GEODETIC SURVEYING IN AUSTRALIA

Paper presented by Australia[1]

High-precision traversing

A network of high-precision traverses coinciding with the network of geoidal profiles as shown in figure I is being measured by the Division of National Mapping.

Except for a section of 500 km in New South Wales, the high-precision work follows existing geodetic traverses observed during the period 1958–1965 with tellurometer models 1 and 2.

The high-precision survey consists of re-measuring of all distances with modern precision EDM equipment and observing of simultaneous reciprocal azimuths. Horizontal and vertical angles from the original survey are adopted.

The survey started in 1966 and, until the successful introduction of laser model 8 geodimeters in late 1969, measurements of lines were carried out with MRA4 tellurometers in two days. The present specifications stipulate that distances shall be measured with a laser geodimeter or, where this is impracticable, with MRA4 tellurometers.

Each line has to be measured in two days, and the measuring frequencies have to be checked with a frequency counter every two weeks.

Astronomical azimuths are determined simultaneously from both ends of a line by observations to *Sigma octantis* on two nights. Wild T3 theodolites are used in this work.

Priority is being given to the survey of the two Pageos satellite triangulation base lines in Australia. Work on the 3,200 km-long east–west base line was completed in December 1969. The survey of the 2,600 km-long north–south base line will be completed in December 1970.

A comparison of the free adjustment of the high-precision survey of the east–west base line with corresponding values of the 1966 national geodetic adjustment is given below:

	Chord distance of E-W base line
National adjustment 1966	3 163 625.133 m
Free adjustment 1969 (high-precision survey)	3 163 623.540 m
Difference	+1.593 m
or	$+0.5 \times 10^{-6}$

The maximum discrepancies occur near the middle of the base line, amounting to 4.5 m in the direction of the line and 5.1 m at right angles to it.

Accuracy of astronomical observations

First-order astronomical observations have been made at about 1,200 stations since 1950. For the first twelve years, Wild T4 theodolites were used for latitude and longitude determinations by Talcott's method and by meridian transits, respectively, and 255 stations were observed by these methods. Since 1962, Kern DKM3A theodolites have been used for latitude determination by circum-meridian altitudes, and longitude determination by the almucantar method (similar to Zinger's method). Azimuths were observed mainly with the Wild T3, although before 1962 a few single-ended observations were made with the Wild T4 and after that date a number of simultaneous reciprocal observations were made with Kern DKM3A instruments.

At each astronomic station at least sixteen pairs of latitude stars and sixteen pairs of longitude stars are observed. For azimuth observations twenty-four zeros are observed, a zero being all observations made at one position of the horizontal circle. Longitudes and azimuths are spread over at least two nights. Latitudes are normally spread over two nights, but may be all observed on one night. At any station the range of the ten best pairs of latitude stars may not exceed 2.0 seconds of arc. On any one night the range of the best six pairs of longitude stars may not exceed 0.2 seconds of time and the mean may not differ by more than 0.12 seconds of time from the mean of the best six pairs on another night. These re-observation limits are seldom approached.

Over the last 20 years re-observations for latitude and longitude have been made at 100 stations for accuracy comparisons. In latitude, the average difference between the determinations is 0.43″, with a standard error of 0.38″ for a single determination. In longitude, the average difference is 0.86″ with a standard error of 0.76″ for a single determination.

On the 156 simultaneous reciprocal azimuths observed on the Pageos base lines, the average difference between the forward and reverse azimuths is 1.16″, with a standard error of 1.42″ for a single determination from one end of a line.

All astronomic observations have been reduced to the conventional international origin.

Determination of the geoid in Australia

Approximately 1,200 astrogeodetic stations will have been observed in Australia by the end of 1970, and a revision of the geoid determination on the Australian geodetic datum (AGD) will be completed by the Division of National Mapping in early 1971.

Geoidal profiles of closely spaced astrogeodetic stations will form a primary framework which will be subdivided by secondary profiles in which some stations will rely on gravimetric calculation for their values of the deflexions of the vertical. An adjustment of all the geoidal profiles, with a weighting system based mainly on station spacing, will provide values of the geoid–spheroid separation (N) for all astrogeodetic stations on the AGD.

Values of N for all regions inside the loops formed by the geoidal profiles will be obtained gravimetrically and will be in sympathy with the values of N at the previously adjusted astrogeodetic stations.

