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Creating, Managing, and Maximising the Potential of Large Online Georeferenced Map Layers

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Summary: This paper shares key insights on the National Library of Scotland's work in creating and maintaining georeferenced map layers, and the new user communities that have been reached through doing so. It describes the georeferencing workflows used to create the layers, and the open-source viewers which allow the georeferenced layers to be viewed. Through web-services, these layers have been very widely used by new user communities. The paper describe these new user communities, and the implications for future online map digitisation, georeferencing and delivery.

Introduction

By autumn 2019, the National Library of Scotland had over 220,000 online zoomable maps, accessible through bounding-box coordinates.¹ However, the most important online content, in terms of user visits and onward re-use, has been georeferenced layers of mapping.² The largest of these seam together thousands of map sheets as single georeferenced layers. Not only are these layers more useful, more engaging and easier to use than the individual sheet maps that form their constituent parts, they are also much easier to re-use in other applications and websites using web-services technologies.

This paper shares key insights on the NLS's work in creating and maintaining these georeferenced layers, and the new user communities that have been reached. It first describes the georeferencing workflows used to create the layers, all of which are easily extendable to other libraries. It then describes and illustrates the open-source viewers (available on Github³) which allow the georeferenced layers to be selected, compared to one another, and viewed. The onward use and re-use of these layers, both on the NLS website, and in other websites is then demonstrated. Work on this was initiated by the NLS Historic Maps API⁴ from 2011, which encouraged more widespread georeferencing and by autumn 2019, around 600 georeferenced layers had been created.⁵ Some of the web-services based on these layers have commercial potential, and libraries have options to raise income from re-use of georeferenced maps, for example, to support further digitisation and georeferencing work.

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¹ At <https://maps.nls.uk/geo/find/>. This 220,000 represents around 20% of the collection, and is part of a long-term programme to scan the collections.

² At <https://maps.nls.uk/geo/explore/>.

³ <https://github.com/NationalLibraryOfScotland>.

⁴ <https://maps.nls.uk/projects/api/>.

⁵ Available at <https://maps.nls.uk/geo/explore/>. A relatively small proportion of these layers seam together more than 100 sheets, and around half of these are First World War trench maps, where the georeferenced layer is just one sheet.

Georeferencing workflow

The NLS georeferencing workflow forms part of the wider map digitisation workflow, which can be represented as a structural model (Fig. 1). At the top are web users, interacting with maps through four main interfaces: a *Find By Place* viewer (for search and retrieval), a standard *OpenLayers* viewer, for zooming and panning map images, an *Explore Georeferenced Maps* viewer, for interacting with georeferenced map layers, and a suite of tools for making available georeferenced maps as web services. The next row down contain the shapefiles, metadata and images behind these interfaces, which are primarily handled through desktop GIS and imaging applications. The third row down consists of metadata and raw images, generated from the paper map collections at the bottom.

