

UNITED KINGDOM

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

“OS was founded in 1791 by the Master General of Ordnance [equivalent to the Minister of Defense today], Charles Lennox, Duke of Richmond. His Grace had been an outspoken supporter of the American colonists in the House of Lords. In December 1775 he declared that the resistance of the colonists was “neither treason nor rebellion, but it is perfectly justifiable in every possible political and moral sense.” Yet less than 10 years later he was a government minister – I think anywhere else in Europe he would have been executed or exiled! He was succeeded as Master General by Lord Cornwallis, who didn’t appear to have suffered any long-term political damage by that unfortunate incident at Yorktown. An early Director General of OS, William Mudge, had served on Cornwallis’s staff in the southern colonies.”

— Russell Fox, Ordnance Survey

The United Kingdom includes England, Scotland, Wales, and Northern Ireland. The latter was included in a previous column on the entire island of Ireland (*PE&RS*, March 1999). Evidence from pre-Roman times includes Neolithic mound-tombs and henge monuments as well as Bronze Age Beaker culture tools, graves, and the famous Stonehenge monument. Brythonic-speaking Celtic peoples arrived during migrations of the first millennium B.C., according to *Webster’s Geographical Dictionary*. England has existed as a unified entity since the 10th century. The union between England and Wales was begun in 1284 and formalized in 1536. En-

gland and Scotland agreed to join as Great Britain in 1707 and with Ireland in 1801. The present name of Great Britain and Northern Ireland was adopted in 1927. The area of Great Britain is slightly smaller than Oregon; the kingdom has a 12,429 km coastline and the lowest point is Fenland (-4 m), the highest point is Ben Nevis (1,343 m). Great Britain is only 35 km from France and is linked by the “Chunnel.” Because of the heavily indented coastline, no location in the country is more than 125 km from tidal waters!

Thanks to the web site of the Ordnance Survey, “England was squeezed between rebellion in Scotland and war with France when King George II commissioned a military survey of the Scottish highlands in 1746. The job fell to William Roy, a far-sighted young engineer who understood the strategic importance of accurate maps. Walk into Ordnance Survey’s Southampton headquarters and you’ll see Roy’s name engraved on the curved glass entrance doors, yet his vision of a national military survey wasn’t implemented until after his death in 1790. By then Europe was in turmoil, and there were real fears that the French Revolution might sweep across the English Channel. Realizing the danger, the government ordered its defense ministry – the Board of Ordnance – to begin a survey of England’s vulnerable southern coasts. In June 1791, the Board purchased a huge new Ramsden theodolite, and surveyors began mapping southern Britain from a baseline that Roy himself had measured several years earlier.

“The first one-inch map of Kent was published in 1801, and a similar map of Essex followed – just as Nelson’s victory at Trafalgar made invasion less likely! Within twenty years about a third of England and Wales had been mapped at the one-inch scale. If that seems slow in these days of aerial surveys and global positioning, spare a thought for Major Thomas Colby – later Ordnance Survey’s longest serving Director General – who walked 586 miles in 22 days on a recon-

naissance in 1819. In 1824, Parliament ordered Colby and most of his staff to Ireland, to produce a detailed six-inch to the mile valuation survey. Colby designed specialist measuring equipment, established systematic collection of place names, and reorganized the map-making process to produce clear, accurate plans. But Colby the perfectionist also traveled with his men, helped to build camps, and arranged mountaintop feasts with huge plum puddings at the end of each surveying season.

“Soon after the first Irish maps began to appear in the mid-1830s, the demands of the Tithe Commutation Act provoked calls for similar six-inch surveys in England and Wales. The government prevaricated but, by then, there was a new power in the land. This was the era of railway mania and if the one-inch map was unsuitable for calculating tithes, it was virtually useless for the new breed of railway engineers. To make matters worse, mapping of England and Scotland remained incomplete and, in 1840, the Treasury agreed that the remaining areas should be surveyed at the six-inch scale. Now, surveyors needed greater access than ever be-

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fore; and so, in 1841, the Ordnance Survey Act gave them a legal right to ‘enter into and upon any land’ for survey purposes. A few months later Ordnance Survey’s cramped Tower of London offices were at the centre of a national catastrophe when fire swept through the Grand Storehouse, threatening to engulf the Crown Jewels in the Martin Tower. Miraculously, the Jewels were saved, and most of Ordnance Survey’s records and instruments were also carried to safety. But the blaze highlighted the Survey’s desperate need for more office space, and prompted a move to Southampton.

