Updating the Geology of the Volta River and Keta Basin of Ghana using Remote Sensing and Focussed Field Mapping

Colm Jordan[1], John Carney[1], Chris Thomas[2] and Paul Turner[1]

[1]*British Geological Survey, Kingsley Dunham Centre Keyworth, Nottingham, NG12 5GG, UK*
Email: cjj@bgs.ac.uk
[2] *British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH 3LA, UK*

Summary

The British Geological Survey (BGS) worked with Fugro Airborne Surveys and the Ghana Geological Survey Department on a European Union funded project (8 AGP GH 027/13) to update the geology and topography maps and undertake prospectivity modelling for an area covering approximately 100,000km^2. The focus of the BGS input was to update the geological knowledge of the Volta and Keta Basins and the resulting maps are being used for a variety of applications including encouraging inward investment by exploration companies who use them as a baseline for choosing prospective zones. Existing published materials were loaded into a GIS along with newly processed satellite and airborne imagery for heads-up geological interpretation. The satellite remote sensing data included 92 Radarsat fine beam images, 24 Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) scenes, and a 50m DTM derived from SRTM. The BGS interpretations and revised geological model were checked and updated over two field seasons using mobile GIS field mapping techniques. 96 topography and geology maps were produced by BGS at 1:100,000 scale. The combination of remote sensing and focussed field mapping enabled the geology of a large area to be mapped objectively within a short timescale. A substantial upgrade to the geological knowledge base of the area is now available to investors and researchers alike. This paper outlines the remote sensing methodology, along with a brief description of those geological results which are not commercial-in-confidence.

1 Introduction

The mineral sector in Ghana has shown significant growth in the past decade, thanks to an investor-friendly environment created by the Government since the mid 1980s. However, the success of the sector, which represents 38% of the total export value and employs more than 36,000 people (*statistics source*: Minerals Commission of Ghana), is unlikely to be sustainable, due to both internal (weak regulatory institutions and geological support organisations) and external (limited exploration funds and fierce international competition) factors. The rapid depletion of known resources through recently introduced intensive mining methods and the lack of discovery of new deposits implies that mineral output may decline substantially over the next 5 to 7 years. Private sector mining operations cannot be sustained, unless the mining institutions improve their operations, provide up-to-date geological and geophysical information to discover new resources and formulate and implement new policies.

The European Union has provided funding to the Government of Ghana, under the Mining Sector Support Programme (MSSP), to support these interventions. The MSSP overall objectives are to sustain the country’s mining sector economic performance, to alleviate poverty by increasing employment and to mitigate the mines’ negative environmental impacts. Its specific purpose is to enhance institutional capacities to effectively promote and regulate the mineral resources sector in order to reverse the current trend of reduced private-sector mineral exploration, while facilitating the development of sustainable medium-term projects.

One MSSP Project was awarded to Fugro Airborne Surveys Ltd. and BGS from November 2006 to March 2009 to carry out work in the Volta River and Keta Basin areas (Figure 1), which together form a major portion of the Ghanaian territory. The total area amounted to 98,000 km^2 which is approximately the same size as Scotland and Wales combined. The project was designed not only to provide a geological framework for mineral exploration and groundwater resources but also maintain and increase the skills of the counterpart Ghanaian geoscientific workforce.