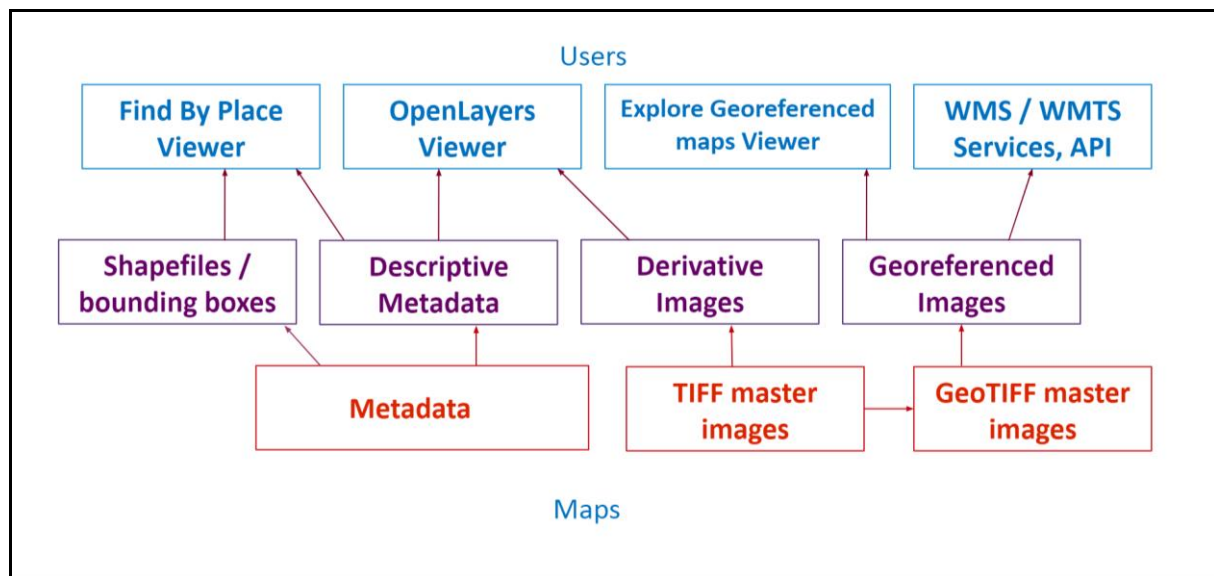


Figure 1: A structural model of the NLS maps digitisation and website components. Paper maps (at the bottom) are made available to users (at the top) through a set of connected modules, incorporating both metadata and images.

At one level, the model is useful for visualising the scanning and georeferencing workflow, moving from the bottom row to the top. The workflow always involves creating bounding boxes for map series before they go online (middle row, left-hand side), so they can be retrieved in our *Find by Place* bounding box viewer (top left)⁶. Whilst all maps are available as zoomable images, only maps which have been created through a sufficiently accurate geodetic process are georeferenced; in practice, this is true of topographic series mapping, particularly from the 19th century to the present day. For those series maps that are georeferenced, seamless layers of georeferenced maps are prepared from the bounding box coordinates (middle row, right-hand side). Various HTML pages support these main components. For example, presenting the structural parent-child relationships between the series and the map, or the parent volume and the map is crucial so all our series have home pages, which are good landing pages for Google, and from where there are links to view the sheets, view the seamless georeferenced layer and view related supporting information - abbreviations, symbols, lettering and a background essay.⁷

⁶ <https://maps.nls.uk/geo/find/>

⁷ See, for example, the Ordnance Survey six-inch to the mile homepage at: <https://maps.nls.uk/os/6inch-england-and-wales/>

A model like this is also useful for planning replacement cycles for different components and the longevity of different types of georeferenced content. The interfaces at the top will need to evolve fast with changing technology and expectations, but if our maps and metadata are captured correctly, these should endure for a much longer period. The georeferenced map services at the top right, described in this paper, are likely to change fast, but the georeferenced tilesets beneath them, and especially the georeferenced images themselves, will endure for longer. The model allows components to be replaced independently of one another — there is no integrated single system whose replacement involves major effort.

For georeferencing, the NLS used early versions of Klokan Technologies' *Georeferencer*⁸ in 2011, which worked well, and continues to work well for certain types of standalone, early mapping (Fleet, et al., 2012). Arguably, it works less well for series mapping, where we may have hundreds or even tens of thousands of sheets of a regular size, scale and specification.

For most British maps, the bounding boxes of these sheet polygons can be obtained⁹ or created in a GIS with knowledge of the projection, sheet size and extents.¹⁰ The *MapSheetAutoGeoref* plugin to QGIS is then used (Jatniek, 2010). In this application, a shapefile of bounding box polygons of map sheets must have an *image_id* field, linking a specific polygon to the relevant image of the sheet relating to that polygon. Once set up with a folder of scanned images and a shapefile, the process involves clicking the four corners of each sheet in succession (Fig. 2). This creates both a outline for cropping the margins of the sheet as well as the relevant corner coordinates for running a *gdalwarp*¹¹ process. The cropping and georeferencing then takes place after completing a batch, and through this process, around 1,000 sheets can be georeferenced in a day. Of course, anomalies such as extended sheets, or insets require manual work, which will take longer, and are, at present, difficult to automate, but fortunately, these sheets are always a small minority in most map series. We then use *MapTiler*¹² to create a seamless layer and present this online.

⁸ Further details at: <https://www.georeferencer.com/>.

⁹ Most British Ordnance Survey map coordinates are available through Ed Fielden's *Coordinate Converter* website.

