	0.5
32	Darwin	23.10.50	5,062,053.8	316.4	.29	-0.9	315.5	0.5
33	Daly Waters.	28.10.50	5,061,871.2	389.3	.35	-0.7	388.6	0.5

These values are relative to the National Gravity Base station value established at the Geophysical Laboratory of the Bureau of Mineral Resources, Geology & Geophysics, at Gordon Street, Footscray.*

Plans showing the exact location of the pendulum stations and brief descriptions of the stations in and around the area are given on page 2 and 3.

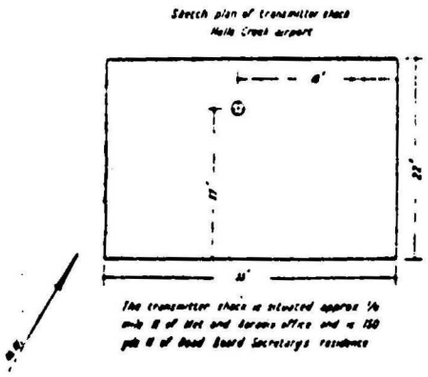
Methods of determining the co-ordinates of the pendulum stations are given below.

METHODS OF DETERMINING CO-ORDINATES OF STATIONS

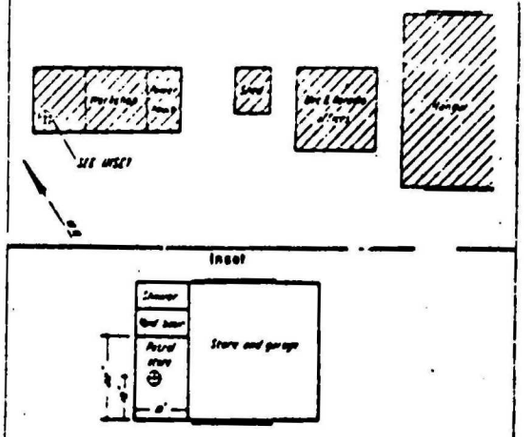
1.	Melbourne	Scaled from 1 inch = 1 mile military map.
29.	Halls Creek	Astro-fix determination made.
30.	Wyndham	From astro-fix at aerodrome latitude checked by observations.
31.	Victoria River Downs	Co-ordinates supplied by National Mapping Division from astro-fix.
32.	Darwin	From aerodrome control tower astro-fix. Very accurate.
33.	Daly Waters	Astro-fix determination made.

* The observed gravity at Footscray was determined by comparison of the periods at Footscray and at Pendulum House, Cambridge, England.

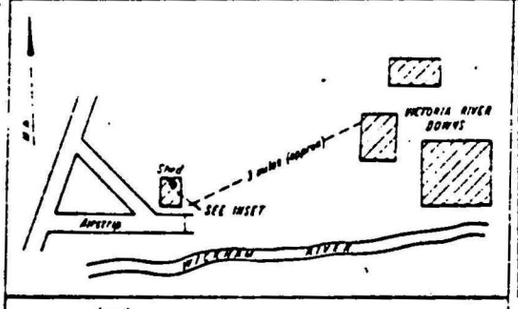
Fig 1

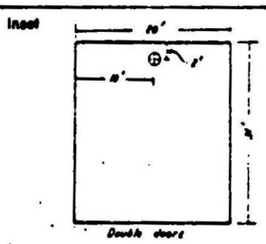


No. 29, HALLS CREEK, W.A.
AERODROME

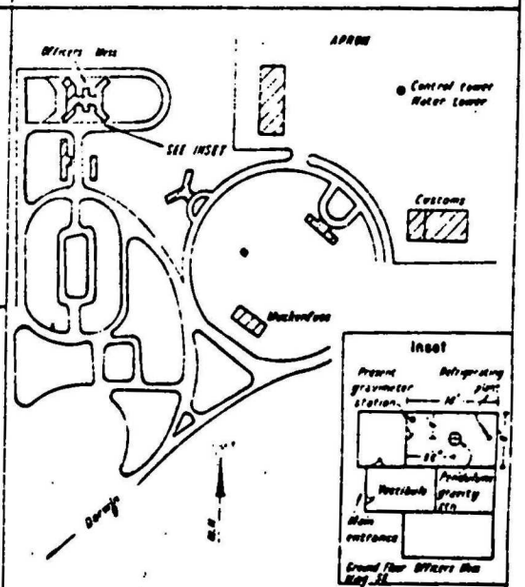


No. 30, WYNDHAM, W.A.
AERODROME

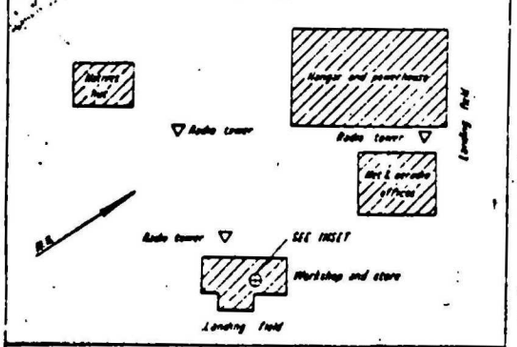


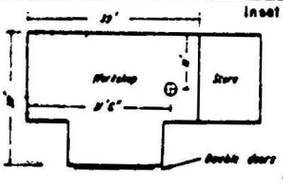


No. 31, VICTORIA RIVER DOWNS, N.T.
CATTLE STATION HOMESTEAD

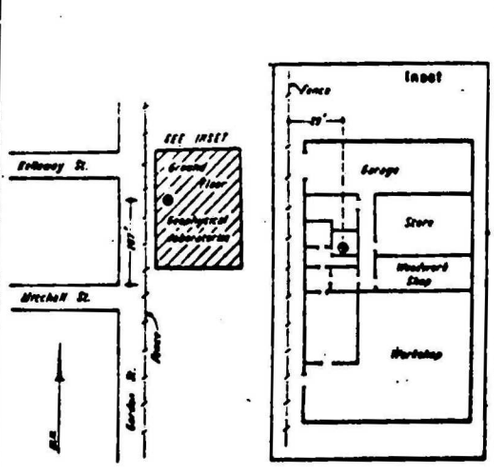


No. 32, DARWIN, N.T.
AIRPORT





No. 33, DALY WATERS, N.T.
AERODROME



No. 1, FOOTSCRAY, VIC.
NATIONAL GRAVITY BASE
GEOPHYSICAL LABORATORY

BRIEF DESCRIPTIONS OF PENDULUM STATIONS

1.	Melbourne, Vic.	In the Geophysical Laboratories of the Bureau of Mineral Resources, Geology and Geophysics, Gordon Street, Footscray.
29.	Halls Creek, W.A.	In the transmitter shack, 150 yards north of Road Board Secretary's residence.
30.	Wyndham, W.A.	In the petrol store at the aerodrome.
31.	Victoria Rivers Downs, N.T.	In a shed at the aerodrome.
32.	Darwin, N.T.	In the photographic room near the Officers' Mess at the aerodrome.
33.	Daly Waters, N.T.	In a workshop at the aerodrome.

The Pendulum Station values given ~~above~~ on page 1 were revised by the B.M.R. in 1961. The revised values of the Pendulum Stations are given below:-

1961 Revised Pendulum Values

Number	Station	Observed Gravity (milligals)	Standard Error	Adj. to Previous Value (1957)
1	Melbourne	979,979.0	Datum	0
29	Hall's Creek	978 ~~798~~,463.0	.5	+1.6
30	Wyndham	978,415.0	.3	- .9
31	Victoria River Downs	978,424.6	.5	- .3
32	Darwin	978,316.2	.1	+ .7
33	Daly Waters	978,388.5	.2	- .1

Refer to folio 70 B.M.R. file 35/G/1, Part B 13 for method employed in readjustment of the Pendulum values.

2. KEEP RIVER SURVEY

The first gravity survey in the search for oil in the Bonaparte Gulf Basin was carried out by Mr. J.P. McGilvray of Mines Administration Pty Ltd (Minad), for Associated Australian Oilfields and Westralian Oil Ltd, in the Keep River Area in 1955.

It covered the Keep River flats east of the N.T./W.A. border and consisted of 355 gravity stations mostly at ½ mile intervals along surveyed lines. In addition, a reconnaissance traverse of limited extent was run north of traverse 6 (see Plate 9).

A description of this survey and the interpretation of the gravity data is given in the report:-

"Geological and Geophysical Report in the Keep River Area, Bonaparte Gulf Basin, 1955" by Glover, J.J., Richardson, L.A. and McGilvray, J.P., - Minad. Report N.T./B.G./20. The survey details given below were obtained mainly from the above report and partly from the following sources:-

1) Department of National Mapping, Canberra.
2) Department of the Interior, Western Australia.
3) From reports of Surveys which tied in to the Keep River Survey.
4) Bureau of Mineral Resources' Files.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels:- Peg 60 M.N. of the N.T./W.A. Border Survey where a height of 200 feet above mean sea level was assumed.
2. Horizontal:- Based on a second order geodetic survey of the N.T./W.A. Border by Messrs. H.C. Barclay and S.J. Stokes of the Department of Lands and Survey (W.A.) between April and July 1937.* The datum used was mile post 60 M.N.** of the Border Survey. The nearest latitude determination to Peg 60 M.N. by Barclay and Stokes was at No.3 Observing Station where a latitude of 15°23'42.44" south was obtained. This observing station is 1835.8 links south of peg 56 M.N. The latitude of peg 60 M.N. was calculated to be 15°20'02" by scaling off from this station. An arbitrary value of 200,000 yards east of Greenwich and 200,000 yards south of

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* Plans of the Survey of the 129th Meridian (King District) can be obtained from 1. Department of Lands and Survey, W.A.
2. Department of National Mapping, Canberra, A.C.T.
See page for important details regarding these plans.

** The stations along the Border Surveys will be indicated with a suffix M.N. to denote the number of miles north of a monolith at latitude 16°12'25" south.

the equator was assumed to be the co-ordinates of peg 60 M.N. See Plate 9 and Appendix B pages 1 to 18.

3. Gravity:- Peg 60 M.N. of the N.T./W.A. Border Survey where the observed gravity was assumed to be the theoretical gravity for latitude 15°20'02" South = (978.40920 gals). *

B. METHOD OF SURVEY

1. Topographic. (Mr. T. Seaton, Authorised Surveyor, now with the Department of National Mapping carried out the survey).

1. (a) Chaining & Levelling. Traverse 1, 1A (Border) 2, 6 (to Station 612), 1W and 2W. Estimated accuracy 1 ft/mile.

(b) Tangential Method. Traverse 3,4,5,6 (Stations 612-622), and 3W. Estimated accuracy 5 ft/mile.

(c) Aerial Photographs. The position of the reconnaissance traverse to the north of traverse 6 was fixed by aerial photographs, the scale of the particular photos used being determined by astrofixes. Elevations were based on gradients measured in the area (mud flats) and assumed constant over the whole area.

2. Loop Closure:-

(a) Level. Traverse 3 (stations 317) and traverse 4 were closed to traverse 2 (station 222) and traverse 4 (station 413) and traverse 5 were closed to traverse 3 (station 334) and elevations adjusted accordingly.

(b) Horizontal. Errors in position did not warrant adjustment.

11 Gravity

1. Worden Gravity Meter No. W.216 with an instrument scale value (maker's) of 0.09095 milligals per division was used. Drift control was obtained by returning to intermediate base stations within the hour.
2. Elevation Factor:- A density of 2.1 gms/cc was used for the Bouguer reduction. This density was determined from two "Density Profiles" run over small sandstone hills- the sandstone being characteristic of sandstones found in the area.
3. Latitude Correction:- Latitude corrections were calculated using the International Ellipsoid formula.
4. Loop Closure:- No opportunity presented itself for the closing of the gravity field traverses.
5. Permanently marked stations:- Cedar stakes were used to mark all stations.

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* This figure is given in the Minad report on the Keep River. The computation sheets show, however that 978.40921 ~~milli~~gals was used for the reduction of the gravity data.

C. TOPOGRAPHIC TIES TO OTHER SURVEYS

(a) Level:- At the time of the survey there were no other surveys carried out in the area to which a level tie could be made and the survey was based on 60 M.N. post of the Border Survey for which a height of 200 feet was assumed.

(b) Horizontal:- The survey used 60 M.N. post of the Border Survey as datum for the survey and border posts 49 M.N. to 55 M.N. and 59 M.N. to 78½ M.N. at ½ mile intervals for horizontal control.

Since this survey was carried out, four other surveys have been tied in to it:-

1 (a) Level:- The first level tie was by the Bureau of Mineral Resources in July, 1956. The tie was between G.21 and 55 M.N. post of the Border Survey. G.F. Clarke of the Bureau, commenced the survey at Station G.1 assuming it to be at mean sea level, took level readings using Askania microbarometers between G.1 and G.21 and tied in to 55 M.N. post of the Border Survey (Minad. Station). A full analysis of the level tie is given under "Bureau of Mineral Resources Survey, July 1956" Vol. 1, Pt. 2)

(b) Horizontal:- The positions of the Stations G 1 to G.21 were plotted from aerial photographs and no bearings and distances between successive stations and between G.21 and 55 M.N. were taken.

2 Level:- The second survey to tie in to the Keep River Survey was the Bureau's survey during September and October, 1956. (See page)

a) Three level ties were made:-

(i) From S.P. 319 on traverse 'A', Spirit Hill, to 50 M.N. post of the Border Survey (Minad Station). (S.P.319 was in turn tied to a bench mark near Kimberley Research Station).

(ii) The second level tie was between S.P. 177 on traverse 'A', Ninbing and 74 M.N. post of the Border Survey.

(iii) Stations G.17 to G.21 surveyed by the Bureau using microbarometers during July 1956, were optically levelled between September and October 1956. G.21 was then tied in to S.S.29 on the Border (Minad Station).

(b) Horizontal:- Horizontal ties to the Keep River Survey were:-

(i) From traverse 'A' Ninbing to 73 M.N. and 74 M.N. posts of the Border Survey (Minad Stations).

(ii) From traverse 'A' Spirit Hill to 49 M.N. and 50 M.N. posts of the Border Survey (Minad Stations).

(iii) From traverse 'B' (Milligan's Lagoon) to 37 M.N. and 38 M.N. posts of the Border Survey - Indirect tie to Minad Stations to the north via the Border Survey. (A full analysis of the level and horizontal ties is given under "Bureau of Mineral Resources Survey, September - October 1956". Vol. 1 Pt. 2

3 The third survey to tie in to the Keep River Survey was the Daly River to Pelican Island coastal reconnaissance survey carried out by Mines Administration Pty Ltd, for Associated Australian Oilfields N.L. in 1957. (Vol. 1 Pt.3).

(a) Level:- The level tie was between K 10 of the Coastal Survey and Station 214 of the Keep River Survey, at the mouth of the Keep River.

(b) Horizontal:- The stations of the Coastal Survey were plotted from aerial photographs and no bearings and distances were taken between successive stations. Station 214 was not positively identified and its reoccupation was only approximate. (A full analysis of the ties is given under "Daly River - Pelican Island Coastal Reconnaissance Survey, 1957" Vol.1, Pt.3).

4 The fourth survey to tie in to the Keep River Survey was the Carlton Gravity Survey between July and November 1961. (Vol. Pt. 4).

(a) Level:- Although five traverses of this survey were within a mile of the Border not one level tie was made to the Border Survey or to the Keep River Survey.*

(b) Horizontal:- Control ties were made from:-

(i) Station N.A to S.S.29 (Minad Station).

(ii) Station E.M. 44 to border mile post 61 M.N.

(iii) Station E.I. 41 to border mile post 74 M.N.

The accuracy of the horizontal survey is considered to be within five feet in one thousand. (A full account of the tie is given under Carlton Gravity Survey, Vol. 1 Pt.4)

E. OTHER IMPORTANT DETAILS OF SURVEY

Gravity and level readings were taken at ½ mile intervals along posts of the N.T./W.A. Border Survey from mile post 60 M.N. to 78½ M.N. and from mile post 49 M.N. to 55 M.N. No gravity readings appear to have been taken between mile post 55 M.N. and mile post 60 M.N. Level readings must have been taken between

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* A helicopter survey is to be carried out by the Bureau in 1966 in the Bonaparte Gulf Area. It should be possible to tie the traverses to the Border Survey and to the nearest Minad Stations during this survey.

49 M.N. and 55 M.N.; however, the positions of the stations between these two mile posts at which levels were read are not shown on the map. The nature of the gravity tie between these two mile posts is also unknown at present.

F. SURVEY DATA AVAILABLE

I GRAVITY.

1. Field Sheets. Appendix 'A' Page 1 to 20.

2. Computation Sheets. Appendix 'B' Page 1 to 18.

Note:- (1) The 2nd and 3rd columns refer to the co-ordinates of the station in terms of the number of yards south of the equator and east of Greenwich respectively. These co-ordinates are relative to an assumed arbitrary value for Peg 60 M.N. of the Border Survey, of 200,000 yards south of the equator and 200,000 yards east of Greenwich.

(2) Two sets of level data are given. The first set under "Reduced Levels" refers to heights of stations relative to Peg 60 M.N. where a value of 200 feet above mean sea level was assumed.

(3) From rod levels obtained in the northern parts of the area, along the banks of the Keep River, it became obvious that the assumed height of 200 feet for Peg 60 M.N. was about 70 feet too high, hence the second set of level data has 70 feet subtracted from the first set. The Bouguer anomaly values are thus based on a value believed to be relative to mean sea level and are only approximate.

II TOPOGRAPHIC

1. Field Sheets:- Cannot be located by Minad.

2. Table of Principal facts:- Appendix 'D' Page 1-8 (Giving station no., bearing distance in feet and elevations).

G. PRINCIPAL OBSERVATIONS

The principal anomaly feature observed was that of a gravity low extending north from the southernmost part of the area surveyed. (See Plate 9).

Glover et al point out that, as the structure is believed to be a sedimentary basin comprised of early Palaeozoic rocks resting unconformably on a basement complex of older rocks, it is possible that the low could be due to the variation in thickness of a suite of rocks of low density overlying rocks of greater density. However, they believe that as only rocks of mature age are concerned, it is likely that the density contrast involved would be small. If so, the thickness of the presumed low density sediments could be substantial at parts where the gravity low has greatest magnitude, (i.e.) at the northern parts of the area surveyed.

While they hold the view that the gravity anomaly distribution could be related to Basin configuration they suggested seismic surveys at selected positions to confirm this.

GRAVITY TIES TO EARLIER SURVEYS

At the time of the survey there were no other surveys carried out in the area to which this survey could be tied.

GRAVITY TIES FROM LATER SURVEYS

Since this survey was carried out three other surveys have been tied to it.

i) The first survey to tie to the Keep River Survey was the B.M.R. Survey by Clarke in July 1956 (See Vol.1 part 2). Station G1 of Clarke's survey was tied to Wyndham Pendulum Station and station G1 to G21 near the border were read. G21 was then tied to 55 M.N. post on the border. Calculation of the tie between G21 and 55 M.N. post (see Vol1, part 2 of Clarke's survey) showed that the observed gravity value at G21 was 0.67 milligals higher than at 55 M.N.

The value of observed gravity at G21 obtained by a tie to Wyndham Pendulum Station was 978397.55 milligals. The absolute observed gravity value at 55 M.N. is therefore 978396.88.

The observed gravity value at Station 55 M.N. post on the border was found by Minad to be 978419.25 milligals, based on an assumed value of 978409.20 milligals at station 60 M.N. post of the Border Survey (Minad Datum).

Hence the assumed gravity value at 55 M.N. is 22.37 milligals too high. It is pointed out (see Vol.1 Part 2) that during Clarke's survey the tie between G1 and Wyndham pendulum station had been miscalculated and the value at G1 should have been .49 milligals higher.

Thus the correct absolute observed gravity values at station G1, 55 M.N. and 60 M.N. should be -

1. G21 978398.04 milligals.
2. 55 M.N. 978397.37 milligals.
3. 60 M.N. 978387.32 milligals.

ii) The second survey to tie in to the Keep River Survey was the B.M.R.'s survey during September and October, 1956 (see Vol.1, Part 2).

The tie was between S.P.319 on B.M.R. traverse 'A' Spirit Hill to 50 M.N. post of the Border Survey (Minad Station).

B.M.R. Traverse 'A' Ninbing was to have been tied, like the level survey, to 74 M.N. post on the border. Unfortunately the gravitimeter became unserviceable just before a reading could be taken.

iii) The third survey to tie in to the Keep River Survey was the Daly River to Pelican Island coastal reconnaissance survey carried out by Mines Administration Pty Ltd, for Associated Australian Oilfields N.L. in 1957 (Vol.1, Part 3). The tie between station K10 of the coastal survey and station 214 of the Keep River Survey, at the mouth of the Keep River.

IMPORTANT DETAILS REGARDING SURVEY PLANS OF THE 129 MERIDIAN

The plans of the survey of the 129 meridian (King District) are given in Vol. IV Pt.4 plates 75 and 76 . A careful study of these plates should be made before commencing any surveys in the area for the following reasons:-

1. Distances between mile posts of the Border Survey are generally 800 links (1 mile) apart, but there are a few that are greater or less than one mile.
2. In a reference at the base of each plan, station numbers are given along with the manner in which they were marked e.g. G 1 tube put in with copper plate on top, Rock cairn built over tube and plate, etc.
3. A mile post with mileage marked thereon need not necessarily represent the actual number of miles north, e.g. at station 31 M.N. a post with the mileage marked thereon was put in 10 links to the north.
4. Latitudes were determined at several stations not necessarily coincident with the mile posts of the Border Survey and their positions and latitude are given on the map.

On plan Corr: 8550/02 of the Department of National Mapping (which is a copy of the Department of Lands and Survey Plan L & S (W.A.) O.P.5518) positions of mile posts 47 M.N. to 78½ M.N. are given. Latitudes were observed at three stations between these mile posts.

1. No.3 observing station Nth=Latitude 15°23'44" Sth. This station is about ¼ of a mile south of 56 M.N.
2. No.4 observing station Nth=Latitude 15°11'6.12" Sth. This station is about ¼ of a mile north of mile post 70 M.N.
3. No.5 observing station Nth=Latitude 15°4'22.98" Sth. This station is coincident with mile post 78 M.N.

on plan Misc. 2483 of the Department of National Mapping (which is a copy of the Department of Lands & Survey plan L & S (W.A.) O.P. 5517) the position of mile posts 17 M.N. to 47 M.N. are given. Latitude readings were taken at one station between these mile posts.

1. No.2 observing station Nth=Latitude 15°40'40.77" Sth. This station is about 1½ miles north of Mile Post 36 M.N. of the Border Survey.

3. BUREAU OF MINERAL RESOURCES SURVEY, JULY 1956

In July 1956 G.F. Clarke of the Bureau of Mineral Resources (B.M.R.) carried out a gravity survey between Station G1 near Carlton Hill Station and G21 near the N.T./W.A. border. Readings were also taken at ½ mile intervals (every second seismic shot point) along seismic traverse 'A' Ninbing from S.P. 1 to S.P. 53. Ties were also made between station G21 and 55 M.N. post of the Border Survey and between S.P. 1 of seismic traverse 'A' Ninbing and station G8. See Vol IV Part IV, Plate 84.

This survey is described in the B.M.R. Record "Report on a gravity survey in the Bonaparte Gulf Basin 1956-1958" Records 1959/20 by R.F. Thyer, P.M. Stott and F.J.G. Neumann.

In the above report the data from this survey along with the survey by P.M. Stott of the B.M.R. between September and October 1956 (see later) has been tied to and integrated with the following surveys.

1. The Keep River Gravity Survey 1955 (see Vol. 1, Part 1).
2. The Central Burt Range Gravity Survey 1957 (see Vol 4, Pt.3).
3. The underwater gravity survey carried out by the Bureau in the coastal waters from Lacrosse Island to Queen's Channel and in the east and west arms of the Cambridge Gulf in July, 1958 (see Vol. 1, Pt.3).

