THE GEODETIC SURVEY OF AUSTRALIA

Paper presented by Australia[1]

PROGRESS OF THE SURVEY

Early history

In 1912, a conference to discuss the survey and mapping of Australia was convened by the Commonwealth Minister for Home Affairs and was attended by the Director of Commonwealth Lands and Surveys, the Surveyor-General and the Government Astronomer of New Zealand, and the surveyors-general of the states of the Commonwealth.

Appended to the report of that conference were detailed descriptions of the trigonometrical surveys that had been completed by the various states. The coverage of the geodetic survey as then reported is shown in figure I.

Of these surveys, only that of New South Wales conformed to first-order standards. The remaining surveys were of varying quality and, although not accurate by modern standards, served as immensely valuable reconnaissance schemes for more recent geodetic surveys.

At the 1912 conference it was recommended that a geodetic survey of Australia should be undertaken by the Commonwealth Government, but no effective action was taken during the next twenty years.

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[1] The original text of this paper, prepared by B. P. Lambert, Division of National Mapping, Department of National Development, Canberra, appeared as document E/CONF.52/L.51.

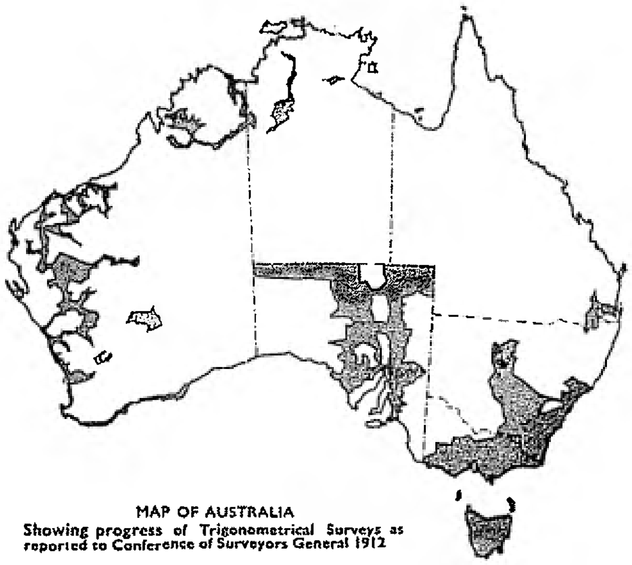

Fig. I—Australia: Trigonometrical surveys, 1912

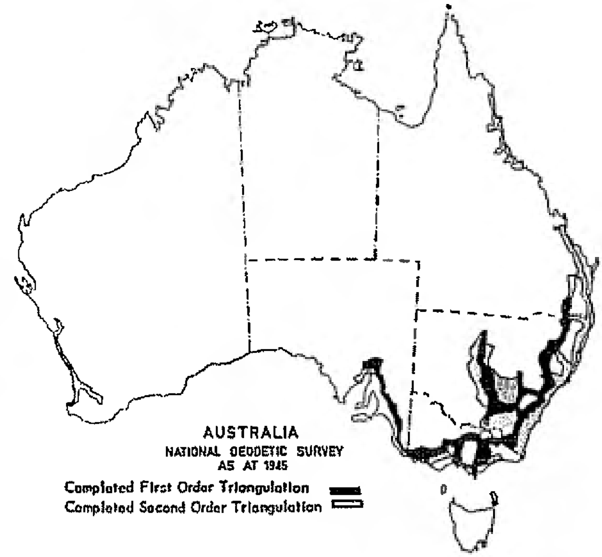

Fig. II—Australia: National geodetic survey, 1945

Reactivation by the Army Survey Corps

In the early 1930s, the Australian Army Survey Corps reactivated the geodetic survey and at first investigated the possible co-ordination of the geodetic surveys already completed by the state authorities in New South Wales and Victoria. This involved a close study of the New South Wales and Victorian records and also recomputation of sections of the triangulation. As a result of these investigations it was decided that the best approach was to run a new survey through both schemes.

This was done and the surveys were later extended into South Australia. The astronomical co-ordinates of the Sydney observatory were adopted as origin and Clarke's 1858 figure of the earth was used for computations.

