GEODETIC ACTIVITIES IN AUSTRALIA TO 1973*

Paper presented by Australia

Geodetic surveys in Australia, on a nation-wide scale, gan relatively late. However, Australian surveyors ve been able to make use of some important innova- ons which became available in Australia in 1956, mely, the introduction of the Tellurometer, automatic velling instruments and electronic computers, as well the availability of commercial helicopters.

The use of these new instruments and the co-operation f all concerned, under the general direction of the ational Mapping Council, has brought about homo- eneous national surveys for both horizontal and verti- al positions.

Many survey authorities in Australia have contributed the successful completion of these surveys together ith a number of private surveyors, who were engaged in velling and astronomical surveys financed by the Com- onwealth of Australia.[1]

Horizontal control[2]

Early trigonometrical surveys in Australia began in lew South Wales in 1828, and subsequently were ndertaken in other states. Most of these surveys were ot connected to one another. During the period 1930–1945, the Royal Australian Survey Corps concen- rated on the co-ordination of existing triangulation in Victoria and New South Wales. By the end of the Second World War, only a small part of Australia was covered with horizontal control surveys of currently acceptable tandard. In 1945, the National Mapping Council of Australia was formed and adopted a basic scheme of a national geodetic survey.

With the introduction of portable electronic distance- measuring equipment, mainly the Tellurometer in 1956, was possible for the National Mapping Council to approve of, and sponsor, gradually extending geodetic survey operations that eventually covered the whole country. Only a further 10 years were required in order to complete a network of geodetic survey over the whole of the Australian continent and Papua New Guinea. At the beginning of this period, the computation of various parts of the existing survey, old and new, was based on 20 different geodetic datums using four different figures of the earth. In March 1966, the whole survey of 58 loops, containing 2,506 firmly marked geodetic stations including 533 astro-geodetic stations and over 50,000 km of Tellurometer traverses, was adjusted by programme VARYCORD, using the method of least squares by variation of co-ordinates on the spheroid. The Austral- ian geodetic survey is particularly strong in azimuth due to the great number of Laplace stations along the traverse network.

Australian geodetic datum

This adjustment resulted in the formation of the Australian geodetic datum, which is a homogeneous system of latitudes and longitudes covering the whole of Australia and Papua New Guinea.

The latitude and longitude of the origin of the Austral- ian geodetic datum, the Johnston Geodetic Station, was determined from a comparison of astronomical and geodetic co-ordinates at 155 survey stations, well distrib- uted over the whole of Australia. This had the desired effect of placing the spheroid very close to the geoid in Australia. The value of the separation of the geoid was everywhere assumed to be zero, and all distances in the adjustment were reduced using trig heights based on mean sea level datums.[3]

New surveys are continually being added by adjusting them to points of the original 1966 adjustment. Over 11,000 geodetic stations are by now computed on the Australian geodetic datum. Figure 55 shows the network of geodetic control on the Australian geodetic datum as at 31 December 1972.

*The original text of this paper, prepared by the Division of National Mapping, Department of Minerals and Energy, Australia, appeared as document E/CONF.62/L.37.

[1]"Geodetic surveying in Australia", *Sixth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. II, *Technical Papers* (United Nations publication, Sales No. E.72.I.20), pp. 145–147.

[2]"The geodetic survey of Australia", *Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. II, *Proceedings of the Conference and Technical Papers* (United Nations publication, Sales No. E.68.I.14), pp. 126–131.

[3]"Adjustment of horizontal control surveys", *Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. II, *Proceedings of the Conference and Technical Papers*. pp. 111–114.