¹⁰ See, for example, the ArcGIS Fishnet tool.

¹¹ <https://gdal.org/programs/gdalwarp.html#gdalwarp>.

¹² <https://www.maptiler.com/>.

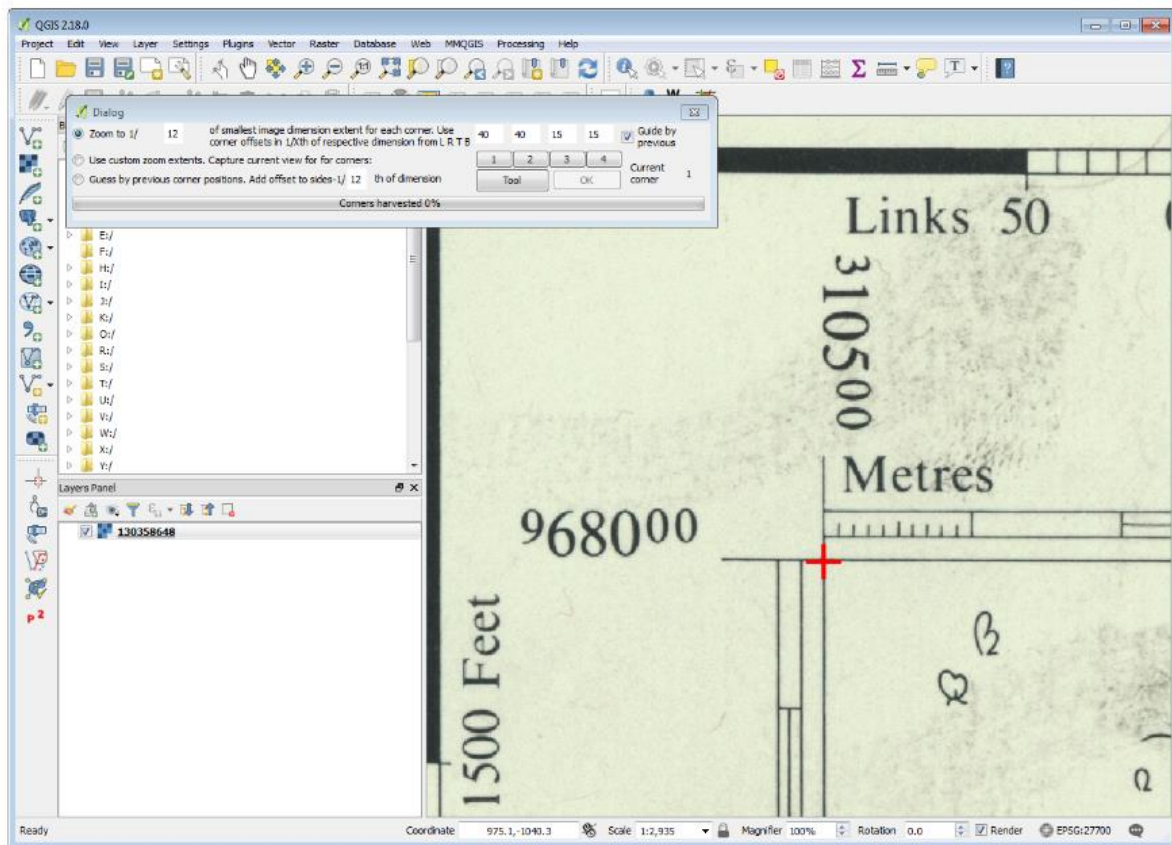


Figure 2: A screenshot from the *MapSheetAutoGeoref* QGIS plugin, illustrating clicking on the top-right corner of a series map.

Open-source viewers

From 2011, the NLS has actively used open-source technologies, particularly *GeoServer* and *OpenLayers*, for its web-mapping applications (Fleet & Pridal, 2012b). Many of the tools that are employed have been created by these broader web-mapping communities, as part of wider collaborative code development activities. In turn, the NLS has also shared all of the code behind its web-mapping applications on Github¹³, and encouraged the wider usage of these open-source technologies through written guidance and workshops.¹⁴ As the technical content of these applications has been described in detail in a recent paper (Fleet, 2019), they will not be discussed further here.

