WILLIAM SMITH, HIS MAPS AND OTHER ENDEAVOURS FROM A DIGITAL PERSPECTIVE--EXTENDED ABSTRACT

Peter Wigley

William Smith's maps have been studied in detail by many researchers interested in Smith's place in the history of geology but few have looked at the maps in the context of modern geological information. The author has been interested in Smith's maps for the past decade and during that time has digitised a number of his maps and incorporated them into a Geographic Information System (GIS).

A major problem in transforming Smith's maps into a GIS is that there is no indication of the projection used on his maps. There are marginal graticules showing latitude and longitude, but no internal lines and although the coastline is recognisable, it does contain positional errors. However, Smith was fortunate to have the talented John Cary as his map maker. Cary's local surveying of town and village positions was excellent and he used much of this information on the elegant base map he produced for Smith's 1815 map.

In order to discover the projection used, a series of iterative tests were undertaken on the map graticules using projections in common use during the early 19th century. Overall the best fit was the Cassini projection. Using this projection, the Smith maps were georeferenced to real world coordinates based on the positions of Cary's towns and villages.

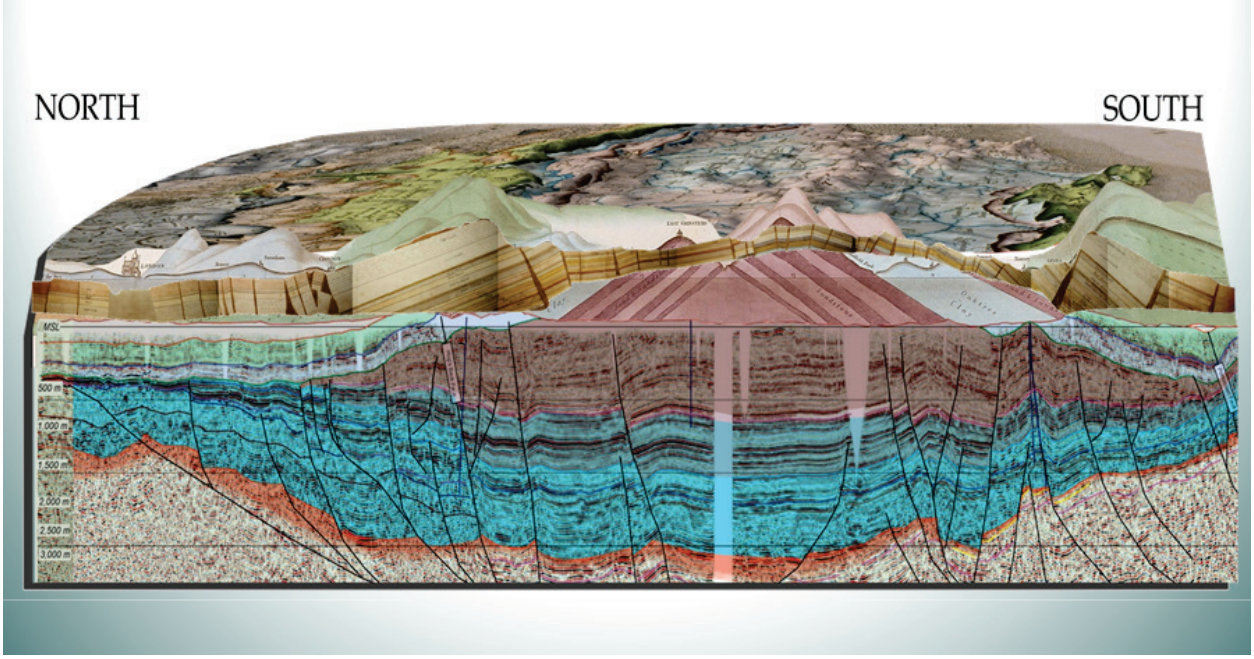
The base map prepared by Cary for the 1815 map essentially predates the 1st Principal Triangulation. However, some of the Smith-Cary county maps were concurrent with early phases of the triangulation and in several cases include information derived from the triangulation.

Once in real world coordinates, Smith's maps can be compared with modern geological mapping. This comparison shows that for much of the Cainozoic and Mesozoic of England Smith's mapping was remarkably good. Modern technology makes it possible to drape Smith's maps on a digital terrain model and view them in 3D. These visualisations dramatically illustrate Smith's complete understanding of the principles of stratigraphy.

Smith's wonderful panoramic cross-sections have been located on his maps as have fossils from his Strata Identified publication. Recently, the Natural History Museum have made Smiths own fossils, illustrated for Smith by James Sowerby, available to the author and these are currently being incorporated into a new publication by Wigley et al called William Smith's Fossils Reunited.

Finally, it should be remembered that Smith was a man of many talents, canal surveyor, mining engineer, and an expert on coastal barriers, harbours and land drainage. He is particularly remembered for his success in draining the Prisley Bog in Bedfordshire, remains of which are still visible today.

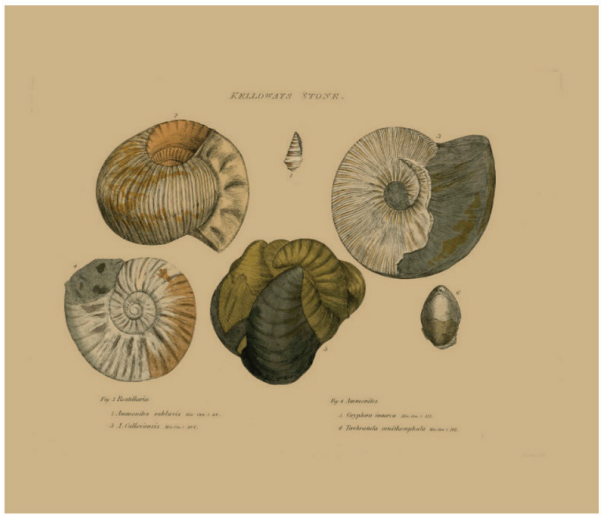
These studies have been incorporated into a new website, William Smith's Maps-*Interactive.* This is a free educational resource which can be found at http://www.strata-smith.com