Between 1935 and 1939, in conjunction with the University of Adelaide, special equipment and techniques were developed which resulted in a marked increase in the accuracy of base-line measurement. These involved the field standardization of invar tapes by the measurement of electrical resistances of previously calibrated steel tapes.

Aircraft reconnaissance was used to locate base lines but unfortunately no Laplace observations were included.

The Second World War intervened and included in the war effort was the extension of the geodetic survey along the north-eastern coast of Australia and the commencement of separate second-order surveys in northern coastal areas of Queensland and in Western Australia.

The Clarke 1858 figure was used in the computation of these separate surveys. Astronomical values were used for the origins of the local Queensland surveys, while the astronomical values of the Perth observatory were adopted in western Australia.

The status of the geodetic survey in 1945 is shown in figure II.

National Mapping Council participation

In 1945, the Commonwealth and state governments agreed to the setting up of a National Mapping Council for the co-ordination of mapping activities in Australia. It then became the responsibility of the Director of National Mapping to plan and direct the National Geodetic Survey, with full regard to the recommendations of the National Mapping Council.

Since its formation, the National Mapping Council has met at least once each year and has, as necessary, made many recommendations in respect of specific geodetic and topographic survey and mapping activities in Australia.

The Council first gave consideration to the practicability of using airborne radar for the geodetic survey but, after reading the reports of a very thorough investigation by the Radiophysics Division of the Commonwealth Scientific and Industrial Research Organization (CSIRO), and in the light of the developments then just beginning in respect of ground instruments for electronic measurement of distances, the council did not recommend proceeding with radar survey.

In 1948, the council resolved that a basic scheme of geodetic survey be proceeded with; this scheme is shown in figure III.

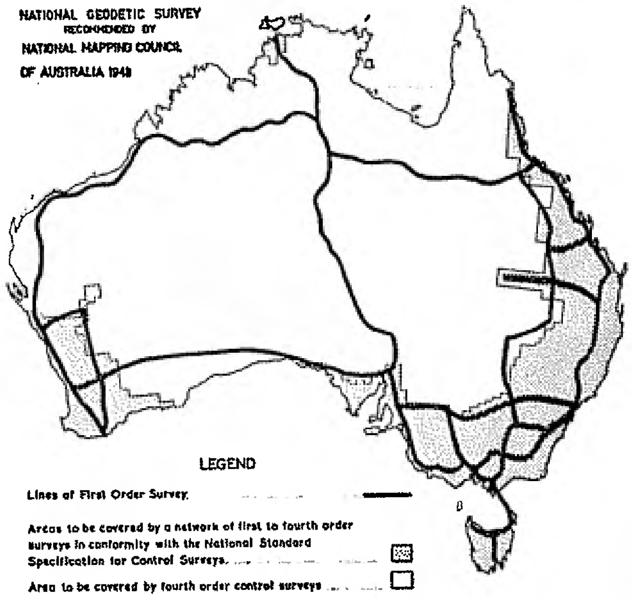

Fig. III—Australia: National geodetic survey recommended by National Mapping Council in 1948

Introduction of electronic distance-measuring equipment

Progress in the implementation of this scheme was slow at first and minor additions were made by the council in 1958 as the work gained impetus with the introduction of the Geodimeter in 1951 and the Tellurometer in 1957.

The base lines previously measured by the Army Survey Corps, using the resistance technique for field standardization, were again measured with the Geodimeter and a value derived for the velocity of light. This value agreed exactly with that which subsequently received international acceptance.

In 1959, the council adopted a much more ambitious scheme for the national geodetic survey (see figure IV below) and added to that basic scheme in 1961 and 1962. Progress in reconnaissance and design was accelerated by the availability of air photographs and the use of low-flying light aircraft for detailed location of stations.

