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The Western Australian border, where is it today?

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In 1829 the Swan River Colony was established by Captain Stirling and England claimed the remaining western portion (New Holland) of the Australia continent up to the NSW border at 129° longitude. Eventually NSW was further reduced in area to create the State of South Australia (SA) and the Northern Territory (NT) that now share the common border with WA. It was not until 1921 that the two states of WA and SA agreed on a process to determine the accepted legal position of the Border. This agreement included the placing of two Cairns, the Kimberly Cairn and the Deacon Cairn, on the border at 129° longitude as determined from adjacent astronomical observations. These two cairns under the agreement now determine the physical location of the border today. In 2012, GPS surveys were carried out at both cairns to determine the accuracy of the two original surveys.

Keywords: WA border; Kimberley Cairn; Deacon Cairn; astronomical observations; GPS surveys; GDA94; Austral pillars

1. Introduction

Under the British, Australian and WA legal systems, land boundaries are clearly defined by common law. The common law definition covers not only boundaries between individual land owners but extends to boundaries that separate Australian States such as the Western Australia (WA), Northern Territory (NT) and South Australia (SA), extending from the Kimberley coast in the north to the Great Australian Bight in the south. As Hallmann (1994) explains, the redefinition of any boundary under common law is more about establishing the intentions of the original parties than adopting a purely mathematical solution – *'Note, however, that the location of a boundary is primarily governed by the expressed intention of the originating party or parties, or where the intention is uncertain by the behaviour of the parties'*. In the case of the WA Border this is complicated by its length (1862 km), the difficulty in determining an exact location on the ground before the advent of GPS, and the number of different parties involved in making determinations on its position, in the years since the 1922 border agreement. The result from all of this is a boundary today that is not a straight line but one having a very small bend and a 127 m east-west step at 26° South latitude, representing a shift of approximately 4.6″ of longitude.

Most people today would probably argue that the exact location of the shared 129° meridian border between WA, the NT and SA is of no real consequence due to its remoteness. However, one also has to remember that this artificial boundary delineates the extent of three different state/territory governments with their own legislation that act on land titles, mining leases, Native Title claims and state services. The location of the WA Border then

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becomes extremely important when trying to deal with pastoral leases, mining tenements and Native Title claims.

This problem concerning the precise location of the WA boundary was highlighted in the Kiwirrkurra and Irrunytju-Papulankutja land claims. The application for this claim was ultimately rejected because the defined geospatial position for their Eastern boundary overlapped the State border with the Northern Territory by 37–42 m (Figure 1) and was not wholly within the State of Western Australia as claimed. This issue of not being able to precisely define the location of the border extends back to the 1890s and affected the granting of cattle leases in the Kimberley in the north of WA.

2. Why 129° East longitude for the Western Australian border? (debunking an urban myth)

The history of why the WA Border is located at 129°E longitude goes back to 1825. Prior to that 'Australia' was divided roughly in half with all the land west of 135°E variously known as *Hollandia* and *Dutch New Holland*, with the balance of the land eastward known as *Terra Australis* and *New South Wales*.

Why was 135°E the divide, how did that eventuate? There has been much written by eminent researchers and authors (Taylor 2006; Marchant 2008; and others) that gives credibility to the story that this line approximated the Spanish and Portuguese occupation divide in a part of the world that was becoming the hub of abundant and lucrative trading opportunities in the fifteenth century.

The first attempt to demarcate the new world between the two major sea powers was by Pope Alexander VI in 1493 at the request of the Spanish rulers King Ferdinand and Queen Isabella (Encyclopaedia Britannica, Treaty of Tordesillas). The line chosen was located 370 leagues west from the western extent of the Portuguese Cape Verde Islands (Azores) and extending from the North to the South Pole.

Figure 1. The Western Australian border, the Ngaanyatjarra claim and the Pitjantjatjara lands (Turnbull 2006)

Herein lies a problem for modern researchers as the league was not a standard unit of length. A league had a number of definitions, from the distance a person can walk in an hour to the distance an average-height person can see out to sea standing on the beach. Depending on the country, a league varies from about 4.4 to about 6.1 km, so calculating the longitude of the Pope's line is problematic. In 1494, under the treaty of Tordesillas (between Spain and Portugal but largely ignored by every other country on missions of discovery), it was extended westward to include the area of South America already occupied by the Portuguese (now Brazil). Scholars have given their best guesses as Longitudes 38°W for the Pope's Line and 46° to 51°W for the subsequent Tordesillas Line (Figure 2). In the western hemisphere there was little territorial dispute between the powers (except more lately the Spanish-speaking Argentinean claim to the Falkland Islands and Antarctica). In the East, however, it was different as there were considerable riches at stake especially in terms of the spice and trade goods.

The Treaty of Tordesillas did not extend around the Earth, so Spain and Portugal eventually (in 1529) brokered a new agreement: the Treaty of Saragossa (or Zaragoza). The Molucca Islands (aka The Spice Islands), just south of the western tip of New Guinea, became the focus of the agreement, with Portugal paying off the Spaniards and agreeing to a demarcation line 13° east of the Islands. (http://en.wikipedia.org/wiki/Treaty_of_Zaragoza)

The Moluccas (aka Maluku Islands) are a group of islands centred about 129°E – another coincidence it seems but in some literature cited as the antemeridian of a 51°W Tordesillas Line. The uncertainty of the length of a league could give a ±5° discrepancy in establishing the longitude, but given the ships' navigators of the day struggled to calculate their longitude to any degree of accuracy the variation was largely irrelevant.

None of this explains the choice of 135°E as the original Border meridian but the best evidence comes from the map produced for the Vereenigde Oost Indische Compagnie, the VOC or Dutch East India Company in 1644 (Figure 3). By now the Dutch were exerting their influence in Asia in the exploitation of trade and colonisation. They were well established in Batavia by 1619 and were