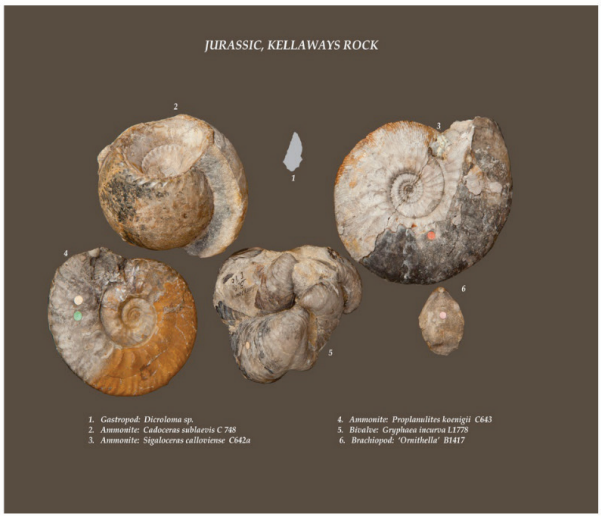


Part of Smith 1815 map in 3D displayed with his cross-section and that of John Farey together with a modern seismic section across the Weald

William Smith's 1799 Geological Map around Bath displayed in Google Earth

Plan of William Smith's Water meadows on Prisley Bog displayed in Google Earth





James Sowerby's engraving of Smiths fossils in a plate from *Strata Identified* compared with his actual fossils in the Natural History Museum

Peter Wigley is a Cornishman and as a child became interested in geology when searching old tin and copper mine spoil heaps for rocks and minerals. He has a BSc in Geology and a PhD in Carbonate Sedimentology, both from University College London. In 1973 he joined ERICO, a geological consulting company and worked on numerous geological projects in the North Sea, Mediterranean, Africa, Middle East and SE Asia. He left ERICO in 1991 to become an independent consultant. In 1995 he joined Lynx Information Systems Ltd, a company he jointly founded, he retired from Lynx in 2015. He is a Board Member of AAPG-Datapages and the Director of Datapages DEO-GIS, which provides online maps and figures from all AAPG publications. In addition to voluntary work for the American Association of Petroleum Geologists, Peter has worked extensively with The Geological Society. As part of their bicentenary celebration in 2007 he helped build a spatial index of their maps, and previously worked on a scanned archive of Sir Roderick Impey Murchison's correspondence. He has received Distinguished Service Awards from both The Geological Society and AAPG. He also has a long -standing interest in William Smith's maps, in 2007 he produced a DVD his maps and is the editor of the WILLIAM SMITH'S MAPS-*Interactive* website. Currently he is working with the Natural History Museum on a publication of William Smith's fossils. Peter is also the editor of the Exploration Fabric of Africa Project (EFA). EFA is a not-for-profit online GIS of Africa containing digital geological, gravity and magnetic maps together with a wide range of other hydrocarbon-related data

Peter lives with his wife Caroline in Devon; they have two married daughters and four grandchildren. Outside of geology he is interested in the opera and classic sports cars.

SELECTED SLIDES FROM TALK

Smith Geology around Bath 1799

Strata in England and Wales Smith 1801 (on Cary General Map)

Smith Geology of England and Wales (A Map GSL) 1815

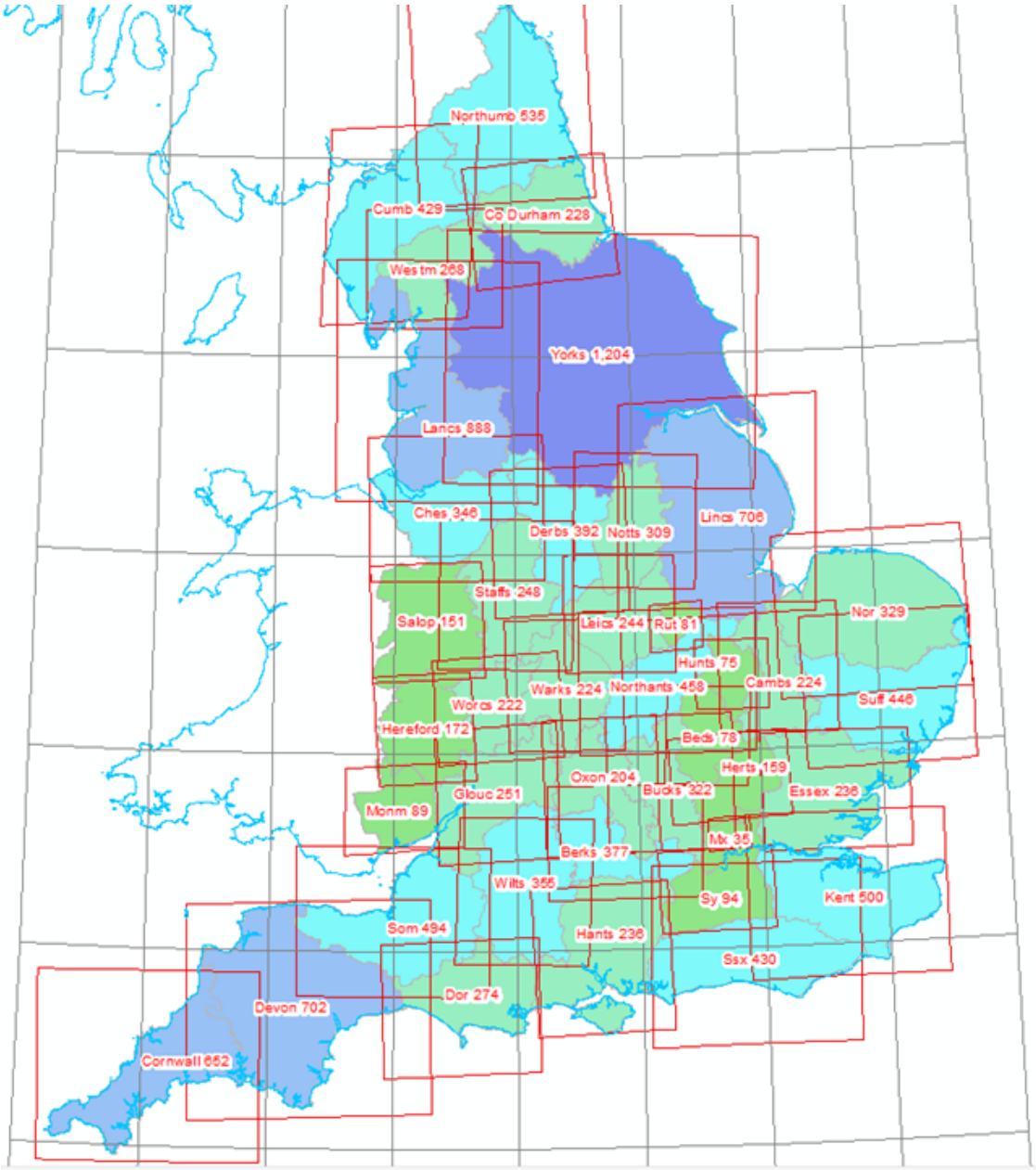
A New Geological Map of England and Wales, with the Inland Navigations; exhibiting the Districts of Coal and other Sites of Mineral Tonnage by W. Smith, Engineer, 1828

