THE SYRIAN ARAB REPUBLIC

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Syria is an ancient country of Asia that once included modern Syria, Lebanon, Israel, and Jordan. There is evidence of human habitation for several thousand years from the mid-third millennium B.C. At different times, the area was under the control of Sumerians, Akkadians, Amorites, Egyptians, Assyrians, and Babylonians. Once part of the Persian Empire, Alexander the Great conquered the region in the fourth century B.C., and it later flourished under the Roman Empire. Syria was overrun by Muslim Arabs in 635-636 A.D., and was ruled by the Ottoman Turks during the Crusades. During the first Crusade, the French established a presence in Antioch, and Godfrey of Bouillon decreed that a Barony be established there. After the Crusades, the Ottoman Turks resumed control for centuries until the British and French invaded during World War I because Turkey was an ally of Germany. Syria saw the end of Turkish rule in 1918. Part of the area (modern Lebanon and Syria) was mandated as a Protectorate by the French following World War I, and the region was called the French *Levant* (Eastern Mediterranean). French troops finally left in 1946 when Syria became independent.

Syria is bounded on the north by Turkey, on the east by Iraq, on the southeast by Jordan, on the southwest by Israel and Jordan, and on the west by Lebanon and the Mediterranean Sea. The chief cities are Aleppo, Damascus, and Homs, all aligned more or less in a meridional arc on the western side of the country. The northeast region of the country has one city of geodetic significance: Hassetché (French) or Al Hasakah. Syria is slightly larger than North Dakota; with its lowest point near Lake Tiberias (200 meters below sea level) and its highest point at Mount Hermon (2,814 m).

In 1799, Napoleon Bonaparte commenced his military campaign for the conquest of Egypt and "Upper Egypt" (the Palestine and Greater Syria). *La Carte d'Egypte et de Syrie* was published by the Dépôt de la Guerre beginning in 1808. The five-sheet map series consisted of 47 *feuilles* (foils or manuscripts), one of which included Acre, Nazareth, Jordan, and the southern tip of present Syria. The ersatz Datum was based on astronomical observations in Cairo and Jerusalem, and was referenced to the Plessis ellipsoid where the semi-major axis a = 6,375,738.7 m and the reciprocal of flattening $1/f$ = 334.29. Much of the coast was actually based on published British Admiralty charts of the time (see The State of Israel, *PE&RS*, August, 2000). The projection was the ellipsoidal Bonne, the "standard" for France and most of Europe at the time. "*Le centre de la projection correspond à l'axe de la grande pyramide du Nord, à Memphis.*" (The center of the projection corresponds to the axis of the great pyramid of the north at Memphis).

In 1918, the French Service Géographique de l'Armée (SGA) was already compiling topographic features with planetable and alidade in Homs, Damascus, Sanameîn, and Haïfa. The geodetic network was calculated on the Clarke 1880 (IGN) ellipsoid where a = 6,378,249.2 m and $1/f$ = 293.4660208, and according to the SGA, the datum origin was at the south end of the Base of Makri Keuî, near Constantinople (Istanbul). The early maps of Turkey were on the Bonne projection, but the projection origin was the finial of the dome of the Aya Sofia Mosque. The Ottoman Turkish (ellipsoidal) Bonne of Syria (1909-1923) projection latitude of origin φ_o = 28° 58' 50.8188" N and the central meridian λ_o = 39° 36' East of Greenwich.

In Old Turkish, "*The Section and Arrangements Table was printed by the National Mapping Office* (of Turkey) *in the Year 1333 of the Moslem Calendar…the calculations were made because of the new lands that have been added. The shape and descriptions were based on Clarke 1880 measurements where the flattening was 1/293.46 and the half axis = 6,378,249.2 meters.*" The angular unit of measurement was the grad (one four-hundredth of a circle, or 0.9 degees), and the scale of the map was 1:200,000. False Northing and False Easting were equated to zero, as was the standard practice of the time in Europe.

