From “Digital Mapping Techniques ‘09—Workshop Proceedings”
U.S. Geological Survey Open-File Report 2010–1335
http://pubs.usgs.gov/of/2010/1335/

BGS·SIGMAmobile; the BGS Digital Field Mapping System in Action

By Colm J. Jordan

Earth and Planetary Observation and Monitoring
British Geological Survey
Kingsley Dunham Centre
Keyworth,
Nottingham NG12 5GG
United Kingdom
Telephone: +44 115 9363227
Fax: +44 115 9363474
email: *cjj@bgs.ac.uk*

Introduction

The British Geological Survey (BGS) first explored the concept of digital field data collection in the early 1990s, with the conclusion that the mobile computing hardware at that time was not suitable. The development was therefore postponed indefinitely. However a stakeholder review of onshore geological mapping, including the means of collecting data, was undertaken in 2001. The review proposed a major change in survey methodology to include “digital field data capture and desk-top compilation” with “a consistent approach across all terrains and scales of survey” (Walton and Lee, 2001). These review outcomes initiated a major new project to update our mapping systems and workflow; the project was called SIGMA (System for Integrated Geoscience Mapping). One outcome of the new workflow is an implemented digital field data collection system designed and built in BGS; it is called BGS·SIGMAmobile. The system has won awards from both ESRI and the AGI (U.K. Association for Geographic Information). Using examples from current mapping projects, this paper briefly outlines the current capabilities of the BGS system, which is available for free download from the BGS Internet site (as described in more detail below).

System Development

Digital field mapping has been an aim of Geological Survey Organisations (GSOs) for many years. A look through a set of DMT Proceedings from a randomly chosen year (2004) highlights some of the work that has been (and still is being) undertaken in North America. Examples from the 2004 proceedings include Buller (2004) and Haugerud and Thoms (2004) both using Personal Digital Assistants (PDAs) in Canada and the United States, respectively, to collect digital field geological data.

One of the first steps in the development of the BGS SIGMA system was to host an international workshop on digital field data capture at our head office in Nottingham in the U.K. in 2001. Colleagues from mapping agencies and surveys across North America and Europe attended and presented their mapping systems. This was beneficial to all attendees, as the workshop ended with an informal agreement to help each other’s developments and cooperate where possible. The presentations from this meeting are available at *http://www.bgs.ac.uk/science/dfdc/home.html*. A similar meeting was held a few years later at the annual meeting of the International Association of Mathematical Geology in Toronto (2005), where the BGS system was presented (Jordan and others, 2005), and another held at the International Geological Congress in Oslo (2008). A session report for the 2008 meeting can also be found at the Web address listed above.

Early incarnations of the BGS system were designed to run on PDAs. A customized version of ESRI ArcPad 6.0.3 (ESRI vendor information is available from *http://www.esri.com/software/arcgis/arcpad/index.html*) served as the front end, whilst a bespoke BGS EVB application containing hard-coded data structure links in a compact database format was used to collect and hold additional relational data (fig. 1). Hierarchical input forms were used to collect various levels of data; index level data were added for each field site and

Figure 1. Screen grabs of the PDA field data capture system, with inset of field use and the complete 'digital toolbox' supplied to geologists.

the "Open Notebook" button gained access to more detailed forms for various mapping modules. The small screen size (approx. 6 x 8 centimeters) was sufficient to display a small map area along with the user's position, which was derived from a Global Positioning System (GPS) grid reference that was served via a Bluetooth GPS device. The field staff were equipped with a 'digital toolbox' containing the PDA, a Bluetooth GPS, a digital camera, and various accessories.

Whilst this was a leap forward from the hardware and software of the 1990s, the screen size was the major limiting factor with the PDA system. It was soon realized that while it was sufficient for point sample collection, it was not suitable for geoscientists working with maps. The screen was too small to visualize enough of the map face to gain a spatial context, and furthermore, annotating the visible area of the maps with lines, polygons, and text proved problematic as much scrolling beyond the current view was required to delineate even the smallest of landscape features. In order to overcome the screen size issue, and to provide additional functionality, BGS developed a system that runs on ruggedised Tablet PCs. We call the Tablet PC system BGS·SIGMAmobile. Internal beta testing began in 2005.