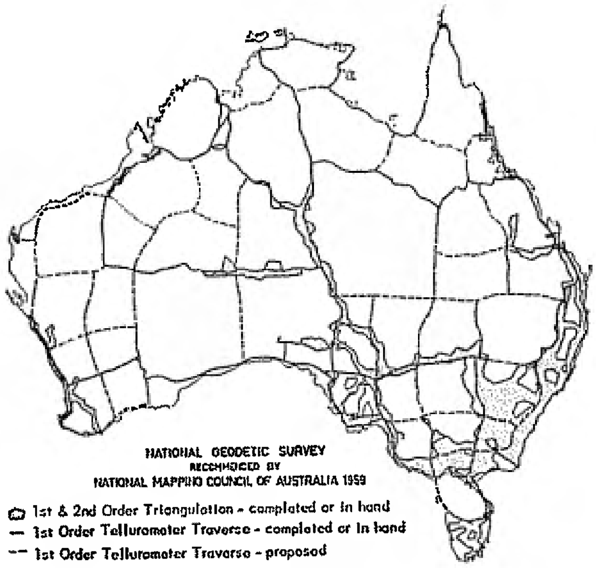

Fig. IV—Australia: National geodetic survey recommended by National Mapping Council in 1959

The Tellurometer very soon proved a practical proposition and first-order traversing became the regular procedure. Special techniques and operational procedures were evolved for the large central desert areas and led to a rapid expansion of the geodetic network. However, early loop closures were disappointing and investigation into the double summation effects resulting from cumulative angular errors led to a much closer spacing of Laplace azimuths.

Extension into New Guinea

In the period 1962–1964, the United States Air Force completed a HIRAN survey which extended from north-eastern Australia to New Guinea and the outlying islands of Australian controlled territory. This HIRAN survey has been integrated with Australian geodetic surveys that have been carried out over the eastern half of the island of New Guinea.

Satellite observations

In recent years, Australia has undertaken satellite observations of geodetic value on behalf of United States agencies. These have included Tranet observations at nine stations and the operation of one Baker-Nunn camera at Woomera.

Present status

The Commonwealth Departments of National Development and the Interior, the Royal Australian Survey Corps and all state and territorial lands departments have contributed to the national geodetic survey, the status of which, as at the end of 1966, is shown graphically in figure V.

NATIONAL GEODETIC DATUM

Concurrently with the field surveys, investigations were undertaken to establish the best value of an origin for the survey and the most suitable figure of the earth.

In 1961, a preliminary analysis was made of the geodetic and astronomical data available by then, along the continuous survey between Sydney and Perth, in order that approximately correct values might be supplied for the Mercury project tracking stations at Woomera and Muchea. This was followed by an analysis of all astro/geodetic comparisons in the vicinity of the 32° parallel; and as a result a preliminary origin was determined at the Maurice station (South Australia).

In 1962, an investigation was made into the most suitable reference ellipsoid that could be derived from available data and one with the following dimensions was adopted: semi-major (equatorial) axis (a) = 6,378,165 m; flattening = $^1/298.3$ m.

In 1963, as the survey and subsequent computations progressed, the Maurice origin was converted to a central origin based on the analysis of 150 astro/geodetic comparisons.

In that analysis, approximate isostatic corrections for the influence of the topography were calculated, but they had only a minute effect on the mean value from the uncorrected values.

In 1965, the National Mapping Council adopted spheroidal dimensions accepted by the International Astronomical Union. It also adopted for an origin the Johnston Geodetic Station, named after F. M. Johnston, a former Commonwealth Surveyor-General and the first Director of National Mapping.

COMPUTATION AND ADJUSTMENT

The whole survey has since been adjusted on this datum by least squares, using the variation of co-ordinates method, first to the main loops, then to the portions of the surveys between the fixed intersections of those loops.

The computations and adjustment were carried out by officers of the Division of National Mapping of the CSIRO CDC 3600 computer.

The final adjustment involved the processing of approximately 18,000 data cards and the closures of 59 loops varying in length from 580 to 2,700 km, with an average length of 1,440 km. The extension into New Guinea involved another 1,500 data cards.

FUTURE INTENSIFICATION

In 1963, a start was made on the intensification of the survey by Aerodist, using trilateration measurements to fix ground stations at the 1° intersections of latitude and longitude and in some instances at the 30′ intersections.

