BRITISH GEOLOGICAL SURVEY
International Division

BGS Technical Cooperation in Africa (1965–90)

Natural Environment Research Council

Technical Report WC/91/47
British Geological Survey
Keyworth, Nottingham NG12 5GG
United Kingdom

British Geological Survey
Natural Environment Research Council

Technical Report WC/91/47
International Geology Series

BGS Technical Cooperation in Africa (1965–90)

S J Mathers (Compiler)

International Division

Cover illustration

Map of Africa, red dots indicate locations of host countries; Bottom left, geological field party investigating geothermal potential in Kenya; Bottom right, dug well in Sudan.

Bibliographic reference

British Geological Survey. 1992. BGS Technical Cooperation in Africa (1965–90). *British Geological Survey Technical Report* WC/91/47.

British Geological Survey Keyworth Nottingham 1992

Introduction

This report summarizes work undertaken in Africa by the British Geological Survey (BGS), formerly the Institute of Geological Sciences (IGS), during the period 1965 - 1990. Most of the work was funded by the Overseas Development Administration (ODA) and was carried out as either technical cooperation (TC) or under the Overseas Service Aid Scheme (OSAS) - Key Cadre arrangements. The report also includes details of a small number of other projects undertaken for international aid agencies such as the United Nations (UN), foreign governments and private sector companies. Work undertaken in Gibraltar and several of the small islands in the Atlantic and Indian Oceans are also incorporated.

Together ODA and BGS have made a substantial contribution to the geoscientific development of many African countries. Indeed, between 1965-90 some 33% of BGS's international work was carried out in Africa, more than in any other region. The principal beneficiaries have been Botswana, Malawi, Kenya, Zambia and Zimbabwe.

In all some 54 projects are described located in 28 countries. The principal geoscience themes covered have been regional geological surveys, hydrogeological studies to detect water resources and geochemical surveys in support of mineral exploration.

A list of the projects described and an index of participating countries are included together with a map of the region showing the locations of the host countries (Fig. 1). The information contained in this report is also held at BGS Keyworth in a database of past international activities.

Review of Projects

A brief summary of the projects carried out is given below arranged by country; the OSAS - Key Cadre programmes are described at the end in a separate section.

Angola

A short geophysical consultancy to Angola was undertaken in 1991 for the United Nations Development Programme (UNDP) to report on the capacity of the National Institute of Geology to undertake geophysical studies. Recommendations for strengthening the Institute through training and donation of equipment were made to UNDP.

Botswana

Between 1974-81 hydrogeologists provided advice to the Geological Survey of Botswana for the siting and installation of wells, and conducted regional appraisals of the groundwater potential in areas earmarked for development.

Interpretation of Landsat imagery and aerial photography of Botswana in 1975-78 led to the publication of a 1:1 million scale geological map and explanatory text of the whole country. This provided the essential geological framework for all subsequent more detailed investigations in the country.

The Molopo Farms project (1980-83) involved geophysical surveys and drilling of an ultramafic layered igneous complex buried beneath the sands of the Kalahari Desert. The geophysical studies included magnetic, gravity and resistivity surveys which enabled the siting of exploration boreholes. Some 46 boreholes were drilled with an aggregate depth of about 10,000m, and studies of the cores were encouraging in terms of their metallic mineral potential. Private sector mining companies are now following-up the work.

Cameroon

Following the Lake Nyos gas-burst disaster of August 1986, which killed 1750 people, BGS initially provided a hydrogeochemist as part of a three-man ODA sponsored disaster relief mission and

subsequently deployed seismologists to monitor the disaster area. The studies complemented those of other international experts in trying to ascertain the cause of the disaster. It was concluded that the gas release from the lake was triggered by either a landslide or earthquake enabling a dense asphyxiating CO_2 gas cloud to flow at high speed down adjacent river valleys for up to 25km. Identification of the causes of such disasters are essential in attempts to predict and prevent a repetition.

Chad

A well-casing and screen system developed in the UK by BGS was installed for the UNDP in Chad in 1975 to help provide water supply.

Egypt

Between 1979-83 BGS geologists undertook several training missions to Egypt to instruct staff of the Egyptian Geological Survey and Mining Authority (EGSMA) in mineral exploration in the Southern Desert. UK study visits were also arranged for nine EGSMA staff to enable them to receive instruction at BGS offices.

Following on from the earlier studies the Eastern Desert Mapping & Training programme (1984-89) provided further 'in-service' training in geological surveying, aerial photograph and satellite image interpretation and report and map compilation. Based on the experience gained from working with British geologists, EGSMA staff are now involved in the systematic mapping of selected areas of the desert in order to produce the essential geological maps and accounts needed as a framework for future development. An institutional twinning arrangement established in 1989 between BGS and EGSMA is enabling further guidance to be provided for the compilation, drafting and publication of the 1:250 000 scale series of geological maps. Further field instruction is also being provided in the Southeastern Desert and the Sinai Peninsula.

In 1987 a short training mission to the Egyptian Research Institute of Water Resources (RIWR) enabled several geophysical techniques useful for detecting groundwater to be demonstrated. With this advice RIWR is currently mounting a programme to evaluate the groundwater of the Sinai Peninsula.

Ethiopia

Hydrogeological studies in southern Ethiopia in 1972-75 involved the siting of wells and watering points for a regional livestock development programme managed by the Ethiopian Livestock and Meat Board and located in a drought-prone region.

Gambia

Two well casing and screen systems developed in the UK were satisfactorily installed in The Gambia in 1975 providing secure water supplies for a school.

Ghana

A brief visit was made by a BGS hydrogeologist to the Afram Plains region of Ghana in 1986 at the request of Wateraid in order to advise on the siting of hand-dug wells and boreholes for water supply.

Kenya

Instruction in field geology and the compilation of geological maps was provided in 1974-76 for four geologists of the Kenyan Mines and Geological Department working in the Samburu District of central Kenya. The succeeding Samburu-Marsabit Project (1980-86) involved the systematic production of geological maps and explanatory memoirs for an area of 100,000Km^2 in north-central Kenya. This project involved four resident BGS geologists and a cartographer and provided substantial 'in-service' training for several Kenyan geologists as well as British Council (BC) -

funded scholarships for study in the UK. Some nine 1:250,000 mapsheets and explanatory texts were published containing a wealth of new information about the region's mineral, water and energy potential. A recent ODA evaluation highlighted the high quality of the geological maps produced by this project and reported that the project showed an annual return on the investment in excess of 10%.

In the eastern coastal belt of Kenya three hydrogeological studies have been undertaken since 1981 to identify new groundwater resources due to the increased demand as the region has expanded rapidly as a tourist centre. The three studies focussed on; the whole southeastern coast region (1981); the Tiwi area (1984-89) and the Chyulu Hills (1984-87).

The Exploration for Geothermal Energy project (1985 - present) is evaluating the geothermal potential of the Rift Valley. The first phase of the project (up to 1987) focussed on detailed studies of the Longonot-Olkaria-Egurru area and more regional characterization of the hydrogeology and water chemistry of the whole Rift. Areas with the highest geothermal potential have been identified in and around the ring structures of Olkaria and Longonot volcanic centres. These studies were carried out in conjunction with UNDP. The second phase of the project (1988-present) is concerned within the northern part of the Rift Valley where several volcanic centres have been shown to have good geothermal potential. The project is scheduled to finish in mid 1992.

The on-going Editorial, Mapping and Training Project was established in 1987 and is endeavouring to help the Kenyan Mines and Geology Survey Department clear a backlog of geoscience publications and maps. An editor is making considerable progress with the backlog aided by the availability of a desk top publishing system provided as part of this project. Training in systematic geological mapping and report writing covering a number of key geological sheets is also in progress under the supervision of a resident BGS geologist.

Lesotho

Between 1965-66 a preliminary evaluation of the diamond potential of kimberlite pipes and alluvial gravels was undertaken in Lesotho. The results indicated the greater potential of the pipes; results from the alluvial deposits were in the main disappointing.

In 1979 a regional gravity survey of Lesotho was conducted to provide information about the deep geological structure beneath the widespread basaltic lavas which overlie the Precambrian basement. The survey indicated the likely presence of a large basic intrusion in the basement, such bodies commonly contain significant metallic mineralization.

Libya

Groundwater studies in Central Cyrenaica were carried out for commercial companies and for the Libyan Government between 1967-75. The work involved collecting data from existing water-supply boreholes, constructing a digital model of groundwater flow in the thick post-Eocene alluvial aquifer, determining water quality and siting production wells.

Malawi

A BGS manager acted as a consultant for UNDP to assist Canadian contractors in the interpretation of an airborne geophysical survey of Malawi between 1986-88. A residential BGS geologist based at the Geological Survey Department in Zomba acted as an instructor in geological surveying, photogeology and map and report compilation between 1987-90.

Morocco

In 1967 a short visit was made to advise the local authorities on groundwater resources for a proposed tourism development at Ksar-es-Seghir in northern Morocco.

Niger

Two short advisory visits have been made to Niger both concerned with tin reserves and processing. In 1971-72 processing trials were undertaken on surficial Quaternary cassiterite-bearing deposits in the arid Aïr Mountains. Trials using a dryflow (fluidized bed) system satisfactorily beneficiated the deposits; estimates of reserves and yield were produced. In 1985 a further study for tin reserves in the same region was undertaken on behalf of a commercial company; a confidential technical report was prepared.

Senegal

New techniques for the estimation of groundwater recharge, using samples collected by a recently developed augering technique, were tested in Senegal. Measurements of recharge are critical in establishing an upper safe limit for groundwater extraction and since the methods employed proved successful they can now be applied to other semi-arid zones.

Sierra Leone

In 1969-74 a residential team of geologists conducted a reconnaissance geological and geochemical survey of some 25,000Km^2 of northern Sierra Leone in conjunction with the local Geological Survey. Detailed geological maps and an explanatory memoir were produced. The geochemical studies identified anomalous values of several metals, including nickel and gold, these are worthy of follow-up by the private sector. The mineralogical laboratory at the Geological Survey of Sierra Leone was overhauled and new equipment installed.

Sudan

The Nyefr Rugaiyiq marble deposit was investigated in 1968 as a source of limestone for cement manufacture. The parts suitable

for use in cement were differentiated by geological surveying from the unsuitable high magnesium (dolomitic) portions of the deposit. Reserve calculations showed at least 1.8 million tonnes of usable material are present.

Swaziland

A national gravity survey of Swaziland was conducted in 1965-69 involving over 2,000 individual measurements providing a fairly uniform coverage. The gravity maps were published by the Geological Survey of Swaziland and have helped guide subsequent mineral exploration strategies. Additional, more detailed, geophysical surveys were also carried out to help define areas of sulphide mineralization.

Tanzania

In 1967 a photogeological map of some 50,000Km^2 of the Mozambique Orogenic Belt was undertaken and checked by field traverses. A photogeological map and account of the area were produced.

Tunisia

In 1972 two BGS geologists participated in an ODA economic evaluation of a fluorite-galena mining prospect in Tunisia. The results remain confidential.

Uganda

Between 1965-68 two BGS staff worked in Uganda to produce photo-geological and geophysical maps of the basement rocks of the Karamoja District and the Bukusu carbonatite complex respectively.

Carbonatite Studies (1968-70) were carried out by a resident geologist working with the Geological Survey of Uganda. Some seven complexes were investigated geochemically indicating

anomalous concentrations of beryllium and rare earth elements. An extensive drilling programme on the Bukusu complex failed to detect potentially-economic zones of mineralization.

Zambia

A groundwater model was developed for the important Kakontwe aquifer near Ndola to assist private sector consultants hired by ODA to investigate and develop the area.

Zimbabwe

The Zimbabwe Minerals Exploration Project (1982-88) conducted integrated geological and geochemical surveys of the Rushinga-Nyamapanda and Harare areas of Zimbabwe leading to the discovery of potentially economic zones of gold, zinc and copper mineralization. Training also formed a key element of this project through 'in-service' field and laboratory instruction and with the provision of BC-funded scholarships for study in the UK. Three 1:100 000 scale maps covering the 13,000Km^2 surveyed together with two detailed bulletins describing the geology of these areas were produced.

The on-going Midlands Goldfield Project started in 1989 and now has two BGS geologists working residentially in Zimbabwe. To-date remote sensing interpretation and field checking have delineated the structural framework of the area which controls the pattern of mineralization. Geochemical soil samples are being taken to help identify mineralized zones.

Surrounding Islands

Seven studies have been undertaken on five islands close to the African continent, they are:

Ascension Island

In 1989 a brief desk study was compiled on the limited onshore and offshore mineral potential of Ascension Island.

Gibraltar

The groundwater resources of the Jurassic limestone aquifer on Gibraltar were investigated between 1979-85. Drilling showed that the highest permeabilities occur, as expected, along fault zones and in karstic zones; recharge was estimated in order to recommend safe extraction rates.

Mauritius

The availability of raw materials for cement and brick manufacture on Mauritius was assessed in 1967 together with attendant geochemical and radiometric surveys for metallic mineralization. Limestones suitable for cement were identified together with brick clays, however, the geochemical and radiometric surveys revealed no significant anomalies which might indicate the presence of metallic mineralization.

St Helena

Two brief advisory visits have been made to St Helena to plan drilling programmes for groundwater and to assess the dangers posed by rockfalls in James Valley.