“The scene was now set for two decades

of wrangling over scales. Throughout this period, Victorian reforming zeal was creating an acute need for accurate mapping. The issue was settled piecemeal until, by 1863, scales of six inches and twenty-five inches to the mile had been approved for mountain and moorland, and rural areas respectively. The one-inch map was retained, and detailed plans at as much as ten feet to the mile were introduced for built-up areas.

“By now, Major-General Sir Henry James – perhaps Ordnance Survey’s most eccentric and egotistical Director General – was midway through his twenty-one year term. James quickly saw how maps could be cheaply and quickly enlarged or reduced using the new science of photography, and he designed an elaborate glass studio at Southampton for processing photographic plates. James planted his name on everything he touched, and later claimed to have invented photo zincography, a photographic method of producing printing plates. In fact, the process had been developed by two of his staff. By 1895 the twenty-five inch survey was complete.

“The twentieth century brought cyclists and motorists swarming onto the roads, and the new Director General, Colonel Charles Close, prepared to exploit this expanding leisure market. But by now, the tide of history was sweeping Ordnance Survey back to its roots. As Britain entered the First World War, surveyors, draughtsmen and printers from Ordnance Survey were posted overseas. Working in appalling conditions alongside the troops, surveyors plotted the lines of trenches and, for the first time, aerial photography was used to capture survey information.

“After the war, Sir Charles, as he now was, returned to his marketing strategy and appointed a professional artist to produce eye-catching covers for the one-inch maps. Ellis Martin’s classic designs boosted sales to record levels, but the war had taken its toll; behind their bright new covers, the maps were increasingly out of date. In an uncanny echo of the mid-nineteenth century, a whole raft of new legislation brought demands for accurate, up-to-date mapping.

“Matters came to a head in 1935, and the Davidson Committee was established to review Ordnance Survey’s future. That same year, a far-sighted new Director General, Major-General Malcolm MacLeod, launched the retriangulation of Great Britain. Surveyors began an Olympian task, building the

now familiar concrete triangulation pillars on remote hilltops throughout Britain. Deep foundations were dug by hand, and staff dragged heavy loads of materials over isolated terrain by lorry, packhorse and sheer brute force. The Davidson Committee’s final report set Ordnance Survey on course for the 21st century. The National Grid reference system was introduced, using the metre as its measurement. An experimental new 1:25,000 scale map was launched, leaving only the one-inch unscathed. It was almost forty years before this popular map was superseded by the 1:50,000 scale series, first proposed by William Roy more than two centuries earlier.

“In 1939, war intervened once again. The Royal Artillery was now responsible for its own field surveys, but over a third of Ordnance Survey’s civilian staff were called up, and its printing presses were kept busy with war production. It wasn’t a soft option. Enemy bombing devastated Southampton in November 1940 and destroyed most of Ordnance Survey’s city centre offices. Staff were dispersed to other buildings, and to temporary accommodation at Chessington. But the military appetite remained insatiable – the Normandy landings alone devoured 120 million maps!

“After the war, Ordnance Survey returned to Davidson’s agenda; the retriangulation was completed, and metric maps began to appear along National Grid sheet lines. Aerial survey helped speed up the new continuous revision strategy, and up-to-date drawing and printing techniques were introduced. But the organization was still fragmented, scattered across southern England in a battered collection of worn-out buildings. All that changed in 1969, when Ordnance Survey moved to its present, purpose-built headquarters on the outskirts of Southampton. Four years later, the first computerized large-scale maps appeared; the digital age had begun. Ordnance Survey digitized the last of some 230,000 maps in 1995, making Britain the first country in the world to complete a programme of large-scale electronic mapping. Computers have transformed the map-making process, and electronic data is now routinely available to customers within 24 hours of being surveyed. The public still knows Ordnance Survey for its comprehensive range of printed leisure maps, yet electronic data now accounts for some 80% of Ordnance Survey’s turnover. Independent estimates show that the national

mapping agency’s data now underpins up to £136 billion-worth of economic activity in Britain – everything from crime-fighting and conservation to marketing and mobile phones.”

