Mapping the geological space beneath your feet

The journey from 2D paper to 3D digital spatial data

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Abstract— **The map is more important than ever, but what it can represent and how it is delivered is changing radically as new geospatial technologies emerge. In the field of geology, paper maps have always aimed to represent the complex three-dimensional world beneath our feet and make it understandable to us at the surface. However, new smart phone mapping applications enable us to take the map with us more easily and to ask questions of it wherever we are, and to add our own observations on to it. Digital survey and modelling technologies will enable geologists to communicate geology in 3D for us, rather than having to translate it to 2D; everyone will then see the geology as the geologist does as we take visualisation from the lab to the street. As an interactive tool the geological map of the future will be very different.**

Keywords- 3D, spatial data, smartphone apps, geology, map, augmented reality, digital mapping

I. INTRODUCTION

In the urban or rural setting, knowing what lies beneath the ground is important for safe and effective land-use but is also interesting to the researcher and to anyone fascinated by their environment. The science of geology strives to understand this third-dimension beneath our feet and make it understandable to us at the surface. Typically, this has been done by adding geological detail to the 2D paper map but advances in communication technology are opening up new ways to collect and convey geological maps through multiple media and dimensions.

Stimulated by the resource and transport needs of the industrial revolution, the first map of the bedrock geology of Britain was produced by William Smith in 1815 [1]. Surveying in ever greater detail, subsequent generations of geologists have added flesh to the bones such that today, the geological map forms just part of a whole-Earth approach to describing the nature of the geological environment how it may affect us. Modern geology underpins economic development and is fundamental to industries interested in the subsurface space and resource whether for construction, oil, minerals, water or storage.

This paper describes how we are moving from depiction of geology on two-dimensional paper to its representation in a multi-dimensional, digital space, and how this is opening up a bright new future for the geological map.

II. WHERE DO PEOPLE ‘MEET’ MAPS?

If you asked someone 10 years ago to show you a map, they would probably have reached for a paper road atlas from their car, a topographical map from their shelf, a sea chart, star map or perhaps a geological map. Now in the ‘age of the screen’ if you asked someone to show you a map, they are just as likely to reach for their mobile smart phone and click on Google Earth or a multitude of other map ‘Apps’ (Applications).

Indeed, it has not taken long for these new digital maps to overtake the paper map. For example, sales of British Geological Survey (BGS) paper maps have declined from the 10,000’s per year in 1999 to 1,000’s per year in 2010, in parallel with trends across the mapping sector. In contrast, the number of downloads of the recently released BGS iGeology [2] App (Fig. 1), which shows the same type of geology as the paper maps, have reached 70,000 in just one year.

This trend may largely be due to the ease of use of such mapping applications on mobile tablets and smart phones, including their inbuilt Global Position System (GPS) technology which allows the map to be centred automatically on where you are standing - something which would have astounded past map makers and has fundamentally changed our view of the world. Such interactive geospatial applications have come to dominate our everyday lives and overtake the traditional world of printed maps and cartography [3].

Another powerful feature of digital mapping applications is their ability to make huge amounts of data available to an individual user, through ‘as you need it’ streaming of data - iGeology, for example, is the equivalent of carrying 500 paper maps covering the UK around in your back pocket. Not only this, but you can tap and interrogate the map to receive additional descriptions of the geology beneath you to help inform decisions relating to your use of the local environment, for example, when buying property or developing land.

Mobile mapping applications are also extremely useful to the mapping agencies serving them out, as they enable a much better understanding of how many people are using the maps, and where. Feedback from users is also much more immediate and meaningful through the online comments and discussions surrounding the applications.

Fig. 1: the BGS iGeology App for smartphone and tablet computer in use in the urban environment.