The French established the Bureau Topographique du Levant in 1918, and after 1920 the chain of triangulation was extended eastward along the northern border with Turkey to Iraq. Planimetric compilation was aided by aerial photography flown by a French military aviation squadron of the 39th Regiment. The Topographic Brigade was commanded by Lieutenant Colonel G. Perrier, who organized the observations for the establishment of an astronomical origin for a datum in the Bekaa Valley of Lebanon that would serve Syria as well. The baseline was measured, and the South End of the Base at Bekaa was the fundamental origin for the as-

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tronomical observations. The latitude of the pillar was observed by Captain Volontat in 1920 with a prismatic astrolabe where Φ_o = 33° 45' 34.1548" N. An azimuth was obtained at the same pillar with a microscopic theodolite by Captain Volontat, by observing Polaris at elongation. The direction was defined to a pillar constructed at the Ksara Observatory where: α_o = 28° 58' 50.8188". Longitude was also observed by the good Captain at the same observatory where Λ_o = 35° 53' 25.26" East of Greenwich. (The longitude was then geodetically transferred to the South End of the Bekaa Base.)

In November of 1997, Colonel George Massaad, then the director of Geographic Affairs of the Lebanese Army, sent me a photograph of the fundamental point at Bekaa South Base. The point is monumented by a stone pyramid that is over 2 m high, is approximately 2 m square, has an (apparently) bronze tablet describing the significance of the monument, is straddled by a great iron skeleton target obviously over 4 meters high, and the entire structure is enclosed by a formal iron fence! The monument recalls the aviation accident that took the lives of Captains Govin and Renaud of the Geodetic Section of the Service Géographique de l'Armée on 15 July 1924 at Muslimié, near Aleppo. Shortly after World War II, the U.S. Army Map Service computed the coordinates of the origin of the Syrian geodetic system (Bekaa) on the New Egyptian Geodetic Datum as φ = 35° 45' 34.2205" N and λ = 35° 54' 36.4962" E. The geodetic coordinates of station Ksara are φ = 33° 49' 25.58" N and λ = 35° 53' 25.26" E. The Bekaa Valley Datum of 1920 is referenced to the Clarke 1880 (IGN) ellipsoid as previously defined.

A check baseline was measured at Bab, and another astronomical position was observed (Laplace Station) where Φ_o = 36° 13' 48.77" N, Λ_o = 37° 30' 30.195" East of Greenwich, and the reference azimuth from Bab to Cheikh Akil signal is α_o = 179° 58' 33.152".

The principal major classical triangulations of Syria are the Aleppo Meridian Chain and the Coastal Series (SGA) 1920-1929, the Djerablous-Mennbidgi Series (SGA) 1930, the Euphrates and Turkish Frontier Primary Series (SGA) 1934-1937, the Hassetché Series (SGA) 1932-1933, the Iraq Petroleum Company Frontier Series (IPC/Syrian Petroleum Company), the Cadastral Central Series (Bureau Cadastre) 1931, the (IPC/SPC) 1934-1941, and the Cadastral Abou Kemal Series.

The Aleppo Chain was the backbone of the triangulation. The scale of the triangulation was governed by the two bases (Bekaa and Bab) which had an internal precision of one part in two million. The other primary work is connected by one or more connecting arcs. This series was based on the measurement of two bases (Bekaa and Bab) with invar wires with an internal accuracy of about 1/25,000. But, in the case of the initial azimuth of the Bekaa Base, a large number of observations were made in order to determine the mean azimuth. The maximum range of the observations was 48" which does not represent good geodetic accuracy. Then a check azimuth, latitude, and longitude were measured at the Bab Base at Aleppo, and the differences from the geodetic values carried through the chain from Bekaa are as follows (Astronomic - Geodetic): $\Delta\varphi$ = –6.318", $\Delta\lambda$ = +10.789", and $\Delta\alpha$ = +21.125". Thus, the S.G.A. decided not to apply a Laplace correction to the azimuths, assuming that the 21" was due to an error at the origin and not over the network. The 21" error was verified by the U.S. Army Map Service by the computation of an azimuth between two stations in the area from utilizing the geographics of the station in terms of the European Datum Mediterranean Loop and the Bekaa Valley Datum geographics. The triangulation was computed on the Clarke 1880 ellipsoid, Levant Zone Grid, Lambert Conical Orthomorphic projection. The Levant Lambert Zone (1920) is based on the French Army Truncated Cubic formulae where the developed meridional arc is expressed in series form and is truncated at terms higher than the cubic. Furthermore, another idiosyncrasy of the French Army formulae is that the Lambert (fully) Conformal Conic utilizes one of the principal radii of the ellipsoid called the Radius of Curvature in the Plane of the Meridian (ρ). The French Army instead substitutes the Length of the Ellipsoid Normal Terminated by the Semi-Minor Axis (υ). Although not strictly conformal, this is the system that was commonly used by the French in all colonies (before World War II) that utilized the Lambert Conic projection. Failure to adhere strictly to the truncation (and above substitutions) will yield coordinates that, although maybe strictly conformal, will differ from published (correct) coordinates in excess of ten meters! The Levant Lambert Zone, also known as the Syrian North Lambert Zone, has a latitude of origin φ_o = 34° 39' N and a central meridian λ_o = 37° 21' East of Greenwich. The Scale Factor at Origin (m_o) = 0.9996256 (secant conic) and the False Easting and False Northing = 300 km.

