Grids & Datums

Kingdom of Denmark

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

According to *Webster's New Geographical Dictionary*, Danes, a Scandinavian branch of Teutons *circa* 6th century A.D, settled the area. Denmark participated in raids on England, France, and the Low Countries in the 8th to 10th centuries. The Danes converted to Christianity in the 10th and 11th centuries, and the United Danish kingdom included Schleswig, Southern Sweden, England, and intermittently Norway. "During the Napoleonic Wars Britain attacked Copenhagen twice, inflicting heavy damage on the Danish fleet in 1801 and leaving much of Copenhagen ablaze in 1807. The Swedes then took advantage of a weakened Denmark, successfully demanding that Denmark cede Norway to them. The 19th century might have started off lean, dismal and dominated by a small Frenchman with a big ego, but by the 1830s Denmark had awakened to a cultural revolution in the arts, philosophy and literature. A democratic movement in Denmark led to the adoption of a constitution on 5 June 1849, which in turn led to the formation of a Danish constitutional monarchy. Germany took control of Schleswig in southern Jutland, after its inhabitants, people of both Danish and German heritage, revolted against the new constitution," thanks to *Lonely Planet*.

Denmark is located in northern Europe, bordering the Baltic Sea and the North Sea, on a peninsula (Jutland) that is north of Germany (68 km), as well as a number of islands that include Sjælland, Fyn, Falster, Lolland, Langeland, and Bornholm. Also part of Denmark are self-governing Greenland and the Færoe Islands. The kingdom is slightly less than twice the size of Massachusetts, the lowest point is Lammerfjord (-7m) and the highest is Ejer Bavenjoj (173m). The coastline is 7,314 km, and the kingdom controls the Danish Straits (Skagerrak and Kattegat), linking the Baltic and North Seas.

The first triangulation and planetable mapping (*Målebordsblade*), of Denmark was performed by the Royal Danish Society of Sciences and Letters (*Videnskabernes Selskab*), from 1762 to 1821. The *Målebordsblade* of the Færoe Islands was performed from 1791 to 1795 and for many years was the basis of hydrographic charts of the surrounding waters. The General Staff was established in 1808, and the Quartermaster General started a new *Målebordsblade* in 1809 at a scale of 1:20,000 for a planned final compilation scale of 1:60,000. In 1830 this plan changed the scale to 1:80,000. From 1842 to 1887 the country was plane-tabled at a scale of 1:20,000 and final sheets were published at that same scale beginning in 1864. A second survey of the country was started in 1887, but coverage was only partial. Based on the old existing *Målebordsblade* of the Færoe Islands, the waters surrounding the islands were hydrographically surveyed from 1899 to 1903 and in 1908. From 1924 to 1937 that part of Slesvig that was returned to Denmark was surveyed. The Geodætisk Institut was established in 1928 by merging the Danish Geodetic Survey (*Den Danske Gradmåling*) and the Topographic Division of the General Staff (*Generalstabens Topografiske Afdeling*), and was responsible for the topographic mapping of the kingdom. In the early 1950s the final publication scales were changed from 1:20,000 and 1:40,000 to 1:25,000 and 1:50,000. The third topographic mapping of Denmark was commenced in 1965 with modern photogrammetric techniques. On 08 September 1987, the Danish Cadastral Department (*Matrikeldirektoratet*), the Hydrographic Department (*Søkortarkivet*), and the Geodætisk Institut were transferred to the Ministry of Housing and renamed Kort- og Matrikelstyrelsen (KMS).

"Now the kicker, y-axis positive north and x-axis positive west. The origin of the sheet lines goes back to an older series (Målebordsblade - First edition, Første Udgave 1901 – Ed.) that was 1 mil north-south by 5/6 mil east-west."

Twenty years ago, John W. Hager, now retired of Army Map Service, later DMA/NIMA/NGA, answered my question regarding the coordinates of the datum origin point for the Old Danish Datum of 1878 at station *283 Agri Bavenhöe* where: Φ_o = 56° 13' 48.217"N, Λ_o = 2° 02' 22.629" West of Copenhagen or Λ_o = 10° 32' 17.271" East of Greenwich. The azimuth of reference was from *No. 283 Agri Bavenhöe* to station *No. 282 Lysnet* where α_o = 294° 31' 14.17", clockwise from North. His reference was from the German Army's *Planheft Dänemark – Planheft Übersichten der Kartengitter Europa, Nordafrika und Vorderasien (Berlin –1942)*.

From that same reference, the earlier Danish triangulation 1817-1870 was reported to have the basic reference at the "Nicolai Tower" or Round Tower (*Runde Tårn*) of the Old Copenhagen Observatory where: Λ_o = 12° 34' 40.35" East of Greenwich. That "basic reference" is likely what the ephemeris was based on with regard to transits of the local meridian at the old observatory's meridian circle. The ellipsoid of reference was the Danish (Andræ) ellipsoid where a = 6,377,104.43 m, and $1/f$ = 300. The later triangulation of 1926-1933 was referenced to the Hayford 1924 (International) ellipsoid where a = 6,377,388 m, and $1/f$ = 297.

continued on page 1210

continued from page 1209

The datum origin point was actually at station *Punkt Nicolai* where: Φ_o = 55° 40' 42.937" N, Λ_o = – 0° 00' 19.908" West of Old Copenhagen Observatory and the azimuth of reference was from *Punkt Nicolai to Store Møllehöi*, α_o = 14° 15' 25.18" clockwise from South, and the baseline was at *Amager 1838* with a length of 2701.0732m, ±4.5mm. Later determinations of the length of this baseline were Amager 1911: 2701.1242m, ±1.4mm and Amager 1934: 2701.137m, ±2mm. Note that both of these last two measurements were performed with invar apparatus. With today's GPS technology as a basis of comparison, it's rather humbling to read what they used to accomplish (*in the old days*), with such simple tools and profound determination and perseverance. A recent note from Hager states, "In the 1817-1870 time frame, longitude may have been measured positive to the west. This does make some sense where Copenhagen is the prime meridian then most of the country, Bornholm excluded, would have positive longitudes."