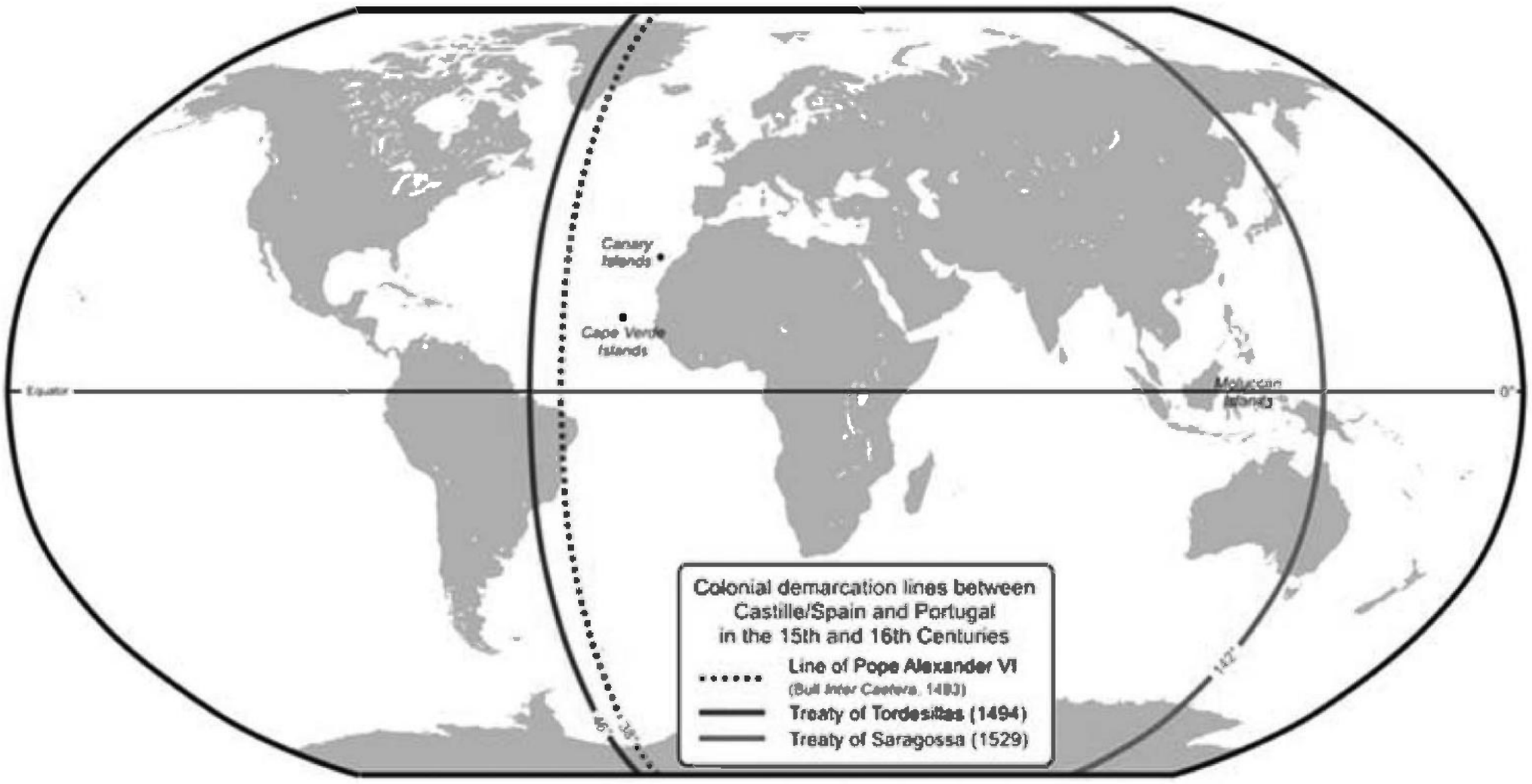

Figure 2. The 1494 Treaty of Tordesillas 46°W meridian (purple) and the 1529 Treaty of Zaragoza 142°E meridian (green) – (from wikipedia, accessed March 2013)

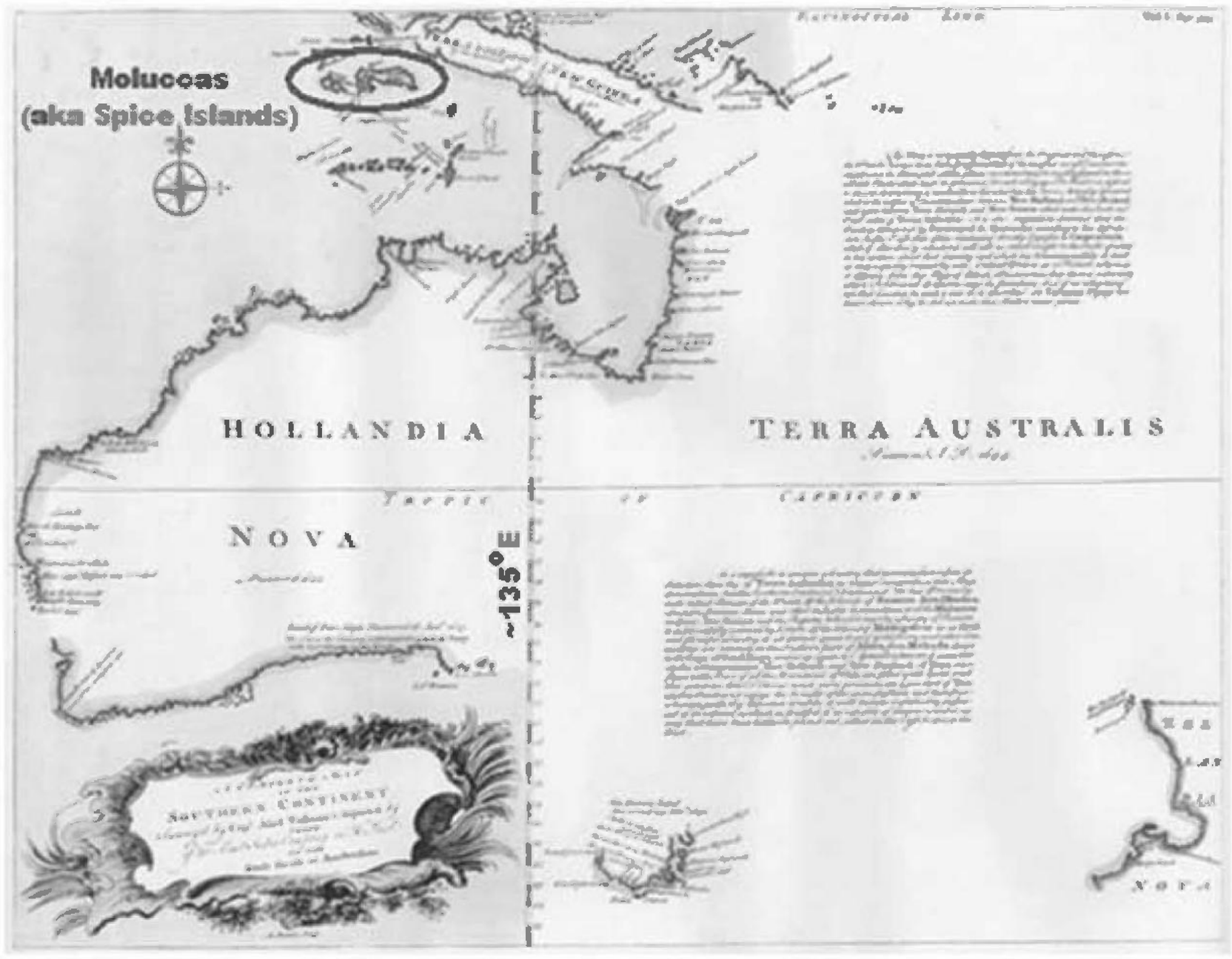

Figure 3. The complete map of the southern continent dated 1644. (http://upload.wikimedia.org/wikipedia/en/3/37/Bowen-_%27%27A_Complete_map_of_the_Southern_Continent%27%27.jpg)

actively exploring the areas of New Guinea and Northern Australia, and although 135° did not correlate with the Saragossa Line, as the antemeridian, it did more closely approximate the more widely accepted longitude for the Tordesillas Line. As David Taylor (Taylor 2006) remarked in his book, titled '*The State of a Nation*', the Dutch seemed to have confined their activities to the Portuguese area of influence in this part of the world, and the 135°E meridian just may have been the accepted line of the day (Marchant 2008).