BGS·SIGMAmobile operates in the field on ruggedised Tablet PCs and laptops running XP for Tablet edition. The system will also run on desktop PCs. A heavily customized version of ESRI ArcMap 9.2 (*http://www.esri.com/software/arcgis/*) serves as the front end with relational data held in a customized Microsoft Access 2003 database. Additional functionality is provided by linking modified versions of InkWriter (software that enables handwriting recognition). BGS coding of the SIGMAmobile system is completed using a variety of inputs including VBA and .NET. It should be noted that BGS·SIGMAmobile is one tool in a full workflow (or toolbox) of digital systems and techniques for data compilation, 3D interpretation, data modeling, field data capture, visualization, and publication, all of which are underpinned by approved corporate databases, databanks, and data models (fig. 2).

BGS·SIGMAmobile is an integrated field system that enables the full array of geoscientific data to be recorded using tick boxes, sketches, drop-down lists, tagged free text, and photographs where appropriate. Spatial location and navigation are gained by built-in GPS whilst the stylus enables points, lines, polygons, and comments to be added to the digital map face. As with the PDA system, additional relational information is added using customized forms and a selection of interfaces. The system is modular, with tabs for various themes or domains of geological data such as structural readings, landslide information, auger/section recording, and so on. Furthermore, there are additional tools including the ability to draw sketches, annotate photographs, produce structure contours, and navigate using bearings. All of the data collected in BGS·SIGMAmobile are tagged with a unique user identifier (UUID) enabling the data to be queried in the office and traced through the corporate repositories.

A choice of tools for adding text, lines, and polygons to the map face is provided, ranging from a basic tool that

Figure 2. Representation of some of the BGS systems and techniques for data compilation, 3D interpretation, data modeling, field data capture, visualization, and publication. All of these are underpinned by approved corporate databases, databanks, and data models.

replicates the pencil and paper routine through to tools that enable topologies and attributed lines to be created in the field. Advanced handwriting software is used extensively to provide legible field notes (even on the map face); however, cursive text can still be used for rough notes where appropriate (fig. 3).

Additional data relating to points of interest are recorded via a master form (fig. 4) with buttons that access various modules relating to types of measurements or specialist entry forms. [It should be noted that not all of the modules shown in Figure 4 are available at present on the freely downloadable version.] These data are held in a relational database and may include text, measurements, sketches, photographs, and so on. Index data, such as grid reference, or UUID, are recorded automatically to save time at each location and to ensure that essential data are not omitted. Drop-down menus and tick boxes are used where possible and efficient to ensure that entries conform to accepted standards and that the agreed nomenclature is used, whilst areas for free-form text are also provided to allow flexibility. Novel systems have been developed and employed to ensure that the data recorded are unambiguous; for example, rather than asking a geologist to tick a box to note use of the right-hand rule when recording a structural measurement, we supply a basic compass which is ticked to identify the method used.

As noted above, the field mapping system is one tool in a geological survey workflow. It is therefore vitally important to develop procedures for easy data preparation / compilation prior to fieldwork, followed by straightforward and efficient data transfer / updates back to corporate databases on return from the field. BGS has tools that enable us to view and import the field data in our counterpart office GIS tool (SIGMAdesktop) and corporate databases, but we have also included some shortcuts in BGS·SIGMAmobile which enable data to be extracted from the field relational database into Excel spreadsheets. In addition to this, one of the developments that BGS is currently focusing on is the ability to transfer automatically all of the field data to our corporate databases with one button click, with quality control (QC) on-the-fly. However, because we are collecting more information in the field than many of the databases are designed to hold, it is resulting in some redesign of databases and some inventive data transfer coding.