Australian levelling adjustment

About 85,000 km of levelling forming 270 loops will be rigorously adjusted by least squares at the end of 1970. Observed differences in elevation corrected by the orthometric correction for the non-parallelism of equipotential surfaces will be used.

Levelling data recorded on special data forms by the

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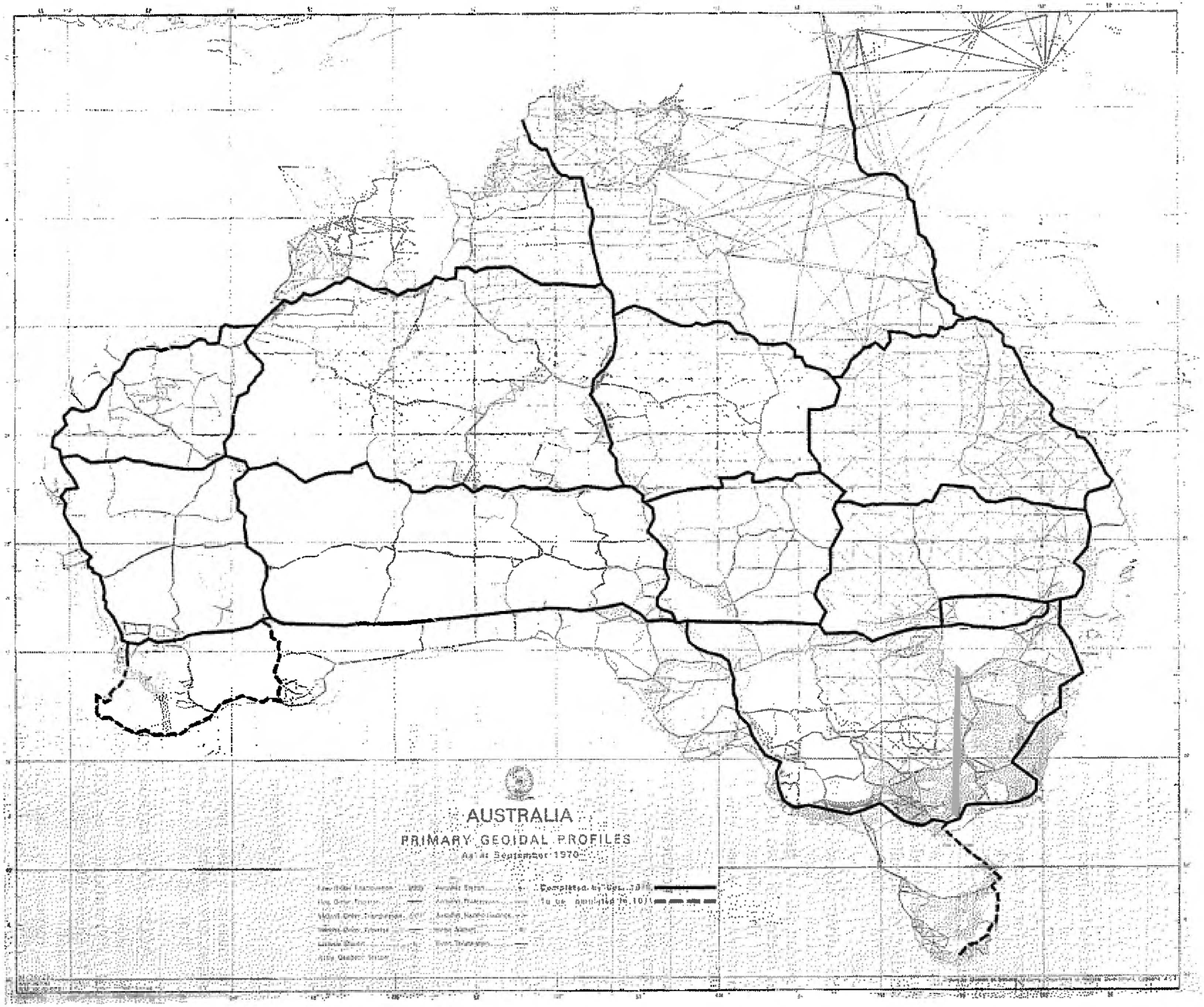

Figure I. Australia: Primary geoidal profiles observing authorities are being received by the Division of National Mapping and are punched on data cards without further transcription. By the end of September 1970 about 80 per cent of the information had been received.