3. British settlement of Australia

Captain Arthur Phillip's commission (letters patent) for the settlement of Terra Australis, in 1788, was to take possession of all land east of 135°E longitude and extending from 10° 37′S latitude to 43° 39′S latitude (Figure 4). This commission actually expanded on the claim made by Captain Cook some 18 years earlier in claiming Terra Australis from 10° 37′S latitude to 38°S latitude and naming the land New South Wales. Although Captain Cook's claim was vague about how far the claim extended westwards, Captain Phillip's commission was

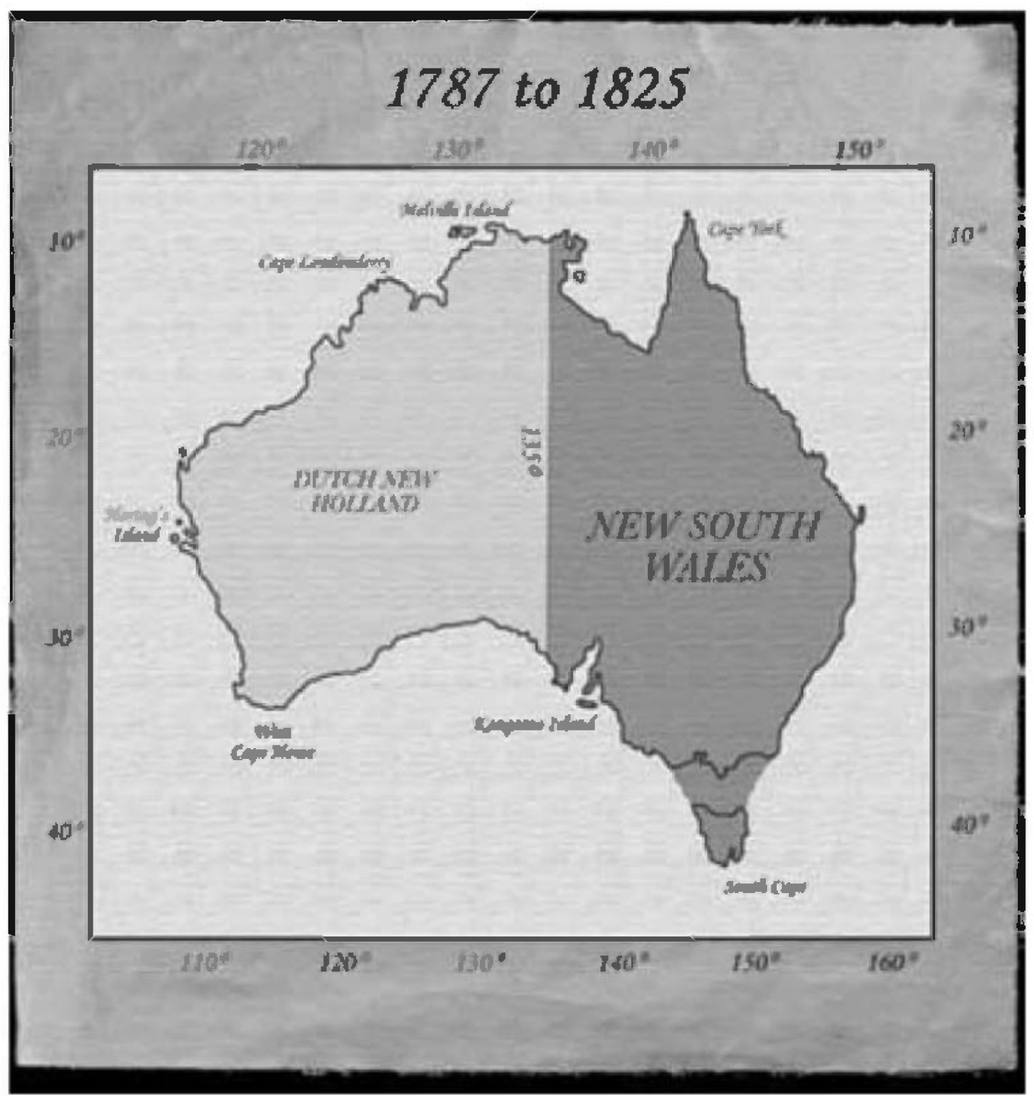

Figure 4. The extent of British territory in New South Wales until 1925. Image from 'Atlas of NSW 2010'

very definite. At the time of the settlement, Holland was at peace with Britain and so it is reasonable to assume they confined their claim to the area recognised as Terra Australis so as not to offend the Dutch (Taylor 2006).

The colonisation of WA was a direct result of the exploration activity by the French in the early years of the nineteenth century. Louis-Claude de Saulses de Freycinet had named the southern coast of the continent 'Terra Napoleon' (Welsh 2004) and he was sent back to carry on further exploration of the southern coastline of Australia between 1817 and 1820. In 1825 when Lieutenant-General Ralph Darling was commissioned as Governor of NSW, the western border of NSW was extended from 135°E to 129°E. This extension of the colony was probably both a response to the increased French interest and to ensure that the new trading post and fort on Melville Island (Fort Dundas) was included in the area claimed by NSW. However, the situation with the French came to a head in 1826 when Lord Bathurst (Secretary of State for War and Colonies) was informed that Dumont D'Urville had set sail for Australian waters with the assumed intention (wrongly as it turned out) to establish a convict colony in New Holland. The result of this report was that Lord Bathurst instructed Governor Darling, on 11 March, to annex the rest of the continent (Welsh 2004). In 1826 Major Lockyer accompanied by 20 soldiers and 20 convicts landed at King George Sound (now Albany) to take possession of the remaining part of the Australian continent.

It was not until 2 May 1829 that Captain Fremantle took formal possession of all land not part of NSW. On 28 April 1831, Captain Stirling was issued Letters Patent appointing him Governor and Commander-in-Chief of the settlement on the west coast of Australia: the Swan River Colony. The Letters Patent limited his authority, in terms of longitude, from Dirk Hartog Island (112°52′E longitude) to the eastern border at 129°E longitude.

So the line in the sand that defines today's Western Australian eastern border was finally formalised – simply: 129°E longitude was chosen to exclude Melville Island from WA, nothing more!

4. First attempts at marking the border

A number of attempts have been made in the last 150 years to mark various sections of the WA Border. This has mainly occurred in areas where there has been development of some kind and it has been desirable to define the limit of WA or the adjoining States. The border today is only crossed by two bitumen roads, one to the extreme north of the State and one to the extreme south of the State, and a single standard-gauge railway line. In addition there are also a number of minor gravel (unsealed) roads, throughout the interior, that also cross the border.