Geology of the County of Gloucestershire William Smith 1819

Cary-Smith Lancashire manuscript showing extensive annotation (some dated as late as 1836)

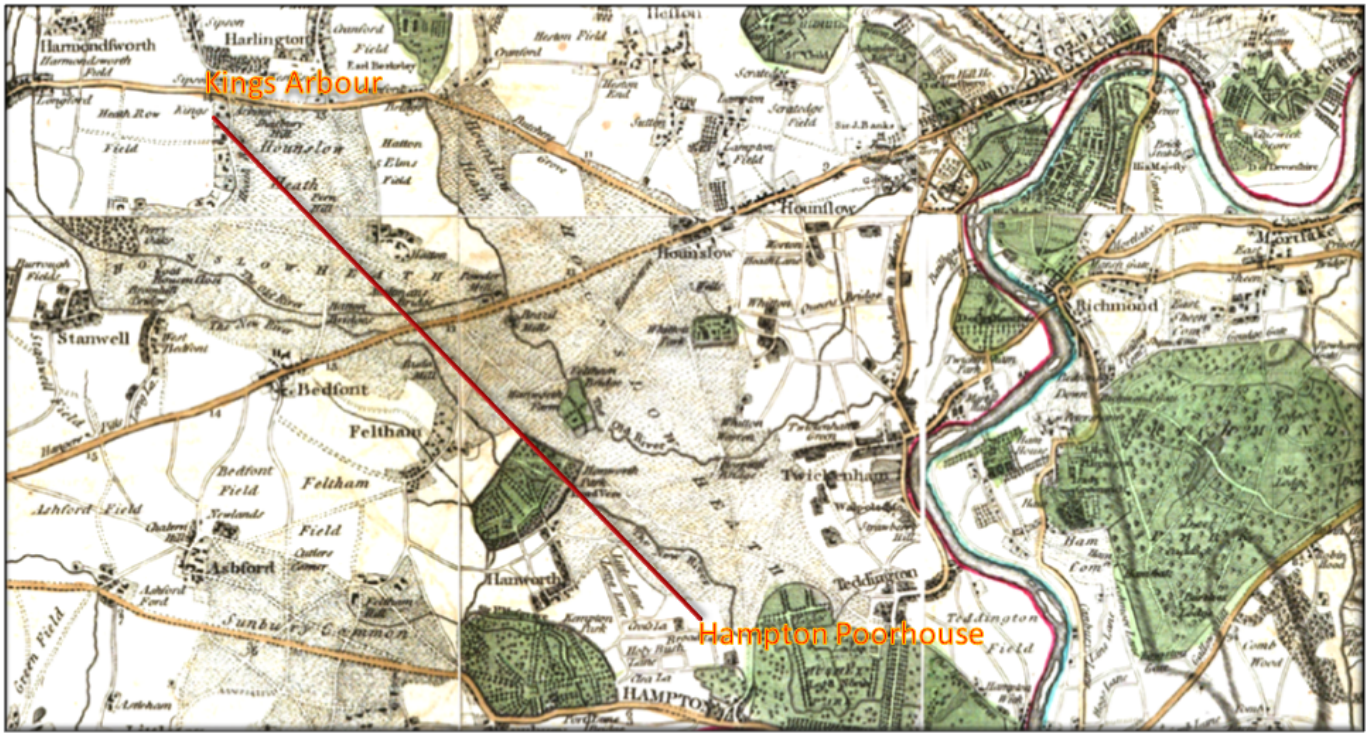
PROJECTIONS

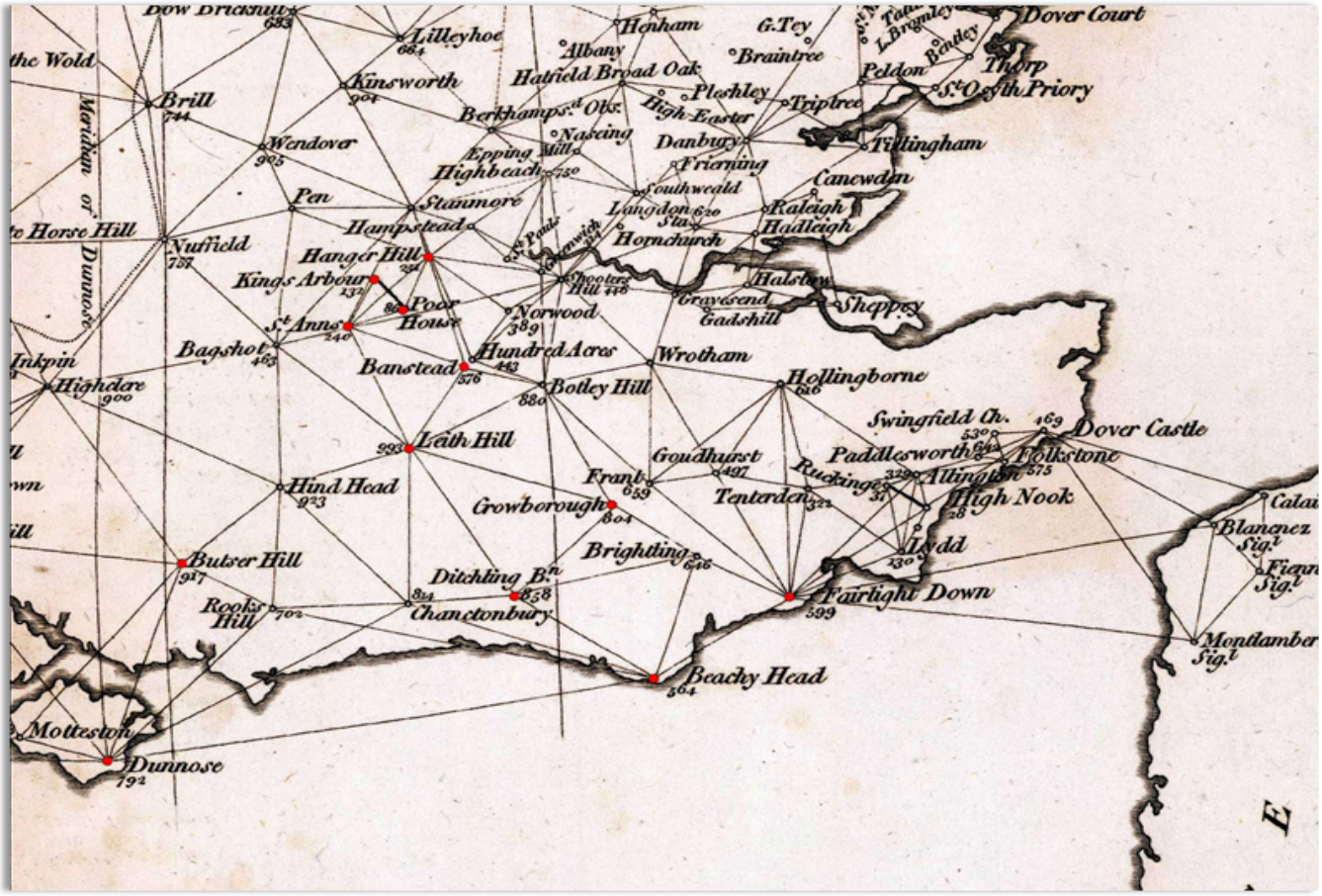
1st order polynomial transformation (affine) was used to project map images to coordinates and coastlines in each of the tested projections. Residual (RMS) errors were calculated based on the framing graticules. Typical errors ranged from over 4,500 metres to less than 1000 metres. Some projections (e.g., Lambert Azimuthal Equal Area) achieved a good fit on the graticule but had a considerably distorted shape. Apart from the residual errors on the graticules, a judgment also had to be made on the fit to places and coastlines. In this regard, it is worth remembering that the maps are all around 200 years old. Essentially, they predate the 1st Principal Triangulation of the country that was started in 1784 and not completed until 1853 (although the first phase was complete by 1796). Although the general shape of England and Wales is excellent on all maps, it does differ from the modern coastline. For example, the Cary and Smith maps show the position of Lands End to be some 7 km north of its actual position; similarly the Isle of Man is offset about 13 km to the northeast. Bonne, Cassini and Transverse Mercator projections all achieved relatively good results. Overall Bonne was the best fit on the Smith 1815 map, closely followed by Cassini (used by the Ordnance Survey for the Old Series 1" maps of England and Wales) which gave a better fit on the Smith County maps. One additional piece of evidence is that projection tests on the large scale General Index to Cary's 1794 New Map of England and Wales which does contain internal coordinate lines gives RMS errors of 1448m for Cassini against 1637m for Bonne. However, the difference in error is too small for any definitive statement to be made as to which projection was used. On balance it is more likely that Cassini used on a sphere was used for both the Smith 1815 and the County maps.

