DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/87

3rd Progress Report Mining sector development and environment project

NDF Credit 156 - 14
Adviser to the Director of the Geological Survey Department (GSD)

Feiko Kalsbeek

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

GEUS

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

G E U S

Republic of Ghana

Ministry of Mines

Minerals Commission

3rd Progress Report

Mining Sector Development and Environment Project

NDF Credit 156-14

Adviser to the Director of the Geological Survey Department (GSD)

August 2003

This report contains restricted information and is for official use only

Prepared by the Geological Survey of Denmark and Greenland

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Enclosures: Geological maps of Fields Sheets 1001A4 (Upper East Region) and 0501B3/B4 (Greater Accra Region)

1. Activities in the period January 1st to June 30th 2003

Under the contract between the Geological Survey of Denmark and Greenland (GEUS) and the Minerals Commission, Ghana, the Geological Survey Department (GSD) was visited by the Adviser (Dr. Feiko Kalsbeek) from January 15th to February 15th, and from April 1st to May 2nd, by Mr. Bjørn Hermansen from January 15th to January 30th, by Dr. Jeroen van Gool from April 21st to May 2nd, by Mr. Leif Thorning from May 18th to May 31st, and by Mrs. Lisbeth A. Christensen from May 23rd to May 31st. Mission reports of these visits are attached to this report.

Apart from these activities GEUS has supported the GSD in various other ways, see Appendix 1.

2. General Conditions

Most of the general conditions as described in the 1st and 2nd Progress Reports have not changed in any significant way. Most progress was made in the field of Data Management – GIS and Database systems.

It was striking that during the Adviser's visits many of the junior geologists were not present. Some were on extended leave, some just did not come. One geologist formally left the Survey after a long period of absence. It appears that, with the present gold prices, it is easier to get jobs (and a much better salary) in the mining industry.

Funding: Funding of the Survey's key activities appears to be even worse than in 2002. There has been little money available for field work, and there is hardly any money for the GSD's daily expenses. It is obvious that, under these conditions, the Survey is not able to perform many of its natural activities.

Perhaps worse than the limited funding is the uncertainty if and when any money will be released. Even if funds have been granted by the government for a particular purpose, such as mapping, this does not mean that the money is actually released in time. Funding for geological mapping in 2003 had actually been appropriated by the government, but no money had been released before the end of March, shortly before the beginning of the rainy season. Under these conditions any planning becomes impossible.

Semi-autonomous status: The 'Draft Geological Survey Act' has been presented to the Sector Minister for consideration but, partly because of a change of Minister, no further steps have yet been taken.

Structure of the GSD: The structure of the GSD previously agreed upon was continued without changes. However, some of the Divisions are not yet fully operative. For example, the Division for Geochemistry cannot function optimally before the chemical laboratory is in use.

The weekly meetings of the Divisionary Heads with the Director, suggested by the Adviser (Inception Report, p.11), have been held rather irregularly. At several occasions the Director has stressed the importance of these meetings but, when he himself is unable to attend because of other obligations, the meetings are commonly cancelled. During the Adviser's visit in January – February 2003, for example, only one meeting with the Divisionary Heads was held.

Cooperation among the different Divisions should be strengthend: Geological mapping, for example, would gain by better cooperation between the Departments of Geological Mapping and Geophysics, and the compilation of geological maps can be made easier by better cooperation between the Divisions of Mapping and Data Management. Such cooperation would be strengthened by the weekly meetings and discussions between the different Heads of Divisions, if these took place regularly.

Geological mapping: Little mapping has been carried out during the first half of 2003. Plans had been made for field work in the Upper West Region (two teams), the Upper East Region (one team), the Volta Region (two teams) and the Western Region (one team). However, no funding had been made available before the middle of March, and therefore these plans largely failed. Since also hardly any mapping had been carried out in November-December, most of the best time of the year for geological mapping (the dry season) was lost, and it will not be possible to produce more new maps this year.

The only field work carried out took place for about one month (18/3 – 13/4) in the Upper East Region (1 team), for about three weeks in the Volta Region (two teams, 20/3 – 13/4 and 24/3 – 13/4), and for ten days in the Western Region (25/3 – 3/4). Mapping was not resumed after Easter because the rainy season had started. Mapping in the Upper West Region had to be cancelled because of technical problems with the vehicle.

Mapping of the Field Sheet in the Volta Region was a continuation of earlier mapping in that area, where the mapping teams were visited by the Adviser and Dr. Martin Sønderholm in November-December 2002 (2nd Progress Report, Appendices 4 and 5). The stratigraphy of the area is not yet well enough understood, however, and, since it is not possible to map this area without a proper insight in the stratigraphy, it is unlikely that mapping of this Field Sheet can be finished this year (see the Advisers brief report to the Director, Appendix 4, Attachment 2).

In April the Adviser and Dr. J. van Gool visited the geologists in the Upper East Region. They could not continue their work because of the lack of funding, but they showed us around in their area. This work had started well and, if funding had been made available for another four or five months of field work, mapping of this Field Sheet could have been finished this year. Dr. Van Gool demonstrated how linear fabrics can be used for the interpretation of the pattern of deformation of rocks. It is important that at least some of GSD's geologists study the methods of modern structural geology in order to improve the mapping.

Later we visited the mapping area in the Western Region, together with Mr. G. Loh. In this area well preserved rocks of the Birimian Supergroup as well as granitoid rocks are beautifully exposed. This area would be eminently suitable for an excursion with a group of Assistant Geologists, which would be of great value in their further training. GEUS has offered to sponsor such an excursion.

During the Advisers visit in April estimates were made for the actual costs of geological/geophysical mapping in Ghana (Appendix 4). It appears that a significant part of the costs is made up of 'allowances', extra payment to the participating staff (of the same order as their normal income). Seen in the light of the very low salaries of GSD staff (as in other governmental departments) this is necessary. However, in the long run it would be preferable if the GSD (after becoming semi-autonomous) could pay its staff better wages so that the allowances could be lowered.

Mapping manual: The Adviser has continued his work with the draft mapping manual (see 2nd Progress Report, Appendix 6). A section on the compilation of geological maps has been added, and a listing of Archive Reports describing the various field sheets for which geological maps are available (Appendix 3 of the manual) has been prepared, see Appendix 7 of this Progress Report. A new edition of the mapping manual has been produced in A5 format for easier use in the field.

Chemical Laboratory: The laboratory in which the Spectro X-2000 is going to be installed is now ready, but the auxiliary instrumentation has not yet been acquired, and the instrument has not been installed. This is unfortunate, since the necessary cooling of the instrument is expensive, and the warranty period is gradually running out. It is strongly advised that the ministry provides funding for the installation of the instrument in order to prevent further waste of money.

It is planned that two members of GSD staff will visit GEUS for training in the analysis of geochemical materials by X-ray spectrometric methods.

Digitizing of older geological maps: The GIS laboratory at the Division of Data Management has continued its work with digitizing old geological maps. Mr. Bjørn Hermansen of GEUS visited the GSD in January 2003 to support the GSD in this activity (see Appendix 3 of this report). It has been decided to add short 'explanatory notes' to these maps in order to make them more useful. These explanatory notes must be prepared by abstracting the original reports to which the maps in question belong, which requires a solid knowledge and understanding of geological issues, and it appears that not all Assistant Geologists can do this professionally. Further general training of the Survey's junior geologists is urgently required.

Three Assistant Geologists employed at the GIS laboratory have been elected for further training at the University of Applied Sciences in Berlin, Germany.

Production of new geological maps: Three new geological maps were produced during the first 6 months of 2003. The first of these (Jirapa East and Tumu West, 1003A2/A4 and B1/B3 in the Upper West Region) was included in our 2nd Progress Report. The other two (Field Sheet 1001A4 in the Upper East Region and Field Sheets 0501B3 and B4 in the Greater Accra Region) are added to this report.

For two of the three maps no progress had been made during the absence of the Adviser, partly because of misunderstandings between the Divisions of Geological Mapping and the GIS laboratory on the necessary procedures, and most of the work was done during the Advisers visits in January-February and in April (see Appendices 2 and 4). Map production greatly benefited by the presence of Mr. Hermansen in January.

While the GIS laboratory is responsible for the technical production of the maps, the mapping geologists must take an active part in drawing boundaries between rock units on the map, the lay-out of the map legend, the drafting of cross sections and the preparation of the explanatory notes. This requires a close cooperation between the geologists and the GIS group. Such a cooperation appeared not to come naturally but had to be encouraged by the Adviser.

In order to assist the map compilation process a section on this topic has been added to the Mapping Manual (see Appendix 7A).

Ghana Mineral Occurrence Database. During a visit to the GSD by Mr. Leif Thorning and Mrs. Lisbeth Christensen a prototype of a Ghana Mineral Occurrence Database (GMODB) was developed in close cooperation with Mr. Kwame Odame Boamah (Head of GSD's Division of Data Management). This was a follow-up on the visit of Mr. Thorning to the GSD in May 2002, and a stay at GEUS by Mr. Boamah in October 2002 (see 1st Progress Report, Appendix 9 and 2nd Progress Report, Appendix 3). Among the different databases needed by the future Ghana Geological Survey the Mineral Occurrence Database was chosen because this was specifically mentioned in the TOR of the contract. Apart from being of direct use for the GSD, the GMODB can be used as an example for the setting-up and using other databases by GSD staff. It is planned that Mr. Boamah later this year will visit GEUS once more in order to gain more experience and further develop the database.

At present only a few of GSDs staff members have access to a PC. It is expected that gradually more PCs will be acquired. If, simultaneously, progress is made with the computer literacy of the staff, many will be able to make use of these databases.

Human Resources Development: Because hardly any field work has been carried out during the first half of 2003 only little could be contributed to GSD geologists skills in field mapping. However, the draft Mapping Manual was handed out to all mapping geologists and may have contributed to their abilities.

Hardly any use has been made of the study collection of thin sections by the junior geologists of the Division of Geological Mapping. As mentioned in earlier reports this is very unfortunate, because a geologist who is unable to verify the mineralogical composition of his rocks in the microscope is of little use to the Survey.

The visits of Mr. Bjørn Hermansen in January and Mr. Leif Thorning in May have been beneficial for further development of the skills in GIS and Database issues at the Division of Data Management. The present stay of three of the Division's junior geologists at the University of Applied Sciences in Berlin for further training in GIS applications will be a significant contribution in this respect.

Records: The Archive Rehabilitation Unit under the direction of Dr. R. Mauer has finished re-editing 100 'Archive Reports' on geological mapping projects carried out in the 20th century. The Adviser has contributed to the process by general advice and by critical proof reading of a number of the Reports. The Archive Reports will be made available to the public on CD-ROM. No decision has yet been made on the manner of distribution of the CD, and no pricing policy has been decided upon.

Ninety-Years Anniversary Celebration: In 2003 the Geological Survey of Ghana will have existed for 90 years, and the Survey has planned to celebrate the occasion with a number of radio and TV presentations during 2003, ending with an international symposium in February, 2004. It is the Director's aim in this way to bring the GSD more into the awareness of the general public (and the Government), and thereby, hopefully, to ensure better support of its activities. GEUS has not been involved in this process, but is willing to help with advice if needed.

Launching of the Anniversary celebration took place on April 3rd, in the presence of a large number of dignitaries, among which the outgoing and incoming Ministers of Mines, the British High Commissioner, and a representative of the German Embassy. For the occasion a small exhibition had been made of rocks, raw materials, publications and maps, to give the participants an impression of the Survey's activities. Launching the Anniversary was a very successful event, with radio and TV coverage, and with a large number of journalists present.

3. APPENDICES

APPENDIX 1. Other GEUS services to GSD

Outside the contract and without outside funding, GEUS has supported the GSD as follows:

- In order to support the work of GSD's Division of Clay Mineralogy and Ceramics, full chemical analyses (XRF) were made of 50 clay samples.
- Fifty-seven thin sections and 38 chemical analyses (XRF) were made of rock samples for the Division of Geological Mapping.

APPENDIX 2.

Republic of Ghana

Ministry of Mines

Minerals Commission

Mining Sector Development and Environment Project

NDF Credit 156-14

Adviser to the Director of the Geological Survey Department

the Advisers 7th visit to the Geological Survey Department

Mission Report – 15 January to 14 February 2003

Prepared by Feiko Kalsbeek

Geological Survey of Denmark and Greenland (GEUS)

Report on the Advisers 7th visit to the Geological Survey

15 January – 14 February 2003
Feiko Kalsbeek

Most of this visit was used with (1) the final production of the geological map Jirapa East / Tumu West (Upper West Region), and (2) further work with the draft Mapping Manual (both included in my 2nd Progress Report). I had also planned to visit the field teams in order to give further support and training in geological mapping, but, although this is the best time of the year for field work, no geologists were out in the field. No money for this purpose for the fiscal year of 2003 had as yet become available.

It appeared that, during my absence, none of the junior geologists has worked with the thin section collection prepared for self-study. During my stay at the Survey I urged some of them to take up this study again, but with limited success. Only in the last week of my stay two of the Assistant Geologists came intermittantly to study the collection. Much of the time several of the Assistant Geologists were not at the GSD during working hours. Also one of the Geologists of the Mapping Division was absent for most of the time.

Map compilation. Although most of the compilation of map sheet Jirapa East / Tumu West had been done in September / October 2002 (see 2nd Progress Report, Appendix 2), numerous practical problems had to be solved before final printing could take place. In fact not much progress had been made during my absence. There were some apparent disagreements between the localities given by the data files and the position of the boundaries between rock units drawn by the mapping geologists. These and other problems were solved during my visit, through close cooperation between GSD's Division of Data Management and the mapping teams, with the assistance of Mr. B. Hermansen (GEUS). Further, a manuscript had to be prepared to be used as 'explanatory notes' to be printed on the map, and a legend had to be made. Since this was the first time in recent years that a geological map was prepared at the Survey, all this work was new and therefore time consuming. With the experience gained during the production of this first map, it is likely that future maps can be produred with greater ease and within shorter time.
Final printing and acceptance of the map took place on February 12th 2003. Since the map is in digital format new information can be added, and other improvements made, in later editions. A copy of the map is included in the 2nd Progress Report.

Mapping Manual. The text and some of the figures for the draft Mapping Manual were ready by the end of 2002. After discussions at the GSD some changes were made during my visit and a number of new figures were prepared and included into the text. It had been anticipated that the draft Manual should be tested for its usefulness in the field, but this was not possible during the present visit, since no field work was going on. A number of copies were made for the field teams that are expected to start mapping when the necessary funding is released. It is anticipated that, during the field work, the mapping geologists will come with requests for more topics to be inserted, and other changes to be made.

Field work. During my stay at the Survey proposals for this year's field work were discussed on several occasions, but because of the uncertain economic situation no firm decisions could be made. The sudden increase in fuel prices in January enhances the uncertainty about field projects for 2003. At a meeting on Thursday 13 February with the Heads of Departments the Director expressed his hope that money would be made available for three months of field work (geological and geophysical field teams). Geological field work was planned for the Upper West Region (two teams), the Upper East Region (1 team), the Volta Region (2 teams) and the Western Region (1 team).

Heads of Divisions meeting. The Heads of Divisions meeting of Thursday 13 February, one day before my departure, was the only one held in this period. Several important topics were discussed, among other items funding and budget, field activities, and the upcoming 90-years anniversity of the GSD. The Director emphasised the importance of the Heads of Divisions meetings, which also should take place at times when he was himself unable to come because of other obligations. I mentioned the problem of the common absence of a number of younger geologists, several of which only rarely come to the office. The Director asked the relevant Heads of Departments to take care that staff under their responsibility did come to work – it is unacceptable they have other jobs while being paid their GSD salaries.

From talks with some of the Assistant Geologists I have understood that their salaries are not adequate to support their families. Therefore they have to find ways to supplement their income, which may explain their irregular attendance at work. Poor remuneration of its staff is one of the many problems facing modernization of the GSD.

APPENDIX 3.

Republic of Ghana

Ministry of Mines

Minerals Commission

Mining Sector Development and Environment Project

NDF Credit 156-14

Adviser to the Director of the Geological Survey Department

Producing Digital Maps and Associated Databases

Mission Report – January 2003

Prepared by Bjørn Hermansen
Geological Survey of Denmark and Greenland

Mission Objective

To make a follow-up on the activities started in January 2002 concerning digital maps and map-databases. This includes 4 main tasks:

1. Producing an index map with data associated to each existing geological map sheet.
2. Starting and maintaining the process of digitising the geological paper maps at the GSD.
3. Building up a human resource capable of handling digital maps through GIS at the GSD.
4. Help introducing GIS methods in the mapping of new areas as well as the production of new geological maps from field data.

This is the third mission report that relates to the chapter 8 in the Inception Report to this project: ”Geological Maps, Records office and Library”. The second report was made after the visit from 23/4 to 7/5 2002. This report describes the project in connection with my third visit at GSD from 15/1 to 30/1 2003.

Status at the 15th of January 2003

Since my visit in May 2002 several matters had changed in a positive direction:

- The hardware in the GIS-laboratory had been supplied with two new PCs of suitable power (1.8 GHz, 256 MB RAM and about 40 GB harddisk). The new PCs also have CD-ROM Writers which ease the backup and data exchange a lot while a LAN is still missing at the GSD. [1]

- The digitising table will probably never work but the method of scanning and digitising on-screen works nicely. (A revised work flow diagram will be attached to this report).

- The geological features of 14 maps (several more than expected) were digitised and the additional attribute data were in the process of being typed in. Most of the maps were from the series produced by BGR and GSD in the years 1991-99 and scanned in black and white last year.

- GEUS had in 2002 scanned 22 maps (b/w). They were now partly georeferenced and ready to digitise.

- The software was updated with the ArcView extension Spatial Analyst and 3-D Analyst.

- The personnel in the Data Management Division had improved their skills partly by experience and partly because the Divisionary Head, Mr. Kwame Odame Boamah, had learnt new skills at his visit in Copenhagen and had taught it to the others.

[1] The main PC at my last visit (Dr. Feiko Kalsbeek) was repaired during my visit and seems still to be of good use.

- The map register in Excel format had not been updated but is seems that GSD has a lot more maps than expected. In the Inception Report the number of existing maps was estimated to 90. In June this number seemed to be increased to approx. 145, but as mentioned in the first progress report it has been reported (by Dr. Mauer) that 368 maps exist at the Survey.

- Data from the first field work since GEUS was Adviser for GSD – the 1003A+B map sheet in Upper West region – was typed into an Excel sheet.

Feiko discussing problems concerning one of the first field maps.

Activities during my visit 15th to 30th of January

- The meta-data about the geological maps (in Excel format) were heavily expanded because Regina started to type in the information about 368 maps. It is by now not known if these maps can or will be digitised.

- The 14 digitised maps were added attribute information and the relevant topological information was "clipped" and "merged" to match every single map. All the maps were re-projected from UTM to decimal degrees – and both versions were stored in ArcView shapeformat as well as in ArcInfo coverages.

- Some additional maps were digitised in the referred period on basis of different scanned maps.

- A map-layout almost ready to print was made for 1003A+B incl. rock-formations, faults and locations with dip/strike and number. Topology was also added to the layout. A test-map was printed out and will be used for the discussions necessary to make the map ready for publishing. The text describing the geology in the map was made by Mr. Solomon Anum.

- The mapping manual made by Feiko Kalsbeek – which will clearly influence the tasks in the GIS-laboratory – was read and commented. Especially the standard for recording field data is important for the GIS-tasks.

- Diagrams and figures for the mapping manual were made for Feiko Kalsbeek.

- A photo editor capable of loading images from digital cameras and merge them together (if they fit) was installed on the PCs. It might be a much faster way to merge scanned parts of a map, which we have done so far using manual methods in Paint Shop Pro.

- The agreed diagram for the working process of digitising maps at GSD was slightly changed due to the new emphasis on scanning maps.

- A working plan for 2003 was suggested and accepted by the head of Data Management Division Mr. Boamah.

- We have now overcome all problems concerning the converting of data from The Ghana Projection to UTM and vice versa. We can use both PC ArcInfo or ArcView with a satisfying similar result.

- The GIS-team – now consisting of 6 persons inclusive Mr. Boamah – has again got some training in new as well as old topics. (Datatypes, topology and how to use Xtools for more advanced editing). The general level is very good because they get still more experience. (Yvonne Anokwa Marfoa has joined the team).

- A new ArcView extension (Symbolizer) was downloaded from the Internet and installed on the PCs in the GIS-laboratory

First print of the result of the field work in the Upper West region. Bjørn, Feiko and Desmond.

New status, conclusions and remarks

The situation concerning the digitising of the geological maps at GSD is very positive now. More maps than expected have been digitised and still more maps have been found to be present at the Survey.

All projection problems have been solved now and most of the maps exist in both UTM coordinates and decimal degrees.

GSD has for the moment sufficient GIS-educated personnel but they still need to get more education especially if ArcGIS will be introduced at the Survey. Three persons in the GIS-laboratory have applied for an ArcGIS course (6 month) in Germany. If just one of them gets this education and comes back working at GSD it will be a major step forward for the GIS-expertise at GSD. The GIS-team will of course still need more experience and knowledge how to solve more complicated situations. GIS-analysis for example has only been briefly discussed until now. However, education was given in some new subjects concerning data structures, topology and Digital Terrain Models.

The hardware in the Department of Data Management is now much more usable than a year ago, but a LAN is badly needed and should have the highest priority now for enhancing the GIS and database situation at the GSD.

Almost all obstacles for the production of new maps following the field work seem to be removed.

The 14 finalised digital maps have been copied to a CD-ROM and can be published as an official CD-ROM from GSD when a short text describing the content and the structure has been made.

Annex 1.

Plans for the period January to October 2003

- GEUS will scan another 40 GSD-maps in black and white for the digitising process.

- GEUS and GSD will prepare and produce one CD-ROM containing a number of digital maps in common formats such as shape-files and PDF-files. Legend-files, tables and a short describing text should come along with the maps.

- The nationwide digital index map should be updated till it mirrors the knowledge of the available maps at GSD.

- Three new maps should be prepared from field data and interpretations (Upper West, Upper East and Accra-Tema).

- The digital version of the 11 maps printed in Germany in the 1990s will be given to BGR.