The data from Clarke's survey will be found incorporated in the Bouguer anomaly map, plate 2, of Thyer et al. The map is reproduced in plate 11 of this compilation. (See Vol. IV, Part 1).

The survey details given below were obtained mainly from Thyer, et al. and also the surveyor's field books, the gravity field sheets, the Bureau's files, and from discussions with G.F. Clarke.

A. DATUMS FOR SURVEY

1. Level: Station G1 which was assumed to be at mean sea level.
2. Horizontal: a) For stations G1 to G21 positions were located using aerial photographs.
   b) S.P.1 to S.P.53 of traverse 'A' Ninbing used 74 M.N. post of the Border Survey as datum for horizontal control.
3. Gravity: Bureau of Mineral Resources Pendulum Station No.30 at Wyndham which has a value of 978415.9 (0) milligals.

B. METHOD OF SURVEY

I. TOPOGRAPHIC

1. (a) The levelling between Stations G1 and G21 and thence to 55 M.N. post of the Border Survey (Minad Station) was carried out using Askania microbarometers 531308 and 531333.

The method used was for one microbarometer to remain at base while the other was read at several stations and returned to base within the hour. Drift curves were then drawn up and the elevations calculated using calibration charts to convert pressure readings (torrs) to feet and to correct the results for temperature.

b) S.P.1 to S.P.53 of Seismic traverse 'A' Ninbing were levelled optically. Bearings and distances between successive shot points were also measured and a horizontal tie made in October 1956 (see later) to 74 M.N. post of the Border Survey.

2. Loop Closure: The traverses were not looped.

II. GRAVITY:

1. A heiland 53 with a sensitivity of 0.08706 milligals per scale division was used. The leap frog method of surveying was used, a return to sub-base stations being made within the hour.
2. Loop Closure: The traverses were not looped.
3. Permanently marked Stations:
   G1 is in the home paddock of Carlton Hill Station and is blazed on a large gum tree with the letter G1 painted in white or marked with a metal tag. G21 west of border peg 55 M.N. is either a 2" x 2"x1 foot wooden peg labelled with a metal tag or is blazed on a tree and G21 painted in white thereon. G8 is at or near a road junction marked with a 2" x 2" x 12" stake with a metal tag or blazed on a tree and G8 painted thereon. To the east of G8 is a 50 feet high conglomerate outcrop. The country is open and suitable for a helicopter to land.
   All the other stations were either marked with 2" x 2" x 12" stakes labelled with metal tags or blazed on trees with the station numbers marked in white thereon. The wooden stakes will probably have rotted by now.

C. TOPOGRAPHIC TIES TO EARLIER SURVEYS

There was no topographic tie between Station G1 and Wyndham. Station G21 just west of the border was tied to Mines Administration Pty Ltd's station: 55 M.N. post of the Border Survey.

Station G1 was assumed to be at mean sea level. Elevations given in Appendix C (see page 7) for stations G1 to G21 and for 55 M.N. post of the Border Survey are with respect to G1 as datum. The elevation obtained at 55 M.N. post of the Border Survey was 26.7 ft.

The elevation obtained by Minad during the Keep River Survey for 55 M.N. was 126.7 ft with respect to an assumed height of 200 ft at 60 M.N. post of the Border Survey. The elevations of Stations G1 to G21 and 55 M.N. are given on page 8 Appendix C with respect to Minad Datum at 60 M.N.

During the B.M.R.'s survey (Sept/Oct, 1956) a tie from station P4 to a bench mark near Kimberley Research Station showed that the assumed height of 200 ft at 60 M.N. was too high by 78.6 ft. The value of 101.48 ft taken as the height of the bench mark was thought at the time to be with respect to Low Water Mark, Wyndham.*

The elevations of stations with respect to the bench mark near Kimberley Research Station are also in Appendix C.

D. TOPOGRAPHIC TIES FROM LATER SURVEYS

Since this survey was carried out, three other Surveys have been tied to it. The stations between which the ties were carried out are given below. Full analysis of the ties are given when discussing the surveys during which the ties were carried out.

1. The first survey to tie to this survey was the Bureau of Mineral Resources' Survey, September/October, 1956 by P.M. Stott (see later). Four ties were made.

a) The first tie was from Station P15 of Stott's survey to stations G17 and G18 of Clarke's survey. In addition stations G17 to G21 surveyed by G.F. Clarke in July 1956 using mirco-barometers were relevelled optically during Stott's survey. However, whereas G21 was tied to 55 M.N. post of the Border Survey, during Clarke's survey it was tied to S.S29 on the border, 2800 links north of 55 M.N. during Stott's survey. On comparing the elevations obtained for stations G17 to G21 by optical levelling with those obtained by using microbarometers, it is seen that errors of as much as 6.7 ft occur (see Appendix C Stott's Survey).Station P15 of Stott's survey was in turn tied to a bench mark at Kimberley Research Station near Station P4.

b) The Carlton traverse G1 to G21 was extended to the south in October 1956. Stott's survey began at G1 and was continued along the highway to the 35-mile post and stations G31 to G35 were read at 2 mile intervals. The survey then proceeded east along the Carlton Crossing - Ivanhoe highway traverse and every 4th mile post was read from 35M to 55M. The stations G31 to G35 and 35M to 55M were levelled using microbarometers.

c) The third tie was between stations 35M and 55M which were levelled using microbarometers, and the 'P' Stations (Stations P1-P15) which were optically levelled.

The tie was made between Station 55M and Station P1 using

d) A gravity tie was made between S.P.73 on traverse 'A' Ninbing and Station G8 of the Carlton traverse via stations N1, N2 and N3. The levels of these stations were obtained using

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* A recent survey has shown that the value of 101.48 ft taken as the height of the bench mark is 25.1 ft too low (see Vol.1, Part IV).

microbarometers. During the barometric level tie between S.P.73 and Station G8 via stations N1, N2 and N3 a height of 242 ft was obtained for G8.

When a recompilation is attempted it is suggested that gravity stations N1 - N3 be ignored. The elevations obtained for them using microbarometers are suspect for the following reasons.

During Stott's survey (see later) two runs were made using microbarometers between S.P.75 on traverse 'A' Ninbing and station G8 on the Carlton traverse. A height of 198 ft was obtained for G8. A discrepancy of 44 ft. Possible sources of error are a) Fault in barometers b) Excessive temperatures or c) Atmospheric disturbances.

In July 1956, optical levelling was also carried out between S.P.75 on traverse A and station G8, but unfortunately did not include the stations N1 to N3. Commencing with a height of *233.54 ft at S.P.75 a height of 252.68 ft was obtained at station G8.

2. The second survey to tie in to Clarke's survey was the Bonaparte Gulf Gravity Survey in September, 1959 by Mines Administration Pty Ltd for Gulf Oil Syndicate (see Vol.1, Pt. IV). Two ties were made from the Bonaparte Gulf Gravity Survey to Clarke's survey and one traverse came to within 4 miles of Clarke's survey.

a) The first tie was from Station 50 of the Bonaparte Gulf Survey, about 4 miles southwest of Ninbing, to S.P.1 on traverse 'A' Ninbing of Clarke's survey.

b) From Station 200 to Station 2 of the Bonaparte Gulf Survey via S.P.35** traverse 'A' Ninbing' of Clarke's survey.

c) Station 262 of the Bonaparte Gulf Survey, at its south-central limit, (see plate 84) is within 4 miles of Stations G12, G13 and G14 of Clarke's survey. If further surveys are to be carried out in the area it will be useful to remember that apart from Stations G17 to G21 of Clarke's survey which were optically re-levelled in October 1956 the remaining stations of Clarke's and Stott's surveys between July and October, 1956 viz G1 to G17, G31 to G35 and 'M' stations 35M to 55M all have microbarometric levels.

A very useful tie traverse would be obtained if stations G8 to G17 were optically levelled and station 262 of the Bonaparte Gulf Survey tied to G12, 13 or 14 of Clarke's survey. As pointed out above S.P.75 on traverse 'A' Ninbing was tied to G8 of Clarke's survey. Thus if a tie is made between station 262 and G8 via G11, 12 or 13 it would result in a second tie to traverse 'A' Ninbing and form a closed loop.

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* Level Datum 250 ft (assumed) at S.P.1 on traverse 'A' Ninbing. It is 195.38 ft with respect to a height of 101.48 ft at bench mark near Kimberley Research Station.

** S.P.35 of traverse 'A' Ninbing is the same station as Station No.1 of the Bonaparte Gulf Gravity Survey.

3. The third survey to tie in to Clarke's survey was the Carlton Gravity Survey by International Resources Survey Inc. Tulsa, Oklahoma for Oil Development N.L. (see Vol.1, Pt.IV)(The topographic survey was carried out under the direction of R. Hare and Associates of Melbourne, Victoria).

The tie was between Public Works Department Bench Mark A.R.38, about $7\frac{1}{4}$ miles N.N.E. of Kimberley Research Station, and S.P.1 of traverse 'A' Ninbing.

Several other stations of the Carlton Gravity Survey came within two miles of Clarke's survey. No mention however, is made in the report on the Carlton Gravity Survey of level ties to any stations of Clarke's Survey.

E. GRAVITY TIES TO PREVIOUS SURVEYS

Station G1 was tied to the Bureau of Mineral Resources Pendulum Station No.30 at Wyndham. Station G21 was also tied to 55 M.N. post of the border survey (Minad Station - Keep River Survey). S.P.1 on Traverse 'A' Ninbing was tied to Station G8 on the Carlton traverse.

1. Wyndham Pendulem Station - G1 Tie (Gravity)

The tie to Wyndham was made on the 23rd July 1956. The figures given below are from field Sheet No. 8008 - (see Appendix A page 2).

Station	Time	Reading
G1	10.15 a.m.	86.0
Wyndham Pend. St.	11.57 a.m.	56.2
	12.03 p.m.	56.1
G1	13.39 p.m.	84.5

The drift over 3 hours 24 minutes was 1.5 divisions which gives .131 milligals using the scale factor of .08706 milligals per scale division. The drift for the average of the two readings at Wyndham is: .772 scale divisions. Calculations give an observed gravity value of 978418.43 milligals for Station G1*, taking the accepted value of the observed gravity at Wyndham Pendulum Station as 978415.9 (0) milligals.

2. Tie Between Station G21 and Mile Post 55M.N. of the Border Survey (Station 55 of Mines Administration Pty Ltd's Keep River Survey

From Field Sheet 8012 (see Appendix A page 2).

G21	12.15 p.m.	361.9	
Minad/AA055	12.49 p.m.	361.2	Tied on 20th July 1956.
G21	13.03 p.m.	362.0	

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* In Records 1959/20 by Thyer, et al, the observed gravity at station G1 is given as 978417.94. This is in error by .49 milligals.

The readings at G21 show a drift of .1 scale divisions or .008706 milliglas over 48 minutes. The drift correction to be applied to 55 M.N. is calculated to be .07 scale divisions. After correcting for drift, calculations give a value of observed gravity for G21, 0.67 milliglas higher than at 55 M.N.

The value of observed gravity at G21 obtained by a tie to Wyndham Pendulum Station was 978397.55 milligals.

The observed gravity at Station 55 M.N. post of the Border Survey was found by Minad to be 978419.25 milligals, based on an assumed value of 978409.20 milligals at Station 60 M.N. post of the Border Survey (Minad datum).

Hence the absolute observed value of gravity at Station 55 M.N. based on a tie to Wyndham Pendulum Station via G21 is 978396.88 milligals and the absolute observed gravity at 60 M.N. is 978386.83 milligals.*

3. Tie Between S.P.1 on Traverse 'A' Ninbing and Station G8

The tie between S.P.1 on traverse 'A' Ninbing and Station G8 was made on 26th July 1956. The figures given below are from field Sheet No. 8019 (see Appendix C

Station	Time	Reading
S.P.1	09.28	226.8
G8	10.52	270.4
S.P.1	12.04	224.5

The average drift over 2 hours 36 minutes was 2.3 scale divisions or .2 of a milligal using the instrument scale factors of .08706 milligals per division. After correcting the reading at G8 for drift (1.24 scale divisions) calculations show that S.P.1 is 3.94 milligals less than Station G8.

The absolute observed gravity at G8 was found to be 978389.41 milligalls by a tie to Station G1, which was in turn tied to Wyndham Pendulum Station. Thus the absolute gravity at S.P.1 is 978385.47 milligals.

The observed gravity given on the computation sheets (see Appendix B, Stott's Survey), for S.P.1 is 978385.58 milligals and is in error by .11 milligals.

Since Clarke's survey was carried out three other gravity surveys have been tied to it.

D. GRAVITY TIES FROM LATER SURVEYS

As the gravity ties were between the same stations as the level ties the reader is referred to 'D' above under "TOPOGRAPHIC TIES FROM LATER SURVEYS". Full analyses of the gravity ties are given when discussing the surveys during which the ties were carried out.

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* These values should have +.49 milligals added to them due to the error in computing the tie between Wyndham Pendulum Station and Station G1.

E. SURVEY DATA

I. TOPOGRAPHIC:-

1. Field Sheets:- (Barometric Survey) in Appendix C, Pages 1 - 6.

2. Computation Sheets. On pages 7 and 8 Appendix 'C' is given the calculation of the levels from the Barometric level survey. The elevation of stations G1 - G21 and 55 M.N. on the border are given in Appendix C page 8.

II GRAVITY

1. Field Sheets:- See Appendix A, pages 1 - 4.
(Data obtained from B.M.R. File No. 56041).

2. Computation Sheets. See Appendix 'B' pages 1 - 4.
(Data obtained from B.M.R. File No. 56042).

Recomputation of Clarke's data will also be found in Appendix 'B' of Stott's Survey obtained from B.M.R. File No. 56044.

BUREAU OF MINERAL RESOURCES SURVEY SEPTEMBER-OCTOBER, 1956

During September and October, 1956 P.M. Stott of the Bureau of Mineral Resources carried out gravity observations along roads and tracks in the north-eastern corner of Western Australia. The area covered by the gravity reconnaissance party in Western Australia lies to the west of the Northern Territory/Western Australia border between 40 miles north and 75 miles north posts of the Border survey and extends westwards to Carlton Crossing on the Ord River, 35 miles from Wyndham. To the east of the border the Spirit Hill area was surveyed. This area is adjacent to the Northern Territory/Western Australian border near latitude 15°30' South. Gravity observations were also made at shot points along seismic traverses, shot by the Bureau in the Ninbing and Spirit Hill Areas (Robertson, ~~46~~ 57)*.

The survey is described in the Bureau Record "Report on a gravity survey in the Bonaparte Gulf Basin 1956-1958" Records 1959/20 by R.F. Thyer, P.M. Stott and F.J.G. Neumann. In the above report the data from this survey along with the previous survey by G.F. Clarke of the Bureau in July 1956 has been tied to and integrated with the following surveys:

1. The Keep River Gravity Survey 1955 (see Vol.1 Part 1)
2. The Burt Range Gravity Survey 1957 (see Vol.1, Part 3)
3. The underwater gravity survey carried out by the Bureau in the coastal waters from Lacrosse Island to Queen's Channel and in the east and west arms of the Cambridge Gulf in July, 1958. (see Vol. ~~II~~ 1, Part 3) The data from ~~Stott's~~ survey will be found incorporated in the Bouguer anomaly map, Plate 2 contained in the above report. This plate is reproduced on Plate 11 of this compilation. The interpretation of this Bouguer anomaly map is given in the above record.

The survey details given below were obtained mainly from the above report and partly from a study of surveyer's field books, gravity field sheets, Bureau's files and from discussions with P.M. Stott.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels: Levels were stated to be based on M.L.W. Wyndham as determined by a tie to a bench mark at Kimberley Research Station near station P4. 101.48 feet was taken as the height

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* The seismic results will be found in Record No. 1957/46 by C. Robertson. Reduced reflection cross-sections from this record are included in this report (see Part 2, Vol.4 Plates 20 ~~and~~ to 22). The location of the seismic traverses is given in Part 2, Vol.4 Plate 19 and a summary of the report will be found in Part 2, Vol.2 of this compilation under "Seismic Compilations" pages 5 to 8.

of this bench mark.

It will be shown later (see under "Topographic ties to later surveys" page 6) that this value is incorrect and is 25.1 feet too low.

2. Horizontal: Datums for the horizontal control are mile posts 56 M.N., 73 M.N., 74 M.N, 49 M.N, 50 M.N., 36 M.N., 37 M.N., 38 M.N., and No.3 observing station 1835.8 links south of 56 M.N. where a latitude of $15^{\circ}23'42.44"$ was obtained by an astrofix during the border survey. See Vol.4, pt.4, plate 75 .

3. Gravity: Observed value of gravity at station G 1 = 978417.94 milligals, based on a tie by G.F. Clarke to Wyndham Pendulum Station. The accepted value of the observed gravity at Wyndham Pendulum Station when the tie was made was 978415.9(0) milligals.

It was pointed out above (Clarke's Survey) that the value given above for G 1 is incorrect. Recalculation of the field data for the tie between Wyndham and G 1 gave a value of 978418.43 milligals. Thus the Bouguer anomalies obtained by the Bureau and private companies using 978417.94 milligals as the observed gravity for G 1 is in error by .49 milligals.

B. METHOD OF SURVEY

I. TOPOGRAPHIC: (Messrs J. Cahill and W.B. Martyr, from the Department of the Interior carried out the survey).

1a Level: Mines Administration Pty Ltd obtained a height of 106.7 ft at 74 M.N. post of the Border Survey during the Keep River Survey in 1955. This height is with respect to an assumed height of 200 feet at 60 M.N. post of the Border Survey.

Seismic traverse 'A' Ninbing was levelled taking as datum an assumed height of 250 feet at S.P. 1. Later, a tie was made to 74 M.N. post of the Border Survey and the assumed height for S.P.1 was found to be 21.30 feet: too low with respect to Mines Administration datum of 200 feet at 60 M.N. post of the Border Survey.

1b. Horizontal: The datum for the horizontal control of seismic and gravity traverse 'A' Ninbing were mile posts 73 M.N. and 74 M.N. of the Border Survey. Bearings and distances of successive shot points from 73 M.N. and 74 M.N. were measured.

The plan of the horizontal tie of seismic and gravity traverse 'A' to 73 M.N. and 74 M.N. posts of the Border Survey is given in figure 2 on page 16.

2a Level: Seismic traverse 'A' Spirit Hill was tied to 50 M.N. post of the Border Survey (a Mines Administration Pty Ltd station). The level readings were reduced using as datum a height of 132.5 feet for 50 M.N. This height was obtained by Mines Administration Pty Ltd by a tie to 60 M.N. post of the Border Survey during the Keep River Survey. It is with respect to an assumed height of 200 feet at 60 M.N. post of the Border Survey.

2b Horizontal: The datums for the horizontal control of seismic and gravity traverse 'A' Spirit Hill were 49 M.N. and 50 M.N. posts of the Border Survey. Starting at 49 M.N. and 50 M.N. posts bearings and distances of successive shot points were measured.

The plan of the horizontal tie of seismic and gravity traverse 'A' Spirit Hill to 49 M.N. and 50 M.N. posts of the Border Survey is given in Figure 3 onpage 17.

3a Level: Two level ties were made to seismic traverses C, D, E and F, from seismic traverse 'A'.

1. From S.P.314 on traverse 'A' Spirit Hill to a temporary bench mark between S.P.416 and S.P.417 on traverse 'C'.

2. From S.P.335 on traverse 'A' Spirit Hill via stations M 1 and M 2 to M 3 a temporary bench mark placed at the north-east end of traverse 'D', $\frac{1}{4}$ mile distant from S.P.461.

   Seismic traverse 'D' was tied to seismic traverse 'C' by a tie from station M 3, $\frac{1}{4}$ mile to the N.E. of S.P.461 on traverse 'D' via station M 4 to a temporary bench mark between S.P. 416 and S.P. 417 on Traverse 'C'.

3b. Horizontal: No bearings and distances were measured along the first tie traverse mentioned above.

Bearings and distances from S.P.335 on traverse 'A' Spirit Hill of successive stations were made via M 1 and M 2 to M 3 (to tie traverse 'D') and from M 3 via M 4 to a temporary bench mark between S.P. 416 and S.P. 417 on traverse 'C', to tie traverse 'D' to traverse 'C'. This traverse from S.P. 335 is part of a traverse which ties the stations in the area of the Kimberley Research Station to those in the Spirit Hill area.

4a Level: Seismic and gravity traverses C, D, E and F are tied to traverse 'B' further to the south the tie being from a temporary bench mark between S.P.456 and S.P.457 on traverse 'E' and S.P.406 at the intersection of traverse 'B' and the Border.

4b Horizontal: No bearings or distances were observed along the above traverse.

Horizontal control for traverse 'B' was obtained from 37 M.N. and 38 M.N. posts of the Border Survey. Starting at these posts, bearings and distances of successive shot points of traverse 'B' were taken.

The plan of the horizontal tie of traverse 'B' to 37 M.N. and 38 M.N. posts of the Border Survey is given in Figure 4 on page 18.

5a Level: Two long traverses tie the levels in the area of the Kimberley Research Station to S.S.29 and 50 M.N. of the Border Survey.

1. From Station P.1 to P.6 and thence from M 13 in decreasing order of station numbers to M 5. M 5 was then tied to a temporary bench mark between S.P.416 and S.P.417 on traverse 'C' (see 3a above). The survey continued via station M 4 and tied in to M 3 a station $\frac{1}{4}$ mile to the N.E. of S.P.461 at the N.E. end of traverse D. From M 3 the survey tied in to S.P.335 on traverse 'A' (Spirit Hill) via stations M 2 and M 1 (see 3a above).

* 2. (See footnote).

The elevations obtained for station P 6 during the 1st and 2nd tie traverses mentioned above are 174.99 and 178.06 feet respectively a mis-tie of 3.07 feet.

5b Horizontal: No bearings and distances were taken along the first tie traverse from P 6 to S.S. 29 and the stations have been plotted from aerial photographs.

Along the second tie traverse bearings and distances were taken from Kimberley Research Station via P 5 and thence from P 6 to S.P.335 on traverse 'A' Spirit Hill. No bearings and distances were taken between P 1 and P 5. These stations were plotted from aerial photographs.

During the second tie traverse, bearings were made on five trigonometrical stations for additional horizontal control. The trigonometrical stations were not identified in the survey books.

(The author has since obtained from the Department of National Mapping a map showing the location of all trigonometrical stations in the area. It is intended to replot

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* From S.S.29 (near 55 M.N. post) to G21 in decreasing order of station numbers to G18. From G18 to P15 and thence in decreasing order of station numbers to P6.

the gravity stations from field data.* When this is done it is hoped that the identity of the trigonometrical stations will become apparent and serve as additional horizontal control).

6a Level: Station P 4 was tied in to a bench mark near Kimberley Research Station. The elevation of P 4 based on an assumed value of 200 ft at 60 M.N. post of the Border Survey was found to be 78.6 ft too high.

6b Horizontal: Distances and bearings of Kimberley Research Station from station P 5 were read.

7a Levels: The Carlton traverse G 1 - G 21 surveyed in July 1956 was extended to the south in October 1956. The survey began at station G 1 and was continued along the highway to 35 mile post (stations G 31 to G 35). The survey then proceeded east along the Carlton Crossing - Ivanhoe Highway traverse and every 4th mile post was read from 35 M to 55 M. These stations from G 1 to 55 M were levelled using microbarometers.

7b Horizontal: No bearings or distances were taken along the above traverse. Position of stations were plotted from aerial photographs.

2. Loop Closure: A loop closure chart for this survey is given in fig. 5, page 19. Misclosures are shown, the maximum being 4.18 feet, but no attempt has been made to distribute the misclosures. It was felt that as the integration of this survey with other surveys will involve relaxation of the loop network, for which uncorrected values are required, it would be more convenient to leave the elevations uncorrected for the present.