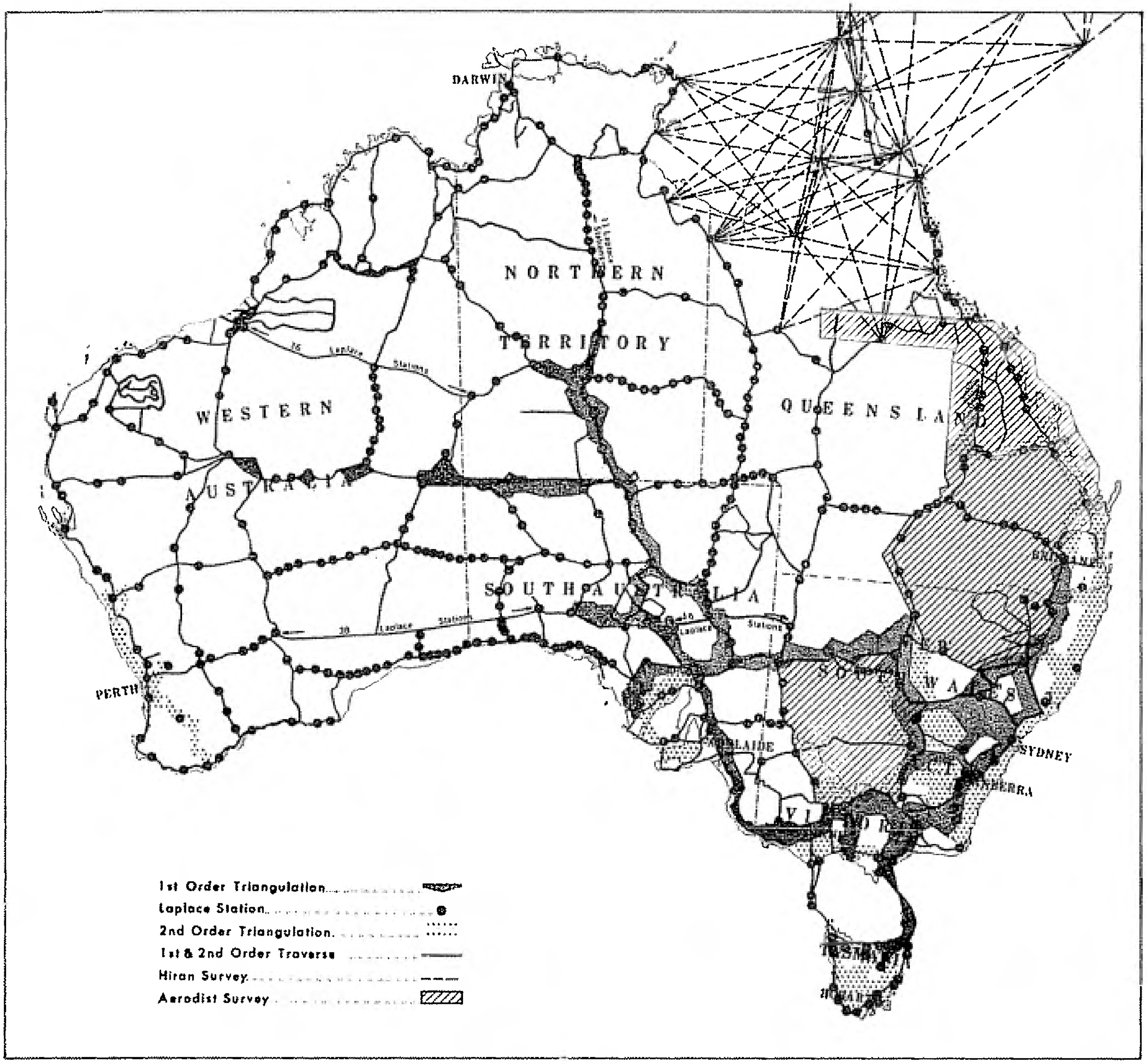

Fig. V—Australia: Geodetic control surveys as at 31 December 1966

This type of trilateration, together with second-order tellurometer traversing, will be used to provide a general pattern of horizontal control over the whole continent. The resultant data will provide direct map control and should be of sufficient accuracy to locate isolated significant errors, if any, that might have slipped through despite the care taken in the primary survey and its adjustment.