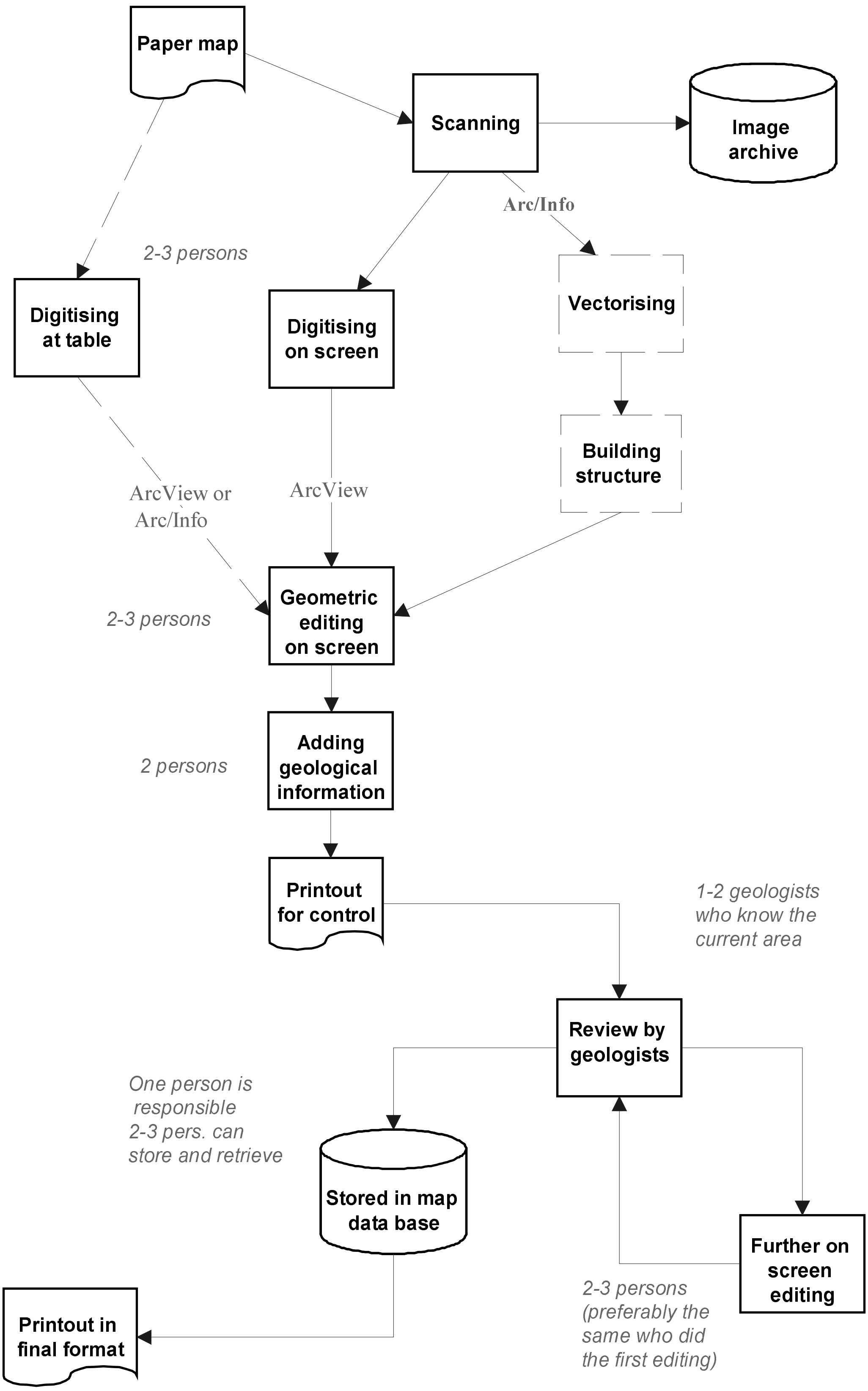
- GSD should try to exchange digital maps and images between the ArcView and the MapInfo platform. This would be useful for the interpretation of field work data.

- GSD should discuss the general layout of the future printed maps – including the legends and colour tables. A standard would be an advantage.

- Contact between the Danish and the Ghanaian partners should be maintained regularly via e-mail. Some on-line support to the GIS-laboratory will be possible.

Suggested by Bjørn Hermansen
Accepted by Kwame O. Boamah
2003

The Working Process of Digitizing Maps at the GSD



Comments and Explanation of the Diagram Showing the Proposed Processes of the Digitising of Maps at the GSD

1. All paper maps can be used – but with varying difficulties.

2. Before digitising an overview of the task must be possible. Thus a spreadsheet containing information about all the printed maps must be made. This spreadsheet (Excel) will be a preliminary meta-database and should along the digitising process be updated each time a map has passed one of the processes shown in the diagram.

Suggested content of the preliminary "meta-database":

Map no.	*Name*	*Scale*	*Year*	*Digitised*	*Scanned*	*Edited geometric*	*Reviewed*	*Edited geological*	*Stored in database*	*Com-ments*

3. Until an A1- or A0-scanner is available the best way to digitise the maps is to do it using the digitising table. This can be done either by using ArcView or Arc/Info. Because GSD has only one license for PC ArcInfo but several licenses for ArcView this would at this moment be the best choice.

4. While the table is not currently working (8/2-02) maps can be scanned in A4-format and merged in MapInfo or Paint Shop Pro. The resulting images can be geo-referenced and used for on-screen digitising. If a large scanner becomes available the digitising process could be speeded up.

5. Some few maps from the 1990s (printed by BGR) might be scanned from the print layer. This could result in rastermaps, which would be possible to process further by automatic vectorising and topology building.

6. The first digitising task could be to do the index map. This would be an easy way to maintain the overview of the progress in mapping and digitising – moreover most of the map sheet borders can be obtained from the digital maps made by the Survey Department.

7. After the initial digitising, the next step is the geometric editing to avoid "dangles" and "unclosed polygons" in the map. Arc/Info would be the best tool for this process.

8. Adding geological information can be done with ArcView or ArcInfo by selecting the features (points, lines or polygons) and typing in the associated information.

9. Many errors will be evident when the digital map is printed out. These should be corrected, but the review by relevant geologists should also include a critical look at the information in the original paper map. If the map is going to be part of the nationwide digital geological mapping, the geological content should be updated when new knowledge of the area becomes available. These changes must be described briefly in the "comment" field of the "meta-database".

10. When the content of a digital map is accepted by the responsible geologist, it is stored in the map-database. Only one person should be responsible for the maintenance and frequent backup of the database.

APPENDIX 4.

Republic of Ghana

Ministry of Mines

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Adviser to the Director of the Geological Survey Department

the Advisers 8th visit to the Geological Survey Department

Mission Report – 1 April to 2 May 2003

Prepared by Feiko Kalsbeek
Geological Survey of Denmark and Greenland (GEUS)

Report on the Advisers 8th visit to the Geological Survey Department,
1 April – 2 May 2003
Feiko Kalsbeek

Most of this visit was used for (1) help with the compilation of the map sheets 1001A4 (Upper East Region, mapped by Mr. E. Mensah), and 0501B3/B4 (Greater Accra Region, mapped by Mr. E. Efah), (2) further work with the Mapping Manual, and (3) visits to field teams (together with Dr. J. van Gool).

During this visit several of the GSD's younger geologists were not present at the Survey. A few were on extended leave, others seemed just not to come. One formally took his leave during my visit after having been absent for a longer period. This is probably the result of the higher prices obtained for gold at this time, and the resulting larger demand for geologists in the mining industry. None of the Assistant Geologists present had worked further with the collection of thin sections, and the microscopes had been stored away.

On my arrival at the GSD on April 2nd I heard that the three young Assistant Geologists at the Division of Data Management had been selected for further training in GIS at the University of Applied Sciences in Berlin. This is a very fortunate development for the Division, although the possibility cannot be excluded that one or more of the three will leave for a better paid position on their return.

I met with Dr. Muff and Mr. Weinmann of the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), who had started their cooperative project with the GSD on urban and environmental geology. It appeared that Dr. Muff was not very well informed on some aspects of GEUS' cooperation with the GSD. For example, he was not aware of the fact that a major effort had been made by GEUS to strengthen the GSD in their GIS work, and he did not know of the ongoing field work. In the future efforts should be made to ensure close cooperation between the various organisations that support the GSD, e.g. those working under the Sysmin programme.

On April 3rd I took part in the Survey's ninety-years celebration. This took place from 10-12 o'clock and was attended by an impressive number of dignitaries. For the occasion a small exhibition was made of rocks, raw materials, maps etc. to give the participants an inpression of the Survey's activities. The Director read a welcome address, during which, among other topics, he mentioned the poor funding of the Survey which makes its work difficult. In his talk the (outgoing) Minister mentioned that the Survey recently had received ¢ 1.8 billion for their new X-ray spectrometer. All in all it was a very successful occasion, with radio and TV coverage, and a large number of journalists present.

In the afternoon I talked with a few Assistant Geologists from the regional offices. They complained bitterly about their miserable emuneration, ~ ¢ 600.000 (~ $ 70) per month. Normally, with field work going on, they have their allowances as an extra income, but without these allowances they can hardly support their families.

During my absence in February and March no progress had been made with the geological map of Mr. Mensah (Field Sheet 1001A4 in the Upper East Region). The GIS laboratory had not received the necessary data files – instead the map had been given to the drawing office for redrawing, which is time-consuming and unnecessary. There was some uncertainty whether or not the data files had been prepared (the Assistant Geologist who had made the data files for the earlier maps was on long-time leave). Since nobody was available to quickly make the new Excel files, and it was important that the map was finished before the GIS staff left for Germany, I prepared the files myself from the hand-written lists (which were not complete). The brief report that had been prepared by Mr. Mensah to be printed on the map as 'explanatary notes' could not be found.

In order to speed up the preparation of the Upper East map, a hand-drawn copy was acquired from the drawing office and scanned. It emerged that the staff of the drawing office was very worried by the fact that part of their work was being taken over by the Assistant Geologists of the GIS laboratory. This problem was later discussed at a Heads of Divisions meeting – it is important, as far as possible, to involve the technical personnel when new methods are being introduced.

More progress had been made with Mr. Efah's map of the Greater Accra Region (0501B3/B4). A draft of this map was on display at the exhibition for the 90-years celebration. However, no explanatory notes and cross-section had yet been made, and the legend as well as a number of other features had to be revised. I helped in finalising the map.

Part of the problems with the map compilations are the result of insufficient cooperation between the Divisions of Geological Mapping and Data Management. Apparently not all mapping geologists are aware of the fact that all the necessary topographic data are available in digital form, and need not to be redrawn in the drawing office. This, and similar problems, could be circumvented if the Heads of Divisions to a larger extent worked as a team, supporting each other instead of concentrating each on his own problems. The weekly Heads of Divisions meetings, if held regularly, can play an important role in this respect.

Because of the problems encountered with the map compilations (both technical and geological), I prepared a new section on this topic for the Mapping Manual. In this section information is given on the format of the data files, on plotting geological boundaries, the layout of the legend and the style of the 'explanatary notes'. Also for the Mapping Manual, a listing was made of all Archive Reports describing different Field Sheets in Ghana (Appendix 2 of the Manual; data provided by the Archive Rehabilitation Unit).

As mentioned in our 2nd Progress Report, good progress had been made by the GIS laboratory in digitizing old geological maps. It has now been decided that each of the newly digitized maps, as is the case with the new maps, should be provided with brief explanatary notes. These notes must be prepared by abstracting the Archive Report to which the original map was attached. It appeares that, with their present level of training, at least some of the Assistant Geologists are unable to do this. They cannot read a professional report with insight, partly because they do not know some of the technical terms, and partly because they are not able to differentiate between main issues and details.

I have observed the same problem with Assistant Geologists proof-reading Archive Reports for the second edition. Here new errors were introduced because the person in question 'corrected' things that were not wrong, and real mistakes were overlooked. It is obvious that further training of the Assistant Geologists must have a high priority for a future Ghana Geological Survey to be functional.

It had been planned to use the second half of April for field work. On Sunday April 13th I left Accra to join the two teams working in the Volta Region (see 2nd Progress Report, Appendix 4 and 5). This visit failed, however, because the teams had stopped field work for the Easter break, and I had to return to Accra on the same day. One of the geologists had sent a message to the Survey that I should not come, but I had not been properly informed on that message. A few days later I interviewed one of the geologists involved in the project, and it appeared that no further work had been done with respect to the stratigraphy of the area (see Appendix 4 of our 2nd Progress Report). It must be concluded that the mapping of this Field Sheet is far from being completed.

On Tuesday 15 April a Heads of Divisions meeting was held. I reported on my unsuccessful visit to the Volta Region, and lamented on the limited funds available for field work. This year hardly any field work will be carried out, and it will probably not be possible to produce any new maps. Most of the months of January to March, the best time of the year for field work, have been lost. In this connection the Director asked me for an estimate of the costs of mapping one ½° map sheet (4 Field Sheets). I made this estimate in cooperation with Mr. G. Loh, Head of the Division of Geological Mapping; it is shown below:

Estimated cost of field work in Ghana

A field team consists typically of 1 geologist, 1 assistant geologist, 1 technician,
1 driver, and up to 4 labourers.

(1) Allowances per month:	Present (¢)	Proposed (¢)*
Geologist	900.000	1.500.000
Assistant geologist	750.000	1.200.000
Technician	600.000	600.000
Driver	500.000	500.000
Labourer 1	420.000	400.000
Labourer 2	420.000	400.000
Labourer 3	420.000	400.000
Labourer 4	420.000	400.000
sum (allowances)	4.430.000	5.400.000
(2) Fuel/month	1.500.000	2.000.000
(3) Imprest/month	600.000	600.000
Total/month/team	6.530.000	8.000.000
One ½° Map sheet (4 teams, 6 months)		192.000.000
Support (allowances)		21.600.000
Total expenses for one ½° Map sheet		**231.600.000**

* Proposed by the Survey

- Under avarage circumstances one team should be able to map 1 Field Sheet (1: 50 000) in 6 months (in 5 months, with 20 working days per month and 4 localities visited per day, 400 localities can be studied; most Field Sheets have less than that number of outcrops – the extra month is added for checking earlier visited localities). However, a wide variation in time needed must be expected for areas of varying difficulty.

- To cover one ½° degree map sheet (four Field Sheets; 1:100 000) 4 teams are needed.

- Allowances for Survey support (thin sections, chemical analyses, GIS and other EDB support): Assuming 2 assistant geologists and 2 technicians for 6 months, with allowances equal to those of the field teams, this will amount to ¢ 21.600.000.

- Total expenses for the mapping of one ½° Map sheet are estimated at ~ ¢ 250.000.000.

- It should be realized that this estimate only includes expenses during the field work. Other items, such as equipment, maintenance of the vehicles etc. are not included here because I do not have the necessary information to do that. The real cost of producing geological maps is therefore much higher than the field work alone.

Comment: From this estimate it appears that a significant part of the cost of field work is made up of 'allowances'. These are large compared with the monthly salaries of GSD staff. For example, an Assistant Geologist receives a monthly salary of ~ ¢ 600.000, and should, according to the present agreement, receive ¢ 750.000 per month in allowances during field work; this is much more than his real expenses during the field work, and for the supporting staff in Accra no expenses at all are involved. Moreover, the Survey has proposed to increase the allowances. Although it is entirely understandable that the Survey attempts to improve the remuneration of its staff in this manner (and the allowances encourage the geologists to take part in the field work) this arrangement is not without its problems.

From Tuesday 22 to Saturday 26 April I visited the field team in the Upper East Region together with Dr. J. van Gool (see his report, Appendix 5). Mr. E. Mensah had spent one month on a new Field Sheet, and this work proceeded in good order. Mr. Mensah provided me with updated listings of field observations from his previous mapping project (Field Sheet 1001A4), and with the explanatory notes to go with his map. I transformed these to Excel and Word files to be used for the map compilation. On returning from the Upper East Region I handed the files to the GIS laboratory, where the map was finalised before our return to Denmark.

From Monday 28 April to Thursday 1 May (May Day holiday) we went into the field in the Western Region with Mr. G. Loh who had just started a new field project there. Mr. Loh showed us a number of key localities with well preserved supracrustal and granitoid rocks, which are beautifully exposed along the coast (see the report of Dr. Van Gool, Appendix 5). This area would be eminently suitable for an excursion with a group of Assistant Geologists, which would be of significant help in their further training. GEUS has offered to sponsor such an excursion. A brief report on our visits to the field teams was delivered to the Director (Attachment 1).

On Thursday and Friday, May 1st and 2nd, the geological maps of areas within the Greater Accra and Upper West Regions were finalised, and copies provided on CD-ROM to be printed at GEUS. This CD-ROM also contains copies of the 14 old maps digitized at the Survey's GIS laboratory. I also received a CD-ROM with the 100 Archive Reports (second edition) prepared by the Archive Rehabilitation Unit. During my stay in Copenhagen, I will prepare abstracts of some of the Archive Reports for use as explanatory notes for the digitized maps.

Attachment 1

Visits to field teams, April 2003

Volta Region. A visit to the two teams (Mr. Akagbor and Mr. Anum) working in the Volta Region was planned for the week before Easter (14-16 April). However, field work had been stopped before I arrived, and because of difficulties in communication between the field teams and the Head Office in Accra I had not been informed hereof.

I talked later with Mr. Solomon Anum about the progress of the work. It appeared that neither the stratigraphy nor the structure of the area were as yet sufficiently well known. Larger parts of the area had now been visited, but the stratigraphy of the area had not been further investigated. I must conclude that it will take much more time to prepare a reliable geological map of the area.

Upper East Region. The field team in the Upper East Region (Mr. Mensah) was visited on the 24th and 25th of April. Not much time had as yet been spent on Mr. Mensah's new Field Sheet, but the work appeared to progress well. Mr. Mensah estimated that with four or five more months of continuous field work he would be able to finish the Field Sheet. I strongly recommend to support this project. In my view this is the only map that can be produced from this year's field work.

Western Region. From April 29th to May 1st Mr. Loh showed us a number of key localities in the Western Region in order to give us an insight into the geology of the Birimian with its associated granitoid rocks. These rocks are beautifully exposed in a number of coastal exposures. The area would be very suitable for an excursion with the younger geologists at the GSD. I strongly recommend that the Survey supports such an excursion to be organised. I will ask GEUS to sponsor this effort – it would be of major significance for the ability of GSD's younger staff to do their own field work. For such an excursion to be successful it will be necessary to make hand samples and thin sections available for the participants in order to be able to integrate field observations with lithological and petrographic information.

F. Kalsbeek
May 2nd, 2003

APPENDIX 5.

Republic of Ghana

Ministry of Mines

Minerals Commission

Mining Sector Development and Environment Project

NDF Credit 156-14

Adviser to the Director of the Geological Survey Department

Dr. J. van Gool's visit to the Geological Survey Department
Mission Report, 21 April to 2 May 2003

Prepared by Jeroen van Gool
Geological Survey of Denmark and Greenland (GEUS)

FIELD REPORT GHANA 2003

Jeroen van Gool

Visit to the Geological Survey Department, April 21 to May 2, 2003

Purpose

The purpose of the travel to Ghana was to visit several of the GSD's geological mapping campaigns, in order to assist the field geologists, to evaluate their working methods and, where needed, to suggest improvements.

Summary of the visit

Two weeks were spent in Ghana, in company of Dr. Feiko Kalsbeek. Both areas visited were in metamorphic rocks of the Palaeoproterozoic Birimian greenstone belts. These fit well with my own expertise from regional mapping projects in medium to high grade metamorphic Precambrian belts in Canada and Greenland. The first week was used to visit the north of Ghana, where Mr. E. Mensah showed us around. Nearly four of these days were spent travelling to cross the country from south to north and back. Mr. Mensah showed us excellent outcrops in a Birimian greenstone belt northeast of Bolgatanga. This gave a good impression of the approach to mapping in such an arid terrain. The second week was spent together with Mr. G. Loh, in an area near the coast in the vicinity of Agona. Some excellent exposures were visited in an otherwise poorly exposed, heavily vegetated region.

A visit to a third mapping area in the Upper West Region was cancelled, since no mapping activity was taking place at the time. The two areas gave an impression of the range of different environments in which geological mapping in Ghana is carried out.

Observations

General

Dense vegetation, laterite soils and lack of significant topographic relief make that large parts of the country are poorly exposed. As a result, geological maps are compiled from isolated observations from outcrops that are often far separated from each other, hampering correlation from one outcrop to the next. Geological boundaries are rarely exposed and most often inferred. This situation improves towards the arid north, where, in the dry season, vegetation is not a problem.

In such areas it is important that all possible information is gathered, both from the outcrop and from geophysical or geochemical methods. Therefore it is surprising to see that, apart from orientation measurements of foliation or bedding, no other structural observations were made during the mapping, and that hardly any use was made of geophysical data, aerial photographs or satellite images.

Observations from the Upper East Region

This is an arid country, savannah with isolated trees and very little vegetation. Accessability is perfect and the absence of dense vegetation makes it possible to walk or drive nearly anywhere, while outcrops can be spotted from a far distance. The outcrops we visited were relatively good, although many contain a crust of several cm of heavily weathered material, which prohibits easy rock identification or detailed observations.

The geology in this area is that of a typical greenstone belt at greenschist facies. Interlayered mafic and felsic metavolcanic rocks are intruded by granitoid rocks, in this case granodiorites. The geology is complicated by zones of intense, steeply dipping foliation. The rocks in these zones, most likely forming north-northeast-trending shear zones, were strongly lineated, with an extension lineation dipping steeply towards east-northeast. Asymmetric mylonitic fabrics (e.g. C-S fabrics) could be used to determine shearing directions, but both dextral and reverse, top to the southeast movements were observed. With the small number of observations, no consistent movement pattern could be concluded, but a more thorough structural analysis can solve the kinematic history of these shear zones. Such structures, as well as fold asymmetries are essential for the understanding of the regional geology as well as the map pattern, and could be of great help for reconstructing a realistic map.

It was observed in many locations, that the colour of the soil closely reflects the underlying lithology:

- Red – basaltic and mafic volcanic and pyroclastic rocks
- Grey – felsic schists and granodiorite
- Pink – the granite exposed in Bolgatanga

These indirect observations can be very helpful in the mapping, but it was not clear to what extent they were used during the mapping.

Observations from the Western Region

Exposure in the visited areas is very poor. Small, heavily weathered outcrops provide a bare minimum of information. Contact relationships of different lithologies are rarely exposed. Several outcrops were visited, of which the ones along the shore of the ocean were of excellent quality. Here detailed observations could be made, while otherwise little more than lithology and strike and dip of foliation can be seen.

Rocks in this region belong to the Birimian Ashanti metavolcanic belt. Layered mafic rocks, some with beautifully preserved primary textures, clearly indicate the volcanic nature of the rocks. The metamorphic grade is at upper greenschist facies and the rocks are generally not strongly deformed, having only a moderate foliation. Associated with the belt are undeformed tonalitic to dioritic rocks. No clear contacts were observed, but the presence of small inclusions of layered mafic rock at Cape Three Points suggests that the granitoid rocks are intrusive into the metavolcanics.

In two quaries (locations 20 and 21 in Attachment 2) such tonalitic rocks have a very strong gneissic fabric and show signs of incipient melting, giving the impression of a much higher metamorphic grade than the surrounding greenstones. Geochronological results have suggested that the granitoids are younger than the surrounding supracrustal rocks, which must mean that the high grade character of the rocks is a primary feature, possibly the result of autometamorphism.