Before BGS field staff use the equipment on mapping projects, they are provided with in-house training, in addition to the standard ArcGIS courses that we present. The training ensures that each geoscientist is aware of the capabilities of the system, how to apply them to the particular mapping application, how to prepare data and care for the equipment, and how to ensure that any health and safety issues of using computing equipment in the field are addressed. The training course spans two days: the first day covers hardware issues and guides geoscientists through the user interface; the second day is divided into a field trip to practice real-world field mapping at appropriate sites, followed by an afternoon session in the office learning how to extract the data from BGS·SIGMAmobile prior to further manipulation and study. We endeavour to group the training course attendees by their field of expertise so that, for example, overseas mappers are trained together in groups, as are bedrock mappers, landslide

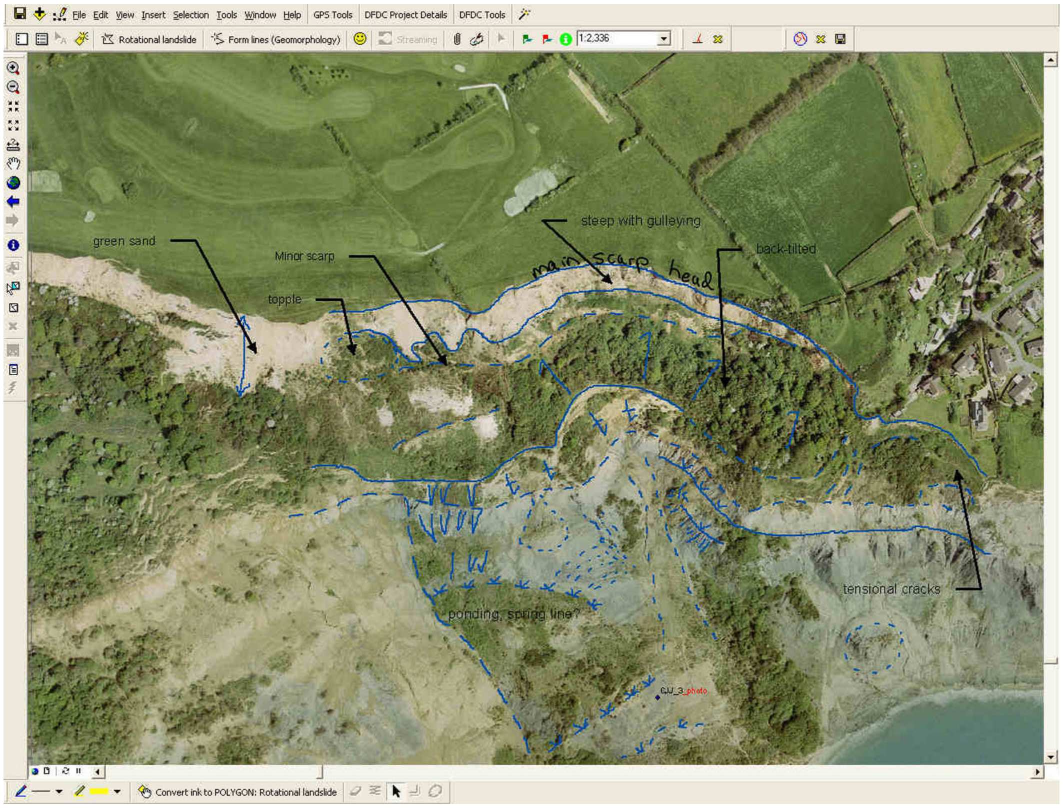

Figure 3. A screen grab of the GUI using data from a landslide at Blackvenn in Dorset, England. Points, lines, and polygons can be added with ease, as can handwriting, either through OCR or left in its native form. Airphoto base image is copyright of UKP/Getmapping Licence No. UKP2006/01.