The first attempt to locate a mark on the Border was by Edmund Delisser in 1866, under instructions of the SA government. He was required to survey a traverse from Eyre's Depot (132°30′E longitude), near Fowler's Bay (in SA), to the colony's boundary on the south coast, a distance of 330 km (Porter 1990). Delisser connected his survey into the South Australian trigonometric network and placed a post on the border at 129°E longitude. In addition to surveying a large portion of the southern coast he also identified a suitable anchorage just westward of Eucla. At the time, the area suitable for a harbour was thought to be on the SA side of the border – we now know it is 15 km west of the SA/WA Border.

In 1867 Lieutenant William Douglas, from Cape Town, arrived in the Eucla area to carry out the necessary hydrographic survey to locate the harbour mentioned by Delisser in 1866. As part of his survey Douglas erected a cairn on the cliffs at 129°E, known thereafter as the Douglas Cairn. A copper plate was nailed to the centre pole of the cairn and read: *South Australia. Provincial Marine Survey – Lat 31° 41′ 0.85″: Long 129° 00′ 00″ East.*

Being the boundary between the Provinces of South Australia and Western Australia.

In 1877 the telegraph line was completed from Adelaide to Albany passing through the Eucla repeater station. This allowed Captain Frederick Howard of HMS Beatrice to resurvey the position of the Douglas Cairn using timing signals obtained from Adelaide. Captain Howard determined the position to be 128°59′58″E, or just inside the province of WA. However, a later connection between the Delisser survey post and the Douglas Cairn gave a longitude of 129°01′54″E. Given the known position of the Douglas Cairn today this would seem to indicate that the Delisser post was actually placed approximately 2′ West of the 129°E longitude line (Taylor 2006). This would certainly explain why the South Australians thought that any potential harbour at Eucla was within their State.

At a later date the two state trigonometric networks were connected. However, the Western Australians and South Australians determined two different values for the Douglas Cairn (Porter 1990).

129° 00′ 39″ East – from SA Network.
128° 59′ 21″ East – from WA Network.

This difference of opinion on the location of the Douglas Cairn was particularly vexing for the South Australian's as the WA government was issuing pastoral leases up to the border as defined by the Douglas Cairn, an encroachment, they thought, of about 1200 m. Today the Geocentric Datum of Australia 1994 (GDA94) longitude of the Douglas Cairn is 128°59′48.96209″E. It would appear that the astronomical and timing methods that Captain Douglas used to ascertain the position of his cairn in 1877 were reasonably accurate.

The location of the border in the north of WA at the end of the nineteenth century was also becoming an issue. Due to the prevalence of cattle tick in the north of Australia the Chief Inspector of Stock, John Craig (Department of Stock), in 1877 recommended that the border in the Kimberley region be surveyed. This would allow pastoralists to fence the border and inspectors to police the importation of cattle from the SA side (today NT). In response to this recommendation, Frederick Drake Brockman of the WA Lands and Surveys Department suggested a method to determine the location of the border. His recommended method was to use the Halls Creek Telegraph Station to provide an accurate timing signal (perhaps from Perth) for the determination of an accurate astronomical position for both latitude and longitude. Once a position fix had been obtained, this station could then be connected to an existing survey mark (J34) close to the border via the existing triangulation network in the area. Using the longitude of this station, J34, it would then be possible to set out a point on the border at 129°E longitude and survey the meridian northward towards the coast.

In the same year the WA Surveyor General also proposed an alternative plan to accurately locate a station in Wyndham from which a triangulation network could be observed to the vicinity of the border. Triangulation network survey marks adjacent to the border could then be used to accurately delineate the border. The estimated cost for either proposal was between £3000 and £5000 (Landgate files 8550/02 and 1191/97) and, due to lack of funds, the Department of Stock's recommendation was never acted upon.

It was not until the agreement to build the Transcontinental Railway was reached in 1907 that there were any serious attempts made to accurately locate the border. In that year, Surveyor Richard Anketell carried out a survey from Kalgoorlie along the proposed railway route and placed a substantial post at the border point. Another Transcontinental Railway surveyor, Norman Bartlett, also connected to the Douglas Cairn and determined its position to be 128° 59′ 37′E (Porter 1990), again very close to today's accepted position.

In 1921 a series of astronomical observations to determine accurate latitude and

Figure 5. The remains of the Western Deakin astronomy pillar being repositioned back in its original position by Landgate Geodetic Surveyors and Curtin University Survey Students in 2012

longitude were taken at Deakin (Figure 5) by astronomers from both the WA and SA governments. These observations were conducted by H. Curlewis (WA Government Astronomer – Figure 6), G. Dodwell (SA Government Astronomer), C. Maddern (SA Observatory) and A Williams from the SA Survey Department. Three large concrete observation pillars had been constructed at Deakin in 1920 and were subsequently used for the astronomical observations. The timing signal used for the astronomical observations was obtained from radio signals received from a number of stations located around the world at Lyons, Bordeaux, Annapolis, Adelaide and Perth. The observations carried out for longitude used three different methods: meridian transits, equal altitudes and Almucantar transits (Porter 1990). This was the first instance of time being determined from a number of stations around the Earth using radio signals to accurately determine longitude. In the day this new method created significant scientific interest from around the world.

The party also travelled to the Kimberley in the same year to carry out a set of astronomical observations just north of the Argyle Station adjacent to the border. Again

Figure 6. WA Government Astronomer Harold Curlewis using a 12 inch Troughton and Simms Theodolite #99 on the border determination expedition at the Austral pillars, c. 1921–22 (Landgate Files 8550/02 and 1191/97)

the same observation techniques were used to determine longitude and latitude. In addition, Surveyor Hambidge connected the two concrete observation pillars (now known as the Austral pillars; Figures 7 and 8) to the existing triangulation network in the area and traversed westward, and marked with a post, the approximate position of the 129°E meridian.

On 4 November 1922 the two state premiers of WA and SA, and the Prime Minister of Australia, signed an agreement to determine how the boundaries should be fixed once and for all. By this stage, SA had been redefined as extending to the 26th South latitude and the NT had been created north of that parallel. The Prime Minister was party to

Figure 7. The 1921 astronomy party at the Austral pillar (Landgate records 2013)

the agreement as the NT was administered by the Commonwealth government at the time.

The agreement between the parties, or letters patent, specified that two permanent marks would be placed on the 129°E meridian. These marks were to be adjacent to stations that had already been determined by astronomical means in the vicinity of the border at Deakin (along the Transcontinental Railway) and the Austral pillars in the Kimberly in 1921. In addition a 'Board of Surveyors-General', from the Commonwealth, WA and SA, was to be formed to supervise the positioning and marking of the 129°E meridian adjacent to the Austral and Deakin Obelisks. The agreement also declared that any further surveys on the meridian would be done in accordance with the principles laid down by the Board from time to time. This in effect gave the Board the mandate to decide on any matters relating to the marking of the border in the future.