II. GRAVITY:

1. A Heiland Gravity Meter No.53 with an instrument scale value of 0.08706 milligals per scale division was used. Drift control was obtained by returning to intermediate base stations within the hour.

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* Maps on a scale of 1 mile = 1 inch showing the location of all seismic traverses and shot points were supplied by the Department of the Interior.

Plan No. C255 (see Plate 70) gives the location of seismic traverses and shot points of traverse 'A' Spirit Hill and traverses B, C, D and E in the Spirit Hill and Milligans Lagoon area.

Plan No. D340 (see Plate 71) gives the location of seismic traverse and shot points of traverse 'A' Ninbing.

Plan D339 giving the location of all gravity stations not on seismic traverses was also supplied by the Department of the Interior. Unfortunately this plan cannot be located either in the files of the Bureau or of the Department of the Interior.

2. Elevation factor: A density of 2.1 gms/cc was used for the Bouguer reduction.
3. Latitude Correction: Latitude corrections were made using the International Ellipsoid Formula.
4. Loop Closure: A loop closure chart for the gravity survey is given in fig.7 on page 20. It appears that the direction of one arrow around the loop made up of G18, M55, M50, SP314, M4, M5, M6 and P6 is incorrect. From the Bouguer anomaly map plate 11, it is seen that between P6 and M6 the direction of the arrow should be anticlockwise. This would give a closure error of .12 milligals instead of 29.56 milligals.
5. Permanently Marked Stations: Most of the stations G1 to G21, G31 to G35, M1 to M13 and P1 to P15 are marked ~~by a bench marked~~ by a bench mark cut into the base of a tree, and a blaze on the trunk of the tree with the station number cut in it. In some cases, no suitable trees were available and in these cases, and along all seismic traverses, stations were marked by a wooden survey peg in the ground. Stations along the Wyndham-Ivanhoe highway were read at every fourth mile post from 35M to 55M from Wyndham. These mile posts are indicated by metal posts bearing a numbered disk. Because of possible re-routing of this road, there is no certainty that these posts still exist, or if they do, that they are in the same positions.

C. TOPOGRAPHIC TIES FROM LATER SURVEYS:

The first survey to tie to the Bureau's Survey of September-October 1956 was the Burt Range Gravity Survey by Mines Administration Pty Ltd for Westralian Oil Limited in 1957 (see Vol.1, Part 3). The tie was to S.P.'s 415, 464 on traverse 'B' and to S.P. 448 on traverse 'E' in the Milligans Lagoon area.

During the B.M.R.'s Survey (September-October 1956) station P4 was tied to a bench mark near Kimberley Research Station the height of which was known with respect to what was thought to be Low Water Mark Wyndham.

A height of 101.48 feet (M.L.W. Wyndham) was taken for the bench mark at Kimberley Research Station. It is not known where this figure of 101.48 feet was obtained from. (In 1959, during the level survey between Wyndham and Victoria River Downs, the Department of the Interior, on a request by the Bureau was to ~~the~~ have tied Wyndham to the Bench Mark at Kimberley Research Station. Unfortunately this bench mark could not be re-located).

There has always been considerable doubt as to the reliability of this Bench Mark.

The first indication that the height of 101.48 feet taken for the Bench Mark at Kimberley Research Station was incorrect came during the Bonaparte Gulf Gravity Survey in 1959 by Mines Administration Pty Ltd, the second survey to tie to Stott's survey (see Vol.1, Pt.4). During this survey some traverses were closed on to a well defined top high water mark and were continued along it to check the consistency of the level. It was found to vary between Rol's of - 0.53 feet and + 1.15 feet relative to B.M.R.'s assumed datum of 192.6 feet above low water mark, Wyndham, for S.P.1. The height of 101.48 feet taken for the Bench Mark at Kimberley Research Station could therefore be 27 feet too low (the approximate figure for highest spring tides.)

The third survey to tie to Stott's survey was the Carlton Gravity Survey by Oil Development N.L. in 1961 (see Vol. 1,Pt.4)A level tie was made between Public Works Department Bench Mark A.R.38 about 7½ miles N.N.E. of Kimberley Research Station and S.P.1 of the Ninbing Seismic traverse 'A'. A height of 114.5 feet, M.L.W. Wyndham at A.R.38 was taken as datum and a height of 218.3 feet was obtained for S.P. 1. The B.M.R.'s value of 192.6 feet based on the bench mark at Kimberley Research Station is therefore 25.7 feet too low as was suspected while levelling during the Bonaparte Gulf Gravity Survey.

The latest value for the elevation of Bench Mark A.R.38 is 113.9 feet presumably obtained by re-adjustment of the network and re-distribution of closure errors. (See Plate 80 which is a reproduction of map P.W.D.W.A.36654 obtained from Public Works Department, Western Australia.) The Bureau's height of 192.6 feet based on the bench mark at Kimberley Research Station is therefore 25.1 feet too low and the correct value for S.P.1 should be 217.7 feet with respect to mean Low Water, Wyndham.

It is suggested that as the tie between Public Works Department bench mark A.R.38 and S.P.1 of the Ninbing seismic traverse 'A' by Oil Development N.L. in 1961 is the most reliable tie so far obtained in the area,future compilations should use their value 218.3 feet less .6 feet (=217.7 feet) to bring it in line with the latest evaluation for bench mark A.R.38 supplied by the Public Works Department, Western Australia. See Plate 80 .

The level ties from other surveys to this survey have been discussed briefly above. Full analysis of the level ties from other surveys to this survey are made when discussing the surveys during which the ties were carried out.

D. TOPOGRAPHIC TIES TO EARLIER SURVEYS

The topographic ties to previous surveys will now be analysed. Stott's survey tied into three previous surveys.

1. The first survey to which Stott's survey was tied is the survey by the B.M.R. in July, 1956 by G.F. Clarke.

Four ties were made:

i) The first tie traverse was from station P6 near Kimberley Research Station to station P15 which was then tied to stations G17 and G18 of Clarke's survey.

In addition, stations G17 to G21 which were barometrically levelled during Clarke's survey w ere relevelled optically during Stott's survey and G21 was tied to S.S.29 on the border (Minad Station).

The levels obtained barometrically by Clarke for stations G1 to G21 and 50 M.N. post of the Border Survey are given in Appendix C, page 7 & 8 of Clarke's survey.

The levels from field book 391 and 392 for the tie traverses from S.P.335 (which is tied to 50 M.N. post of the Border) to station P1 and from S.S.29 on the Border (Minad Station) to station P6 are given in Appendix C pages 12 & 13. The loop closure chart mentioned ~~above~~ on page 5 are with respect to these figures.

A comparison between the height obtained by Clarke and Stott for stations G17 to G21 is given in Appendix C, page 13. The maximum difference between the two sets of heights was 6.70 ft.

The level data used by Stott for the reduction of the gravity data is given in Appendix C pages 10 and 11. It will be noticed that he took the mean of the two values obtained by ties to 50 M.N. and S.S.29 of the Border Survey. The uncorrected barometric levels used by Stott (see Appendix C page 11) are compared with the levels obtained by Clarke (see Appendix C pages 7 & 8), on page 14 of Appendix C, there is a constant difference of .8 ft for stations G1 to G19 and .9 ft for station G21.*

The method used by Stott to adjust the barometric levels (see Appendix C pages 10 & 11) for station G1 to G21 and stations 35 M to 55M was to accept the heights of 104.2 ft for P1 and 63.90 ft for G17, obtained optically as correct and apply a correction linearly in successive increments between P1 and G17. The method used does not appear satisfactory particularly when a height for G8 obtained optically by a tie to S.P. 75 on traverse 'A' Ninbing is available for further control on the barometric levels.

The elevation of station G8 obtained by a tie from S.P.75

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* I am not aware how Stott obtained these values.

was 195.38 feet. Stott obtains a value of 193.7 for station G 8 by adjusting the barometric levels. (See Appendix 'C', page 11)

The method of adjustment of the barometric levels of Clarke and Stott making use of the optical levels at G 8, G 17 and P 1 is given in Appendix C, pages 17 to 19.

ii) The second tie between Stott's survey and Clarke's survey was between station G 31 and G 1. The Carlton traverse G 1 to G 21 was extended to the south in October 1956. Stott's survey began at G 1 and was continued along the highway to the 35 mile post and stations G 31 to G 35 were read at 2 mile intervals. The survey then proceeded east along the Carlton Crossing - Ivanhoe highway and every 4th mile post was read from 35 M to 55 M*.

iii) The third tie was between stations 35 M to 55 M, which were levelled using microbarometers, and the 'P' stations (P 1 to P 15) which were optically levelled. The tie was between station 55 M and P 1 using microbarometers. The method of adjustment of the barometric levels making use of the levels obtained optically at stations G 8, G 17 and P 1 are given in Appendix 'C' pages 17-19.

iv) Three level ties were made between traverse 'A' Ninbing and station G 8.

The first was by Clarke between S.P. 75 and G 8 via N 1, N 2 and N 3 using microbarometers. Later S.P.75 to station G 8 was optically levelled and a height of 252.68 obtained with respect to an assumed height of 250 feet at S.P. 1 on traverse 'A' Ninbing as datum.** Unfortunately stations N 1, N 2 and N 3 at which gravity readings were taken were not reoccupied. During Stott's survey S.P. 75 to G 8 via N 1, W 2 and N 3 was again levelled using microbarometers. Unfortunately the levels obtained by Clarke and Stott for G 8 by a tie to S.P.75 on traverse 'A' Ninbing differed by 44 feet. It is suggested that stations N1, N 2 and N 3 be omitted from any future gravity compilation

2. The second survey to which Stott's survey was tied was the Keep River Survey by Mines Administration Pty Ltd in 1955 (see Vol. 1, Part 1)

Two long traverses tie the levels of Stott's survey in the area of the Kimberley Research Station to stations S.S.29 and 50 M.N. post along the border. (Minad stations).

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* The 'M' refers to the numbers of mile posts from Wyndham along the Wyndham - Ivanhoe highway. Because of the possible re-routing of this road there is no certainty that the mile posts still exist or if they do, that they are in the same positions.

** i) 272.98 ft (Minad datum - 200' assumed at 60 M.N.)
ii) 195.38 ft (101.48 ft at bench mark near Kimberley Research Station as datum)

A level tie was also made between traverse 'A' Ninbing and 74 M.N. post of the Border Survey (Minad Station).

i) The first level tie was from station P 5 to P 15 and thence along the Carlton traverse from station G 17 to G 21. G 21 was then tied in to S.S.29 on the border.

The levels were reduced using a value of 133.34 feet for the height to the top of Border Post S.S.29. This value is with respect to 60 M.N. post of the Border Survey (Minad datum) for which a height of 200 feet was assumed.* The height obtained for station P 6 by a tie to S.S. 29 was 178.06 feet. The elevation of stations obtained on this tie traverse 'A' is given in Appendix C, page .

ii) The second level tie was from P 1 to P 6 and thence from M 13 to M 1 in decreasing order of station numbers to M 1. M 1 was then tied to S.P.335 on traverse 'A' Spirit Hill. The levels were reduced using as datum a value of 199.39 feet for S.P.335 on traverse 'A'.

As mentioned above (see page 3) S.P. 335 on traverse 'A' was tied to 50 M.N. post of the Border Survey and the height of 199.39 feet used for the reduction of the levels on traverse 'A' is with respect to a height of 132.50 feet for the top of 50 M.N. post of the Border Survey**.

The elevation obtained for P 6 by a tie to 50 M.N. post of the Border Survey was 174.99 feet, a mis-tie of 3.07 feet from that obtained by the tie to S.S.29 of the Border Survey.

The elevations of stations obtained by these ties are given in Appendix C pages 12 & 13.

iii) The third level tie was between traverse 'A' Ninbing and 74 M.N. post of the Border Survey. The levels of this traverse were reduced using an assumed height of 250 feet for S.P.1 and a height of 103.48 feet was obtained at S.P.170 near the north eastern end of the traverse a few miles west of the border.

A tie was then made between 74 M.N. post and S.P.177 at the north eastern end of the traverse and stations S.P.177 to S.P. 170 were read in decreasing order of shot point numbers. The levels for this part of traverse 'A' were reduced using 106.70 feet as the value for the top of 74 M.N. post and are therefore

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* S.S.29 was tied to 60 M.N. post of the Border Survey (Minad datum) during the Keep River Survey by Minad.

** The height of 132.50 feet for the top of 50 M.N. is with respect to an assumed height of 200 feet at 60 M.N. post of the Border Survey (Minad Datum) and was obtained by Minad during the Keep River Survey, 1955 by a tie between 50 M.N. and 60 M.N. posts of the Border Survey.

with respect to an assumed height of 200 feet at 60 M.N. post of the Border Survey (Minad datum)*. A height of 124.78 feet was obtained for S.P. 170 by this tie.

The assumed datum at S.P.1 of 250 feet is therefore 21.30 feet too low with respect to 74 M.N. post of the Border Survey (Minad datum).

3. The third survey to which this survey was tied is not known. However it was tied to a bench mark near Kimberley Research Station near station P.4. A height of 101.48 feet was taken for this bench mark** which was thought at the time to be with respect to Low Water Mark, Wyndham ***.

Two level ties were made between the bench mark at Kimberley Research Station and station P 4. There was a mis-tie of .40 feet between these two ties which was distributed along the tie traverse giving an elevation of 107.75 feet for station P 4.

A tie from station P 4 to 50 M.N. post of the Border (Minad Station) showed that the assumed height of 200 feet at 60 M.N. post was 78.6 feet too high with respect to M.L.W. Wyndham.

The difference in elevation of 78.6 feet between the Bench Mark near Kimberley Research Station and the assumed height of 200 feet at 60 M.N. post of the Border Survey (Minad datum) was obtained in the following way:-

i) A tie from 50 M.N. on the border (Minad Station)**** gave an elevation of 186.35 feet for P 4 with respect to Minad datum at 60 M.N.

ii) A height of 107.75 feet was obtained for station P4 with respect to what was thought to be Mean Low Water Wyndham by a tie to the bench mark near Kimberley Research Station
It was mentioned above (see page 4) that there was a mis-tie in the elevation of P 4 of 3.07 feet between the first tie traverse to the Keep River Survey which tied to S.S.29 on the border (Minad Station) and the second tie traverse which tied to 50 M.N. post of the Border Survey.

It was also mentioned under "LOOP CLOSURE" (see page 5) that closure errors were present but were not distributed around the

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* The value of 106.70 feet for the top of 74 M.N. post of the Border Survey was obtained by Minad by a tie to 60 M.N. post of the Border Survey during the Keep River Survey in 1955 (see Vol.1, Part 1)

** I am not aware where the surveyors obtained this value from.

*** A recent survey has shown by a tie between P.W.D. bench mark A.R.38 and S.P.1 on traverse 'A' Ninbing that 101.48 feet taken as the height of the bench mark near Kimberley Research Station is 25.1 ft too low. (See Vol. 1, Part IV).

**** Station 50 M.N. was tied to 60 M.N. (Minad datum) by Minad during the Keep River Survey, 1955 and its elevation is therefore with respect to an assumed height of 200 feet at 60 M.N.

loop at present. When the closure errors are distributed around the loop the height of station P4 will no longer be 186.35 feet and the difference between the bench mark near Kimberley Research Station and 60 M.N. (Minad datum) will no longer be 78.6 feet.

The
A recent survey the Carlton Gravity Survey by Oil Development N.L. in 1961 (See Volume 1 Part 4) has shown that the value of 101.48 taken as the height of the bench mark near Kimberley Research Station with respect to Mean Low Water Wyndham is 25.1 feet too low. Thus a further correction must be applied to the elevations based on the bench mark as datum to bring them to Mean Low Water Wyndham.

F. GRAVITY TIES TO EARLIER SURVEYS

Stott's survey tied in to two previous surveys:-

1. Bureau of Mineral Resources Survey, July 1956 by G.F. Clarke.
Four ties were made.

   (a) The first tie traverse was from station P1 near Kimberley Research Station to P15, which was then tied to station G18 of Clarke's survey.
   Details of the tie will be found in Appendix A, page 9 from field sheet 8117.

   (b) The second tie from Stott's survey to Clarke's survey was between station SP75 on traverse 'A' Ninbing and station G8 on the Carlton traverse.
   Details of the tie are given in Appendix 'A' page 8 from field sheet 8045.

   (c) The third tie was between G31 of Stott's survey and G1 of Clarke's survey. Details of the tie are given in Appendix A, page 8 from field sheet 8046.
   The survey by Clarke in July, 1956 between G1 and G21 was extended to the west. Stott's survey began at G1 and was continued along the highway to the 35 mile post and stations G31 to G35 were read at 2 mile intervals. The survey then proceeded east along the Carlton Crossing-Ivanhoe traverse and every fourth mile post was read from 35M* to 55M. Station 55M was then tied to station P2.

2. The second survey to which Stott's survey was tied is the Keep River Survey by Minad for Associated Australian Oilfields and Westralian Oil Ltd, in 1955.
The tie was between SP320 on traverse 'A' Spirit Hill and 50 M.N. post on the border. Details of the tie are given in Appendix A, page 1, from field sheet 8020.
There was no direct tie to SS29 on the border, as although level readings were taken between G17 and G21 and 50 M.N. post on the border no gravity readings were taken at these stations. An indirect tie however exists between Stott's survey and 50 M.N. post on the border (Minad Station) as Stott's survey tied to Clarke's survey at station G18 and G18 was tied to 50 M.N. post (Minad Station) during Clarke's survey.
While a level tie was carried out between B.M.R. traverse 'A' Ninbing and 74 M.N. post on the border, no gravity tie was carried out as the gravimeter broke before commencing readings at 74 M.N. post (Minad Station).
Stott's survey also tied SP406 on traverse 'B' in the Milligans

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* Station 35M is the same station as station G35.

Lagoon - Spirit Hill area to Border Post 37 M.N. of the border survey. A useful tie traverse would result if some future survey ties 37 M.N. to Minad station 49½ M.N. of the Keep River Survey to the north. For details of the tie between SP406 on traverse 'A' and 37 M.N. see Appendix A, page 3, from field sheet 8029.

G. GRAVITY TIES FROM LATER SURVEYS

Since this survey was carried out, three other surveys have tied to it.

1. The 1st survey to tie in to Stott's survey was the Central Burt Range Gravity Survey by Minad for Westralian Oil Limited in October 1957. Two ties were made.

   (i) Stations R52 to R56, at the northern end of the survey and SP448 on traverse 'E' of the B.M.R's survey in the Milligans Lagoon area as Datum. An observed gravity for Sp468 of 978456.55 milligals was assumed. The Bouguer anomaly obtained for SP448 by the reduction of the gravity data to the above datum was 39.57 milligals. The Bouguer anomaly obtained for SP448 from the B.M.R.* by Minad was -0.30 milligals. The Bouguer anomalies for all stations tied to SP448 were therefore adjusted by taking 39.87 milligals from each.

   (ii) SP415 on traverse 'B' of the B.M.R.'s Survey in the Milligans Lagoon area was used as datum for the rest of the stations. An observed gravity value of 978453.95 milligals for SP415 was assumed. The Bouguer anomaly obtained for SP415 by the reduction of the gravity data to the above datum was +35.75 milligals. The Bouguer anomaly obtained from the Bureau* by Minad for SP415 was -4.3 milligals. The Bouguer anomalies calculated for all stations tied to SP415 were therefore adjusted by taking 40.05 milligals from each.

   The other two surveys which tied to Stott's surveys tied indirectly only. They are the Bonaparte Gulf Gravity Survey in September, 1959 by Minad for Gulf Oil Syndicate (see Vol.1, Pt. IV), and the Carlton Gravity Survey by International Resources Survey Inc., Tulsa, Oklahoma for Oil Development N.L. between August and November, 1961 (see Vol.1, Pt. IV). The

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* Taken from folios 73 and 75. File B106NT/1/2, from the Gravity Section (B.M.R.) files in Melbourne.

ties were to Clarke's survey in July 1956 to which Stott's survey is tied (see under "D. Gravity ties from later Surveys" on page 6 of Clarke's survey.

H. SURVEY DATA AVAILABLE

1. Field Sheets: See Appendix A, Pages 1-9, from B.M.R. file No. 56041.

2. Computation Sheets: Three sets of computation sheets are presented.

The first set, Appendix B, part I, pages 1-6 is from B.M.R. file No. 56042.

The second set, Appendix B, part II, pages 1-10 is from B.M.R. file No. 56044.

The elevation of stations are 2 feet lower in Appendix B part II than in Appendix B, part I as the elevations in part I had the approximate instrument height of 2 feet added to surface levels. The observed gravity values is .5 milligals higher in part II than in part I. The error in calculation of the tie between Wyndham Pendulum Station and G1 was mentioned on page 5 of Clarke's survey. This error was probably recognised and recalculations carried out using the correct value for G1 and the correct station elevations.

The third set, Appendix B, part III pages 1-7 are from B.M.R. file No. 56041.

II TOPOGRAPHIC

1. Field Sheets of the barometric survey are given in Appenix C, pages 1-9.

No computation sheets of the barometric survey were located. However, the level data used by Stott for the gravity reduction are given in Appendix C pages 10 and 11 for the barometric levels.

2. Table of Principal facts: The elevation used by Stott for the reduction of the gravity traverses in the Milligans Lagoon-Spirit Hill traverse are given in Appendix C, Part 1, pages 1-16 and for those on traverse 'A' Ninbing in Appendix C, Part II, pages 1-16.
The latitudes and longitudes read off from Plates 70 and 71 (vol.IV, Part IV) from the Department of the Interior, for the Milligans Lagoon-Spirit Hill traverses are given in Appendix E part 1, pages 1-4 and for traverse 'A' Ninbing in Appendix E part 2, pages 1-6.