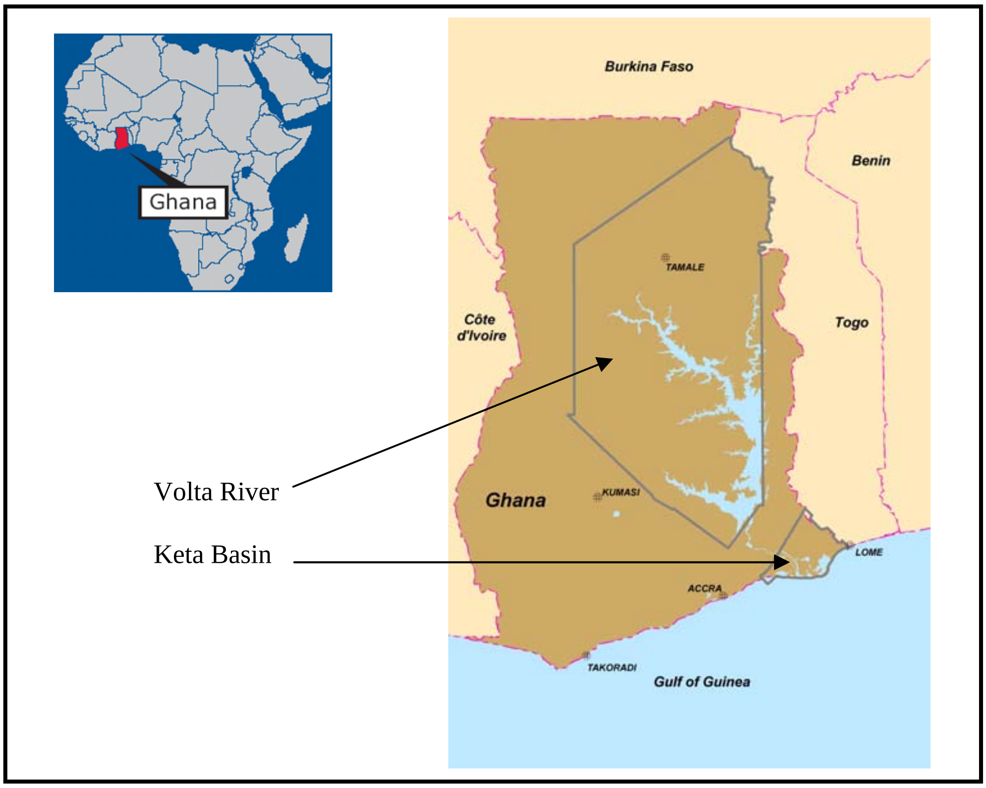


Figure 1. Location map of the Volta River and Keta Basins in Ghana

The project was very complex, combining existing geological models and research with satellite data, airborne geophysics and fieldwork. Only a few aspects of the project can be covered in the format of this extended illustrated abstract.

2 Methodology

The BGS methodology (Figure 2) is divided into three stages. The first stage (outlined in blue) involved compiling and assessing any available appropriate information, which was collected during visits to Ghana as well as from UK institutions and other European collections. These data were assessed before those deemed reliable were used to produce an outline geological model, *i.e.* a conceptual model of the geology of the Volta and Keta Basins. A Geographic Information System (GIS) was used to compile, compare and collect all spatially-enabled datasets throughout the project, as well as for image interpretation, prospectivity modelling and map production.

The early steps in Stage 2 run concurrently with Stage 1, so while existing geological publications were collected and analysed, the BGS also acquired a range of remote sensing datasets including Landsat TM, ETM and Radarsat imagery as well as a Digital Terrain Model (DTM). The imagery were geocorrected using ephemeris data from the satellite sensors along with Ground Control Points (GCPs) from the differential GPS survey. Following manipulation in digital image processing software to highlight geological features, the imagery was interpreted in light of the geological model, and then brought to the field on customised BGS mobile GIS's so that reconnaissance fieldwork could be undertaken prior to producing 96 preliminary geological and topographical maps at 1:100,000 scale.

Stage 3 (outlined in red below) consisted of integrating the newly-acquired Fugro geophysical datasets and re-evaluating the geological interpretation during a second season of fieldwork. Additional rock samples were collected in the second field season and the most appropriate from the two field seasons underwent multi-element and fire assay analyses.

