Grids & Datums

Republic of South Africa

by Clifford J. Mugnier, C.P., C.M.S.

According to *Lonely Planet*, "South Africa's history extends back to around 40,000 *BC* when the San people first settled Southern Africa. By *AD* 500, Bantu-speaking peoples had arrived from West Africa's Niger Delta. Competing colonial European powers began settling here in small numbers from the 17th century, mostly in the Cape. Widespread colonial settlement of South Africa began in the 19th century. From 1836, groups of Boers dissatisfied with British rule in the Cape Colony trekked off into the interior in search of freedom. In a decade of migration known as the Great Trek, increasing numbers of Voortrekkers (Fore-trekkers – pioneers) abandoned their farms and crossed the Senqu (Orange) River. Reports from early missions told of vast, uninhabited – or at least poorly defended – grazing lands. Tensions between the Boers and the government had been building for some time, but the reason given by many trekkers for leaving was the 1833 act banning slavery. The Great Trek coincided with the *difaqane* (forced migration) and the Boers mistakenly believed that what they found – deserted pasture lands, disorganized bands of refugees and tales of brutality – was the normal state of affairs. This gave rise to the Afrikaner myths that the Voortrekkers moved into unoccupied territory or arrived at much the same time as black Africans. The Great Trek's first halt was at Thaba 'Nchu, near present-day Bloemfontein, where a republic was established. Following disagreements among their leadership, the various Voortrekker groups split, with most crossing the Drakensberg into Natal to try and establish a republic there. As this was Zulu territory, the Voortrekker leader Piet Retief paid a visit to King Dingaan, and was promptly massacred by the suspicious Zulu. This massacre triggered others, as well as a revenge attack by the Boers. The culmination came at the Battle of Blood River (1838) in Natal. While the Boers sustained some injuries, more than 3,000 Zulu were killed, reportedly causing the Ncome River to run red. After this victory (the result of vastly superior weapons), the Boers felt their expansion really did have that long-suspected stamp of divine approval. The 16 December victory was celebrated as the Day of the Vow until 1994, when it was renamed the Day of Reconciliation. Several short-lived Boer republics sprang up but soon the only serious contenders were the Orange Free State and the Transvaal. The republics' financial position was always precarious and their economies depended entirely on cattle. Most trade was by barter. Just when it seemed that the republics, with their thinly spread population of fiercely independent Boers were beginning to settle into stable states, diamonds were discovered near Kimberley in 1869. Britain stepped in quickly and annexed the area. The Boers were disturbed by the foreigners, both black and white, who poured in following the discovery and were angry that their impoverished republics were missing out on the money the mines brought in. Long-standing Boer resentment became a full-blown rebellion in the Transvaal and the first Anglo-Boer War, known by Afrikaners as the War of Independence, broke out. It was over almost as soon as it began, with a crushing Boer victory at the Battle of Majuba Hill in 1881, and the republic regained its independence as the *ZAR* (*Zuid-Afrikaansche Republiek* – South African Republic). With the discovery of a huge reef of gold in the Witwatersrand (the area around Johannesburg) in 1886 and the ensuing explosive growth of Johannesburg (Jo'burg) itself, the ZAR was suddenly host to thousands of *uitlanders* (foreigners), black and white. This only intensified the Boers' grievances that had begun during the earlier diamond rush. In 1899 the British demanded that voting rights be given to the 60,000 foreign whites on the Witwatersrand. Paul Kruger (*ZAR* president 1883–1900) refused, and demanded that British troops be withdrawn from the republic's borders, leading to the second Anglo-Boer War. The conflict was more protracted than its predecessor, as the British were better prepared. By mid-1900, Pretoria, the last of the major Boer towns had surrendered. Yet resistance by Boer *bittereinders* (bitter enders) continued for two more years with guerrilla-style battles, which in turn were met by scorched-earth tactics by the British. In May 1902, the Treaty of Vereeniging brought a superficial peace. Under its terms, the Boer republics acknowledged British sovereignty."

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"Nelson (Rolihlahla) Mandela, South Africa's most popular anti-apartheid leader, had witnessed the rise and decline of apartheid firsthand. In the mid-1980s, after more than twenty years in prison for opposing apartheid, he assumed a central role in helping to end it. Government and opposition leaders met for talks – tentative ones at first, and then with greater confidence and amid more publicity – and they agreed on a general approach to political reform. Four years of difficult and uneven progress, amid escalating violence and competing political pressures, finally paid off in 1994, when South Africa held its first multiracial democratic elections. And while both

sides could claim some of the success in achieving this historic goal, both sides also faced even greater challenges in trying to establish a stable multiracial society in the decades ahead" (*U.S. Dept. of State, Country Studies, 2012)*.