The adjustment will be carried out in two phases. In the first phase, five regional nets of about 140 junction points each will be adjusted separately by the method of observation equations. The second phase combines the five networks into a whole by a condition-equation adjustment. Variance–covariance matrices will be computed for each regional net and for the whole net.

All computer programmes written in Fortran IV have been tested and proved on a CDC-3600 computer on which the adjustment will be carried out.

The adjustment programmes allow the differences in height at each tide gauge between the bench-mark and mean sea level to be allocated any weight between zero and infinity.

Mean sea level has been determined at some thirty tide gauges around Australia for the common three-year period from 1 January 1966 to 31 December 1968.

Figure II shows a preliminary comparison of levelling with mean sea level right around the coastline of Australia.

The determination of the Australian height datum will be obtained from the adjustment of the whole levelling network linked to mean sea level at the tide gauges with weights at gauges varying between zero and infinity.

"Deep" bench-marking

The Division of National Mapping has been establishing stable "deep" bench-marks constructed of vertically driven copper-coated tubular steel rods sealed at both ends against moisture and protected at ground level by a loose-fitting concrete collar.

Recent development of a suitable stainless-steel-clad rod and fittings by Tubemakers of Australia, Limited—B.T.M. Division—now provides a cheaper bench-marking material which tests have shown to be more corrosion-resistant than the copper rods.

Rods are driven vertically by an Atlas Copco petrol-driven "Cobra" rock drill breaker installed on a truck-mounted vertical-driving rig. Two men are able to complete the installation of a 12-ft deep bench-mark in less than 15 minutes at a total cost of about $5.34.

Third-order levelling procedures

Levelling parties of the Division of National Mapping, working under good weather conditions and in reasonably flat country, have each been able to complete up to 22 miles of one-way third-order levelling during a normal working day.

Each party, comprising an instrument man and two staff men, is equipped with two vehicles. The staff men, each driving a vehicle, "leap-frog" along the levelling route with the backsight staff man picking up and driving the instrument man to the next set-up before proceeding to his next forward staff position.

Electronic computing

A brief description follows of some major computer programmes written in the Division of National Mapping. All programmes are written in Fortran for a CDC-3600.

Reduction of distances measured electronically

TELLYHT computes tellurometer distances and trigonometrical heights, or either separately, along a traverse.

GEODIMET computes sea-level distances from geodimeter 8 observations.

Co-ordinate conversion

TMCOORD converts latitudes and longitudes to eastings and northings and the reverse on any transverse Mercator grid.

LAUF converts rectangular co-ordinates from one grid to another.

Distance and azimuth on the spheroid

ROBBINS computes distance and forward and reverse azimuth, given the latitude and longitude of two points, from Robbin's formulae for lines up to 1,000 miles.

AZARC is similar to the ROBBINS programme, but Rudoe's and Sodano's fourth formulae are used for extremely long lines on the spheroid.

Traverse on the spheroid

CLARKROB computes traverses on the spheroid. It lists closures in latitude, longitude and azimuth round loops of traverses in networks of any complexity.

Astronomy

STARCORD updates star co-ordinates to the instant of observation. The fourth fundamental catalogue for 1950 is held on magnetic tape.

LATCOMP computes circum-meridian latitude observations. After rejecting latitudes beyond a specified limit, the mean, the range, standard deviation and standard error of the mean area computed.

ALMUCOMP computes astronomical longitudes from almucantar observations. After rejecting longitudes beyond a specified limit, the mean, range, standard deviation and standard error of the mean are computed.

ASTRO combines the STARCORD, LATCOMP and ALMUCOMP programmes into a single programme.

SIGMA computes astronomic azimuths observed from *Sigma octantis*. The right ascension and declination and the curvature corrections are computed internally.

ALMUPRED predicts stars for almucantar longitude observations.

MERIPRED predicts stars transiting the meridian.

Horizontal adjustments

VARYCORD is a computer programme for the least-squares adjustment of angles, azimuths and distances on the spheroid. It is designed to adjust traverses, triangulation, Hiran and Aerodist trilateration, separately or in combination. It does not adjust heights.

Height adjustment

A series of programmes is being finalized to adjust large levelling, trigonometrical height and similar networks. The two main programmes are based on least-squares adjustment in phases. The phase I adjustment is by observation equations and the phase II adjustment by condition equations. Variance–covariance matrices are computed.