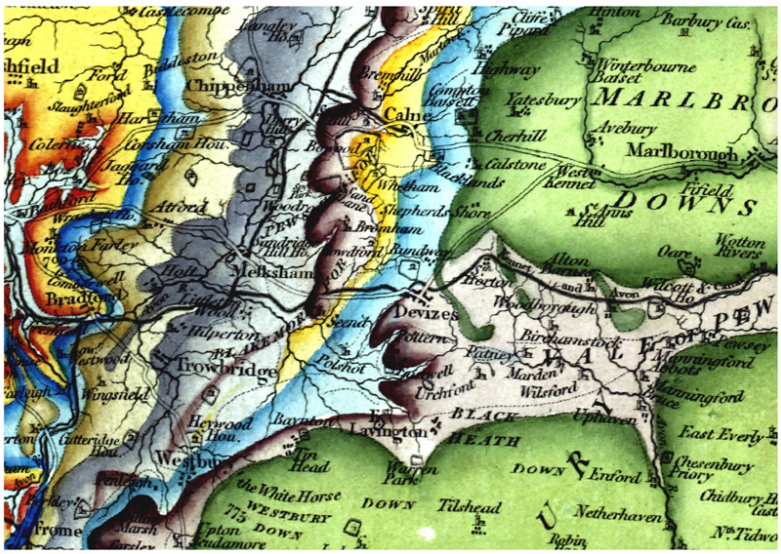


Residual errors for individual County Maps

PRINCIPAL TRIANGULATION OF GREAT BRITAIN

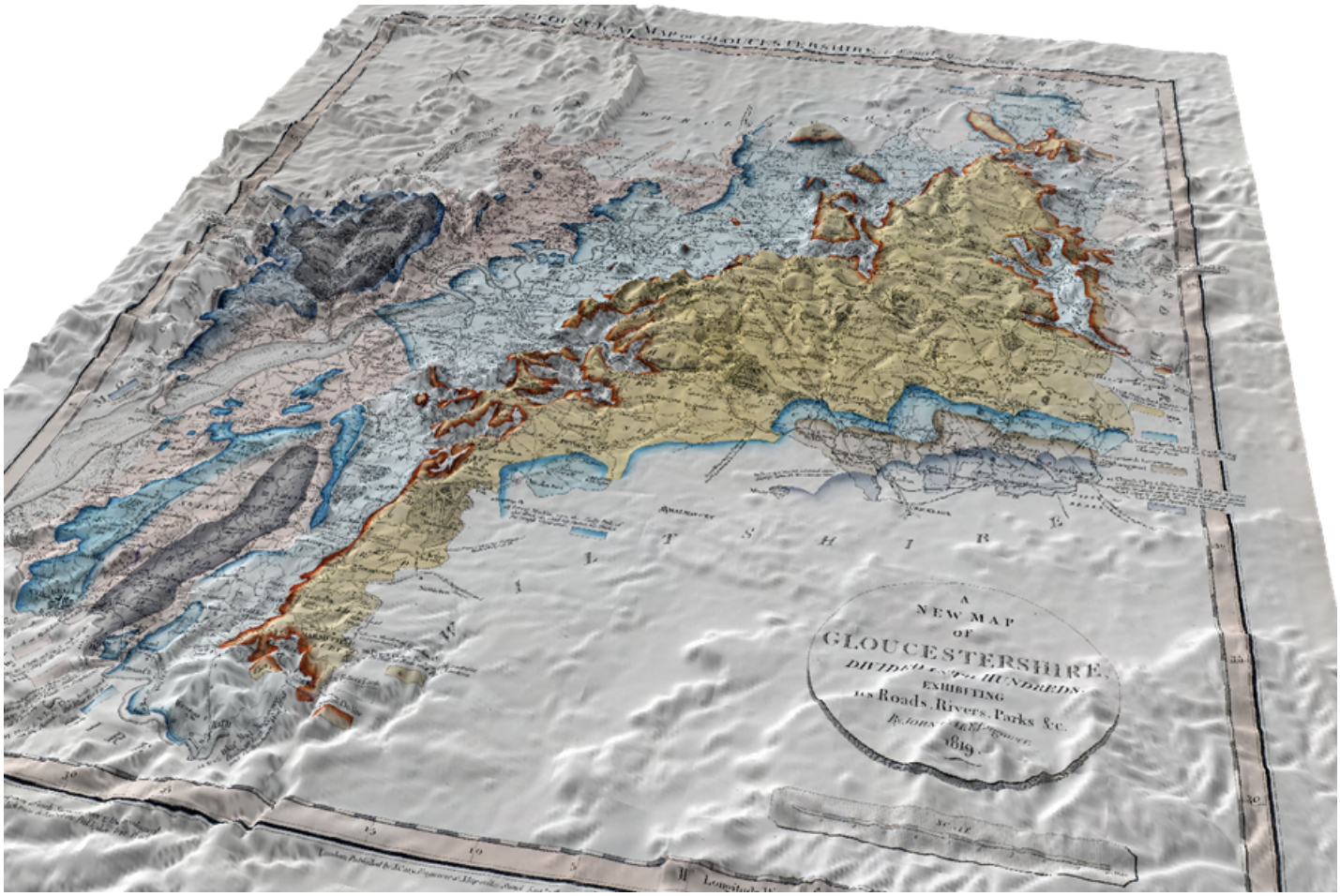






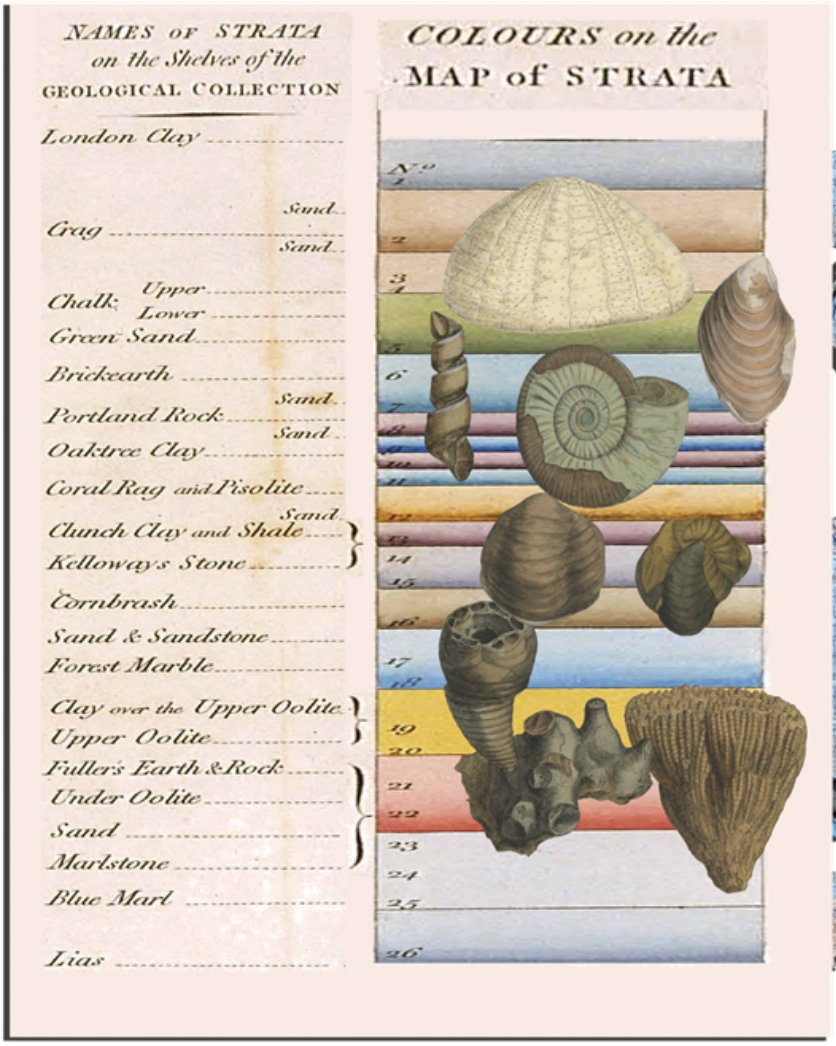
This series of three slides illustrates how the base map was compiled; the three maps are from part of the county of Wiltshire. The first map is from Cary's 1794 New Map of England and Wales and shows in extraordinary detail roads, canals, rivers, towns and villages included by Cary. The second map is a de-colored Smith 1815 map and shows how Cary and Smith simplified the road network, reduced the number of towns and villages located (and reduced the size and style of the typeface) while at the same time emphasizing topographic features. Incidentally, Cary, ever mindful of commercial implications, ensured that the outlines of the estates of wealthy landowners were always included. This map also shows Smith's engraved geological lines. The third map is the corresponding part of the 1815 map which was hand-colored to show the geology.