An object of my curiosity for decades regarding Danish enigmas (hopefully all solved herein), was the references to the "Buchwald Projection," mentioned in the *Planheft* as well as other equally obscure sources, as far as the English language is concerned. During the 1990s, I used to lecture at the Stennis Space Center in southern Mississippi when I was still a member of the Faculty of Civil Engineering at the University of New Orleans. My students were comprised mostly of employees of U.S. Naval Oceanographic Office (NAVO) and the Naval Research Laboratory (NRL). I spent a lot of time rummaging through the Maury Oceanographic Library, which is part of NAVO next door to the local branch of the NRL. I found the1924, Number 1 issue of "*Bulletin géodésique*" that contained an obituary for Frants Andreas BUCHWALDT (1874-1923), pages 104-106. Apparently, Captain Buchwaldt of the Danish Navy was as revered a scientist as Captain Maury was of the U.S. Navy. The Danish System of 1934 that used the Buchwaldt projection for Denmark was a Lambert Conformal (tangent) Conic projection where: ϕ_o = 56° 13' 48.217" N, λ_o = 10° 32' 17.271" East of Greenwich, the scale factor at origin by definition, (m_o) = 1.0, and False Easting = False Northing = 200 km.

Thanks to an undated manuscript (circa 1950s) by the late Jacob A. Wolkeau of Army Map Service (AMS), a Circular dated 31 May 1935 was issued by the Minister of the Interior for the German Reich and Prussia, entitled *Amalgamation of Land Survey Offices*. "The circular implements the technical proposals of the 1921 Survey Committee in regard to the unification of the triangulation and altametric system of the several states and the adoption of the Prussian Geographical Coordinate system and datum throughout the Reich. … The progress so far achieved is confined in the main to North Germany … while in Mark Silesia the main triangulation has been completed and connection affected with the new Danish Triangulation." An analysis of the observations of classical triangulation in Europe later published by AMS included the "System 34" of Denmark that was observed from 1926-1933. Of the 64 triangles in the adjustment of observations with Hildebrand theodolites, the average error of figure closure was 0.43", and the maximum error was 1.823".

A Danish Military Tangent Lambert projection was known to exist from 1926 - ? (unknown), and was referenced to the Danish (Andræ) ellipsoid. The Latitude of Origin, ϕ_o = 55° N, the Central Meridian, λ_o = 10° 22' 40.35" East of Greenwich, the Scale Factor at Origin by definition, (m_o) = 1.0, and False Easting = False Northing = zero. A "British Grid" that covered Denmark was the *Northern European Zone III (1925-1948)*. It was also a Lambert Conformal Conic projection; but was used in the secant case such that: the Latitude of Origin. ϕ_o = 57° 30' N, the Central Meridian, λ_o = 20° East of Greenwich, the Scale Factor at Origin, (mo) = 0.99904, False Easting = 900,000 m, and False Northing = 543,365.71m. The ellipsoid of reference for this ersatz datum was the Bessel 1841 where: a = 6,377,397.155 m, and $1/f$ = 299.1528.

In January of 1988, I received a note from Hager regarding the Færöes: "Enigma for 1987. A 1:20,000 scale series of maps for the Faeroes (*Second edition, Anden Udgave 1941 – Ed.*) – no grid, no graticule. How do you position them? Finally found a book in Danish that gave the clues. Sheet size is $^5/_4$ mil west to east by 1 mil south to north. Is mil in Danish the same as mil in English? Book also says 9.42 km. by 7.53 km., so a mil is a mil. Datum point is Tørshavn, Φ_o = 62° 00' 49.1" North, Λ_o = – 06° 45' 22.5" West of Greenwich. Lambert Conformal Conic projection, Latitude of Origin, ϕ_o = 62° North, Longitude is 3 minutes west of the datum, or λ_o = – 06° 48' 22.5" West of Greenwich, False Northing and False Easting each equal to zero, Scale Factor, (m_o) = 1. Now the kicker, y-axis positive north and x-axis positive west. The origin of the sheet lines goes back to an older series (*Målebordsblade - First edition, Første Udgave 1901 – Ed.*) that was 1 mil north-south by $^5/_6$ mil east-west. The grid for the sheet lines thus starts at 0 meters north and –3,140 meters in easting. All this on the Danish ellipsoid, a = 6,377,104.43 m, and $1/f$ = 300." (Note that the Tørshavn Datum has a date associated with an astronomical observation in 1896.)

In May 1998, Anna B.O. Jensen and Finn Bo Madsen published *A New Three Dimensional Reference Network in Denmark*. The new system is called REFerencenet DanmarK or REFDK, and is based on 94 stations that include the larger islands. The transformation parameters, modified to the standard rotations used in the United States, from European Datum 1950 to REFDK are: ΔX = –81.070 m, ΔY = –89.360 m, ΔZ = –115.753 m, Rx = +0.48488", Ry = +0.02436", Rz = +0.41321", and Δs = 1.0 –0.540645 $\times 10^{-6}$. The average error of transformation is estimated at ±20 cm. A test point provided by the Bundesamt für Kartographie und Geodäsie is as follows: **FROM** Denmark ED50: ϕ = 56° 51' 00.0" North, Λ_o = +08° 26' 24.72" East **TO** ETRS89 (REFDK): ϕ = 56° 50' 57.82" North, Λ_o = +08° 26' 19.88" East.

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.