Seychelles

The groundwater potential of the principal Seychelle Islands was assessed by a visiting hydrogeologist in 1974. The study identified new groundwater resources and recommended trial well construction and pumping tests to establish the potential yield. In 1973 a geophysicist estabished gravity base stations on Mahé and Praslin, the data gathered has recently been digitized as

part of the ODA-BGS Research and Development Programme and has been made available to oil companies presently assessing the region.

OSAS - Key Cadre Programmes

The Overseas Service Aid Scheme (OSAS) and the succeeding Key Cadre appointments enable experienced BGS geoscientists to take up established positions within the geological survey departments of less developed countries in order to strengthen their capacity. Such missions differ from the now more common technical cooperation (TC) projects in which BGS staff work alongside counterpart staff on specific agreed projects. The work of staff seconded under the OSAS - Key Cadre arrangements is very varied since they undertake any geoscientific study that may be required by the local government. BGS geologists have occupied very senior positions in many foreign geological surveys and have often acted as the principal advisors to the host government. Over the last 25 years the number of OSAS - Key Cadre postings has declined as many positions became filled by local appointees. In Africa BGS staff have served in seven countries, Botswana, Kenya, Malawi, Swaziland, Uganda, Zambia and Zimbabwe. At present staff are in post (Key Cadre) in Botswana and Zimbabwe. Brief summaries of the work are as follows:-

Botswana

BGS staff have served in Botswana since 1968 amounting to a total staff deployment of about 110 years of effort. Regional geological surveying has produced geological maps of large parts of the country. Mineral recconnaissance programmes have detected many metalliferous and industrial mineral deposits, together with occurrences of diamonds and coal deposits. Water supply and geotechnical studies have also been undertaken. BGS staff occupied the positions of Director and Deputy Director of the Geological Survey of Botswana for many years prior to the localization of these posts. Two geoscientists remain in post under Key Cadre arrangements.

Kenya

The vast majority of BGS work in Kenya has been implemented as TC projects with only two years of staff time deployed under the OSAS scheme. In 1968-70 a geologist was engaged in mineral exploration work with the Mines and Geological Department based in Nairobi. In particular a lead-silver deposit at Kinagoni was evaluated which was also the subject of a brief follow-up visit in 1984.

Malawi

BGS geologists served with the Geological Survey Department in Zomba between 1965-87 when the final post became localized. Over this period about 60 staff years of effort was deployed mainly in the fields of regional geological surveying and mineral exploration and evaluation. Water supply and geotechnical work were also undertaken. The post of Director was filled by BGS staff for many years.

Swaziland

Between 1970-81 BGS geologists were seconded to serve with the Geological Survey and Mines Department in Mbabane comprising at total input of about 25 years of staff time. Detailed geological surveying, geophysics and drilling were undertaken in order to develop the coal deposits in the Karoo sequence as a source of energy for a thermal power station. Other mineral resources evaluated included gold and tin deposits. A new national geological map of Swaziland was compiled and published. Other topics covered included water supply and investigation of the geothermal potential of hot springs.

Uganda

Between 1965-70 a total of five years of BGS staff effort was deployed to work with the Geological Survey of Uganda at Entebbe.

Several metallic mineral deposits were evaluated including beryl-bearing pegmatites and various tin and tungsten occurrences in southwest Uganda. Staff on secondment helped organize the 50th Anniversary Conference of the Geological Survey at which they made several presentations and led field excursions. A geochemical atlas covering some 26,000Km^2 of Uganda was compiled utilizing data derived from analyses of 17,000 bedrock and regolith samples recovered from water supply boreholes.

Zambia

BGS geologists served with the Geological Survey Department between 1970-79 providing a total deployment of about 35 years of BGS staff time. The main themes of the work were systematic regional geological surveying, evaluation of industrial and metallic mineral deposits and geotechnical studies for infrastructure development.

Zimbabwe

Since 1987 BGS has seconded staff to the Geological Survey of Zimbabwe under Key Cadre terms; to-date about five years of staff time has been involved. The main function is to train local geologists in geological surveying, map compilation and report writing thereby strengthening their capacity to carry out independent investigations. A BGS scientist is acting as the Chief Economic Geologist with the Geological Survey of Zimbabwe.

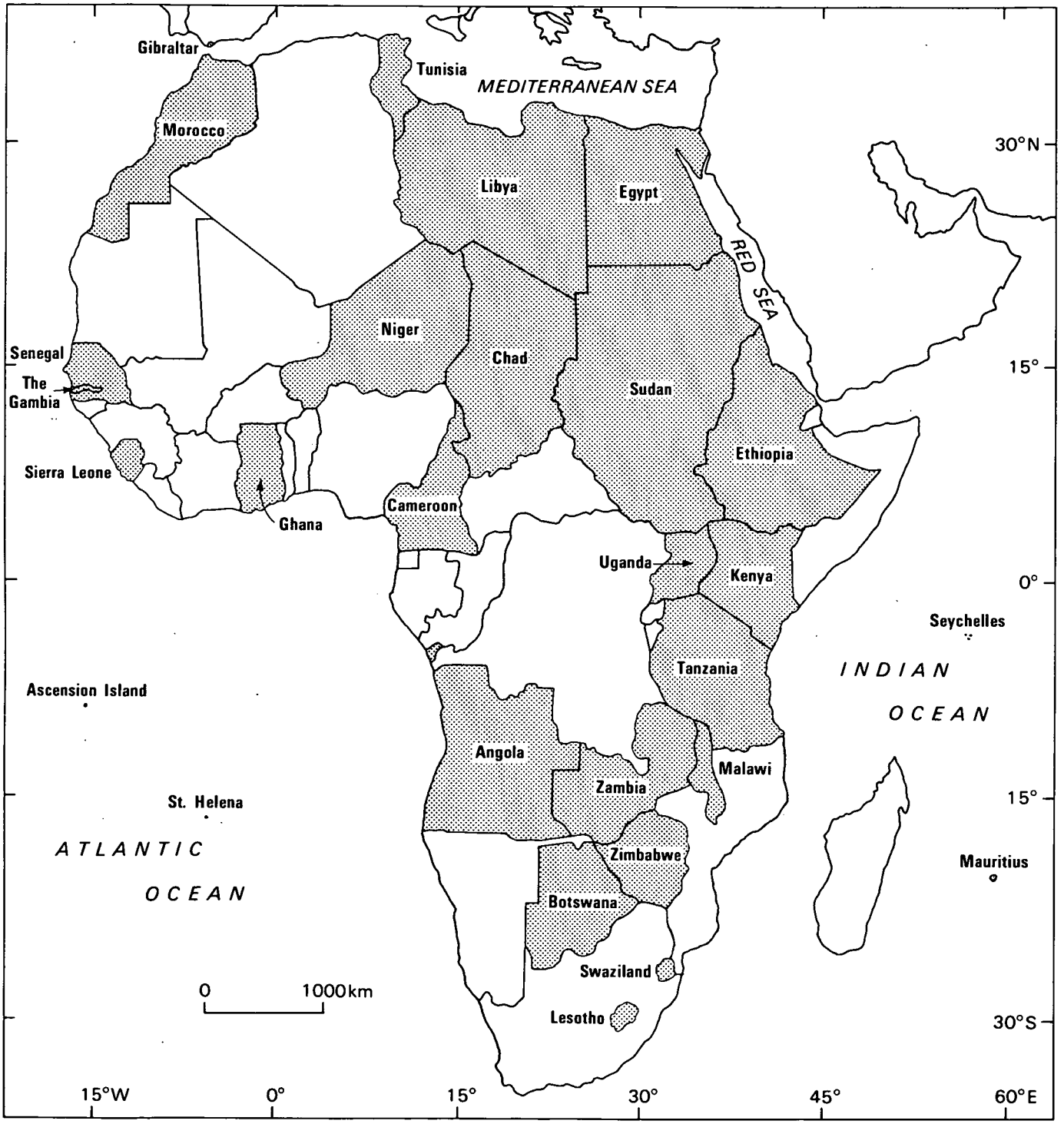


Figure 1. Map of Africa showing the locations of collaborating nations.

LIST OF PROJECTS

No.	Location	Project Title	Date(s)
1	Angola	Geophysics Consultancy, Angola	1991
2	Botswana	Groundwater Evaluation Project	1974-81
3	Botswana	Remote Sensing Interpretation	1975-78
4	Botswana	Molopo Farms Project	1980-83
5	Cameroon	Lake Nyos Disaster	1986-87
6	Chad	Design & Installation of Well Casings & Screens, Chad UNDP Contract	1975
7	Egypt	Southern Desert Geological Project	1979-83
8	Egypt	Eastern Desert Geological Mapping & Training	1984-89
9	Egypt	BGS-EGSMA Institutional Twinning	1989-On going
10	Egypt	Hydrogeophysical Training in Egypt	1987
11	Ethiopia	Water Supply Studies	1972-75
12	Gambia	Design and Installation of Well Casings & Screens	1975
13	Ghana	Advisory Visit to Wateraid Projects in the Afram Plains	1986
14	Kenya	Field Training & Mapping Project	1974-76
15	Kenya	Samburu-Marsabit Project	1980-86
16	Kenya	Tiwi Aquifer Study	1984-89
17	Kenya	Aquifer Studies Coastal Region, Kenya	1981
18	Kenya	Chyulu Hills Water Resources Study	1984-87
19	Kenya	Exploration for Geothermal Energy	1985-On going
20	Kenya	Editorial, Mapping and Training Project	1987-On going
21	Lesotho	Preliminary Evaluation of Diamond Deposits	1965-66
22	Lesotho	Regional Gravity Survey	1979
23	Libya	Groundwater Study, Central Cyrenaica, Petroleum Companies	1967-70
24	Libya	Groundwater Study, Central Cyrenaica, Libyan Government	1971-75
25	Malawi	Economic Geology Consultant - Malawi Geophysics - UNDP	1986-88
26	Malawi	Field Mapping and Training	1987-90
27	Morocco	Ksar-es-Seghir Tourism Development	1967
28	Niger	Cassiterite Processing	1971-72
29	Niger	Exploration for Alluvial Tin, Adrar Chiriet	1985
30	Senegal	Groundwater Recharge in Senegal	1988-91
31	Sierra Leone	Training, Geological Mapping and Mineral Reconnaissance, Northern Sierra Leone	1969-74
32	Sudan	Nyefr Rugaiyiq Marble Deposit	1968
33	Swaziland	Geophysical Work in Swaziland	1965-69
34	Tanzania	Photogeology of Orogenic Belts	1967
35	Tunisia	Economic Viability Assessment of a Fluorite-Galena Mining Project	1972
36	Uganda	Photogeology and Geophysics, Uganda	1965-68
37	Uganda	Carbonatite Studies	1968-70
38	Zambia	Groundwater Modelling	1977
39	Zimbabwe	Zimbabwe Minerals Exploration Project	1982-86
40	Zimbabwe	Midlands Goldfield Project	1989-On going
41	Ascension Island	Ascension Island Desk Study	1989
42	Gibraltar	Gibraltar Groundwater Investigation	1979-85
43	Mauritius	Pozzolan and Minerals Study	1967

44	St Helena	Groundwater Investigations, St Helena	1987
45	St Helena	Study of Rockfalls in James Valley	1975
46	Seychelles	Seychelles Groundwater Study	1974
47	Seychelles	Gravity Survey, Seychelles	1973
48	Botswana	OSAS Work in Botswana	1968-On going
49	Kenya	OSAS Work in Kenya	1968-70, 1984
50	Malawi	OSAS Work in Malawi	1965-87
51	Swaziland	OSAS Work in Swaziland	1970-81
52	Uganda	OSAS Work in Uganda	1965-70
53	Zambia	OSAS Work in Zambia	1970-79
54	Zimbabwe	OSAS Work in Zimbabwe	1987-On going

NOTE ON PROJECT SIZE

On the Project Summary Forms the size of individual projects is given on a scale of 1 (very large) - 5 (small). Broad descriptions of these five categories are as follows

Size 1 Large multidisciplinary studies carried out by sizeable residential teams with considerable specialist support; usually running for 5 - 10 years; making a major contribution to the development of geological knowledge and potential of the host country.

Size 2 Important regional studies carried out by residential teams with specialist support usually upto 5 years in duration, making a significant contribution to geological knowledge of the host country.

Size 3 Residential projects undertaken by 2 - 3 staff with some specialist support, generally about 3 years duration often concerned with particular themes or topics

Size 4 Small projects on specific topics usually involving non-residential input from a small groups of specialists or an individual.

Size 5 Short minor consultancies, training and advisory visits carried out by 1 - 2 staff usually with specific objectives.

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 1**

TITLE: GEOPHYSICS CONSULTANCY, ANGOLA

LOCATIONS: Angola

PROJECT SIZE: 5

DATES: 1991

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

A BGS Geophysicist visited Angola for 2 weeks on behalf of UNDP to assess the local capabilities, equipment and training needs in exploration geophysics.

The visit forms part of a UNDP initiative for the strengthening of the National Institute of Geology (INAGEO) can and promotion of mineral investment (UNDP Project ANG/89/025).

PROJECT RESULTS

The restricted consultants report listed overleaf contains details of geophysical equipment and personnel currently at INAGEO.