The original triangulation of Britain was carried out between 1783 and 1853 and is known as the “Principal Triangulation.” Jesse Ramsden, a gifted but dilatory gentleman, built the theodolite where the overall size of the horizontal circle measured 3 feet in diameter and was divided to a precision of a tenth of an arc second! (That’s the same precision as the Wild Heerbrugg T-4 astronomical theodolite still manufactured as recently as the 1980s). Major General William Roy once wrote, “On one occasion he (Ramsden) attended at Buckingham Palace precisely as he supposed at the time named in the Royal mandate. The King remarked that he was punctual as to the day and hour, while late by a whole year!” The genius responsible for the final adjustment and computation of the Principal Triangulation of 1783-1853 was Colonel Alexander Ross Clarke who also computed the Clarke ellipsoids of 1858, 1866, and 1880. The network selected by Clarke was an interlocking system of well-conditioned triangles. In 1967, the Ordnance Survey wrote, “This network was geometrically of great strength since it involved no fewer than 920 condition equations to find corrections to 1,554 observed directions subsequently used to fix 218 points.” The One-Inch map series referred to a map scale of one inch equals one mile. The One-Inch Scottish Bonne projection (1852-1936) was based on the Principal Triangulation and had a central meridian $\lambda_o = 4^\circ \text{ W}$, a latitude of origin $\varphi_o = 57^\circ 30' \text{ N}$, a scale factor of unity, and with no false Origin. The One-Inch English and Welsh Cassini projection (1919-1936) was also based on the Principal Triangulation and had a central meridian $\lambda_o = 2^\circ 41' 03.5620'' \text{ W}$, a latitude of origin $\varphi_o = 53^\circ 13' 17.2740'' \text{ N}$, a scale factor of unity, and with no false Origin.

The counties of the United Kingdom were based on local Cassini-Soldner projections that had the typical scale factor equal to unity, no false origin, and a single triangulation station as the projection origin. System Ben Auler ($\varphi_o = 56^\circ 48' 50.3889'' \text{ N}$, $\lambda_o = 4^\circ 27' 49.7064'' \text{ W}$) served the counties Canna, Eigg, Muck, Rhum, Sanday, and Skye of the Inner Hebrides and Inverness of Scotland. System Ben Cleuch ($\varphi_o = 56^\circ 11' 08.8438'' \text{ N}$, $\lambda_o = 3^\circ 46' 05.2765'' \text{ W}$) served the counties Clackmannan and Perth

continued on page 1094

continued from page 1093

of Scotland. System Ben Clibrig (1839) ($\varphi_o = 58^\circ 14' 07.8780''$ N, $\lambda_o = 4^\circ 24' 35.3627''$ W) served the county of Sutherland, Scotland. System Black Down (1797, 1840) ($\varphi_o = 50^\circ 41' 10.3186''$ N, $\lambda_o = 2^\circ 32' 52.4856''$ W) served the counties Dorset and Somerset of England. System Bleasdale ($\varphi_o = 53^\circ 54' 55.351''$ N, $\lambda_o = 2^\circ 37' 20.752''$ W) served the county of Lancashire, England. System Brandon (1822) ($\varphi_o = 52^\circ 24' 19.820''$ N, $\lambda_o = 0^\circ 37' 21.040''$ W) served the counties Durham and Northumberland of England. System Broadfield ($\varphi_o = 55^\circ 47' 59.8320''$ N, $\lambda_o = 4^\circ 32' 20.5920''$ W) served the county of Renfrew, Scotland. System Brown Carrick ($\varphi_o = 55^\circ 24' 26.5714''$ N, $\lambda_o = 4^\circ 42' 41.1291''$ W) served the counties Ayr, Wigtown, and Kirkcudbright, Scotland. System The Buck ($\varphi_o = 57^\circ 17' 51.1940''$ N, $\lambda_o = 2^\circ 58' 32.0297''$ W) served the counties Aberdeen, Banff, East Lothian, Fife, Kincardine, Kinross, Midlothian, and West Lothian of Scotland. System Cairn Glasher ($\varphi_o = 57^\circ 20' 22.8895''$ N, $\lambda_o = 3^\circ 50' 30.5116''$ W) served the county of Nairn, Scotland. System Cleisham (1840) ($\varphi_o = 57^\circ 57' 50.6850''$ N, $\lambda_o = 6^\circ 48' 41.4340''$ W) served the Outer Hebrides.