The central point is that through georeferencing, historic maps can be used in a range of new ways which these open-source viewer tools enable. For example, the ability to fade transparency, to measure distances and areas, view side-by-side, or swipe layers vertically or horizontally, are all powerful and useful functions. Georeferenced maps can be compared to other maps in endless novel and engaging ways, such as through a spyglass window¹⁵, or combined with digital elevation data to be viewed in 3D.¹⁶

¹³ <https://github.com/NationalLibraryOfScotland>.

¹⁴ For example, the GeoCart 2018, Putting Historical Maps Online workshop.

¹⁵ For example, the NLS Spy viewer.

¹⁶ The NLS 3D viewer takes advantage of *Cesium-OpenLayers* integration.

Onward use and re-use

One of the main initial catalysts for promoting the re-use of NLS' georeferenced maps was the release of the *Historic Maps API* in 2011 (Fleet & Pridal, 2012a).¹⁷ This essentially provided a way of embedding an historical georeferenced map of England, Scotland and Wales from the 1920s inside another website. The layer was distributed on cloud-based hosting to allow good scalability and responsiveness. From 2011-2018, this saw 6.7 million sessions and 10.8 million page views, and was used by a broader range of institutions than our traditional online user base. What was surprising was not just the popularity of the API in basic usage, but also the wide variety of user communities who made use of it, beyond the traditional physical map user base. It has been used in a very wide range of websites, including those devoted to outdoor recreation (walking, cycling, climbing, canoeing), archaeology (including metal detecting), family history, local history, railways, photography, teaching, and archives. A number of free and commercial mobile applications have used the API. It has also given very useful publicity to the NLS historical maps, and encouraged the availability of new georeferenced historical mapping.

The *Historic Maps API* continues to be free, but a further set of layers was launched in 2015, with the intention that development and hosting costs would be partly covered by subscriptions of £99 to £199 per year.¹⁸ From 2017, subscriptions have covered the annual hosting costs of ca. £4,000-£5,000 per annum. These layers have been used very widely too, for example, as backdrop layers in applications for viewing historic place names of Wales (Fig. 3)¹⁹, viewing archaeological sites in Scotland (Fig. 4)²⁰, viewing local authority information²¹, and in a number of commercial applications, described further below.