Figure 8. The 1921 Austral astronomy observation pillars (the Austral pillar in the foreground) (Landgate 2012)

The agreement was also quite specific in that these two marks would define the border, even if proved by better survey methods in the future to be slightly off the 129°E meridian. From the Deakin locality (Deakin Obelisk) the border was to be defined as a line true South to the coast and true North to the 26th parallel, the border between the NT and SA. At the Kimberley mark (Kimberley Obelisk) the border was to be defined by a line true North to the coast and true South to the 26th parallel.

The question that arises from this agreement is the Board's intentions for the border between the Kimberley Obelisk and the Deakin Obelisk. Did they expect a straight line between the two adopted pillars or did they expect to have a small misclose at the 26th parallel?

5. Marking the border, post 1922

In 1926 Surveyor Hambidge accurately chained a calculated distance of 2943.49 m eastwards from the Deakin astronomical stations along the Transcontinental Railway to set out the Deakin Obelisk (Figure 9) on the border at the 129°E meridian (Landgate file records). In addition he also set out a second cairn 1669.69 m due south of the Obelisk. This was the first official portion of the border marked between WA and SA.

In 1927 Surveyors W. Brown and T. Cleave, from the Lands and Surveys Department of WA, set out the Kimberley Obelisk on the 129°E meridian. This involved accurately traversing 2637.86 m in a north-westerly direction from the Austral Pillars. In addition, the surveyors also placed a cement post 1609.34 m due south of the new obelisk along the border.

It was not until 1935 (Landgate files 8550/02 and 1191/97 2013) that further marks were placed along the border in the Kimberley district by Surveyor H. Barclay and assistant Surveyor H. Spigl. In this survey campaign they managed to survey 16 miles and 30 chains north and 87 miles and 36 chains south of the Kimberley Obelisk. The main purpose of this survey was to identify the border for the fencing of pastoral leases. The border was marked every mile with a concrete-filled galvanised pipe with a numbered copper plate, sunk below ground level and a rock cairn built over it.

In 1936 further survey work along the border was carried out by Surveyors H. Barclay and S. Stokes. During this season they surveyed a further 128 miles and 6 chains further southwards from the previous year.

Figure 9. Deakin Obelisk – Surveyor Hambidge in 1926 and Curtin University Student Ashley Plaiche in 2012

In 1937 Surveyor Barclay and Stokes were once again sent back to the Kimberley to continue the border survey. In this campaign the remaining section of border north of the 1935 survey was carried out to the coast, a distance of 61 miles and 78 chains. The last survey mark, a concrete-filled galvanised pipe, was placed at the edge of the firm ground just landward of the mangrove swamps of the coast, 78 miles, 28 chains and 40 links from the Kimberley Obelisk. Barclay stated that over the full length of the surveyed border the difference between the carried-forward azimuth and the astronomically observed azimuth did not exceed the 2″ as specified by the Board.

6. Surveyor general's corner

No further border work was carried out until the late 1960s. In 1963 the marking of the NT and SA Border along the 26th parallel of latitude (Taylor 2006) was commenced. The survey was to originate at the Mt Hearne trigonometric station and an Obelisk was to be established on the 26th parallel. From this point the survey was to extend eastwards to the Queensland Border on the 138thE meridian and westward to the WA border on the 129th E meridian. In the initial border marking proposal it was planned to only mark up to within 0.5 miles (800 m) of the 129th E meridian.

Due to the possibility of large-scale mine deposits being found and developed in the vicinity of the WA, NT and SA border it was decided that the intersection of the 26th S parallel with the 129th E meridian should be marked. On 9 March 1967 the Board met to determine how the intersection should be marked. The membership of the Board was constituted under the 1922 agreement with the addition of the NT Surveyor General as an invited guest. At this meeting it was decided that the wording of the 1922 agreement would be strictly adhered to and the 129th E meridian would be extended north from Deakin Obelisk and south from the southernmost border mile post (207MS) placed in the 1936 border survey from Kimberley Obelisk by Barclay. The revised latitude and longitude of these two marks had been recalculated from geodetic surveys and connections carried out by the Division of National Mapping of the Department of National Development. The longitude for Deakin was determined to be 129° 00′ 01.8584″E and the 207MS mile post as 128 59″ 57.2933″E on the 1966 Australian Geodetic Datum (AGD66). This in effect meant that a step in the border would be created along the 26th parallel.

From the correspondence preceding this meeting it is clear that the legal advice provided in 1919 by Mr G. Castle, Crown Solicitor from the Commonwealth Attorney Generals Department (Landgate files 8550/02 and 1191/97 2013), was used to decide on how the intersection of the border and the 26th parallel was to be determined by the Board. In Mr Castle's determination, point 9 states that '*The line laid down would remain the boundary even though it were ascertained at a future date that the line did not actually represent the 129th meridian of East Longitude*'. This determination provided the legal principle for adopting not only both the Kimberley Obelisk and Deakin Obelisk, but any future marks placed on the border under the direction of the Board.

On 9 March 1967 the Board met in Canberra to discuss the location and marking of the border intersection. The choices available to the Board were to either adopt a calculated line from the mile post 207MS (the last post placed in the 1935/1936 Border survey) to Deakin and intersect this line with a point on the 26th parallel or adopt the literal meaning of the 1922 agreement. A line joining these two adopted marks would have given a mid-azimuth of 359° 59′ 36″, clearly a considerable difference from the True North line specified in the 1922 agreement. The minutes of the board meeting are quite clear in that the Board decided to adopt the literal meaning of the 1922 agreement and extend a true south line from mile post 207MS and a true north

line from Deakin. The adoption of the mile post 207MS recognised the legal status of the Barclay border marks and protected any improvements (that is, the fences) between this point and the Kimberley Obelisk.

The preliminary survey work to locate the two marks for the border was carried out by Mr B.M. Allwright, a surveyor from the Lands and Survey Branch of the NT. This preliminary work included a traverse from existing geodetic marks in the area to a point located close to the intersection of the three States, now known as SG Corner TP. On 4 June 1968 a party of seven people including the Surveyors General of WA (Mr H. Camm), SA (H.A. Bailey) and NT (Mr P.J. Wells) arrived at the Border intersection site to supervise the final marking (see Figure 10). Mr Allwright made the final measurements from his connecting traverse and placed the two border pillars at the agreed longitudes. The ground distance between these two marks is given as 126.958 m. Due to the presence of the three Surveyors General, this border corner has since become known as 'Surveyor General's Corner'.

Figure 10. The Surveyors General of the day at Surveyor General's corner in 1968. From left to right, Messrs H. Camm (WA), H. Bailey (SA) and P. Wells (NT) – each standing in his respective state or territory

7. Recent marking of the Western Australian border

In November 1970 Mr H. Houghton was instructed by the Western Australian Department of Lands and Surveys (renamed Landgate in 2007) to mark the border from the Eyre Highway to the coast, a distance of 5450 m. The main reason for this survey came from a query by the WA Commissioner of Main Roads in 1969 regarding the accuracy of the border position in relation to the sealing of the WA section of the Eyre Highway.