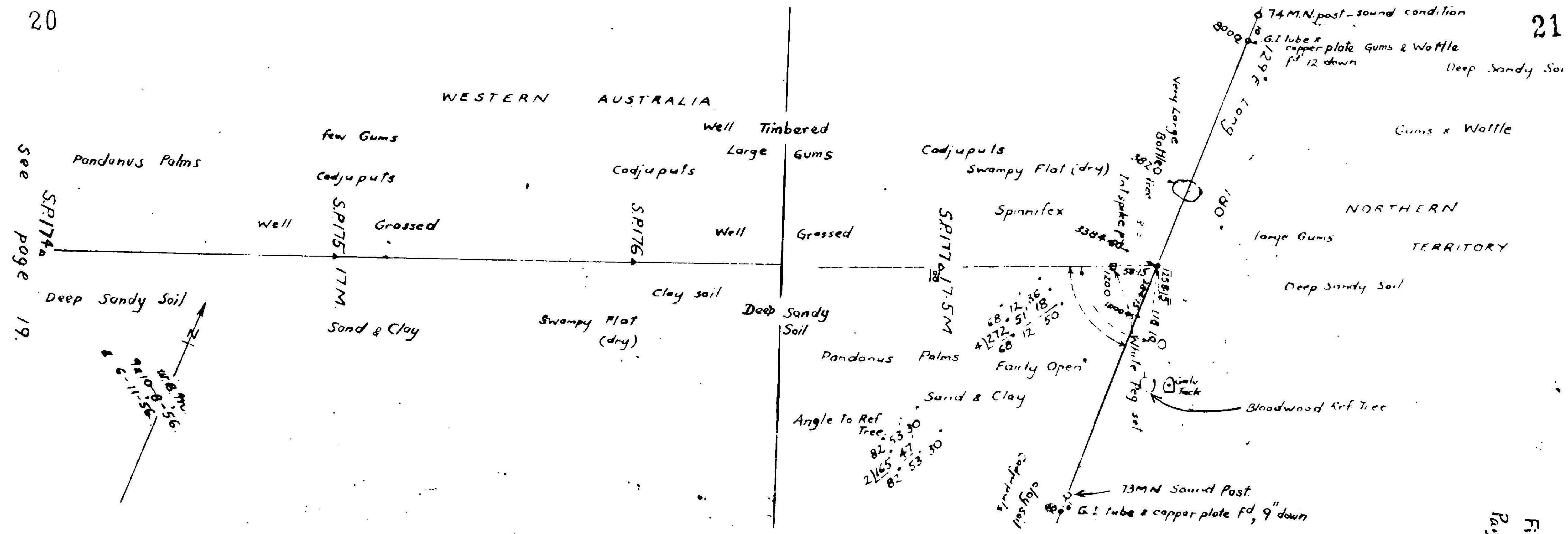
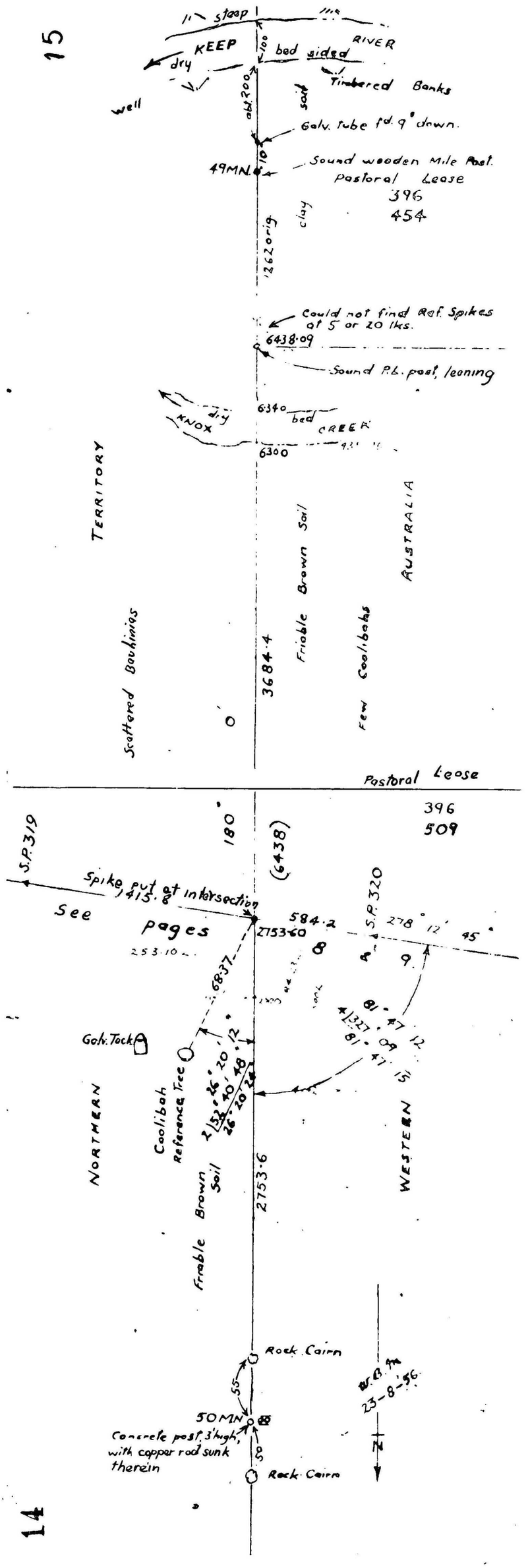

20
21
WESTERN AUSTRALIA
NORTHERN TERRITORY
See page 19.
S.P.174a
S.P.175
S.P.176
S.P.177
17 M.
17.5 M
Pandanus Palms
Deep Sandy Soil
few Gums
Cadjuputs
Well
Grassed
Sand & Clay
Swampy Flat (dry)
Clay soil
Well Timbered
Large Gums
Deep Sandy Soil
Spinnifex
Fairly Open
Angle to Ref Tree
74 M.N. post - sound condition
G.I. tube & copper plate fd 12 down
129°E Long
Gums & Wattle
Deep Sandy Soil
large Gums
Very Large Bottle tree
Bloodwood Ref Tree
73 MN Sound Post
G.I. tube & copper plate fd, 9" down

Fig 2
Page 16.


15
1 in 1 steep
RIVER
KEEP
dry
bed sided
Timbered Banks
well
abt 200
sand
Galv. tube fd. 9" down.
49MN
Sound wooden Mile Post.
Pastoral Lease
396
454
clay
1262 orig
Could not find Ref. Spikes
of 5 or 20 lks.
6438·09
Sound P.L. post, leaning
KNOX
dry
6340
bed
CREEK
6300
TERRITORY
AUSTRALIA
Scattered Bauhinias
3684·4
Friable Brown Soil
Few Coolibahs
Pastoral Lease
396
509
S.P 319
180°
(6438)
Spike put at intersection
See
pages
253·10
584·2
2753·60
S.P 320
278° 12' 45"
8
9
6837
Galv. Tack
Coolibah
Reference Tree
NORTHERN
WESTERN
Friable Brown Soil
2753·6
Rock Cairn
55
50MN
Concrete post 3' high,
with copper rod sunk
therein
50
Rock Cairn
W.B.M.
23-8-56
14

WESTERN AUSTRALIA

NORTHERN TERRITORY

Well Timbered with Flood Gums

Well Grassed

Deep Sandy Soil

Well Grassed

Baobab Trees

Flood Gums

Ratches of Grass

6506·1

Bauhinias & Coolibahs

Crab Hole Country

Well Grassed

Friable Clay Soil

Sand on Clay

Crab Hole Country

Scattered Bauhinias

Crab Hole Country

Gah pipe f.d under rock cairn

38M N

Sound post f.d

1000

Sound post f.d

Gah Pipe f.d under rock cairn

37M N

1035

Sound Post

see enlargement above

Spike put on Intersection Dummy

S.P. 406

see page 5

page 1

1493·6

1493·69

Grey Gums

Gah Tack

Reference Tree

Flood Gum Reference Tree.

Gah Tack

Gah Pipe under Rock Cairn.

37M N Post

see below

Temp 75

Angle to Ref Tree

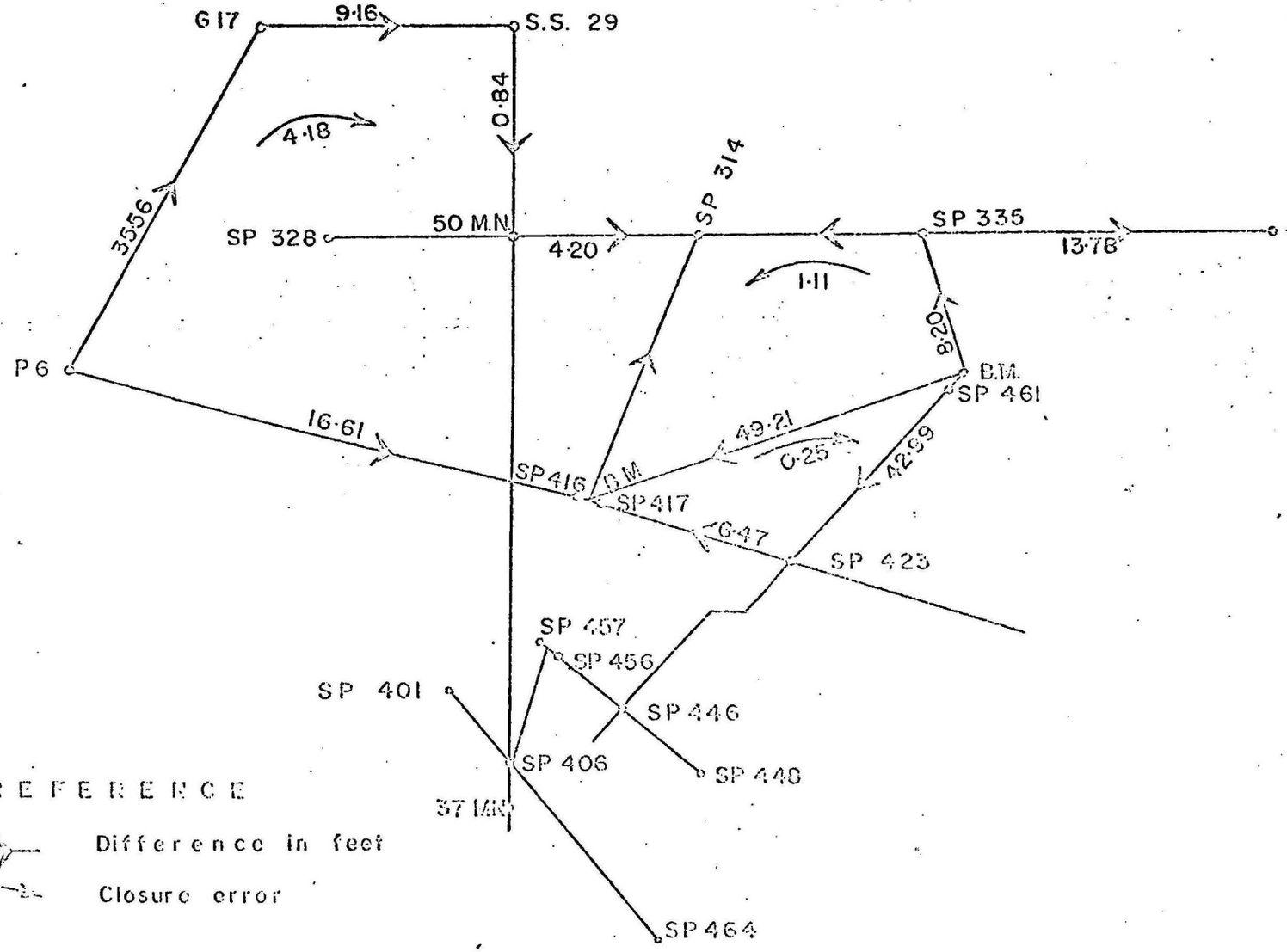
144° 21'

144° 21'

Fig 4
Page 18

ELEVATION LOOP CLOSURE CHART

SPIRIT HILL, MILLIGANS LAGOON AREA



STATION		ELEVATION
	SS29	133·34
	G 17	142·50
	P 6	178·06
	SS 29	133·34
Minad difference	50 MN	132·50
	50 MN	132·50
	SP 328	149·01
	SP 314	128·30
	SP 355	199·39
	SP 351	185·61
B.M between	SP 416	157·27
and	SP 417	
	SP 423	163·74
B.M.¼mile from	SP 461	206·73
	SP 355	199·39
B.M. near	SP 401	207·59
B.M.between	SP 416	160·38
and	SP 417	
	P 6	174·99

REFERENCE

0·01 — Difference in feet

Closure error

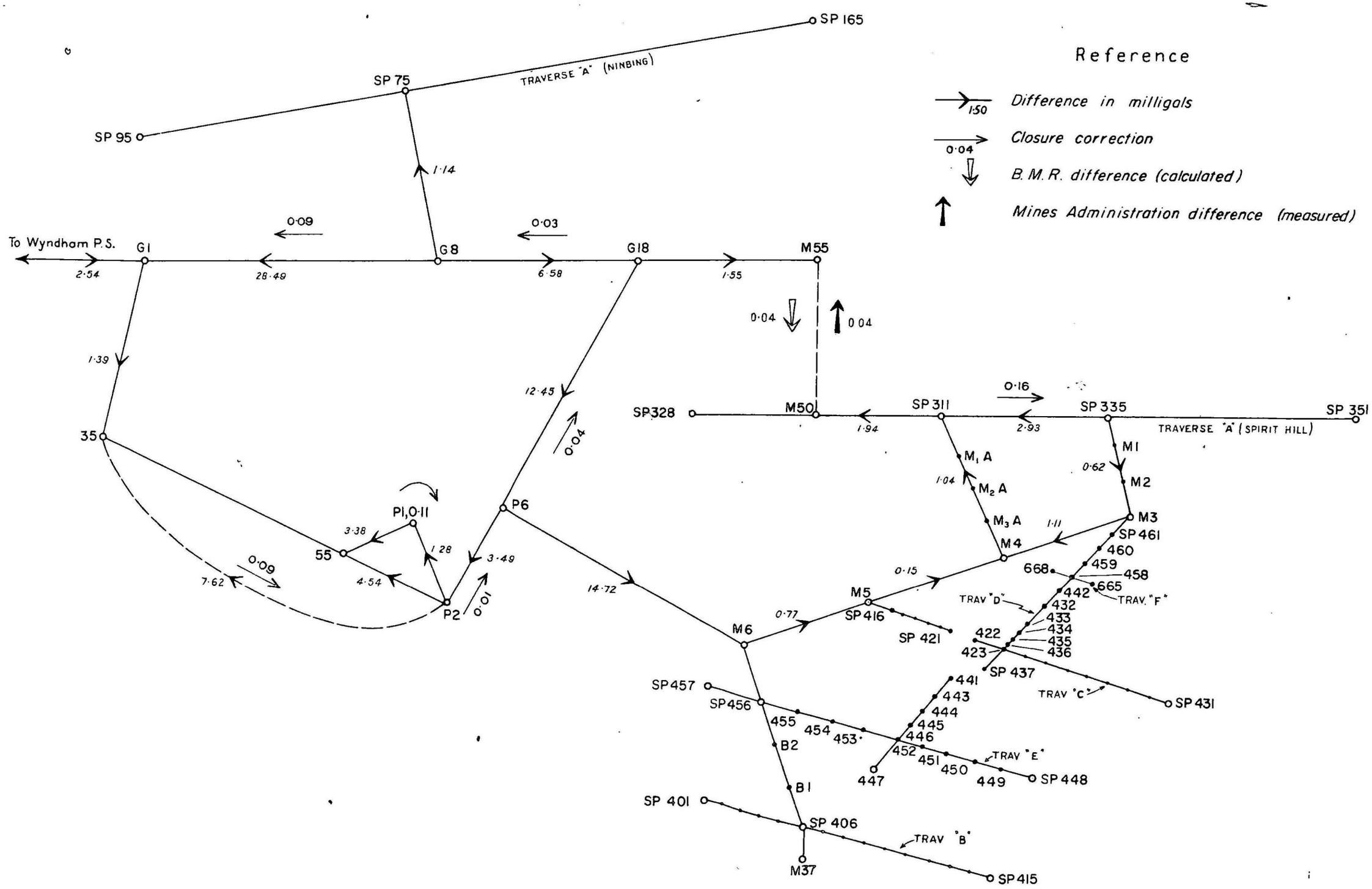
Bureau of Mineral Resources, Geology and Geophysics: September 1965

To accompany Record No 1963/165

Figs 5
Page 19.

DIAGRAMMATIC LOOP CLOSURE CHART (GRAVITY)

NINBING, SPIRIT HILL AND MILLIGANS LAGOON AREA



Reference

- 1·50 — Difference in milligals
- 0·04 — Closure correction
- B.M.R. difference (calculated)
- Mines Administration difference (measured)

5. PORT KEATS AREA

~~In the following year,~~ During August, September and October, 1956, Mines Administration Pty Ltd, carried out a reconnaissance gravity survey for Associated Australian Oilfield N.L. (see Plate 1).* This survey was in the Port Keats Area and consisted of 125, ½ mile stations. One major line (with some minor offshoots) was run west from the edge of the Macadam Range towards the coast for approximately 60 miles to near Port Keats Mission Station (see Plate 10). The results of this survey and the interpretation of the gravity data is contained in the report:-

"Preliminary Geological and Geophysical Report, Port Keats Area, Northern Territory 1956" NT/BG/27 by Derrington S.S., Warren A., and Burbury J.E. 1957. (Burbury was responsible for Section 5 of the report "Reconnaissance Gravity Survey"). The survey details given below were obtained mainly from the above report.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels:- An assumed height of ten feet at Peg 54 (apparently along Kurriyippi Creek, and south of the Port Keats Mission road), was used as a datum for the reduced levels. This peg was found to be level with high water mark of the high tides on 4th October, 1956.
2. Horizontal:- The meridian was established from two of three astrofixes taken in the area:-
   1. Fossil Summit A.W.3 (station 77). Its latitude was found to be $14^{\circ}31'31.6"$ south.
   2. Kulshil (A.W.1). Its latitude was found to be south.
   3. The third astrofix (A.W.2) was taken near the Port Keats aerodrome outside the limits of the survey. Its latitude was found to be south.
3. Gravity:- Gravity readings were reduced through gravity station No1, its elevation was approximately 90.2 feet above mean sea level relative to Peg 54. Its latitude was calculated to be $14^{\circ}20'46.8"$ with respect to the astrofixes at Fossil Summit and Kulshil.

   A gravity value of 978388.98 milligals was assumed for gravity station No.1.

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* Plates will be found in Volume IV, Part I.

B. METHOD OF SURVEY

I. Topographic:- (Mr. A. Warren, Authorised Surveyor, and his assistant Mr. K.H. Dunn employed by Mines Administration Pty Ltd carried out the survey).

Direct chaining and levelling was used throughoug the survey. This method was ideally suited to the flat topography and the heavily timbered areas, but an indirect method could have been used on the open plains.

The survey commenced on 27th August 1956 at the foothills of the Macadam Range and terminated on 13th October, 1956, on the south bank of Port Keats Creek, about four miles from the Mission Station. Commencing at Station No.1 bearings, distances and differences in elevation between successive stations were read. The level differences were then reduced through Station 54 where a height of 10 feet above mean sea level was assumed. See Appendix D pages 1 to 3.

2. Loop Closure:- The traverses were not looped.

II GRAVITY:-

1. Instruments used:- Worden Gravity Meter No.216 with a calibration factor of 0.09095 milligals per scale division. Drift was controlled by returning to intermediate base stations within the hour.
2. Elevation Factor:- A density of 2.0 gms/cc was used for the Bouguer corrections.
3. Latitude Correction:- Latitude corrections were calculated using the International Ellipsoid formula.
4. Loop closure:- The traverses were not looped.
5. Permanently marked stations:- Split hardwood and cypress pines were placed at all gravity stations and they could be re-located to tie in to this survey.

C. TOPOGRAPHIC TIES TO OTHER SURVEYS

At the time of the survey no other surveys had been carried out in the area to which this survey could be tied. Since then, three surveys have been tied in to the Port Keats survey.

1) The first tie was by the Bureau of Mineral Resources in 1957 during the Daly River Crossing to Port Keats survey (see page 4). It was carried out to tie the gravity survey in the Darwin-Katherine area to the Port Keats Gravity Survey. The tie was made to peg 7 of the Port Keats Survey.

2) The second survey to tie to the Port Keats Survey was the Daly River to Pelican Island coastal reconnaissance survey carried out by Mines Administration Pty Ltd for Associated Australian Oilfields N.L. in 1957 (see page 13).

Two ties were made:-

a) Between station B51 of the coastal survey and peg 79 at the eastern end of the Port Keats Survey.

b) Between station S.58 of the coastal survey and peg 128 at the northern end of the Port Keats Survey.

3) The third survey to tie into the Port Keats Survey was the Pearce Point Survey by Compagnie General De Geophysique for Australian Aquitaine Petroleum Pty Ltd in 1963. They tied to a peg which was thought to be No.128 of the Port Keats Survey.

D. GRAVITY TIES TO OTHER SURVEYS

The gravity ties were between the same stations as the topographic ties, with the exception of the Daly River Crossing Survey which tied to station 11 and station 8 of the Port Keats Survey, whereas the topographic tie was to station 7. Full accounts of these ties, topographic and gravity, are given when discussing the corresponding surveys.

PRINCIPAL OBSERVATIONS

An overall drop of 44 milligals from the edge of the Macadam Range* to the Port Keats Mission was observed. Burbury (op cit.) believes that such a drop over a distance of approximately 30 miles may be indicative of rapid thickening of Palaeozoic sediments below the flat lying Permian sediments observed in the area.

A reversal of the gravity trend of eight milligals, five miles west of the Macadam Range was interpreted as an expression of a Proterozoic anticlinal structure that is considered to exist along the edge of the Macadam Range.

Burbury considers the Proterozoic sandstones to be of a similar density to the Palaeozoic sandstones in the area and hence most likely that granite or gabbro intrusions into the anticline are responsible for the eight milligals rise over the anticline. Also, as the structure lies so close to the Proterozoic outcrop he did not think it likely that any Palaeozoic sediments occur in the anticline.

F. SURVEY DATA

I TOPOGRAPHIC:-

1. Field Sheets:-

2. Table of Principal Facts:- See Appendix D, pages 1 to 3.

II GRAVITY:-

1. Field Sheets:- See Appendix A, page to .

2. Table of Principal Facts:- See Appendix B, pages 1 to 4.

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* The drop of 44 milligals referred to is not a continuous one. A continuous fall actually occurs between Peg 26 and the Port Keats Mission, within a distance of 20 miles.

DALY RIVER CROSSING - PORT KEATS SURVEY

In the following year the Bureau of Mineral Resources ran a survey from Daly River Crossing to tie the survey in the Darwin - Katherine area to the Port Keats Survey by Minad. This survey is described in Records No. 1959/72 "Report of a Reconnaissance Gravity Survey in the Darwin - Katherine Area, Northern Territory, 1955-57" by Messrs. P.M. Stott and W.J. Langron. (See Vol. IV, Part I , Plates 6 and 8 and Vol. IV, Part IV, Plates 72, 73 and 74).

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels: Northern Territory Administration Lands & Survey Bench Mark No.1 at the wharf in Darwin.
2. Horizontal: Fountain Head Railway Siding on the north Australian Railway between the trigonometrical and astronomical station at Adelaide River Railway Station and the astronomical station at Burrundie railway siding.
3. Gravity: Bureau of Mineral Resources Pendulum station No.32 at Darwin Airport which has an observed gravity value of 979,315.5(0) milligals.

B. METHOD OF SURVEY

I TOPOGRAPHIC: (Mr. B. Courtenay and others of the Department of the Interior, A.C.T. Survey Section, carried out the survey).

1a. Levels: The stations were levelled using a theodolite.

1b. Horizontal: Stations were plotted on aerial photographs.

2. Loop Closure: The traverses were not looped.

II GRAVITY:

1. Instruments used: Heiland gravity meter type GSc2, No.58 with a calibration factor of 0.1106 milligals per scale division was used. Drift was controlled by returning to intermediate base stations within the hour.

2. Elevation Correction Factor: A density of 2.0 gms/cc was used for the Bouguer corrections.

3. Latitude Correction: Latitude corrections were calculated using the International Ellipsoid Formula.

4. Loop Closure: The traverses were not looped.

5. Permanently Marked Stations: 2" x 2" wooden pegs driven into the ground, the nearest tree blazed with the station number painted thereon. (See Vol. IV, Part IV Plates 72, 73 and 74 for station descriptions.

C. TOPOGRAPHIC TIES TO EARLIER SURVEYS

a) Level: This survey between Daly River Crossing (Station D12) and station 7 of the Port Keats Survey by Minad is linked to the traverse from Fountain Head Siding on the North Australian Railway to station D12. The levels on the North Australian Railway traverse are in turn tied to the Northern Territory Administration Lands and Survey Bench Mark No.1 at the wharf in Darwin.

b) Horizontal: Latitudes and longitudes were determined at two astronomical stations on the traverse connecting station D48 at Fountain Head Railway Station on the North Australian Railway (midway between Darwin and Katherine) and station D12 at the Daly River Crossing. Two astronomical stations were also observed between station D12 at the Daly River Crossing and station 7 of the Port Keats Survey by the Department of the Interior, A.C.T. Survey section. These stations are approximately 9 miles and 13 miles to the north-north-east and north-east respectively of Station 7 of the Port Keats Survey. (see Vol. IV, Part IV, Plates 72, 73 and 74).

D. GRAVITY TIES TO EARLIER SURVEYS

The gravity traverse between station D12 at the Daly River Crossing linked the B.M.R.'s Survey in the Darwin - Katherine area to the Port Keats Survey by Minad. The survey in the Darwin - Katherine Area used Bench Mark No.1 as datum for the survey as the Pendulum Station at Darwin Airport could not be reoccupied. However, the gravity interval between the Pendulum station and Bench Mark No.1 had been read previously by Bonini (Woolard, et al, 1952).

