



& GRIDS DATUMS

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 Turkey was originally printed in 2005 but contains updates to their coordinate system since then.

The landmass east of the Dardanells, the Sea of Marmara, and the Bosphorus is known as Anatolia. The region was inhabited by an advanced Neolithic culture as early as 7,000 *B.C.*, and metal instruments were in use by 2,500 *B.C.* The Hittite culture was replaced by several peoples until the 4th century *B.C.* when Alexander the Great of Macedonia conquered all of Anatolia. The Byzantine Empire ruled Anatolia until defeated by Seljuk Turkish forces in 1071 *A.D.* Troops of the Osmanlı Dynasty moved into southern Europe and defeated Serbian forces at the battle of Kosovo in 1389. The Ottoman Empire flourished until multinational European forces drove Ottoman troops to cede substantial European territory in the Treaty of Karlowicz (1699). During WWI, the Turkish alliance with the Kaiser caused England, France, and Russia to declare war on the Ottoman Empire. After WWI, Atatürk, founder of the present-day Republic, repulsed a Greek attempt to expand Greece's postwar allotment of Ottoman territory. The Palestine was lost to the French and British Mandates, and the 1923 Treaty of Lausanne, negotiated between the Atatürk government and the Allies, defined control of the Bosphorus and the territorial extent of the new Republic of Turkey. During WWII, the government of Atatürk's successor, İsmet İnönü, maintained neutrality despite German pressure throughout the war. Turkey is now a member of NATO and of the United Nations, and is becoming part of the European Union.

REPUBLIC OF TURKEY



The westernmost extremity of Turkey is Thrace, the European segment bounded by Bulgaria (240 km) (*PE&RS*, January 2002), and Greece (206 km) (*PE&RS*, December 2002), on the north by the Black Sea, on the Southwest by the Aegean Sea, and on the southeast by the Sea of Marmara. Anatolia is a peninsula surrounded on the north by the Black Sea, on the south by the Mediterranean Sea, Syria (822 km) (*PE&RS*, September 2001) and Iraq (352 km), on the west by the Aegean Sea, on the northwest by the Sea of Marmara, on the east by Iran (499 km), Azerbaijan (9 km), and Armenia (268 km), and on the northeast by Georgia (252 km).

In 2004, the International Society for Photogrammetry and Remote Sensing convened its XXth Congress in Istanbul, Turkey. Associated with that meeting, the General Command of Mapping in Ankara prepared a marvelous text available in a PDF file entitled *The Illustrated History of Turkish Cartography*. The oldest map in history was found at Çatalhöyük in central Anatolia, and was dated as originating in 6,200 *B.C.* with Carbon₁₄ methods. The next major contribution to Turkish cartography was by Piri Reis, born in the late 1460s. He was a pirate, naval admiral, captain

Photogrammetric Engineering & Remote Sensing
Vol. 82, No. 9, September 2016, pp. 671–674.
0099-1112/16/671–674

© 2016 American Society for Photogrammetry
and Remote Sensing
doi: 10.14358/PERS.82.9.671

of Egypt, cartographer, and master of oceanography. By today's standards, the mapping of Turkey and the world by the Ottoman Turks was of a thematic nature through most of the 19th century. Large-scale mapping was accomplished by planetable and alidade, with control being established graphically through resection with the planetable. Much of Europe had been mapped in similar fashion in the 18th century; with geodetic control being utilized mostly in the latter half of the 19th century.

The General Staff of the armed forces established the first Turkish surveying school in 1818. After the foundation of both *Mühendishane-i Berri-i Hümayun* (the Artillery School) and the Military Academy, the young officers were sent to France, England and Prussia for education on western science and techniques. The first Cartographic Branch of the Armed Forces was formed in 1853. However, little geodetic surveying and mapping was performed for decades. Classical triangulation started in the Vardar Basin, and one year later, in May of 1896, a 7,235.520 m baseline was measured in Eskisehir with Brunner invar apparatus. One of the geodesists working on this project was Captain Mehmet Sevki, later to be promoted through the ranks to Major General and revered as the father of Turkish geodesy. Hydrographic surveys were beginning to be performed by the navy during these same years, and supporting triangulation was used for numerous harbor surveys and passages. In 1909, the survey office was upgraded to the Survey Commission. A series of topographic maps was started in 1911, and was based on the (1906-1923) Bonne projection where: the central meridian, $\lambda_0 = 28^\circ 58' 50.8188''$ East of Greenwich, the latitude of origin, $\phi_0 = 39^\circ 36' 00''$ N, and the scale factor at origin, $m_0 = 1.0$. Note that the longitude given above is but one of the various values published for the position of the center of the dome of the Aya Sofia mosque (originally built as the Cathedral of Constantinople), but the Turks actually used Aya Sofia as their Prime Meridian. (The relation of their Prime Meridian to Greenwich was immaterial to the usefulness of Turkish maps for Turkish applications.) The ellipsoid of reference was the Clarke 1880 modified by General Sevki where: $a = 6,378,249$ m and $b = 6,356,515$ m. Note that these parameters were published in 1333 of the Moslem calendar and were hand-written in *Old Turkish*, the norm at the time, and the angular unit of measurement was the centesimal Grad ($360^\circ = 400^g$).