Recommendations are made for future training needs, equipment and aid programmes in order that INAGEO conduct geophysical exploration work.

OUTPUT (Reports, Papers, & etc)

Evans, R. B. 1991. Geophysical consultancy to Angola for the United Nations. October 1991. BGS Technical Report WK/91/15R.

WORKSHOPS AND PRESENTATIONS

Workshop given to INAGEO geologists on geophysical exploration.

PROJECT STAFF

R. B. Evans

FUNDING UNITED NATIONS DEVELOPMENT PROGRAM (UNDP)

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 2**

TITLE: GROUNDWATER EVALUATION PROJECT

LOCATIONS: Botswana

PROJECT SIZE: 3

DATES: 1974-81

COLLABORATING ORGANISATIONS

Geological Survey of Botswana

PROJECT OBJECTIVES

Provision of hydrogeological advice to the Geological Survey of Botswana.

Implementation of detailed programmes of well installation and regional assessments of groundwater resources to assist with national development projects and plans.

PROJECT RESULTS

A large number of production wells were sited and installed for the W Ngwaketse Ranching Project.

Regional studies of Groundwater resource evaluation and planning (1977-81) involved drilling trial wells, pumping tests, recharge experiments and isotope tracer studies. In particular the Serowe and Letlhakeng areas were evaluated and recommendations for development were made.

Groundwater Reserves were evaluated for the development of a new Diamond Mine at Jwaneng.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

I. N. Gale
J. Peart

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 3

TITLE: REMOTE SENSING INTERPRETATION

LOCATIONS: Botswana, UK

PROJECT SIZE: 3

DATES: 1975-78

COLLABORATING ORGANISATIONS

Botswana Geological Survey

PROJECT OBJECTIVES

Systematic interpretation of Landsat 1 imagery and aerial photography of Botswana.

Limited field checking to vertify findings.

PROJECT RESULTS

The results of the interpretation were written-up in the publications overleaf, they represent a considerable advance in knowledge of the regional geology and structure of Botswana.

A new 1:1 000 000 photogeological map of Botswana is presented.

The map and accounts of the geology provide the essential framework for subsequent detailed exploration for minerals, energy and water resources by parastatal organisations and the private sector.

OUTPUT (Reports, Papers, & etc)

1:250 000 Geological Interpretation on overlays for 33 Landsat scences covering Botswana.

Mallick, D. I. J., Habgood F. & Skinner, A. C. 1981. A geological interpretation of Landsat imagery and air photography of Botswana. IGS Overseas Geology and Mineral Resources No 56. 35 p 2 Maps.

WORKSHOPS AND PRESENTATIONS

Workshop on 'Landsat imagery interpretation for regional geological surveying' for staff of African geological surveys held in Lobatse, Botswana in November 1977. Tutors: D. I. J. Mallick, R. L. Johnson, J. G. W. Greenwood.

PROJECT STAFF

Dr D. I. J. Mallick
F. Habgood
A. C. Skinner

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 4

TITLE: MOLOPO FARMS PROJECT

LOCATIONS: Botswana

PROJECT SIZE: 3

DATES: 1980-83

COLLABORATING ORGANISATIONS

Geological Survey of Botswana
University of Zimbabwe

PROJECT OBJECTIVES

To delineate the Molopo Farms layered ultramafic-mafic igneous complex and to identify any zones of potentially economic mineralization (chromite, copper, nickel and platinum group metals).

The area involved comprises 8,500 square miles of terrain; the complex is overlain by thick sands of the Kalahari Desert and Tertiary deposits therefore geophysics and drilling were key elements of the study.

PROJECT RESULTS

A gravity survey with 2km station spacing was conducted with the aid of the helicopter. A pre-existing aeromagnetic survey was digitised and replotted. All available water borehole records and sludge samples from the area were examined. The results of these three techniques were used to provide a regional interpretation of the form of the ultramafic and mafic rock masses. Ground-based magnetic, gravity and resistivity surveys were used to provide a more detailed interpretation of the geological structure and to select sites for core drilling.

Forty-six boreholes were drilled to an aggregate depth of 10,000m. In the north of the project area, 1.7km of layered ultramafic rocks were proved, together with separate bodies of mafic rock, most of them unlayered. Patches of sulphide mineralisation containing traces of platinum-group elements were located in the lowest 200m of the layered ultramafic sequence. In the south, the uppermost 1.85km of a layered mafic/ultramafic body was proved by drilling; the total thickness of this body is estimated at 6km. An 0.18m thick layer of coarse-grained pyroxenite containing copper and nickel sulphide but no detectable platinum group elements was encountered.

These results proved sufficiently encouraging for two private sector mining companies to conduct programmes of further exploration, including drilling, in parts of the project area. No economic mineralisation has so far been encountered, but exploration is still continuing.

OUTPUT (Reports, Papers, & etc)

Main Reports

Gould, D, Rathbone, P A & Kimbell, G S. 1987. The geology of the Molopo Farms Complex, southern Botswana. Volume 1 - Text. Bulletin of the Geological Survey of Botswana, No.23. 178pp + 4 maps.

Gould, D, Rathbone, P A & Kimbell, G S. 1989. The geology of the Molopo Farms Complex, southern Botswana. Volume 2 - Appendices. Bulletin of the Geological Survey of Botswana, No.23. 245pp.

Other references

Kimbell, G S, Burley, A J, Parker, M E, Pease, S F & Barton, K J. 1984. The gravity survey of the Molopo Farms area, southern Botswana. Bulletin of the Geological Survey of Botswana, No.30. 101pp. + 2 maps.

Gould, D, Rathbone, P A, Kimbell, & Burley, A J. 1986. The Molopo Farms Complex, Botswana - a possible target for Bushveld-type mineralisation. In Gallagher, M. J, Ixer, R A, Neary, C R, Pribell, G & Shard, H M. (Editors). Metallogeny of basic and Ultrabasic rocks. 319-331. (London: Institution of Mining and Metallurgy).

Kimbell, G S. 1987. Geophysical investigations of the Molopo Farms Complex, southern Botswana, [abstract]. Geophysical Journal of the Royal Astronomical Society, Vol.89, 491. [Abstract of presentation at 11th UK Geophysical Assembly, Durham, 1987].

Kimbell, S F, Self, S J & Evans, R B. 1987. BGS digital aeromagnetic data of the Molopo Farms area, southern Botswana. BGS Technical Report RG/87/21.

Gould, D. 1986. The Molopo Farms Project - Mineral Exploration in the Kalahari, Edinburgh Geologist, Vol.19, 1-8.

Gould, D & Rathbone, P A. 1985. The geological structure of the Molopo Farms Project area. In Hutchins, D G & Lynam, A (Eds). Proceedings of a symposium on the mineral exploration of the Kalahari. Geological Survey of Botswana Bulletin No.29. 160-186.

Additionally seven unpublished reports of the Geological Survey of Botswana were also produced.

WORKSHOPS AND PRESENTATIONS

Presentations at:-

Seminar on the Mineral Exploration of the Kalahari, Gaborone, Botswana, 1983.

Metallogeny of Basic and Ultrabasic Rocks, (IMM Meeting), Edinburgh, 1985.

11th UK Geophysical Assembly, Durham, 1987.

PROJECT STAFF

Dr D Gould
Dr P A Rathbone
G S Kimbell
Dr A J Burley
M E Parker
S F Kimbell
K J Barton
R J Peart

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 5**

TITLE: LAKE NYOS DISASTER

LOCATIONS: Cameroon

PROJECT SIZE: 4

DATES: 1986-87

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

BGS provided a hydrogeochemist as part of a 3 man ODA sponsored disaster-relief mission following the gas-burst disaster at Lake Nyos, NW Cameroon which killed 1750 people in August 1986.

On the recommendation of that mission, a seismological team from BGS conducted a 6-month seismic monitoring project in and around the Lake in order to examine the possibility that volcanic activity beneath the Lake had triggered the gas release.

PROJECT RESULTS

The UK team complemented the work of other teams of international experts in trying to understand the cause of gas release.

It has been concluded that pure volcanic CO_2 dissolved in high concentrations in Lake Nyos was released into the atmosphere producing a dense asphyxiating cloud that flowed at high-speeds up to 25 km along adjacent river valleys. The gas release was probably initiated by an earthquake or landslide.

This is the first time such a gas emission has been recorded and studies of the Nyos disaster have considerable importance in trying to predict and prevent other similar events worldwide.

Whilst there was considerable earthquake activity in the general volcanic province around Lake Nyos, no seismic activity was detectable from beneath the Lake itself. This observation indicated that a volcanic eruption trigger was unlikely.

OUTPUT (Reports, Papers, & etc)

Walker, A B, Redmayne, D W and Browitt, C W A. 1988. Seismic monitoring of Lake Nyos, Cameroon, following the gas release disaster of August 1986. BGS Technical Report WL/88/14.

Walker, A B, Redmayne, D W & Browitt, C W A. 1992. Seismic monitoring of Lake Nyos, Cameroon following the gas release disaster of August 1986. In: Geohazards - Natural and man-made. Edited by G J H McCall, D J C Lamming and S C Scott, Chapman and Hall, London 1992, pp.65-79.

Walker, A B, Redmayne, D W & Browitt, C W A. 1992. Lake Nyos Disaster: Earthquake trigger or volcanic activity? Natural hazards in West and Central Africa. Vieweg, Braunschweig, Edited by S J Freeth, K M Onuoha and C O Ofoegbu, pp.109-136.

WORKSHOPS AND PRESENTATIONS

Presentation of seismic monitoring programme to the International Conference on the Lake Nyos Disaster, Doula.

Seismic monitoring of the Lake Nyos Maar, Cameroon. International Volcanological Congress, IAVCEI Mainz 3-8 September 1990.

Seismic monitoring of Lake Nyos, 15th colloquium of African Geology Abstracts. CIFEG-service Documentation et Editions, Avenue de Concyr, BP 6517-45065 Orleans, Cedex, France.

Seismic monitoring of Lake Nyos (Cameroon). Presented at UK Geophysical Assembly, 1988.

PROJECT STAFF

A B Walker
D W Redmayne
C W A Browitt
T Turbitt
G D Ford
S N Morgan
P S Day
A Millar
D L Petrie
P C Marrow

FUNDING ODA Disaster Relief

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 6**

TITLE: DESIGN & INSTALLATION OF WELL CASINGS & SCREENS, CHAD UNDP CONTRACT

LOCATIONS: Chad, UK

PROJECT SIZE: 5

DATES: 1975

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

To install, on an experimental basis, fibreglass well casings and screens (designed by BGS on an ODA Research Contract) to improve the quality and reliability of groundwater supplies in dug wells.

PROJECT RESULTS

The casing/screen system was successfully designed and tested in the UK prior to attempts to install it.

One casing/screen system was installed in Chad funded by UNDP.

OUTPUT (Reports, Papers, & etc)

Day, J B W. 1974. Ministry of Overseas Development Research Contract for the development of plastic (fibreglass) well linings, (minipuits). Final Report IGS Technical Report WD/ST/74/5.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

K H Murray
J B W Day

FUNDING United Nations Development Programme (UNDP)

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 7**

TITLE: SOUTHERN DESERT GEOLOGICAL PROJECT

LOCATIONS: Egypt

PROJECT SIZE: 4

DATES: 1979-83

COLLABORATING ORGANISATIONS

Egyptian Geological Survey and Mining Authority (EGSMA)

PROJECT OBJECTIVES

Mineral exploration of the southern part of Egypt mainly in terrain covered in part by desert sands and underlain by basement rocks.

The project was implemented on a non-residential basis, involving winter fieldwork and laboratory studies in Egypt and data processing and interpretation in the UK. Study visits were organized to enable counterpart staff to visit the UK.

PROJECT RESULTS

Areas of old gold mining are thought to be worthy of detailed re-examination.

A total of nine Egyptian counterpart geologists undertook British Council funded study visits to the UK to work at BGS offices.

OUTPUT (Reports, Papers, & etc)

Jeffrey, D H & Bean, J H. 1983. Mineral reconnaissance of the Bir Tarfâwî basement area, Western Desert, Arab Republic of Egypt. IGS Overseas Division internal report, with grey-scale geochemical maps.

Bean, J H, Hudson, J & Jeffrey, D H. 1983. Report on the 1980-82 mineral reconnaissance programme in the Eastern Desert southeast of Aswan, Arab Republic of Egypt. IGS Overseas Division internal report with a series of geochemical maps at 1:100,000 scale.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr J H Bean (Project Manager)
D H Jeffrey
J Hudson

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 8**

TITLE: EASTERN DESERT GEOLOGICAL MAPPING & TRAINING

LOCATIONS: Egypt

PROJECT SIZE: 4

DATES: 1984-89

COLLABORATING ORGANISATIONS

Egyptian Geological Survey and Mining Authority (EGSMA)

PROJECT OBJECTIVES

Training in geological map-making and production for staff of EGSMA provided by short-term advisory and training visits involving:-

a) 'on the job' field instruction in the Eastern Desert

b) UK and Egypt-based instruction in the interpretation of aerial photographs and satellite imagery

c) provision of equipment and advice on the production of geological maps

PROJECT RESULTS

a) 1984-86 Field mapping training and detailed survey of part quadrangle, Bir Fawakhir area. Draft map subsequently incorporated in 1:250,000 quadrangle sheet programme (see also Project No.9).