The values adopted in calculating the observed values of gravity in the Darwin - Katherine Area are:

	milligals
B.M.R. Pendulum Station, Darwin	978315.5(0)
Difference between Pendulum Station and Bench Mark 1 (Bonini)	-2.5
Bench Mark No.1	978313.0(0)
Difference between Darwin Pendulum Station and Muckenfuss Station Katherine Airport (Bonini)	+28.4
Katherine Airport (Muckenfuss Station)	978343.9(0)

After all readings had been corrected for instrument drift, the Railway Traverse was adjusted to close on the Katherine Station; these values were kept constant during subsequent adjustments to connecting traverses.

The gravity datum for the Daly River Crossing to Port Keats Survey is therefore at Fountain Head Siding the gravity value of which was adjusted to tie to Darwin Pendulum Station and to the Muckenfuss Station at Katherine Airport.

E. PRINCIPAL OBSERVATIONS

Important data on densities and conclusions from the report which may help in the interpretation of the Bouguer anomalies in the Bonaparte Gulf Basin are given below:-

1. The gravity method applied in the Darwin-Katherine area reveals the presence of large scale variations in Bouguer anomalies and in particular the wide distribution of positive Bouguer anomalies.

2. Local gravity 'highs' of from four to five milligals were associated with basic intrusives.

3. The association of decreased Bouguer anomalies with outcropping granite; this association is obvious over the Rum Jungle Granite, the Hermit Hill Granite, the Cullen Granite and Prices' Springs Granite. The drop in Bouguer values over outcropping granites varied from 20 to 26 milligals.

4. The major features on the gravity profiles are not readily explained. The extensive area over which Bouguer Anomalies have been located is possibly associated with the Indonesian Tectonic zone of Vening Meiniz (1948).

5. Stable Archaean areas around Cannon Hill and Southwest of Hermit Hill are indicated by a steep rise to high positive Bouguer values.

6. It is possible that the Darwin area is influenced by the large disturbances of the gravitational field which occur in the Indonesian Archipelago. Howell (1959, Fig.19.5) shows that the northern part of the Northern Territory lies on the south flank of the East Indies gravity "trough" and submarine stations observed in the area by Vening Meiniz (1948) show a positive anomaly about 200 miles north of Darwin.

7. There is little evidence, either from density measurements* or field observations, to show whether or not there is any marked variation in the composition of the basement or of any significant density difference between the basement rocks and Proterozoic sediments. It is concluded that the major gravity features are related to changes in depth to the earth's basaltic layer and by inference to changes in level of the "basement complex".

F. SURVEY DATA AVAILABLE

I GRAVITY

1. Field Sheets: See Appendix A, pages 1 to 3.

2. Computation Sheets: See Appendix B, pages 1 to 3.

II TOPOGRAPHIC

1. Field Books: For stations D12 (on Box at Police Station Fence at Daly River Crossing - North Bank) to station D68 and station D16 to K1 and thence to K4 survey data given in Field Books B.M.R. F38, F48, T31, T36, T38, T39, T42, T43, L148, L149, L150, L151, L152, L155, L157, L159, L242, L250, L251, L254-259, L264, L265 (see Vol. IV, Part IV, Plate 74).

For stations K5 to K26 and a tie to peg 7 of the Port Keats survey by Minad. Field Books B.M.R. L264 and 265. (See Vol.IV, Part IV, Plate 73).

The Field Books mentioned above are with the Department of the Interior, A.C.T. Survey Section, Canberra.

2. Table of Principal Facts: The elevations given on plates 73 and 74 with

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* A large number of density measurements were made along gravity traverses. The highest density recorded was 3.08 gm/cc., the sample being a dolerite from the ? Hermit Hill Complex and the lower densities being a granite near Yeurralba with a density of 2.50 gm/cc, and 2.44 gms/cc for the Depot sandstone. See Appendix E pages 1-7 for a list of samples, localities and densities.

respect to Railway Datum are included in Appendix B with respect to Mean Sea Level (Darwin). Mean Sea Level Darwin is 112.0 feet lower than Railway Datum.

3. Density Determinations: Density measurements made along gravity traverses of the Darwin-Katherine survey will be found in Appendix E, pages 1-7.

7. CENTRAL BURT RANGE AREA

The first of two surveys carried out in 1957 by Mines Administration Pty Ltd was a limited one of about 35 miles of traverse in the Central Burt Range area for Westralian Oil Limited. Seventy one stations were read at ½ mile intervals (see plate 12).

The description of this survey and the interpretation of the gravity data is given in the Report:-

"Gravity Survey, Burt Range Basin, Northern Territory" by J.E. Burbury of Mines Administration Pty Ltd, October 1957 (N.T./3/36).

The survey details given below were obtained mainly from Burbury's report, partly from a study of the surveyor's field books, gravity field data, and calculation sheets for the Bouguer anomalies.

SURVEY DETAILS

a. DATUMS FOR THE SURVEY

1. Levels:- Three shot points of the Bureau's traverses in the Milligans Lagoon Area in 1956 were used as datums for the survey:-

   a) S.P.415 Traverse 'B' - Elevation used 106.30 ft.
   b) S.P.464 Traverse 'B' - Elevation used 112.50 ft.
   c) S.P.448 Traverse 'E' - Elevation used 96.35 ft.

   (see later under "METHOD OF SURVEY" for further details of these datums).

2. Horizontal:- Bearings and distances of successive stations were taken and horizontal ties were made to S.P.415, S.P.464 and S.P.448. Horizontal ties were also made between station R17 and 34 M.N. post of the Border Survey and from stations R23 and R34 to 28 M.N. post of the Border Survey.

   Three sun observations were also taken as a check on the bearings of traverses.

3. Gravity:- Two datums were used for this survey.

   (i) Stations R52 to R56, at the northern end of the survey used S.P.448 on traverse 'E' of the Bureau's survey in the Milligans Lagoon area as datum.

   An observed gravity for S.P.448 of 978456.55 milligals was assumed.

   The Bouguer anomaly obtained for S.P.448 by the reduction of the gravity data to the above datum was 39.57 milligals. The Bouguer anomaly obtained for S.P.448 from the Bureau* by Mines Administration Pty Ltd was -0.30 milligals. The Bouguer anomalies calculated for all stations tied to S.P.448

*Taken from folios 73 and 75. File B106NT/1/2, from the Gravity Section (B.M.R.) files in Melbourne.

were therefore adjusted by taking 39.87 milligals from each.*

(ii) S.P.415 on traverse 'B' of the Bureau's survey in the Milligans Lagoon area was used as a datum for the rest of the stations.

An observed gravity of 978453.95 milligals for S.P.415 was assumed.

The Bouguer anomaly obtained for S.P.415 by the reduction of the gravity data to the above datum was +35.57 milligals. The Bouguer anomaly obtained from the Bureau** by Mines Administration Pty Ltd for S.P.415 was -4.3 milligals. The Bouguer anomalies calculated for all stations tied to S.P.415 were therefore adjusted by taking 39.87 milligals from each.

(If a recompilation of the gravity data from gravity surveys in the Bonaparte Gulf area is attempted note that the adjustments made above to tie to the Bureau's stations at S.P.448 and S.P.415 of traverse 'E' are not sufficient. A recalculation of the tie between the pendulum station at Wyndham and station G1 (see Vol.I, Part 2), to which the above stations are tied, has shown that the observed gravity value at G1 is in error by .49 milligals. Hence to obtain the correct observed gravity values for stations tied to S.P.415 and S.P.418 a further adjustment of +.49 milligals must be made).

B. METHOD OF SURVEY

I TOPOGRAPHIC (The survey was carried out by Mr. J. Cahill of the Department of the Interior, Perth in September, 1957).

The major part of the survey was carried out in a loop from S.P. 415 traverse 'B' through stations R13 to R51 and thence from R51 through R6 in decreasing order of station numbers to R1. R1 appears to be the same station as S.P.464 of traverse 'B'. No level readings were taken between R1 (S.P.464) and S.P.415 during this survey. However, the difference in levels between these two shot points had been read by the Bureau between September and October, 1956 (see Vol. I, Part 2).

The remaining stations consisted of three branch traverses and were not looped.

a) Station R12 to Station R7 along the Keep River.

b) Station R21 to R57 and thence in increasing order of station numbers to R71, the western limit of the survey.

c) Station R56 in decreasing order of station numbers to R52 with a tie in to S.P.448. This last branch traverse, in the northern part of the survey was not tied in to the traverses to the south. However, traverse 'E' was tied in to traverse 'B' during the Bureau's survey in 1956.

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* In making these corrections, station R55 on plate 12 was shown (in error) to be -5.87 instead of -5.84 milligals.

** See folios 73 and 75. File B106NT/1/2, from the Gravity Section (B.M.R.) files in Melbourne.

The datums used for the survey were:-

S.P.415 Elevation used 106.30 ft.

S.P.464 Elevation used 112.50 ft.

S.P.448 Elevation used 96.35 ft.

These datums were taken from field books 421 and 422 (Burt Range Survey) and were based on a bench mark near Kimberley Research Station which was thought to be tied to Low Water Mark, Wyndham.*

The elevations supplied by the Department of Interior for the Bureau's surveys in 1956 in the Milligans Lagoon and Spirit Hill areas were:-

S.P.415 185.31 (given as 185.3)

S.P.464 191.09 (given as 191.1)

S.P.448 174.95 (given as 175.0)

These figures are from the surveyor's field book (No.389, September - October, 1955) and were determined using an assumed datum of 200 ft for 60 M.N. part of the Border Survey. A later tie between Station 60 M.N. of the Border Survey and the bench mark at Kimberley research station showed that the assumed height of 200 ft at 60 M.N. was 78.60 ft too high (see Vol.I, Part2).

The elevations which should have been used as datums for the Burt Range Survey are:-

S.P.415 Elevation 106.71 ft.

S.P.464 Elevation 112.49 ft.

S.P.448 Elevation 96.35

Thus, the elevations given for all stations with S.P.415 as datum are in error by .41 ft while the elevations for all stations with S.P.464 as datum are in error by .01 ft.

The original elevations for the Central Burt Range Survey from field books 421 and 422 are given in Appendic D together with the corrected values. They are with respect to the bench mark at Kimberley Research Station as datum.

A more recent survey in the area, the Carlton Gravity Survey in 1961 (see Vol.I,Pt.4) tied from the Public Works Department bench mark A.R. 38 to S.P.1 on Ninbing traverse 'A', and found that the Bureau's value at S.P. 1 was 25.1 ft too low. The Bureau's height at S.P.1 was based on the bench mark at Kimberley research station. The assumed elevation at the Kimberley bench mark was therefore in error by 25.1 feet, and all related elevations should also be adjusted. The corrected elevations are shown in Appendix D.

Loop Closure:- The loop closure chart for the level survey is given in Appendix D, Page 4. A closure error of .38 ft was found in the 22 mile traverse encircling the Central Burt

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*A recent tie from P.W.D. Bench Mark A.R.38 to S.P.1 on traverse 'A' Ninbing has shown that the 101.48 ft taken as the height of the bench mark near Kimberley Research Station is 25.1 ft too low.

Range. This error was distributed around the loop.

Elevations of all stations corrected for errors in datums and with closure errors distributed around the loop are given in Appendix D.

II GRAVITY

1. Instruments used:- Worden gravity meter No.216 with a scale constant of 0.0909 milligals per division with a reading accuracy of 0.1 scale divisions was used.
2. Elevation Correction Factor:- 0.06826 milligals per foot* being the combined Free-Air and Bouguer correction factor corresponding to a density of 2.1 gms per c.c. for the near surface rocks.
3. Latitude Corrections:- Calculated using the International Ellipsoid Formula.
4. Loop Closure:- A closure error of 0.14 milligals in the observed gravity values was found in the 22 mile traverse encircling the Central Burt Range. This error was distributed around the traverse; the necessary correction per half hour duration being approximately 0.003 milligals. The accuracy of the survey was estimated to be 0.04 milligals.
5. Permanently marked stations:- All stations were marked with a wooden peg and the following bench marks placed:-
   (a) On tree 34 ft S.E. of station R42.
   Bench Mark height 177.29 ft Station R42, 177.72 ft.
   (b) On tree 60 ft S.W. of Station R25
   Bench Mark height 217.6 ft Station R25, 217.51 ft.
   (c) On tree at Station R21
   Bench Mark height 239.92 ft Station R21, 239.44 ft.
   (d) On stump at Station R36.
   Bench Mark height 247.62 Station R36, 247.62 ft.
   (e) On tree, 3 chains east of Station R59.
   Bench Mark 157.21 Station R59, 153.02 ft.

The elevations given above have not been corrected for the errors in datum values and for closure errors. See above under "METHOD OF SURVEY". The elevations of the stations corrected for closure errors and for errors in datums are given in Appendix 'D'.

C. TOPOGRAPHIC TIES TO OTHER SURVEYS

a. Levels:- As mentioned above under "METHOD OF SURVEY" this survey was tied to the Bureau's Survey in 1956 in the Milligans Lagoon area. The ties were to S.P.464 and S.P.415 on traverse 'B', and S.P.448 on traverse 'E'.

b. Horizontal:- See under "METHOD OF SURVEY".

D. GRAVITY TIES TO OTHER SURVEYS

See under "METHOD OF SURVEY".

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*The elevation correction factor 0.06826 milligals per foot is incorrect; it should be 0.06726 milligals per foot.

E. IMPORTANT OBSERVATIONS

The Bouguer anomaly map, (Plate 12) was interpreted as indicating a deepening and broadening of the sedimentary trough south from Milligans Lagoon towards the Central Burt Range. The lowest gravity values occur immediately to the west of the Amphitheatre fault in the vicinity of gravity station R37 and Burbury considers this to indicate the thickest sedimentary section. To the east of the area surveyed, a line of steep gravity gradients closely follows the surface expression of the Cockatoo fault and it is considered to be an expression of this fault. The gradient across the fault is greater in the north than in the south. Burbury by graphical means interprets the gradient as representing a throw of over 5000 ft in the south and even greater in the north. He points out that while the gravity profile across the Cockatoo fault in the Amphitheatre area indicates a downthrow to the west, surface geology shows the Burt Range Limestone in the west faulted against the Nigli Gap Sandstone indicating the west side to be upthrown. Burbury considers that the difference in interpretation is due to the major movement along the Cockatoo Fault being prior to or during deposition of the Burt Range Limestone, and that minor (reverse) movements occurred after deposition of the Nigli Gap Sandstone.
No other structural elements are expressed by the Burt Range Gravity Survey.

F. SURVEY DATA AVAILABLE

I GRAVITY

1. Field Sheets: Field data ~~is~~ are given in Appendix 'A' pages 1 to 3. They were not obtained directly from the field sheets but from tabulated data supplied by Mines Administration Pty Ltd.

2. Table of Principal Facts: Calculation sheets for the Bouguer anomalies are given in Appendix 'B' pages 1 ~~to 3~~. and 2 .

II TOPOGRAPHIC

1. Field Books

   a) Levels will be found in Field Book 421 and 422

   b) Horizontal. Bearings and distances between successive stations are given in Field Books 131, 132 and 133.
   (The field books mentioned above are with the Department of the Interior, Canberra. Copies of these books are on file in the Basins Study Group, Petroleum Exploration Branch, in Canberra).

2. Table of Principal Facts:

Elevation of stations (unadjusted) taken from the field books are given in Appendix 'D' page 1.

Elevations corrected for error in datum values at S.P. 415 and S.P. 465 are given in Appendix 'D' page 2.

Elevations corrected for error in datum values at Kimberley Research Station are given in Appendix 'D' page 3.

A loop closure chart is given in Appendix 'D' page 4 and the method of distribution of the closure error on page 5.

The elevation of stations after adjustment of the loop closure errors are given in Appendix 'D' pages 6 and 7.

8. PORT KEATS SURVEY (COASTAL), 1957.

The second gravity survey by Mines Administration Pty Ltd in 1957 was for Associated Australian Oilfields carried out during April, May and September 1957. It was a reconnaissance survey along the coast from the mouth of the Daly River to Pelican Island, approximately 28 miles west of the Keep Inlet. 157 gravity stations were read at one to two mile intervals.

No separate report appears to have been written on this survey but it is described in the report:-

"Regional Gravity Survey, Bonaparte Gulf Basin, North-Western Australia, 1957" by J.E. Burbury, NT/2/46,

which is a compilation of data from several surveys carried out by the Bureau of Mineral Resources and Mines Administration Pty Ltd between 1955 and 1957. The location of the gravity stations along with the Bouguer contours are shown on plate 13 (See Vol. IV, Part I).

The Survey details given below have been obtained mainly from the above report and partly from a study of the calculation sheets of the gravity survey supplied by the company and from discussions with Mr. J. Burbury.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Level: The gravity readings were taken at sea level and elevations of stations determined relative to Darwin tide datum* by reference to the Admiralty Tide Variation Tables. Burbury estimates the accuracy of the levels to be ± 5 feet.

2. Horizontal: The positions of the stations were plotted on airphotographs** and later transferred to 4 miles to the inch maps. Burbury estimates the accuracty of the positions to be ± 1000 feet in latitude.

3. Gravity: The gravity data was reduced using a value of 978341.69 milligals at station 128 of the Port Keats Survey. The survey later tied in to the Keep River Survey, the tie being between station K10 of the coastal survey and station 214 of the Keep River Survey.

The Bouguer anomaly obtained at station 214 was found to be 4.65 milligals lower than the value obtained during the Keep River survey and 4.65 milligals was added to all Bouguer values. The corrected Bouguer values are therefore with respect to Peg 60 M.N. of the Border Survey where an

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*Darwin tide datum is 28.42 feet below a bench mark on the N.E. face of the S.W. abutment of the jetty (Burbury - Personal communication).

**Positions of coastal stations in the vicinity of the Daly River are marked on a B.M.R. mosaic probably in the possession of George Thomas. The positions of stations further south are marked on National Mapping's Port Keats air-photos which were returned by Minad to Melbourne. (See file B106WNT/1/2).

assumed value of 978409.20 milligals was taken to be equal to the observed value of gravity at that station.

B. METHOD OF SURVEY

I. TOPOGRAPHIC:- As mentioned above gravity readings were taken at sea level and elevations of stations determined relative to Darwin tide datum, by reference to the Admiralty Tide Variation Tables.

II GRAVITY

1. Instruments used:- Worden Gravity Meters Nos.207 and 216 were used.

   The scale constants were:-

   a) Meter No.207:- 0.10135 milligals per scale division.

   b) Meter No.216:- 0. milligals.per scale division.

   Repeat readings at sub-base stations were made as often as possible throughout the day but in most cases only one repeat was made daily. The maximum drift over an interval of hours was milligals.

2. Elevation Correction Factor:- .06954* milligals per feet corresponding to a density of 2,0 gms per c.c of the near surface rocks.

3. Latitude Correction:- Latitude corrections were calculated using the International Ellipsoid formula.

4. Loop Closure:- The traverses were not looped. Burbury estimates the gravity values to be accurate to within ± 0.15 milligals.

5. Permanently Marked Stations:-

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* Burbury in his report (page 4) states that the readings were reduced using a Bouguer correction factor of 0.06826 milligals per foot corresponding to a density of 2.1 gms per c.c. From the field sheets it appears that 0.06954 milligals per foot corresponding to a density of 2.0 gms per c.c. was used.

C. TOPOGRAPHIC TIES TO OTHER SURVEYS

The coastal survey tied in to two previous surveys.

1. The Port Keats Survey.
2. The Keep River Survey.

1. The first survey to which the coastal survey tied was the Port Keats Survey by Minad in 1956.

Two ties were made.

a) Between station S.58 of the coastal survey and peg 128 at the northern end of the Port Keats Survey.

The tie was made via an intermediate station SA 1.

An elevation of 110 feet relative to Darwin Tide Datum was obtained at station 128* of the Port Keats Survey.

During the Port Keats Survey an elevation of 90.88 ft was obtained at station 128 relative to an assumed height of 10 feet at peg 54 and an elevation of 43.9 feet was obtained at peg 7.

A tie by the Department of Interior to peg 7 during the Daly River Crossing to Port Keats gravity survey (see page 4), obtained a height of 160.4 feet (see Plate 73).

This height is relative to Railway datum.** Darwin Town Datum is 102.75 feet ~~below~~ above Railway Datum and Mean Sea Level (Darwin) 112.0 feet ~~below~~ above Railway Datum.

The levels of peg 7 with respect to the various datums are therefore as follows:-

1. 160.4 feet (Railway Datum).
2. 57.65 feet (Darwin Town Datum).
3. 48.40 (Mean Sea Level, Darwin).

The assumed height of 10 feet at peg 54 of the Port Keats survey is therefore 4.5 feet too low and should be 14.5 feet (Mean Sea Level, Darwin).

The elevation of station 128 is therefore 95.38 feet with respect to mean sea level Darwin and 104.63 feet with respect to Darwin Town Datum from which it appears that Darwin Town Datum is somewhere between Darwin Tide Datum and Mean Sea Level as a height of 110 feet was obtained for station 128 with respect to Darwin Tide Datum.***

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* It is not yet known how the level tie was carried out.

** The Railway traverse is tied to the N.T.A. Lands & Survey bench mark No.1 at Darwin.

*** Burbury estimates that the accuracy of the levels obtained during the coastal survey is ± 5 feet. Therefore it would perhaps be better to accept the value given by the Department of the Interior as being the more reliable. Also as Mean Low Water (Darwin) is likely to be different from Mean Low Water (Wyndham) it would perhaps be best in future compilations to convert all heights to Mean Sea Level.

b) The second tie to the Port Keats survey was between B51 of the Coastal survey and B52 which is peg 79 at the eastern end of the Port Keats survey by Minad.

During the Port Keats Survey the elevation of peg 79 with respect to an assumed height of 10 ft. at peg 54 a datum was found to be 9.6 ft. (See Appendix D, Page 2 of the Port Keats Survey.

It was shown above that the assumed height of 10 ft. for peg 5 was found to be 4.5 ft. too low by the tie from Daly River Crossing to peg 7 of the Port Keats Survey. The elevation of peg 7 with respect to Mean Sea Level is therefore 14.1 ft.

As the datum for the coastal survey is with respect to Darwin Tide Datum and its relation to other datums unknown it is suggested that stations S58 and B51 of the Coastal survey be adjusted to Mean Sea Level by accepting the values at station 128 (95.38 ft.) and 79 (14.10 ft) as correct and the elevation of all coastal stations adjusted accordingly.

The accuracy claimed for the Coastal Survey by taking readings at sea level and reducing them to Darwin Tide Datum using the Admiralty tide variation tables is $\pm$ 5 ft. This is a further reason why the figures obtained by the Department of the Interior's tie between Daly River Crossing and peg 7 of the Port Keats Survey by Minad should be accepted as more likely to be correct.

2) The tie to the Keep River Survey was between station K 10 of the coastal survey and station 214.

An elevation of 24 feet with respect to Darwin tide datum was obtained by this tie.

During the Keep River Survey an elevation of 84.3 feet was obtained at station 214 (see Vol.I, Part I :). This elevation is with respect to an assumed height of 200 feet at peg 60 M.N.

A tie by the Bureau in September 1956, (see Vol.I,Pt.II)between 60 M.N. and a bench mark near Kimberley Research Station showed that the height of 200 feet assumed at 60 M.N. was 78.6 feet too high with respect to M.L.W.Wyndham. A later tie between P.W.D. bench mark A.R.38 and S.P.1 on traverse 'A' Ninbing made during the Carlton Gravity Survey in 1961 showed that the height taken for the bench mark near Kimberley Research station was 25.1 feet too low. Hence the assumed height of 200 feet at 60 M.N. is 53.5 feet too high with respect to M.L.W. Wyndham.