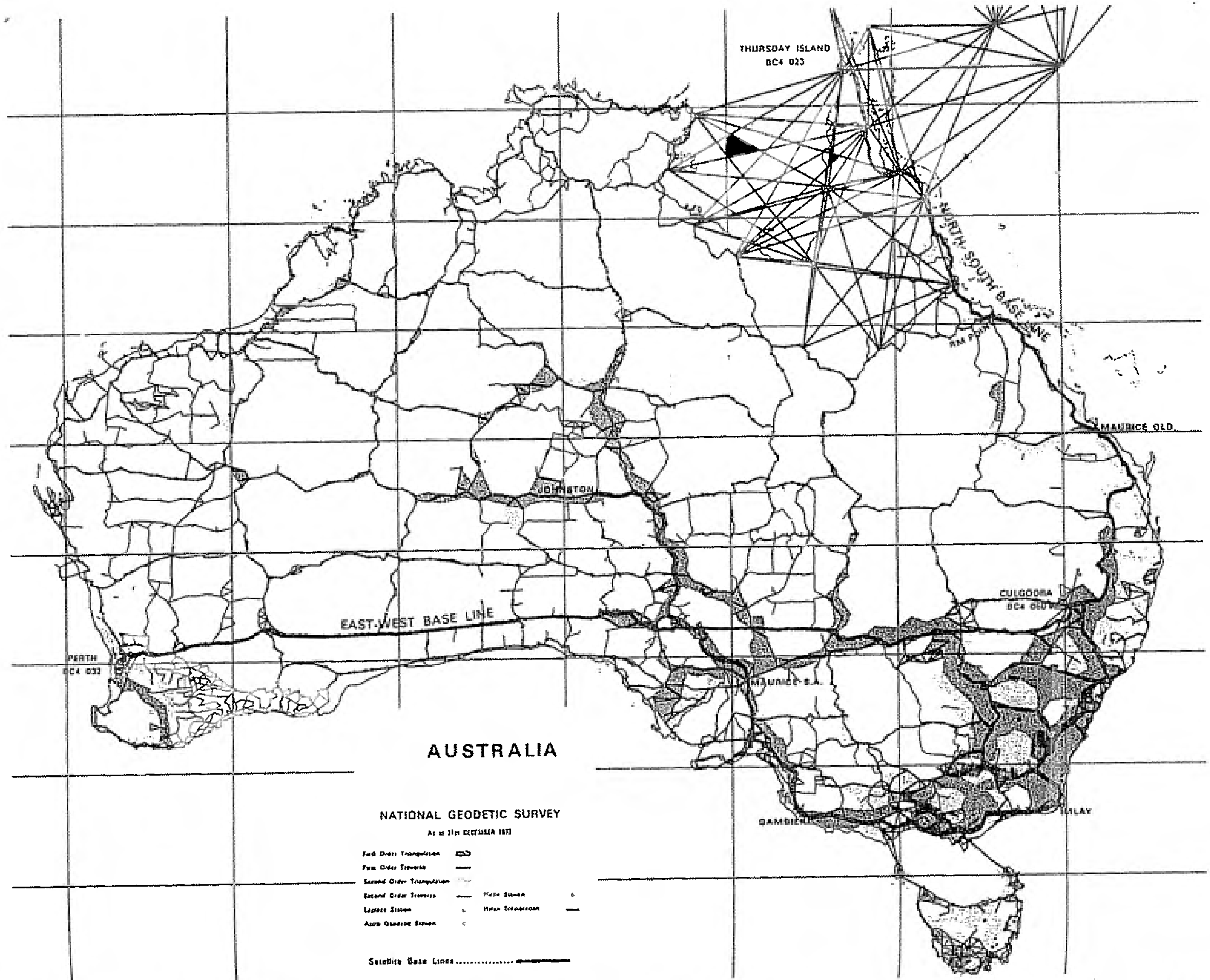

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Figure 55.—Australia: national geodetic survey

PRECISION TRAVERSING

A network of precision traverses has been measured by the Division of National Mapping. It links all Australian capitals except Hobart with the Johnston origin and contains the two satellite base-lines. Except for a section of 500 km in New South Wales, the traverses follow existing geodetic work observed during the period 1957–1965 with Tellurometer models 1 and 2.