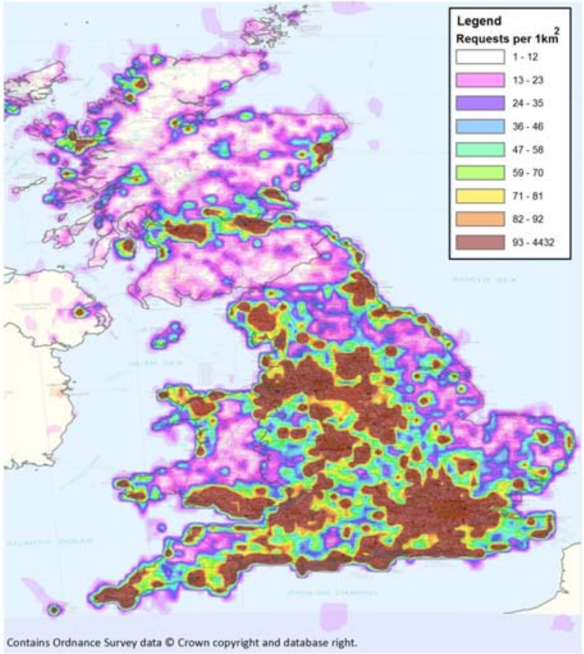

Fig. 2: Distribution map showing where the iGeology map has been interrogated by people using their smartphones and mobile tablets (September 2010 to November 2011).

The results can be quite startling. Since its launch in late 2010, BGS iGeology has been downloaded nearly 100,000 times from 56 countries around the world. The map in Fig. 2 shows where iGeology is being used in the UK. This map has been generated by knowing which areas of data are being downloaded by the user, and is the first time it has been possible to clearly see where BGS geological maps are being most used. The implications of this are very considerable, not least in planning where surveying work and research can be targeted for the greatest benefit to the user community.

From the map in Fig. 2 it is evident that most of the usage of geological maps is within urban areas and that there is a direct correlation between population density and usage. The most likely explanation for this is that our users are interested in the geology around where they live and work, or where they are considering using or developing land, which is often in the urban setting. However, there are some areas that do not follow this trend, for example the south coast of England and the Isle of Skye. We believe this is attributed to areas with interesting geological formations, where educational field trips take place or where the public is simply fascinated by the geology before their eyes and beneath their feet.

All of this is changing the way we as mapping agencies, and our customers, think about and interact with maps and, indeed, is leading us to question, what is a 'map'? The map is transforming from a physical organic 2D object that connects us to our physical world, to a digital construct which shares information on our environment with us as we move through it.

III. Expanding Dimensions (3D Going Underground)

Although these new style of digital applications are increasingly sophisticated and interactive, they still essentially 'trap' us in the two-dimensions of our phone or computer screens. This will always be extremely useful of course because the part of the world in which we live is in a sense a two-dimensional surface. An encounter with the third dimension is for most of us restricted to climbing a hill or descending into a valley, which on a paper topographical map may be represented by contours or artificial shadowing to give a 'two-and-a-half' dimensional impression.

However, when trying to convey the 3D complexity of the geological underworld, 2D representation is always going to be limited. It is this largely invisible third dimension which is more difficult to imagine, so we have up to this point relied on the skill of the geologist to 'read' the landscape and extrapolate to depth (a skill know as 3D acuity) and project it to us via the 2D map [4].

So the emergence of 3D communication technologies for the collection and visualization of information has great potential in the science of geology. The following sections describe some progress in this field including the exciting possibilities of a virtual reality world.

IV. A New Way of Map Making

As this progress has been made in mobile display of mapping, significant advances have also been made 'behind the scenes' in the use of new technology by geologists to collect and analyse information on the third dimension.

Leading this, as part of a digital geological workflow, the BGS GeoVisionary project (a collaboration with Virtalis Ltd, a British-based virtual reality company [5]) has revolutionised geological visualisation with software that allows seamless streaming of terabytes of data, merging digital geological maps, aerial photography, satellite imagery, field-slips, historical topographic maps, and subsurface 3D geological models, cross-sections and boreholes.