Slightly less than twice the size of Texas, South Africa is bordered by Botswana (1,840 km) (*PE&RS*, May 2004), Lesotho (909 km) (*PE&RS*, June 2008), Moçambique (491 km) (*PE&RS*, September 1999), Namibia (967 km) (*PE&RS*, August 2006), Swaziland (430 km), and Zimbabwe (225 km) (*PE&RS*, November 2003). The terrain is comprised of a vast interior plateau rimmed by rugged hills and narrow coastal plain; the lowest point is the Atlantic Ocean (0 m), and the highest point is Njesuthi (3,3408 m). (*World Factbook, 2012*)**.**

"The pursuit of the figure of the earth has a long and interesting history in South Africa. The year 2001 marked the 250th anniversary since the prominent astronomer-geodesist Abbe de LaCaille set foot on South African soil to catalogue the Southern stars by their celestial co-ordinates of right ascension and declination. Shortly after his arrival at the Cape, LaCaille set out to measure a meridian of arc in the southern hemisphere as no such measurement existed. Abbe de LaCaille measured a triangulation arc northwards from Cape Town, to determine the figure of the earth and obtained a result which indicated that the curvature of the earth was less at southern latitudes than at corresponding northern ones. This perplexity was later to be verified by Sir Thomas Maclear, Her Majesty's Astronomer at the Cape. Sir George Everest visited the Cape in 1820 and inspected the site of LaCaille's meridian arc. His experience in the Himalayas led him to believe that the presence of considerable mountain masses in the Cape could have caused some anomalous disturbance thus falsifying the astronomical latitude determinations made by LaCaille. Sir Thomas Maclear was tasked to verify LaCaille's meridian arc and commenced such in 1840, completing the task in 1848. The arc was extended southward beyond the possible gravitational effect of Table Mountain to Cape Town and northwards towards Namaqualand. Indeed, it was confirmed that the predictions made by Everest of a large disturbance of gravity at LaCaille's northern zenith sector station amounting to more than eight seconds of arc, accounted for the error in the observations made by LaCaille. The Cape coastal triangulation of Captain Bailey and Henry Fourcade was a chain of triangles tied to the southern end of Maclear's arc extending eastwards from Cape Town to the then Kei River frontier of the Cape Colony. Sir David Gill, Her Majesty's Astronomer at the Cape in 1879 began to study the general question of the Geodetic Survey of South Africa. Gill found Bailey's field records to be erroneous and inconsistent. However, the concept of the scheme of triangles was adopted by Gill. It was Gill's dream to commence an arc following the 30th meridian and stretching from Cape to Cairo, through the Levant and terminating at Nordkapp. A chain of triangles forming the backbone of the 30th meridian was to provide the geodetic control for countries traversed by the arc. Gill being appointed the honorary scientific adviser of the Geodetic Survey set sail and landed in Durban in 1883 under the command of Captain William Morris. The field party set out to measure the Pietermaritzburg base, which was then extended by triangulation to the geodetic chain. The geodetic chain later was extended northwards towards Newcastle. The chain was carried south-west from Pietersmaritzburg to Port Elizabeth, then northwards from Port Elizabeth to Kimberly. These geodetic operations were completed before the Anglo-Boer War of 1899-1902, after which the work was extended over the Orange Free State and Transvaal up to the former Rhodesia where the 30th meridian also commenced also under the instruction of Sir David Gill. Astronomical observations of latitude and longitude were made at frequent intervals in order to position the geodetic chains on the earth, and azimuth observations to orient the work to the earth's axis of rotation. Sir David Gill had taken great care in choosing a datum point free of 'considerable deviation of the plumb-line' for the geodetic survey. Differences between astronomic and geodetic measurements showed that his triangulation on the datum and the chosen Clarke 1880 ellipsoid was in good agreement with the figure of the earth in South Africa. From the 1920's onward the Trigonometrical Survey undertook extensive geodetic surveys. In the mid 1930's the Kaitob base and the Mtubatuba base were measured. Land Surveyor, H. S. K. Simpson played a key role in these surveys. These were the last of the taped baselines before the advent of the EDM (electromagnetic distance measurement). (*Note that the Tellurometer EDM was invented and manufactured in South Africa – Ed.*). Recent additions to the geodetic framework include a looped chain of triangulation passing through the Mtubatuba baseline which was attached to the northern Natal section of the 30th meridian. The northern Transvaal section of the 30th meridian arc was extended eastwards toward the Moçambican border; a loop of geodetic triangulation running parallel to the Botswana border was attached to the western side of the 30th meridian arc. In the northern Cape, Surveyors Leipoldt and Heatlie connected the northern end of Maclear's arc to the Port Elizabeth-Kimberly chain, while Surveyor Connan split this area in two with a north-south chain. Meanwhile, Mr D. P. M. Rosseau, took charge in the geodetic surveys in Namibia. The points of the geodetic survey were too far apart for a surveyor to connect to this system and therefore a densification of the Geodetic survey network was required. The Natal Trigonometrical Survey established a secondary triangulation spreading throughout Natal emanating from the 30th arc of meridian. Many farm beacons were thus established in terms of a spheroidal rectangular or Cassini-Soldner projection co-ordinates. This was the original co-ordinate system of the Geodetic survey which was later to be superseded by the Gauss Conform system thirty years later. The Cassini-Soldner co-ordinate calculations were found to be awkward by Oscar Schreiber, who later influenced Van Der Sterr in using the Gauss Conform projection. The work of Johannes Jacobus Bosman, Director of Secondary Triangulation in the Cape Colony is also worth mentioning. Bosman, under the direction of Gill established a chain connecting the northern end of Maclear's arc eastwards over the Kalahari Desert to connect with the geodetic chain near Kimberly. Colonel Winterbotham