Recommendations

The poor grade of exposure makes it essential to use any source of information about the geology of the subsurface. In the first place are aeromagnetic maps a good help during mapping, particularly if they could be provided to the mapping teams at the same scale as the Field Sheets (i.e. 1: 50 000). They would be useful for the distinction of structural trends, large fault structures and for the outlining of different domains. Here it is essential that the field geologist not only has a copy of the interpreted map, created by geophysicists on the basis of the aeromagnetic data, but also has access to the original data, since certain data are lost in the process of making the interpretation. Also during the stage of the compilation should such maps be used; they can easily be incorporated in a GIS system.

In the arid parts of the country, where overgrowth is not a problem, satellite images could be a great help for outlining the extent of the different lithologies and the large-scale map pattern. Low-resolution satellite images from the northern part of Ghana, taken from the Internet, clearly show a lineament which offsets boundaries between lighter and darker regions. High quality and more detailed images would likely give a lot more information. Investment in satellite images of the northern arid part of the country could be beneficial to the field geologists. A paper copy in the same scale as the geological map would be of help during the mapping in the field. Furthermore, a digital image, that can be over/underlaid on the geological map in GIS computer programs, would be of great help during digital compilation of the map.

Beside the use of maps produced by geophysical methods, field mapping could be improved by use of the methods of modern structural geology . Especially the use of structural analyses in the field, but also in a GIS system could help the geologists with preparing better maps. It is recommended that at least a few of the Survey's geologists get acquainted with these methods.

ATTACHMENT 1 Time schedule

Monday, April 21
Flight from Copenhagen over Amsterdam to Accra. Arrived in Accra in the evening. Stayed overnight in the SSNIT guesthouse in Accra.

Tuesday, April 22
Visited the Geological Survey Department in Accra together with Dr. Feiko Kalsbeek. Met with Director Philip Amoako and several of the senior and principal geologists. Attended a meeting with several of these people later in the morning. Prepared for trip to the Upper East Region, where we would stay in Bolgatanga. In the afternoon, we drove by car northwards through Kumasi to Techiman, where we arrived about 20:30 and stayed overnight.

Wednesday, April 23
Continued to drive north, arrived in Bolgatanga early in the afternoon. Met with Mr. Mensah, Regional Director of the GSD office in Tamale, who now holds office in Bolgatanga while doing field work in this area. He showed us around the next two days. Stayed overnight in the GNAT guesthouse in Bolgatanga.

Thursday, April 24
First field day, see field notes. Mr. Mensah showed us around in his new map area, northeast of Bolgatanga.

Friday, April 25
Second day in the field with Mr. Mensah, see field notes. Visited mainly two sites where local people illegally carry out gold mining operations. In the afternoon started driving back south and stayed overnight in Kintampo.

Saturday, April 26
Drove on towards Accra. Stopped in Kumasi, visiting a museum in an old Ashanti temple and a craft market. Afterwards drove to Lake Bosumtwi, to look at this 1.1 million years old impact crater. Arrived in Accra in the evening.

Sunday, April 27
Quiet day. Met with Mr. Geoffrey Loh in the evening.

Monday, April 28
Spent the morning in the office. Left thereafter with Dr. Kalsbeek and Mr. Loh for the Western Region. Arrived in Agona late afternoon. Stayed in the Busua Beach Resort.

Tuesday, April 29
Mr. Loh showed us some key outcrops in the area he mapped in the late 90's during a cooperative project with the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR, Germany). All these rocks are part of the Ashanti belt of the Birimian. Visited old castle in Dixcove which was used by the English and Portuguese during the slave trade.

Wednesday, April 30

Mr. Loh took us to several locations west of Agona, some along the coast and one in a quarry. Last two outcrops were of medium to high grade gneisses, which on first sight I would have interpreted as basement to the Birimian because of their relatively high metamorphic grade. But these gneisses are currently being interpreted as young intrusives into the greenstones and metasediments, based on geochronological data.

Thursday, May 1

We visited one more quarry outcrop in the morning and drove back to Accra. On the way we stopped in Elmina, where we visited the castle. We arrived in Accra late in the afternoon.

Friday, May 2

Prepared for departure, said goodbye to GSD colleagues, and left for the airport at ca 19:00.

Saturday, May 3

We flew overnight to Amsterdam and, after a brief stopover, left for Copenhagen where we arrived about 9 o'clock in the morning.

ATTACHMENT 2, Field notes

(1) Upper East Region
Thursday, April 24

Day in the field with Mr. Mensah, east-northeast of Bolgatanga in Birimian greenstone belt.

Location 1

Zanelerigu village, 10° 46.522' N - 0° 44.633' E
(EM 213/03)

Strongly foliated mafic and felsic rocks, interlayered on the scale of tens of meters and displaying a mylonitic fabric. Predominantly greenschist mafic schists, all strongly silicified and deformed at upper greenschist to lower amphibolite facies. Locally rocks are cherts (result of far-going silicification) and they contain large quartz veins, locally more than 10 m wide.

Structure: rocks contain anastomosing foliation and steep lineation, locally L-S fabric (strong linear fabric). Foliation is overall steeply dipping predominantly towards SE, NNE trending. A stretching lineation (Ls) plunges steeply ENE. However, horizontal surfaces show S and C planes indicating dextral shear.

Locally pyroclastic rocks, mafic matrix contains felsic angular fragments 0.5 - 3 cm in diameter in foliation plane (X-Y plane of strain ellipse), but aspect ratios of 1:5 in X-Z plane, indicating significant flattening during deformation.

The rocks are all strongly weathered so that rocks are difficult to recognize, but with use of hammer fresh pieces are easily obtained. Thin sections from samples can give further information on lithology, metamorphic grade and deformation. The soil is deep red in the mafic parts, gray in the felsic parts. Bands of grey and red soil extend along strike from the outcrops. Walking across strike through unexposed ground, similar bands of alternating grey and red soil are encountered on the scale of tens of metres, suggesting that the felsic and mafic rocks alternate on this scale, but with the mafic ones dominating.

Sulfide mineralisation occurs in the mafic parts. Only a few hundred metres away from this outcrop the soil associated with the mafic parts is “mined” on a small scale for gold by local people (galamsey).

Location 2

10° 47,930' N - 0° 42,137' W
(EM214/03)

Manganese-bearing, finely layered rock. chemical sediment. Reminds me of the finely layered iron ore formations of the Labrador trough. Black weathering – subcrop, large pile of rocks but none seem in place. Mn-bearing mineral (or is it haematite/goethite?) is concentrated in thin layers. Fracture planes are heavily stained with Mn oxide, so it is difficult to get fresh surfaces.

Location 3

10° 47.957' N - 0° 42.239' W

Chert, partly homogenous, fine-grained, but locally rocks preserve an original porphyritic (porphyroclastic?) character. Could possibly be a silicified granodiorite, or maybe rhyolite (or pyroclastic rock?).

Location 4

10° 46.814' N - 0° 41.990' E
(EM041/03)

Metabasaltic rock with thin veins of granodiorite. Location lies to the east of the shear zone. The basalt is dark green, massive, homogeneous and structureless. Chalcopyrite/pyrite mineralisation, locally semi-massive along 1-2 mm thin quartz veins and near the granodiorite veins. Locally small spots (up to 0.5 cm in diameter) of malachite mineralisation.

Location 5

Dusi. 10° 47.199' N - 0° 41.677' E

Small outcrop of granodiorite. Medium grained and homogeneous, containing K-feldspar, plagioclase, quartz and hornblende. Few small (diameter up to 2-3 cm) mafic inclusions occur. The outcrop itself is just a few m^2, but it is surrounded by a larger area of ca. 5 x 20 m^2 containing large boulders of the same rock type (subcrop). The light colour of the soil in a large area surrounding this subcrop indicates that it must be a fairly large occurrence of granodiorite.

Friday, April 25
Further field work with Mr. Mensah.

Location 6

Nangodi. 10° 50.496’ N - 0° 41.336’ E

Sheared metabasalt containing chlorite, actinolite and plagioclase, with quartz lenses and thin granodiorite veins. Rocks have a well-developed cleavage, which is folded in asymmetric S-folds. S 070/80 N, L subvertical, parallel with the fold axis.

100 m to the south, across strike: volcaniclastic/pyroclastic rock, mafic matrix with felsic fragments of up to 3 cm diameter (Fig. 1). Rocks have overall a spotted appearance, but only locally the fragments are clearly recognisable. Also here a steep lineation and a steep S-C fabric, which indicates SE-side up thrust movement. S 058/84 SE, L 148/84.

Figure 1. Pyroclastic rock on locality 1 near Zanelerigu village

Location 7

Nangodi. Northwest of road, no coordinates.

Old mine site closed in the 1940's. One mine shaft mantled partly with concrete. Nowadays ca. 40 m deep, but has originally been deeper (up to 100 m?). There are several narrow (up to 1 m diameter) shafts, which reach up to ca. 50 m deep, which are used presently by people for small scale illegal mining (galamsey). Gold is hosted in quartz veins in a sheared part of the greenstone belt. Quartz veins vary in thickness between 10 and 20 cm and about 1 m. Material is processed (crushed, panned and concentrated) totally by hand.

Ca. 1 km to the southwest, along strike of the quartz vein in the first mine, and to the southeast of the road, is another illegal mine site. Same conditions.

Location 8

On the way back to Accra, ca 70(?) km south of Bolgatanga. Outcrop along the road, at the escarpment forming the boundary between the Birimian and the unconformably overlying Voltaian sandstones.

Voltaian sandstones here overlie a homogeneous pink granite. Few isolated pebbles to cobbles on the contact, but not a real basal conglomerate. The sandstones show several small fault structures. One is a small thrust, exposed length about 3 metres, southeast dipping and northwest vergent (Fig. 2). It is located about 3 metres above the unconformity. Although the displacement on this fault is only in the order of one meter, it indicates that contractional forces have acted upon these sandstones. Also one small extensional fault was observed about 20 metres to the northwest, downdropping the NW side. The relationship between the extensional and contractional structures is not known.

Figure 2. Small thrust structure in Voltaian sandstone, few metres above the basal unconformity. Height of the rock face is about 3 metres.

(2) Western Region

A second trip was made to the Western Region. The visited outcrops were all within the Birimian. Both greenstone belt rocks, "basin" sedimentary rocks and intrusive granitoids were studied. Mr. Loh, Head of GSD's Division of Geological Mapping, showed us around, and we were accompanied by Dr. Kalsbeek.

Tuesday April 29

Location 9

Butre

Birimian pillow basalts. Very nicely preserved pillow basalts form part of the Ashanti belt. Pillows are up to about 70 cm in diameter and show good concentric layering in the margins of the pillows. Angular and rounded sides of the pillows indicate way up.

Location 10

Dixcove. At the foot of the castle, surrounding the garbage dump site of the village.

Type locality of the Dixcove granite, a granite intruding into the Ashanti greenstone belt, thus called "belt type granite". It is a homogeneous, undeformed, relatively fine-grained (grain size up to 3 mm) granite to granodiorite, with hornblende as main mafic phase. One small (diameter about 5 cm) xenolith of a layered mafic rock was observed. Contact relationships of this granite with the surrounding greenstone belt rocks are not exposed, but its position, undeformed state and mafic inclusions suggest that the granite intruded into the greenstone belt.

Location 11

Akyeanny village at Sweni River, in the middle of the village.

Arenitic massive to coarsely layered sandstone, locally silty and well layered on small scale. Mixed grains, predominantly plagioclase and quartz, but also a small percentage of mafic minerals. The rocks appear undeformed, but may have a very weak fabric. On the east side of the village, near the water occurs a polymictic conglomerate. Pebble to cobble size clasts consist mainly of clastic material, i.e. it looks like an intra-formational conglomerate. According to Mr. Loh this conglomerate belongs to the Tarkwaian, which lies unconformably on top of the Birimian Supergroup.

Location 12

Adooda village, blocks on the beach.

Basin metasediments, layered volcaniclastic rocks with green weathering colour, amphibole + plagioclase-rich ± quartz ± chlorite. Layering on scale of 5 cm to 40 cm, with graded bedding. We did not observe any solid outcrop, so top-bottom criteria were not valid. It is possible that the clastic material consists of re-deposited volcanic material from the greenstone belt, and that these sedimentary sequences are overlying (at least some of) the greenstones.

Location 13

Cape Three Points, at the foot of the lighthouse.

Dixcove granitoid. Dark porphyric tonalite, dated at ca. 2100 Ma. Plagioclase phenocrysts up to 1.5 cm in diameter in a dark matrix, rich in mafic minerals, probably hornblende-rich. Rocks are homogeneous and appear totally undeformed (massive), with some thin (5 cm) bands that show a foliation. It was not obvious if this is a syn-intrusion flow structure, or whether it indicates local solid state deformation. These rocks intrude in to the volcaniclastic series. One small inclusion of a layered mafic rock was observed.

Location 14

Ca. 800 m west of the lighthouse at Cape Three Points. Walk along the beach.

Very good outcrops of metabasalt of the Birimian greenstone belt. Rocks are dark green and highly foliated, and consist predominantly of chlorite and plagioclase, possibly with actinolite. 10-20 cm wide, discordant porphyritic dykes could represent the equivalent of the porphory at the lighthouse (Location 13).

1 km further west: similar foliated basalt, but overall well layered rock. Contains several layers of pyroclastic rocks/lapilly lavas. Particles from 5 to 40 mm in diameter. This layered rock i cross-cut by a 20 cm wide, highly discordant mafic dyke.

Wednesday, April 30

Proceeding with Mr. Loh in the Western Region. Drove from Agona through the Western limb of the Birimian Ashanti belt into the basin sediments of the Birimian.

Location 15

Ancobra River Beach, road cut.

Strongly weathered rock, very soft, impossible to see anything else than a main foliation. Looks like a predominantly micaceous rock (pelite). According to Mr. Loh this is an argillaceous volcaniclastic rock, locally graphitic. The rocks may be very aluminous, having large amounts of white mica. Locally the rock is graphitic, resulting in a black colour of the "fresh" surfaces. There are some vague layers visible which appear to be highly folded.

Location 16

Road cut on road from Nkroful to Salman.

Heavily weathered graphite schist (locally more than 70 % graphite?) – overall pelitic rock. Rock contains rusty spots which could represent weathered pyrite. Foliation 027/70 SE, crenulation lineation 043/18.

Location 17

Just N of Ancobra River, where the road crosses the river.

Phyllitic metabasalt. This is a thin (1 km) slice of Birimian greenstones within the basin metasediments. The soil developed from these rocks is again characterised by a deep red weathering colour.

Location 18

Bonsha River/Agona Wasa.
Polymictic conglomerate with well rounded boulders. This conglomerate belongs to the Kawere unit of the Tarkwaian. The rock is slightly foliated.

Drove 1½ hour eastwards.

Location 19

Abuesi, outcrop on the beach.

Migmatitic gneiss with highly tectonised lenses and schlieren of amphibolite. This is a quartzo-feldspathic gneiss with amphibole as main mafic mineral. The rocks have an upper amphibolite facies appearance and appear to be partially melted. The rocks have a history of multiple phases of deformation since the gneissic fabric is folded. They are cut by thin felsic dykes. Granite veins from this outcrop have been dated at 2104 Ma, whereas a metamorphic monazite gave an age of 2102 Ma.

Problem: The metamorphic grade of these gneisses is higher than the surrounding metasediments, and the deformation history appears more complex than that of the surrounding rocks. On first inspection one would interpret these rocks as “older” than the metasediments they were found in. But the age determinations suggest that they are younger than the metasediments.

Figure 3. Tonalite with strong gneissic foliation at location 20.

Location 20

Quarry near Takoradi harbour.

A high grade dioritic to tonalitic rock, rather rich in hornblende, with a strong gneissic fabric and local melt patches (Fig. 3). The rocks are strongly retrogressed, and much of the amphibole is replaced by chlorite. They are intruded by up to one metre wide, slightly discordant granitic veins. Mr. Loh explained that age determinations suggest that this rock is intrusive into the Birimian supracrustals. This poses a problem because the metamorphic grade of these rocks is higher and deformation more complex than in the surrounding supracrustal rocks. A solution could be that the metamorphic grade was established during or just after intrusion, i.e. it is the result of autometamorphism.

Thursday, May 1st (Labour day)

We visited two quarries in the morning. We got no acces to the second, which is still in operation. Drove back to Accra.

Location 21

Supong quarry.

This is similar to location 19. High grade, well foliated, biotite-rich gneisses with partial melts. No folds observed. We discussed if this was an orthogneiss or paragneiss. The high biotite content could suggest it is a paragneiss, but similar gneisses in Greenland have commonly proved to be orthogneisses.

APPENDIX 6A.

Republic of Ghana

Ministry of Mines

Minerals Commission

Mining Sector Development and Environment Project

NDF Credit 156-14

Adviser to the Director of the Geological Survey Department

Development of a mineral occurrence database prototype

Mission Report – 15 to 31 May 2003

Participating GEUS consultants:

Leif Thorning

Lisbeth Christensen

Prepared by Leif Thorning
Geological Survey of Denmark and Greenland

Mission Report

Mining Sector Development and Environment Project, NDF- Credit 156-14: Adviser to the Director of the Geological Survey Department (GSD)

18 – 31 May 2003: Development of a mineral occurrence database prototype

Leif Thorning

Head, Department of Economic Geology, GEUS Final version 30 June 2003

Table of Content

The information contained in this Mission Report relies on the information we have received from managers and other staff at many talks and meetings during the two-week mission. However, the choice of subjects to treat in the report, as well as the wording of facts and opinions, represent our perceptions and recommendations, and the statements in this report are in no way binding for the other parties to the various meetings. We apologise for any inaccuracies, errors or omissions that may be present in the text and would of course be pleased to receive any comments.

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Mission Objective

This mission was a follow-up to LTH's mission to Accra in May 2002 (General analysis and discussion of GSD database issues) and the mission of Mr. K. O. Boamah (KB) to Copenhagen in October 2002 (Study of GIS and database issues). Prior to the mission it was decided jointly by GSD, the project leader Dr. F. Kalsbeek and LTH that the subject of the mission should be a future mineral occurrence database for the GSD. It is not in the TOR of the project to deliver a finished database; rather the focus should be on discussing all aspects of the subject and provide relevant advice to the Director on how the GSD should organise and carry out the continued development of the mineral occurrence database and other databases essential for carrying out its responsibilities. The mission included elements of human resource development and capacity building; one of the best ways to introduce the relevant personnel of GSD to the details of database construction would be to build a prototype of the database and let GSD use and experiment with this for some months. The next step in the development of the database could then be taken in August during KB's second visit to GEUS, to a larger extent building on the experiences gained by the involved participants from GSD during the period from May to August.

Participating Consultants from GEUS

Two Consultants from the Department of Economic Geology, GEUS, participated in this mission: Leif Thorning (head) and Lisbeth Christensen (system programmer).

Programme and summary of activities

18 May 2003:	Leif Thorning (LTH) departure Copenhagen over London to Accra with British Airways, arrival Accra 20:25 local.
19 May 2003:	As introduction to the two week mission, LTH gave talk to managers at their weekly meeting on "Various management aspect of organisational databasing of mineral occurrences".
19 May – 23 May 2003:	Discussions with GSD managers about requirements of the database, the associated procedures, organisational ties, etc. All related to the creation and use of the database. Production of version 1.3 of the (early draft) design document, delivered to GSD for comments on the 23rd of May.
23 May 2003:	Lisbeth Christensen (LC) departure Copenhagen over London to Accra with British Airways, arrival Accra 20:25 local time.
24 – 25 May 2003:	Relaxation; discussion (LTH and LC) of further details of attributes leading to version 1.5 of design document.
26 May 2003:	National Holiday; Consultation KB, LTH and LC; database structure constructed by LC and LTH according to design document 1.6; most default values etc. decided. Work plan for the week finalised.

27 May – 30 May 2003:	Detailed building of database functions – multiple consultations with GSD participants – running update of design document – input of sample data.
28 May 2003	Meeting with Mr. Richard Afenu, Minerals Commission.
29 May 2003	Talk by LTH for a few selected GSD managers and employees: Using basic functions of Access 2000 for building a database.
30 May 2003	Talk with Mapping Division about geological descriptions in the database. Live demonstration of the Ghana Mineral Occurrence Database for the management group and others followed by brain storming session (Afternoon 14:00 – 16:15; see slides in Appendix 1).
31 May 2003	LTH & LC depart Accra with BA78 at 22:35 via London to Copenhagen (arrival 1 June 2003 at noon).
Subsequently in Copenhagen (until shipment of deliveries to GSD, Ghana)	Smoothing details in the database and correcting a few minor omissions; finalisation of design document (addition of user hints and examples of screen-forms) and mission report; addition of lists to look-up tables based on Excel sheets received 12 June 2003 from GSD; addition of a standard report facility; creation of the two versions of the database; transfer to CD-ROM and shipment.

Organisational issues of data base development

In the report for the mission last year (May 2002), many issues concerning the internal workings and routines in GSD and their influence on the building of digital databases in GSD were discussed. The report also touched briefly on inter-organisational issues relevant for GSD. In this mission in May of 2003, further attention was given to such issues, but as a demonstration of the various aspects of concrete database construction, the construction of one specific database was initiated (a mineral occurrence database, only one of the many databases that GSD needs to construct). Over the two weeks this database was taken from initial ideas to the stage of first prototype, as an example to be studied and followed by GSD. This will benefit GSD in the process of general modernisation, which must be expected in the near future, when one of the EU Sysmin projects will deal with very ambitious plans for inter-organisational, co-ordinated and distributed databases in the Ministry of Mines. A better grasp of databases than what is presently within the capabilities of GSD will be needed for a professional handling of GSD responsibilities related to this future database project.

It was the intention of the Consultants to demonstrate that if a sufficiently disciplined, goal oriented professional approach is applied, it is possible to created a database well suited to the organisation in which it must work. During this mission this was done for one database, but a similar process must be applied for the other important databases obviously needed in GSD. In the Consultants' opinion this means that GSD has much concentrated and focused work ahead in order to be well prepared for the upcoming projects.

The Consultants would, however, also like to emphasise that it is possible to build a database fairly quickly and efficiently with the excellent tools provided by a professional relational database programme such as Access 2000. However, this does not take away the need for a very careful analysis prior to the construction of the database. The many important issues related to definition of responsibilities, organisational set-up, sources of data, requirements for the outputs etc., etc., are equally important and will always take the larger part of the total time needed for the creation and implementation of a corporate database. As a rule of thumb it is common to plan with 80% of the time being used for such issues, while 20% of the time will be set aside for the IT-technical database construction.

The design document for the database can be seen in Appendix 6B. It contains much of the discussion as well as the description of the database. Therefore, the following three sections of the Mission Report focus on three important issues for how GSD should handle its responsibilities and assigned function, as it indeed was confirmed during the analysis phase of the database construction.