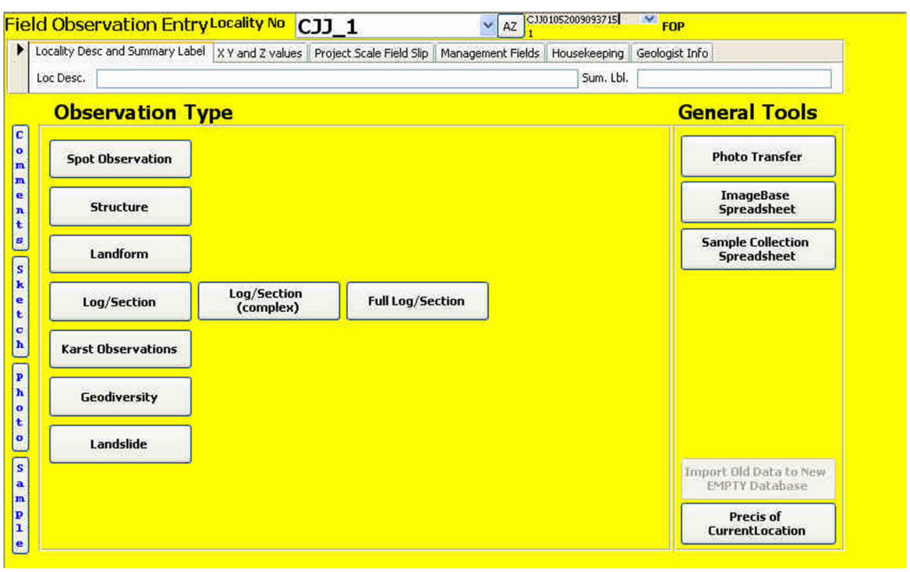

Figure 4. The master form from which modular data (including sketches) can be recorded in a relational database.

specialists, and so on, so that relevant modules of the system are explained in sufficient detail whilst others that might not be of interest to a particular mapping domain are reviewed but not dealt with in great detail.

ArcGIS is the prevalent GIS software in BGS at the moment; therefore, despite the addition of many buttons and tools in our system, the graphical user interface (GUI) of BGS·SIGMAmobile has retained much of the standard ArcGIS appearance. This ensures that the system is easier to learn because most of our geoscientists already are competent in the use of ArcGIS.

Hardware

The first hardware used by BGS was the Itronix GoBook (*http://www.gd-itronix.com/*) and, subsequently, the GoBook DuoTouch. The GoBook specifications included an IP54 ruggedness rating, 8.4-inch transmissive (dual mode active and passive) screens, a Pentium M 1.1 GHz processor, 1280 MB of RAM, a 40 GB hard drive, and integrated GPS. When equipped with a single internal (main) battery, they weighed 2.1 kilograms (kg) and had a nominal battery life of 3.5 hours. An additional battery could be 'piggy-backed' onto the back of the unit to provide additional power. The main (internal) battery can be changed but the procedure requires a screwdriver to remove a cover, so this was not recommended in the field. Whilst it is understood that the advertised battery life is nominal, and is greatly affected by the external temperature, screen brightness, and processes running (GPS, WiFi), it was our experience that the battery rarely provided power for 3 hours even for carefully maintained or new batteries. Furthermore, despite following the maintenance and calibration instructions, it was our experience that the batteries rarely lasted more than a couple of years before refusing to accept a charge. We also found that the screens had two weaknesses:

1. They were difficult to view in bright sunlight. This was partly addressed by the DynaVue system (*http://www.gd-itronix.com/index.cfm?page=Products:DynaVue*), but on the GoBooks it seemed to produce a grid pattern on the screen that was distracting to some users.

2. They were very prone to scratching, and protective transparent screen covers further reduced the visibility.

More recently BGS moved to a hardware system with a larger screen and longer battery life, namely the Xplore iX104 series (*http://www.xploretech.com/index.pl*). Also IP54 rated, the units that were available when ordered by BGS use a 1.2GHz processor, the screens are 10.4-inches diagonally, the nominal battery life is 5 hours, and the weight remains at 2.1 kg. In our experience, the screens are also more scratch-resistant than the GoBooks, whilst also being much easier to read in bright conditions, and the larger size is much preferred by the field staff. The batteries are warm-swappable and do not need to be 'piggy-backed'. Whilst the iX104 is more rugged than the GoBook, we have had several screens break when dropped in the field, and we have found replacing them to be very costly. In our experience it generally takes 6 weeks for the repaired unit to be returned from the U.K. reseller / supplier, and it needs a full reinstallation of all software and systems upon its return, which burdens us with a large overhead of IT support.