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conducted a minor triangulation based on the geodetic survey of the Orange Free State. By 1919 a considerable amount of trigonometrical control became available for cadastral and mapping purposes. New concrete beacons were built over the old centre points, points were re-observed and co-ordinates were recomputed in the Gauss Conform system. This revision was initiated in 1919 by the newly appointed Director of Trigonometrical Survey, Willem Cornelis van Der Sterr. The present structure housing the Chief Directorate: Surveys and Mapping is named after him. The Primary triangulation scheme continued under the direction of Van Der Sterr and computations were carried out in Mowbray under the watchful eyes of geodesist Oscar Schreiber. Primary order triangulations of 40 km sides were reconnoitred to fill the open spaces encircled by the loops of geodetic chains. The interpolation followed into the primary points of the secondary order triangulation nets. Thereafter, the tertiary stations followed with these points being intersected by rays observed to and from the surrounding fixed secondary stations. Sub-tertiary intersections were conducted in urban areas, often to church spires, in order to provide control for street traverses which connect the underground reference marks placed at street intersections and upon which urban surveys are based. This highlights the description of the unified trigonometrical system upon which all mapping, cadastral and engineering surveys are based" (*Chief Directorate: Surveys & Mapping, Dept. of Land Affairs, Mobray, Cape Town, South Africa, 2001*).

Thanks to John W. Hager, the classical geodetic origin of the Cape Datum/Arc 1950 Datum is at Buffelsfontein (in Port Elizabeth) where: Φ_o = 33° 59' 32.000" S, Λ_o = 25° 30' 44.622" E, azimuth to Zuurberg measured from South: α_o = 183° 58' 15.00", ξ = –3.46", η = –0.59", h_o = 280.1 m, and the ellipsoid of reference is the Clarke 1880 where: a = 6,378,249.145 m, and $^1/_f$ = 293.465. The Gauss Conform Transverse Mercator Grid system has 2° wide central meridians at: 17°E, 19°E, …, 31°E, 33°E.

"No arbitrary scale factors or false origins are applied to the co-ordinates; X is measured positive southwards from the equator and Y positive westwards from the nearest odd meridian. The unit of measurement since the 1970's is the International metre" (*Chief Directorate: Surveys and Land Information, 1995, personal communication*).

The new geodetic datum in South Africa is termed "Hartbeeshoek 94 Datum" and is referenced to the GRS80 ellipsoid where: a = 6,378,137. m, and $^1/_f$ = 298.257222101. The 3-parameter transformation **from** Cape Datum **to** Hartbeeshoek 94 Datum is where:

ΔX = +134.7 m, ΔY = +110.9 m, ΔZ = +292.7 m (*op.cit. Chief Directorate, 1995*). High-accuracy transformations are available from the Chief Directorate: Surveys and Land Information in the form of software that operates in somewhat similar fashion to the NADCON package of the U.S. National Geodetic Survey. The government of South Africa has also developed a high-accuracy geoid model for their country, and a GPS Real Time Network provides full-country coverage for high precision surveys.

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