Co-ordination in the Ministry of Mines

A mining law and its associated directives and/or regulations will normally define clearly what the roles of various offices in the relevant Ministry are in relation to licensing, monitoring of activities and reception of company information. This is probably also the case in Ghana, but without having carried out a complete analysis it does appear to the Consultant from conversations with representatives of GSD and the Minerals Commission that not all issues are entirely clear to everybody. There seems to be good reason to take a closer look at the assigned responsibilities of the various organisations, especially because a new mining law is under preparation. The judicial and legal foundation for the functions of the GSD must be concrete and well understood by everybody in the organisation, in the rest of the Ministry and by external 'clients' as e.g. exploration- and mining companies.

Ideally, the Ministry should aim for a sharing of all required databases. This is the explicit goal of the upcoming Sysmin project, as far as the Consultant can judge, based on the (insufficient) knowledge presently available to him. However, for this to be successful it is very important that the responsibilities are clearly defined for each of the organisations involved and that the information becoming available is truly shared. The Consultant discussed this with a representative from the Minerals Commission, but the issue must be further explored by GSD.

It could be an option to start on the joint development of the future databases already now, e.g. between GSD and the Minerals Commission. There will be many issues to discuss and agree to immediately when the new project starts and it would be beneficial for the success of the project if the offices involved initiate the analysis now. For instance, the goals for and functions of a shared National Mineral Occurrence Database should be agreed upon by all, and preferably before the project starts. The Ghana Mineral Occurrence DataBase

(GMODB) created during this mission can best be thought of as a training exercise for GSD, providing an opportunity to establish an overview over GSD's 'own data' in preparation for the time when such data must be delivered to a future, shared database.

Although it was not much discussed during this mission, promotional issues will also play a role for the databasing undertaken by GSD. Internationally, the competition for the attention of and subsequent investments by mining companies has become very tough. It is of paramount importance that GSD can supply accurate, up-to-date information concerning its knowledge of geologically based opportunities in Ghana. The databases that the Consultant has discussed with GSD during the two missions are all necessary for a professional handling of this responsibility.

Reports from companies

One source of information and data for the GMODB are the reports delivered to the Ministry by mining- and exploration companies operating under license in Ghana. This is an important source of information and it must be handled correctly by GSD. According to the impressions gained by the Consultants, two issues are of particular concern in the present situation in Ghana:

Accuracy of information

Some expressed the opinion that data from the companies could not always be trusted, because the companies – for reasons of their own - were not accurate in their reporting. This is of course not acceptable for a government and if this is really true, it should be a point of great concern for the Ministry. Based on international experience it is definitely the best for the companies and for the public authorities that a state of trust exists between them, and if this is not the case, measures should be taken to improve the situation. This aspect should be considered carefully in relation to the writing of new mining law and regulations. For the GMODB it is important that the information received is correct and complete. It is not possible for GSD to verify every bit of information, and it needs to be able to trust the information so that all available information can be used in the assessment of mineral resources that GSD must carry out for the public.

Similarly, GSD must take great care that the data and information originating from GSD activities are accurate and complete, so that companies can act with confidence in their accuracy.

Confidentiality

Data extracted from exploration reports or from production reports are confidential for a certain period of time. But the GSD may use the data for its own purposes, also in the period of confidentiality. It is important for the success of such rules that GSD strictly upholds the confidentiality. In the GMODB facilities have been included for keeping a record of the confidentiality period for each entry into the database. It is necessary that the employees with access to the database are very conscious about the rules and observe them at all times, also when it concerns databases and the use of the data therein.

Design of the Ghana Mineral Occurrence Database (Prototype)

The necessary details related to the structure of and background for the Ghana Mineral Occurrence Database are explained in the design document (Appendix 6B) and will not be repeated here. Normally a design document is more concise and contains less discussion than the one produced by the Consultants together with Kwame Boamah during the first week of the mission. However, the Consultants elected to include some of the pre-design thinking and deliberations in the document to make it more useful as a pedagogic introduction to the subject of database design. This also underlines the fact that a database is not an isolated facility, but rather a versatile tool, which is very dependant on the organisational environment in which it must function.

The Ghana Mineral Occurrence Database development embarked upon now should not just be the creation of a fixed database of a number of mineral occurrences in Ghana, stable and unchanging once all the required information has been entered for the mineral occurrences that can be identified at the present moment of time. It should be a live database, continuously expanded with new data as soon as they become available. It should also undergo frequent technical updates to keep it at par with the development of the IT environment in GSD. Only then will it be a useful investment for the Ministry in its promotional and administrative functions, and be a GSD tool for the understanding and mapping of the mineral resources of Ghana.

Content of the beta version of GMODB

The content of the Ghana Mineral Occurrence Database originates from the Geophysics Division, representing an extract of information used by this group in their preparation of geophysical interpretation maps. There are various sources of the c. 316 sites, and in the brief time available for the creation of the database, the Consultants have not tried to confirm or in any way control the quality of the information. This would be a task for GSD to undertake, adding such information as can be found. At the present time there are many fields for all records that just contain the default data automatically put in by the database if no ‘real data’ are available.

Preferably, the GSD management should plan and immediately initiate an internal project involving sufficient manpower and time to supplement the information already in the database and to add new data.

Delivery

The delivery to GSD subsequent to the mission described in this report encompass:

1) This Mission report.

2) Design document for Ghana Mineral Occurrence Database.

3) Ghana Mineral Occurrence Database – beta version, in two forms:

   a) A master Copy with full access to all functions and structures in the database. This version will allow a competent user to change the structure of the database, add new fields etc. Also full access to all data in the database (type .mdb).

   b) A User Copy of the database, which will give access to all data in the database, and data can be added and modified. However, it will not be possible to change the structure of the database (type .mde).

Copies of the documents will be forwarded by e-mail and on a CD-ROM for safekeeping. The CD-ROM will also contain some digital photos taken by the Consultants during the mission.

Advice to the Director

The result of this mission is more technical in character than was the case for the first mission in May of last year. However, in the course of the work with the database, some more general issues emerged, calling on the attention of the management and the directorship. We will mention the most important ones:

- The recommendations made in the mission report from the May 2002 mission still hold; we have now gone through the detailed analysis of one of the databases pointed to in that report, and the general point must be made that a similar process will be necessary for all of the databases required by GSD. The importance of good management prioritising according to organisational responsibilities and duties cannot be emphasised enough.

- A mineral occurrence database is central for all geological survey organisations and it should include all available information if at all possible. The Consultants recommend that clear instructions be given to all personnel involved in its construction and subsequent daily use concerning the need for accuracy and care in the handling of confidential information. If the confidentiality of company data cannot be assured, it may be necessary to limit the database to public information. But then it will not be the best possible tool for the GSD.

- It should also be remembered that 'handling the confidentiality' also means that data should not be held confidential longer than needed – are all the regulations concerning confidentiality in agreement with best international practise, i.e. is there an end to a confidentiality period?

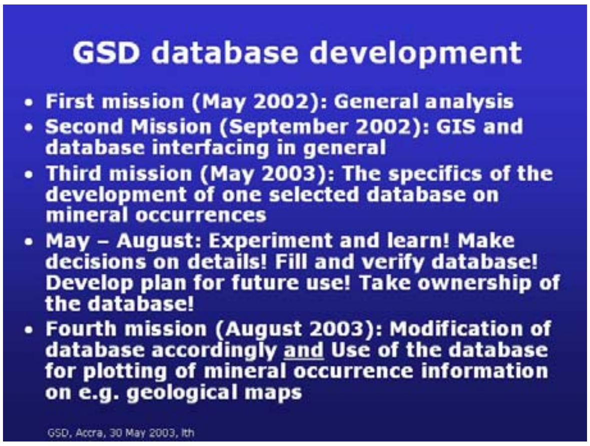
- Although not based on a thorough study, the Consultants believe that there is a need for confirmation of some organisational structures in the Ministry and the divisions of responsibilities defined thereby. If this is well defined in the new law then it will be important to instruct employees accordingly; at the present time significant uncertainties exist, e.g. concerning the processing of company reports.

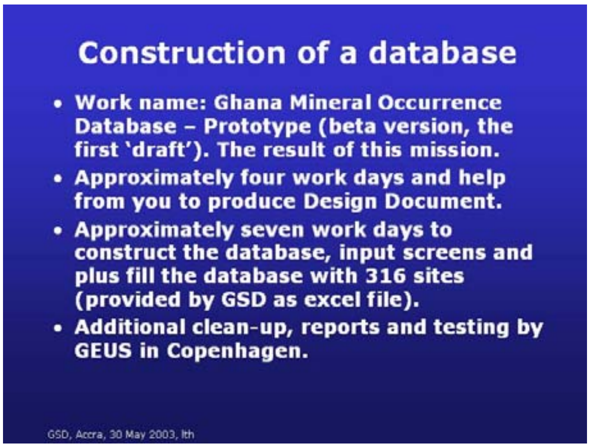
- The management should consider to set up an internal GSD project drawing on its own resources for (1) the verification of existing data in the database, (2) the addition of more detailed and complete data to the existing entries (the many fields with 'not determined' or 'not known'), and (3) to organise and carry out the search for and input of additional sites from other sources.

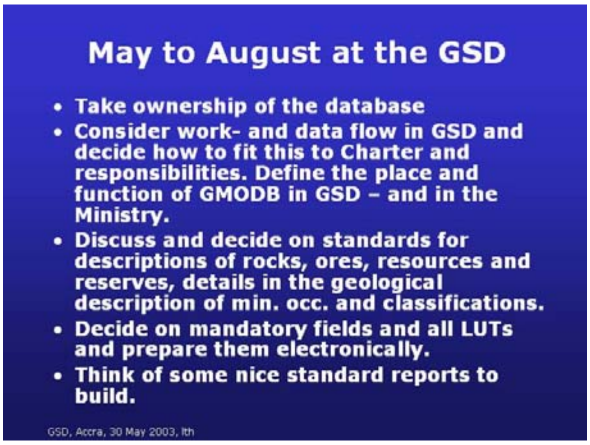
- The management of GSD should consider how to set up clear work routines for the reception and treatment of company data, in accordance with the letter of the law and regulations and to the benefit of the GMODB. One important element will be the process of extracting useful information for the GMODB.

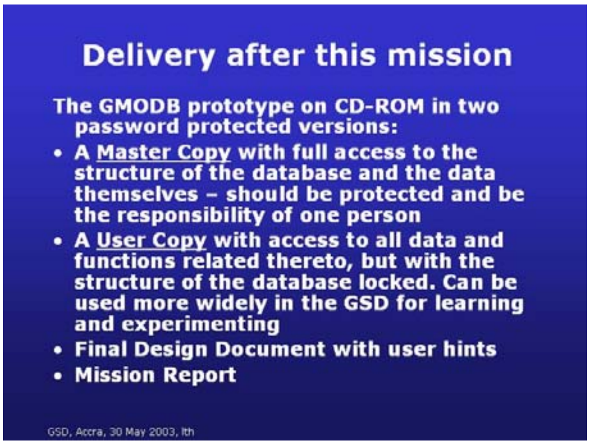
Implicit in the text of the design document and the discussion therein are many issues that call for clear management decisions. The Consultant will be pleased to discuss this in more detail according to need.

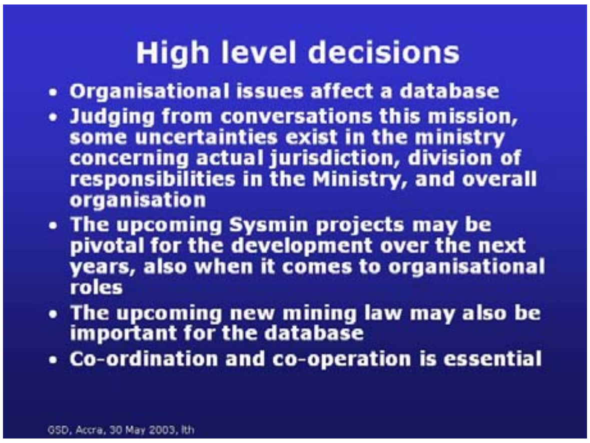
Attachment 1: PowerPoint slides from seminar

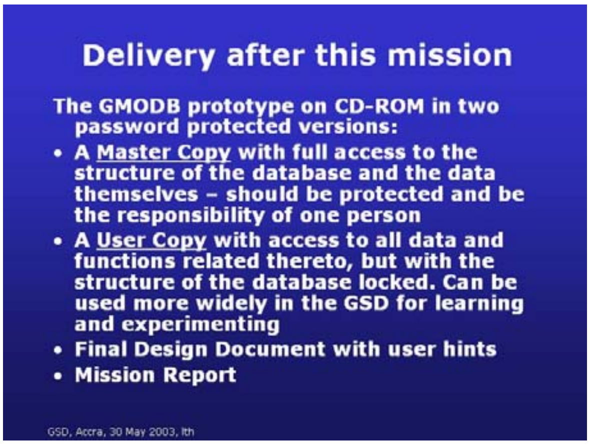












APPENDIX 6B.

Design Document No. 1
Version: 9   Confidential: No
Date: 30 June 2003
Author(s):
Leif Thorning, Kwame Odame Boamah
and Lisbeth Christensen

Title:
Ghana Mineral Occurrence Database for GSD
– a simple prototype

This file last saved at Monday, 30 June 2003 by Leif Thorning

Table of Content

History of this design document

Versions 1.0 to 1.2 of this document were work versions during the initial production of the document during the period 19 – 23 May in Accra by LTh & KB.

Version 1.3 was released to GSD as an ***early draft*** of the Design Document for perusal and checking by GSD managers and employees directly involved now or in the near future, asking for any comments before the database was constructed.

Versions 1.4 and 1.5 were work versions used over the weekend and on 26 May by LTh & LC to improve a number of details in the attribute definitions, but containing no modifications as a result of comments from GSD personnel. It was decided for version 1.5 to change the names of the attributes so that they were all max 8 characters and the definitions were polished to be included as bar text on the forms. Decisions were also made concerning some of the Look-up Tables (LUTs).

Version 1.5 was used by LC as the basis for the first construction of tables (26 May).

Version 1.6 was further supplemented with additional comments and a few new paragraphs on main issues of the data modelling and LUTs. Some minor corrections of a few attributes were carried out to fit the developing data model and decisions on default values were taken for most of them. Some of the sections in the text were rearranged.

Version 1.7 contained some additions to the text and was crosschecked with tables in the database to co-ordinate mandatory fields etc.

Version 1.8 the design document at the presentation meeting at GSD, Friday the 30th of May at the end of mission

Version 1.9 contains some additional corrections and two new sections on the use of the database (Technical notes and illustrations of input screens) written in Copenhagen after return from the mission. This is the version delivered to GSD at the end of June 2003.

Introduction

This design document was written during a mission 20 – 30 May 2003 to the Geological Survey Department, Ministry of Mines, Ghana, under the Mining Sector Development and Environment Project, NDF credit 156 -14. This was LTh's second mission concerning GSD databases and by decision of Dr. Feiko Kalsbeek and the Director it focused on one particular database development, providing the next step towards a ***Ghana Mineral Occurence Database (GMODB)****,* thereby serving as an example of ***specific*** database construction, building upon and adding to the ***general*** knowledge about databases discussed during LTh's first mission to Accra in May 2002 and KB's visit to GEUS in Copenhagen later in 2002. Looking ahead, it is planned for KB to visit GEUS again in August of 2003, at which time further development of the Ghana Mineral Occurrence Database will take place, probably mostly related to the interfacing of the database to GIS and the production of maps based on the content of the data-base.

The concept of a design document like this one has been developed at the Department of Economic Geology, GEUS, as a convenient way to produce and document the information and decisions required before the programming of a database is started. Most developers of programmes or IT systems have some similar way of handling this very important phase of software or database development. Experience tells us that it is an important and indispensable first step. If done carefully, it will save much time in the total process by minimising the risk of errors and misunderstandings, which often cause many delays later in the process. It is a recommendation to GSD to adapt some similar working method.

The requirements for the GMODB as detailed in this document was reached as a compromise taking into account the limited time available and focusing on realistic objectives within the present formal structure of the Ministry of Mines. While wider perspectives of a Ghana Mineral Occurrence Database were discussed and evaluated during the mission, the database construction was limited to the most immediate objectives of the GSD. Some of the issues are briefly discussed below and in the Mission Report.

It was thus not the intention during one brief mission to produce the final and perfect mineral occurrence database for the GSD, but just to produce a reasonable first prototype, which can serve as a platform for further thought, training, experimentation etc. before the form of the final authoritative database is decided. The discussions and trial usages of the database between May and August are further hoped to provide a good object of training for the personnel directly involved and also for the management, which has to consider many issues related to such a database, e.g. who should run it, carry out the required quality control, direct the future development, give priorities to geographical areas and/or commodities etc., etc.

The name Ghana Mineral Occurrence Database is just a ‘work name’ chosen by the Consultants for easy reference in this document. The personnel and managers of GSD should discuss alternative names and make the final decision. A couple of alternatives referring to mineral resources rather than mineral occurrences (more emphasis on the figures for resources), could be:

National database of mineral resources in Ghana – this signals a high level of ambition; maybe the first version will not deserve this name, but it certainly declares the goal of the project!

GSD database of mineral resources in Ghana – most external costumers would still expect this to be a pretty complete database, but the name probably signals the limited ambition of having a database containing information available to GSD.

Purpose and use of the database

The prime objective of the GMODB should be to fulfil the duties defined in the charter of GSD. This means the database should

1. Provide an accurate and complete overview of the mineral resources of Ghana,

2. Perform as the main tool for the storage and use of all mineral occurrence information from Ghana available through diverse sources to GSD,

3. Provide the basis for servicing the Government authorities, the general public and the mining industry,

4. Provide part of the basis for scientific endeavours by the GSD and its partners,

5. Provide part of the foundation for promotional activities directed towards the national and international mining industry.

In the long run, the users of the GMODB should not be limited to scientists in GSD or to organisations in the ministry alone. Ideally, it should be made available to the general public and especially the mining industry, preferably over the Internet, but if that is not achievable then via regular CD-ROM editions. Confidentiality issues will of course apply according to Ghana laws and regulations.

However, it is probably the most realistic approach at this early stage of the development to put emphasis on the internal use of the database. This means in practical terms create a database that can be useful for all relevant divisions within the GSD.

Organisational responsibilities

Through the formal structure of the Ministry of Mines, the role of organisations such as the Geological Survey Department, the Mines Department and the Minerals Commission are defined with respect to a number of issues of importance for an organisation-wide mineral resource database. Nevertheless it seems that there are some issues that should be discussed with a view to finding solutions that all could agree to, concerning some especially important functions of a resource database. In the Consultant's view, a database as the GMODB described in this document, should be a ***National*** database, i.e. it should be the authoritative source of information on the subject for Ghana. For that to be true it must be ensured that the database contains ***all*** relevant data and that the data are ***true***, without errors, and ***complete***. Normally, there should only be one such database in a Ministry of Mines, i.e. it must be decided which of the departments in the ministry should host and run such a database, of course with the understanding that all departments should have access to the information. It is also important then to define the organisational responsibilities for handling the input of data to the database. For instance, the GSD will have easy access to information obtained during its own field work campaigns and probably also on what is published in the international scientific literature, but it would be totally dependant on the routines set up for the reception of company reports delivered to the Ministry under license conditions. Unless these routines make sure that all relevant reports reach the GSD, there is a serious risk that the database will be incomplete and thus of less value to all users. Of course, interconnected with this are other issues of confidentiality, trust and competence, equally important for the success of a GMODB. Some of these issues are discussed below.

Assuming that the focus of GSD activities should be the geoscience end of the spectrum of interest relevant for such a database, the GMODB described in this document leaves out information and data related to the production from mines, the economical aspects of activities and the licensing and general management of a mining cadastral system. The Consultant thus assumes that these matters are handled elsewhere in the Ministry, perhaps by the use of separate databases. Even in this situation it would make perfect sense to include links to e.g. license number or other pertinent administrative information kept in other databases, but this has only been done to a very limited extent in this first version of the GMODB. Sufficient information is not available to the Consultants at this time to do anything else.

The minimum ambition for the GMODB would in the Consultants view be to create a database that contains ***all information on the subject that is available to the GSD***. This must be considered the minimally defined responsibility of the GSD, namely to organise and compile all data concerning mineral occurrences, which are in the domain and care of GSD. This will also prepare GSD for competent participation in future projects aiming at integrated and distributed databases, e.g. the upcoming EU Sysmin projects, whether or not GSD's role will be that of a data supplier or the host of the Ministry database.

Existing data at the GSD

The Consultants have from the Geophysics Division been provided with an Excel file containing some three hundred plus records on mineral occurrences covering all of Ghana; these originate from a 1994 World Bank Project (Greg Fernet, US) and have been used in MapInfo generated geophysical interpretation maps. In a separate dataset, the Geophysics Division has selected and improved the information and added a few sites of their own, but only for the areas targeted in the airborne geophysics programme. The information (number of attributes per mineral occurrence) is limited. The GMODB will hold all the attributes defined in this dataset and for most entries there will be need to add more information if possible.

It was pointed out that the publication "Gold Deposits of Ghana" – report on CD-ROM (?) contained much information that need to be included. This publication must be studied by the Consultants and/or GSD to make sure that GMODB can contain the information.

Field teams of GSD will during mapping make observations of mineralisations. In the Geological Mapping Manual developed for GSD in this project by Dr. Feiko Kalsbeek, there are some brief remarks in section 14 on how to register and sample mineral occurrences. The GMODB will be cable to hold the information that the manual is recommending to observe. Cases of artisanal or small scale mining (including illegal mining) are usually put on the map as indications, and should also be entered into the database.

There may be other internal sources of data not yet revealed to the Consultants (21/5/2003).

Other sources of data

The Minerals Commission runs a mineral occurrence database, which contains information relevant for the GMODB. Probably the nucleus of this is similar to the 1994 WB data collection. A meeting was arranged with the Minerals Commission to look into possibilities of sharing data. The Minerals Commission also extracts data from company reports, but apparently the process is not active at the present time. Mr. Richard Afenu expressed readiness to co-operate, sharing data etc, but the Consultant cannot at the present time say how this can be done in practice, so this is a subject for GSD to follow up. The Minerals Commission has decided to pause in further development until the Sysmin project starts, and has great expectations to the Ministry-wide database system which will be developed.

Company reports from exploration and mining in Ghana under officially granted licenses will be one of the most important sources of input, absolutely needed if the database is to be complete. It is of course assumed that the figures given by mining companies are true, accurate and complete. One prerequisite for this is that the mining companies can trust the authorities to keep the confidentiality promised in the contract with the company, i.e. the license to operate. As already mentioned it is further important that all the reports reach those officers responsible for the feeding of the database. If companies omit the delivery of reports to the authorities or if the report actually delivered to the ministry does not reach the office of the person responsible for the GMODB, the data cannot be entered into the database.