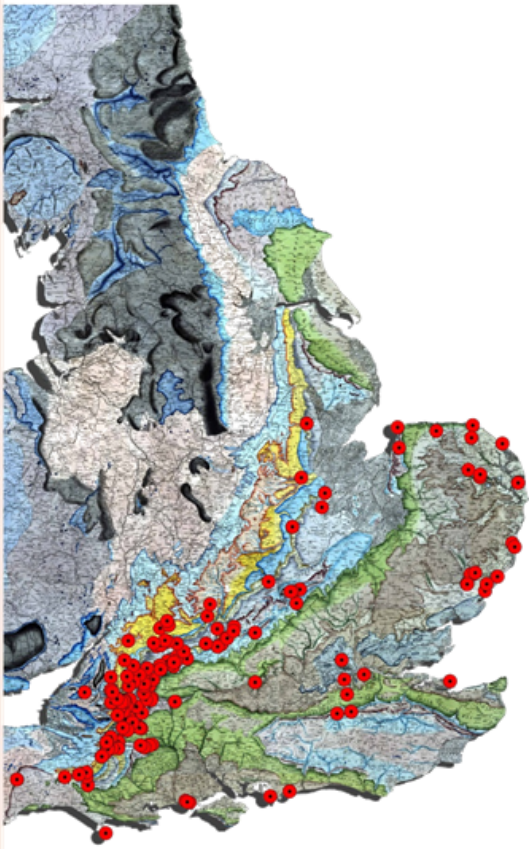
SMITH'S MAPS IN THREE DIMENSIONS



The Shuttle Radar Topography Mission (SRTM) was flown from the Space Shuttle Endeavour in February 2000 and used Interferometric Synthetic Aperture Radar to obtain a high resolution digital elevation database for much of the Earth. The resolution of the raw data was one arc second (30m). Initially 30m data was only available for the USA, elsewhere the resolution was 90m; recently 30m data has been released for the rest of the world. The data are freely available from NASA. In 2009 another dataset called ASTER GDEM was released and although covering 99% of the Earth's surface the true resolution of the data is lower than SRTM. In the display above SRTM data have been converted into a 90m grid of cells each containing an elevation value in metres and assigned a colour. In the display shown below geological information from Smith's County Geological maps and Cary County maps enhanced by Smith 1815 geology have been draped upon the SRTM elevation model in order to give a three dimensional aspect. William Smith's maps shown in 3D demonstrate, yet again, his complete understanding of stratigraphic concepts and his remarkable ability to convey that understanding in his maps. His technique of graduated tinting of outcrops already gave an impression of relief even in two dimensions. In 3D the effect is even more impressive.