A recent addition to the BGS hardware store are two GETAC V100 (*http://www.getac.com*) rugged touchscreen notebooks, with screens that rotate to enable the kit to transform into rugged Tablet PCs. The specifications at the time of writing include a 10.4-inch screen, 120 GB hard drive, 1 GB of RAM, integrated GPS, battery life of 8 hours, and an IP54 rugged environment rating. Clearly, computing technology develops quickly and this is the preferred system used by BGS staff. The integrated keyboard provides additional functionality and flexibility, whilst the nominal 9-hour battery life (at 1.95 kg) is a bonus. The GPS antenna is flush with the tablet casing so is not prone to damage when the unit is being carried or if it is dropped. The hard drive can be removed easily and swapped to another unit. A brief review of hardware, with additional photographs, can be seen at *http://www.bgs.ac.uk/science/dfdc/home.html*.

Case Studies

BGS·SIGMAmobile is used extensively in traditional mapping and other more specialised projects across the United Kingdom and overseas in Africa, the Middle East, the USA, and elsewhere. The author has personal experience using the system on a GETAC in the deserts of the United Arab Emirates (UAE) from January to March 2009, on an iX104 during successive field mapping campaigns in Ghana, and on a GoBook over several months of field mapping in Madagascar, whilst it has also been used on an oil exploration project in Tajikistan (Jordan and others, 2009). The UAE, Ghana, and Madagascar include highly varied terrains and climatic conditions such as desert, tropical rainforest, savannah, and estuarine/coastal zones, and experience at those locations forms the basis for this multi-location case study. Systems were set up in each project to gain maximum benefit from BGS·SIGMAmobile. These three projects have in common such facts as:

- large areas needed to be mapped in very short timescales, and so efficient use of field time was essential;
- large amounts of disparate data (such as aerial/satellite imagery, airborne geophysics, and historic geology and topographic maps) were required in the field;
- navigation was often difficult;
- the clients were keen to see modern mapping techniques utilised.

A current BGS mapping project in the UAE includes field teams of six BGS geologists, with each geologist equipped with a rugged field device. The majority of staff used iX104s, while the author took the opportunity to test the newly released GETAC hardware. Figure 5 illustrates some of the ways that the system was employed in the project. Whilst paper plots of the satellite imagery were brought as backup (fig. 5A) the author did not make use of them at all, finding that the imagery was used more efficiently 'live' on the rugged field computer, with the traverse lines plotted onto a series of base layers such as Landsat ETM satellite imagery (fig. 5B). The imagery was acquired from NASA and processed by specialists in the BGS Earth and Planetary Observation and Monitoring Team. BGS·SIGMAmobile in its most basic form was used as a navigation aid (fig. 5C) with a GPS location symbol guiding the route-finding across the remote desert landscape, which is devoid of any roads or acknowledged route ways. When an outcrop or suitable exposure was located in the field, the data recording functionality of BGS·SIGMAmobile was used (fig. 5D). Periodically, the field teams met in the UAE field base, and all of the data (including points, lines, polygons, and all associated relational data and photos / sketches) were shared, linework was cleaned, and new traverses were planned (fig. 5E). The digital point and line data were used as a basis for the maps and reports that will be output from the project.

Inevitably, some staff found the move to the digital working environment easier than others, but because of the team environment, support was available to those less confident / capable with the new techniques. The desert environment did reveal some issues with the hardware; for example, on occasion the iX104s struggled to gain and hold GPS lock, whilst the GETAC never had such difficulties.