Office and laboratory training, especially remote sensing/photogeology and petrography.

1986-89 Extension of field mapping training; evolvement of regional quadrangle mapping programme.

b) EGSMA geologists training in field mapping techniques and structural geology. Advice and training was also provided to 6 EGSMA geologists attached to the Sinai mapping group (1985).

OUTPUT (Reports, Papers, & etc)

Bennett, J D & Mosley, P N. 1987. Tiered-tectonics and evolution, Eastern Desert and Sinai, Egypt. Extended Abstract in Matheis, G & Schandelmeier, H. (Eds.), Current Research in African Earth Sciences, 79-82. 14th Colloquium on African Geology, Berlin, 18-22 August 1987. A A Balkema Rotterdam.

O'Connor, E A, Mosley, P N, McDonald, A J & Hawkins, M P. 1987. Lithotectonic mapping in the Eastern Desert using Landsat TM. Extended Abstract In: Matheis & Schandelmeier, H. (Eds.), Current Research in African Earth Sciences p.317-320, 14th Colloquium on African Geology, Berlin, 18-22 August, 1987. A A Balkema Rotterdam.

Romany, R F, O'Connor, E A, Johnston, T P, Omar, M & Mohamed, G. 1990. The Amnut granitoid complex: a re-appraisal of Phanerozoic intrusives in the Berenice District, Eastern Desert, Egypt. p.97-101. Annals of the Geological Survey of Egypt. Vol.16. 1986-1990.

Robertson, S, O'Connor, E A & Nasr, B B. 1990. The Amnut-Akab El Nyuem Alkali granitic-gabbro complex, Southeastern Desert, Egypt. In: 15th Colloquium on African Geology, Nancy. September 1990. p.407. Abstract.

WORKSHOPS AND PRESENTATIONS

Presentations given at:

14th Colloquium on African Geology, Berlin, 1987.
15th Colloquium on African Geology, Nancy, 1990.

PROJECT STAFF

Dr E A O'Connor
Dr P N Mosley
M Hawkins
Dr R N Annells
P J Pitfield
T P Johnston
S Robertson

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 9

TITLE: BGS-EGSMA INSTITUTIONAL TWINNING

LOCATIONS: Egypt

PROJECT SIZE: 5

DATES: 1989-On going

COLLABORATING ORGANISATIONS

Egyptian Geological Survey and Mining Authority (EGSMA)

PROJECT OBJECTIVES

Advisory visits to train and monitor the progress of counterpart Egyptian geologists in geological map making and report writing.

Geological mapping and 'on the job' training in part of the southeastern Desert.

Drafting and publication of a new series of 1:250 000 geological maps of Egypt, the initial 4 sheets cover areas mapped by BGS/EGSMA geologists during the 1980's (see project No. 8).

PROJECT RESULTS

To date include:

Several training sessions for Egyptian geologists in field geology in the southeastern desert and the Sinai Peninsula.

Workshops on geological map compilation and production.

OUTPUT (Reports, Papers, & etc)

Johnson, R L. 1991. Annual Report on BGS/EGSMA Professional Linkage Scheme. BGS Technical Report WC/91/9R.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr E A O'Connor
S Marsh

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 10

TITLE: HYDROGEOPHYSICAL TRAINING IN EGYPT

LOCATIONS: Egypt

PROJECT SIZE: 5

DATES: 1987

COLLABORATING ORGANISATIONS

Institute of Hydrogeology (IH) Wallingford
Egyptian Research Institute of Water Resources (RIWR)

PROJECT OBJECTIVES

To undertake a short geophysical training mission to RIWR to demonstrate the use of equipment donated to them as part of an EC-funded project "Sinai Water Resources Study", and help in interpretation of data gathered.

PROJECT RESULTS

The geophysical equipment provided for the Sinai Project is for Electromagnetic (EM) and Induced Polarisation (IP) studies.

The RIWR staff are capable of conducting resistivity soundings but the EM and IP equipment could not be demonstrated in the field due to malfunction. Operation of the equipment and the principles involved were explained.

Considerable further monitoring and training will be needed to enable RIWR to undertake the geophysical studies needed for the Sinai Water Resources Study.

Recommendations for further provision of advice and training were made together with a planning document for the next stage of the water resources study.

OUTPUT (Reports, Papers, & etc)

Institute of Hydrology 1987. Report on the Sinai Water Resources Study: Project Assessment (SEM/01/220/002).

WORKSHOPS AND PRESENTATIONS

Local seminars were held on hydrogeophysical techniques

PROJECT STAFF

R M Carruthers
Dr R B Bradford (IH)

FUNDING European Community (EC)

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 11**

TITLE: WATER SUPPLY STUDIES

LOCATIONS: Ethiopia

PROJECT SIZE: 3

DATES: 1972-75

COLLABORATING ORGANISATIONS

Livestock and Meat Board, Imperial Ethiopian Government

PROJECT OBJECTIVES

Water Supply Studies of 28,000 km^2 of drought-prone Southern Ethiopia for a regional livestock development project being implemented by the local government.

PROJECT RESULTS

The Hydrogeological studies enabled the siting of livestock watering points and wells.

Supervision of well drilling to provide adequate water resources for livestock development in drought-stricken Southern Ethiopia.

OUTPUT (Reports, Papers, & etc)

Manning, P I. 1973. Hydrogeological Survey of Jijigga and Gursum Awrajas for the Jijigga Livestock Development and Livestock Marketing Projects. IGS Hydrogeological Report 73/1.

Farr, J L. 1975. Drilling Supervisory Visit to Ethiopia, January - April 1975. IGS Report No. WD/OS/75/2.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

P I Manning
J L Farr

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 12

TITLE: DESIGN AND INSTALLATION OF WELL CASINGS & SCREENS

LOCATIONS: Gambia, UK

PROJECT SIZE: 5

DATES: 1975

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

To install, on an experimental basis, fibreglass well casings and screens (designed by IGS on an ODA Research Contract) to improve the quality of groundwater supplies in dug wells.

PROJECT RESULTS

The casing/screen system was successfully designed and tested in the UK prior to attempts to install it abroad.

Two casing/screen systems were provided in the Gambia. One of the systems installed secured sustainable water supplies for a local school.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

K H Murray
J B W Day

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 13**

TITLE: ADVISORY VISIT TO WATERAID PROJECTS IN THE AFRAM PLAINS

LOCATIONS: Ghana

PROJECT SIZE: 5

DATES: 1986

COLLABORATING ORGANISATIONS

Wateraid (UK)
Water Resources Research Institute (WRRI) Ghana Government

PROJECT OBJECTIVES

To provide Wateraid project staff in the Afram Plains with technical advice on borehole siting and hand dug well construction. Cooperate with WRRI in demonstrating techniques of borehole siting for groundwater supplies.

PROJECT RESULTS

Project areas appraised, field surveys undertaken, results and recommendations given in visit report.

OUTPUT (Reports, Papers, & etc)

Buckley, D K. 1986. Report on advisory visit to WATERAID projects in Ghana Jan-Feb 1986. BGS Hydrogeology Report.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

D K Buckley

FUNDING WATERAID (UK)

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

PROJECT NO: 14

FORM A3

TITLE: FIELD TRAINING AND MAPPING PROJECT

LOCATIONS: Kenya

PROJECT SIZE: 3

DATES: 1974-76

COLLABORATING ORGANISATIONS

Mines and Geological Department, Nairobi

PROJECT OBJECTIVES

Training of geologists in detailed geological mapping, map making, data analysis and report preparation.

PROJECT RESULTS

1975-6 Training of 5 geologists (groups of 3 and 2) disrupted by security situation in the field and reassignment to other Departmental or Resources Ministry posts.

1974-5 Supervision and Training was provided for 4 Kenyan geologists from the Mines and Geological Department in the detailed mapping of Basement Metamorphic rocks of the Samburu District. In a concentrated course project objectives were met.

OUTPUT (Reports, Papers, & etc)

Project 2nd year participants produced a detailed 1:25,000 map (Special) of the Siambu area (223km^2) in the Samburu District and an accompanying geological report (fate unknown).

Progress and staff reports were produced monthly, quarterly, annually and on termination of the project.

WORKSHOPS AND PRESENTATIONS

For internal training only, photogeology, petrography etc.

PROJECT STAFF

D Green (ODA - Contract Project Leader 1974-75)
Dr B E Leveridge (Project Leader 1975-76)

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 15**

TITLE: SAMBURU-MARSABIT PROJECT

LOCATIONS: Kenya

PROJECT SIZE: 2

DATES: 1980-86

COLLABORATING ORGANISATIONS

Mines and Geological Department
Ministry of Environment and Natural Resources, Nairobi

PROJECT OBJECTIVES

To produce geological maps, accounts and information on mineral and water resources within the 100.000 km^2 Samburu-Marsabit area of north-central Kenya, the area comprises 17% of Kenyan territory.

The phase I of the project was planned to cover the southern part of the area by detailed surveying, the following phase II investigated the northern part on a reconnaissance basis.

PROJECT RESULTS

Geological surveying and geochemical sampling of the area was accomplished and benefitted greatly from the availability of Landsat TM Imagery.

Detailed information on the geology is contained in 9 reports listed overleaf each with an accompanying 1:250.000 geological map.

Considerable industrial and metallic mineral potential has been identified together with sites worthy of evaluation for geothermal energy.

Advice on the siting and development of infrastructure, notably dam sites within the area has been provided.

5 Kenyan geologists have received detailed 'on the job' training in geological surveying and 2 cartographers were trained, 4 Kenyan geologists subsequently received British Council scholarships to study in the UK.

The project was recently evaluated by ODA (Report EV 498) the report findings highlight the sound identification of the project and the high quality geological maps produced and training provided.

OUTPUT (Reports, Papers, & etc)

Charsley, T J. 1984. The Nanyuki Formation - a glaciofluvial fan deposit in "Geology for the Development of Kenya" Geological Society of Kenya Publication No 2 p 23-29.

Charsley, T J. 1987. Geology of the North Horr area (Degree sheet 12) Mines and Geological Department, Nairobi, Kenya. Report 110 40 p + map.

Charsley, T J. 1987. Geology of the Laisamis area (Degree Sheet 28) Mines and Geological Department, Nairobi, Kenya. Report 106 70 p + map.

Hackman, B D. 1987. The Samburu-Marsabit Geological Mapping and Mineral Exploration Project 1980-86. BGS Technical Report MP/87/26R.

Key, R M. 1987. Geology of the Marsabit area (Degree Sheet 20) Mines and Geological Department, Nairobi, Kenya. Report No 108 42 p + map.

Key, R M. 1987. Geology of the Maralal area (Degree Sheet 27) Mines and Geological Department, Nairobi, Kenya. Report No 105 93 p + map.

Hackman, B D. 1988. Geology of the Barringo - Laikipia area (Degree Sheet 35) Mines and Geological Department, Nairobi, Kenya. Report 104 79 p + map.

Key, R M and Watkins, R T. 1988. Geology of the Sabarei area (Degree Sheets 3 and 4) Mines and Geological Department, Nairobi, Kenya. Report III 57 p + map.

Ochieng, J O, Wilkinson, A F, Kagasi, J and Kimono, S. 1988. Geology of the Loiyangalani area (Degree Sheet 19) Mines and Geological Department, Nairobi, Kenya. Report 107 53 p + map.

Wilkinson, A F. 1988. Geology of the Allia Bay area (Degree Sheet 11) Mines and Geological Department, Nairobi, Kenya. Report 109 54 p + map.

Hackman, B D, Charsley, T J, Kagasi, J, Key, R M, Siambi, W S and Wilkinson, A F. 1989. Geology of the Isiolo area (Degree Sheet 36) Mines and Geological Department, Nairobi, Kenya. Report 103 88 p + map.

WORKSHOPS AND PRESENTATIONS

Presentations at:

1st Conference of the Geological Society of Kenya 1984

PROJECT STAFF

Dr B D Hackman (Project Manager)
Dr R M Key
Dr A F Wilkinson
T J Charsley
G R Wood (Cartographer)

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 16**

TITLE: TIWI AQUIFER STUDY

LOCATIONS: Kenya

PROJECT SIZE: 4

DATES: 1984-89

COLLABORATING ORGANISATIONS

Kenyan Ministry of Water Development (MOWD)

PROJECT OBJECTIVES

Short term:

- assessment of the quantity of groundwater resources in the study area
- to find a freshwater supply for domestic use of the local population & tourism industry
- to understand the hydrogeological parameters of the area
- to assist early development where feasible of identified sources in resource studies for local population

Long term:

- strengthening of Water Resources Departments capability in practical groundwater exploration and assessment of water resources
- to provide a strong base for long-term water planning for the area
- to provide a basis for assessment and development of groundwater potential in other areas

PROJECT RESULTS

An initial resources study (1984-86) of the coastal strip of Kenya from the Tanzanian border to Malindi identified the Tiwi area (south of Mombasa) as having highest potential for development.

Kenyan Ministry of Water Development requested a second phase to develop the resource. Training of a Kenyan geologist in computer simulation was undertaken at Wallingford in Summer 1987. The agreement between ODA and MOWD was for BGS to provide expertise in groundwater development, ODA to provide funding of borehole construction and pump installation and MOWD to provide distribution network. Failure by MOWD to meet their commitment to the project resulted in ODA terminating agreement in February 1989.