The Mapping Division now has a routine whereby the reports (monthly, quarterly, terminal) delivered to the Director of GSD are studied with the purpose of extracted relevant information concerning mineral occurrences. A form has been constructed and a file is now being built by one of the employees in the Mapping Division. Ideally, the GMODB should be able to hold the information presently compiled on the form, and the ***GMODB should be the tool used to handle this function in the Mapping Division.***

Confidentiality

While most data collected from previous publications and data gathered on GSD field work can be considered open file data, the same cannot be assumed for data received from companies exploring or from mining properties in Ghana. There are rules of confidentiality to consider for the information contained in the reports delivered to the authorities according to the rules defined in the licenses issued to the company. It is assumed by the Consultants that such rules are clearly defined for the state's safe-guarding of confidential information, and these rules must therefore be built into the database. The minimum requirement is that the release date, i.e. the date the information becomes public and no longer protected by confidentiality, must be stored with each record in the database. Users of the database must know and respect what this means, i.e. that the information must not be released outside the authorities (probably a 'need-to-know' criteria could be applied), unless the owner of the data has granted specific permission. Different countries have different rules for this, and principles and details are often spelled out in the mining laws and regulations. If the mining law is under revision, this is an issue that GSD should pay special attention to.

Verification and quality control

Populating a database using old sources of data or relying on perhaps uncertain or unreliable numbers from various reports creates some inherent problems of verification and quality control. Although the database will contain the reference to the original source, the owner of the database takes on a certain responsibility for the quality of the content of the database. Ideally, all attribute values should be verified. Is this really the accurate position? Do we really believe this is a good geological/genetic model? Also, using old compilations of mineral occurrences, there is the risk of getting duplicate entries, because the same site may be entered twice under different names, etc. Verification and quality control is essential for all entries.

There are many questions of this type, which highlight the need for accuracy and precision, but obviously it is not practical or feasible to insist on visits to all mineral occurrences in order to check on the data. However, every opportunity to do so should be exploited and other means of checking the content should be considered and applied whenever possible. All paths of input must be analysed and arranged so as to minimise the risk of erroneous input to the database. It is probably a good idea to give some indication of the soundness and reliability of the data in the database.

Interfacing to GIS

Although not a main issue for the mission May 2003, the need for future use of the content of the data-base in ArcView or other GIS systems is recognised by the Consultants and this will be a main point of attention during Mr. Kwame O. Boamah's work stay at GEUS in Copenhagen in August 2003. The common GIS programs, ArcView and MapInfo, and most other GIS systems have built in interfaces to Access 2000, making it possible to extract any combination of data from the database. So this will not be a problem in itself for GMODB. Various details in how to do this and how to display information will be discussed in August. The basic principle will be that the information in the database will be available to all map producers within the GSD and that the information can be plotted on any map where it makes sense.

Hardware and software

The database will be programmed in Access 2000 and will run on any machine on which MS Office 2000 runs. All modern PC's have ample capacity for the database as described in this document. In future versions the database will be server based, but provided the licenses and set-up are correct this will not be a problem to arrange.

Notes on the use of the database

Later in the process a proper, but brief manual should be produced. Some of the information in this document, but not all the discussion, should be incorporated in the user manual. At this time only a few comments are given on users of the system and some basic requirements concerning security, because these may have an impact on details in the programming of the database. The last sections of the design document contain hints to users, supported by illustrations showing the input screen-forms for the database.

General use

It is intended that the database should be reachable by many in the GSD, but that it shall be ***known*** which persons have access to the database. Not all users should be allowed to modify and add to the content of the database. The profile of the general user must be taken to be employees of GSD, who know and understand the rules of confidentiality, have a reasonable command of computer use, and have been given the explicit right to see and use the data in the database. He/she should only be allowed to read from the database, or transfer data from the database into some other system, e.g. GIS systems for the purpose of including the information on a map. Although the data are removed from the database, the rules of confidentiality of course still apply.

To avoid unintended destruction of the content of the ‘master database’, the general user should not be allowed access to this at all. It is better that the compiler (see below), at dates of his or GSD’s choice (e.g. when the database content is of sufficient quality and completeness) produces a CD-ROM version of the database and distributes this to divisions with interests in the use of the data. ***This CD-ROM must be clearly marked with the name of the database, the version number and the date of this version number***. All users of the data can then refer to this when they apply the data to other purposes. When sufficient new data have been input to the database, a new version with a new date can be produced on a new CD-ROM. This arrangement is especially well suited to GSD as long as there are no LAN facilities. When these are established, other solutions involving server-based databases will be possible.

Compilers

In the present situation concerning computer facilities at GSD, it is recommended by the Consultant to appoint one employee the function as ***compiler***. Under supervision if necessary (concerning both computer use and principles for the harvest of input data), the compiler should be given the responsibility of inputting data to the GMODB. If necessary, some training should be given to the compiler, but it is equally important that he or she can be trusted to work systematically and carefully, so that the data in the database can be trusted. It cannot be left to the compiler alone to make all the choices and judgement calls as to quality and relevance of the input data; geologists and other specialists should support him/her for this.

The compiler should be given full time access to a good PC with all the relevant programs. The computer should have facilities for writing CD-ROMS, and maybe also a proper back-up system with duplicate disks or similar. The master copy of the database should reside on this computer.

Security

Probably all versions of the database should have a password access system. The risk of inadvertently loosing a CD-ROM with all the data, of which some are confidential, must be reduced to a minimum. Should it happen anyway, a password system may at least provide some hindrance for the illegal use of the data.

The procedures used by the compiler must be planned so that the risks of errors are reduced as much as possible. A systematic system of back-up should be established.

The master copy of the GMODB must also be password protected. The version forwarded with the delivery at the end of the mission in May 2003 does not have password facilities implemented.

Requirements and specifications for the database

The designs of the Ghana Mineral Occurrence Database (GMODB) must take into account the following criteria, functions, and standards to the highest degree possible. The issues are listed in random order within the main groups given (but may in a later edition of the design document be re-organised). This section of the document together with the definitions of attributes basically contains a summary of the designer's instructions to the data modeller and programmer for the construction of the database. After the construction of the database this list provides a reminder of what the end user can reasonable expect the GMODB to 'deliver'.

General:

- The database must be able to contain all summary results from field work by GSD, information from company reports, and information from previous compilations.
- The database system should be programmed in Access 2000 assuming a Windows 2000 or XP environment.
- The first version can be assumed to be a one licence/one machine version, but it will at a later time be desirable to move to a server version with several simultaneous users.
- GMODB must be exportable (e.g. via CD-ROM) in such a way that the database itself and all the images and links are transferred and available on the receiving system.
- Language in the database and on screens, reports etc. must be English.
- Simple, standard Access solutions are preferred when possible. Extra programming should be kept to a minimum and if necessary should be specifically documented.
- It must be possible to handle different categories of users.

Input:

- The GMODB must have an opening screen, which gives access to all functions and forms.
- The GMODB should be fairly simple to use and enter data into. Input in the normal situation should be screen-forms organised in a logical manner. These forms should be useable by any person with a basic understanding of IT and databases.
- As many as possible of the input fields (attributes) should be given help texts, constraints etc. to help the user. Whenever possible, the field shall be given a pre-defined standard value automatically. Specification will be given in the list of attributes.

- It should be possible to insert large amounts of data from Excel files in one operation by a qualified person.

- The database will use a number of Look-up tables (LUTs). There must be tools for their maintenance and editing.

- GMODB must have the ability to receive, store and re-display images, such as maps, photos, and other figures, probably by use of the hyperlink field type in Access or images stored directly.

- Security measures should be set to prevent accidental erasure of data by inexperienced users.

- Back-up facilities and requirement must be defined.

Search and output:

- GMODB should be easy to search. Standard searches should be pre-defined.

- Results of searches should be directed to screen – if necessary special search forms should be constructed. Input forms should also be useable as search forms.

- Pre-defined reports (to file or paper) may be necessary for certain standard, often repeated operations.

The issue of resources and reserves

Many countries use different ways of defining resources and reserves; many adopt the nomenclature of big producing countries like Australia, Canada and USA, but although there are similarities between these they are not exactly the same. The UN has made attempts to provide a common system and GSD has been given a copy of the report of this work group (mid nineties), although it is uncertain if and to what extent the recommendations of the work group have been adapted around the world. The report does, however, provide a good discussion of the issues at stake. The Consultant cannot recommend one system or another without more study, which would be outside the TOR of the contract under which this activity is carried out. The Consultant can urgently recommend that this be made an object of study and decision in the Ministry, so that an official Ghana system of classification can be adopted in the database, or so that any system presently used in the Ministry can be adopted. Until then, the geologist of GSD will define how they wish to understand the two terms resource and reserve and the prototype of the GMODB will be arranged to agree with this.

Attributes and tables

Based on the above and adding more (technical) attributes necessary for a number of reasons not dwelt on here, the following main logical tables describe what information needs to be in the database as it is presently conceived at GSD. Explanatory comments and pointers have been added as notes to the attributes. These also contain small discussions of principle matters and technical details and should be studied.
Based on the definitions of attributes and their internal relationships, the proper tables of the data model must be constructed by the programmer at the next step of the database development. The actual working tables in the final database may turn out different from the logical tables described here, because certain technical attributes have been added or because the data modelling process indicated that the tables needed to be broken down (normalised) in a different way. One consideration in this context is the need to make sure that the database could be expanded with new attributes without this causing too much trouble for the programmers. The final data model as presented by Access 2000 will be shown after the final work session in August.

General comments

The information on each of the following tables is systematic and organised according to a few basic principles:

- The table name appears in the upper-left corner of the table.

- Each attribute in a table is given an identification number consisting of two letters derived from the table name and a number. This design document goes through several versions before the final version can serve as documentation, and while this happens, the identification numbers may change occasionally.

- The attribute number in heavy black indicates that the attribute is mandatory. This means that information ***must*** be filled into this field, before the database will accept the input of a record.

- For some attributes it is necessary to define a code for ‘unknown’ or ‘not applicable’ or similar. Notes on this will appear under the ‘Comments’ column in the table, together with hints on whether or not the code should be entered automatically and then modified by user, if he has valid data to replace it with?

- Some attributes will be given the type LUT (Look-up table). This means that the attributes can only take one of the values in the LUT. Sometimes the LUT will be a special table with given entries supplied in advance or created by the user according to the situation. In other cases, the LUT will be another table in the database, which is checked before entry is allowed.

- Look-up tables are usually finally defined during data modelling. In this note a few preliminary look-up tables have been included in the description. They will be finally described in the final edition of the design note and user manual (probably August – September 2003).

- Sometimes changing LUTs demand special user privilege. Notes under ‘Comments’.

- The first attribute in all tables has the added code of _id. This is always a unique identifier generated by the database at the time of entry. In any table there can never be two primary key entries to this attribute that are the same. It can therefore always be used to pick out one record in a table.

- In some tables the second attribute is also an ‘_id’ type but here the ‘_id’ refers to another table, it is a ‘foreign key’. The two ‘_id’ attributes together define a composite key, which is necessary to pull out information on a specific mineral occurrence.

- All the tables contain four attributes, usually put at the end of the list in this document. These are for ‘house-keeping’ purposes, and are minimal compared to what many database systems demand. Basically these attributes will (if properly filled out at each session involving insertion or modification of the table) tell future users of the database who first input the record into the database and at what date this happened; if the record is modified later, the date and user name for this will also be recorded, but this will be replaced at the following modification (i.e. only a record of the most recent modification is stored in the database).

The tables

The database consists of a number of tables, and each table describes in attributes some part of the information required to be stored in the database. During the mission to Accra in May 2003 the following tables have been defined, following discussion with GSD managers and employees:

- **Table (Mineral occurrences - main):** As the name implies this is the main table containing the attributes used to describe the mineral occurrence. It will be supported by a number of look-up tables and supplemented by the other tables.

- **Table (Resources):** In this table is collected all estimates, quotes etc. of the total resource of a mineral occurrence. This is put in a separate table because it will allow for more than one estimate for each mineral occurrence (at different times or for different commodities). See note on resources and reserves.

- **Table (Reserves):** Similar to resources – definitions must be clarified, see discussion above.

- **Table (Images):** This table will contain links to and information about digital images relating to a mineral occurrence. There can be many from any mineral occurrence. The image can be a photo, a sketch, a map etc. in e.g. TIF format.

- **Table (References):** In this table it has been attempted to include different types of references (equal to documentation for the data) such as references to publications, reports, licenses, and companies.

These five tables are the nucleus of the simple prototype of the GMODB. More tables may be added, the present selection reflects the strategic decision not to include details of licensing, economics, etc. in the database. These tables will sometimes be used as look-up tables for each other. It may also be decided at a later time to add more attributes to some of the tables, or some of the attributes may be dropped because they turn out to be superfluous the way GSD decides to use the database.

In addition many proper look-up tables are contemplated. How many of these it will be possible to implement at the present time is uncertain, because it depends on a number of factors: availability of digital versions of the appropriate lists, clarification of definitions, and final decisions by those involved. There are several reasons why look-up tables are a good idea and should be used as extensively as possible. To mention a few,

- Only 'legal' values for the attribute can be entered.
- No spelling mistakes, therefore searches based on LUT fields are accurate.
- The LUT can be maintained on an organisational wide basis, defining e.g. the consensus of all departments.
- In practice, the editing of the LUTs can be carried out by the compiler (by consent of the group concerned), who can add or modify according to how developments take place. Other users can thus be helped to use consistent and homogeneous terms in agreement with the GSD approved definitions.
- Once a LUT has been constructed it can also be used in other databases, thus making certain that different databases use the same definitions/options of common attributes.

The following look-up tables are suggested in the description of the tables, but not described in detail in this document at this time. Those look-up tables that have been put in place will usually be preliminary ones to be further developed by GSD.

- **Look-up table (Regions):** List of Regions in Ghana. If this list is called from a field, one more name from the list can be entered automatically in the field by pointing to it with the cursor.
- **Look-up table (Districts):** Similar for Districts. Depending on how this is done, the two LUTs may be combined into one, removing the risk of putting a District into the wrong Region.
- **Look-up table (Positioning method):** An indication of how the site was positioned.
- **Look-up table (Geological map sheet):** The official GSD map list.
- **Look-up table (Topo map sheet):** The official Ghana Survey map list; standard scale of 1:50,000.

- **Look-up table (Genetic deposit type):** List of standard genetic models adapted by GSD as internationally recognisable description of a mineral occurrence or deposit.

- **Look-up table (Ghana class):** Similar for the classification of the resource in terms of how well determined and known etc., according to official Ghana definitions.

- **Look-up table (Alterations):** Typical alterations of importance for mineralisations.

- **Look-up table (Host rocks):** List of officially recognised rock (type) names by the GSD.

- **Look-up table (Ore minerals):** List of ore minerals acknowledged by the GSD.

- **Look-up table (Other minerals):** Similar list of other minerals.

- **Look-up table (Type of occurrence):** List of various types of occurrences, such as prospect, deposit, mine, etc.

- **Look-up table (Commodities):** GSD official list of commodities.

- **Look-up table (Type of image):** List of various types of digital images.

- **Look-up table (Users):** List of the users allowed by GSD to input and modify in the database.

- **Look-up table (Reliability):** GSD score for the overall reliability of the information about a given mineral occurrence.

- **Look-up table (Importance):** GSD score for the overall importance of the mineral occurrence site.

- **Look-up table (Confidentiality):** List of the various stages of confidentiality which are relevant according to Ghana's laws and regulations.

The division into different tables indicated here may not be final. The reasoning behind the splitting into different tables has to do with the process of normalisation (an important concept for relational databases and object-oriented analysis), reducing the number of empty spaces in the database, and avoiding redundancy and other unwanted effects in the database. When entering data into the database via a screen-form, the splitting into tables will not necessarily be evident, because the input screens will be constructed according to the logical way of entering information. When retrieving information from the database via pre-constructed screen-forms, the same is true. When retrieving data by use of Structured Query Language (SQL) tools, the user needs to understand concepts like e.g. joining of two tables in order to produce a printout involving information from more than one table. SQL can be considered an international standard for setting up searches in relational databases.

In the following pages the tables and their attributes are described. The notes at the end of each table in this document are important; they contain discussion of options and consequences of choices, and some technical details. In doing so they provide an indication of how relational databases work and the type problems one must be prepared to face when constructing a database. In some cases the word ***'Decide!'*** is included in the comments column; this means that GSD should preferably make a decision now on this. If this is not done, the Consultant will make a choice, at least for now.

TABLE (Mineral Occurrences - main)

Attribute Ref no	Attribute name	Definition	Type	Comments
MO1	Mi_oc_id	Database identification (generated by db) of records in the table Mineral Occurrences	Integer; Primary key	Unique; generated by db; the user has no influence over this attribute
MO2	Name_1	The name used locally/officially for the mineralisation	Char	These two attributes give space to the naming. Conventions must be defined how to use them, supplement or alternative. Default: not known
MO3	Name_2	Alternative or supplementing name	Char	
MO4	Main_Typ	The type of mineral occurrence (Indication to Closed Mine)	LUT	LUT legal values could be: • Indication • Mineralisation, • Prospect, • Deposit, • Artisanal Mining • Mine, concept • Mine, under construction • Mine, Active • Mine, Inactive • Mine, Closed • Mine, illegal • Not Known Default Not known Note 1
MO5	Longitud	Longitude of the mineralised site (Decimal Degrees East)	Real	Decimal degrees. Also code for not known, e.g. co-ordinates of lower left corner of permissible range. Check within Ghana limits of –3.5 to 1.5 Degrees East. Default 1.5
MO6	Latitude	Latitude of the mineralised site (Decimal Degrees North)	Real	Decimal degrees. Also code for not known, e.g. co-ordinates of lower left corner of permissible range. Check within Ghana limits of 4.5 to 11 Degrees North, Default 4.5 Note 2
MO7	Height	The height of the site above sea level in meters	Real	One height; Default -1
MO8	Pos_Meth	The method used to find the position of the site	LUT	LUT must be expandable, but could include at least: • Measured by GPS • Read off map • Taken from company report • Surveyed • Not known Default: Not known
MO9	Pos_acc	Estimate, guess or description of positional accuracy	Char	Guess or estimate a figure (units) or describe in text; Default: Not known
MO10	GSD_Sht	Number of GSD geological map sheet	Char or LUT	LUT of all GSD geological maps could be used. Default: Not known
MO11	Topo_Sht	Ghana Survey topographical map sheet number	Char or LUT	Probably the official maps have all been defined, numbered and named. Could be arranged in LUT. Default: Not known Note 3
MO12	Region	Name of Region	LUT	Official names only, therefore a LUT; a list of all Regions should be set up as a LUT. Note 4
MO13	District	Name of District	LUT	Similar if set up as LUT; alternatively typed in by user. Default: Not known
MO14	Village	Nearest village or town	Char	Free text. Default: Not known

MO15	Gen_type	Classification of genetic type according to international methods	LUT	LUT of GENETIC DEPOSIT TYPES or geological model for the genesis of the deposit according to accepted international system. – Must also contain 'not determined' Default: Not known Note 5
MO16	Pre_Cls	Geologist's preliminary classification	Memo	Free text – can be used until a final conclusion can be reached
MO17	Gha_Clss	Classification of resource according to Ghana's adopted system	LUT	This could be a LUT if e.g. the UN International Framework Classification for Reserves/resources is adapted.
MO18	Width	Estimate/guess of width of mineralisation (meters)	Real	Code for 'not known'; could be -1
MO19	Length	Estimate/guess of length of mineralisation (meters)	Real	Code for 'not known'; could be -1
MO20	Av_Thick	Estimate/guess of the average thickness (meters)	Real	Code for 'not known'; could be -1
MO21	Area	Estimate/guess of the area of deposit projected to surface	Real	Estimate; and code for 'not known' -1 (km^2)
MO22	T_ Overbu	Estimate/guess of the average thickness of overburden	Real	Estimate in metres or code for unknown –1
MO23	Structur	Description of important structures for the mineral occurrence	Memo	Free text to define all important structural features important for the formation of mineralisation.
MO24	Host_rck	Description of the host rock	Char or LUT	Free text or LUT containing a list of common (or all) rock names; the attribute should be able to hold a list of rocks separated by comma; preferably the full name(s) in English **Decide!**
MO25	Ore	Description of the Ore	Char	Free text with a name or common denominator for the ore. Default: not determined
MO26	Age_ore	Age of the Ore (=age of mineralisation)	Char	The estimated age and an indication of method of dating and other relevant information – therefore Char, not Real. Default: Not determined
MO27	Ore_Min1	The most important Ore mineral	LUT	LUT containing a list of common (or all) ore minerals. Default: Not determined
MO28	Ore_Min2	The second most important Ore mineral		Same LUT as MO27
MO29	Ore_Min3	The third most important Ore Mineral		Same LUT as MO27
MO30	Oth_Min1	The most important other mineral present	LUT	LUT containing a list of common (or all) minerals (contains 'not determined' = default)
MO31	Oth_Min2	The second most important other mineral present		Same LUT as MO30
MO32	Oth_Min3	The third most important other mineral present		Same LUT as MO30
MO33	Main_Co1	The most important commodity	LUT	LUT containing a list of commodities: contains 'not determined'; default also 'not determined'
MO34	Main_Co2	The second most important commodity	LUT	Same LUT and default as MO33
MO35	Main_Co3	The third most important commodity	LUT	Same LUT and default as MO33
MO36	Alterati	Important alteration process	LUT	LUT containing common alteration processes; Default: 'Not determined'.
MO37	Reliab	GSD score for reliability of information on this mineral occurrence	LUT	LUT (reliability) Define score 1 – 5: evaluate and give score: default: '0' for no score.
MO38	Importan	GSD score for importance of this mineral occurrence site	LUT	LUT (importance). Similar. Note 6
MO39	Gen_com	General comments of the user's choice	Memo	Free text
MO40	History	A brief account of the history of the site of mineral occurrence	Memo	Free text

MO41	Confiden	Confidentiality Status	LUT	LUT of stages of confidentiality, e.g. • Closed file Company data • Open file Company data • Open file GSD data • Closed file GSD data • Limited access • Public • Not known =default
MO42	Rel_data	The date when information can be released to the public	Date	If the mining law sets a limit to the confidentiality period, the release data should be input from the start. Default 1-1-2100
MO43	Frst_Ent	Date for the first entry of this record into the database	Date/time	Generated by database
MO44	Na_F_Ent	Name of the person who is responsible for the first entry of this record	LUT	A LUT of Users must be constructed containing those authorised to enter data into the database.
MO45	Lst_Mod	Date/time for the most recent modification of this record	Date/time	Generated by database:
MO46	Mod_by	Name of the person responsible for the most recent modification of this entry	LUT	LUT (Users) default None

Notes:

1. The number and character of the permissible values in the LUT reflect the GSD's choice of how detailed the information in the database should be. The values suggested here will make it possible to distinguish between mines with different status. If that is not required by GSD, just one value MINE will suffice.