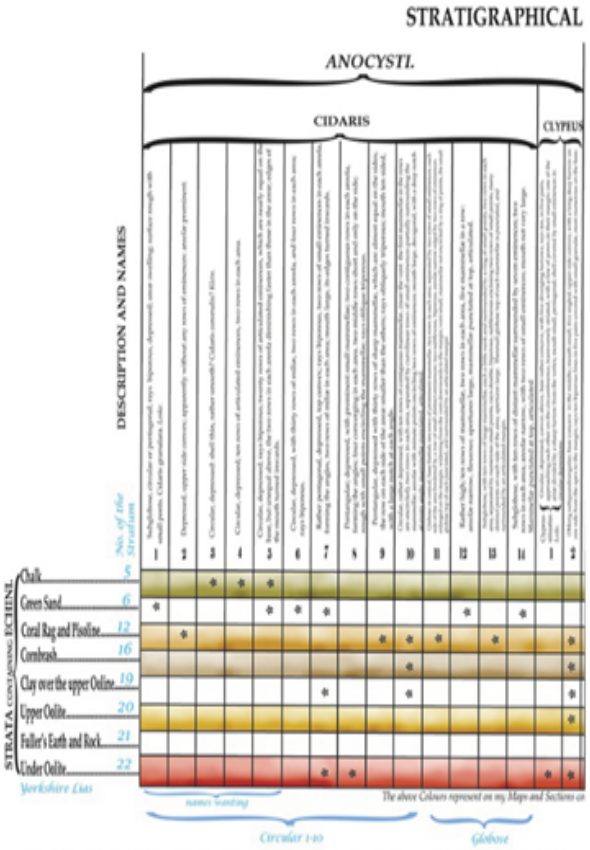
SMITH'S TABLE OF STRATA

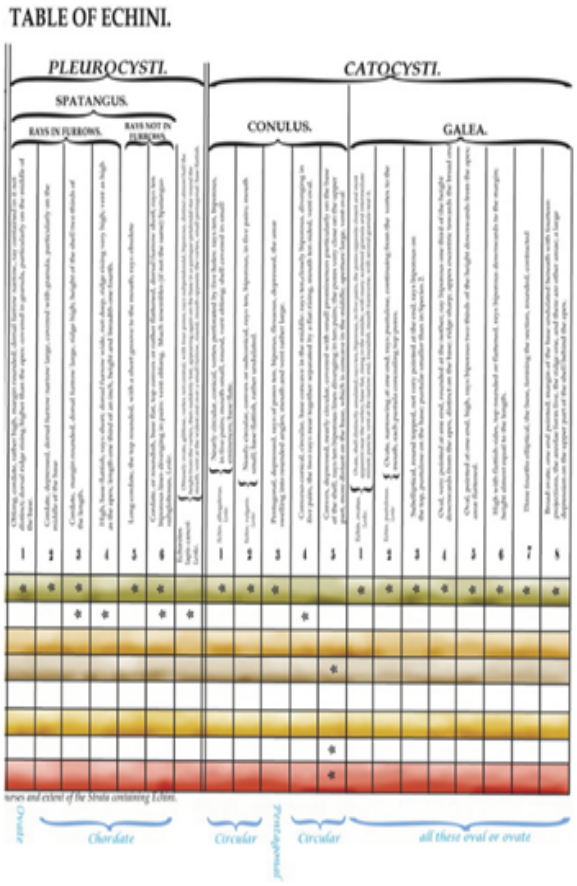




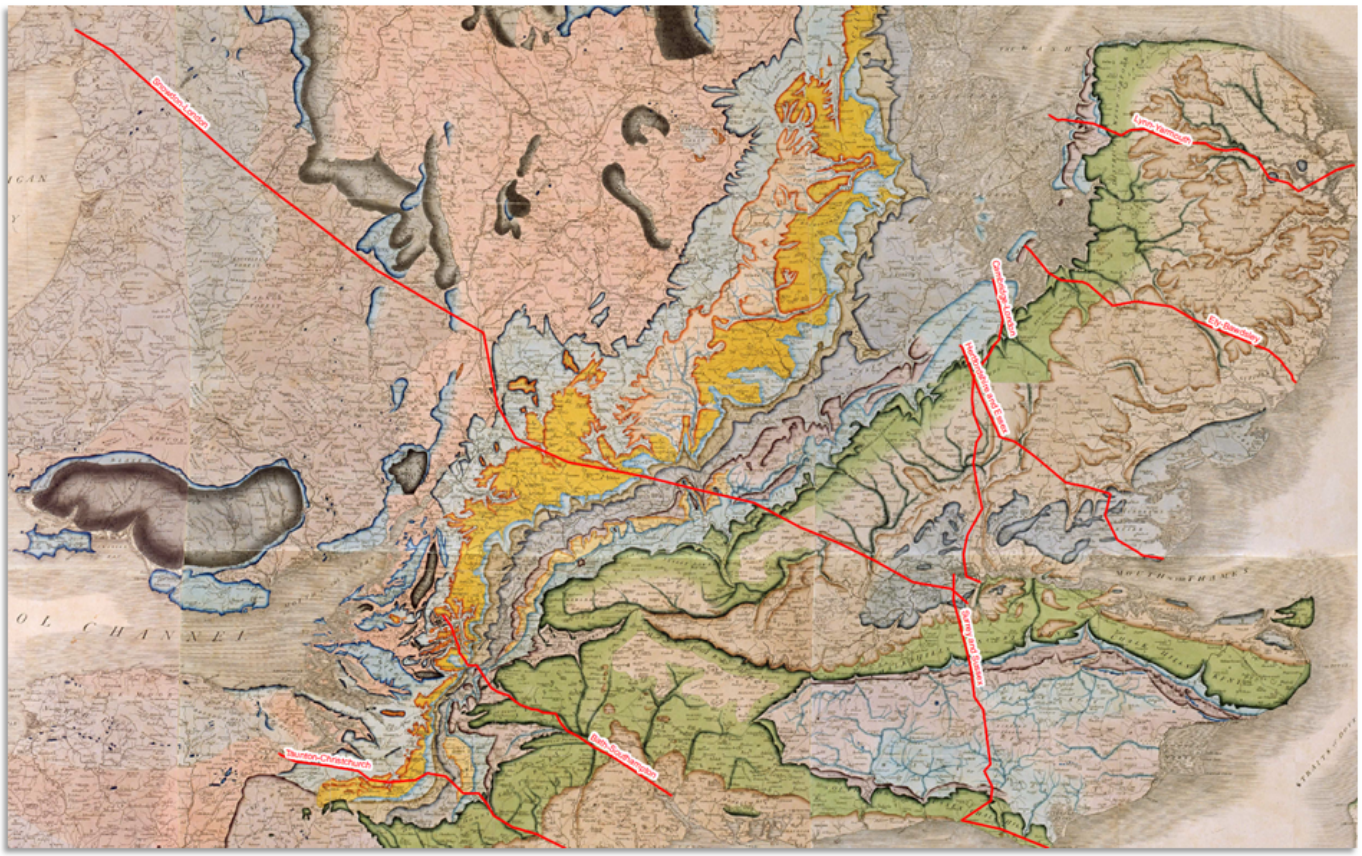
William Smith first became interested in what he called "the ordering of strata" when he was employed as a surveyor on the Somerset Coal Canal in 1795. Through detailed study of canal sections, he managed to separate several repetitious clay formations and also to separate the Upper and Lower Oolite (Torrens, 2003, p.161). By August 1797, Smith had made his first attempt at a more general order of strata starting with Number 1 "Chalk Strata" and descending to Number 28 "Limestone" below the Coal Measures. In June 1799, at the home of the Revd Joseph Townsend, Smith dictated his famous "Order of the Strata in the Bath area" to the Revd Benjamin Richardson (Phillips, 1844, p.29) and during the course of several iterations it evolved into the geological table, part of which is shown in the slide

