Italian Republic

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

According to *Lonely Planet*, "The Etruscans were the first people to rule the peninsula, arriving somewhere between the 12th and 8th century BC. They were eventually subsumed within the mighty Roman Empire, leaving little cultural evidence, other than the odd tomb." Thanks to the *CIA Factbook*, "Italy became a nation-state in 1861 when the city-states of the peninsula, along with Sardinia and Sicily, were united under King Victor Emmanuel II. An era of parliamentary government came to a close in the early 1920s when Benito Mussolini established a Fascist dictatorship. His disastrous alliance with Nazi Germany led to Italy's defeat in World War II. A democratic republic replaced the monarchy in 1946 and economic revival followed. Italy was a charter member of NATO and the European Economic Community. It has been at the forefront of European economic and political unification, joining the Economic and Monetary Union in 1999."

Italy has a coastline of 2,700 km that includes the Ligurian Sea, the Tyrrhenian Sea, the Mediterranean Sea, the Ionian Sea, the Adriatic Sea, and the Gulf of Venice. It borders the following countries: Austria (430 km)(*PE&RS,* March 2004), France (488 km)(*PE&RS,* January 2001), Holy See (Vatican City) (3.2 km), San Marino (39 km), Slovenia (232 km)(*PE&RS*, December 1997), and Switzerland (740 km)(*PE&RS,* August 2001).

The Italian map *Grande Carta d'Italia* was created in 1862 by the decision of the parliament of the United Kingdom of Italy. The topographic survey for the new map was cast on the Bonne projection centered on the intersection of the 40°N parallel and the meridian of the Capodimonte Observatory where: Λ_o = 14° 15' 27.91" East of Greenwich. The Istituto Topografico Militare was created in 1862 and renamed Istituto Geografico Militare (IGM) in 1882. In 1875, it was decided to extend the topographic survey from the former Kingdom of Naples to the entire territory of the United Kingdom of Italy. The primary datum origin of the triangulation system around Rome was observed by Prof. Respighi in 1874 at the vertical axis of the round turret of Monte Mario. The geodetic coordinates of the origin are: φ_o = 41° 55' 25.42" N and λ_o = 12° 27' 14.00" East of Greenwich, (actually λ_o = 00° 00' 00" since it was considered the national Prime Meridian), and with an azimuth to Monte Gennaro where: α_o = 62° 38' 20.03". These geodetic coordinates were derived from the astronomic observatory of Capodimonte near Naples. In 1875, the projection of the *Carta d'Italia* was changed to the Polyhedric projection, *Projezione Naturale*. The coordinates of Castello Monte Mario remained unchanged until the adjustment of the European Datum of 1950, even though the station was astronomically observed in 1904-1905 and in 1940. In 1886, the Italian Cadastre was formed, and the projection used to this day for Italian cadastral plans is the Cassini-Soldner. (The mapping equations for the Polyhedric projection and for the Cassini-Soldner projection are in the ASPRS *Manual of Photogrammetry*, 5th edition).

The origin of the Genova Datum of 1874 for Northern and Central Italy was observed where: Φ_o = 44° 25' 08.48" N and Λ_o = 8° 55' 21.08" East of Greenwich and with an azimuth to Monte del Telegrafo where: α_o = 117° 31' 08.86". The origin for Castanea delle Furie Datum for South Italy and Sicily was observed where: Φ_o = 38° 15' 53.380" N and Λ_o = 15° 31' 18.435" East of Greenwich and with an azimuth to Milazzo where: α_o = 271° 09' 16.26". The origin for Guardia Vecchia Datum for Sardinia was observed where: Φ_o = 41° 13' 21.15" N and Λ_o = 9° 23' 59.21" East of Greenwich (–3° 03' 13.29" West of Rome, Monte Mario), and with an azimuth to La Curi where: α_o = 156° 51' 01.34". All of these 19th century Italian datums were referenced to the Bessel 1841 ellipsoid where: a = 6,377,397.15 m, and $1/f$ = 299.1528.

The baselines were measured with the Bessel base apparatus consisting of bimetallic bars of iron and tin as follows: Foggia (1859-1860) 3,939.4206 m ±1/1,319,000; Catania, Sicily (1865) 3,692.1800 m ±1/587,000; Crati (1871) 2,919.5530 m ±1/751,000; Lecce (1872) 3,044.2301 m ±1/836,000; Udine (1874) 3,248.5785 m ±1/1,504,000; Somma (1878) 9,999.5380 m ±1/2,288,000; Ozieri, Sardinia (1879) 3,402.2287 m ±1/1,890,000; Piombino (1895) 4,621.5696 m ±1/945,000.