The system allows teams of geologists to carry out a 'virtual survey' of an area before commencing fieldwork, building an understanding of the terrain and the geology beneath the ground (Fig. 3). This initial assessment allows surveyors to effectively target fieldwork in areas where surveying is most required. On completion of fieldwork, surveyors can check their field interpretation in the virtual landscape. This team approach allows colleagues to collaborate, better enabling communication and scientific understanding. Another powerful aspect of GeoVisionary is to demonstrate the three-dimensional geology to collaborators and other observers with the added context of their own spatial data.

These changes in surveying techniques can be likened to geologists moving from making a jigsaw (the traditional 2D map) to building a Rubik's cube (the 3D geological model) of surfaces and volumes and in the process has opened up new opportunities and ways to deliver knowledge on our environment. 'Surveying' is still as important as ever but is now increasingly carried out in 3D digital environment – the map is still with us but has expanded in all dimensions.

Resulting from this new approach to mapping, today's 3D geological models show a huge variety of information, from the basic rock type (e.g. Chalk or Clay), to their chemical and physical properties and how fluids (such as water) or gases (such as CO_2) move through the various layers of geology, introducing the 4^{th} dimension of time. How certain we are of the presence of a particular rock type or structure can now be analysed and presented as a statistical probability thus adding deeper meaning to the modern map. In the future we will be able to dice and slice a geological model to deliver not just a map of the surface geology but from any specified depth from metres to kilometres, tailored to the user requirement.

V. DELIVERING 3D ENVIRONMENTAL INFORMATION TO THE MASS MARKET

Despite these advances in visualisation and surveying, there is still some distance to go in terms the widespread delivery and understanding of 3D information. As a community of modern geological map makers one of our key challenges is to bring the 3D presentation of geological models 'out of the lab' and to the mass market in the way we have done for 2D mapping with the first release of iGeology.

Fig. 3. Three-dimensional surveying using the BGS GeoVisionary system.

Some significant advances have already been made in the wider market place in display of 3D images via personal computer, for example, using software applications which allow 3D projections to be spun around by the user (e.g. Smithsonian National Museum of Natural History online 3D collection [6]). These techniques have a bright future (particularly as 3D screen technologies improve) but it is perhaps technological advances in the mobile and augmented reality computing field which have the greatest potential for aiding 3D visualization in the field of geology. Such technology is already in use in the astronomy field, with smart phone Apps such as SkyView (e.g. available via Apple's App Store) and our aim is to bring it to the field of geology.

As part of this, research and development is well under way at the BGS to develop 'augmented reality' applications for the mobile phone which can overlay the geology on the landscape as you look at it, and display the layers of geology beneath your feet where you stand (Fig. 4). The aim is to effectively dissolve the separation between the landscape around you and the information about that landscape locked up in a 2D map. This is an exciting prospect because it will empower the map by linking it in a 'real' way to the landscape you are observing, without requiring specialist skills in reading a 2D geological map.

Such augmented reality is made possible by the technology built into most smart phones. A camera provides the background view, GPS provides your location, an electronic compass gives the direction the camera is pointing, accelerometers measure tilt and an Internet connection provides access to digital map and elevation data.

For future development the augmented reality technique is also applicable to sub-surface information. An imaginary quarry could be cut anywhere in the landscape to show vertical sections through the geology. Such technology has the potential to really bring the map alive.

Fig. 4: BGS prototype 'augmented reality' Smartphone app for displaying the geological map over the landscape.

VI. MAPS – A NEW FOLD

As we expand beyond the restrictions of the 2D paper map to a digital construct capable of producing a 3D image of the space beneath your feet, is this the future 'point of discovery' for your local geology? Will future generations not buy paper maps because they have never used them? Is this the end of mapping as some may fear?

Philosophical debates aside, we would argue that modern communication technology is in fact driving a new generation of maps and rejuvenating the collection of environmental information to make them. This new generation of maps will take you beyond the restrictions of two-dimensions, to encompass the whole space around you. You will be able to view in 2D and 3D and to print out a tangible object if that is your desire. You will be able to use these new maps to analyze your environment and to look into the 4th dimension of time.

By accessing the vertical (or z) element in your space you will be able to undertake your own journey towards the centre of the earth. You are becoming part of the map.

ACKNOWLEDGMENT

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