The survey was subsequently carried out and two concrete marks were placed on the border either side of the Eyre Highway. In addition Mr Houghton placed a concrete post and cairn (SSM Border Cairn) 246 metres north from the High Water Mark. Again the longitude used to set out these marks from adjacent Standard Survey Marks (SSMs) was the 1967 accepted longitude of the Deakin Obelisk of 129° 00′ 01.8584″. However, there is no evidence in the Landgate files that the Board ever accepted these marks as officially delineating the WA SA Border.

At a meeting in Hobart on 6 October 1970, the Board decided to mark a section of the NT and WA border from 20° 20′ 41.4″S to 20° 46′ 02.67″S. This was the western boundary of an area known as the Mongrel Downs Section. The initial traverse along the border was carried out from the NT trig stations NTS522 and NTS523 by NT surveyors in 1970. However, due to an industrial dispute by the NT surveyors in 1971 and its subsequent lack of any real importance, the actual boundary marks for this section of the border were never placed.

8. Border survey 2012

In 2012 a small southern section of the WA border was surveyed by fourth-year surveying students from the Department of Spatial Sciences, Curtin University, under the direction of Geodetic Surveyors from Landgate. The purpose of this survey was to accurately

determine the longitude position of the Deakin Obelisk using GPS and use this information to redefine the Eyre Highway border crossing. This had become necessary due to the original marks placed by Mr H. Houghton having been destroyed during the construction of the WA Border Quarantine Station. The highway border crossing point was remarked, as per the 1922 agreement, by placing the new marks true south of the Deakin Obelisk.

At the Eyre Highway crossing point two temporary marks were placed to provide a coordinated baseline close to the road and adjacent to the border. GPS Sokkia GSR2700 dual-frequency receivers were then set up over these two marks, the Border Cairn and the Deakin Obelisk. The timing of the placement of these instruments was designed to provide at least 24 hours of simultaneously recorded dual-frequency GPS observations for all four marks.

The RINEX data for all four observations were submitted to Geoscience Australia's (GA) online GPS processing service (AUSPOS). This service calculates high-accuracy coordinates from RINEX data using the available International GPS Service (IGS) Rapid Orbit information and the results are emailed back to the user usually within 5 minutes.

An observed point position using the AUSPOS service is determined from a dual-frequency solution using the nearest 12 IGS and Asia-Pacific Reference Frame (APREF) stations (Figure 11). As stated by Dawson *et al.* (2001) this service can be used to provide positioning to a high accuracy anywhere in Australia or the world. Dawson *et al.* (2001) quote figures of 20 mm horizontal and 50 mm vertical positional accuracy for 6 hours of continuous observations and 10 mm horizontal and 10 to 20 mm vertical positional accuracy for 24 hours of continuous observations. AUSPOS has been upgraded since the Dawson *et al.* (2001) paper was written and unfortunately GA has not published a revision which states how good the results are now. The AUSPOS GDA94 coordinates of the two temporary marks and Deakin Obelisk were used to calculate where the ground marks north and south of the Eyre Highway needed to be placed to replicate the (AUSPOS) longitude at Deakin Obelisk, being 129° 00′ 06.9083″E.

A GPS survey at the Kimberley Obelisk was carried out in November 2012 by Landgate Geodetic Surveyors. This survey also recorded 24 hours of continuous dual-frequency GPS data. The data were subsequently processed using the AUPOS service to provide an improved GDA94 coordinate for the Kimberley Obelisk (Figure 11). The two Obelisks that

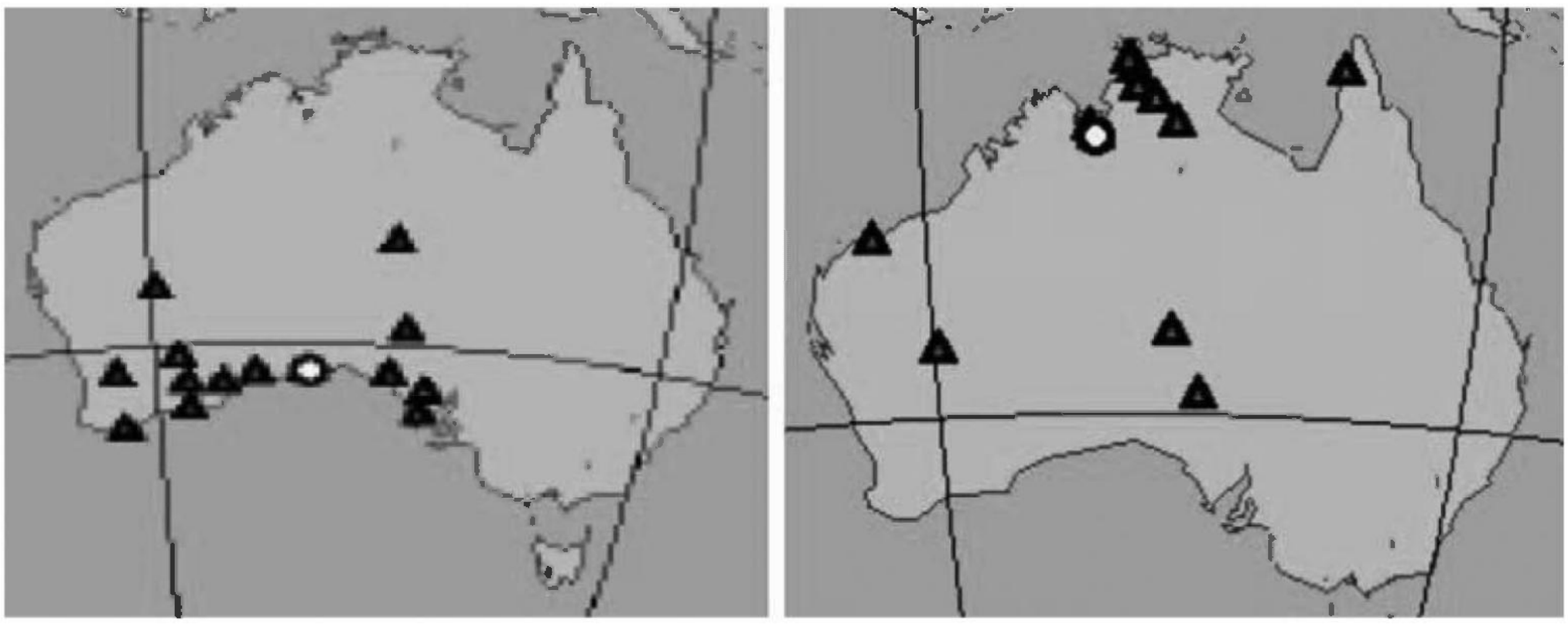

Figure 11. IGS and APREF stations used for the AUSPOS processing of the Deakin Obelisk and the Kimberley Obelisk 2012 GPS data

mark the border now have very accurate GDA94 coordinates based on the same survey and calculation methodology and conducted at a similar epoch.