Considering the shape and topography of Italy, it was decided to cover the entire kingdom with a closed first order net. By adapting to the terrain, the sizes and shapes of the classically observed triangles vary considerably. For instance, the triangles in Liguria, along the French boundary, in Puglia, and in Sicily all have an average side length of 22 km, while the average side length of the triangles in central Italy measure 55 km. The smallest first order side, Monte Trazzonara-Trasconi in the province of Puglia has a length of 12.5 km, and the largest side of Monte Capanna-Punta Maggiore di Monte Nieddu connecting the islands of Elba and Sicily has a length of 232 km. The locations of the baselines enumerated above were selected in such a manner that the connecting chains consisted of 20-25 triangles and did not exceed a length of 400 km.

After 1890, the first order net *Rete Geodetica Italiana Fondamentale*, was revised, partially resurveyed, and destroyed marks were restored. The revision was sufficiently accurate north of the parallel of Rome to warrant an update, and the Genova Datum of 1908 was based on the new coordinates of the origin (pillar on the terrace of the observatory of the Naval Hydrographic Institute) as: φ_o = 44° 25' 08.235" N and λ_o = 8° 55' 15.709" East of Greenwich and with an new azimuth to Monte del Telegrafo where: α_o = 117° 31' 08.91". The Bessel 1841 remained as the ellipsoid of reference. The geodetic coordinates referring to the Genova Datum of 1908 were published in 1919.

To this first order net were attached: the first order net in Venezia Giulia (Littoral) extended from the sides Udine – Monte Kanin and Udine – Aquileia and was observed in 1930-1031. All the first order stations except for Učka (Monte Maggiore) are collocated with the *K. und k. III* Austro-Hungarian Military triangulation. The first order net in Venezia Tridentina (South Tyrol) was observed for the purpose of the boundary survey between Italy and Austria, and was executed in 1921-1923. In 1944-1945, the net was rigorously adjusted to the Genova Datum of 1908. During World War II, the eastern coast of the Adriatic Sea was occupied by the Italian Army, and the Dalmatian chain was established in 1942. This chain of 37 stations represents a first order link between the Udine and Foggia baselines. The Italian first order net was tied in 1876 with the triangulation of Tunis, in

continued on page 890

continued from page 889

1900 with Malta, in 1928 with the triangulation of France with a new connection projected in 1955 and observed in 1957, in 1941 with the triangulation of Greece, in 1951 with Corsica, and in 1953 with the triangulations of Switzerland, Austria, and Yugoslavia.

After WWI, the Austro-Hungarian Empire disintegrated and Italy succeeded in pushing its northeastern frontiers to the watershed separating the Adriatic Basin from the Danubian Basin. In order to assure a more favorable boundary from a military aspect, Italy annexed parts of the former Austrian provinces of Tyrol, Carinthia, Carniola, Dalmatia, and the entire Littoral province including the cities of Trieste and Fiume (Rijeka). The classical geodetic network of Italy has merged with the cadastre. The cadastre is comprised of two basic types, the Tyrol and the Trentino, and the major part of the cadastre corresponding to the remainder of Italy, The cadastral plans have traditionally been cast on the Cassini-Soldner projection as mentioned earlier, but they have been essentially locally-referenced to church spires or other prominent features. The result has been a system of local Cassini-Soldner coordinate systems that total 849 origins! Recent work in the cadastral offices has been to compute transformations of the local systems into the national triangulation network established by the IGM.