Geodetic baselines measured before WWI included: Bakirkoy (Istanbul) 1909 (4396.703 m), Edirne 1911 (2919.240 m), Adapazari 1911 (3483.862 m), Ezurum 1912 (6127.396 m), and Aleppo 1915 (7477.857 m). The first order triangulation performed during this period was mainly in support of the Balkan War of 1912. By then, Brigadier General Şevki was involved with triangulation and mapping that extended through much of European Turkey (Edirne Region) to the Çanakkale Strait (Dardanelles). Remember that at the time the Prime Meridian for these topo sheets was the Aya Sofia mosque. Aerial photography was utilized by the Ottoman

Empire during WWI (1914-1918), but it is thought to have been for reconnaissance purposes only. Note that during this same time period (1917), the British were the first to use aerial photography for actual military mapping of Turkish fortifications in the Palestine during WWI (*PE&RS*, August 2000).

The General Directorate of Mapping was established by law on 02 May 1925 in the newly formed Republic of Turkey. New classical triangulation necessitated the observation of baselines that included: Ankara 1925 (2050.426 m), Izmir 1928 (9536.311 m), Dardanelles 1929 (3250.321 m), Eskisehir 1931 (second observation), Maltépé (Istanbul) 1932 (4279.455 m), Balıkesir 1933 (6106.972 m), and Korkuteli (Bozova) 1935 (6346.447 m). These post-WWI baselines were observed with the new French Carpentier invar apparatus. With the exception of the Edirne baseline that had an average error of 1/300,000, all the other baselines measured after the war had errors better than one part per million.

The first Turkish ventures into photogrammetry were in the 1930s, first with terrestrial applications and later with aerial. Foreign consultants carried out earlier experiments. In 1937, the first Zeiss C-5 Universal Stereoplanigraph was purchased, and German technicians were assigned to Ankara to assist in training as well as production. With the Wehrmacht's penchant for geodetic intelligence, Turkish military topographic sheets somehow found their way to Berlin. The new president of the republic, İsmet İnönü, insisted on maintaining neutrality during WWII. Nevertheless, there was great German interest in Turkey. The holiest place in all of Turkey is the Aya Sofia mosque. Being the national Prime Meridian, there was keen academic interest in the relation of the great dome with respect to Greenwich. The local datum for European Turkey was at the Kandilli Observatory where the geodetic coordinates are: $\phi_0 = 41^\circ 03' 48.899''$ N and $\lambda_0 = 29^\circ 03' 55.2''$ East of Greenwich. This was also the origin for the new Gauss-Krüger Transverse Mercator projection for European Turkey (used from 1932-1946), and the relation of the great dome to Greenwich was necessary in order to recast the Bonne Grid to the TM Grid. The connecting survey between the Turkish first-order triangulation net and the mosque was assigned in 1934 to Major Niyazi, also an accomplished photogrammetrist. One of the first things the major had to do was find the center of the dome. "As it is known the upper sections of Aya Sofia are covered with lead plates. The lead layers near the pillar were removed, approximately 15 centimeters of earth underneath was dug and a geodetic bronze rod was set with cement. The center of this little bronze rod is the head of Aya Sofia triangulation." Previous determinations of the position of Aya Sofia included: French Captain Gautier in 1816-1820 ($\Phi = 41^\circ 00' 12''$ N, $\Lambda = 28^\circ 59' 01''$), Nautical Table London in 1888 ($\Phi = 41^\circ 00' 16''$ N, $\Lambda = 28^\circ 58' 59''$), *Connaissance de Temps* in 1912 ($\Phi = 41^\circ 00' 29.8''$ N, $\Lambda = 28^\circ 58' 58''$), General Sevki ($\Phi = 41^\circ 00' 26.56''$ N transferred from Bakirkoy), and Brigadier General Abdurrahman ($\Phi = 41^\circ 00' 31.034''$ N

transferred from Eskisehir). Major Niyazi finally determined the coordinates of Aya Sofia as: ($\Phi = 41^{\circ} 00' 30.0709''$ N, $\Lambda = 28^{\circ} 58' 52.7238''$ West of Greenwich), but there was a problem. The major published his findings in *Old Turkish!* A certain couple of German Photogrammetric Technicians knew their photogrammetry and Zeiss C-5 Stereoplanigraphs very well, but they were apparently oblivious to geodetic publications published in *Old Turkish*. During WWII, there was a catastrophic military defeat of German and Axis forces in the European Turkish region of Edirne. The secret *Planheft* of the Wehrmach mentioned that there was an unexplained shift in the longitudes (and Eastings) of native maps in the region of Edirne! I do not think this was just a “coincidence” that happened to affect indirect artillery fire control.