The Syrian South Lambert Zone (1920) has a latitude of origin φ_o = 33° 18' N and a central meridian λ_o = 36° 00' East of Greenwich. The Scale Factor at Origin m_o = 0.999625769 (secant conic), the False Easting = 500 km, and the False Northing = 300 km.

In 1922, the *Travaux du Cadastre et d'Amelioration Agricole des Etats, de Syrie, des Alaouites et du*

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Liban sous Mandat Francais established the SCHEMA DE LA PROJECTION STÉRÉOGRAPHIQUE which was based on the Roussilhe Oblique Stereographic projection. The latitude of origin φ_o = 34° 12' N, the central meridian λ_o = 39° 09' East of Greenwich, the Scale Factor at Origin m_o = 0.9995341 (secant plane), and the False Easting and False Northing = zero. This Grid has caused some consternation in the literature because attempts to substitute the fully conformal formulae of Paul D. Thomas' "Conformal Projections" fail to yield correct transformation results. In fact, the Roussilhe formulae were developed by the Hydrographer of the French Navy in the late 19th century, and this was a common grid used on many hydrographic surveys by the French well into the 20th century. Other variations of the Oblique Stereographic projection include the "Stereographic Double" projection used by Canada (*PE&RS*, December, 1997), and the Hristow "Stereo 70" used by Romania (*PE&RS*, May, 2001). Commercial software packages seem to universally ignore the different stereographic formulae (and others) that are legally defined in several countries around the world, with the exception of my own academic stuff and that written by Roger Lott of British Petroleum, Inc. for the European Petroleum Studies Group (EPSG). For example, using a test point, φ = 37° 00' 00" N, λ = 42° 09' 00" E, X = 267,078.434 m, Y = 314,642.621 m, m = 1.0005837, and γ = +1° 44' 49.8".

The only Syrian fundamental point is at Hassetché, where Φ_o = 36° 36' 23.100" N, Λ_o = 40° 46' 20.550" East of Greenwich, and the reference azimuth from to Tell Amaa is α_o = 172° 44' 59.4" from south, Clarke 1880 ellipsoid. All triangulation coordinates on this northeastern Syrian Datum have since been converted to the Bekaa Valley Datum of 1920. The Hassetché Series is the basic series for the triangulation in the eastern half of Syria. When the astronomical observations at the Hassetché Datum point (the South Terminal of the Hassetché Base) are compared to the geodetic value for this point based on the Bekaa Valley Datum, the differences (Astronomic - Geodetic) are as follows: $\Delta\varphi$ = –3.956", $\Delta\lambda$ = +10.508", and $\Delta\alpha$ = +20.940". The Hassetché triangulation was computed on the Syrian Oblique Stereographic Grid (1922).

Since 1989, the Syrians have used a new four-zone grid based on the Gauss-Krüger Transverse Mercator projection, being referenced to the European Datum of 1950 which uses the International 1924 ellipsoid where a = 6,378,388 m and $1/f$ = 297; the Latitude of Origin by definition is the Equator, the False Easting of each zone is 200 km, the False Northing is zero at the Equator, the Scale Factor at Origin is 0.99974996, and the Central Meridians of the four zones are as follows: Tretya = 31° 30'E, Sortya = 34° 30'E, Patya = 37° 30'E, and Sestya = 40° 30'E.

The latest available transformation parameters from the Bekaa Valley Datum of 1920 in Syria to the WGS84 Datum are ΔX = –182.966 m, ΔY = –14.745 m, and ΔZ = +272.936 m. The mean planimetric error for these parameters is 5 meters. Example test point: Bekaa Datum Origin φ = 33° 45' 34.1548" N, λ = 35° 54' 37.1188" E, and H = 870.513 m. WGS84 Datum coordinates of the same point: φ = 33° 45' 33.8602" N, λ = 35° 54' 40.6802" E, and h = 868.64 m. Thanks go to John W. Hager for his assistance, and to others.