The height of 84.3 feet obtained at station 214 with respect to 60 M.N. as datum is therefore 30.8 feet with respect to Mean Low Water Wyndham. Darwin tide datum must therefore be 6.8 feet lower than Mean Low Water, Wyndham. Burbury (see page) estimates the accuracy of the coastal levels to be $\pm$ 5 feet and the 6.8 feet difference is almost within the limits of accuracy of the survey. It is suggested that if a recompilation of the gravity data is attempted the height of 30.8 feet at station 214 obtained by Minad by a tie to 60 M.N. and the tie to bench mark A.R38 be used with a correction of - 12.5 ft.applied in order to keep to the one datum of Mean Sea Level.

D. GRAVITY TIES TO OTHER SURVEYS

The coastal survey tied to two previous surveys

1. The Port Keats Survey.
2. The Keep River Survey.

1. The first survey to which this coastal survey was tied was the Port Keats Survey by Minad in 1956.

Two ties were made.

a) Between station S.58 of the coastal survey and peg 128 at the northern end of the Port Keats Survey.
b) Between station B.51 of the coastal survey and peg 79 at the eastern end of the Port Keats Survey.

2. The gravity tie to the Keep River Survey was between station K 10 of the coastal survey and station 214 of the Keep River Survey.

It was mentioned above (see page) that an assumed value of 978 milligals was used as datum for the coastal survey. When the survey tied in to station 214 of the Keep River Survey the Bouguer anomalies obtained differed by 4.65 milligals and this amount was added

to all Bouguer values to bring them to the assumed gravity datum of 979409.20 milligals which was taken to be equal to the observed gravity at Peg 60 M.N.

By adding 4.65 milligals to all stations a good approximation of the Bouguer anomalies with respect to 60 M.N. as datum is readily obtained. However, if a recompilation is attempted the following points must be taken into account:-

a) The Bouguer reduction of the coastal survey used a height of 24 feet for station 214 and a Bouguer correction factor of 0.06954 milligals per foot corresponding to a density of 2.0 gms per c.c.

b) The Bouguer reduction of the Keep River Survey used a height of 14.1 feet approximately above mean sea level and a Bouguer reduction factor of 0.06826 milligals per foot corresponding to a density of 2.1 gms per c.c.

c) The difference in Bouguer anomaly values at St.214 due to the use of different elevations and different Bouguer reduction factors is 0.69 milligals.

d) The height of 14.1 feet was obtained by taking 70 feet* from 84.1 feet obtained with respect to an assumed height of 200 feet at 60 M.N. (Minad datum).

e) It was mentioned above (see page) that a later tie, during the Carlton Gravity Survey, has shown that the 200 feet assumed to be the height at 60 M.N. is 53.5 feet too high with respect to mean low water Wyndham. Hence the correct value for station 214 should be 30.8 feet. The elevations given in Appendix B Vol.1, Part 1) of the Keep River Gravity Survey and Appendix B, pages 1 to 6 for the Port Keats (Coastal Survey) should therefore be corrected accordingly.

f) That the gravity data given in Appendix B pages 1 to 6 for the Port Keats coastal survey should be recomputed using the correct elevations and a Bouguer reduction factor of 0.06826 milligals per feet corresponding to a density of 2.1 gms per c.c. of the near surface rocks, this being the density which was used in the reduction of the other surveys.

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* From rod levels obtained in the northern parts of the area, along the banks of the Keep River, it became apparent that the assumed height of 200 feet for peg 60 M.N. was about 70 feet too high.

E. SURVEY DATA AVAILABLE

I GRAVITY

1. Field Sheets: Appendix 'A', pages to .

2. Computation Sheets: Appendix 'B', pages 1 to 6.

II TOPOGRAPHIC

1. Field Books: None. Readings were taken at sea level and reduced to Darwin Tide Datum by reference to the Admiralty Tide Variation Tables.

2. Table of Principal Facts: Elevations are included in Appendix 'B' pages 1 to 6.

In 1957, J.E. Burbury integrated the results of the coastal reconnaissance survey with all gravity surveys carried out by Minad and the B.M.R. between 1955 and 1957.

"Regional Gravity Survey, Bonaparte Gulf Basin Northwestern Australia, 1957", by J.E. Burbury.

The above report contains a number of important observations on significant trends, densities etc and gives an interpretation of the Bouguer anomaly map (see Plate 13).

Extracts from the report by Burbury are given below:-

G E O L O G Y

"The interpretation of structural features in the basin by the gravity method is dependent on the existence of one or more density contrasts within the stratigraphic section. Two such contrasts are indicated in the section:

(1) Top of Burt Range limestone.
(2) Top of Lower Proterozoic

The average density for the Burt Range limestone, as determined from five hand specimens, is 2.65, while the average density for the overlying sandstones and limestones is 2.4. This gives a density contrast of 0.25 at the top of the Burt Range limestone.

The density contrast within the Proterozoic sequence is a little more obscure owing to the variation in rock types within the sequence. However, it is considered that a density contrast of 0.2 to 0.3 would exist between the Upper Proterozoic sediments and the igneous and metamorphic rocks of the Lower Proterozoic Lamboo Complex.

Interpretation of the gravity results will be complicated by the possible occurrence of both these density contrasts producing an additive effect on the gravity while the density contrast at the top of the Lower Proterozoic is likely to occur throughout the whole basin, the presence of the Burt Range limestone at depth in both the Carlton and Port Keats sub-basins is unknown and hence its effect on the gravity in these areas can only be based on assumption."

RESULTS AND INTERPRETATION

"The major features of the anomaly pattern is the development of strong negative anomalies (gravity lows) in the vicinity of the Port Keats Mission Station, the Keep River Inlet and the Central Burt Range.

The low in the Port Keats area has a minimum value of -10 milligals, is elongate north-south and appears to be open at the northern end. South from this low the gravity rises to a value of approximately +20 milligals over the Queens Channel and then falls to approximately -4 milligals in the low over the Keep River Inlet. This low is closed, is slightly elongate east-west and appears to extend north-west into the

Joseph Bonaparte Gulf in the form of a broad trough. To the south the low extends into a narrow trough, which rises gradually to a value of +8 milligals approximately 6 miles north of Spirit Hill. South from here the gravity falls and the trough broadens out into a low in the Central Burt Range area where the minimum value is -16 milligals.

These three lows appear to be directly related to the three sub-basins of the Bonaparte Gulf Basin. In each case the position and shape of the gravity lows conform very closely to the geological mapping of the basins, and all regions of high gravity surrounding the lows correspond with areas mapped as Proterozoic basement rocks.

Hence, it is reasonable to assume that the gravity contours are directly related to the contours on the basement surface, that is at the density contrast at the top of the Lower Proterozoic.

It must be remembered that where the Burt Range limestone occurs in the section the gravity will also be related to the depth and thickness of this formation.

Accurate estimations of the thickness of Palaeozoic sediments in the different sub-basins is complicated by the lack of knowledge of these density contrasts. In the Carlton sub-basin, the Cockatoo Sandstone and the Burt Range limestone dip north-east below the Weaber Sandstone in the Ninbing area, with an accompanying fall in gravity of approximately 20 milligals in the same direction. Assuming a density contrast of 0.25 to be at the top of the Burt Range limestone and disregarding other possible contrasts, a thickness of sediments of approximately 9,000 feet would be expected above the Burt Range limestone in the area around the Keep Inlet. This figure however, is far in excess of any measured thickness of sediments above this horizon and indicates that the lower density contrast is jointly responsible for the observed drop in gravity and that the depth to the top of the Burt Range limestone in this area must be far less than 9,000 feet.

In the Burt Range sub-basin a thickness of approximately 7,000 feet of Devonian sediments (Cockatoo sandstone and Burt Range limestone) dip eastwards (into the basin) with an accompanying drop in gravity of approximately 25 milligals, which is comparable to the drop observed in the Ninbing area of the Carlton sub-basin. Hence, it could be postulated that a similar thickness of Devonian sediments would occur in the Carlton sub-basin.

In the Port Keats sub-basin the presence of the Burt Range limestone and other Lower Palaeozoic units is unknown, but they could possibily occur below the Port Keats Group. The pronounced gravity low around the Port Keats Mission does indicate a considerable thickness of sediments above the Lower Proterozoic rocks. In the eastern half of the Port Keats area a large gravity high indicates the presence of a basement ridge at shallow depth below the Permian cover. The axis of this high

strikes north-south across the mouth of the Daly River. The presence of a basement ridge is confirmed by information from coal bores put down by the South Australian Mines Department in 1903. A bore on Cliff Head, 4 miles west of the Daly River mouth, struck granite at 720 feet, while a bore in Anson Bay, 10 miles to the south-west, penetrated 1,500 feet of sediments without striking granite.

It is suggested that west of this granite ridge Palaeozoic sediments could be expected below the Port Keats Group. However, the possibility of Upper Proterozoic sediments occurring west of this ridge (below the Port Keats Group), cannot be disregarded, as a thick section of Proterozoic sediments above the Lower Proterozoic complex could account for the gravity pattern.

Between the Port Keats and Carlton sub-basins an interesting gravity ridge extends west-north-west through the Queens Channel. The maximum observed gravity value over the ridge is +20 milligals and possibly higher values would exist to the west where no control is available. This high gravity value over the ridge, compared with similar values throughout the basin, indicates that Proterozoic basement rocks would occur at, or very close to, the surface in this area. The possibility of an old exposed basement ridge in this area would explain the presence of large granite and quartzite boulders found along the shoreline west of the Keep Inlet. During the course of the coastal gravity survey, outcrops of what appeared to be Carboniferous sandstones were observed on Pelican Island (approximately 24 miles west of Keep Inlet), dipping south at approximately 10 degrees. This is a reversal of the general trend of the Carboniferous rocks in the Carlton sub-basin, and could indicate that the Palaeozoic rocks of the Carlton sub-basin terminate against the southern side of the Proterozoic ridge in the Queens Channel.

Gravity results on the eastern side of both the Burt Range and Carlton sub-basins, have confirmed the presence of the Cockatoo fault. Gradients of up to 5 milligals per half mile have been observed across the fault.

The gravity profile over the Cockatoo Fault in the Amphitheatre area (Burt Range) indicates the downthrown side of the fault to be to the west, while surface geology shows the Burt Range limestone, on the west, faulted against the Nigli Gap sandstone, indicating the western side to be upthrown. It is considered that only minor movements of the fault, after deposition of the Nigli Gap sandstone, have brought about this phenomenon, the major movement of the fault having been prior to or during deposition of the Burt Range limestone, when the western side was strongly downthrown.

Graphical interpretation has shown that the displacement of the Cockatoo fault in the Amphitheatre area would be in excess of 5,000 feet, while further north, east of Milligans Lagoon and Spirit Hill, the steeper

gravity gradient could indicate an even greater displacement. It is possible that along the northern extension of the Cockatoo fault subsequent uplift of the western block after deposition of the Nigli Gap sandstone did not take place or that the movement was less than on the Cockatoo fault in the Amphitheatre area. Also in the north, low density Carboniferous sandstones are faulted against the Upper Proterozoic rocks, giving a large density break and hence a large effect on the gravity across the fault, while in the south, higher density Devonian limestone is faulted against Lower Proterozoic rocks, making the density break and hence the gravity effect smaller".

DARWIN - WYNDHAM

(Underwater Gravity Survey)

In 1958 the Bureau of Mineral Resources carried out a marine gravity survey in the area using a "North American Marine" underwater gravity meter installed on a 60' motor launch the M.V. Kano. The details of this survey are given in the Bureau of Mineral Resources Record 1959, No.156 entitled

"Preliminary Report of an Underwater Gravity Survey Darwin-Wyndham 1958" by L.W. Williams and S. Waterlander.

No Bouguer anomaly map is given in this report as the data from this survey had already been tied to and integrated with the Keep River and Burt Range gravity surveys by Mines Administration and the land reconnaissance surveys by the Bureau in Western Australia in 1956. Plate 14 gives the location of the gravity stations. The data from this survey (see "Table of Principal Facts" Appendix B pages 1 to 10) has been used to compile the Bouguer anomaly map plate 11.*

The text of preliminary report on the underwater gravity survey by Williams and Waterlander is given below.

1. INTRODUCTION

As a continuation of the marine gravity surveys in waters to the north of Australia, combined regional and detailed surveys were carried out between Darwin and Wyndham using a "North American" underwater gravity meter installed in M.V. Kano, a 60-ft motor launch under charter.

Following a request from Associated Australian Oilfields, N.L. for work on Permit to Explore No.2, four traverses, with stations at one-mile intervals, were run at right angles to the coast to the north of Port Keats. Another traverse was run from Port Keats towards Keep Inlet with stations at two- or five-mile intervals.

At the request of Gulf Oil Syndicate a traverse was run from Keep Inlet to Cambridge Gulf with stations at two-mile intervals. This traverse was extended to tie into the Wyndham pendulum station.

Because the inlets opening into Cambridge Gulf are so shallow and the currents so strong, the underwater gravity meter was not used in them, but readings were taken around the shore using a Worden gravity meter.

The survey vessel left Darwin on 16th July, 1958 and the survey was completed at Wyndham on 1st August, 1958.

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* This is a reproduction of Plate 2 contained in the Bureau Record "Report on the gravity survey in the Bonaparte Gulf Basin 1956-58" by R.F. Thyer, P.M. Stott, and F.J.G. Neumann.

For a summary of the above report see page to .

2. FIELD WORK

On all traverses except those with 1-mile station intervals, the drift control on the underwater gravity meter was obtained from ties to Darwin and Wyndham pendulum stations. Also, numerous land readings with a Worden gravity meter and ties to existing land stations enabled a check to be made in case "jumps" occurred.

On the traverses with station intervals of 1 mile (Traverses 86, 87, 88 and 89) and for the Cambridge Gulf survey with the Worden gravity meter, drift control was maintained by repeat readings on base stations.

Station positions were located wherever possible by using a horizontal sextant and/or a compass bearings to land marks. Where this was not possible (outer ends of traverses 86, 87, 88 and 89, and generally between Pearce Point and the mouth of Cambridge Gulf) the positions were determined using dead rockoning and the ship's log.

3. REDUCTION OF RESULTS

All anomalies have been reduced to Mean Sea Level (M.S.L.) using Admiralty Tide Tables to allow for the state of the tide.

The results were first reduced for Bureau of Mineral Resources regional gravity requirements using observed gravity values, determined with the underwater gravity meter, and based on pendulum station values. A density of 2.67 g/c.c. was used.

To fit in with existing land surveys carried out by Mines Administration, the results of the more detailed traverses were then reduced by adjusting the observed gravity value of the first station on each detailed traverse to an adjoining land station. This was done by assuming that the underwater gravity station and the land station had the same Bouguer Anomaly, and accepting the observed gravity value given for the land station. A density of 2.0 g/c.c. was used in this reduction.

The observed gravity values measured with the underwater gravity meter at the first station on each detailed traverse have been compared with the observed gravity values given by Mines Administration for the adjoining land stations. The results are given in the following table.

STATION NO.	COMPANY SURVEY			B.M.R. SURVEY		
	Observed Gravity	Obs.Gravity at M.S.L.	Int.	Observed Gravity	Obs Gravity at M.S.L.	Int.
	978	978		978	978	
B16 (86)	334.68	335.58		317.47	316.10	
			+7.11			+5.16
B26 (87)	342.00	342.69		323.28	321.26	
			+4.80			+6.39
S18 (88)	345.96	347.49		328.20	327.65	
			-9.20			-10.01
S24 (89)	337.53	338.29		319.17	317.64	
			+5.12			+6.05
B37 (90)	341.53	343.41		325.10	323.69	
			+56.30			+67.60
A9 (106)	397.83	399.71		392.67	391.29	

It will be seen that successive intervals agree fairly well, considering that the underwater gravity stations were not exact reoccupations, with the exception of the interval between B37 (90) and A9 (106). As this interval was checked with the B.M.R. Worden meter, it is considered that the B.M.R. interval is the more reliable.

4. RESULTS

The results described here are those based on pendulum station values and assuming a density of 2.67 gms/c.c. The anomalies obtained by fitting the underwater gravity meter measurements to existing land stations and using a density of 2.0 gms/c.c. are listed in the table, but are not discussed.

The Bouguer Anomalies, positive at Darwin, remain positive until the north side of Anson Bay. They then become negative and the largest negative value is recorded near Hyland Bay, slightly north of Port Keats.

There is a maximum at Station 101, near the centre of Queen's Channel and another minimum at Station 116, east of Cambridge Gulf.

The values become positive entering Cambridge Gulf and remain positive to Wyndham.

Along the more detailed traverses, the anomalies on Traverse 86 show a small maximum; on Traverse 87 and 88 they become more negative going west, and on Traverse 89 they become slightly more negative and then increase at the western end.

To summarise, the following gravity surveys were carried out during the period 1955 to 1958:

1. Keep River Gravity Survey, 1955 (see Vol. I, Part1).
2. Bureau of Mineral Resources Survey, July 1956. (see Vol. I, PartII.
3. Bureau of Mineral Resources Survey, September-October 1956. (see Vol. I, Part II.
4. Burt Range Gravity Survey. October, 1957. (see page 7).
5. The Underwater Survey carried out by the Bureau in the Coastal waters from Lacrosse Island, to Queen's Channel and in the east and west arms of the Cambridge Gulf in July, 1958. (See page 24.).

The results of these surveys were then integrated into a report by Thyer, Stott & Neuman (1959) and a Bouguer Anomaly Map was prepared (see Plate 11*). The report contains a number of important observations on significant trends, densities, etc., and parts are reproduced below, verbatum.

GEOLOGY

"There is little evidence to suggest whether or not substantial variation in thickness of the upper Proterozoic sediments occur beneath the Palaeozoic sediments in the Bonaparte Gulf Basin. Traves (1955, p.92) considers that since Lower Proterozoic times there were various diastrophic movements ranging in age from before Middle Cambrian to Middle and Upper Carboniferous associated with the formation of the troughs in which the sediments of the Bonaparte Gulf Basin were deposited. It seems probable that in these troughs the Palaeozoic sediments are underlain by Upper Proterozoic sediments which have been folded and eroded prior to the deposition of the Palaeozoic sediments.**

This process would result in a local thinning of the Proterozoic section on the flanks of the troughs and/or relative thickening coincident

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* "In preparing the Bouguer anomaly map (see Plate 11), the Bouguer values taken from the company's maps (Traves, 1956) have been reduced by 22 milligals. This correction makes due allowance for the difference in elevation and gravity datums between the company's survey and the Bureau's. The values on Plate 11 are reduced to Bouguer values at M.L.W. Wyndham and are based on the pendulum value of 978415.9 (0) milligals at Wyndham.

In reducing the results of the gravity survey along the coastal waters the readings taken with the underwater gravity meter were reduced from the sea bed to low water mark, Wyndham using a density of 1.03 gms/cc for sea water and 2.0 gms/cc for the average rock density. The readings taken with the Worden gravity meter at mean sea level were reduced to L.W.M. Wyndham using a density of 2.0 gms/cc. "

** I later give evidence (See Volume III) to support the view that the Upper Pre-Cambrian rocks are unfolded while the Lower Pre-Cambrian rocks have been folded and eroded prior to the deposition of the Upper Pre-Cambrian rocks.

with the Palaeozoic troughs."

"THE GEOPHYSICAL PROBLEM"

"In the Bonaparte Gulf Basin the total thickness of all members of the Palaeozoic section is about 15,000 feet but in any one locality the thickness may not be more than 5,000 feet. Little is known about their average density. The results of tests on surface samples of various sediments taken from the area are shown on Table 1, (see Appendix E, page). The sandstone samples have an unusually low density. The samples are dry and partly weathered and it is likely that the density of the sandstones at depth would be substantially higher. Sandstones predominate but in places there are thick sections of limestone and shale. The average density of the sediments is probably of the order of 2.4 to 2.5 gm/cc and that of the average basement rocks is of the order of 2.7 to2.8 gm/cc. The Upper Proterozoic sediments, if relatively uniform in thickness throughout the area, would have little influence on the gravitational field except for an overall reduction proportional to their thickness. If there is localised thickening of the Upper Proterozoic sediments coincident with the Palaeozoic sub-basins, some part at least of the gravity deficiency observed over the sub-basins is due to this thickening."

"In sedimentary basins in which the sediments have been deposited in a subsiding basement trough, the depression of the basement itself gives rise to a gravity deficiency. The earth's crustal layers become progressively more dense in depth and more fluid- a depression of the relatively light, near-surface crust displaces denser and more fluid material leading to a local mass deficiency and reduction in gravitational field".

"The gravity observations in the Bonaparte Gulf Basin are presented in the form of a Bouguer anomaly map (see Plate 11). The observations have been corrected for the normal change in gravity with latitude and elevation. In general, the Bouguer values are either positive or only slightly negative over outcropping Upper Proterozoic rocks that border the Palaeozoic sub-basins, but are more negative over the sub-basins. As indicated above the decrease in values is probably caused by the combined effects of:-

(i) The presence of various thicknesses of Palaeozoic sediments.
(ii) Local thickening of the Upper Proterozoic sediments.
(iii) Depression of the basement rocks.
(iv) Lateral variations in density of the basement rocks. These may result in variation in gravity being superimposed on the other effects mentioned above".

"Effects (i), (ii) and (iii) are not necessarily unrelated. It is likely that there is close correlation between the thickness of the Palaeozoic sediments and the amount of basement depression. Local thickening of the Upper Proterozoic sediments, if present, might coincide with the Palaeozoic troughs.

Although there is considerable uncertainty in the interpretation of the gravity data, the fact that there is a close relation between the gravity anomalies and the basin structures lends support to the belief that variation in gravity can be related directly to variation in the thickness of Palaeozoic sediments. Estimation of the thickness of these sediments from the gravity data alone would not be justified, but it is possible that a satisfactory empirical relationship could be derived by comparing the thickness of sedimentary rocks indicated by the seismic results with corresponding gravity anomalies".*

RESULTS

The gravity contours are based on fairly widely dispersed data; it is emphasised that no great reliance can be placed on the detailed shape of the contour pattern. The broad pattern of the contours, however, reveals significant trends which are outlined below.

(a) A predominating north-easterly trend is apparent in the gravity contours in the eastern portion of the Bouguer Anomaly Plan, where steep gradients occur. This trend runs from the northern bank of the Keep River, opposite Mt. Septimus, toward Sandy Creek but the gradients are less steep and the contours more easterly. It appears to extend further east beyond the Trapper Hill and Buffalo Hill region. On the east side of the trend gravity Bouguer values are in general from fifteen to twenty milligals higher than to the west of it.

(b) The trend of steep gradients described in (a) above is followed further west by a somewhat irregular pattern of low gravity anomalies. Further west Bouguer values again increase along another well expressed north-easterly trend of contours, which extends from the Eight Mile Creek area along the eastern side of the Pincombe Range and ends east of the Weaber Range.

(c) In contrast with (a) and (b) it will be noted that over the wide area northwest of the Pincombe and Weaber Ranges the overall trend in the gravity contours is north-westerly, except for a number of local gravity 'Highs' and 'Lows' which run almost at right angles to the general north-westerly trend. These local anomaly features are restricted to the area bounded by the zero and minus ten milligal contour lines.

(d) The two major trends, mentioned above, show gravity intensity increasing southeast and southwest out of an extensive gravity 'Low' with approximately ten milligals closure, which centers southwest of the head of Keep Inlet between Latitudes 15°00' and 15°15'. For convenience this will be referred to as the 'Keep Inlet Low'.

(e) The 'Keep Inlet Low' extends mainly in an east-west direction. It is restricted to the north by increasing Bouguer values which were established by the underwater survey along the northern edge of the gravity map.
The southern end of an extensive gravity 'High' which develops into a maximum further out to sea in the Joseph Bonaparte Gulf is indicated at Underwater Gravity Station No.107 (Bouguer anomaly = +6.0 milligals). East of this 'High' a trough-like

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*In the later section on "Correlation between Bouguer Anomaly Profiles, Geology and Substructures as indicated by Seismic Reflection and Refraction Shooting" Vol.III, the negative gravity anomalies which occur in some areas are shown to correspond with thick sediments (as indicated by seismic results), but in other areas, particularly to the west of Port Keats and Hyland Bay, positive gravity anomalies coincide with apparently thick sedimentary deposits.

extension of the 'Keep Inlet Low' runs northward across Queens Channel.