System Craigowl ($\varphi_o = 56^\circ 32' 52.4204''$ N, $\lambda_o = 3^\circ 00' 48.5178''$ W) served the county of Angus, Scotland. System Cruach-na-Sleagh ($\varphi_o = 56^\circ 07' 08.9328''$ N, $\lambda_o = 5^\circ 43' 34.1145''$ W) served the counties Argyle, Arran, and Bute of Scotland and Coll, Islay, Jura, Mull, and Tiree of the Inner Hebrides. System Cryn-y-Brain (1852, 1853) ($\varphi_o = 53^\circ 02' 16.8715''$ N, $\lambda_o = 3^\circ 10' 22.2907''$ W) served the counties Denbighshire and Flintshire of Wales. System Danbury (Church) Spire (1844), ($\varphi_o = 51^\circ 42' 57.9220''$ N, $\lambda_o = 0^\circ 34' 32.9299''$ E) served the counties Cambridgeshire and Isle of Ely, Huntingdonshire, Soke of Peterborough, Norfolk, and Suffolk of England. System Derrington Great Law ($\varphi_o = 55^\circ 26' 08.9646''$ N, $\lambda_o = 2^\circ 26' 34.6838''$ W) served the county of Berwick, Scotland. System Ditchling (1793, 1845) ($\varphi_o = 50^\circ 54' 04.0149''$ N, $\lambda_o = 0^\circ 06' 21.7531''$ W) served the county of Sussex, England. System Dunnet Head (1838) ($\varphi_o = 58^\circ 40' 10.1679''$ N, $\lambda_o = 3^\circ 22' 13.4365''$ W) served the county of Caithness, Scotland. System Dunnose (1793, 1844) ($\varphi_o = 50^\circ 37' 03.7288''$ N, $\lambda_o = 1^\circ 11' 50.1015''$ W) served the counties Berkshire, Buckingham, Derby, Hampshire,

Isle of Wight, Leicester, Lincoln, Northampton, Nottingham, Oxford, Rutland, Warwick, Wiltshire, Worcester, and Stafford of England. System Dunrig (1816, 1850) ($\varphi_o = 55^\circ 47' 59.832''$ N, $\lambda_o = 4^\circ 32' 20.592''$ W) served the county of Peebleshire, Scotland. System Finlay Seat ($\varphi_o = 57^\circ 34' 42.2883''$ N, $\lambda_o = 3^\circ 14' 26.5655''$ W) served the county of Moray, Scotland. System Forest Hill ($\varphi_o = 54^\circ 25' 30.700''$ N, $\lambda_o = 2^\circ 43' 41.593''$ W) served the county Westmorland of England. System Foula (1821) ($\varphi_o = 60^\circ 08' 26.2436''$ N, $\lambda_o = 2^\circ 05' 38.4808''$ W) served the counties Orkney, and Zetland, Scotland. System Hart Fell (1816, 1847) ($\varphi_o = 55^\circ 24' 28.9742''$ N, $\lambda_o = 3^\circ 24' 00.1634''$ W) served the county of Dumfries, Scotland. System Hensbarrow (1790, 1843) ($\varphi_o = 50^\circ 22' 58.8532''$ N, $\lambda_o = 4^\circ 49' 05.1029''$ W) served the counties Cornwall, and Isles of Scilly, England. System Highgate ($\varphi_o = 51^\circ 41' 1''$ N, $\lambda_o = 4^\circ 50' 1''$ W) served the county of Pembroke, Wales. System High Pike ($\varphi_o = 54^\circ 42' 19.3478''$ N, $\lambda_o = 3^\circ 03' 26.5277''$ W) served the county of Cumberland, England. System Hollingbourne ($\varphi_o = 51^\circ 16' 10.380''$ N, $\lambda_o = 0^\circ 39' 55.564''$ W) served the county of Kent, England. System