On these traverses, measurements were made as described in the section concerning satellite base-lines. Almost all stations on these traverses are astro-geodetic stations.

After the completion of the two base-lines, most distances along the traverses, begun in 1970, have been measured with model 8 laser Geodimeters and a few with MRA4 Tellurometers. Lines of up to 70 km in length have been measured with the model 8 Geodimeter employing up to 42 prisms. Smoke, dust particles in the atmosphere, shimmer and hazy conditions have at times restricted the use of the laser Geodimeter, while high humidity in coastal regions limited the range of MRA4 Tellurometers.

This network of precision traverses is included in the formation of the geodetic model of Australia, described below.

SATELLITE GEODESY

During the past decade, Australian surveyors have become increasingly involved with satellite geodesy. The field-work has included the survey of two long base-lines in Australia between satellite camera stations and observations at three BC4 camera sites for the world-wide Passive Geodetic Earth Orbiting Satellite (PAGEOS) triangulation, the geodetic connexions to 51 satellite tracking facilities at 24 tracking sites and the assistance given to observation teams of PAGEOS, the Sequential Collection of Ranges (SECOR) and the tracking network (TRANET).

One satellite base-line between Perth and Culgoora in New South Wales is 3,200 km; the other between Thursday Island and Culgoora is 2,300 km.[4] The two base-lines follow traverses and triangulation which are part of the 1966 adjustment. The Division of National Mapping remeasured all distances along the two traverses connecting the base terminals, mainly with MRA4 Tellurometers and in part with model 8 laser Geodimeters. It observed astronomical azimuths simultaneously from both ends of a line on two nights along every line in pure traverse and every second line in triangulation. Almost every station along the two base-line traverses is an astro-geodetic station. The Royal Australian Survey Corps co-operated with authorities of the United States of America in the making of BC4 observations at Perth, Culgoora and Thursday Island.

Observations along both base-lines were reduced to the spheroid using Australian height datum heights and spheroid-geoid separations, N, from the 1971 geoid determination and were then adjusted by programme VARYCORD, holding the common terminal at Culgoora fixed.

Geodetic information sheets for all satellite tracking stations and radio telescopes in Australia have been prepared by the Division of National Mapping and are available upon request.

VERTICAL CONTROL[5]

Levelling of geodetic standard with permanent marks placed at adequate intervals began slowly in Australia. Before 1956, about 5,000 km of geodetic control levelling had been completed in three of the six states of the Commonwealth of Australia. Between 1956 and 1960, an additional 16,000 km were levelled; and at the end of 1970, a total of over 150,000 km had been completed to provide nation-wide coverage.

The completion of this programme was made possible only by the adoption of third-order levelling techniques; and the letting of contracts, for marking and levelling, to private surveyors under the supervision of the states Surveyors-General. A total of 232 such contracts, worth about $2 million, were arranged during the period 1961–1970.

As part of the Australia mapping programme, the Division of National Mapping, on behalf of the National Mapping Council, and with the help of various state and other authorities, organized a programme of tidal readings at 33 tide-gauge stations around the coastline of Australia. The objective of this programme was to obtain simultaneous recordings at all stations on a continuous basis for a common period of one year in order to compute mean sea level at those stations pertaining to the same epoch.

The Division of National Mapping sent a survey team to visit each tide-gauge. The team's job was to calibrate the tide-gauge recorder against a standard instrument, to establish additional permanent marks so that there were at least three permanent marks near every tide-gauge and to determine the difference in height between the gauge zero and the permanent marks, as well as to take photographs of all important fixtures of the tide station.

The adjustment of selected loops of the continental net took place in May 1971. Observed orthometric differences based on theoretical gravity were used.

AUSTRALIAN HEIGHT DATUM

The datum surface resulting from the adjustment of the Australian levelling net with minor modification in two metropolitan areas has been termed the Australian height datum and adopted by the National Mapping Council as the datum to which all vertical control for mapping is to be referred. The datum surface is that which passes through mean sea level at the 30 tide-gauges and through points at zero Australian height datum height vertically below the other 467 primary junction points.[6]

Figure 56 shows the Australian Levelling Survey on the AHD as of 31 December 1972.