(f) A distinctive feature in the anomaly pattern is an isolated gravity 'High' which coincides with the Pincombe Ranges. It is terminated further west by a relatively narrow zone of low Bouguer anomaly - the "Ivanhoe Low" - established at Station No.51M (-11.1 milligals) north of Ivanhoe and at Station No.B9) - 11.7 milligals) on the Carlton Hill-Point Spring traverse. The axis of the "Ivanhoe Low" appears to swing in an arc from Ivanhoe to Pander Ridge and for some distance northwest beyond the Carlton Hill road, although further gravity data are needed to establish its trend precisely.

(g) Anomalous features of relatively small extent are present in the area which extends between the zero and minus ten milligals contour lines from the Pincombe and Weaber Ranges northwest toward the Cambridge Gulf. A gravity 'High' of limited extent, which requires more detailed coverage for accurate contouring, exists south of Ninbing. Bouguer values south of Lacross Island near the head of Cambridge Gulf are exceptionally high, followed by a somewhat elongated zone of low values south of Shakespeare Hill.

(h) Highest Bouguer anomaly shows on the Contour Plan is at Station No.137 (+ 15.3 milligals) of the Underwater Survey opposite Adolphus Island near the northwestern corner of the gravity map. A minimum in the gravity data was established at Station No.R.38 (-38.7 milligals) in the Burt Range area.

"DISCUSSION OF RESULTS"

"It is immediately evident that gravity values over outcropping Proterozoic rocks are generally higher than over the Palaeozoic basins.

East of the Keep River-Sandy Creek anomaly trend, Upper Proterozoic beds occur, including sandstone, dolomite and shale of the Victoria River Group. Near Cockatoo Creek and south-east of the Burt Range area, members of the Lower Proterozoic Group including igneous rocks of the Lamboo Complex and Halls Creek Metamorphics crop out.

In the western portion of the surveyed area, along the course of the Order River and west of Cambridge Gulf, outcrops of Upper Proterozoic beds appear at the surface, indicating a basement 'High'. This is clearly shown as a gravity 'High', which has a north-easterly extension under Palaeozoic rocks of the Weaber Range.

From the aspect of structural geology the trends of the gravity contours over the western and south-eastern portion of the plan emphasise the margins of two structural units of major proportions, namely the Kimberley Block to the west and the Sturt Block to the east.

The deeper structure of these blocks is associated with pronounced unconformities between Lower Proterozoic and older rocks which are covered by almost flat lying Upper Proterozoic beds. Variations in the gravity anomaly observed upon typical block areas are most likely due to lateral variation in density between folded or intruded rocks, which compose the deeper basement. This interpretation is offered to explain the gravity maximum between Slab Hill and Flat Top Hill west of Cambridge Gulf and to the west of Adolphus Island, where Upper Proterozoic sediments with gentle dips crop out.

The steep gravity gradients in the south-eastern portion of the contour plan from Keep River to Sandy Creek and some distance further north-east suggest a major fault or a system of faults which form the

western margin of the Sturt Block. This fault system seems to be an extension of the known Cockatoo Fault south-east of the Burt Range area.

It is of interest to note that the gravity picture indicates that faulting is less pronounced at the extreme south-western end where Permian beds extend across the main fault to the east.

From gravity data the vertical displacement on the fault appear to be greatest between the Keep River and Sandy Creek where Permian sediments occur in outcrops west of the fault in contact with Proterozoic beds to the east.

Further north-east beyond Sandy Creek the gravity gradient decreases which might indicate that the fault gradually disappears and that the eastern margin of the sedimentary basin is determined by a monoclinal flexure rather than a fault.

East swinging gravity contours opposite the Spirit Hill area suggest minor cross faulting almost perpendicular to the main fault plane. On the northern bank of the Keep River, where the Cockatoo Fault is intersected by the course of the river, gravity contour lines also swing east and indicate minor faults diverging from the main fault.

The zero gravity contour which in the western portion of the surveyed area, swings north-west from Pander Ridge toward the tidal flats east of Cambridge Gulf indicates in a general manner the boundary between the Cambrian and Devonian rocks which crop out in this area. However, gravity data is sparse in this area and more are needed to establish the contour trends accurately. The contours further north-east also run more or less parallel to the strike of the sediments, including Permian beds, which gently dip north-east.

Faulting which marks the margin of the Kimberley Block appears from the gravity evidence to be different structurally to the fault zone, including the Cockatoo Fault, which bounds the Sturt Block. A structural pattern of 'horst" and "graben" tectonics prevails east of the Pander Ridge, including the "Ivanhoe Graben" (Traves 1955) of Devonian sediments, terminated farther east by the Proterozoic block of the Pincombe Range.

South of Ninbing a gravity "high" of limited extent is possibly a horst-like ridge beneath a cover of Devonian and Permian rocks. This suggestion is supported by a reversal in the dips of the Devonian beds shown on the geological map approximately two miles south-west of Ninbing. Minor faulting with north-westerly trends is known east and west of Ninbing.

However, a much denser grid of gravity stations would be required to correlate the gravity anomaly more accurately with known geological data.

No gravity data are available immediately northwest of the Carlton Hill-Ninbing road, as this area is hard of access. However, gravity results obtained during the course of the survey in coastal waters near the head of Cambridge Gulf reveal a gravity "high" of plus four milligals extending south of Lacrosse Island, followed to the east by an elongated "Low" of minus elevan milligals south of Shakespeare Hill.

On Lacrosse Island Upper Proterozoic rocks crop out while along the cape near Shakespeare Hill rocks of Devonian age are known. The contrast between the high and low gravity anomaly produces steep gradients along a north-northeast trend between Lacrosse Island and Shakespeare Hill. This trend suggests the existence of a fault, which might form one of the margins of a deep graben under the gravity "Low".

If this interpretation of the gravity picture is substantially correct, it appears likely that deep troughs similar to the "Ivanhoe Graben" extend over a considerable distance along the south-western margin of the Palaeozoic basin.

Summing up all the gravity and geological data available, it seems reasonable to assume that an extensive fracture zone lies approximately between the zero and minus ten milligal contours from the Pincombe Range to the Cambridge Gulf.

It is evident that gravity values observed over the surveyed area are generally lower on the Palaeozoic basin areas. The assessment of the total probable thickness of the sediments, deposited in deeper sections of the Bonaparte Gulf Basins is difficult, owing to the great variation in the specific densities between Palaeozoic limestones and sandstones (see Table No.1).

The gravity effect of the Burt Range Limestone and the assessment of the thickness of sediments in the Burt Range Sub-basins has been dealt with in a separate report, (Neumann 1959).

The gravity results must be also considered in conjunction with the seismic results obtained in this area, which are also subject of a separate report (Robertson 1957). The lowest gravity values observed during the survey were obtained at the southern limit of the gravity data south of Mount Septimus. The deeper part of the Burt Range Sub-basin is probably to the south of Mount Septimus. However, acid intrusions at depth, similar to the Lamboo Complex Granites, which crop out nearby along the Cockatoo Fault, might also contribute to the relatively low Bouguer anomaly in this area.

Assuming that in the first approach the low gravity values of the anomaly picture can be correlated roughly to relatively thick sections of sediments, the overall interpretation of the gravity data suggests the existence of a relatively deep sedimentary basin centred south-west of the head of Keep Inlet.

Extending south-west from this are two embayments separated by the outcropping Upper Proterozoic rocks of the Pincombe Range. The western embayment coincides with the Carlton Sub-basin and the eastern with the Burt Range Sub-basin.

Gravity contours also indicate embayments extending west and east from the centre of the "Keep Inlet Low". A north-eastern extension of this "Low" is indicated across Queens Channel into the Port Keats Sub-basin.

It is significant that the Keep Inlet Basin, suggested from gravity data available at this stage is elongated east-west with its main axis approximately perpendicular to the general strike of the Palaeozoic sediments, which crop out along the coast of the Joseph Bonaparte Gulf and which indicate that the main axis of the basin may extend north-northeast".

TABLE 1

DENSITY DETERMINATIONS OF STRATA SAMPLES FROM BONAPARTE GULF BASIN

Sample No.	Type	Locality	Dry sample density
AAD/KR/1	Upper Proterozoic	Pincombe Range	2.53
2	Antrim Plateau Volcanics	Ord River Crossing	2.80
3	Skewthorpe Formation	Skewthorpe Ridge	2.79
4	Hart Spring Sandstone	"	2.22
5	Clarke Sandstone	Clark Jump-up	2.13
6	Cockatoo Sandstone	Cockatoo Sands	2.00
7	Burt Range Limestone	Burt Range	2.62
8	Engâ Sandstone	Enga Ridge	2.13
9	Septimus Limestone	Mt. Septimus	2.64
10	Spirit Hill Limestone	Spirit Hill	2.66
10A	" " "	" "	2.61
11	Sandstone overlying Spirit Hill Limestone	" "	2.05
12	Sandy Creek Limestone	Sandy Creek	2.63
13	Point Spring Sandstone	Point Springs	2.11

MOYLE RIVER SURVEY

During April and May, 1959, Mines Administration Pty Ltd carried out a survey over an area of approximately 30 sq. miles north of the Moyle River in the Port Keats Aboriginal Reserve. Both detailed and regional work was carried out. The detailed survey consisted of 70 stations at approximately 1000 feet intervals. The regional work consisted of ten regional stations which were established up the Moyle River using a helicopter.

A description of this survey and the interpretation of the gravity data is given in a report by Minad for Associated Australian Oilfields entitled:

"Gravity and Geological Investigations north of the Moyle River, Port Keats Area, Northern Territory"
(N.T./2/72) by J.E. Burbury.

Summaries and extracts from the Geophysical portion of the report are given below -

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels. A height of 13 feet relative to Darwin Tide Datum at station S.27 of the Port Keats (Coastal) Survey was taken as the datum.
2. Horizontal. Station S.27 of the Port Keats (Coastal) Survey.
3. Gravity. An observed gravity of 978351.15 milligals obtained at station 1 by a tie to S.27 of the Port Keats (Coastal) Survey.

B. METHOD OF SURVEY

I TOPOGRAPHIC

a) Levels. A stadia was used for the survey. The detailed survey commenced at station 1 at the base camp. There was a level tie between station 1 of this survey and station S.27 of the Port Keats (Coastal) Survey. An elevation of 13 feet relative to Darwin Tide Datum was taken for station S.27. This elevation was obtained for S.27 during the Port Keats (Coastal) Survey by taking gravity readings at sea level and reducing them to Darwin Tide Datum.

b) Horizontal. A stadia was used for measuring direction and distances for station S.27 of the Port Keats (Coastal) Survey. The position of this station was established from aerial photographs.

c) Loop Closure. The traverses were not looped.

II GRAVITY An observed gravity value of 978351.15 milligals was obtained at station 1 by a tie to S.27 of the Port Keats (Coastal) survey. A value of 978344.07 milligals was taken to be the observed gravity value at S.27. This value was obtained during the Port Keats Survey.

Instruments used. Worden gravity meter No.216 was used for the Survey. No mention is made of what the calibration factor of the instrument was. During the Keep River Survey (see Vol.1, Part 1) Worden No.216 was also used and at that time the calibration factor of the instrument was given as 0.09095 milliglas per foot.

2. Elevation correction factor. Not mentioned in text.

3. Latitude Correction. The theoretical gravity was read from tables based upon the International Ellipsoid Formula.

4. Loop Closure. The traverses were not looped.

5. Permanently marked stations. Not mentioned in text.

C. TOPOGRAPHIC TIES TO EARLIER SURVEYS.

The survey commenced at station S.27 of the Port Keats (Coastal) Survey. A height of 13 feet was taken for it. See page 1 under A "DATUMS FOR THE SURVEY".

This survey is tied indirectly via the Port Keats (Coastal) Survey to the Port Keats (Land) Survey (See Vol.1, Part 3) and to the Keep River Survey (see Vol1, Part 1).

D. TOPOGRAPHIC TIES FROM LATER SURVEYS

There ~~has~~ have been no ties to this survey from later surveys.

E. GRAVITY TIES TO EARLIER SURVEYS.

See page 1 under A "DATUMS FOR THE SURVEY".

F. GRAVITY TIES FROM LATER SURVEYS.

There ~~has~~ have been no ties to this survey from later surveys.

G. PRINCIPAL OBSERVATIONS.

"Trend lines observed on airphotographs of the area just north of the Moyle River indicated the possibility of a geological structure in that area.

It was decided that a combined geological and gravity survey should be carried out in order to determine the presence of a geological structure".

The Bouguer anomaly map of this survey is given in Volume IV, Part 1, plate 15.

"The gravity values rise gradually from station 70 south-east to station 65 with an average gradient of 1 milligal per mile; no major irregularity occurs in the gradient that could indicate a geological structure at depth. The general south-west trend of the contours confirms the possibility of a gravity ridge over the Moyle River - as indicated by the regional traverse".

"The detailed geological and gravity survey north of the Moyle River failed to confirm the presence of a geological structure in that area".

SURVEY DATA AVAILABLE

H. I GRAVITY

1. Field Sheets. Appendix A. This data ~~has~~ have not yet been obtained from the company.

2. Table of Principal Facts. See Appendix B pages 1 to 3.

II TOPOGRAPHIC

1. Field Sheets or field books. These have not yet obtained from the company.

2. Table of Principal Facts. Elevations will be found in Appendix B above. Bearings and distances were taken by a stadia between successive stations but have not been obtained. The stations are shown plotted on plate 15 (Vol.IV, Part 1), which is a reduced reproduction of sheet 1 of the Moyie River Survey.

BONAPARTE GULF GRAVITY SURVEY

(WESTERN AUSTRALIA)

In the same year (1959) during the month of September, Mines Administration Pty Ltd carried out the first subsidized survey in the Carlton area (see Vol. IV, Part IV, Plate 17).

Gravity values were observed and plotted over an area of approximately 1400 sq. miles bordered on the north by the Joseph Bonaparte Gulf and on the east by the West Australian - Northern Territory border.

A network of widely spaced traverses totalling 160 miles in length ~~were~~ was read at ½ mile intervals. Two hundred and eighty gravity stations were established. A description of the survey and the interpretation of the Bouguer Anomaly Map is given in a Petroleum Search Subsidy Acts publication No.47 (in press) entitled -

"Bonaparte Gulf Gravity Survey, Western Australia, 1959 by Gulf Oil Syndicate".

The survey details given below were obtained mainly from the above report and partly from a study of surveyor's field books and the Bureau's files. Extracts and summaries from this report are also given below.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels: A height of 192.6 ft above low water mark, Wyndham at S.P.1 on B.M.R. Seismic traverse 'A' Ninbing.

2. Horizontal: "Base maps (photomosaics) compiled by the Lands and Survey Department of Western Australia. They were on a scale of one mile to one inch and showed latitudes each 15 minutes and longitudes each 30 minutes. Observation points were set out using airphoto pairs supported by compass, vehicle speedometer or pacing, and previous survey data*".

(A plan accuracy to within 0.1 minute of true geographical position is claimed for this work).

3. Gravity: The gravity values are based on an assumed gravity value of 978404.91 milligals at Peg 58, situated at Old Ninbing Homestead. The Bouguer values calculated at S.P.1 based on the above value of observed gravity was 11.82 milligals higher than that of the B.M.R..

A correction of 11.82 milligals was therefore applied to all stations.

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* B.M.R.'s gravity surveys between July and October, 1956.

B. METHOD OF SURVEY

I TOPOGRAPHIC. (Levelling was carried out by the West Australian branch of the Commonwealth Department of the Interior, Perth).

A Zeiss automatic level was used to level most of the points, but some minor traverses were levelled with a Cook, Troughton & Sims precise level. A double reading staff was used throughout and, where possible, readings were made in closed loops. Levels were tied to S.P.1 of the Bureau's Carlton Seismic and gravity traverse 'A', Ninbing.

Loop Closure. "The Western loop between shot points 54 and 109 showed a vertical misclosure of 0.9 feet over the total distance of 50 miles*. The eastern loop from shot points 54 to 35 and gravity station 9 to 176** closed back on shot point 54 with an error of 1.0 feet in 24 miles. The remaining traverses closed on to a well defined top high water mark and were continued along it to check the consistency of the level. It was found to vary between Reduced Levels of minus 0.53 feet and +1.15 feet, relative to B.M.R. assumed datum value of 192.6 feet above low water mark, Wyndham for S.P.1. Therefore all values used in this and previous surveys could be 27 feet too high (the approximate figure for highest spring tides)".

After having established a close check at three separate localities on a well defined high water mark, 25 miles were pegged out along this level without further levelling***.

II GRAVITY

1. Instruments used: Worden gravity meter No.207 which had a sensitivity of 0.10135 milligals per scale division and an anomaly accuracy of $\pm$ 0.05 milligals was used.

Gravity meter readings were controlled for drifts by returning to sub-base stations every two hours.

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* Station 107 at the N.W. end of the gravity survey almost coincides with shot point 109 of B.M.R.'s Seismic traverse 'A', Ninbing see fig. page the loop referred to is from B.M.R.'s shot point 54 (traverse 'A' Ninbing), through gravity stations 51 to 85 and from thence in a westerly direction from stations 96 to 106, 155 to 148 (in decreasing order of station numbers) and from station 145 to 107 (in decreasing order of station numbers).

** The loop referred to is made up of the following sides:-

S.P.54 to S.P.35 on B.M.R. Seismic and gravity traverse 'A' Ninbing. Station 1 (B.M.R. S.P.35) to Station 9, station 9 to 168 to 176. Station 176 to 176A and thence in increasing order of station numbers to station 183. Station 183 was tied to station 58 at old Ninbing homestead and stations 58 to 50 (B.M.R. S.P.54) were read in decreasing order of shot point numbers.

*** Refer to file 62/1902 Part No.1, folio 4.

2. Elevation correction factor. A Bouguer density factor of 0.06726 milligals/feet was used.

3. Latitude Correction. Was read from tables based upon the International Ellipsoid Formula.

4. Loop Closure. No loop closure chart was supplied. However, adjustments must have been made as in the report it is stated that: "The accuracy of the survey was estimated by considering the respective accuracies of the gravity observations, the latitude corrections and the elevation corrections. These are considered to be 0.05, 0.03 and 0.01 milligals respectively. The total error, which equals the root mean square of these three errors is 0.06 milligals.

C. TOPOGRAPHIC TIES TO EARLIER SURVEYS

1. Level. Four ties were made to B.M.R.'s seismic and gravity traverse 'A' Ninbing. The ties were to S.P.1, S.P.54, S.P.35 and S.P.109 near the south west end of the traverse. S.P.109 is not shown on Plate 17 in Volume IV, Part ~~IV~~ 1, but on page 19 of field book 497 it is stated to be about 2 feet to the north east of station 107 which is marked with a 2" x 2" stake (see fig. 9 page 6). A bench mark (Bridge nail put in butt of a leaning tree) was placed during the survey near S.P.109. The position of this bench mark relative to S.P.109 is shown in fig. 9 page 6 .

No peg was found showing the exact location of S.P.109 and hence ties were made to pegs on either side of it to peg 11 and peg 1, 110 feet to the northeast and southwest respectively of S.P.109 on B.M.R. Seismic and gravity traverse A.

Starting with a height of 185.1 feet at B.M.R. S.P.54 the western loop was surveyed and tied to station a (B.M.R.'s S.P.35). There was a mis-tie of .9 feet. By comparing the elevation given in Appendix B with those in the field books it is seen that this mis-tie of .9 was not distributed around the loop*.

On Plate 17 (Vol.IV, Part IV), the stations shown as 250-262 have been misnumbered. From the table of principal facts (Appendix B) both the sequence of the station numbers and their latitudes indicate that the station numbers should be 230 to 239 and 259 to 262.

2. Horizontal. Horizontal ties are to the same stations as the level ties with an additional control tie between station 229 and S.S.47. This station is 6 miles east (by speedo) of station 229 and the station number was found blazed on a bottle tree. Peg 229 is at high water mark while at S.S.47 the rod level to the foot of

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* For the present it is perhaps advisable to leave the elevations unadjusted.

the tree was about 1 foot above high water mark.

D. TOPOGRAPHIC TIES FROM LATER SURVEYS.

The Carlton Gravity survey (see later) tied to the this survey. The tie was between P.W.D. bench mark A.R. 38 near Kimberley Research Station and S.P.1 in B.M.R.'s Seismic and gravity traverse 'A' Ninbing.

E. GRAVITY TIES TO EARLIER SURVEYS.

The gravity ties were to the same stations as the level ties (see under 'C' above.)

F. GRAVITY TIES FROM LATER SURVEYS.

One survey, the Carlton Gravity survey (see later) tied in to this survey. The tie was between Wyndham, Pendulum Station and S.P.1 of the B.M.R.'s seismic and gravity traverse 'A'.

G. (RESULTS AND CONCLUSION OF THE GULF OIL SURVEY).

Density contrasts were suggested at the contact of the Upper Proterozoic and overlying Palaeozoic sediments. The coincidence of gravity maxima with outcropping Upper Devonian limestone was also noted; however, the possibility that the maxima may be due to an underlying ridge of Proterozoic or volcanic rocks was not overlooked. N.F. Schneeberger, who wrote the final report on the survey for G.O.S., points out the biostromal and reef-slope facies development in the Upper Devonian limestone, similar to its stratigraphic equivalent in the Fitzroy Basin.

The Upper Devonian limestone outcrops follow the easternmost of three sets of gravity "highs" delineated by the survey. The westernmost set coincides with an area of Cambro-Ordovician outcrop; it has a north-north-westerly trend but swings towards the north at the northern end. A similar, but smaller, anomaly occurs to the east in an area of (?) Upper Devonian Sandstone. A zone of negative anomaly separates it from the outcrops of Upper Devonian limestone and the third and most extensive belt of gravity "highs", which also trend north-north-westerly from Ninbing to Knob Peak.

Other features delineated are -

(i) an east-north-eastern spur of the Pincombe Ridge "high" in the southern part of the area;

(ii) a prominent gravity "low" area, north-east of Pincombe Range;

(iii) another prominent gravity "low", south-west of Pelican Island, which extends south-east towards the minima of (11) - (ii) and (iii) are separated, however, by a broad "gravity ridge";

(iv) this "gravity ridge" feature and the spur from the Pincombe Ridge have trends in common with the faulted, north-east trending, eastern margin of the Bonaparte Gulf Basin,

(v) There is no clear indication of faulting except perhaps near Knob Peak towards the northern end of the Upper Devonian limestone (reef) outcrops.

It is suggested in conclusion that the reef facies may extend on to gently sloping continental shelf east of the Ninbing-Knob Peak ridge, between the two areas of marked gravity "lows", and along the northern side of the Pincombe Ridge and its spur.