In addition, the GPS data observed in the 1996 Statefix survey in WA for the SSMs adjacent to mile post 207MS and the Surveyor General's corner pillars were also reprocessed to provide the most accurate GDA 94 coordinates. This, while not being ideal because of the age of the GPS data, enabled the positions of two other key marks on the State border to be recalculated using modern processing techniques. Therefore the longitude of all the major marks on the border has been updated and improved through resurvey or reprocessing to enable a direct comparison (Table 1).

9. The Western Australian border – today's position

Today's position of the border, in terms of the coordinates of the key monuments surveyed under the direction of the Board, can be determined to a high degree of accuracy (Table 1). However, these GDA94 coordinates are based on the Geodetic Reference System 1980 (GRS 80) ellipse and will be slightly different to an astronomical position determined on the geoid due to the deflection (deviation) of the vertical at each observation point. The most common method of determining these values in the past was to use the difference between the observed astronomical values and the calculated geodetic values for a mark (Laplace Station) on the reference ellipsoid. In the case of the border, the best astronomical values available are based on the observations taken at the Deakin (1921) and the Austral pillars (1922). However, these values would be of no help in determining the absolute accuracy of the original placement of the Obelisks as they would include the errors associated with the astronomical observations themselves and the errors within the geodetic network.

Of more interest in determining the absolute accuracy of the original position of the border Obelisks is to look at their AGD66 values used in 1967. The ANS spheroid was deliberately orientated to minimise the deflection of the vertical (Featherstone 1999) across Australia. If one assumes that there are only minor deflections of the vertical then the Kimberley Obelisk was placed about 2.73″ west of the 129°E meridian and the Deakin Obelisk 1.86″ east of the 129°E meridian (Table 1).

A second method that can now be used to determine the deflection of the vertical is to use the latest geoid model for Australia – AUSGeoid09 (Figure 12). This geoid model, provided by GA, allows the computation of the geoidal separation (N) and the deflections in the Prime Meridian (ξ_g) and Prime Vertical (η_g). The theoretical astronomical latitude and longitude can then be approximated using the

Table 1. 1967 AGD66 adopted longitudes as compared to 2012 GDA94 AUSPOS longitudes

Mark name	AGD66 longitude (1967)	GDA94 longitude – 2012 processing	AUSGeoid09 deflection of prime vertical (η_g) in seconds*	Calculated astronomical longitude
Kimberley Obelisk	128° 59′ 57.2674″	129° 00′ 01.65892″	−0.91 (−1.59)	129° 00′ 00.71″
Mile Post 207MS	128° 59′ 57.2933″	129° 00′ 01.76630″	−3.18 (−3.54)	128° 59′ 58.40″
SG Corner West	128° 59′ 57.2933″	129° 00′ 02.05290″	−6.40 (−)	128° 59′ 54.93″
SG Corner East	129° 00′ 01.8584″	129° 00′ 06.61724″	−6.41 (−)	128° 59′ 59.49″
Deakin Obelisk	129° 00′ 01.8584″	129° 00′ 06.90828″	−6.50 (−5.94)	128° 59′ 59.35″

*Values in brackets are the calculated values derived from Laplace observations

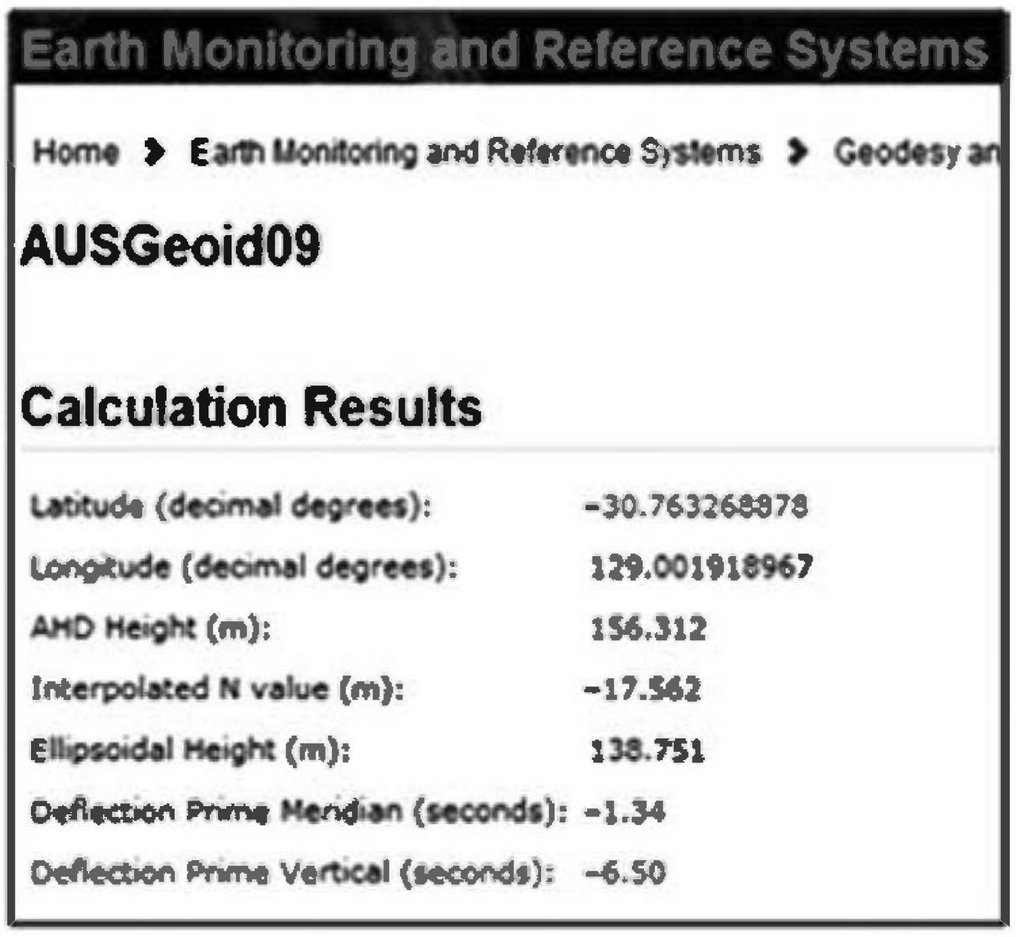

Figure 12. Calculation of the deflection of the vertical values for the Deakin Obelisk using the AUSGeoid09 interpolation program provided by GA

following formulae (Featherstone 1999):

$$\Phi_A = \Phi_G + \xi_g \tag{1}$$

$$\lambda_A = \lambda_G + (\eta_g / \cos\Phi) \tag{2}$$

where subscript A = Astronomic, subscript G = Geodetic and subscript g = geoid.

Note these formulae ignore the small influence of the curvature of the plumbline (Featherstone 1999).

