& GRIDS & DATUMS

THE REPUBLIC OF BOLIVIA

BY Clifford J. Mugnier, CP, CMS, FASPRS

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on The Republic of Bolivia was originally printed in 2001 but contains updates to their coordinate system since then.

The Bolivian highlands were the location of the advanced Tiahuanaco culture, circa the 7th to 11th centuries. The Aymara Indians followed and were conquered in the 15th century by the Inca Indians. The Incas were subsequently conquered in the 1530s by Hernando Pizarro, the half-brother of Francisco Pizarro who conquered Peru. Bolivia achieved independence from Spain by proclamation of Simón Bolívar on August 6, 1825 when General Antonio José de Sucre invaded Characas. A map of Bolivia that was printed on a 1928 Bolivian postage stamp precipitated a war with Paraguay in the 1930s over the Gran Chaco region! After learning about that postage stamp, I began collecting "map stamps" of the world.

The eastern part of Bolivia has low, hot, fertile land watered by many rivers. In the central part of the eastern slope of the Andes, there is a high plateau region that includes part of the Gran Chaco. Lake Titicaca is in the western part of the central ranges and the highest peaks which include Cerro Illimani at 6,882 m. The lowest point in Bolivia is the Rio Paraguay at 90 m.

Bolivia has had a cartographical history quite unlike that of any of the other west coast republics of South America. Not only did the period of instrumental surveys begin much later in the Republic of Bolivia, but until 1921, when the American Geographical Society began the compilation of the La Paz 1:1,000,000 sheet, there had never been a general map of the country that could be described as an exhaustive compilation. J. B. Pentland, an English explorer and cartographer, opened the era of exploration and discovery in Bolivia with his work on the Altiplano and in the Eastern Cordillera of the Andes that he carried out in 1827 and 1828. His surveys and later work in 1837-1838 were published as charts by the British Admiralty in 1830 and 1839, respectively. The most important part of Pentland's work was his determinations

of altitudes and astronomical positions, the latter of which were used for many years as the basis for survey work in and for all compiled maps of the areas he covered. His determinations of altitudes in the Cordillera Real not only attracted the attention of other explorers to this hitherto little-known section of the Andes, but also gave rise to much controversy. That was because they indicated that the highest crests of the Bolivian section of the Andes were among the highest, if not actually the highest, in the whole Cordillera. It was believed, up to that time, that the snow-capped volcanoes of Ecuador held that distinction. Meanwhile in 1830, Alcide d'Orbigny, a French anthropologist and geologist, had begun the explorations that resulted in his *Carte Générale de la République de Bolivia* at a scale of approximately 1:1,575,000, published in 1835-1847 in his *Voyage dans l'Amérique Méridionale*.

Thanks to Sequoia Read of the Defence Geographic and

Photogrammetric Engineering & Remote Sensing
Vol. 85, No. 5, May 2019, pp. 341–342.
0099-1112/18/341–342

doi: 10.14358/PERS.85.5.341

Imagery Intelligence Agency, I received excerpts of a 1935 book entitled, *Die Karten der Cordillera Real und des Talkessels von La Paz (Bolivien)*. The authors were Prof. Dr. Carl Troll, and the famous photogrammetrist, Dr. Richard Finsterwalder!Finsterwalder detailed his excellent terrestrial photogrammetric survey of the volcanoes around La Paz.

The "Topographic Desk of the Southeast" was combined with the "Major General Topographic Cabinet of the State" in 1936 to form the Instituto Geográfico Miliar (IGM). Initially formed in the city of Cuevo, the institute was relocated to Cochabamba in 1939 and finally moved to La Paz in 1942. By the end of 1948, "La Ley de la Carta" (The Law of the Map) was decreed establishing IGM as the monopoly for mapping the nation. I have discussed this concept common to many Latin American nations as a vehicle to help fund the military because of the low existing tax base. Argentina (see *PE&RS*, December, 1999, pp. 1361-1363) and Ecuador (see *PE&RS*, May, 1998, pp. 542-543) are no exceptions to this custom.