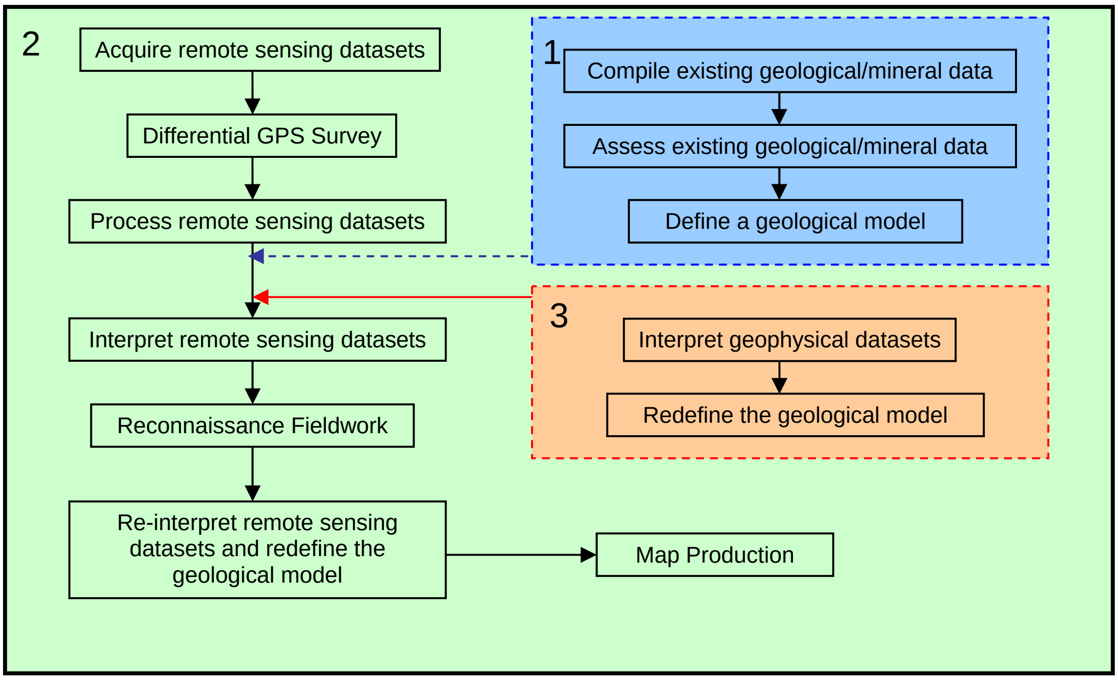


Figure 2. Flow chart of the methodology applied to the mapping and remote sensing

3 Image Processing & Interpretation

Three satellite remote sensing datasets were acquired; Landsat (TM & ETM), Radarsat and a DTM. Twelve Landsat TM and twelve ETM scenes were required for complete coverage of the Volta and Keta Basins (Figure 3). The Landsat data were primarily used to distinguish and outline Quaternary and Holocene sediments/features such as alluvium and estuarine deposits. The imagery were also used to update the existing 1:100,000 scale topographic maps of the regions. In addition to fundamental band combinations (such as 4,5,7; 7,4,1), we also produced and used band ratios and principal components images to highlight lithological and mineral heterogeneity.