One phenomenon evident from the Australian levelling network is the rise of mean sea level, along the north-east coast of Australia between Brisbane and Cape York,

[4] Australia, Division of National Mapping, "Two Australian base-lines for the Pageos world triangulation", technical report 11.

[5] "The levelling survey of Australia", *Fifth United Nations Regional Cartographic Conference for Asia and the Far East*, vol. II, *Proceedings of the Conference and Technical Papers*, pp. 114–115; Australia, Division of National Mapping, "The adjustment of the Australian levelling survey 1970–1971", technical report 12.

[6] "The adjustment of the Australian levelling survey 1970–1971"; Australia, National Mapping Council, "The Australian height datum", special publication No. 8.

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Figure 56. Australia: national levelling survey

1.5 m. A number of theories have been put forward to account for this rise along part of a theoretical equipotential surface. The presence of the coral reef, prevailing ocean currents, the temperature and salinity of the water, and the shallowness of the water have been considered. None gives a satisfactory explanation.

Adjustment of trigonometrical heights

Immediately after the completion of the levelling adjustment, trigonometrical heights of horizontal control stations were adjusted to the Australian height datum. To date, heights of all the stations included in the 1966 adjustment, which contributed to the establishment of the Australian geodetic datum, have been computed in terms of the Australian height datum, as well as heights of stations in many supplementary horizontal control sections.

The geoid in Australia

A preliminary geoid for Australia was determined in 1966 by Irene Fisher of the United States Army Topographic Service. About 550 astro-geodetic stations on the Australian height datum were available for this determination.

In 1971, a new geoid in relation to the Australian geodetic datum was determined. The first stage of that project was the computation of sections of primary geoidal profiles along traverses where the spacing of astro-geodetic stations was generally less than 35 km. Those sections formed large loops which were broken up by geoidal profiles along traverses where the spacing of astro-geodetic stations was often in excess of 50 km. A weighted-squares adjustment provided values of N for 1,133 astro-geodetic stations.

Values of N and the deflections of the vertical were computed from gravity data at 51 geodetic stations and at 1,679 points on a half-degree grid inside the loops formed by the geoidal profiles. The gravimetrically computed values were adjusted, loop by loop, into the system defined by the adjusted values of N at the astro-geodetic stations on the loop perimeter.

The results of the geoid adjustment were used to plot a geoid contour map of Australia based on the Australian geodetic datum. The range of the geoidal heights is about 22 m.

Diagrams showing contours of the components of the deflection of the vertical have also been plotted, as well as a diagram showing the deviation of the plumb-line. Deviations of up to 20 inches occur in Australia.

Precision control networks

The advent of integrated surveys and the availability of modern electronic distance-measurement equipment have given rise to a demand for precision survey networks in areas of intense development and high land prices. Part of these new precision control networks are coincident with previously adjusted networks; and, where practical, it is proposed to seek National Mapping Council approval to local modifications of the Australian geodetic datum to absorb the new precision networks.

Networks of this kind are being surveyed and adjusted in New South Wales, South Australia and Western Australia.

Geodetic model of Australia

Preparations are currently in hand to readjust all the geodetic surveys in Australia to form the geodetic model of Australia, making use of all modern surveys completed since 1966. The resultant data will be used for scientific purposes only and are not intended to supplant the data of the Australian geodetic datum for general survey and mapping purposes.