The following is another fascinating excerpt from Major Niyazi's description of the enormous field work associated with the Aya Sofia Dome Survey: “The geometric equipment of the post consisted of one large Hildebrandt theodolite, six heliotropes, five geodetic projectors, twelve storage batteries and one small Wild theodolite, while the participating staff consisted of assistants Lieutenants Hilki and Kemal, one permanent sergeant and twenty-one soldiers for general duty and heliotrope communications, besides myself. We also had tents and animals. Assigning three soldiers to each heliotrope we placed them at designated points, and to insure the long stay of these troops on the mountaintops beside the first-order points, we gave them whatever supplies they needed. We also constructed caves as shelter in their long vigil. On some of these points we found caves already constructed in 1933, so we utilized them. In the matter of transportation, motorized transports first brought our equipment to the slope of the mountains, then horses, donkeys, ox and horse carts took it to the mountaintop. During the transportation of equipment the officers of the post paid most attention to the transportation of the large theodolite and they saw to it that there was always an officer in charge of this instrument. After the instrument was taken out of the spring carriage one or more soldiers always carried it on their shoulders to the top of the mountain.” The entire unit spent about a year in the field while observing the triangulation for the dome!

For Anatolia proper, the national system was the Mesedag Datum (near Ankara) where: $\Phi_0 = 39^{\circ} 52' 10.451''$ N and $\Lambda_0 = 32^{\circ} 34' 38.430''$ East of Greenwich and $H_0 = 3255$ m. Other local datums included the Balikesir Datum of 1933 for the region south of the Sea of Marmara (Mysia) where: $\Phi_0 \sim 39^{\circ} 37' 37''$ N and $\Lambda_0 \sim 27^{\circ} 57' 37''$ E, and the Söke Datum for the region of southwest Turkey (Caria) where: $\Phi_0 \sim 37^{\circ} 45' 37''$ N and $\Lambda_0 \sim 27^{\circ} 22' 30''$ E. I believe it is likely that all of these old datums were referenced to the Clarke 1880 ellipsoid as modified by General Şevki.

According to a 1981 personal communication I had with Professor I. Kasim Yasar of the Middle East Technical University in Ankara, the parameters of the (1932-1946) Gauss-Krüger Transverse Mercator were: “Latitude of Origin, ϕ_0 = Equator, Longitude of Origin, $\lambda_0 = 27^{\circ} \text{ E} - 45^{\circ}$

E in 3° intervals with Zones for all of Turkey and was used with a scale factor at central meridian $m_0 = 0.99992$ only for cadastral purposes and then abandoned. False Easting at origin = Zone number $\times 10^6 + 500,000$ meters, False Northing at origin = zero, Measurement unit = meter, and Ellipsoid name = International, Madrid 1924. Since 1946 this system was replaced with the identical system in all respects except that the zone width was changed to 6° and $m_0 = 0.9996$ is still in use (*as of 1981 – Ed.*) and the system of projection is Gauss-Krüger for all of Turkey to a map scale 1/25,000. In addition to ... this and only for cadastral maps of scale 1:5000, we employ again the Gauss-Krüger projection system in 3° interval width with the scale factor at the central meridian $m_0 = 1.0000$.”

The U.S. Army Map Service began computing the “Central European Adjustment” in the late 1940s after WWII. The adjustment was carried to Turkey through Greece and Bulgaria, in part using the Czarist Russian Zapiski journals of the 19th century in which the local origin was at the minaret of the main mosque in Kyustendja (now Constanta, Rômania) where: $\Phi_0 = 44^{\circ} 10' 31''$ North, $\Lambda_0 = 28^{\circ} 39' 30.55''$ East of Greenwich. Note that this longitude is a **correction** from that published for Rômania (*PE&RS*, May 2001), thanks to Dr. Momchil Minchev of the Bulgarian Geoinformation Company. “The Central European Adjustment” was later renamed the *European Datum of 1950*. For the remainder of the 20th century, information on the geodetic foundation and the ED50 network in Turkey remained a military secret and its use was denied to all, *including to official civilian government surveyors!* The cadastral agencies were forced to establish their own networks, independent of the National Triangulation and National Leveling networks that were military secrets. In this respect, Turkey was definitely following old European custom.