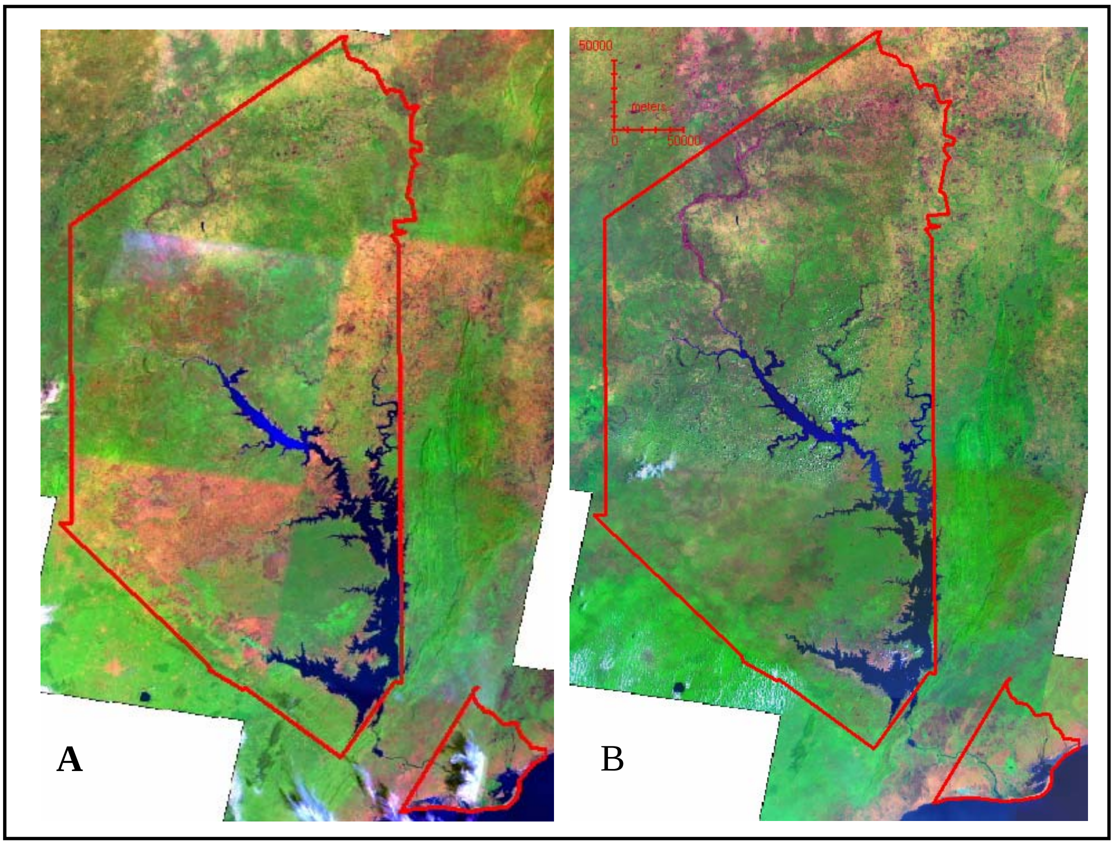


Figure 3. Landsat image mosaics, band combination 7,4,1. A) TM data; B) ETM data

Ninety-two fine beam (6.25m) Radarsat frames were acquired. Initial checks of the data indicated that rectification using the ephemeris data produced inaccuracies up to 320m so the images were compiled into strips and rectified using Ground Control Points (GCPs) referenced against the Landsat data and the dGPS survey. An average of 200 GCPs were used per strip resulting in a total number of approximately 3,600 GCPs. A mosaic was subsequently produced to make the task of interpretation easier as the geologist is not distracted by contrast variations that are due to image variance rather than geological features (Figure 4).

A (DTM) with a 50 m horizontal grid spacing and a predicted vertical accuracy of less than 16m was derived from the Shuttle Radar Topography Mission (SRTM) data. The DTM extends 1km beyond the periphery of the project area and also includes the region between the Volta and Keta Basins so that modelling and interpolations, such as the creation of contours extended smoothly to the limits of the area. Before the DTM was used to derive new information such as contours and geological features, it was necessary to ascertain and confirm its spatial accuracy. The DTM elevations were compared with those from the differential GPS survey and the difference values were plotted to assess the overall vertical accuracy. The results indicate that the vertical accuracy is well within 16m (normally lying within 10m except for 16 points which were affected by forest canopy or cliff edges. The data were used in a variety of guises including shaded reliefs, 1st derivative and perspective views in visualisation packages such as GeoVisionary™.