The input data will be adjusted by programme VARUDEL, which is identical to programme VARYCORD, with the following exceptions:

(*a*) It uses Rudoe's formula instead of Robbins' in the computation of azimuth and distance between co-ordinates of points and vice versa;

(*b*) It computes the parameters of relative error ellipses of adjusted points;

(*c*) The maximum number of variable points is 200 instead of 100;

(*d*) The differences between parameters of the geodetic model of Australia and the Australian geodetic datum are:

- (i) The flattening of the spheroid will be changed to that of the reference ellipsoid of 1967, i.e., from $1/f = 298.25$ to $1/f = 298.247$;
- (ii) The minor axis of the spheroid will be rigorously defined to be parallel to the pole of the Conventional International Origin (CIO).

The data for the adjustment based on the geodetic model of Australia will have all astronomical latitudes, longitudes and azimuths reduced to the CIO pole and all observed distances reduced to the spheroid using Australian height datum heights and 1971 N values. Laplace azimuths between the three PAGEOS triangulation stations at the ends of the two Australian satellite base-lines, determined from satellite observations, will be included.

The adjustment will result in co-ordinates of the geodetic model of Australia of the 140 odd junction points of the geodetic network in the first instance. Thereafter, only selected survey stations, such as radio telescopes, satellite tracking stations and other important stations, will have their co-ordinates computed in terms of the model.

Comparison of earth-centred geodetic datums with the Australian geodetic datum

A number of such comparisons have been made at single stations and groups of stations, for which co-ordinates on the Australian geodetic datum and on earth-centred geodetic datums are available. This is a continuous process with more comparisons becoming available and more up-to-date earth-centred datums being determined.

The best that can be said about these comparisons at the moment is that they present a most confusing picture. However, there are indications that the work currently being done by agencies of the United States of America on development of a world geodetic datum will clarify the issue.

A considerable effort has been put into the local testing of the United States Navy Navigational Satellite System (NNSS) for geodetic positioning. Although observations at various stations have, in themselves given acceptable consistencies over a period of from three to four weeks, there have been marked differences between results obtained from receiving equipment of different manufacture when used at different time periods.

Possible explanations are differing software procedures or periodical changes in the location of the geocentre by the monitoring authorities.

Positional Astronomy Section of Division of National Mapping

The Division of National Mapping took over the Positional Astronomy Section of the Mount Stromlo Observatory in September 1971. This section, equipped with a photo zenith and with modern time-keeping equipment, including three atomic clocks, determines variations in the rotation of the earth and the position of the earth's pole in conjunction with similar observatories in other parts of the world. Photo-zenith observations can also be used to determine the movement of the earth's crust between observatories.

Similar results can be obtained by making laser rangings to reflectors left on the moon and to artificial satellites equipped with reflectors.

A lunar laser-ranging system has been made available to the Division of National Mapping by the National Aeronautics and Space Administration of the United States of America (NASA). The system will be set up near Canberra, A.C.T., and is expected to be operational in April 1974.

Crustal movement surveys

In August 1973, the Division of National Mapping planned to observe a network of triangles formed by six concrete pillars 2-15 km apart, in the Markham Valley of Papua New Guinea. Re-observation is planned in 1975 and at five-year intervals thereafter.

The site of the survey and the exact location of the firmly placed observation pillars on either side of the geological fault have been selected by the Bureau of Mineral Resources, Geology and Geophysics, which expects the survey to disclose mainly vertical movements of the crust on either side of the fault.

Observations to detect vertical movement will be carried out by first-order levelling, and for horizontal movements by angular and laser geodimeter measurements.

A second site for a crustal movement survey in Papua New Guinea is across the St. George's Channel between New Britain and New Ireland. Trial observations with laser Geodimeters of distances up to 62 km across the Channel and final selection of the pillar sites are scheduled for September 1973. If practicable, the initial survey of this crustal movement survey network is planned for 1975.

Conclusion

Australia is fortunate indeed in being one of very few large countries having homogeneous geodetic control systems, both horizontal and vertical, surveyed with modern instruments during a short span of time.

These systems form the base for all future mapping in Australia. Looking forward, they provide a firm base for national reference and retrieval systems without which full efficiency in all future automated thematic, resources, topographic, aeronautical and marine mapping and charting cannot be achieved.