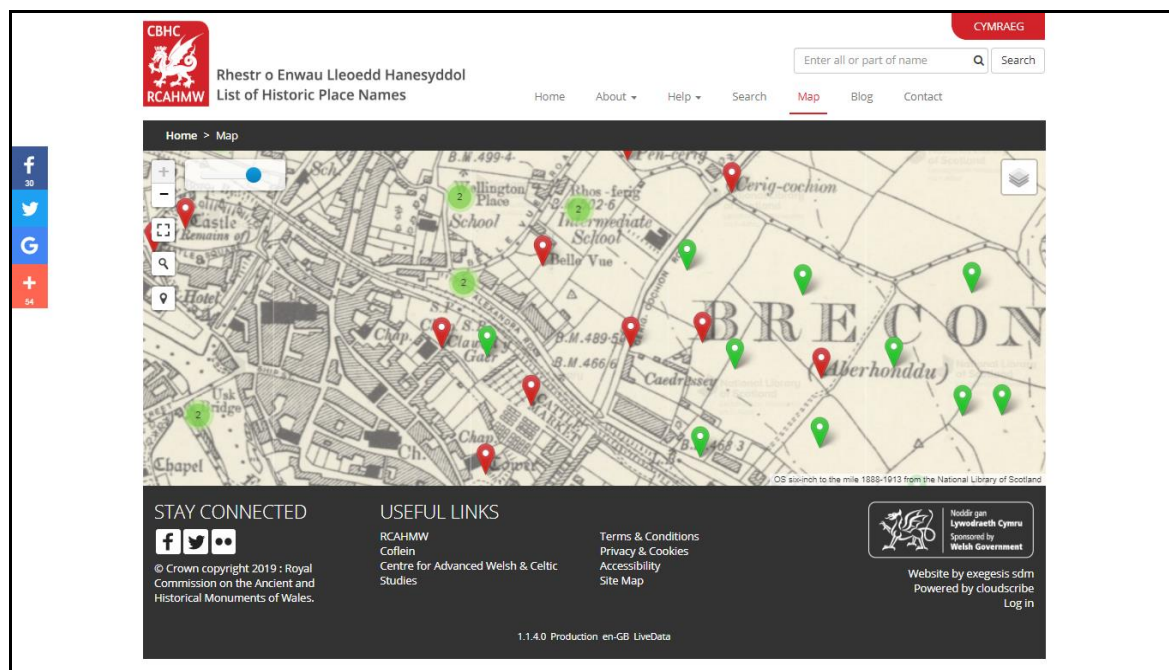


Figure 3 : The Historic Placenames of Wales map viewer, with the NLS background 1900s layer supplied as a web-service - <https://historicplacenames.rcahmw.gov.uk/placenames/map>.

¹⁷ Further details can be found on the NLS Historic Maps API web page.

¹⁸ Further details can be found on the NLS Subscription API web page.

¹⁹ <https://historicplacenames.rcahmw.gov.uk/placenames/map>.

²⁰ <https://pastmap.org.uk/map>.

²¹ For example, Staffordshire Past Track or Dorset Explorer.



Figure 4 : PASTMAP: exploring Scotland's historic environment, with NLS background 1840s-1880s mapping supplied as a web-service - <https://pastmap.org.uk/map>

Once georeferenced, maps can be combined with any other geolocated data, and so there are limitless possibilities for combining maps and data from different institutions to provide new ways of visualising content. For example, a recent application that the NLS has been involved in, include the *Scots-Italians Map Viewer*²², mapping the locations and areas of origin of Italians in Scotland in the 1930s, a collaboration with the National Records of Scotland. The *Scotland - Land Use Viewer*²³ - combines historic with contemporary land use mapping to show 20th century land-use change. Another interesting collaboration was illustrated by NLS putting online detailed maps of Jamaica in 1804 by James Robertson²⁴, a Shetlander who travelled to Jamaica, and the Legacies of British Slave Ownership project at University College London (Fig. 5). Their website brings in Robertson's georeferenced 1804 mapping of Jamaica to position records relating to estates and their slave owners back in Britain.²⁵

²² <https://maps.nls.uk/projects/italians/>.

²³ <https://maps.nls.uk/projects/landuse/>.

²⁴ <https://maps.nls.uk/jamaica/>.

²⁵ <https://www.ucl.ac.uk/lbs/maps/caribbean/jamaica>.