OUTPUT (Reports, Papers, & etc)

Carruthers, R M. 1985. Report on geophysical studies relating to the coastal aquifer of the Mombasa District, Kenya. BGS Regional Geophysics Report 85/4.

Adams, B. 1986. Tiwi Aquifer Study, Final Report, June 1986.

Adams, B. 1986. Sabaki Groundwater Investigation, December 1986.

Adams, B & Macharia, H. 1987. The Tiwi Aquifer Study - some of the techniques used in an investigation of the groundwater resources of the coastal strip of Kenya - African Water Technology, February 1987.

WORKSHOPS AND PRESENTATIONS

Presentations at:

African Water Techology Conference, Nairobi, February 1987.

PROJECT STAFF

B Adams
R M Carruthers

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 17

TITLE: AQUIFER STUDIES, COASTAL REGION, KENYA

LOCATIONS: Kenya

PROJECT SIZE: 5

DATES: 1981

COLLABORATING ORGANISATIONS

Ministry of Water Development and Mines and Geology Department, Kenya

PROJECT OBJECTIVES

Hydrogeological study of the coastal area of eastern Kenya from the Tanzanian border northwards to the Sabaki river (about 200 km).

To study potential groundwater sources of the Kenya coastal region.

PROJECT RESULTS

Cainozoic sediments were identified as having greater groundwater resource potential than the Karroo rocks further inland.

The Pleistocene reef complex sands of the coastal strip, which are unconsolidated or semi-consolidated were shown to have the greatest potential and capable of high well yields.

Appropriate borehole construction including screen and gravel packing was recommended for development of these resources. They are capable of high yields but subject to saline intrusion.

Recommendation made for a more detailed survey. (Project No. 16).

OUTPUT (Reports, Papers, & etc)

Buckley, D K. 1981. Report on a visit to assess Groundwater Potential of the Kenya Coast south of Malindi. IGS Technical Report No.WD/08/81/7.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

D K Buckley

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 18

TITLE: CHYULU HILLS WATER RESOURCES STUDY

LOCATIONS: Kenya

PROJECT SIZE: 3

DATES: 1984-87

COLLABORATING ORGANISATIONS

Institute of Hydrology, Wallingford
Kenyan Ministry of Water Development
Kenyan Mines and Geological Department, Ministry of Environment and Natural Resources

PROJECT OBJECTIVES

The Chyulu Hills are a range of recent volcanic hills lying in southeastern Kenya, some 50km long and rising up to 1000m above surrounding semi-arid lowlands.

Springs derived from the hills supply the coastal port and tourist centre of Mombasa (by 200km pipeline) and local villages. The principal objective of the study was to provide the Ministry of Water Development with a detailed water resources survey of the Chyulu Hills area, including water balances, details of rainfall and spring discharges, and the hydrogeology of the area.

PROJECT RESULTS

Collection of field data (including a number of new sites) 1984-87.
Compilation of available earlier data.
Petrographic and geochemical studies; geological mapping.
Development of model linking flow in the major (Mzimal spring) and distributed rainfall over the hills.
Consideration of development of water resources.
Recommendations for future, more detailed, work in certain specific areas.

OUTPUT (Reports, Papers, & etc)

BGS 1988. The Chyulu Hills Water Resources Study, Kenya: 1984-87. 2 Volumes. BGS Technical Report WD/88/5C.

Wright, E P & Gunston, H. 1988. Hydrogeology of the Chyulu Hills Basalt Aquifer, Kenya. Geolis (Lisbon), 2,1, pp.38-49.

Geological map of the Chyulu-Oloitokitok area (coloured) Kenya 1:125,000 (Geology) sheet 59SE Quarter. ODNRI 1988.

Geology of the South Chyulu Hills. Map 1:125,000 (black & white). ODNRI 1988.

WORKSHOPS AND PRESENTATIONS

"Hydrogeology of the Chyulu Hills Basalt Aquifer, Kenya". Presented at Symposium "Hydrogeology of volcanic terrains", Funchal, Maderia, September 1987.

PROJECT STAFF

H Gunston - (on secondment from IH for the study)
Dr E P Wright

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 19**

TITLE: EXPLORATION FOR GEOTHERMAL ENERGY

LOCATIONS: Kenya

PROJECT SIZE: 2

DATES: 1985-On going

COLLABORATING ORGANISATIONS

Ministry of Energy and Regional Development, Nairobi, Kenya
United Nations Development Programme (UNDP)
Lancaster University UK

PROJECT OBJECTIVES

To evaluate the geothermal potential of the Kenyan Rift Valley.

The BGS contribution comprises geological, geochemical and hydrogeological studies and is being carried out jointly with the local authorities and UNDP.

PROJECT RESULTS

The work is divided into 2 phases:-

Phase 1 (1985-88) involved geological surveying of the Longonot-Olkaria-Egurru area coupled with a regional hydrogeological and hydrochemical investigation of the southern and central part of the Rift Valley. Areas with the highest geothermal potential lie within or adjacent to large ring structures at Olkaria and Longonot. These structures indicate the presence of large shallow magma bodies (heat sources) of geologically very young age. These heat sources lie south of Lake Naivasha and across the presumed path of water flowing underground out of that lake. The Olkaria ring structure has the most apparent potential as it localises very numerous young volcanic subcentres, has the greater number of fumaroles and has a far higher radon emission. The south-west quadrant of the Longonot caldera also has potential but surface indications are largely masked by a later blanket of ash. The coincidence of high values of soil-gas carbon dioxide with the tectono-volcano axis running from Longonot crater in the area of Mt Margaret also indicates a possible potential resource area. The relatively narrow thermal zone at Eburru together with the lack of a recogniseable thermally active ring structure would, on the criteria used above, indicate that this area might have a lower potential than the unexplored parts of Olkaria, or even Longonot.

Phase II (1988-92) is extending geothermal prospecting to the northern part of the Rift from Lake Baringo to Lake Turkana focussing in particular on six volcanic centres.

Counterpart geologists successfully completed British Council sponsored MSc courses in the UK.

OUTPUT (Reports, Papers, & etc)

Project Technical Reports

Bibliography of the geology of the Kenya Valley, with emphasis on the geothermal potential. BGS GEN/KEN/1.

Geological and Geological mapping (Progress Report). BGS GEN/KEN/2.

Regional Hydrogeological Investigations (Progress Report). BGS GEN/KEN/3.

Compilation and interpretation of rock geochemical data for the Longonot Volcano and the Greater Olkaria Volcanic complex. BGS GEN/KEN/4.

The geology of Longonot Volcano, the Greater Olkaria Volcanic Complex and adjacent areas. BGS GEN/KEN/5.

Rn/CO_2 investigations at Longonot, and Olkaria and surrounding areas. BGS GEN/KEN/6.

Hydrogeology Progress Report, March-August 1987. BGS GEN/KEN/7.

Petrography and Mineralogy of lithic clasts and other rock specimens from the Longonot area, Kenya. BGS GEN/KEN/9.

Scientific Publications

Allen, D J, Darling, W G and Burgess W G. 1989. Geothermics and hydrogeology of the southern part of the Kenya Rift Valley with emphasis on the Magadi-Nakuru area. BGS Research Report SD/89/1

Johnson, R L (compiler). 1990. Exploration for Geothermal Energy Project Phase II 1988-92. Report on Review Meeting - Nairobi 1990. BGS Technical Report WC/90/46.

Clarke, M C G, Woodhall, D G, Allen, D and Darling, G. 1990. Geological volcanological and hydrogeological controls on the occurrence of geothermal activity in the area surrounding Lake Naivasha Kenya. Ministry of Energy, Nairobi Kenya. 138 p + 3 maps.

Allen, D J and Darling, W G. In press. Geothermics and Hydrogeology of the Kenya Rift Valley between Lake Baringo and Lake Turkana. BGS Draft Research Report.

WORKSHOPS AND PRESENTATIONS

Presentation at a Geothermal Seminar - Review of Phase II Progress Nairobi 1990 (Technical Review Meeting).

PROJECT STAFF

Dr M C G Clarke (Project Manager Phase I)
Dr P Dunkley (Project Manager Phase II)
Dr M Smith
W G Darling
D J Allen
D G Woodhall

FUNDING ODA Technical Cooperation

Exploration for Geothermal Energy in Kenya

A technical co-operation project:
Peter Dunkley

Examining and sampling hot spring deposits.

Currently, most of Kenya's electricity is generated by hydroelectric power stations and an important contribution is also made by oil-fired thermal generation with geothermal sources being of tertiary importance. For various reasons however, attention is being turned to geothermal sources as most promising for meeting demand in the future. In keeping with this long term strategy, ODA have been funding a programme of geothermal exploration in the Kenya Rift Valley since 1985.

From 1985-87 an investigation of the Longonot-Olkaria-Eburru area of the central part of the Rift Valley was made by BGS in collaboration with the Kenyan Ministry of Energy. This was undertaken in association with a UNDP project.

The current phase of the project began in 1988 and covers the northern part of the Rift Valley, extending from Lake Baringo in the south to Lake Turkana in the north, with some reconnaissance exploration also being undertaken around the shores and on the islands of Turkana. When this phase ends in 1992 the basic inventory of the country's geothermal prospects will be complete.

Six major volcanic centres, aligned along the axis of the northern sector of the Rift, were identified as geothermal exploration targets from earlier, ODA-supported, regional geological mapping by the Kenya Geological Survey department.

The present investigation comprises detailed geological mapping of the six centres and the collection of samples of hot water and gases for laboratory analysis. Rock samples have been submitted for radiometric age determination and an evaluation of the hydrogeology of the area is being made. From a consideration of the surface form, geological history and age of the volcanos, it is possible to predict whether large bodies of hot rock are present at shallow depths beneath them. From chemical and physical analyses of water and gases, estimates of temperatures at depth can be made, bearing in mind that steam at a temperature of at least 200 degrees centigrade is required for power generation. Geothermal systems are associated with five of the volcanic centres within the northern part of the Rift, and in addition, hot water systems occur along the margins of the Rift floor where they are located on major boundary faults.

Hot ground is characterised by the growth of a distinctive sedge, *Abilgaardia lispidula*, and by red or white clays produced by the alteration of the rock by steam and hot gases. Areas which were formerly hot but are now inactive are similarly characterised by red or white clays. The location of areas of red soil is well-known to the local Pokot and Masai who use the red clays to colour their hair and faces. This aspect of geothermal exploration can be undertaken by asking the local people the source of their cosmetics !

Hydrogeological information obtained from water boreholes and wells, rivers and lakes, has been used to produce a model for the movement of groundwater within the region. Hydrogen and oxygen isotope analysis of rainfall, surface waters, groundwaters, hot springs and steam constrain the model further, because each of the potential water sources has a characteristic isotopic signature.

The integrated physical/geochemical model indicates that there is sufficient groundwater recharge in the region to sustain the exploitation of the geothermal systems despite the aridity of the area. There is substantial subsurface outflow from Lake Baringo northwards beneath the volcanic centres along the axis of the Rift. The much wetter, higher plateau areas to the west and east of the Rift are also areas of recharge. Even on the semi-arid Rift floor significant infiltration is believed to take place during heavy storms.

The project has sometimes been hazardous; for example, the steam jets on the summit of Paka are sacred to the spear-carrying Pokot people who live on and around the mountain. As part of an agreement over access, the team provided a Pokot village with a source of drinking water by constructing, at one of the steam jets, a condenser made of oil drums and aluminium pipes.

Helicopter support was essential in the arid, trackless country to the north. On one occasion, the failure of the helicopter engine to start, following a landing on the summit of Emuruangogolak led to a 36 hour walk over very rough lava fields under desert conditions whilst on Silali the field party had to make a hasty retreat when faced with a particularly aggressive pride of lions.

Field-work has now been completed and results are being evaluated. Preliminary findings are that the best places for further investigation, largely by geophysical methods, are on the Paka and Silali volcanoes. Happily these areas are out of sight of the scenic Lake Baringo and its tourist facilities.

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 20

TITLE: EDITORIAL MAPPING AND TRAINING PROJECT

LOCATIONS: Kenya

PROJECT SIZE: 3

DATES: 1987-On going

COLLABORATING ORGANISATIONS

Kenya Mines and Geology Survey Department

PROJECT OBJECTIVES

Training of Kenyan junior professional staff in field geology and report preparation; strengthening of the host departments editorial capacity in order to ensure more effective dissemination of information.

Clearing a backlog of publications by Desk Top Publishing.

PROJECT RESULTS

8 reports edited and published to end 1991.

OUTPUT (Reports, Papers, & etc)

Walshaw, R D. 1991. Report on Training and Editorial Project - Kenya. BGS Technical Report WC/91/3R.

Walshaw, R D. 1991. Report on a second mission to the Mines and Geological Department, Kenya. BGS Technical Report WC/91/24R.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr P. N. Mosley
Dr R. D. Walshaw

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 21

TITLE: PRELIMINARY EVALUATION OF DIAMOND DEPOSITS

LOCATIONS: Lesotho

PROJECT SIZE: 4

DATES: 1965-66

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

A preliminary evaluation of the diamond-bearing potential of kimberlite pipes and alluvial gravels in Lesotho.