As part of a World Bank project, the author spent two seasons mapping the geomorphology of 255,000 km^2 of Madagascar at 1:500,000 scale. Prior to the use of BGS·SIGMAmobile, it was not uncommon to transport up to 30-35kg of paper plots of maps, satellite images, geophysical data and reports / papers to the country for a single mapping campaign. This author required no paper plots when the digital

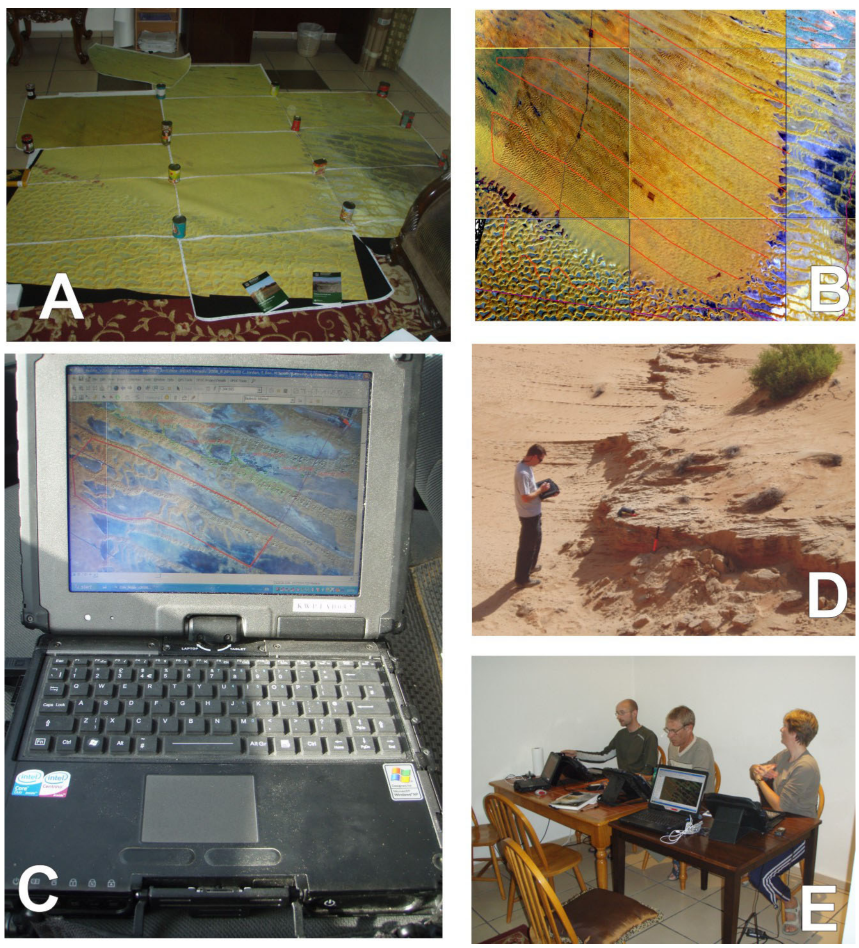

Figure 5. Images from the UAE mapping project, 2009. (A) Paper plots laid out on a floor; (B) same area as A illustrated in a GIS with the traverse lines annotated in red; (C) BGS·SIGMAmobile as a navigation aid, on the passenger seat of the 4x4; (D) GETAC used in the field with a stylus; and (E) staff cleaning / comparing / sharing their digitising in the field office.

field system was used. As in the UAE, one of the primary benefits of the digital system was basic navigation, both when traveling by road and also when conducting traverses by foot. Whilst the system commonly was used to collect point information, the main usage was to record geomorphological linework. Following basic topological cleaning whilst in the field, a legend was added by BGS Cartography staff in the United Kingdom, and the final maps were produced in a streamlined and efficient workflow.

In Ghana, BGS field teams were deployed over 3 years to remap the Volta River and Keta Basins (a combined area of approximately 98,000 km^2), as part of an airborne geophysics project funded by the European Union and conducted in cooperation with the Ghana Geological Survey Department (GSD). The airborne geophysical data were acquired by Fugro Airborne Surveys Ltd., and counterpart support was supplied by the GSD. Vast amounts of remote sensing (airborne and satellite) data were acquired during the project, along with gigabytes of scanned maps and reports, and one of the main challenges was to make these data available in the field. Having BGS·SIGMAmobile in Ghana ensured that navigation was made easier, data were collected to accepted standards, and the baseline data were to-hand when required at the outcrop or when travelling between exposures (Jordan and others, 2008). The pre-fieldwork interpretation was undertaken digitally and then added to or modified on BGS·SIGMAmobile in the field before being transferred back to the master GIS for map production.