PROBABLE ACCURACY

Scale standardization is based on the internationally accepted value for the velocity of electro-magnetic waves in vacuo and on the application of proper corrections for "atmospherics".

The precision of lengths, azimuths and co-ordinates of the origin may be assessed internally from closure data and estimated from the corrections applied in the course of the national adjustment.

External comparisons can be made with the United States Air Force HIRAN Survey in New Guinea and with any available data derived from satellite geodesy.

Origin

A final comparison with 275 well-spaced astro/geodetic stations gave mean deflections of:

Meridian $(A - G) = +0.12''$

Vertical parallel $(A - G)\cos\varphi = -0.33''$

A similar comparison in respect of all available 573 astro/geodetic stations gave a mean deflection of $+0.05''$ and $-0.58''$ respectively. These comparisons indicate that the continental consistency of the co-ordinates of the origin is likely to be within $\pm 0.5''$.

However, available comparisons with satellite observations indicate that there is a substantial and uniform slope of the geoid across Australia, with a maximum rise from the south-west to the north-east.

On the other hand, a shift of from 30 to 120 m in the satellite Cartesian co-ordinates will bring about a very good agreement with the geoid.

It would appear better to await later developments before arriving at any conclusion in this matter.

Scale and azimuth

In the course of the national adjustment, an analysis of observations led to the following estimate of standard errors:

Laplace azimuth (relative to the adopted origin): single end, ±1″; double end non simultaneous, ±0.7″; double end simultaneous, ±0.6″.

Intermediate: about ±1″ (depending on spacing of Laplace azimuths).

Distances: Tellurometer: rms error of 0.03 m plus $^3/10^6$.

In practice, the linear accuracy is affected by the errors accumulated in carrying forward trigonometric heights and by the lack of knowledge of geoidal undulations.

Loop closures

The average length of 59 loop surrounds was 1,440 km. The average misclosures were, in both latitude and longitude, ±2 m and in vector ±3.1 m.

The actual adjustments applied to 161 sections of these loops averaged ±0.56″ in azimuth and ±0.45 m in distance. The average length of these sections was 278 km.

As a test of internal consistency, three sets of independent traverses were selected, crossing from side to side of the continent and averaging about 4,800 km in length (see figure VI).

The co-ordinates of the national adjustment were adopted at a common starting point for each group. The co-ordinates of the terminals of the individual traverses were computed and then compared with the national adjustment values.

The results are listed in the annex on page 131. They show an average displacement in latitude and longitude of 1 $1/10^6$ of the traverse length with a maximum of 2 $3/10^6$.

The means of the groups of three independent terminal values were then compared with the national adjustment value. The average direct map distance from start to finish is 3,300 km and the average of the displacements of the means along and perpendicular to the respective direct lines is ±2.4 m, while the maximum displacement is 4.7 m.

Comparison with HIRAN measurements

In the adjustment of the surveys covering north-eastern Australia and the Territories of Papua and New Guinea,

Fig. VI—Australia: Independent traverses averaging 4,800 km tellurometer distances were weighted much more favourably than HIRAN measurements.

One hundred and six HIRAN lines were included ranging from 136 to 877 km long, and the rms value of the adjustments to these lines was −6.2 m, regardless of length. There was a slight bias of +0.15 m which, on the average length of 562 km, gives a ratio of $0.3/10^6$.

Estimated accuracy

There would appear to be a 9 per cent probability of errors in azimuth (with respect to the adopted origin), and in length not exceeding for individual lines, 7.5 parts in 10^6, and across the continent, 1.5 parts in 10^6.

MANPOWER INVOLVED

With so many organizations contributing, it is difficult to assess the over-all manpower involved.

However, the following figures are available in respect of one organization only.

During the years 1963 to 1965 inclusive, approximately forty personnel of the Geodetic Branch of the Division of National Mapping completed 12,000 km of first-order tellurometer traversing and 280 Laplace observations. The range of their activities covered reconnaissance, initial planning, field surveys, tabulation and reduction of data and preliminary computations.

The nature of the terrain in which surveys were undertaken during that period varied from the deserts of central Australia to the mountains of New Guinea.