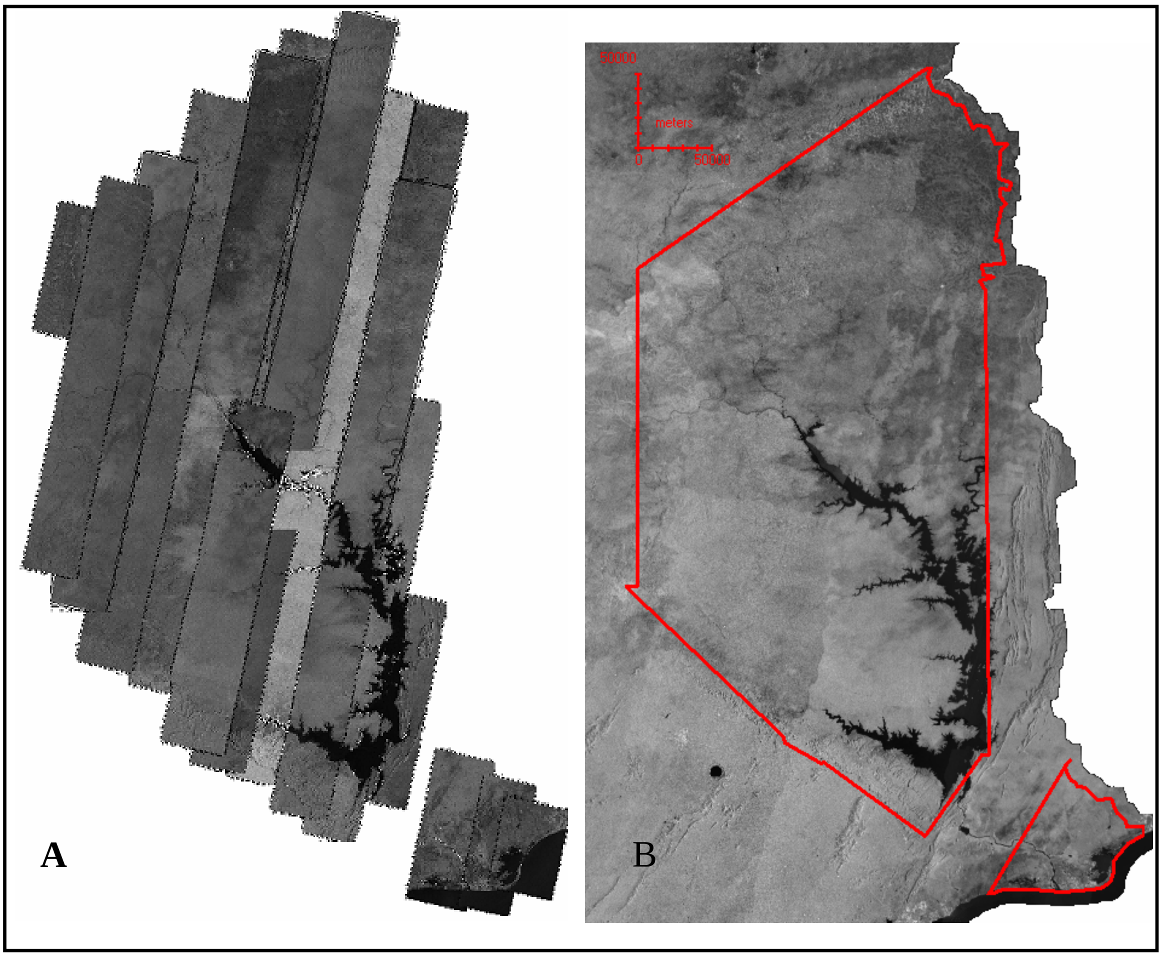
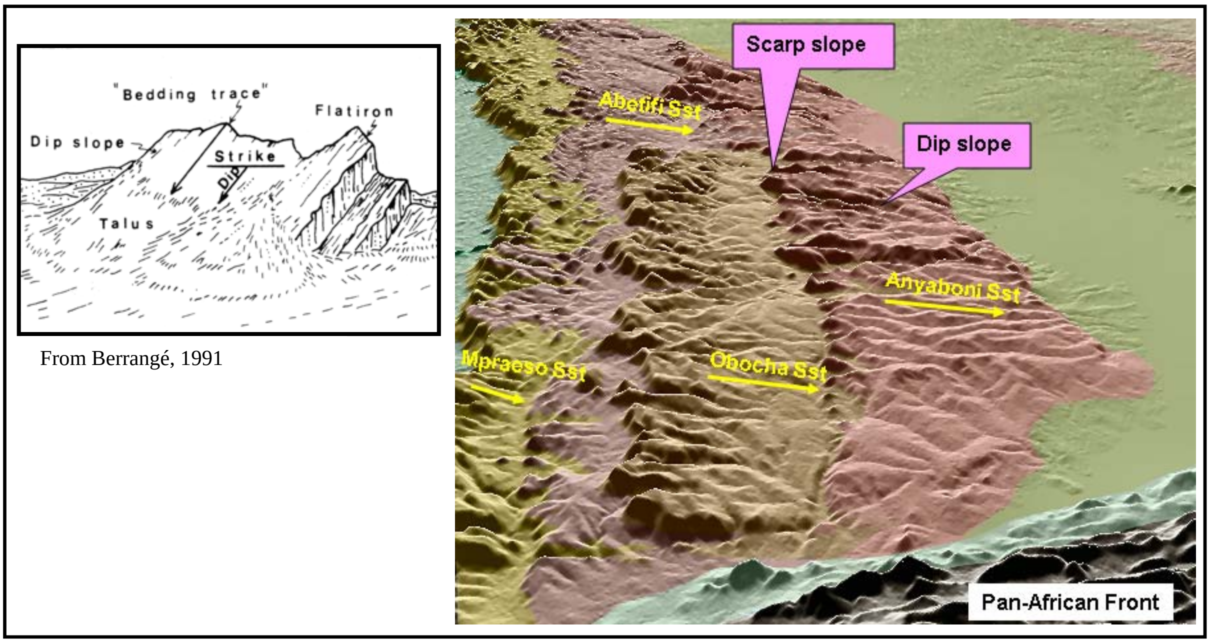