PROJECT RESULTS

Some 451 trial pits were sunk and 19 trenches excavated to evaluate 9 kimberlite pipes; alluvial gravels were tested over a linear distance of 60 miles.

Samples recovered were processed using traditional methods and the overall grade of individual pipes was estimated.

Apart from immediately downstream of pipes the alluvial gravels gave disappointing results. The results from the pipes were more encouraging.

Recommendations were made to the government of Lesotho for the establishment of a mining law and a small mines department to regulate exploration.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

E S P Meaton
T Hick
A C Marlowe
S D Lyle

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 22

TITLE: REGIONAL GRAVITY SURVEY

LOCATIONS: Lesotho

PROJECT SIZE: 5

DATES: 1979

COLLABORATING ORGANISATIONS

United Nations
Department of Mines & Geology, Lesotho

PROJECT OBJECTIVES

To conduct a regional geophysical gravity survey of Lesotho as background information on the deeper geological structure which has important bearing on minerals, water and energy resources.

PROJECT RESULTS

The Survey comprised about 800 observation stations spaced on average 6 km apart, in order to investigate the deep geological structure beneath the extensive cover of basalt lavas. A major gravity high was interpreted as due to basic rocks within the Precambrian basement.

OUTPUT (Reports, Papers, & etc)

Burley, A J, Kimbell, G S, Patrick, D J, Turnbull, G and Kashamburi, R. 1982. A Gravity Survey of Lesotho. IGS Overseas Geology and Mineral Resources No 60 27 p 2 maps.

Kimbell, G S & Turnbull, G. 1986. BGS regional gravity digital data of Lesotho. British Geological Survey, Regional Geophysics Research Group Report, No.86/17.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

A J Burley
G S Kimbell
D J Patrick
G Turnbull

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 23

TITLE: GROUNDWATER STUDY, CENTRAL CYRENAICA, PETROLEUM COMPANIES

LOCATIONS: Libya

PROJECT SIZE: 4

DATES: 1967-70

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Hydrogeological appraisal of 250.000 km^2 of Central Cyrenaica which is underlain by thick post-Eocene alluvial deposits.

PROJECT RESULTS

An electrical model was constructed to simulate groundwater flow through the anisotropic post-Eocene alluvial deposits with the aim of investigating the ratio of vertical to horizontal permeability in the vicinity of wells.

The substantial number of existing water-supply boreholes drilled by oil companies were investigated and their groundwater sampled, the variation of water quality was determined and isotopic studies suggest that little recharge of the aquifer is occurring, anomalously high concentrations of nitrate observed are probably related to nitrogen-rich deposits within the aquifer.

OUTPUT (Reports, Papers, & etc)

Wright, E P. 1967. Interim report on the hydrogeological investigations carried out in Concessions 65 and 80, Libya, October to December 1967. IGS Unpublished report to BP Ltd.

Wright, E P. 1968. Supplementary report on the hydrogeological investigations carried out in Concessions 65 and 80, Libya, October to December 1967. IGS Unpublished report to BP Ltd.

Wright, E P & Edmunds, W M. 1969. Hydrogeologial studies in Central Cyrenaica, Libya. IGS Unpublished report for BP Ltd and Nelson Bunker Hunt, Report WD/69/3. pp.31.

Wright, E P & Edmunds W M. Hydrogeological Studies in Central Cyrenaica, Libya. Symposium on the Geology of Libya, University of Libya, 1971. p.459-481.

WORKSHOPS AND PRESENTATIONS

Hydrogeological Studies in Central Cyrenaica, Libya. Symposium on the Geology of Libya, University of Libya, 1971.

PROJECT STAFF

Dr E P Wright
J F T Houston
Dr W M Edmunds

FUNDING British Petroleum, Nelson Bunker Hunt and Oasis Oil Company of Libya

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 24

TITLE: GROUNDWATER STUDY, CENTRAL CYRENAICA, LIBYAN GOVERNMENT

LOCATIONS: Libya

PROJECT SIZE: 3

DATES: 1971-75

COLLABORATING ORGANISATIONS

Kufra and Sarir Authority, Libyan Government

PROJECT OBJECTIVES

To augment earlier hydrogeological studies in Central Cynenaica (Project 23) with a view to large-scale groundwater development, either for irrigation at the well site development area, or for conveyance to coastal areas (The Great Man-made River Project).

PROJECT RESULTS

The study investigated the groundwater resources of 86,000 km^2 of N Central Cynenaica, trial wells were installed and pumping tests performed to determine potential yields. Detailed studies of water quality were also performed and the aquifer behaviour has been predicted using mathematical models.

Subsequently a Production Field of 500 wells was installed, designed to irrigate 50.000 hectares

OUTPUT (Reports, Papers, & etc)

Reports

Edmunds, W M. 1972. Carbon Isotope Investigations, Libyan Arab Republic. IGS Unpubished report WD/ST/72/9.

Benfield, A C. 1972. Post-Oligocene sediments Jalu Region, Sirte Basin, Libya. IGS Unpublished Report WD/72/5.

Kitching, R. 1973. Report on groundwater model of Jalu-Tazerbo Area, Libyan Arab Republic. IGS Unpublished Report WD/ST/74/1.

Wright, E P, Benfield, A C, Edmunds, W M & Kitching. 1973. Jalu-Tazerbo Project Phase 1 Interim Report + 12 Appendices. IGS Report WD/73/10, pp.56. Appendices describe detailed work at each site.

Benfield, A C. 1973. Jalu-Tazerbo Project, Phase 2 Area Geological Studies: Preliminary assessment of Post-Oligocene Sediments in Region of N of Latitude 27°20'N. IGS Unpublished Report WD/74/11.

Benfield, A C. 1974. Jalu-Tazerbo Project, Phase 1 Area. Investigations of Clay Beds within the saturated zone of the Post-Middle Miocene Calenscio Formation by Gamma Ray logging. IGS Unpublished Report WD/ST/74/8.

Wright, E P, Benfield, A C, Edmunds, W M & Kitching R. 1974. Jalu-Tazerbo Project: Phase 1. Final Report. Institute of Geological Sciences/Kafra and Sarir Authority, Published Report pp.91 (+ two Appendices).

Wright, E P. 1975. Jalu-Tazerbo Project: Phase 2. Final Report + 4 Appendices. IGS Report pp.74. Appendices describe detailed work at each site.

Papers

Edmunds, W M & Wright, E P. 1979. Groundwater recharge and palaeoclimate in the Sirte and Kafra basins, Libya. Journal of Hydrology 40. p.215-241.

Benfield, A C & Wright E P. 1981. Post-Eocene sedimentation in the eastern Sirte Basin, Libya. In: Geology of Libya (Eds. Salem M J & Busrewil, M T). Academic Press, London. Vol.2, p.463-499.

Edmunds, W M. 1981. The hydrogeological characterisation of groundwater in the Sirte Basin, using strontium and other elements. In: Geology of Libya (Eds. Salem, M J & Busrewil, M T). Academic Press, London. Vol.2, p.703-714.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr E P Wright
Dr W M Edmunds
Dr A C Benfield
M Price
I N Gale
K Murray
J Black
Dr R Kitching
S L Shedlock
P J Chilton
I B Harrison

FUNDING Libyan Government

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 25**

TITLE: ECONOMIC GEOLOGY CONSULTANT - MALAWI GEOPHYSICS, UNDP

LOCATIONS: Malawi

PROJECT SIZE: 5

DATES: 1986-88

COLLABORATING ORGANISATIONS

Geological Survey Department, Malawi
Paterson, Grant & Watson (Toronto)

PROJECT OBJECTIVES

A BGS Manager acted as Economic Geology Consultant for the UN to assist contractors Paterson, Grant and Watson in the interpretation of the results of a national airborne geophysical survey of Malawi commissioned by the UNDP in 1984-85.

PROJECT RESULTS

The six-week consultancy involved a visit to Malawi and three short visits to Toronto to liaise with contractors Paterson, Grant and Watson.

The BGS Manager guided the contractor giving advice on the geology, structure and mineral potential of Malawi and helped interpret the geophysical data and together with a BGS geophysicist assessed the contractors final report.

OUTPUT (Reports, Papers, & etc)

Johnson, R L. 1986. Interpretation of Airborne Survey Results, Malawi - Mission Report on Visit to Malawi 1-15 November 1986.

3 Short Mission Reports to Toronto by R L Johnson. BGS Technical Reports MP 86/31R
MP 87/10R
MP 87/23R

Johnson, R L & Evans, R B. 1988. Review of Paterson, Grant and Watson Ltd. Draft Final Report UN Project MLW/80/030. BGS Technical Report WC/88/7R.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr R L Johnson
R B Evans

FUNDING United Nations Development Programme (UNDP)

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 26

TITLE: FIELD MAPPING AND TRAINING

LOCATIONS: Malawi

PROJECT SIZE: 3

DATES: 1987-90

COLLABORATING ORGANISATIONS

Geological Survey Department (GSD), Zomba, Malawi

PROJECT OBJECTIVES

A BGS geologist acted as an instructor in field mapping and training with the Geological Survey Department.

PROJECT RESULTS

Instruction in photogeology, geological surveying, map preparation and report writing was given to five trainees from the GSD. Under supervision these local geologists are producing 1:25,000 scale detailed geological maps of the Nkhotakota Game Reserve which will be incorporated into a regional compilation 1:250,000 map.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr B Klinck

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 27

TITLE: KSAR-ES-SEGHIR TOURISM DEVELOPMENT

LOCATIONS: Morocco

PROJECT SIZE: 5

DATES: 1967

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

To advise on water supply for an ODA project to develop tourism at Ksar-es-Seghir, Northern Morocco.

PROJECT RESULTS

A short advisory visit was undertaken and the potential supply of surface and ground water was invesitgated and reported on.

OUTPUT (Reports, Papers, & etc)

Short reports

Water Supplies from underground and surface sources at Ksar-es-Seghir, Northern Morocco.

Reconnaissance of the site for proposed tourist resort at Ksar-es-Seghir, Northern Morocco.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

J B W Day

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 28

TITLE: CASSITERITE PROCESSING

LOCATIONS: Niger

PROJECT SIZE: 4

DATES: 1971-72

COLLABORATING ORGANISATIONS

Warren Springs Laboratory

PROJECT OBJECTIVES

To test the feasibility of extracting cassiterite on a commercial basis without the use of water, from eluvial and alluvial deposits in the Aïr Mountains of Niger. Trials for production of cassiterite concentrates using the Dryflow (fluidized bed) system proved successful.

PROJECT RESULTS

Field testing was performed using several types of dry-flow processing methods.

The vicinity of the deposits was mapped geologically to obtain a better understanding of their distribution and a gross estimate of the 'reserves'/tonnages was prepared.

OUTPUT (Reports, Papers, & etc)

IGS Internal report: Cassiterite distribution and reserves (tonnages). Wadi Taronadji Aïr.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr D Bleakley
Dr J Baldock
J A Bain
D A Briggs

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 29

TITLE: EXPLORATION FOR ALLUVIAL TIN, ADRAR CHIRIET

LOCATIONS: Niger

PROJECT SIZE: 5

DATES: 1985

COLLABORATING ORGANISATIONS

Ministre des Mines, ONAREM, Niamey, Niger

PROJECT OBJECTIVES

Examination of present alluvial tin workings in Niger at El Meki.

Assessment of potential alluvial prospect at Adrar Chiriet.

Exploration for tin in the Aïr Massif around Adrar Chiriet.

PROJECT RESULTS

The work was undertaken and a commercial-in-confidence report produced for the client.

OUTPUT (Reports, Papers, & etc)

Commercial-in-Confidence Report for Edlow Resources. Exploration for Alluvial Tin, Adrar Chiriet, Niger, Africa.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

M J Brown

FUNDING Commercial (Edlow Resources Ltd, USA)

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 30

TITLE: GROUNDWATER RECHARGE IN SENEGAL

LOCATIONS: Senegal

PROJECT SIZE:

DATES: 1988-91

COLLABORATING ORGANISATIONS

University of Dakar
Université de Paris-Sud

PROJECT OBJECTIVES

To make improved and integrated estimates of groundwater replenishment history for a cross-section of the Sahel where climate has been variable during the last 25 years and over a timescale of centuries.

PROJECT RESULTS

A field sampling technique has been developed using hand augers to collect pore-water samples from the unsaturated zone instead of costly drilling operations; replenishment is estimated by a chloride mass balance technique. It has been verified using tritium and also by comparison with the water quality of the shallow phreatic aquifer.

This approach is of worldwide application for semi arid zones as it establishes an upper safe limit for groundwater extraction.

OUTPUT (Reports, Papers, & etc)

Edmunds, W M. 1991. Recharge of Groundwater in Senegal: Seminar on the Results of ODA Project. BGS Technical Report WD/91/11R.

Edmunds, W M, Gaye, C B & Fortes, J-Ch. 1991. A record of climatic and environmental change contained in interstitial waters from the unsaturated zone of northern Senegal. Proceedings of the International Symposium on Isotope Techniques in Water Resources Development. IAEA Vienna.

Cook, P G, Edmunds, W M & Gaye C B. in press. Estimating palaeorecharge and palaeoclimate from unsaturated zone profiles. Paper submitted to Water Resources Research.