2. It is suggested only to include latitude and longitude in decimal degrees. It would be possible to also include the position in x and y of whatever standard system is required, but then it would be necessary to include a routine checking that the two different definitions of position are similar, i.e. points to exactly the same place. Otherwise you run the risk of having inconsistent data in the database.

3. If the Ghana Survey Topographical maps are all numbered and titled, it would be advantageous to make this into a LUT. This LUT could be made more useful in itself by including not only the number and name (one of which is probably all you need in this table for a mineral occurrence), but also additional attributes as year of latest editions, etc. etc. Provided this information could be obtained from the source, the LUT would be very useful in many other contexts.

4. If Ghana has an official list of regions, counties, communes or whatever is relevant here, this should be acquired and set up as a look-up table. This look-up table would also be useful for any other database involving locations in the country and would ensure that all databases referring to it use the same administrative divisions and names.

5. Genetic model is a label for how the geologist thinks a mineralisation has formed. There are several different systems that can be applied: USGS has published a number of reports on Deposit Models; the Canadians and the Australians have published other but similar systems. At this time the Consultant is not aware of the tradition for this in Ghana and has put in a variation of a Canadian system, but GSD should adapt their own system for use in Ghana.

6. The two 'score' attributes are meant as a way for GSD to score, assess the overall reliability of the information/data for a mineral occurrence and the importance of a mineral occurrence. This presumes a scheme for how GSD wishes to use the data. It could e.g. be used to carry out a quality control of sites and assign a value indicating that this site has been checked and is good (score 5 for reliability); or it could be used to indicate that in GSDs opinion, this is a particularly important site for the regional characterisation of the mineral environment or the understanding of the geological model (score 5 for importance). Similarly, score 1 would indicate that the data should be used with caution or the site may be interesting in itself, but in GSDs opinion probably carries little importance in the general scheme of things. This is an example where GSD takes the step from purely registering information to using the information in a mineral assessment or for the construction of a metallogenic map.

Future extensions: It has already been mentioned that it is possible to ask for a much more detailed description and that would call for more attributes. However, for each attributed added, more work is called for to keep the database running and data coming in.

Judging from the few examples of sets of input data made available at this time, information of grades is not often available; in the present version of the database it can be entered as part of the description of the ore. If it is required it is also possible to include a 'grades' field for each commodity, but the consultants would prefer not to do that until GSD has discussed and decided how the terms resources, reserves, grades, etc. should be defined and used in GSD. If there are no traditions concerning this at the present time at GSD, the Consultants can suggest to study the US Geological Survey nomenclature, perhaps together with the Canadian and Australian systems for inspiration.

TABLE (Resources):

Created LTh 21/5/2003; modified LTh/LC 26 May

Attribute Ref no	Attribute	Definition	Type	Comments
RO1	Reso_id	Unique identifier of records in the resource table	Integer, Primary Key	Generated by database system
RO2	ROMO-ID	The mineral occurrence (identified by its id in the mineral occurrence table) to which this resource estimate is relevant	Foreign Key MO1	This means that the at any time existing content of the MO table determines what can be entered here Note 7
RO3	Commodit	The commodity for which the resource has been calculated	LUT	The LUT should contain all the possible commodities plus the code 'Combined'; this last option is used for a combined calculation of the three main commodities described for the MO33 Note 8
RO4	Date_esto	The date at which the estimate of the size of the resource was done	Date	There must be a code for 'date not known' = default = 1-1-1000 Note 9
RO5	Who_est	The person, company, etc. who is responsible for the estimate	Char	Free text containing the identification: Default: 'not known'
RO6	Comment	General comments	Memo	Free text containing any comment or explanation deemed necessary
RO7	Frst_Ent	Date/time for the first entry of this record into the database	Date/time	Generated by database
RO8	Na_F_Ent	Name of the person who is responsible for the first entry of this record	LUT	A LUT of Users must be constructed containing those authorised to enter data into the database.
RO9	Lst_Mod	Date/time for the most recent modification of this record	Date/time	Generated by database
RO10	Mod_by	Name of the person responsible for the most recent modification of this entry	LUT	LUT (Users) Default none

Notes:

7. Note that records in this table can only be filled if a pre-existing MO-ID (MO1) can be referred to. This means that estimates or guesses of resources are only relevant if they can be attached to a specific mineral occurrence.

8. Most of the attributes are just free text. If it is possible to define a reasonably fixed set of values for the attributes, LUTs can be considered.

9. Note that if a new estimate is done at a later date, the information should be entered not by modifying the date and size of an existing entry, but by creating a new entry in the table with a new date and new size of resource.

Future extensions: Depending on how Ghana desires to define resource and reserve, modifications may become necessary. For now, this and the following table simply allows the storage and documentation of two figures related to a mineral occurrence.

TABLE (Reserves):

Created LTh 21/5/2003; modified LTh/LC 25 May

Attribute Ref no	Attribute	Definition	Type	Comments
RE1	Rese_id	Unique identifier of records in the reserve table	Integer; Primary Key	Generated by database system
RE2	REMO_ID	The mineral occurrence (identified by its id in the mineral occurrence table) to which this reserve estimate is relevant	Foreign Key MO1	This means that the at any time existing content of the MO table determines what can be entered here Note 10
RE3	Commodit	The commodity for which the reserve has been calculated	LUT	The LUT should contain all the possible commodities plus the code 'Combined'; this last option is used for a combined calculation of the three main commodities described for the MO33
RO4	Date_est	The date at which the estimate of the size of the reserve was done	Date	There must be a code for 'date not known'
RO5	Who_este	The person, company, etc who is responsible for the estimate	Char	Free text containing the identification: code for 'not known'
RO6	Comment	General comments	Memo	Free text containing any comment or explanation deemed necessary
RO7	Frst_Ent	Date/time for the first entry of this record into the database	Date/time	Generated by database
RO8	Na_F_Ent	Name of the person who is responsible for the first entry of this record	LUT	A LUT of Users must be constructed containing those authorised to enter data into the database.
RO9	Lst_Mod	Date/time for the most recent modification of this record	Date/time	Generated by database
RO10	Mod_by	Name of the person responsible for the most recent modification of this entry	LUT	LUT (Users)

Notes:

10. Note that this table is exactly equal to the table of resources. The same comments apply.

TABLE (Images):

Created LTh 21/5/2003; modified LTh/LC 25 May

Attribute Ref no	Attribute	Definition	Type	Comments
IM1	Imag_id	Unique identification of each image in the image table (generated by database)	Integer; Primary Key	Unique; generated by db
IM2	IMMO_ID	Reference to the mineral occurrence for which this image is relevant	Foreign Key MO1	LUT (Mineral occurrences - main); records can only be entered into this table if MO1 exists
IM3	Imag_Typ	Description of Image Type	LUT	LUT of different types, e.g. scanned map, photo, sketch Default: Not known Note 11

IM4	Imag_Txt	A descriptive text to the image	Memo	Free text; should be thought of as text to a figure
IM5	Imag_Inf	A specification of technical details	Memo	Free text; formats (TIF, JPG, etc), resolution etc. Note 12
IM6	I_Source	The source of the image	Char	Free text Default: Not known
IM7	I _Cright	The correct copyright statement	Char	Free text Default: Not known
IM8	Image	The name (address) of the file containing the image	Hyperlink	Note 13
IM9	Comments	Any other comments	Memo	Free text
IM10	Frst_Ent	Date/time for the first entry of this record into the database	Date/time	Generated by database
IM11	Na_F_Ent	Name of the person who is responsible for the first entry of this record	LUT	A LUT of Users must be constructed containing those authorised to enter data into the database.
IM12	Lst_Mod	Date/time for the most recent modification of this record	Date/time	Generated by database
IM13	Mod_by	Name of the person responsible for the most recent modification of this entry	LUT	LUT (Users)

Notes:

11. The LUT (IM3) is used to store the type of image; at the present time, these could be e.g.: Site Photo, Figure, Model, Geological Map, Regional Geology Figure, Exploration/Exploitation site photo. These are the images requested in the write-up above.

12. IM3 – 7 relates to details behind the image; these can be used as additional search parameters, but they are not critical.

13. The image itself is stored by a link to the file containing the image. This means that conventions will have to be defined for where/how to store these files. Probably a fixed and lasting directory structure for the images must be defined. Browsing this directory structure and accepting the correct file will generate the hyperlink entry to an image. Alternatively, the image itself could be stored (technical detail to check).

Future extensions: If one considers displaying maps with locations and links to images, it may be a good idea to include a position for each image (IM9&10) unless the position of the mineral occurrence itself is sufficiently accurate. This can be used as a quick and dirty display on a map e.g. by giving opportunity for a hotlink in ArcView from a symbol placed at the position indicated.

TABLE (References):

Created LTh 20/5/2003; modified LTh/LC 26 May

Attribute Ref no	**Attribute**	**Definition**	**Type**	**Comments**
RF1	Ref_id	Unique identification of each record reference in the reference table	Integer; Primary Key	Unique; generated by db
RF2	REFMO_ID	The mineral occurrence for which this reference is relevant	Foreign Key MO1	LUT (mineral occurrences -main); records can only be entered if MO1 exists (DMO1) Note 14
RF3	Company	Name of the company responsible for the information	Char	Free text Default: Not known
RF4	Lic_no	Official license number for the property on which the mineral occurrence is situated	Char	Free text Default: Not known
RF5	Lic_date	The date at which the above information on license was true	Date	Entered by user. Default: 1-1-1000
RF6	Authors	Names	Char	Free text

RF7	Year	Year of the publication	Integer	1500<year<9999
RF8	Title	Title of the reference	Char	Free text
RF9	Journal	Name of journal and pages etc.	Char	Free text
RF10	Comments	Any comments	Memo	Free text
RF11	Frst_Ent	Date for the first entry of this record into the database	Date	Generated by database
RF12	Na_F_Ent	Name of the person who is responsible for the first entry of this record	LUT	A LUT of Users must be constructed containing those authorised to enter data into the database.
RF13	Lst_Mod	Date/time for the most recent modification of this record	Date/time	Generated by database
RF14	Mod_by	Name of the person responsible for the most recent modification of this entry	LUT	LUT (Users)

Notes:

14. Can the reference be relevant for more than one mineral occurrence? If so, how handle? List of MOX here?

Technical note to the database

Already in the choice of 'logical tables' described above, a number of choices were made. As explained in the introduction, the time available for the construction of this prototype database was limited and that alone made it necessary to limit the number of facilities and details that could be built into the prototype at this time. Further limitations were unavoidable, because the values of many of the LUTs have to be discussed at GSD, some probably at length, before a decision can be made and the digital version of the required lists be constructed. In such cases the Consultants have just included a simplified LUT which can be used in the beginning, but which as soon as possible should be edited to be more detailed, contain more choices on the list and/or be more in agreement with the Ghana/GSD traditions and environment.

In relational databases there are often several different ways to structure the relationships between the different tables and also to the look-up tables. The normalisation process can be taken to various levels. In this prototype, the simpler-to-use options have mostly been chosen, resulting in some danger for duplicity in some cases, i.e. many records with nearly the same content. There are ways of avoiding this, but it was agreed not do use these methods just yet. GSD personnel need to obtain more experience and form more firm opinions on the best and most suitable procedures related to the use of the database and it must be seen whether or not the practices anticipated by the Consultants actually become relevant, before more complicated structures and facilities are applied.

Hints to users - with examples of input screens to GMODB

In August 2003 a more detailed user manual can be produced. For now, a few hints have been included in the Design Document, partly to give a general impression of the database for readers interested in the subject, but not likely to use the database themselves, but mainly to provide some hints to actual users, to help them get started.

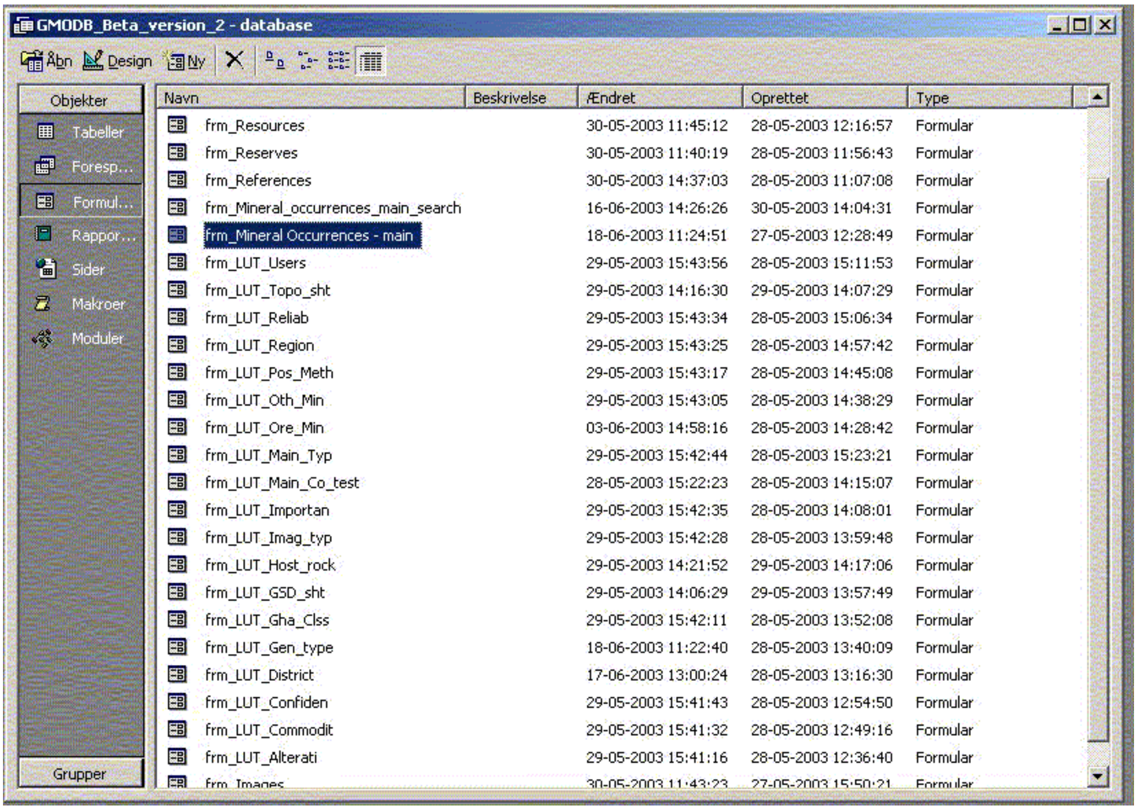


Figure 1: Overview of screen-forms in GMODB prototype. Double click on the one indicated and you will see the screen shown in Figure 2.

To open the database, find the file GMODB_prototype file in pathfinder and double-click on it. Find the overview of the ***screen-forms*** in the database, and double-click on the form indicated in Figure 1. If password protection has been installed, you will first have to give the password when prompted. In the final version of the database, GMODB will automatically open on this form as the main form for the operation of the database.

Figure 2 shows the main screen-form from which there is access to all fields in the database as well as to all tables and look-up tables. This form and its main segments will be briefly explained in the following notes, although this is only a preliminary description.

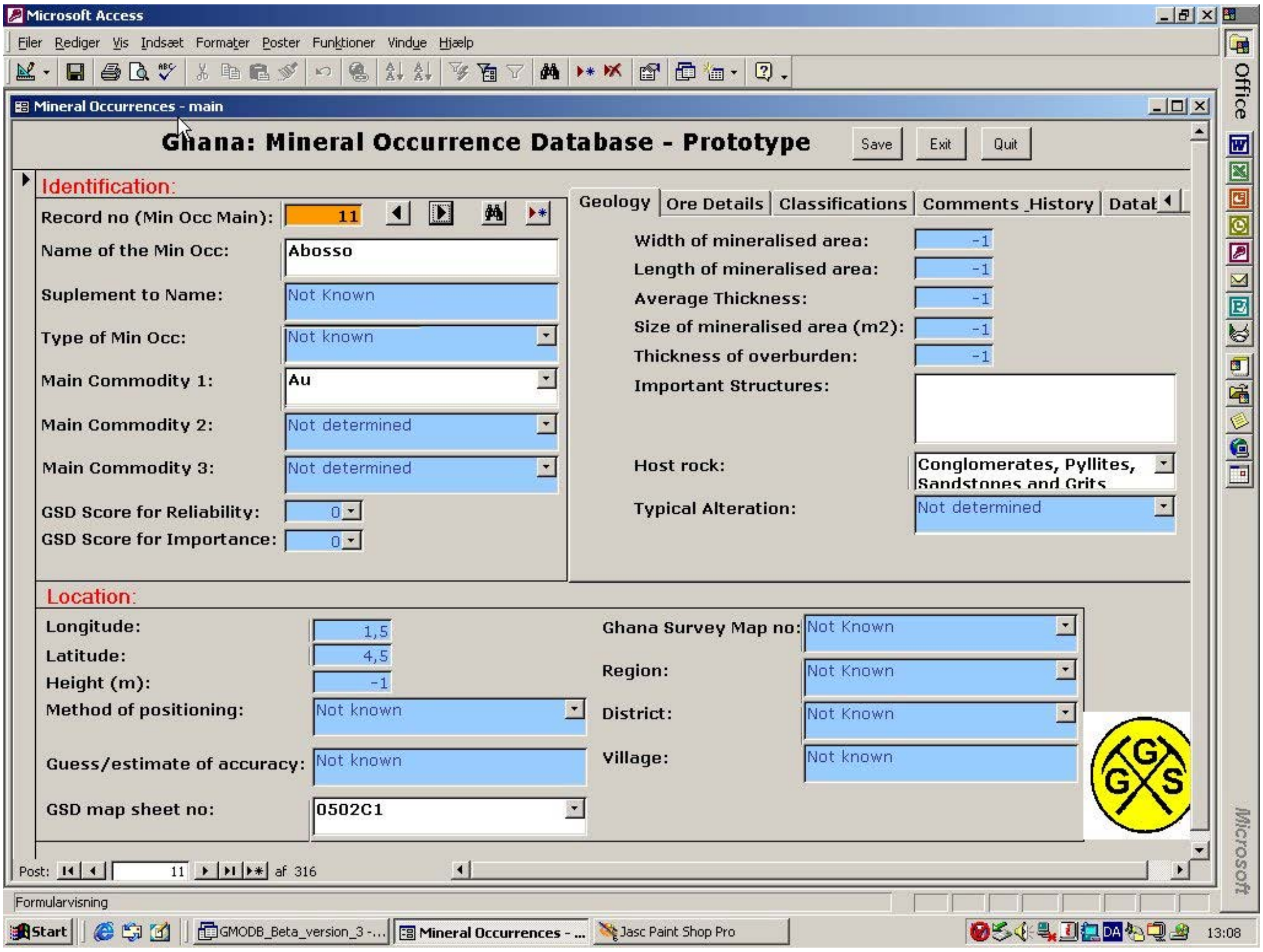


Figure 2: Main mineral occurrence input screen-form

The main screen-form has three sections, 'Identification', 'Location' and a segment with many sub forms arranged with labels on bars (upper right). Clicking on the bar text along the upper edge will give access to the various sub forms. Note that there are scroll-arrows in the upper right corner to scroll between all the sub forms.

The fields have different colours and these are meaningful, providing assistance to the user. Red colour indicates that the field will be filled automatically by the database – the entry in this field is generated by the database and the user cannot enter anything via the keyboard. Blue field means that the field has been filled automatically by a default value, because the user does not have (or did not have) any values for this field in the record. The user can overwrite such entries with legal values for the field. Fields with a thin line to the left of the field are mandatory – i.e. the database will only accept the input if all these fields are filled with data provided by the user or with the default value. Fields with a button showing a small arrow pointing downwards, have a LUT attached to them, and can only be filled by one of the values in the LUT (this will always include the default). The values in the LUT will become available as a drop down list by clicking on the small arrow (see Figure 3).

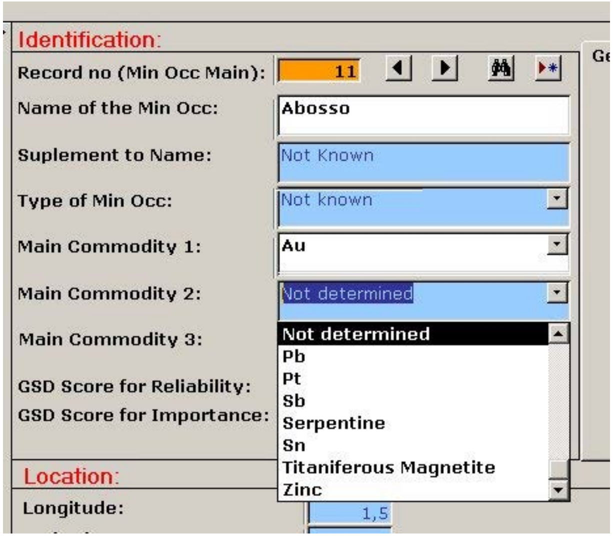


Figure 3: Example of a drop down list (in field Main Commodity 2). Click on the value you want to enter into the field.

Entering data for a new mineral occurrence should always start at the ‘identification’ segment of the input-screen and moving on to the location segment. Once these have been filled, additional data can be entered via the sub forms shown in Figure 4. Remember that for these four sub forms (and for the sub form for database administration, see Figure 6) the information entered will be stored for the mineral occurrence id shown in ‘Identification’ and together with the information on identification and location visible on the screen.

The selection of attributes shown on the sub forms still relate to the main table (see the section of this Design Document giving the details of the tables in the database). Further discussion is warranted with GSD, because there are any number of additional attributes that could be relevant, all depending on how GSD decides to actually use the database in fulfilling responsibilities. GSD has therefore been asked to discuss this in the period from May to August of 2003, so that the finalisation of the database construction planned to take place in August in Copenhagen during Kwame Boamah’s visit there, can benefit from that discussion. Should there be more details about the host rock? About metamorphic facies? Etc.