The southwestern portion of Bolivia is well controlled with classical triangulation arcs, and some high-precision electronic distance meter traverses cover the southeastern portion of the country. The northern half of Bolivia is relatively devoid of triangulation control. Vertical control does extend to the northern provinces, and 1:50,000-mapping covers the southern half completely and the northern latitudinal half of the northern half.

The Republic of Bolivia is on the Provisional South American Datum of 1956 (PSAD 56) with the origin in the town of La Canoa, Venezuela where Φ_o = 08° 34′ 17.170″ North, Λ_o = – 63° 51′ 34.880″ West of Greenwich, and the defining azimuth to station Pozo Hondo (α_o) = 40° 22′ 45.96″. The ellipsoid of reference is the Hayford 1909 where the semi-major axis, a = 6,378,388 meters, and the reciprocal of flattening, $^1/_f$ = 297. In 1977, James W. Walker presented and published a paper at the Pan American Institute of Geography and History that included the seven-parameter transformation from PSAD 56 in Bolivia to the WGS 72 Datum where: ΔX = +268.20 m, ΔY = – 129.21 m, ΔZ = +408.13 m, scale = – 1.79024x10^{-5}, R_X = – 1.549″, R_Y = – 0.742″, and R_Z = – 0.416″. However, Walker pointed out that the rotations and scale factor had magnitudes equal to the uncertainty, so the actual parameters had little to do with reality. For that reason, the transformation parameters from the South American Datum of 1969 (SAD69) coordinates for Bolivia to the WGS 72 Datum were only offered in terms of three parameters. I have not been able to locate anything in Bolivia that is referenced to SAD69.

All late 20th century large-scale mapping of Bolivia appears to be referenced to the PSAD 56. The Grid of choice for Bolivia is the Universal Transverse Mercator (UTM). However, a Lambert Conformal Conic does exist in Bolivia that is referenced to the WGS 72 Datum where the Northern Standard Parallel φ_n = – 12° South, the Southern Standard Parallel φ_s = – 20° South, the False Northing Latitude of Origin φ_o = – 20° South, the Central Meridian λ_o = – 64° West of Greenwich, and the False Easting is 500 km. The ellipsoid of reference is the WGS 72 where a = 6,378,135 meters and the reciprocal of flattening, $^1/_f$ = 298.26. Other ancient Datums known to exist in Bolivia include the Arequipa Astro from the boundary surveys of the 19th century with Peru, and the Pepito and Poto Astros. John W. Hager believes that the vertical Datum is referenced to Arica in Chile.

Update

Since 2001, Bolivia has entered into a cooperative agreement for the Geocentric Reference System for the Americas, termed "SIRGAS," a Spanish acronym. Extensive geophysical research has been initiated in Bolivia with respect to crustal motion and volcanic activity. The CGPS network in country consists of 43 CGPS station sites, with 11 GPS stations recently installed in response to the Pisagua 8.2 magnitude earthquake on 1 April 2014. As of November, 2014 more than 240 GPS stations had been observed with dual-frequency GPS receivers.[1, 2]

Topography of the Uyuni salt flats determined with kinematic GPS was published in 2008.[3]

Significant gravity survey were published in 2015 for the Bolivian Central Andean Plateau,[4] but there seems to be zero data publicly available on transformation parameters from the PSAD 56 or the SAD69 datums to the current SIRGAS system. The Bolivian military IGM offered no response to my queries.

1 http://www.sirgas.org/fileadmin/docs/Boletines/Bol19/56_Heck_et_al_2014_CrustalMotionBolivia.pdf

2 https://pubs.geoscienceworld.org/gsa/geosphere/article/14/1/65/525536/50-years-of-steady-ground-deformation-in-the

3 https://academic.oup.com/gji/article/172/1/31/2081107

4 https://etd.ohiolink.edu/!etd.send_file?accession=osu1437668357&disposition=inline.

This column was previously published in *PE&RS*.