H. SURVEY DATA

I TOPOGRAPHIC

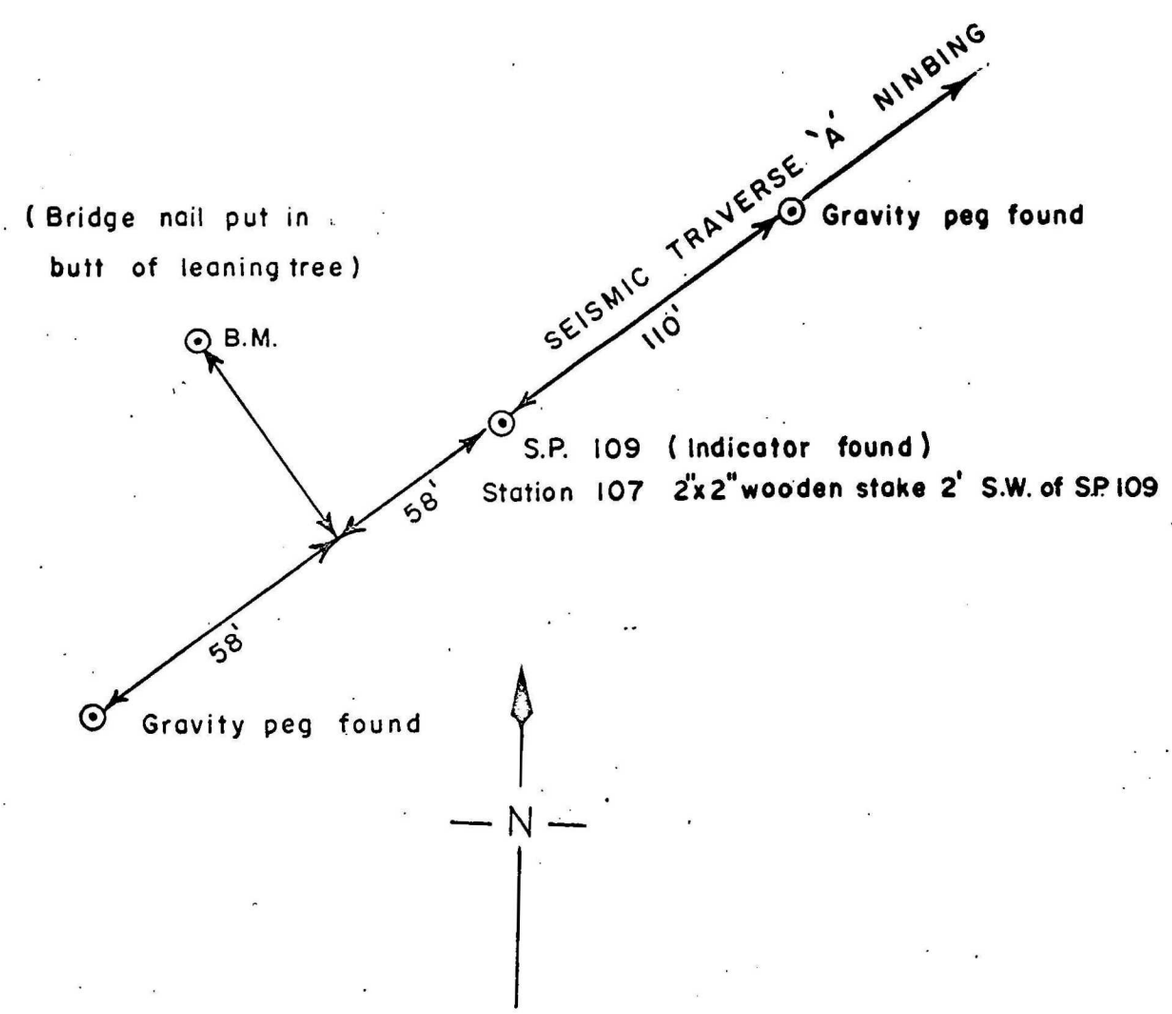
1. Field Sheets. Level data from this survey will be found in Field Books 475, 495, 496 and 497 of the Department of the Interior (Western Australia) and in the table of principal facts Appendix B.

II GRAVITY

1. Field Sheets. Have not been able to obtain them as yet.

2. Table of Principal Facts. Appendix B, pages 1-9.

PLAN OF HORIZONTAL TIE
between
SHOT POINTS 109, 107 AND BENCH MARK



Between the 12th and 23rd September 1960, the Bureau of Mineral Resources carried out a survey between Wyndham Pendulum Station and Newcastle Waters (Station L128) via Victoria River Downs Pendulum Station. The location of the traverse - traverse 73 - is shown in fig. page . Surface control for part of this traverse is given in Vol. IV Part IV, Plates 67 and 68. The Cambridge and Auvergne 4-mile sheets with traverse 73 shown on them were the only ones available when this report was being written. Recently the surface control for the rest of the survey was completed by the Department of the Interior, A.C.T. Survey Section, and maps, showing traverse 73 on a scale of 1:250,000 can now be obtained of the following 4-mile sheets.

1. Waterloo.
2. Delamere.
3. Victoria River Downs.
4. Cambridge.
5. Newcastle Waters (Map Mis. 69).
6. Daly Waters.
7. Auvergne.

They show traverse 73 from Wyndham to Newcastle Waters and also traverse 72 and 71. Traverse 71 is from Newcastle Waters to Daly Waters and traverse 72 is from Daly Waters to Nutwood Downs.

These maps will later be included as an addendum to the surface control maps in Vol.IV Part IV of my record.

A. DATUMS FOR THE SURVEY

1. Level: Station L128, a bench mark at Newcastle Waters Post Office fence for which a height of 685.5 feet was used and P.W.D. bench mark B1 - a concrete block in front of office, Wyndham, for which a height of 26.0 feet was used.

2. Horizontal: Progressive mileage readings were taken along the road from station L128 (Newcastle Waters) to Wyndham. The stations were plotted on aerial photographs which were later transferred to photo compilation sheets.

3. Gravity:

L.128 (Newcastle Waters). An observed gravity value of 978439.02 milligals was taken for this station. This value was obtained by Mr. M.D. Helfer* of the University of California

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* A regional gravity survey in Australia was carried out by Mr. M.D. Helfer of the University of California between 1960-61 with a La Coste - Romberg geodetic meter D.L. No.1. Meter milligal values were calculated using the manufacturers calibration tables. See B.M.R. File 35/G/1 Part B3, folios 2-11, for the stations, date and time of occupation, meter milligal values, and difference in milligals from Darwin. On folio 63 will be found a short account of this survey. For further information on this survey write: Mr. M.D. Helfer, University of California, Institute of Geophysics and Planetary Physics, Los Angles Laboratories, Los Angles 24, California.

by measuring the difference between the Pendulum Station at Daly Waters (978388.5 milligals) and Newcastle Waters.

Pendulum Stations at Victoria River Downs (978424.9 milligals) and at Wyndham Pendulum Station (978415.00 milligals) were also used as datums for the survey.

B. METHOD OF SURVEY

I Level: The survey commenced at Newcastle Waters (Station L128) which has an elevation of 685.5 feet and optical levelling was carried out between successive stations to P.W.D. bench mark B1 in front of the office at Wyndham. The following P.W.D. bench marks were reoccupied

P.W.D. B.M. No.B47
P.W.D. B.M. No.B60
P.W.D. B.M. No. 'R'.

and bench marks (blazed trees) were placed at intervals along the route.

2. Horizontal: See above under "Datums for the Survey".

The leap frog method of surveying was used, a return to sub-base stations being made approximately with the hour. Ties were made to the three pendulum stations mentioned above.

C. SURVEY DATA AVAILABLE

I TOPOGRAPHIC

I. Elevations: Station descriptions, progressive mileage, mileage from previous station, the 4-mile sheets and elevations of stations are given in Appendix C, pages 1-9.

The elevations will also be found in Appendix B, pages 1-5.

II. GRAVITY

1. Field Sheets: Appendix A, pages 1-15.

2. Computation Sheets: The observed gravity for station of traverse 73 are given in Appendix B, pages 1-5.

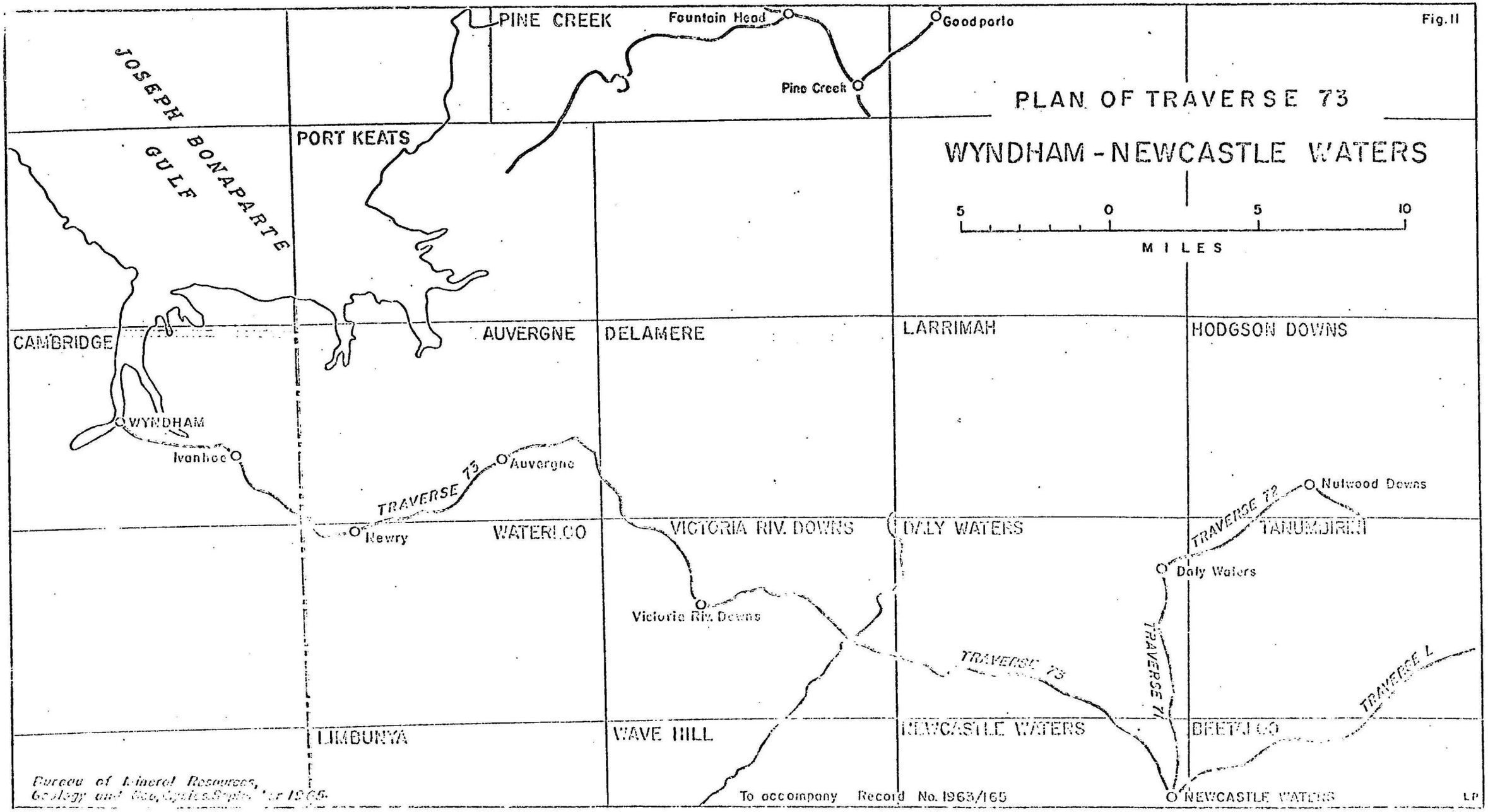
PINE CREEK
Fountain Head
Goodparla
Pine Creek
PLAN OF TRAVERSE 73
WYNDHAM - NEWCASTLE WATERS
5 0 5 10
MILES
JOSEPH BONAPARTE GULF
PORT KEATS
CAMBRIDGE
AUVERGNE
DELAMERE
LARRIMAH
HODGSON DOWNS
WYNDHAM
Ivanhoe
TRAVERSE 73
Auvergne
Newry
WATERLOO
VICTORIA RIV. DOWNS
DALY WATERS
TANUMIRRI
Victoria Riv. Downs
Daly Waters
Nutwood Downs
TRAVERSE 72
TRAVERSE 71
TRAVERSE L
LIMBUNYA
WAVE HILL
NEWCASTLE WATERS
BEETALOO
NEWCASTLE WATERS
Bureau of Mineral Resources, Geology and Geophysics Brch. cr 1965.
To accompany Record No. 1963/165
LP

Fig. 11

15.

CARLTON GRAVITY SURVEY

The semi-detailed survey in the Carlton Area was followed by a detailed one between August and November, 1961 in the same area. The Survey was by International Resource Surveys Inc., Tulsa Oklahoma for Oil Development N.L.

The survey consisted of 260 gravity stations which broadly traversed that portion of the Carlton Basin which had not been covered by the earlier surveys, (see Plate 17).

The description of this survey and the interpretation of the Bouguer anomaly map will be found in the report:-

Oil Development N.L.
Carlton Gravity Survey,
P.E. 127H Western Australia. 1961 by
International Resource Surveys Inc., Tulsa
Oklahoma.

Extracts and summaries from this report are given below.

SURVEY DETAILS

A. DATUMS FOR THE SURVEY

1. Levels:- All levels in this survey are based on the Public Works Department Bench Mark A.R.38 about 7¼ miles N.N.E. of Kimberley Research Station for which an elevation of 114.67 feet was used. This elevation is relative to a datum of low water, ordinary spring tides, Wyndham, the datum being 12.5 feet below mean sea level.

2. Horizontal:- Horizontal control was based on mile posts and S.S. Stations (M.N.74, S.S.53, S.S.38, S.S.47, S.S.29) and to Knob Peak Military Trigonometric Station.

3. Gravity:- The gravity values are based on the gravity value at pendulum station B.M.R. No.30 at Wyndham. A series of gravity bases ~~were~~ was established along the main road from the pendulum station to the Kimberley Research Station. B.M.R. Pendulum Station No.30 has an observed gravity value of 978415.9(0) milligals.

B. METHOD OF SURVEY

I TOPOGRAPHIC:- (The topographic survey was carried out under the direction of R. Hare and Associates of Melbourne, Victoria).

1. A Wild T16 Theodolite, Watts Automatic level and a C.T.S. Level were the instruments used.

i) Levels:- The level survey was carried out in closed loops.

ii) Horizontal:- Stations were located by chaining along straight bulldozed grid lines and the distances checked by stadia.

"South of the Weaber Range the grid is based on line NB laid between the Bench Mark at Kimberley Research Station and Shot Point 1 of the Bureau of Mineral Resources Ninbing Seismic Traverse. A control tie was made from NA 1A to S.S.29 (latitude 15°23'53"S, longitude 128°59'44"E) of the Survey of the Department of Lands, Western Australia.

North of the Weaber Range, the Bureau of Mineral Resources Ninbing Seismic Traverse was re-located and used as a base line. Control tie were made from N.M.44 to border mile post M.N.61 (latitude 15°18'57"S, longitude 128°59'44"E); from E.I.41 to mile post M.N.74 (latitude 15°07'37"S, longitude 128°59'44"E); from E.A.2 to Knob Peak Military Trigonometric Station (latitude 14°56'15"S, longitude 128°34'08"E) and S.S.53 (latitude 14°54'15"S, longitude 128°34'57"E) M.N.8 to S.S.38 (latitude15°01'45"S, longitude 128°52'05"E); and N.L.1 to S.S. 47 (latitude 14°54'49"S, longitude 128°46'03"E."

2. Loop Closure:- A loop closure chart for both the level and horizontal positions is given in fig 10 page 7 The standard of levelling was maintained so that loops closed to within 0.5 $\sqrt{M}$ feet; where M is the length of the traverse in miles.

II GRAVITY:

1. Worden gravity meter No.468 with a constant of .08586 milligals per scale division, as determined from calibration between B.M.R. bases at Alice Springs, Northern Territory. 25% of the stations metered were reoccupied and the majority of these checked to within .05 of a milligal. Drift was measured by returning to sub-base stations within two hours, taking readings and plotting variations on a linear time scale.

2. Elevation Factor:- 0.067 milligals per foot based on a density of 2.1 grams per cubic centimeter.

3. Latitude Correction:- Theoretical gravity from the International Ellipsoid Formula.

4. Loop Closure:- No loop closure chart was supplied.

5. Permanently Marked Stations:- All stations at 40 chain intervals were marked by 2 hardwood stakes driven into the ground. The nearest trees to the stakes were blazed at approximately 5 feet above ground level and an aluminium tag fixed to the blaze.

C. TOPOGRAPHIC TIES TO EARLIER SURVEYS.

This survey tied to two previous surveys, the Ninbing Survey referred to above and a P.W.D. Survey, and 6 traverses came to within a mile of the Border Survey. No level or gravity readings were taken at the mile posts on the border although horizontal ties were made to several of them. (See page 1, under "Datums for the Survey").

1. The first level tie was to Public Works Department Bench Mark A.R.38 for which an elevation of 114.5 feet was used. The latest value for the elevation of Bench Mark A.R.38 is 113.90 feet presumably obtained by re-adjustment of the network and redistribution of closure errors. (See Plate 80 which is a reproduction of map 36654/ of the Public Works Department, Western Australia).

2. The second level tie was to shot point 1, B.M.R. Seismic and Gravity traverse 'A', Ninbing. A height of 218.3 feet was obtained for S.P.1 using 114.5 feet as the datum height at A.R.38. The B.M.R.'s value of 192.5 feet based on the bench mark at Kimberley Research Station is therefore 25.7 feet too low. The latest value for A.R.38 is 113.90 feet hence the height of S.P.1 relative to M.L.W. Wyndham is 217.7 feet.

For the horizontal ties to stations on the border see page 1 under "Datums for the Survey".

D. GRAVITY TIES TO EARLIER SURVEYS

This survey was tied to two previous surveys. It began at Pendulum station B.M.R. No.30, Wyndham, and tied in to S.P.1 of the B.M.R. Seismic Gravity traverse 'A', Ninbing, where an observed gravity value of 978386.09 milligals was obtained.

The value obtained by the B.M.R. for S.P.1 by a tie to the Pendulum Station at Wyndham was 978385.58 milligals. In discussing this tie between the Pendulum Station and station G 1 of B.M.R's Survey in 1956 (Clarke's Survey) I have shown that the value of 978417.94 milligals obtained for G8 was in error by .49 milligals and it should be 978418.43 milligals. This value obtained for S.P.1 by a tie to G 1, is also in error by the same amount and should be 978386.07 milligals. This figure is just .02 milligals different from that obtained during the Carlton Gravity Survey (ie) ~~The value obtained for S.P.1 during the Carlton Gravity survey was~~ 978386.09.

E. SURVEY DATA

I TOPOGRAPHIC:

Field Sheets:- Field Books Nos. 1 to 10 have been obtained from Oil Development N.L. and are in the files of the B.M.R. Basins Study Group, Canberra. Books 1 - 10 contain the level data and Book 10 also gives the bearings and distances. The elevations are also given in Appendix B, pages 1 to 13.

II GRAVITY

1. Field Sheets:- Copies of the field sheets are given in Appendix A, pages 1 to 59.

2. Table of Principal Facts:- Station Nos. Latitude, Longitude, Elevation, observed Gravity and Bouguer anomalies are given in Appendix B, pages 1 - 13.

F. IMPORTANT OBSERVATIONS (See Plate 17 in Vol.IV, Part IV).

"In the extreme south of the survey, a strong gravity maximum coincides with an anticlinal axis shown on the geological maps of the Bonaparte Gulf Basin. The deepest part of the Basin also coincides with a regional gravity minimum, hence it is reasonable to assume that good correlation exists between Bouguer profiles and sub-surface structures i.e., that gravity highs are indications of basement uplifts and gravity lows the expression of sedimentary basins. If this assumption is correct the thickest sedimentary section is along the eastern edge of the survey with the lowest Bouguer values at station N.W.11".

The Bouguer anomaly map indicates four regional features north of the Weaber Range.

(1) The Point Springs gravity low round Peg 74.

(2) The Queens Channel gravity high. - The gravity saddle indicated by the Bureau of Mineral Resources (Thyer et al 1959) was found to be further south than indicated.

(3) The Pelican Island gravity low.

(4) The highest gravity values were found on the western edge of the surveyed area.

Assuming that normal correlation exists between the Bouguer anomalies and the sub-surface structures and that a density contrast of 0.16 gms/c.c. exists between the Proterozoic and Palaeozoic sediments, depth estimates based on curves obtained by Skeels (1963) give:

(1) The Point Springs low greater than 6000 feet of Palaeozoic sediments.

(2) The Queens Channel "high" 2,500 feet.

(3) The Pelican "low" about 4800 feet (gravity control poor).

(4) The anomaly gravity gradient on the western edge of the surveyed area possibly represents an increase in density of the sediments above basement i.e., the gravity gradient produced by the increase in depth to basement has been cancelled out by the presence of rocks in the basin which are of greater density than the basement.

"All these anomalies have, on the whole, gentle gradients and are quite large. This indicates broadly that the cause of these anomalies is also very large... A second set of anomalies, described below, occurs south of the Weaber Range. These anomalies are smaller and sharper than those described above and are probably caused by near surface geologic conditions.

(1) Low near Station N.B.6. This is a large gravity low reaching a value of - 12 milligals. The gradients associated with this anomaly are of the order of 4 milligals per mile compared with the general slope of 1 milligal per mile north of the Weaber Range. The north-south axis of this anomaly is longer than the east-west axis. It coincides with outcropping Ordovician and Cambrian sediments. These sediments have an average density of 2.1 gm/c.c. some o.2 gm/c.c. less than the supposed density of the sediments in the Carlton sub-basin. Hence the negative anomaly on the surface outcrop of the Ordovician and Cambrian. 2,040 feet of sediments is indicated above Proterozoic basement.

(2) An irregular high is centred around E.P.17 and 18. It is divided into two sections by a gravity low at E.P.13. The size of the distorted anomaly is about one milligal. Another similar anomaly is at E.P.21. The anomaly at E.P.24, 28 could be connected to the anomaly E.P.17, 12. The overall picture is thus distorted by the two negative areas. The general high gravity value is interpreted as due to the presence of limestone, while the small graben like anomalies possibly represent faulting and a general thinning of the limestone in that area.

(3) A gravity low located at N.H.1 is parallel to the two distorted negatives in the last anomaly. The anomaly differs slightly from the two negatives mentioned in the above paragraph. Firstly although the gradients are reasonably steep on the E.P. traverse line they do not extend too far north, and secondly if the regional trend is subtracted from the anomaly, a positive 1.3 milligals residual is obtained. This signifies an increase in thickness of limestone in this area, probably through synclinal rather than faulted structure".

A residual Bouguer Anomaly map was presented in the report of the Carlton gravity survey but is not included in this compilation. However the maximum anomalous areas are outlined on Plate 17.

Nine anomalies have been indicated numbered 1 to 9 and graded A, B or C, 'A' being the strongest and 'C' the weakest. The grades were assigned on the basis of the physical characteristics of the anomaly. The suffix INC after the numeral means that the anomaly is not a closed one.

A detailed description of these anomalies is given in the report. The survey was not sufficiently detailed to delineate the areal extent and exast centre of the anomalies by the residual method.

However, the authors believe they are adequate for the planning of a seismic programme; the most attractive area for a seismic programme is covered by anomalies Nos. 3, 4 and 5. "

Fig 10

STATION LOCATION AND RELEVANT SURVEY DATA FOR A GRAVITY FOR PART OF THE PERMIT TO EXPLORE N°127 H W.A.

0 1 2
Scale in Miles

PROJECTION : TRANSVERSE MERCATOR

CONTROL TIES SHOWN +2----- ASS53
+34

FIELD BOOK PAGE FOR HORIZONTAL LOOP CLOSURE DETAIL : +23 +24 +25------E1
10 (page 105)
+35

DIRECTION OF TRAVERSE AND VERTICAL LOOP CLOSURE DETAIL :

NB
+6 55 +17 ---EM
+7

GRAVITY SURVEY FOR
OIL DEVOPMENT NO LIABILITY
JULY - OCTOBER 1961

THIS SHEET PREPARED BY KENNETH FLETCHER
NOVEMBER 1961

15°0'
15°10'
15°20'
15°30'
129°0'

POINT PEARCE GRAVITY SURVEY

Records on gravity surveys carried out after 1962 will be issued later as addendums to this compilation.

However, as Appendix 'A' of this survey has already been printed it is included in this compilation.

The survey was carried out between May and September, 1963 by Compagnie Generale De Geophysique for Australian Aquitaine Pty Ltd. The final report for this survey has been submitted to the B.M.R. and is now open for public examination.

SURVEY DATA AVAILABLE

I GRAVITY

Field Sheet: Appendix 'A' pages 1 to 72.