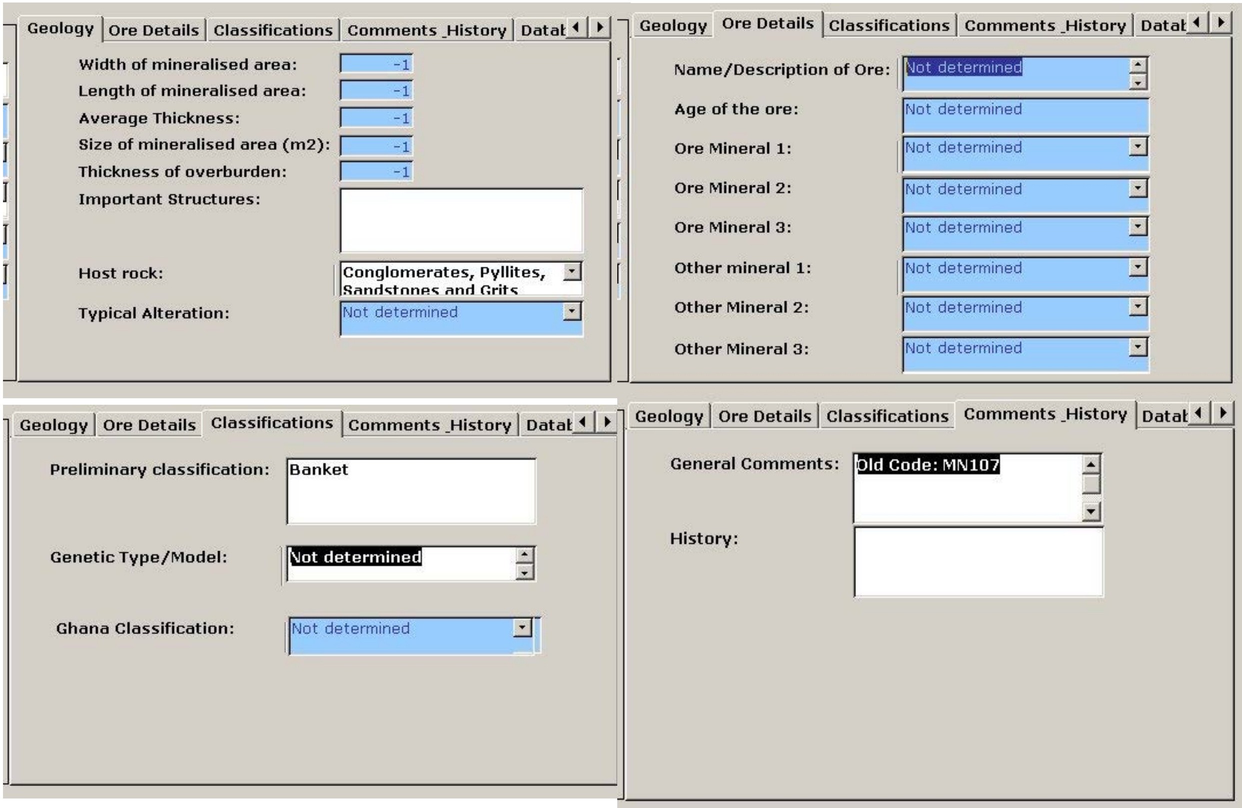


Figure 4: Four sub-forms used to enter information on a mineral occurrence. All information on these sub-forms is related to the mineral occurrence which is displayed in the 'Identification' and 'Location' segments of the main screen-form.

The extensive use of LUTs has been explained. Normally, in a well run-in database, these LUTs would all be finished and polished containing exactly what is needed. However, in the present case when the database is still under development, not all LUTs are ready. GSD has been given the job of deciding on the information required to be contained in them, and some are nearly ready. In order to be able to handle the LUTs the database has been equipped with a tool providing access to each of the look-up tables, so that additional values can be added and necessary editing performed. The access to the LUTs has been placed in one of the sub forms and is shown in Figure 5 together with one example of a LUT opened for editing. Please note that by mistake one LUT is missing, but it will be provided in the database delivered with this document.

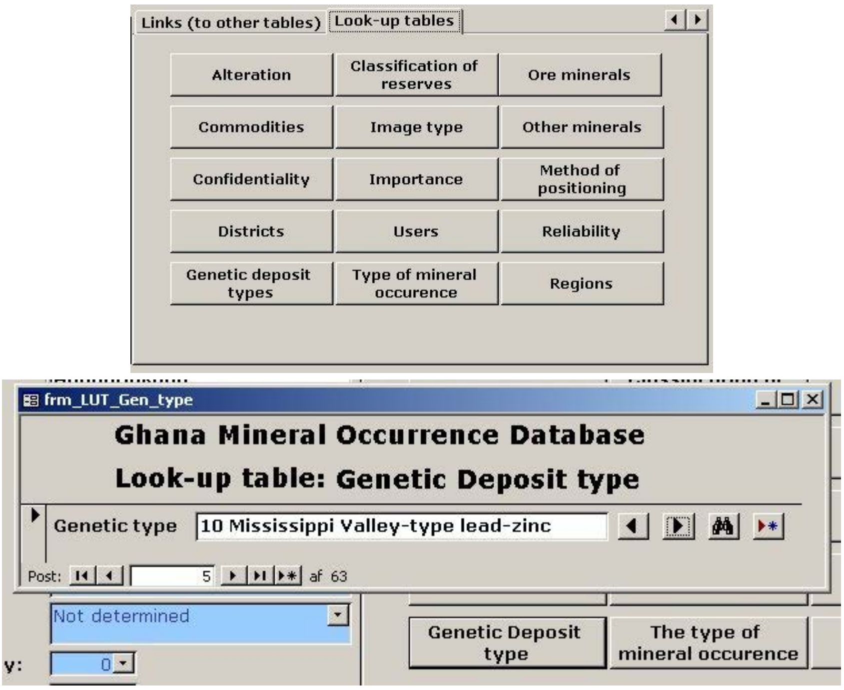


Figure 5: Upper part of the figure shows the sub-form giving access to all look-up tables. The lower part of the figure gives an example of one LUT (Genetic Deposit Types), which has 63 different values that can be used. Additional values can only be entered here, and this should only be done by consensus. Step between the values using the small buttons with arrows.

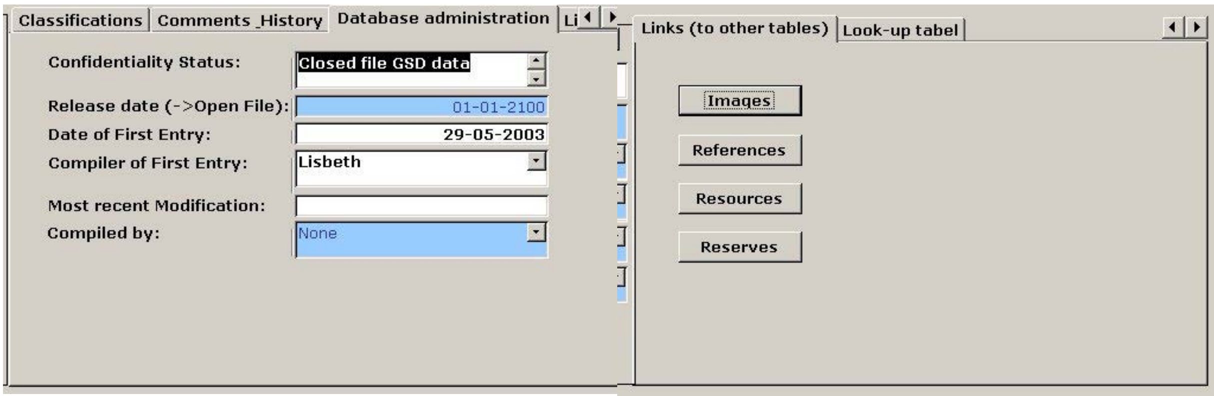


Figure 6: The sub-form to the left is for 'book keeping', providing a record of who entered the information on this mineral occurrence the first time and when, and the same for the most recent modification. The sub-form to the right gives access to other tables containing additional information relevant for the mineral occurrence displayed on the main screen-form, see Figures 7 to 10.

When operating a database it is often essential to be able to document who entered what information into the database. In Figure 6 is shown the sub form used for registration of this. The attributes on this sub form relate to the main table of mineral occurrences, and will receive input from the user and give him/her an opportunity to register as the person who is responsible for the input of a record, or for the modification of a record. Probably GSD should decide who will have this type of access to the database and include the names in the LUT of users. In any case, the use of these attributes demands care and accurate information from the user.

In Figure 6 is also shown the last sub form of the main screen, giving access to the four supporting tables in the database. The type of content of these four tables is indicated on the buttons, which will open the corresponding forms (Figures 7 to 10). Remember that although these are separate tables, the information must still be related to a mineral occurrence. To make sure no misunderstanding arises, this must be given specifically, see the following figures. In no case can the information be entered into the database without a mineral occurrence record number is given. Please note also that each of the forms contains the attributes needed to keep track of who entered or modified the information of the table in question.

If data relevant for any of these four forms are available for a record of mineral occurrence at the initial recording of data, then these forms should be filled as well. It is also possible to come back at a later time, if e.g. a new map has been located and scanned and is required to be linked to an existing entry in the database. Especially, this may be relevant for the registering of estimates of reserves and resources, where there may be many entries for one mineral occurrence, please see the discussion of this subject elsewhere in the document, but for all of the four forms, multiple entries for one mineral occurrence are possible.

Please note that the database does not contain any estimates of resources or reserves. However, in the test data there are a few estimates. ***The Consultants suggests that GSD uses these data as an exercise: find the data in question, identify the proper mineral occurrence and enter the estimates correctly***. This exercise will help the future users understand the principles applied.

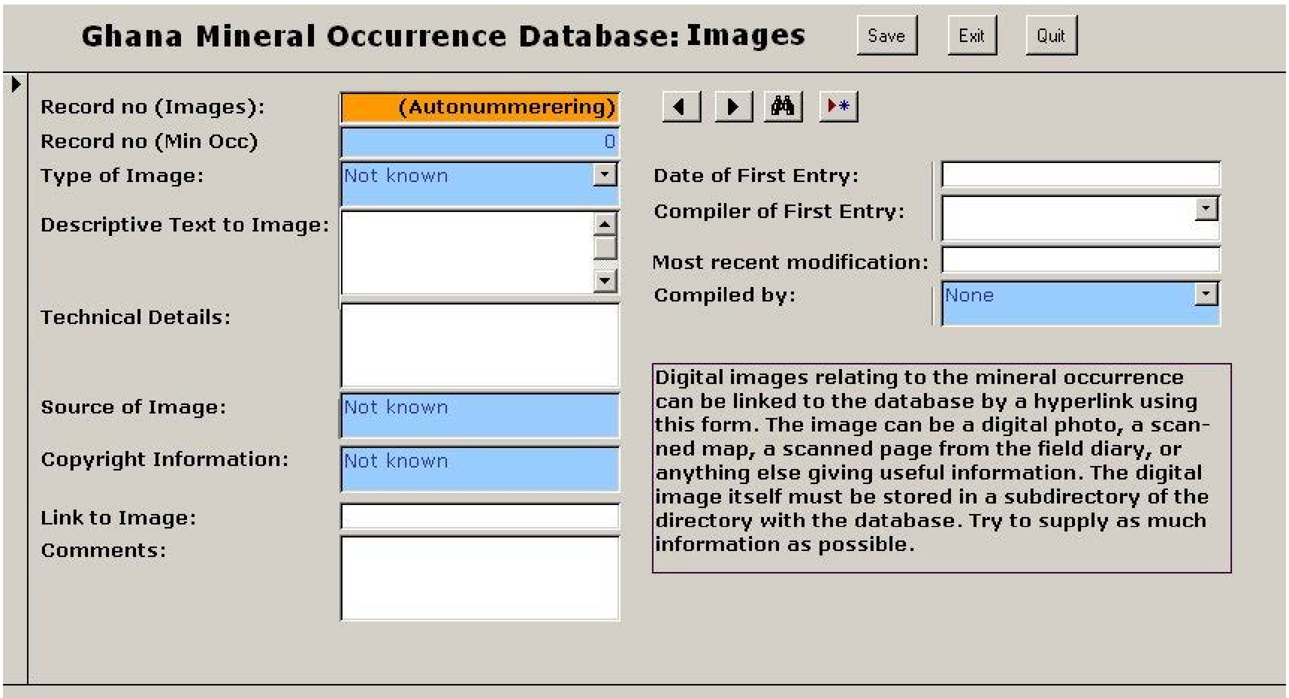


Figure 7: Input screen-form to the table (Images). Information can only be entered if the mineral occurrence already exists, i.e. has been entered into the main table.

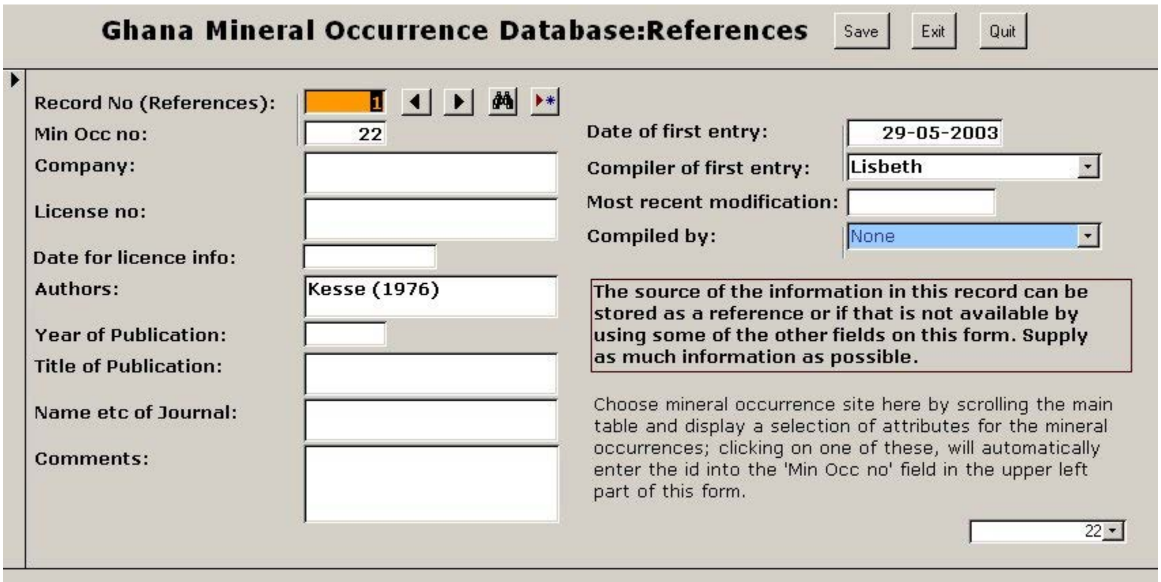


Figure 8: The entry form for documenting the source of the information. Note that the tool provided in the lower right corner on this form probably will be included in all four forms. The tool gives access to a scroll of existing entries in the main mineral occurrence table, so that the user can find and use the correct one for the entry on this form.

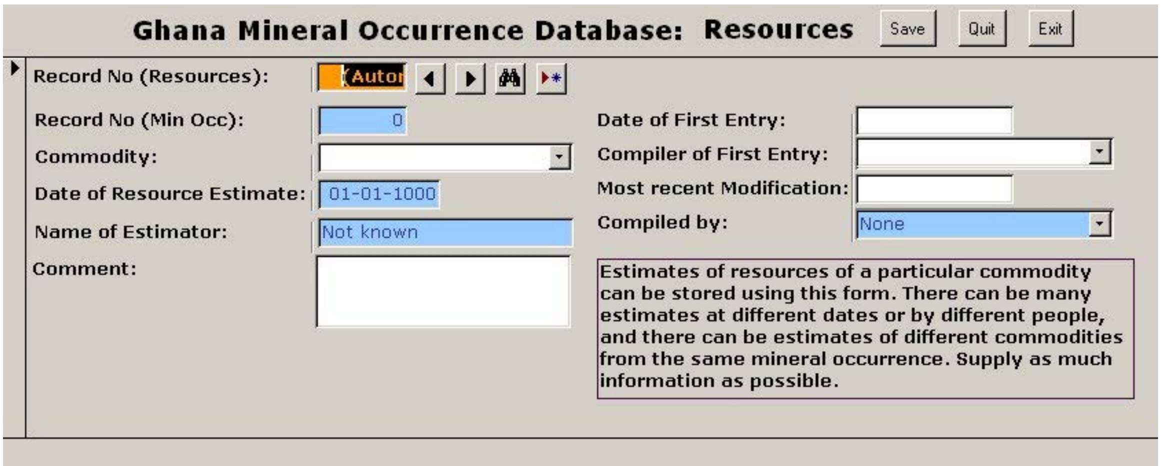


Figure 9: Entry form for estimates of resources of a mineral occurrence.

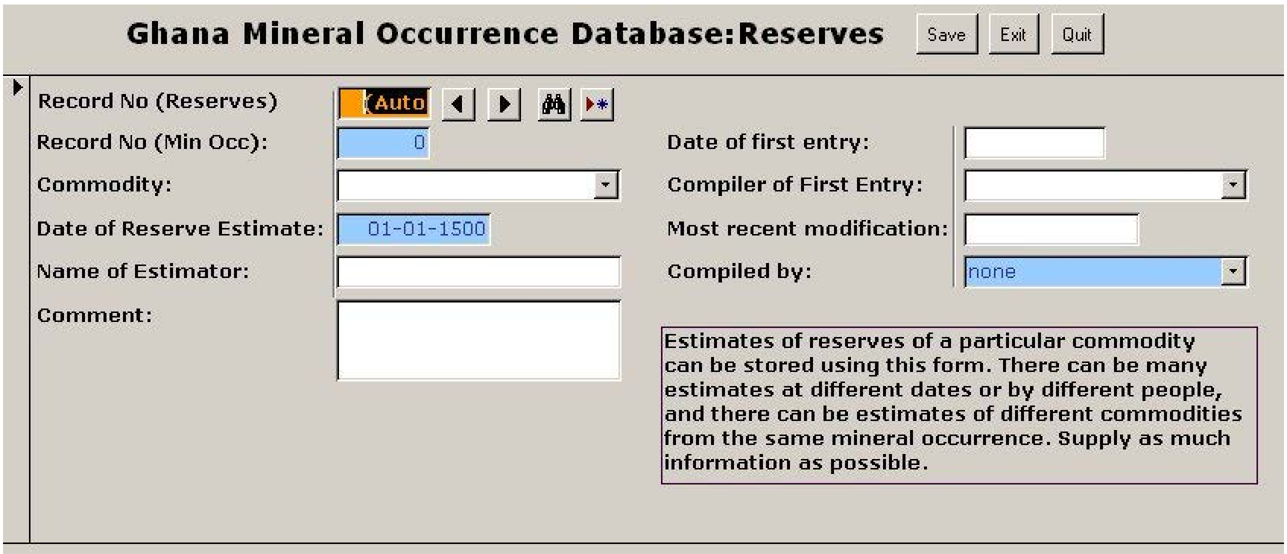


Figure 10: Entry form for estimates of reserves for a mineral occurrence.

Please note that the illustrations used here in this design document not are based on the final version of the database given to GSD; for production reasons that was not possible. Therefore, there will be small differences between what the illustrations show and what the actual database shows.

APPENDIX 7.

App. 7A.

Chapter 18. Map sheet compilation and production

Geological maps are most easily produced at the Survey's GIS laboratory in close cooperation with the mapping geologist. With all data in place – list of localities, rock types (if necessary checked by thin sections or chemical analyses), structural measurements etc., a preliminary digital map can be produced within a few days.

Spread sheet. Digital map compilation starts with the list of localities and observations. These must be delivered to the GIS laboratory as a spread sheet in Excel as follows:

- The first column lists the locality name, e.g. EM066/02.

- The second column gives the latitude of the localty, registered by GPS, e.g. 10°45.15´ (degrees and minutes, minutes with two decimals). It is not necessary to add the symbols ° and ´, but the degrees and minutes must then be separated by a space:
  10 45.15.

- The third column gives the longitude, e.g. 2°12.13´ (or 2 12.34).

- The fourth column lists the rock type dominant at the locality, e.g. granite. In sedimentary terrains the formation name should be given, e.g. Togo formation.

- The fifth column gives the strike of bedding or foliation, in degrees east of North, up to 180°.

- The sixth column gives the amount and direction and dip of bedding or foliation. The direction of dip is N, E, S, W, NE, SE etc. Examples: 25E, 85N, 60NE.

Further columns can be used for other information, e.g. on rock samples. This information, however, is not needed for the preliminary map compilation.

The GIS laboratory has all the topographical information to be shown on the map – contour lines, roads, villages etc. The geological information from the Excel spread sheet is then superposed on the topographical map, showing all localities and rock types in their correct position. Localities are shown as small circles, with different colours according to rock type, and with the locality number. A plot of this preliminary map is prepared for the geologist to draw the boundaries between different rock units within his area, as well as faults, lineaments etc.

Boundaries. In order to draw geological boundaries, the geologist has also to use observations that cannot be incorporated in an Excel file, and that thus are not present on the provisional plot. The colour of the soil in unexposed terrain, for example, may give a clue as to where the border between a granite and a sequence of metabasaltic rocks may be situated (see p. 32). Drawing geological boundaries relies heavily on the experience of the field geologist, it cannot be done by computer.

Apart from field observations, for drawing geological boundaries some geometric rules must be taken into consideration. Subhorizontal beds, for example, must run (more or less) parallel to contour lines; they cannot be strongly discordant to the contours (p. 46). Finally, boundaries between rock units must be in agreement with the age relationships observed or interpreted during the field work. An older rock cannot cut across a border between younger rocks (p. 37).

Apart from rock boundaries other features, such as faults and lineaments, must be drawn at this time. This is best done with the help of aerial photographs.

After the boundaries and other items have been drawn on the preliminary map (by hand), they have to be transposed onto the digital map. This is most easily done by copying them on a transparent sheet of paper which can then be scanned and transferred onto the digital map.

Legend. Simultaneously with the process of drafting boundaries etc., a lay-out for the legend for the map must be prepared. This should be separated into groups of related rock types, arranged according to age, youngest at the top, see opposite page.

Each rock type will be represented on the map with a specific colour (for Birimian rocks see the colour code in Appendix 3). The actual outcrops are shown on the map with small circles in the same colour for two reasons: (1) it shows on which hard observations the map is based, and (2) it permits to show minor rock occurrences within larger units, for example a single outcrop of tonalite within a large granite body, or a local quartz vein within metabasaltic rocks. In the legend the various rock types are therefore shown both as a rectangular box (for the rock at large), and as a circle of the same colour (for the single outcrop). Some rock types (e.g. quartz veins) do not occupy areas that can be shown correctly on a 1:50 000 or 1:100 000 scale map. These are shown as outcrops only.