The national geodetic adjustment occupied a further 4 to 5 personnel from about 1964 to 1966. They were engaged in the development of programmes and procedures and in processing the tabulated data supplied by the organizations participating in that survey.

PROBABLE FUTURE EXTENSION

The aerodist equipment has been used successfully to measure distances of up to 250 km, and it is hoped to extend that to 300 km in order to measure trilateration schemes that will connect offshore islands to the national geodetic survey.

Geodetic satellites may be used, in the triangulation mode to fix the position of more distant islands such as Cocos and Norfolk.

Preparations are already in hand in anticipation of the proposed world-wide geodetic satellite triangulation scheme.

CONCLUSION

There is good evidence that the Australian national geodetic survey is of high accuracy in respect of horizontal co-ordinates. The national levelling survey, now in hand, will improve its vertical accuracy.

It will be of the greatest interest in future years to compare this survey directly with the long-range azimuths and distances that will surely be measured in the course of future geodetic satellite operations.

Annex

CLOSURE OF TRANS-AUSTRALIAN TRAVERSES*

1. Hooghly, Vic, to McDrill, NT.

Opening co-ordinates of Hooghly from national adjustment: −38° 23′ 18″.3263 −146° 27′ 53″.1433
McDrill from national adjustment: −14° 34′ 26″.4479 −133° 02′ 28″.4322

McDrill from:	Traverse distance(km)	φ″	Δφ″	Δφ(m)	*ppm*	λ″	Δλ″	Δλ(m)	*ppm*
East traverse	4,596	26.6433	+0.1954	+6.01	+1.31	28.3241	−0.1081	−3.24	−0.70
Centre traverse	3,646	26.3060	−0.1419	−4.36	−1.19	28.5860	+0.1538	+4.60	+1.26
West traverse	4,985	26.3650	−0.0829	−2.55	−0.51	28.4554	+0.0232	+0.69	+0.14
				10.37	2.50			7.84	1.96
Range: Means (ignoring signs)	4,410	26.4381	0.1401	4.31	0.98	28.4552	0.0950	2.84	0.64

2. Gunjin, WA, to Cullarin, NSW

Opening co-ordinates of Gunjin from national adjustment: −31° 59′ 24″.6345 −116° 07′ 45″.1273
Cullarin from national adjustment: −34° 43′ 31″.9812 −149° 23′ 39″.4708

Cullarin from:	Traverse distance(km)	φ″	Δφ″	Δφ(m)	*ppm*	λ″	Δλ″	Δλ(m)	*ppm*
North traverse	4,974	32.3515	+0.3703	+11.41	+2.29	39.4320	−0.0388	−0.99	−0.20
Centre traverse	4,082	31.8361	−0.1451	− 4.47	−1.10	39.2546	−0.2162	−5.50	−1.35
South traverse	4,990	32.0982	+0.1170	+ 3.61	+0.72	39.3179	−0.1529	−3.89	−0.78
				15.88	3.39			4.51	1.15
Range: Means (ignoring signs)	4,682	32.0953	0.2108	6.50	1.39	39.3348	0.1360	3.46	0.74

3. Brown Range, WA, to Fair Hill, Qld.

Opening co-ordinates of Brown Range from national adjustment: −24° 54′ 04″.0734 −133° 42′ 59″.3515
Fair Hill from national adjustment: −27° 03′ 29″.4632 −151° 43′ 36″.8653

Fair Hill from:	Traverse distance(km)	φ″	Δφ″	Δφ(m)	*ppm*	λ″	Δλ″	Δλ(m)	*ppm*
North traverse	6,269	29.3443	−0.1189	− 3.66	+0.58	36.9437	+0.0784	+2.16	−0.34
Centre traverse	4,291	29.7071	+0.2439	+ 7.51	−1.75	37.1441	+0.2788	+7.68	+1.79
South traverse	5,135	29.8080	+0.3448	+10.61	−2.07	36.6944	−0.1709	−4.71	+0.92
				14.27	2.65			12.39	2.13
Range: Means (ignoring signs)	5,232	29.6198	0.2359	7.26	1.39	36.9274	0.1760	4.85	0.93

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*See figure VI on p 130.