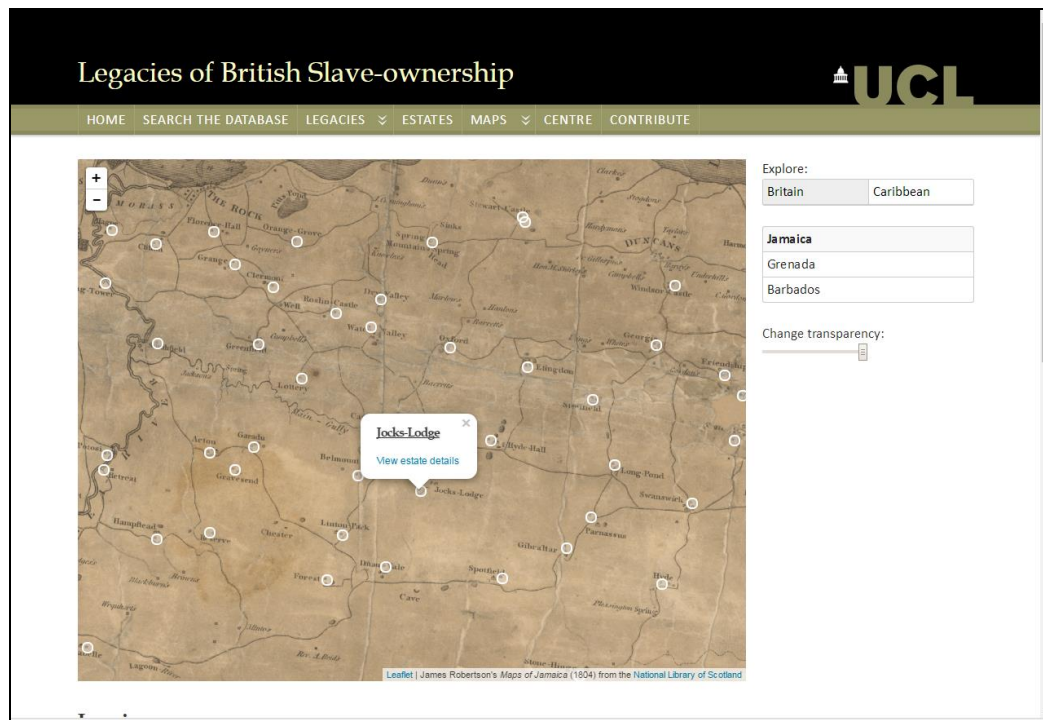


Figure 5 : The Legacies of British Slave Ownership website, overlaying records for slave plantation estates over an early 19th century georeferenced map of Jamaica from NLS, made available as a web-service - <https://www.ucl.ac.uk/lbs/maps/caribbean/jamaica>

Through web-services, georeferenced maps can be made available to the OpenStreetMap community too.²⁶ This allows historic maps to be brought into the OpenStreetMap iD and JOSM editors, and used for tracing features. Many historic buildings, communications infrastructure, and related features may show up more clearly on historic maps than modern-day satellite imagery (for example, if areas are in shadow, or concealed by trees, etc.). Web-services also allow georeferenced historic maps to be brought into desktop GIS such as ArcMap or QGIS as a Web Map Tile Service.²⁷ Although, at present, it is not easy to discover web-map services for historic maps, we can foresee the development of services like the *Leaflet TileProviders*²⁸, to make the discovery and onward use of georeferenced historic map layers easy too.

Once georeferenced, maps can be used for extracting features or names, creating very useful new datasets. For example, NLS was a partner in the *GB1900 Place Name Project* which successfully crowdsourced all the place names on detailed maps of Great Britain from a century ago (Southall et al., 2017). The transcription phase began in September 2016, gathering each name from two independent transcribers, for achieving better accuracy. As the maps were georeferenced, by clicking on the map in the *GB1900* transcription interface, the geographical coordinates were instantly recorded for the name (Fig. 6). The transcription phase formally ended in January 2018 with 2.52 million confirmed names, released under CC-0 terms for encouraging onward re-use.²⁹ When compared to other gazetteers, *GB1900* is the most detailed historical gazetteer certainly for Britain and possibly for anywhere: it has a greater volume of geo-located entries and a better abil-

²⁶ https://wiki.openstreetmap.org/wiki/National_Library_of_Scotland.

²⁷ The standard MapTiler output provides a step-by-step guide for bringing georeferenced maps into ArcMap or QGIS.

²⁸ <https://leaflet-extras.github.io/leaflet-providers/preview/>.

²⁹ The *GB1900* names can be viewed at <http://geo.nls.uk/maps/gb1900/>. They can be queried in the NLS *Explore Georeferenced Maps* viewer, with the map then positioning to the selected name. The names can be downloaded from the Vision of Britain download page.

ity to locate places and features identified in other historical sources beyond administrative hierarchies (Southall & Aucott, 2019). We are at an early stage in feature-coding the GB1900 gazetteer, but even with basic keyword searching and extraction, useful distributions of selected names and features can be created (for example, the spatial distribution of footpaths (Fig. 7).