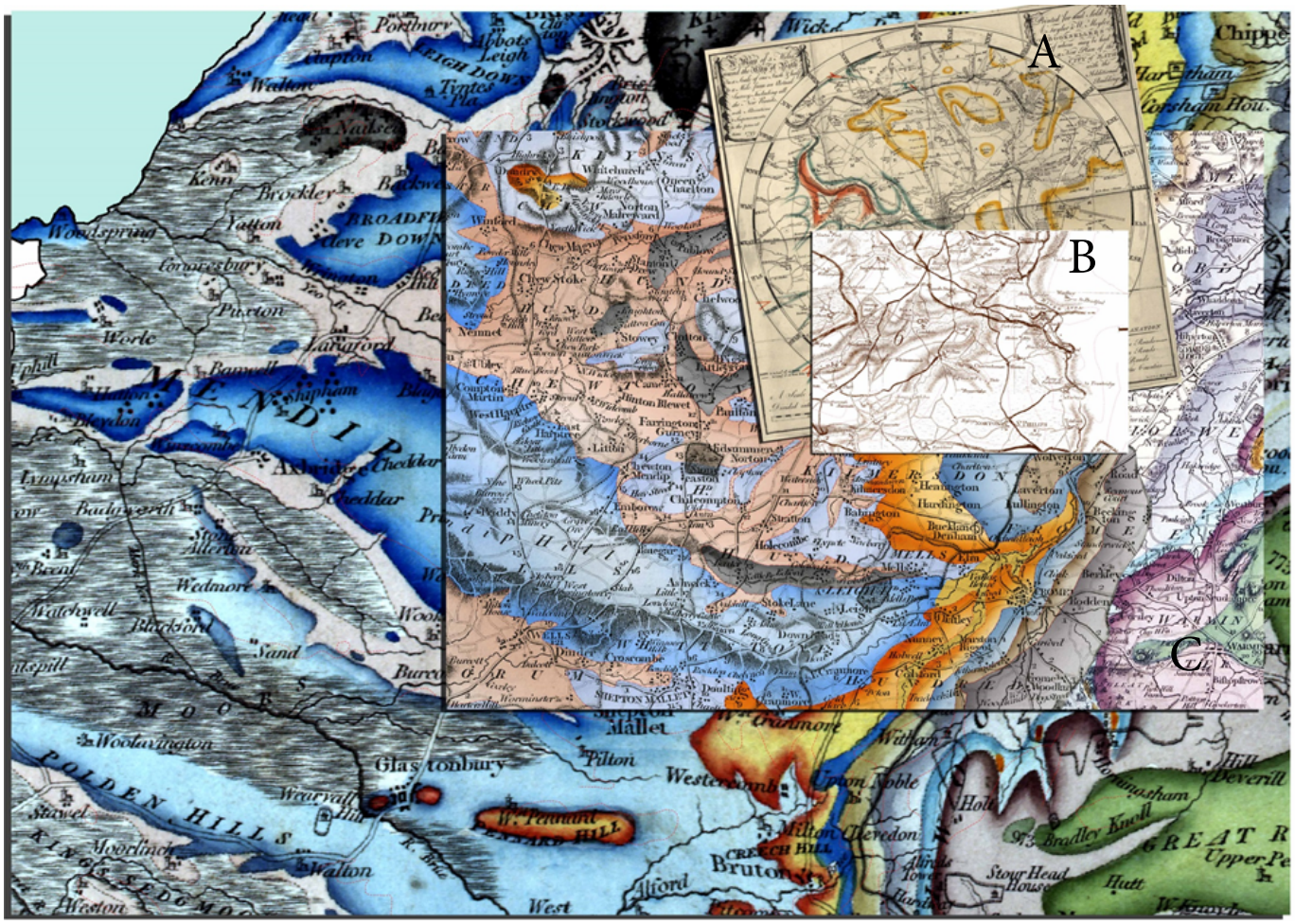
SMITH'S STRATIGRAPHIC RANGE CHARTS





LOCATION OF WILLIAM SMITHS GEOLOGICAL SECTIONS





The 1815 map measures over eight feet by six feet and was printed on 15 sheets. This map was the canvas upon which Smith documented his observations; he would not have used it in the field as the scale was too small. Smith did make an early experiment using a Cary one inch to twenty mile (approximately 1:1,300,000) map but he stated that the "maps were spoiled by speculating on the ranges of stratification without sufficient data" (Smith 1815 p. 27). His memoirs also record that he coloured a map in the vicinity of Bath and also used the Day and Masters County Survey of Somerset (1782) (Phillips, 1844, p.27).

The slide is a digital compilation of maps of the English counties of Somerset and Wiltshire shown at various scales. The map (A) was Smith's first attempt at a geological map drawn on a circular map around Bath by Taylor and Meyler (1799) with an approximate scale 1 1/2 inch to 1 mile. Map (B) is part of a detailed map of Somerset produced by Day and Masters at a scale of 1 inch to 1 mile. Map (C) is a reconstruction of the geology of Somerset using a rare Cary New Map of the County of Somerset (from the collection of Hugh Torrens) which contains original engraved geological line work by Smith at a scale of approximately 1 inch to 3 miles. The above-mentioned maps overlie a part of Smith's famous 1815 geological map, more properly called "A delineation of the Strata of England and Wales, with part of Scotland" which is at a scale of 1 inch to five miles. All these maps are currently in a GIS and therefore maps of differing scales seamlessly overlay one another. In the early 19thC, scale adjustment was more difficult but not insurmountable. In the next slide, in addition to the maps, an instrument called a pantograph is illustrated. A pantograph is a mechanical device used to copy and scale maps or diagrams; one arm of the pantograph has a pointer, the other a pen or scribe. Using the pointer to trace the original line work a copy could be generated, the scale of the copy depending on the position of the arms of the linkage. Smith was very familiar with this instrument. In his journal entry for Friday 18th December 1789 , the twenty year old Smith records time spent "Repairing and Setting the pentograph [pantograph]" before he "began to reduce the Plan of a Mr C. Norton's allotments". (OUMNH Archive, Diaries, WS/B0 p.55). It is almost certain that Smith would have used a pantograph to reduce geological lines from his field maps on to the 1815 base map. It is important to realize that although Smith's final map may have been small scale, its content was derived from his large scale field maps.


MEMORANDUMS, OBSERVATIONS, and Appointments, in DECEMBER, 1789.
DECEMBER, 12th Month, has xxxi Days.
Week 51
Account of Money
Received
Paid or Lent
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Repairing
Pentograph
began reducing the Plan of
Edward Wells

WILLIAM SMITH MAP SOURCES USED IN THE PROJECT

UK Onshore Geophysical Library

Special thanks to
Hugh Torrens
Tom Sharpe
Dave Williams
Jill Darrell
Di Clements
Malcolm Butler (UKOGL)
http://www.strata-smith.com

WILLIAM SMITH'S MAP-INTERACTIVE WEBSITE

This new website has been funded by the UK Onshore Geophysical Library (UKOGL). The website is a free-to-all educational resource designed for teachers and students as well as academicians and anybody with an interest in the life and work of William Smith. A number of fine examples of Smith's 1815 map are available on the website together with all of Smith's published county geological maps and a number of unpublished county maps. The principal feature of the website is an interactive map viewer which enables users not only to view the maps but also to overlay one against another and compare them with modern geology, wells, seismic and current topographic maps. Users can also display Smith's magnificent geological sections and view 3D animations of his maps. The website also has information on the map sources, Smith's biography, stratigraphy, coordinates, 3D maps and a section concerning the "Map That Might Have Been". The digital images of maps used in this website have been provided by The Geological Society of London, Oxford University Museum of Natural History, National Museum of Wales, Stanford University and Nottingham University. The website is located at http://www.strata-smith.com