Figure 4. Radarsat imagery; A) fine beam strips and B) 25m resolution mosaic

The appearance of the ground surface depends on a complex interaction of a number of factors, the most important of which are climate (both regional and local), tectonic setting, stage of geomorphic development, lithology, and structure (Berrangé, 1991). Each of the remote sensing datasets has a specific 'strength' in terms of what geological or geomorphological information it can contribute. The texture of the landscape from the Radarsat and DTM, along with the spectral properties of the Landsat datasets contributed information regarding lithological variations (although this was limited) as well as structural information. An understanding of the bedding is essential for a remote sensing interpretation of the geological structure; although detailed fieldwork is a prerequisite in areas where no bedding can be seen due to deep weathering, cover by superficial deposits, or simply due to lack of bedding in the succession. Bedding manifests itself in various ways on the remote sensing imagery, the clearest being the 'bedding trace', which is the line separating the dip slope from the relatively steeper scarp slope (Figure 5). In the example below, the DTM of the Kwahu escarpment is shown in perspective view with the interpreted geology overlaid in semi-transparent colour. The viewer is looking from southeast to northwest parallel to the trend of the bedding trace, i.e. along strike. The dip trend is from left to right i.e. towards the northeast.



From Berrangé, 1991

Figure 5 Relationship between strike/dip and bedding trace in the Kwahu Plateau (SW Volta River)

4 Reconnaissance Fieldwork

Reconnaissance geological mapping was conducted over two field seasons. The fieldwork objectives were to verify the image interpretation and conceptual geological model, to visit mineral localities and to examine exposures of as many geological units as possible. Over 700 localities were recorded and samples were collected for various analyses including thin section, fossil identification and multi-element and fire assay. Lithological information was mainly obtained from roadside and drainage ditch exposures, but advantage was also taken of quarry exposures and debris from excavations, particularly for reservoirs, water wells, pit latrines and telecommunication tower construction. Satellite imagery and DTM data were continually referred to in the field, allowing the integration of lithological and landform observations with features discerned on the imagery. Bedrock and surficial boundaries were verified and revised in the field.

5 Geological Map

The revision of the geological model is outwith the scope of this abstract but will be published separately in due course in collaboration with our Ghanaian colleagues. For a review of the geological model and project datasets please refer to Carney et al (2008), [1]Jordan et al (2008) and [2]Jordan et al (2008). Figure 6 provides a basic overview of the increased detail that has been added by the BGS mapping, even though it cannot illustrate the lithostratigraphic updates. A full legend has not been provided here for the maps but please contact info@gsd.ghanamining.org for access to the maps and accompanying databases.