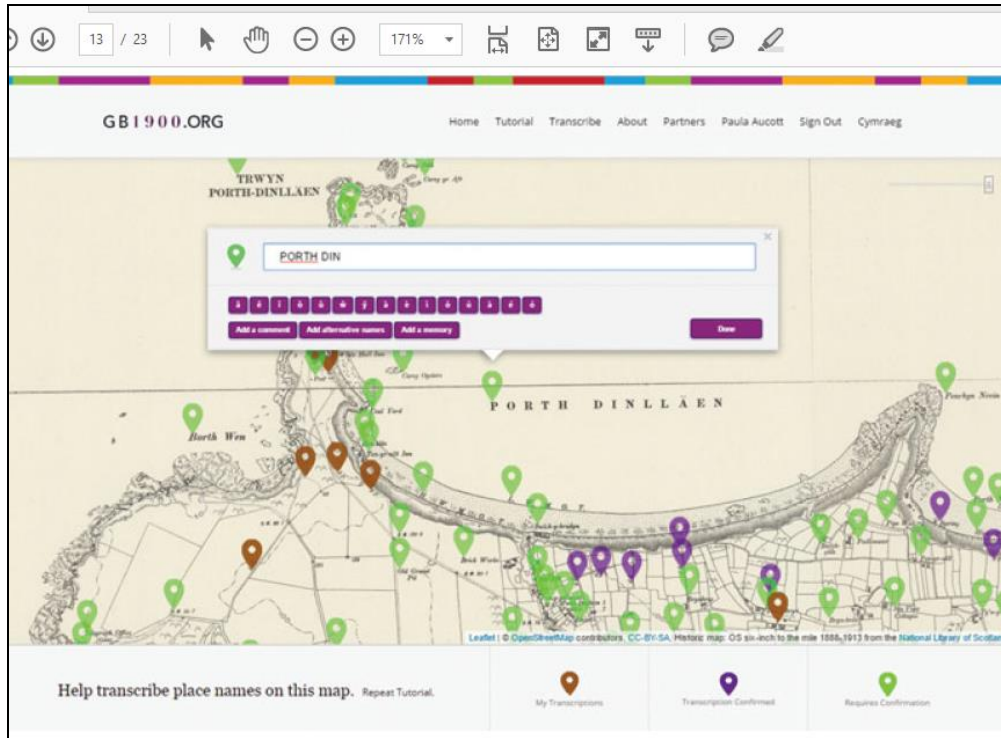


Figure 6 : The GB1900 transcription interface. Brown pins were those names worked on by the logged-on transcriber; green pins meant further work was needed - the name had been transcribed just once or the transcriptions didn't match; purple pins had two separate matching transcriptions and were complete.

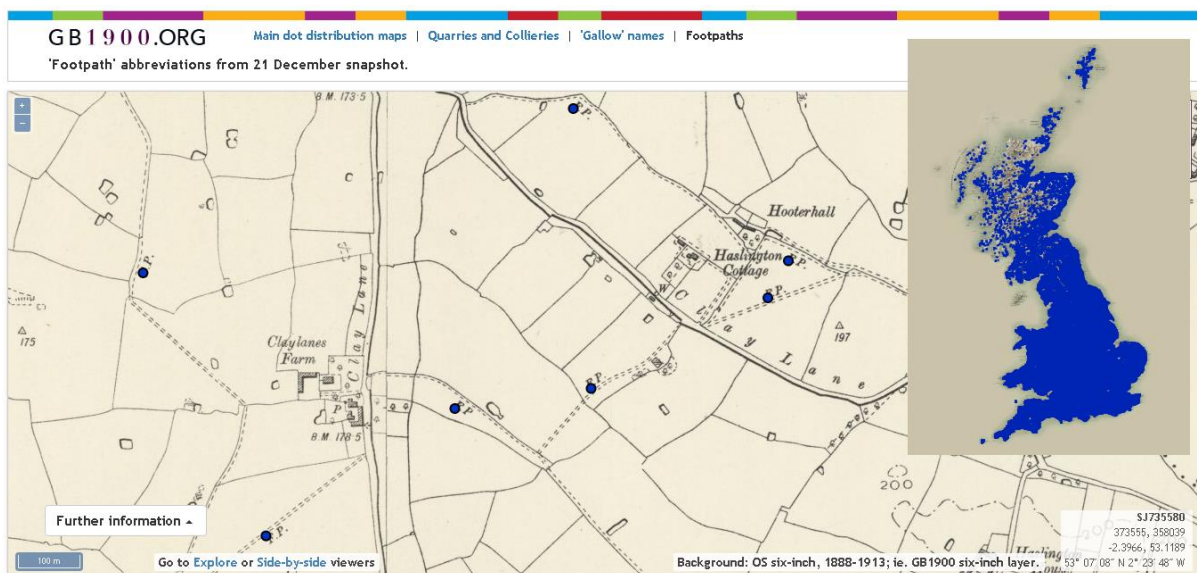


Figure 7 : There are 387,444 'F.P.' or 'Footpath' abbreviations in the GB1900 gazetteer, which are useful in locating historic rights of way.