Summary

The challenge of developing a digital mapping workflow is being met by the British Geological Survey using several bespoke systems (fig. 2), one of which is the field data capture system called BGS·SIGMAmobile. The system has been used successfully in projects across the globe, in varied terrains and climatic conditions. Brief examples from the UAE, Ghana, and Madagascar highlight the successful application of the system to current and recent mapping projects. BGS is still modifying the system to make it more efficient, to add new input mechanisms, and to add new modules, but it has proven its worth to our field staff with encouraging feedback being received by the development team, including statements highlighting the preference of the digital system over the traditional pencil and paper notebook and maps.

As noted above, the system is still being upgraded to increase functionality and efficiency, but the current system is available for free download to both academic and commercial users from *http://www.bgs.ac.uk/science/3dmodelling/sigma.html*. Users need to have their own ArcGIS and Microsoft Access 2003 licenses onto which the BGS system will run. When downloading the system, users must agree to send any modifications and (or) upgrades to BGS so that they can be added to future releases if appropriate. We hope that making the BGS system freely available will encourage shared development of an international standard system, leading to increased cooperation and knowledge exchange. We invite you to download a copy today.

Acknowledgments

Sincere thanks are due to the dedicated team of GIS and database developers for building an award-winning system of which they should be truly proud. We were helped by field staff who provided constructive feedback, while the support of management throughout development and implementation is gratefully acknowledged. This paper is published with the permission of the Executive Director, British Geological Survey (NERC).

References

Buller, G.H.D.P., 2004, GanFeld: Geological Field Data Capture, *in* Soller D.R., ed., Digital Mapping Techniques ’04 – Workshop Proceedings: U.S. Geological Survey Open-file Report 2004-1451, p. 49-54, *http://pubs.usgs.gov/of/2004/1451/pdf/buller.pdf*.

Haugerud, R.A., and Thoms, E.E., 2004, Geologic Data Assistant (GDA): An ArcPad Extension for Geologic Mapping, *in* Soller D.R., ed., Digital Mapping Techniques ’04 – Workshop Proceedings: U.S. Geological Survey Open-file Report 2004-1451, p. 55-64, *http://pubs.usgs.gov/of/2004/1451/pdf/haugerud.pdf*.

Jordan, C.J., Bateson, Luke, Bow, Jennifer, Newell, Andy, Napier, Bruce, and Sabine, S.J., 2009, GeoVisionary™ software for 3D visualisation and petroleum exploration in southern Tajikistan: RSPSoc 2009 Annual Conference and Proceedings, *http://nora.nerc.ac.uk/8854/*.

Jordan, C.J., Bee, E.J., Smith, N.A., Lawley, R.S., Ford, Jon, Howard, A.S., and Laxton, J.L., 2005, The development of digital field data collection systems to fulfil the British Geological Survey mapping requirements, *in* Proceedings of the International Association of Mathematical Geology 2005: GIS and Spatial Analysis, Toronto, v. 2, p. 886-891, *http://nora.nerc.ac.uk/8434*.

Jordan, C.J., Carney J., Turner P., Bateson L., McDonnell, P., and Thomas C., 2008, Application of digital data to the Airborne Geophysics Project in the Volta Basin, *in* Kalsbeek, Feiko, ed., The Voltaian Basin, Ghana Workshop and Excursion, March 10-17, 2008, Abstract Volume: Geological Survey of Denmark and Greenland (GEUS), p. 91-94.

Walton, G., and Lee, M.K., 2001, Geology for our Diverse Economy: Report of the Programme Development Group for Onshore Geological Surveys: Keyworth, British Geological Survey (NERC), 99 p.