Edmunds, W M, Gaye, C B & Cook P G. in press. Direct evidence for hydrogeological change in the sahel during the past half millenium. Paper submitted to Nature.

WORKSHOPS AND PRESENTATIONS

Seminar on the project results held in Dakar in December 1990 for Senegalese Government and international aid organizations, 100 people attended, widespread press coverage.

Presentation of project work to the President of Senegal at Wallingford 1988, widely reported in the media.

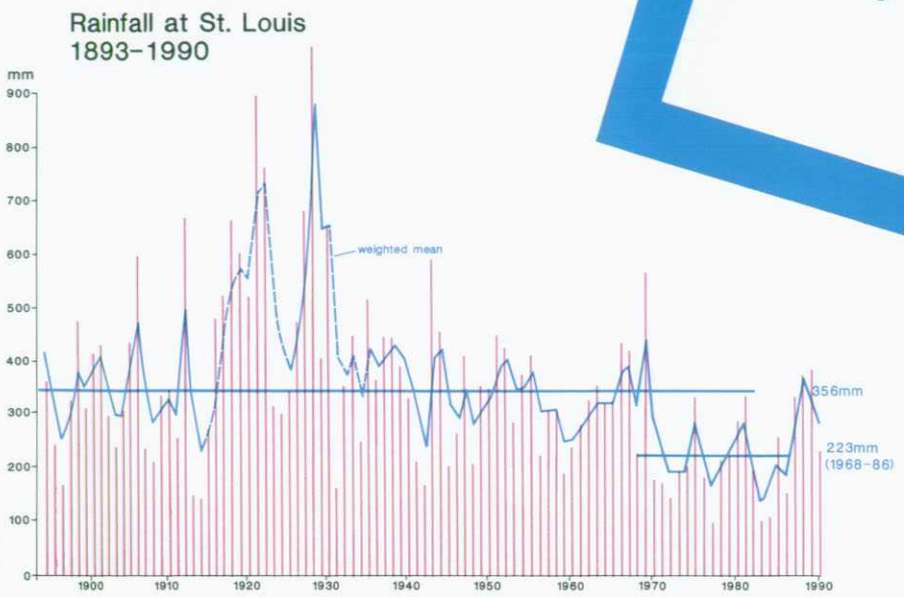
PROJECT STAFF

Dr W M Edmunds
J Talbot

FUNDING ODA Technical Cooperation

BRITISH GEOLOGICAL SURVEY

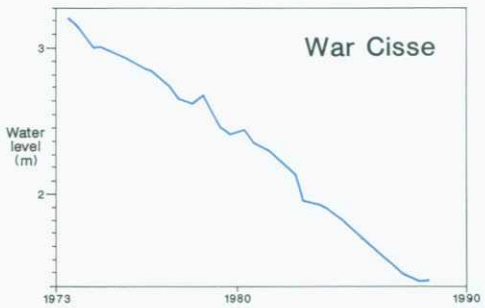
ESTIMATION OF RECHARGE TO AQUIFERS IN SENEGAL



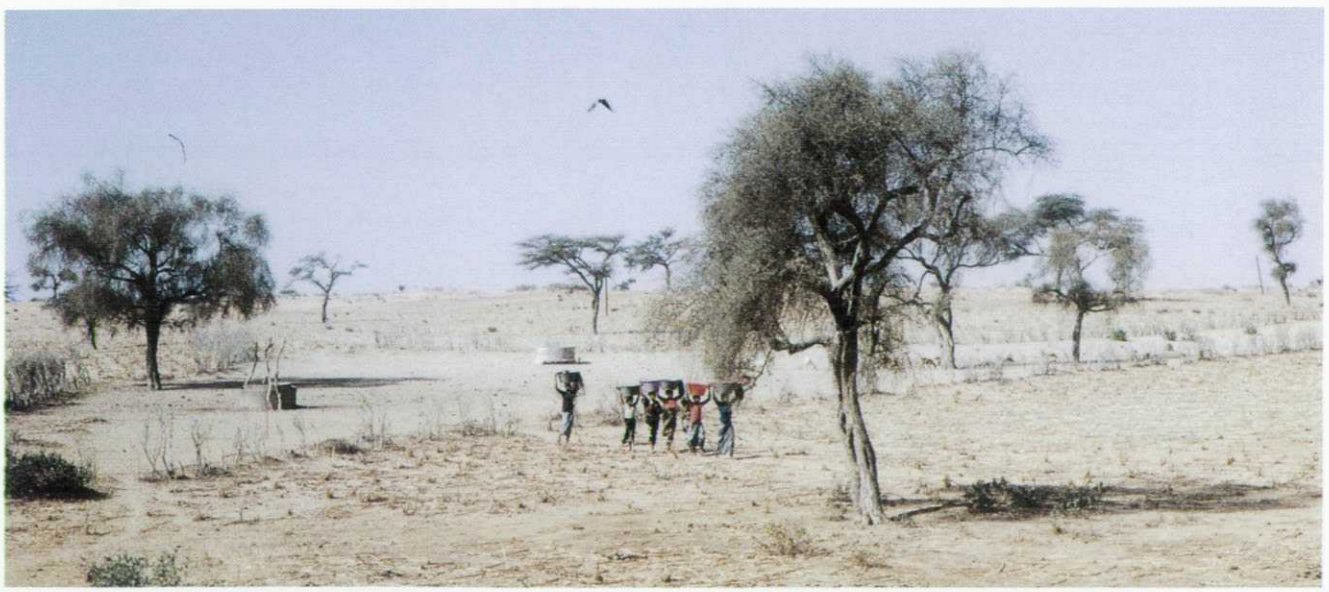
Record of the Sahel drought (1968–86) in Senegal (left) and declining phreatic groundwater levels at Ware Cisse, northern Senegal

The Problem: lower rainfall—falling water tables.

In semi-arid regions of the world groundwater is likely to be the only perennial source of water supply. Some aquifers may only have been recharged by rain falling during wetter climatic periods and groundwater is effectively being mined. Elsewhere present day rainfall may be too low under certain conditions to provide significant replenishment. What therefore is the amount of groundwater that can be safely and sustainably abstracted? Recent research in Senegal has developed a simple yet powerful geochemical technique for estimating both the current recharge and the recharge history. This makes use of the chemical and isotopic information contained in the water of the unsaturated zone.

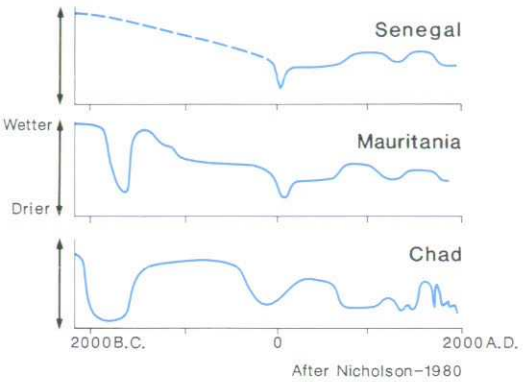


This project has been set against the recent catastrophic Sahel drought which in Senegal resulted in an 18-year period with a 36% fall in rainfall. At the same time there has been a steady decline in water levels, typically 0.1–0.2 metres per year. This has presented serious problems particularly to villagers who rely on water supplies from traditional wells.

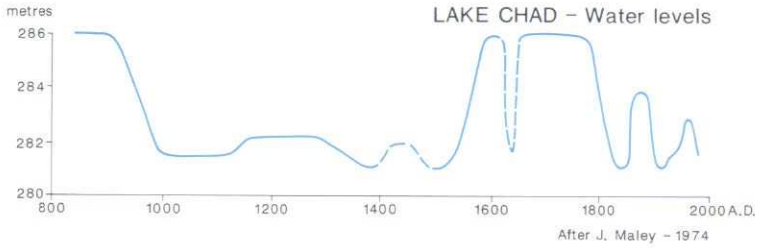


Climate history of West Africa in historic times

It has been possible to construct a history of climate change before rainfall records began by studies of the geological record. Careful study of lake and marine sediments, fauna (diatoms, shells etc) and archaeological records by various scientists has enabled the sequence of wetter and drier episodes of past millennia to be reconstructed. Wetter periods correspond to times of significant groundwater recharge.



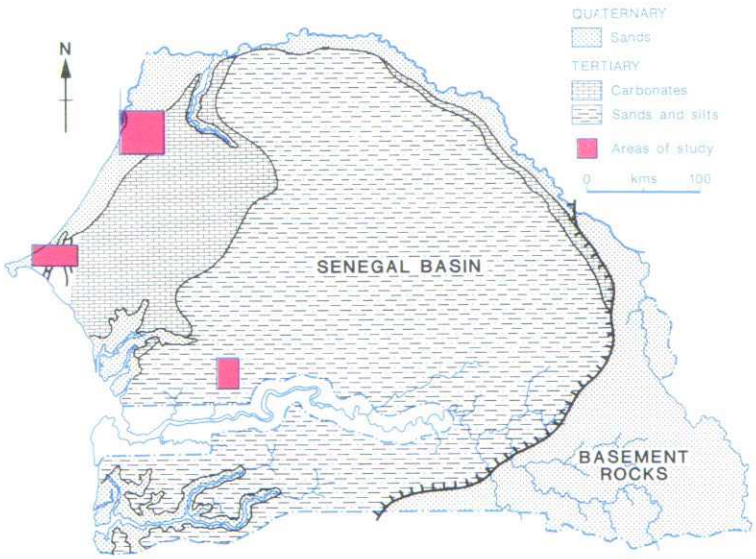
Climatic changes in Senegal during the past four millennia set against the detailed record for Lake Chad, shown in more detail below



Senegal

Senegal has undergone important climatic changes in the past millennia and the excellent record of lake levels of Lake Chad may be used to supplement the relatively incomplete record for West Africa. The significantly wetter climate of the 17th and 18th centuries is confirmed from historical journals, in which mangrove swamps and former lakes are reported in the vicinity of the Senegal River. The geology of Senegal is dominated by a sedimentary basin. Many sandy sediments in the basin as well as overlying dune sands are ideal for sampling in the present investigations.

Sampling the unsaturated zone using hand-auger



Simplified geological map of Senegal with sites of present investigations. Sandy superficial deposits (Quaternary) overlie much of the country

Methods of investigation

Profiles of sand have been obtained by one of two methods 1) using a lightweight hand auger, 2) by sampling dug wells being constructed for water supply by government teams or non-governmental organisations. The auger technique is rapid and relatively cheap and profiles up to 35 m have been obtained, some to the water table. The water in these samples, taken at 25 or 50 centimetre intervals, is extracted by elutriation or centrifugation for chemical analysis, and by distillation for the investigation of stable isotope ratios (oxygen and hydrogen). Moisture contents were also recorded.

The small volumes of water obtained (5–10 millilitres) are sufficient for measurement not only of chloride but for a substantial range of other elements using ICP emission spectrometry, which provide information on geochemical evolution, past environments and recharge history.

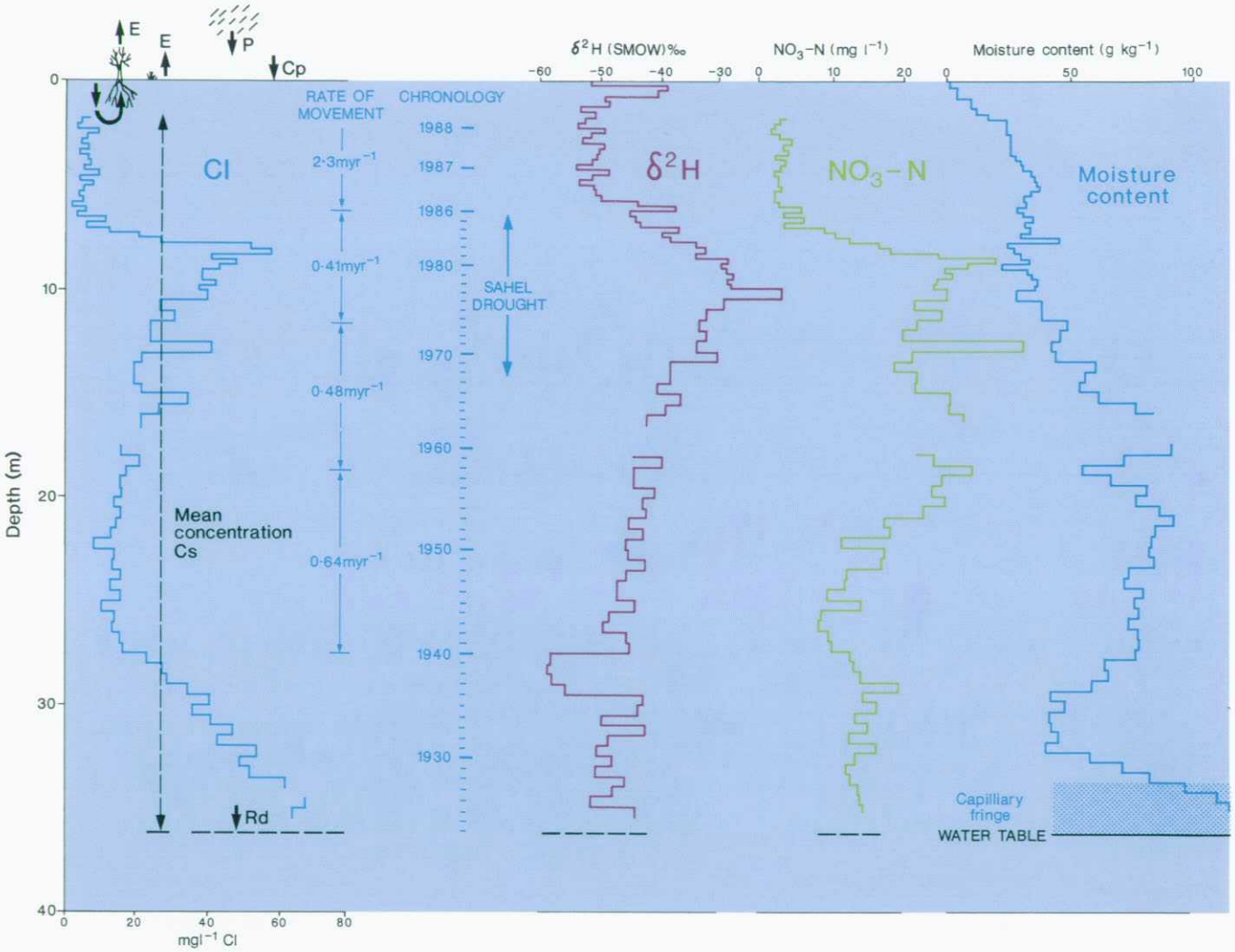
Water samples were also obtained from shallow wells in the vicinity of the research area. These provide a regional assessment of groundwater chemistry concentrations which enable improved estimates of recharge (using chloride) to be made as well as studying quality problems associated with the use of traditional wells.