The process of scanning maps, georeferencing them, presenting them online as seamless layers, and especially the development of web-services, as well as the creation of new datasets through extraction and vectorisation, all create new resources that have a value. Libraries have the option to make these freely available or to generate income from them. In many countries, including the United Kingdom, there is an assumption that libraries should make available their collections at no charge. Online viewing of maps and georeferenced layers are free, and libraries may also provide extensive free support by e-mail and telephone. But providing georeferenced web-services can be distinguished from these free services and made available for a fee. If funds are generated, they can support the provision of new georeferenced layers or the costs of suitable cloud hosting. Through this approach, libraries can develop a wider range of georeferenced maps, as well as more scalable and sustainable hosting than if these developments have to be funded completely from internal resources.

In the last decade, especially through the provision of historic georeferenced maps as web-services, the NLS has supported a growing number of commercial applications, including:

- Archaeological site consultancy - examining archaeological features using historic maps.³⁰
- Assessing environmental risk - for example, the risk of subsidence or environmental contamination through previous land uses, revealed through historic maps.³¹
- Conveyancing of property and land - boundaries and former land-uses are a key geospatial dataset for buying and selling of property.
- Custom wallpaper and fabric - once georeferenced, bespoke location-based wallpaper based on historic maps can be ordered.³²
- Location-based gifts and bespoke graphics.³³
- Genealogy - historic map layers can be integrated with geolocated genealogical records.³⁴
- Graphics and jigsaws - seamless layers of mapping provide more potential for attractive customised images of particular places, without needing to worry about map sheet boundaries!
- Use in print media publications (covers, illustrations, calendars, etc.).

Several of these communities are significantly broader or different from the traditional map library user communities. In other words, the creation of georeferenced layers of mapping, and making these available as web-services, reaches a new and broader user base. This is partly because it allows easy re-use in other websites, but also due to the ability for other companies or institutions to combine other data or services with the layers. By recognising this, libraries can also choose to prioritise the digitisation and georeferencing of maps that meet the needs of these new user communities. These are particularly for detailed maps of urban areas, but more generally can include maps with striking aesthetics, and pre-20th century maps, whose font and styles carry a noticeably different aesthetic too. The provision of a country-wide layer of a particular time period is relevant too, especially for archaeological or genealogical users. Whilst some of these series maps may be digitisation priorities for the needs of traditional map user communities too, digitisa-

³⁰ Much of this use is in desktop applications, but a recent example of an external website, using NLS historic maps, is AOC Archaeology's Whiteadder interactive map viewer (<http://whiteadder.aocarchaeology.com/>).

³¹ For example, the reports available from Future Climate Info (<http://futureclimateinfo.com/our-reports/>), Groundsure (<https://www.groundsure.com/report/map-insight-historical-maps/>), or Landmark Information Group (<https://www.landmarksolutions.co.uk/case-study/historical-map-data>).

³² For example, from Redcliffe Imaging (<https://www.custom-wallpaper-printing.co.uk/wallpaper-map-historic-nls.html>).

³³ For example, Atlas-and-i's personalised vintage map location products (<https://www.atlas-and-i.com/>).

³⁴ For example, The Genealogist's Map Explorer (<https://www.thegenealogist.co.uk/maps/>), or FindMyPast's 1939 Register (<https://www.findmypast.co.uk/1939register>).

tion of other new series maps may be seen as higher priorities for the role they may play as a georeferenced web-service.

Conclusion

Georeferenced layers based on series mapping can cover extensive areas, and are relatively straightforward to create with series bounding boxes. Libraries may well need to create these bounding boxes anyway for retrieval purposes. These georeferenced layers are much more popular and reach significantly more users than the constituent ungeoreferenced maps that they are made up of. They can easily integrate with existing Open Geospatial Consortium web-services, allowing the layers to be easily brought into desktop or other web-mapping viewers. This allows many new applications to be created, with other institutions bringing expertise and content to create more engaging and useful results than libraries could achieve on their own. Large georeferenced layers allow significant new opportunities for gazetteer generation, feature extraction and vectorisation, and they have a significant income-generation potential if libraries choose to exploit this.

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