Using the formula above for Deakin Obelisk would give a correction to the longitude of $-7.56''$. Applying this correction to the GDA94 longitude gives an astronomical longitude of $128°\,59'\,59.35''$E. In the case of the Kimberley Obelisk using the formula above, this would give a correction to the longitude of $-0.95''$. Applying this to the GDA94 longitude gives an astronomical longitude of $129°\,00'\,00.71''$E. This value is

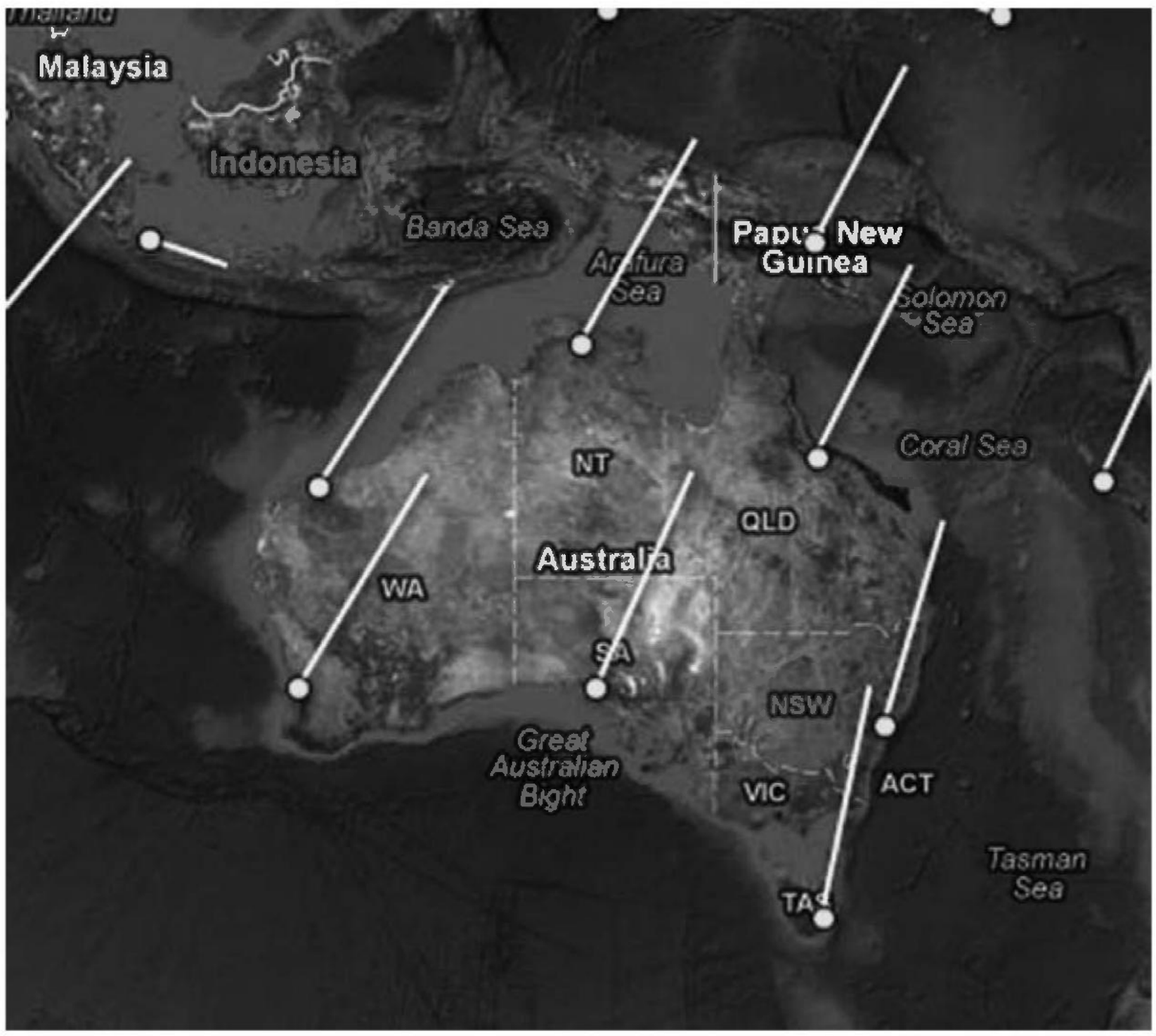

Figure 13. NASA JPL map showing the direction of movement of the Australian Observation stations due to plate tectonics. http://sideshow.jpl.nasa.gov/post/series.html. Accessed March 2013

about 3.44″ larger than the AGD66 published value. However, these differences are most likely due, in part, to the propagation of errors through the geodetic network in the AGD66 adjustment.

A further complication when comparing positions of marks over a long period of time to a high degree of accuracy is the movement of Australia in a north-easterly direction due to continental drift. In 1922 the theory of continental drift was largely unknown and unmeasurable. However, today the movements of the world's tectonic plates are tracked using a world-wide network of over 2000 continuously operating GNSS reference stations (CORS). This information is processed by NASA's Jet Propulsion Laboratory (JPL) and provides an annual rate of movement in latitude and longitude for each site in the world network. For the site located in Darwin (Figure 13) the annual movement has been measured to be 59 mm in latitude and 36 mm in longitude. Similarly the site located at Ceduna has annual rates of 59 mm in latitude and 29 mm in longitude (accessed from JPL website 2013).

This means that the two Obelisks placed in 1927 have shifted eastwards by approximately 3.1 m or 0.103″ in longitude (Kimberley) and approximately 2.5 m or 0.095″ in longitude (Deakin). This is not a large amount in terms of the accuracies possible and errors associated with placing the two obelisks using the available technology in 1927. However, it does highlight the point that a boundary that is defined by a mathematical value alone is in fact one that is moving in relation to the physical point on the ground.

10. Conclusion

The purpose of this paper was to research how the location of the WA SA NT border came about and to discuss the issues associated with actually marking the border on the ground.

Having accepted that 129°E was chosen to rationalise the territorial requirements of the Government of the day by keeping Melville Island out of WA, the focus for the administrators, later, was to decide how to mark the border.

In her Letters Patent of 1890, Queen Victoria probably did not imagine the border to be anything other than a straight line stretching from coast to coast. The practical reality and the enormity of the task of setting out such a long, straight baseline were only identified after the initial marking of the border in 1921. The Letters Patent of 1922 addressed this problem by instructing that a Board be established with the authority to determine how and by which principle, from time to time, the border should be marked. Significantly it acknowledged that better methods for determining the position of the meridian would evolve but declared that, irrespective, the original border markers would prevail over a more 'academic solution'.

The question that will likely continue to be debated is whether the Board's instruction to introduce a step at Surveyor General's Corner was in the spirit of the Queen Victoria declaration, and later the 1922 Letters Patent. By adopting the common law principle of protecting established occupation (as monumented by Surveyor Barclay's 207 mile post) and knowing what we now know, perhaps adopting a straight line to Deakin and beyond would not have been unreasonable.

What the 2012 Curtin University and Landgate resurveys of the Kimberley and Deakin Obelisks confirmed was that the accuracy of the 1921 astronomically derived longitudes (129°E) when compared to the calculated 2012 values (129° 00′ 00.71″E and 128° 59′ 59.35″E respectively) is truly impressive. It is only when we convert to the geodetic coordinates of the marks that the academic issues of deflection of the vertical, curvature of the plumbline, continental drift and datum definition arise to complicate what was previously a very simplistic description of the Border.

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