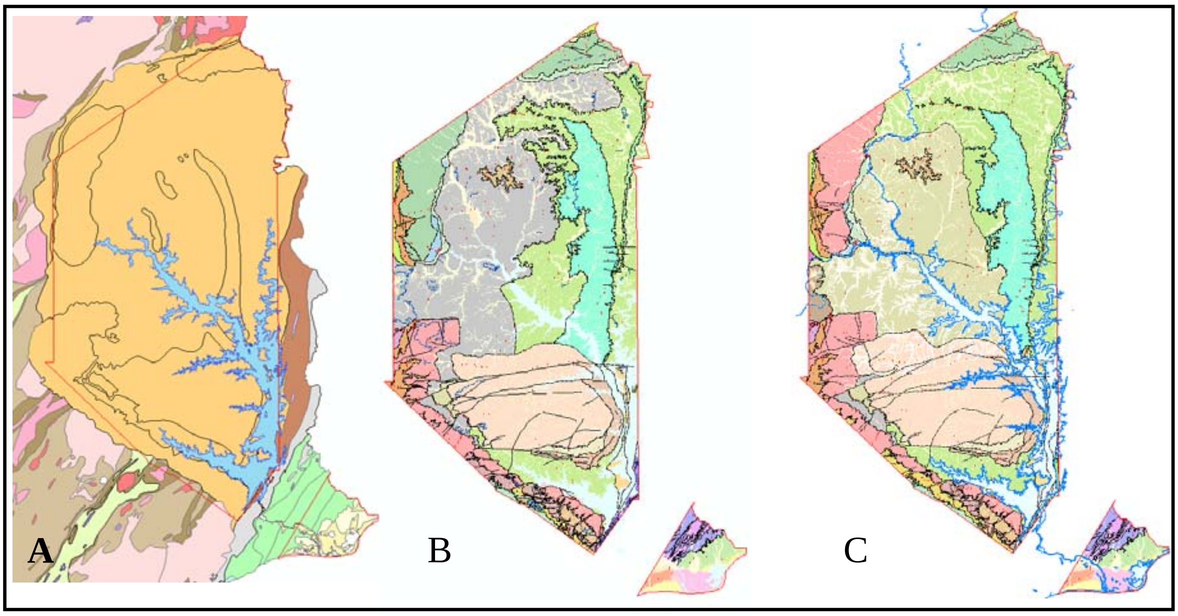


Figure 6. A basic illustration of the modifications to the geology over the course of the project. A) Original geological map (after Bates, 1954), B) update after 1st BGS field season, C) update after 2nd field season.

6 Conclusions

Mapping an area the size of Scotland & Wales combined, with the limitation of just four months of fieldwork meant that remote sensing was going to be a fundamental part of the project. Furthermore, the project area is characterised by dense vegetation and subdued relief, and apart from the hilly tracts that form the rim to the Volta Basin, there are very few rock exposures. Given such conditions, it is felt that the geological map revisions have vindicated the importance of using remote sensing imagery to interpret geology. A revised set of geological maps were produced (incorporating an updated lithostratigraphy) and are available from the GSD.

7 Acknowledgements

The authors would like to thank the Director and staff of the Ghana Geological Survey Department for their assistance during the project and their permission to publish this abstract. This paper is published with the permission of the Executive Director of the British Geological Survey (NERC).

References

BERRANGÉ, J.P. (1991) Aerial photography, photogeological interpretation and mapping: course notes. *British Geological Survey Technical Report WC/91/36*. 75pp

BATES D A (1954) Geological Map of Ghana. Published by the Geological Survey Department of Ghana.

CARNEY J, JORDAN C J, THOMAS C AND MCDONNELL P (2008) A revised lithostratigraphy and geological map for the Volta Basin, derived from image interpretation and field mapping. In: Kalsbeek (ed) *The Voltaian Basin, Ghana Workshop and Excursion, March 10-17, 2008, Abstract Volume*. pp 19-24. ISBN 978-87-7871-233-2.

Ghana Minerals Commission: Mining Portal of Ghana
http://www.ghana-mining.org/ghweb/en/ma/mincom.html

[1]JORDAN C J, CARNEY J, THOMAS C AND MCDONNELL P (2008) Application of remote

sensing and field mapping to a revision of the geology of the Volta Basin. In: Kalsbeek (ed) *The Voltaian Basin, Ghana Workshop and Excursion, March 10-17, 2008, Abstract Volume*. pp 87-90. ISBN 978-87-7871-233-2.

[2]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 (ed) *The Voltaian Basin, Ghana Workshop and Excursion, March 10-17, 2008, Abstract Volume*. pp 91-94. ISBN 978-87-7871-233-2.