Lanark Church Spire ($\phi_o = 55^\circ 40' 20.8037''$ N, $\lambda_o = 3^\circ 46' 19.8904''$ W) served the counties Dumbaron, Lanark, Stirling, and Roxburgh of Scotland. System Leith Hill Tower (1792, 1822, 1824) ($\phi_o = 51^\circ 10' 32.8895''$ N, $\lambda_o = 0^\circ 22' 10.9797''$ W) served the county of Surrey, England. System Llangeinor ($\phi_o = 51^\circ 38' 26.6535''$ N, $\lambda_o = 3^\circ 34' 17.0360''$ W) served the counties Anglesey, Brecknock, Caernarvon, Cardigan, Carmarthen, Glamorgan, Merioneth, Montgomery, and Radnor of Wales and Hereford, Monmouth, and Salop of England. System Nantwich Church Tower ($\phi_o = 53^\circ 04' 00.3405''$ N, $\lambda_o = 2^\circ 31' 09.1414''$ W) served the county of Cheshire, England. System Rippon Tor ($\phi_o = 50^\circ 33' 57.0563''$ N, $\lambda_o = 3^\circ 46' 12.0872''$ W) served the county of Devon, England. System St. Paul's (1848) ($\phi_o = 51^\circ 28' 15.9830''$ N, $\lambda_o = 0^\circ 22' 47.6011''$ W) served the counties of Bedford, Essex, Hertford, London, and Middlesex, England. System Sandhope Heights ($\phi_o = 55^\circ 30' 10.253''$ N, $\lambda_o = 3^\circ 02' 31.092''$ W) served the county of Selkirk, Scotland. System Scour-na-Lapach (1846) ($\phi_o = 57^\circ 22' 10.3858''$ N, $\lambda_o = 5^\circ 03' 31.5613''$ W) served the counties of Ross and Cromarty, Scotland. System South Berule (1846) ($\phi_o = 54^\circ 08' 57.5699''$ N, $\lambda_o = 4^\circ 40' 05.2960''$ W) served the Isle of Man, England. System York Minster (1846) ($\phi_o = 53^\circ 57' 43.1879''$ N, $\lambda_o = 1^\circ 04' 49.7302''$ W) served the counties York and Yorkshire, England.

The re-triangulation of Great Britain was not based on a single origin point. However, it was not based on any new length measurements, either. The overall size of the network was constrained to agree with the old 18th century Principal Triangulation using the old coordinates of 11 primary stations adjusted by Clarke. Therefore, the Ordnance Survey of Great Britain 1936 datum (OSGB36) does not have a single origin point. The ellipsoid of reference is the Airy 1830 where $a = 6,377,563.396$ m and $b = 6,356,256.910$ m. The overall size of the OSGB36 is based on the measurement of a single distance between two stations on Hounslow Heath in 1784 using 18-foot glass rods! The error incurred by using this scale constraint yielded an error in the length of the entire country of only 20 meters! The War Office Grid (1927-1950) was based on the Cassini-Soldner projection and had a central meridian $\lambda_o = 1^\circ 11' 50.1360''$ W, a latitude of origin $\phi_o = 50^\circ 37' 03.7480''$ N, a scale factor of unity, False Easting = 500 km, and False Northing = 100 km. Introduced in 1931,

the English Yard Belt Transverse Mercator ($m_o = 0.9996$, False Easting and False Northing = 1,000,000 yds.) was short-lived and was replaced by a slightly different metric version in 1945 and it continues to be used. The current system is the National Grid. Although the equations published appear to be a Gauss-Krüger expansion to the 5th derivative, they are cast as *latitude differences* from the False Northing latitude of true origin = 49° N. The central meridian = 2° W, and the scale factor at the central meridian, commonly mistaken for that of the TM Yard Grid and the UTM Grid, is different in that by definition, $m_o = 0.9996012717... \equiv \text{Log}_{10} m_o = 1.99982680$, exactly. I would love to find out where that number came from. The False Easting is 400 km and the False Northing is – 100 km.

The Ordnance Survey seven-parameter transformation from OSGB36 to WGS84 *modified to the standard American rotation convention* used by the National Geodetic Survey (NGS) and by the National Imagery and Mapping Agency is $DX = +446.448$ m, $DY = -125.157$ m, $DZ = +542.060$ m, scale = $-20.4894 \cdot 10^{-6}$, $R_x = -0.1502''$, $R_y = -0.2470''$, and $R_z = -0.8421''$. "OSGB36 is an inhomogeneous Terrestrial Reference Frame by modern standards. Do not use this transformation for applications requiring better than 5 metre (*sic*) accuracy in the transformation step, either vertically or horizontally. Do not use it for points outside Britain." The above transformation parameters were extracted from *A Guide to Coordinate Systems in Great Britain*, a "pdf" file downloaded from the Ordnance Survey's web site, www.gps.gov.uk. Higher accuracy transformations are possible utilizing the free software available from the Ordnance Survey in the form of OSTN02, a bi-linear interpolation package similar in concept to the NADCON package of the NGS. The British Geoid Model, OSGM02, is available and is free from the Ordnance Survey. The stated vertical accuracy is 2 cm in mainland UK and 4 cm for other areas. I hope that other nations will follow the example of the United Kingdom, Australia, Mexico, and the United States in making critical national geodetic transformation models available at no charge to the public. I am indebted to Russell Fox, soon to retire from the Ordnance Survey, and to John W. Hager, now retired from NIMA, for their patience over the years in helping me to compile this mass of data on the UK.

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