Prof. Boaga recast Gauss' original equations for the Transverse Mercator into a truncated series specifically for the Italian Peninsula, and he computed tables in 1945. The grid system is based on the datum recomputed for Italy during WWII, named Roma 1940 Datum. The datum origin is at the original castle at Monte Mario, where: Φ_o = 41° 55' 25.51" N ±0.027" and Λ_o = 00° 00' 00" = 12° 27' 08.40" East of Greenwich, and with an azimuth to Monte Soratte where: α_o = 06° 35' 00.88" ±0.12". The ellipsoid of reference is the Hayford 1909 (International 1924) where a = 6,377,388 m and $1/f$ = 297. The Italian Geodetic Commission determined the new coordinates of Monte Mario in 1940, and adopted the International ellipsoid in 1942. The Gauss-Boaga Transverse Mercator (mapping equations are published in the ASPRS *Manual of Photogrammetry*, 5th edition), is comprised of two zones: West Zone (I) from 6° to 12° 27' 08.40" East of Greenwich (meridian of Monte Mario), and East Zone (II) from 11° 57' 08.40" (meridian 30' West of Monte Mario) to 18° 30' East of Greenwich. An overlapping zone of 30' is limited by the meridians of 11° 57' 08.40" and 12° 27' 08.40" East of Greenwich to coincide with the column of the 1:100,000 scale sheets of the *Carta d' Italia* confined between the –0° 30' and 0° 00' (Monte Mario) meridians. The scale factor at origin (m_o) = 0.9996, the False Easting for Zone I (West) = 1,500,000 m and for Zone II (East) = 2,520,000 m.

After WWII, the U.S. Army Map Service established the European Datum of 1950 (ED50) and recomputed all classical triangulation of Europe, North Africa, Asia Minor, and the Middle East. Subsequent military mapping of the affected countries has been on ED50, referenced to the International ellipsoid. Civilian surveying and mapping has usually been retained on local native datums until recent decades since the advent of the GPS satellites. According to *the historical document and apparently no longer supported DMA Technical Report 8350.2,* the transformation parameters from ED50 to WGS84 for Sardinia are: Δa = –251 m, $\Delta f \times 10^4$ = –0.14192702, ΔX = –97 m ±25 m, ΔY = –103 m ±25 m, ΔZ = –120 m ±25 m, and this is based on a solution of 2 points published in 1991. Furthermore, from ED50 to WGS84 for Sicily: ΔX = –97 m ±20 m, ΔY = –88 m ±20 m, ΔZ = –135 m ±20 m, and this is based on a solution of 3 points published in 1991. *Note that these values are no longer authorized for official United States Department of Defense use.* (It's about time!) According to the European Petroleum Studies Group (EPSG), peninsular Italy transformation parameters from Rome40 to WGS84 are: ΔX = –225 m, ΔY = –65 m, ΔZ = +9 m. Note that no accuracy estimates are given, nor are the number of points used in a solution given. Therefore, the user should exercise caution in implementing these values.

On the other hand, *official* transformation parameters for Italy 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 Sardinia, for Rome 1940 to ETRS89: ΔX = –168.6 m, ΔY = –34.0 m, ΔZ = +38.7 m, R_x = +0.374", R_y = +0.679", R_z = +1.379", Δs = –9.48 ppm. In Sicily, for Rome 1940 to ETRS89: ΔX = –50.2 m, ΔY = –50.4 m, ΔZ = +84.8 m, R_x = +0.690", R_y = +2.012", R_z = –0.459", Δs = –28.08 ppm. In Peninsular Italy, for Rome 1940 to ETRS89: ΔX = –104.1 m, ΔY = –49.1 m, ΔZ = –9.9 m, R_x = –0.971", R_y = +2.917", R_z = –0.714", Δs = –11.68 ppm. These 7-parameter transformations cannot be truncated to just three-parameter translations only, without complete recalculation of the least squares solutions for only three parameters. Do not truncate the above-published rotation and scale change parameters. The transformations with the above seven parameters for the different regions of Italy are expected to yield positions of about 3 to 4 meters accuracy. An example test point published for Peninsular Italy is for Rome 1940: φ = 40° 26' 12.48" N, λ = 17° 49' 32.52" E transforms to ETRS89: φ = 40° 26' 14.80" N, λ = 17° 49' 32.58" E. Andrew Glusic of the U.S. Army Map Service originally published most of the historical details contained herein in an internal document in 1959.

Cliff Mugnier teaches Surveying, Geodesy, and Photogrammetry at Louisiana State University. He is the Chief of Geodesy at LSU's Center for GeoInformatics (Dept. of Civil and Environmental Engineering), and his geodetic research is mainly in the subsidence of Louisiana and in Grids and Datums of the world. He is a Board-certified Photogrammetrist and Mapping Scientist (GIS/LIS), and he has extensive experience in the practice of Forensic Photogrammetry.