The times are changing for geodetic Turkey. *Official* transformation parameters for Turkey are now published by the International Association of Geodesy (IAG), the *Bundesamt für Kartographie und Geodäsie* (German Federal Office for Cartography and Geodesy), and Eurographics. Note that the European sign convention for rotations is opposite from the United States (and Australian) standard. Therefore, the U.S. standard sign convention for rotations is listed in the following parameters. In Turkey, for ED50 to ETRS89: $\Delta X = -84.1$ m, $\Delta Y = -101.8$ m, $\Delta Z = -129.7$ m, $R_x = +0.0''$, $R_y = +0.0''$, $R_z = +0.468''$, $\Delta s = +1.05$ ppm. This 7-parameter transformation cannot be truncated to just a 3-parameter translation only, without complete recalculation of the least squares solutions for only 3 parameters. Do not truncate the abovepublished rotation and scale change parameters! The transformation with the above 7 parameters for Turkey is expected to yield positions of about 2 meters accuracy. An example test point published for Turkey on the European Datum 1950: $\phi = 37^{\circ} 08' 35.8''$ N, $\lambda = 28^{\circ} 28' 25.32''$ E, which transforms to ETRS89: $\phi = 37^{\circ} 08' 32.07''$ N, $\lambda = 28^{\circ} 28' 23.79''$ E. The mathematical equations for all the projections and

datum transformations referred to herein are contained in the ASPRS Manual of Photogrammetry, 5th edition, 2004.

UPDATE

The Turkish National Fundamental GPS Network (TNFGN – TUTGA) has been established in 2001 with some stations re-observed due to the 1999 earthquake. There are about 682 stations computed in ITRF 2005.0. The Turkish National Vertical Control Network (TNVCN-99) was established with the adjustment of 243 lines of 25,680 points with a total length of 29,316 km. The current geoid model is TG-09, and the General Command of Mapping is working on a plan for height modernization with a 1-cm Turkish geoid model (2007-2011 Term Report of Turkish National Geodesy Commission, General Command of Mapping, Ankara, 2011). Thanks to Cole Billeaud for research assistance.

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or the Louisiana State University Center for GeoInformatics (C⁴G). This column was previously published in *PE&RS*.

CORRECTIONS

In the August 2016 issue of *PE&RS*, two papers were printed with minor errors.

Future Landsat Data Needs at the Local and State Levels: An AmericaView Perspective

Ramesh Sivanpillai and Russell G. Congalton

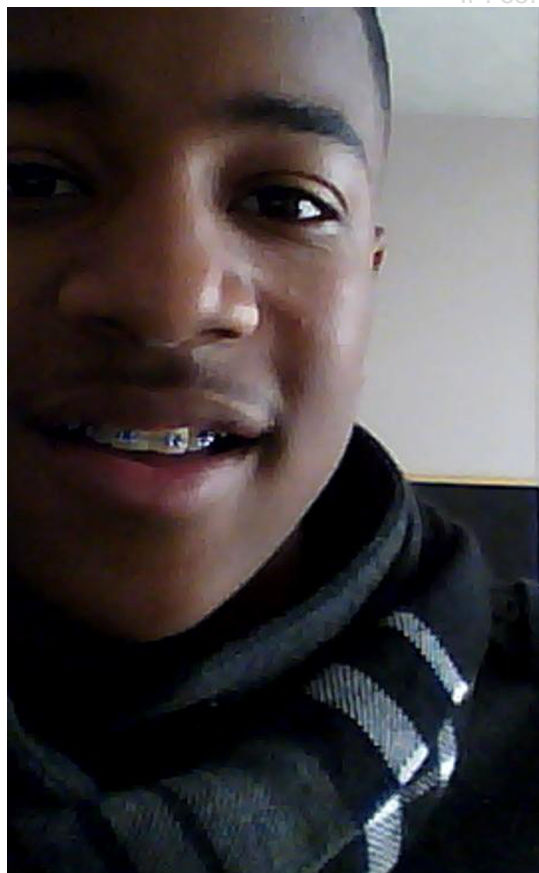
and

Automatic Extraction of Road Networks from GPS Traces

Jia Qiu and Ruisheng Wang

Corrected versions of the articles are available at www.asprs.org.

Delivered by Ingenta
IP: 65.190.59.15 On: Fri, 23 Mar 2018 15:39:45



Too young to drive the car? Perhaps! But not too young to be curious about geospatial sciences.

The ASPRS Foundation was established to advance the understanding and use of spatial data for the betterment of humankind. The Foundation provides grants, scholarships, loans and other forms of aid to individuals or organizations pursuing knowledge of imaging and geospatial information science and technology, and their applications across the scientific, governmental, and commercial sectors.

**Support the Foundation, because when he is ready
so will we.**

asprsfoundation.org/donate