Cross sections. The geologist responsible for the map compilation must consider whether or not one or more cross sections will be a help for the understanding of his map. If the geologist does not understand the structure of the area himself (which may well be the case in areas of poor outcrop) a cross section may be misleading and should not be printed on the map. For example, in the map sheet area Jirapa East and Tumu West (Upper West Region), for which the legend is shown in Fig. 26, there are large bodies of metagabbro for which it is not known whether they are steep-sided plutons or subhorizontal sheets – the outcrops and the topography of the area do not permit to decide on this question. In a section, however, the metagabbros must be shown either as plutons or as sheets, and there would be a fair chance that the user of the map gets incorrect information. Therefore, no section is given with that map. On the other hand, a section is provided for the new geological map of the Greater Accra Region. Old granitoid rocks are here interthrusted with

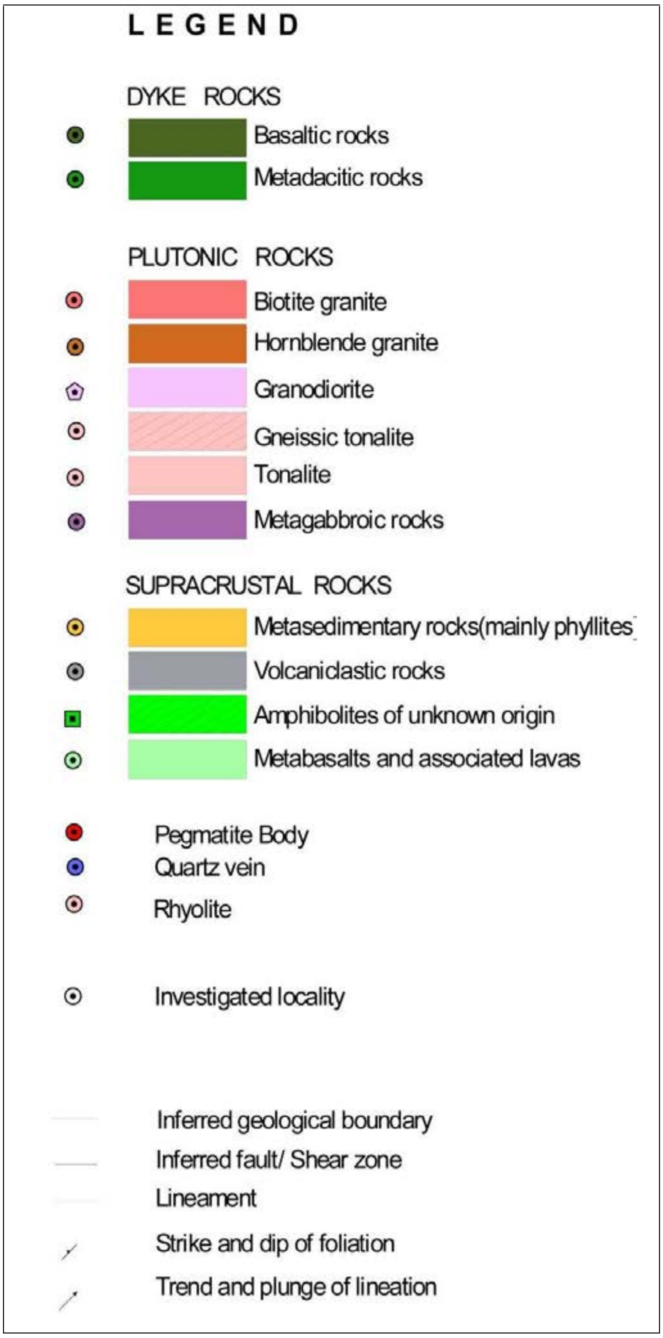


Fig. 26. Example of a map legend. This is the legend for the geological map Jirapa East and Tumu West in the Upper West Region

metasediments of the Togo sequence, and both are subhorizontally overlain by Phanerzoie sediments. The profile section is here of great help for the understanding of the map.

An important point to consider is the vertical scale of a cross section. Commonly variations in elevation of an area are small compared to horizontal distances. This is illustrated in Fig. 27 which shows an island, ca. 8 km long and about 200 m high, consisting of shallowly East dipping sedimentary strata. Two cross sections are shown. In the upper one the horizontal and vertical scales are the same. This section gives a true picture of the topography of the island, but it is clear that it cannot be used to illustrate the geology. In the second section heights are exaggerated by a factor of 10 (as indicated by the scale to the left). On this section the geology of the island can be properly shown.

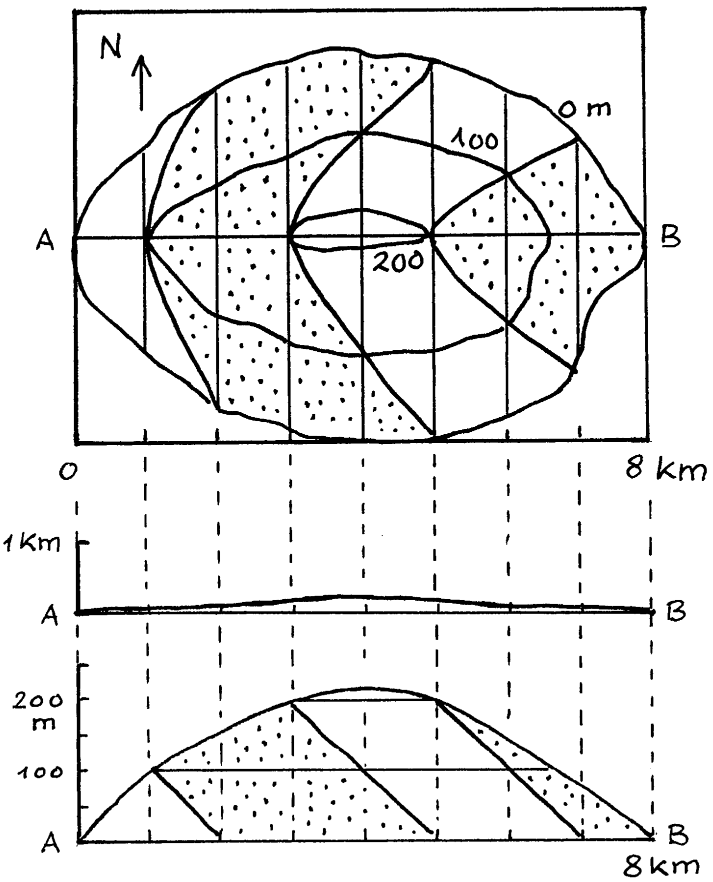


Fig. 27. Geological map with shallowly E dipping strata and two cross sections. In the lower section the heights are exaggerated by a factor ten. As a consequence the bedding appears much steeper than it is in reality (see text).

However, by exaggerating the height of the section, the dips of the beds are also exaggerated. As seen on the map and the section, the beds fall 100 m per kilometre towards East. This is equivalent to a dip of ca. 5°, but on the section the dip would appear to be 45°.

The best approach for the preparation of a cross section is by trial and error to find the section with the smallest exaggeration of heights, on which the geology can still be clearly illustrated. Remember to give both the horizontal and vertical scales on the section.

Explanatory notes

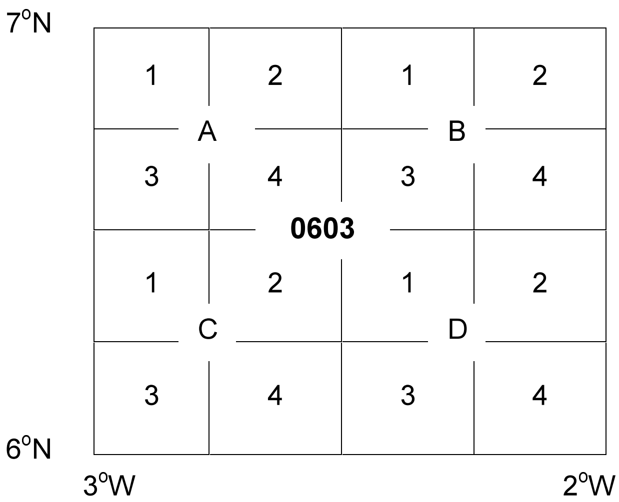
Some explanatory notes must be added to every map. These should be brief (of the order of 1200 words), and give (1) some general information on the area – location, accessibility, topography, clima, vegetation, exposure, previous work, etc., (2) brief description of the main lithologies and stratigraphy, (3) brief description of structures – bedding, foliation, folds, faults etc., and (4) economic geology – mineral occurrences, sand and clay deposits, rocks that can be used as building materials or for road construction etc. Give as much factual information with as few words as possible – speculative aspects may be presented in the final report on the area but not in the explanatory notes.

App. 7B.

Addition to the Mapping Manual

Appendix 2 (of the Mapping Manual)
Archive Reports and Bulletins, dealing with specific Field Sheet areas in Ghana

Most Bulletins and Archive Reports are for sale at the Geological Survey Department of Ghana; Archive Reports (without maps) are available on CD Rom. Field Sheets are numbered as shown in the figure below; in southern Ghana they also have independent Field Sheet numbers (see the listing below). For square numbers see map on opposite page. For areas mapped during the German – Ghana cooperative projects full map sheet descriptions have been published by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Germany.



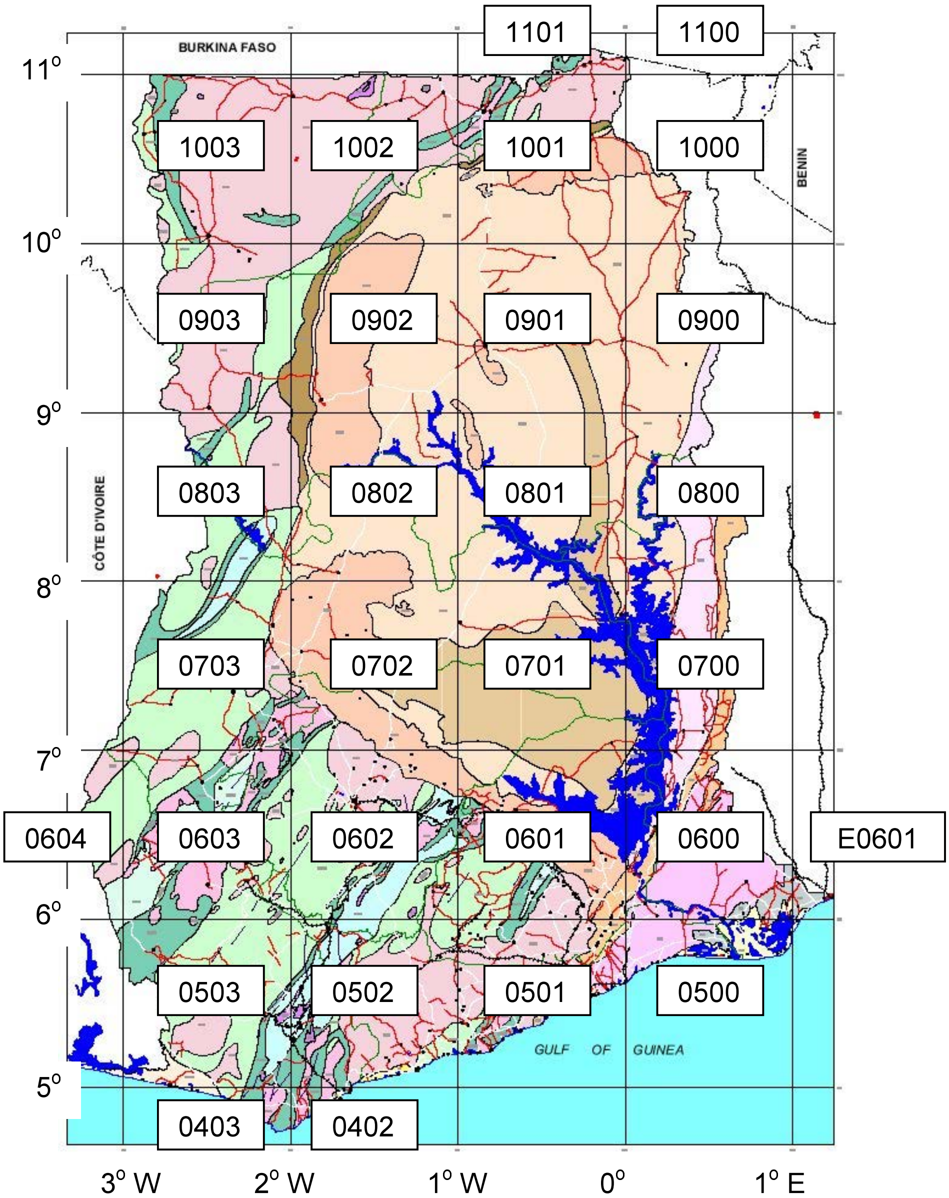
Subdivision of 1° squares into sixteen 15' Field Sheets and the numbering convention used

Square 1101 (N of 11°N, 0-1°W)
Only parts of 1101D3 and 4 lie within Ghana
Bull. 19, no Archive Reports

Square 1100 (N of 11°N, E of 0°E)
Only a small area in 1100C3 lies within Ghana
Bull. 19, no Archive Reports

Square 1003 (10-11°N, 2-3°W)
1003A3/4 and C1/2, AR 6, 32, 50, 51, 63, 70
1003D3/4, AR 63

Square 1002 (10-11°N, 1-2°W)
1002A1-4, Bull. 35
1002B1-4, Bull. 36
1002B3/4, AR 70



Subdivision of Ghana in 1˚ squares and their numbering

Square 1001 (10-11°N, 0-1°W)
1001A1-4, Bull. 25
1001B1-4, Bull. 19
1001A3, AR 8
1001B3, AR 8, 10
1001C1/2, AR 8, 94
1001D1/2, AR 95

Square 1000 (10-11°N, 0-1°E)
Only parts of A and C lie within Ghana
1000A1/3, Bull. 19, no Archive Reports

Square 0903 (9-10°N , 2-3°W)
0903A2, AR 3, 6, 8, 53
0903D1/2, AR 60, 61, 63

Square 0902 (9-10°N , 1-2°W)
0902B3/4, AR 94

Square 0901 (9-10°N , 0-1°W)
0901C3/4, AR 70
0901D3, AR 10, 95

Square 0900 (9-10°N , 0-1°E)
Only parts of this square lie within Ghana
0900C1, AR 85
0900C4, AR 59

Square 0803 (8-9°N , 2-3°W)
0803B3, AR 54, 60
0803D1, AR 55

Square 0802 (8-9°N , 1-2°W)
0802A1, AR 61
0802C1/2, AR 94

Square 0801 (8-9°N , 0-1°W)
0801B3, AR4
0801C2, AR6
0801D1, AR4

Square 0800 (8-9°N , 0-1°E)
Only quadrants A and C lie within Ghana
0800C4, AR58

Square 0704 (North of 7°N, W of 3°W)
only a very small area of Ghana lies within this square
0704D4 (Field Sheet 154), AR 19, 96

Square 0703 (7-8°N, 2-3°W)
0703A1-4, no Field Sheet no., no Archive Reports
0703B1, no Field Sheet no., AR 4
0703B2-4, no Field Sheet nos, no Archive Reports
0703C1 (Field Sheet 159), AR 47, 96
0703C2 (Field Sheet 160), AR 83, 91
0703C3 (Field Sheet 157), AR 19, 47, 96
0703C4 (Field Sheet 158), AR 19, 96
0703D1 (Field Sheet 163), AR 35, 48, 56
0703D2 (Field Sheet 164), AR 57, 93
0703D3 (Field Sheet 161), AR 35, 48
0703D4 (Field Sheet 162), no Archive Reports

Square 0702 (7-8°N, 1-2°W)
0702A1 (no Field Sheet no.), AR 4
0702C3 (Field Sheet 165), Bull. 41
0702D1 (Field Sheet 171), AR 6

Square 0701 (7-8°N, 0-1°W)
0701A1, AR 2, 4
0701B1, AR 10

Square 0700 (7-8°N, 0-1°E)
Only the westernmost parts of this square lie within Ghana
No Archive Reports for quadrants A and B
0700C1 (Field Sheet 183), no Archive Reports
0700C2 (Field Sheet 184), AR 33, 49
0700C3 (Field Sheet 181), no Archive Reports
0700C4 (Field Sheet 183), AR 20
0700D1 (Field Sheet 187), AR 34, 49
0700D3 (Field Sheet 185), AR 34, 49, 70

Square 0604 (6-7°N , W of 3°W)
Only parts of B2/4 and D2/4 lie within Ghana. No Archive Reports
Square 0603 (6-7°N, 2-3°W)
0603A1 (Field Sheet 119), no Archive Reports
0603A2 (Field Sheet 120), AR 84
0603A3 (Field Sheet 117), AR 42
0603A4 (Field Sheet 118), AR 42
0603B1 (Field Sheet 123), AR 7, 76, 89
0603B2 (Field Sheet 124), AR 7, 75
0603B3 (Field Sheet 121), AR 7, 76, 86, 87
0603B4 (Field Sheet 122), AR 7, 74
0603C1 (Field Sheet 79), AR 4, 8, 44

0603C2 (Field Sheet 80), AR 4, 46
0603C3 (Field Sheet 77), AR 4, 8, 45
0603C4 (Field Sheet 78), AR 4, 43
0603D1 (Field Sheet 83), AR 72, 80, 90
0603D2 (Field Sheet 84), AR 73, 80
0603D3 (Field Sheet 81), AR 6, 74, 80
0603D4 (Field Sheet 82), AR 6, 73, 80, 92

Square 0602 (6-7°N, 1-2°W)
0602A1 (Field Sheet 127), AR 9, 70, Bull. 27
0602A2 (Field Sheet 128), AR 9, 70, Bull. 39
0602A3 (Field Sheet 125), AR 8, 9, 70
0602A4 (Field Sheet 126), AR 2, 6, 8, 9, 62, 70, Bull. 26
0602B1 (Field Sheet 131), AR 4, 9, Bull. 31
0602B2 (Field Sheet 132), AR 4, 9, Bull. 33
0602B3 (Field Sheet 129), AR 4, 6, 9, 62, Bull. 31
0602B4 (Field Sheet 130), no Archive Reports
0602C1 (Field Sheet 87), AR 2, 8, 9, 73
0602C2 (Field Sheet 88), AR 2, 8, 26
0602C3 (Field Sheet 85), AR 2, 3. 8, 9, 73
0602C4 (Field Sheet 86), AR 2, 3, 8, 9, 65
0602D1 (Field Sheet 91), AR 9, 62, Bull. 30
0602D2 (Field Sheet 92), AR 9
0602D3 (Field Sheet 89), AR 30
0602D4 (Field Sheet 90), no Archive Reports

Square 0601 (6-7°N, 0-1°W)
0601A1-3 (Field Sheets 135, 136, 133), no Archive Reports
0601A4 (Field Sheet 134), AR 77
0601B1 (Field Sheet 139), AR 2, 6
0601B2 (Field Sheet 140), AR 2,6
0601B3 (Field Sheet 137), AR 2, 4, 6
0601B4 (Field Sheet 138), AR 4, 9
0601C1 (Field Sheet 95), AR 8
0601C2 (Field Sheet 96), AR 8, 28
0601C3 (Field Sheet 93), AR 8, 67
0601C4 (Field Sheet 94), AR 8
0601D1 (Field Sheet 99), AR 4, 8
0601D2 (Field Sheet 100), AR 4, 8
0601D3 (Field Sheet 97), AR 8, 38
0601D4 (Field Sheet 98), AR 8, 36

Square 0600 (6-7°N, 0-1°E)
0600A1 (Field Sheet 143), AR 8
0600A2 (Field Sheet 144), AR 8, 16
0600A3 (Field Sheet 141), AR 8
0600A4 (Field Sheet 142), AR 8, 10, 16
0600B1 (Field Sheet 147), AR 16,

0600B2 (in Togo)
0600B3 (Field Sheet 145), AR 82
0600B4 (Field Sheet 138), AR 2, 4, 6
0600C1-4 (Field Sheets 101-104), Bull. 43
0600C1 (Field Sheet 103), AR 23
0600C2 (Field Sheet 104), no Archive Reports
0600C3 (Field Sheet 101), AR 23
0600C4 (Field Sheet 102), AR 23
0600D1 (Field Sheet 107), AR 81
0600D2 (Field Sheet 108), AR 37
0600D3 (Field Sheet 105), no Archive Reports
0600D4 (Field Sheet 106), no Archive Reports

Square E0601 (6-7°N, E of 1°E)
Only parts of C1 and C3 lie within Ghana. No Archive Reports

Square 0504 (5-6°N, W of 3°W)
Only small parts of this square lie within Ghana. No Archive Reports

Square 0503 (5-6°N, 2-3°W)
0503A1 (Field Sheet 41), AR 7, 8, 68
0503A2 (Field Sheet 42), AR 7, 68
0503A3 (Field Sheet 39), AR 7, 68
0503A4 (Field Sheet 40), AR 7, 68
0503B1 (Field Sheet 45), AR 5, 7
0503B2 (Field Sheet 46), AR 5, 7, 92
0503B3 (Field Sheet 43), AR 5, 7
0503B4 (Field Sheet 44), AR 5, 7, 9
0503C1-4, (Field Sheets 13-16), no Archive Reports
0503D1 (Field Sheet 19), AR 2, 5, 7, 66
0503D2 (Field Sheet 20), AR 2, 3, 5, 7, 40, 66
0503D3 (Field Sheet 17), AR 2, 5, 7
0503D4 (Field Sheet 18), AR 2, 3, 57, 99

Square 0502 (5-6°N, 1-2°W)
0502A1 (Field Sheet 49), AR 3, 8, 41
0502A2 (Field Sheet 50), AR 3, 8, 41
0502A3 (Field Sheet 47), AR 3, 5, 6, 8, 9, 41
0502A4 (Field Sheet 48), AR 3, 5, 6, 8, 27, 41
0502B1-4 (Field Sheets 51-54), no Archive Reports
0502C1 (Field Sheet 23), AR 2, 3, 7, 8, 88, 98
0502C2 (Field Sheet 24), AR 2, 3, 8, 10, 88, 98
0502C3 (Field Sheet 21), AR 2, 3, 9, 10, 39, 70, 78, 88, 98
0502C4 (Field Sheet 22), AR 2, 3, 8, 9, 10, 88, 98
0502D1 (Field Sheets 27), no Archive Reports
0502D2 (Field Sheet 28), Bull. 34
0502D3 (Field Sheet 25), no Archive Reports
0502D4 (Field Sheet 26), AR 31, 79, Bull. 29

Square 0501 (5-6°N, 0-1°W)
Sotheastern parts of this area are off-shore
0501A1 (Field Sheet 57), AR 17, 29, 64, 67
0501A2-4 (Field Sheets 58, 55, 56), no Archive Reports
0501B1 (Field Sheet 61), Bull. 32, no Archive Reports
0501B2 (Field Sheet 62), Bull. 32, AR 70
0501B3 (Field Sheet 59), Bull. 32, AR 8, 70
0501B4 (Field Sheet 60), AR 8
0501C1 (Field Sheet 31), AR 1, 2, 7, 8, 24, 25
0501C2 (Field Sheet 32), AR 2, 7, 8, Bull. 24
0501C3 (Field Sheet 29), AR 2, 7, 8, 24, 25
0501D1 (Field Sheet 33), Bull. 32, no Archive Reports

Square 0500 (S of 6°N, 0-1°W)
Most of this area is off-shore. No Archive Reports

Square 0403 (S of 5°N, 2-3°W)
Most of this square is off-shore
0403A2 (Field Sheet 1), no Archive Reports
0403B1 (Field Sheet 4), AR 2,5, 7, 21
0403B2 (Field Sheet 3/5), AR 2, 5, 7, 18, 22, Bull. 37
Square 0402 (S of 6°N, 1-2°W)
Most of this square is off-shore
0402A1 (Field Sheet 7), AR 2, 5, 6, 7, 8, 22, Bull. 37
0402A2 (Field Sheet 8), AR 2, 5, 6, 7, 8, 78, Bull. 37