Geochemical profiles in water in the unsaturated zone

Interpretation of profiles

The chemical information in the pore waters can be interpreted to give 1) recharge estimates, 2) recharge history, 3) water quality and potential pollution problems.

Chemical profiles of water in the unsaturated zone



Estimation of recharge

One of 13 profiles from the Louga area is used to illustrate the technique. This profile reached the water table at 36 m. The surface runoff in this sandy terrain is negligible and the direct recharge **R**d) may be calculated from the equation:

$$\mathbf{R}d = \mathbf{P}\mathbf{C}p/\mathbf{C}s$$

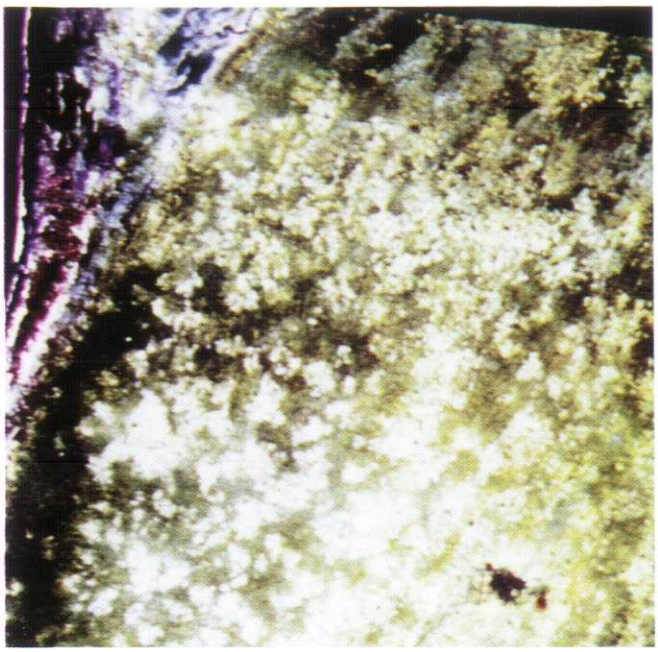
where **P** is the relevant mean annual precipitation, **C**p is the mean chloride in rainfall and **C**s is the mean chloride in the profile. In this example **R**d = 45 mm.

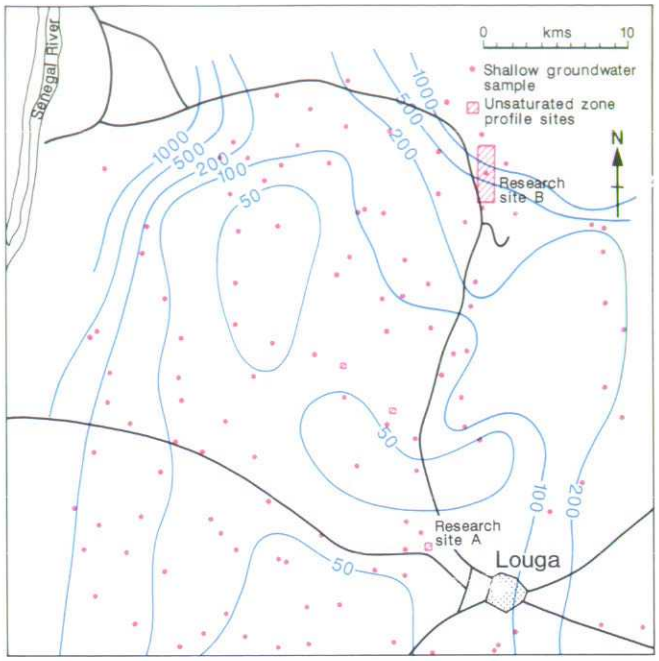
Recharge history

Using the moisture content it is then possible to calculate the rate of downward movement and thence the residence time. The recharge estimate derived above is an average for a 60 year period, i.e. the water now entering the aquifer fell as rain in about 1930. The oscillations of chloride show that the recharge rate has not been constant. The period of Sahel drought can be seen as a zone of high chloride concentrations. This is also emphasized by the less negative values for δ^2H which show that the water from this period is enriched in the heavy isotope, deuterium, as a result of greater evaporation during the drought. Other profiles with higher chloride concentrations and/or from greater depths may enable the recharge history over periods up to two thousand years (or more) to be determined.

Water quality

The chemical analyses provide further information on imputs to the aquifer (both natural and man-made). Of interest here are the high concentrations of nitrate. These values often in excess of 10 milligrams/litre NO_3-N, are unrelated to pollution but arise from natural fixation by plants or micro-organisms, with subsequent concentration by evaporation.





LANDSET 4 Photograph (9.2.86) of north-west Senegal and region sampled in the water quality and recharge study. Cultivated areas stand out white around villages in contrast with natural vegetation (green). On the map contours of chloride concentration (blue) in waters from shallow wells are used to compare with profile data and to estimate recharge at a regional scale. Research sites show in red

Recharge on a regional scale

The techniques developed here enable long-term recharge estimates to be made at one point on the map, Measuring recharge for an area is one of the most difficult problems in hydrogeology—not least as a result of spatial variability due to changes in vegetation, soil type and texture, slope etc. The geochemical techniques nevertheless enable a number of points within a region to be assessed and integrated. Within the one square kilometre control area A west of Louga, 7 profiles gave a mean **C**s of 82 milligrams per litre of chloride, corresponding to a long-term recharge of 13 mm per year. The variability as measured by the standard deviation (±42 milligrams per litre) is consistent with the present and recent vegetation contrasts within the sand dune areas.

Fortunately the regional recharge rates can be cross-checked using the chloride concentrations in water samples from below the water table, taken from traditional wells. The chloride map (above) suggests relatively high recharge in the central region, but much lower recharge in the north and east where changes to a less permeable lithology occur. Since chloride is only derived from atmospheric sources, the regional map can be used to produce areal estimates of recharge. For area A the recharge to groundwater is estimated at 13 000 cubic metres per square kilometre but in area B is considered to 1 100 cubic metres per square kilometre of more brackish water. Overall this area has very favourable recharge characteristics. Natural recharge far exceeds domestic water used by traditional village methods (some 300 million litres per square kilometre per year), even during a drought when recharge may be halved. The falling water tables in Senegal are most likely to be due to the short-term low rate of recharge seen by the aquifer, exacerbated by natural leakage or abstraction from deeper aquifers; a more precise water balance is still required.

Reference

EDMUNDS, W M, DARLING, W G and KINNIBURGH, D G. 1988. Solute profile techniques for recharge estimation in semi-arid and arid terrain. pp 139–157 in: I Simmers (ed.). *Estimation of Natural Groundwater Recharge.* D Reidel.

Further enquiries:

Hydrogeology Research Group
British Geological Survey
Maclean Building
Crowmarsh Gifford
Wallingford, Oxon OX10 8BB
Tel: 0491-38800 Telex: 849365

or

Département de Geologie de la Faculté des Sciences de l'Université Cheikh Anta Diop. Dakar. Senegal.

This study has been carried out in collaberation with the Universite de Paris-Sud.

Funding for British Geological Survey (BGS) research into recharge estimation is provided by the Overseas Development Administration (ODA). BGS is a component body of the Natural Environment Research Council (NERC)

Département de Geologie
de la Faculté des Sciences
de l'Université Chiekh
Anta Diop de Dakar
and
British Geological Survey

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 31

TITLE: TRAINING, GEOLOGICAL MAPPING AND MINERAL RECONNAISSANCE, NORTHERN SIERRA LEONE

LOCATIONS: Sierra Leone

PROJECT SIZE: 3

DATES: 1969-74

COLLABORATING ORGANISATIONS

Geological Survey of Sierra Leone

PROJECT OBJECTIVES

Overhaul and reorganisation of the Mineralogical Laboratory in the Geological Survey of Sierra Leone. Installation of equipment.

A Reconnaissance survey of northern Sierra Leone (above 9°N) to produce geological maps of the region and identify mineral potential. The area covers some 25,000km^2.

PROJECT RESULTS

About 25,000 km^2 of northern Sierra Leone (above 9°N) was covered by reconnaissance geological mapping, geophysics, geochemical sampling and water resources studies.

Detailed geological maps of the area were prepared together with a comprehensive memoir which describes the stratigraphy, structure, petrography and orogenesis of the area.

The economic potential identified includes bauxite deposits in the Kambia area and mineralised greenstone belts and quartzites in the basement gneisses in the Kamakwie area which are a potential source of gold and base metals. The regional geochemical survey involved the collection of over 3100 stream sediment samples and 600 heavy mineral concentrates. The studies identified anomalies rich in Ni, Co, Cu and Au.

OUTPUT (Reports, Papers, & etc)

Final Report 1974, in two parts.

Part 1 Geology and 1:250 000 (2 sheets) maps
Part 2 Mineral Resources and Geochemistry. Locality map and 8 element maps 1:250 000

Macfarlane, A, Crow, M J, Arthurs, J W, Wilkinson, A F and Aucott, J W. 1981. The geology and mineral resources of northern Sierra Leone. IGS Overseas Memoir No 7, 103 p, 6 Maps.

WORKSHOPS AND PRESENTATIONS

Short courses were given in Mineral Separation and Heavy Minerals Identification to counterpart staff.

Lectures given at Fourah Bay College in Clay Mineralogy.

PROJECT STAFF

A Macfarlane (Project Manager)
Dr I R Basham
J W Arthurs
Dr A R Date
Dr M J Crow
Dr A F Wilkinson
Dr J W Aucott

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 32

TITLE: NYEFR RUGAIYIQ MARBLE DEPOSIT

LOCATIONS: Sudan

PROJECT SIZE: 5

DATES: 1968

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Geological assessment of the Nyefr Rugaiyiq Marble deposit as a suitable material for portland cement manufacture.

PROJECT RESULTS

The complex geological structure of the marble deposits and their relationship to unsuitable dolomitic deposits was established by geological mapping.

Reserves of about 1.8M tons of low-Mg marble were identified together with a further 250,000 of inferred ore and recommendations for the further exploration necessary were made.

OUTPUT (Reports, Papers, & etc)

IGS 1969 Annual Report for 1968, Brief details p.47-48.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr K Bloomfield

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 33

TITLE: GEOPHYSICAL WORK IN SWAZILAND

LOCATIONS: Swaziland

PROJECT SIZE: 4

DATES: 1965-69

COLLABORATING ORGANISATIONS

Geological Survey of Swaziland
United Nations Development Programme (UNDP)

PROJECT OBJECTIVES

Gravity Survey of Swaziland

Assisting the Swaziland Government (then a British colony) by providing counterpart geophysical assistance for a UNDP mineral survey.

PROJECT RESULTS

Over 2.000 gravity stations were established at about 1-mile intervals on all the roads resulting in a fairly uniform national coverage, more detailed measurements were made of the Usushwana complex.

The gravity maps were subsequently produced by the Geological Survey of Swaziland and their interpretation helped with a comprehensive assessment of mineral potential.

Detailed Induced Polarization (IP) studies were also carried out on sulphide mineralization targets identified by airborne electromagnetic surveys.

OUTPUT (Reports, Papers, & etc)

Masson-Smith, D J & Evans R B. 1966. Gravity Survey of Swaziland, 1965 Field Work and reduction of observation. IGS Overseas Division Geophysical Report No.33.

Evans, R B. 1967. Ground Geophysical Surveys in Swaziland, September 1966 - January 1967. IGS Geophysical Division Report No.37 (Confidential).

Evans, R B & Burley, A J. 1969. Variable Frequency Induced Polarization Surveys in Western Swaziland. IGS Geophysical Division Report No. GP/0/41 (Confidential).

Burley, A J & Andrew, E M. 1969. Induced Polarization Surveys in North West Swaziland. IGS Geophysical Division Report No. GP/0/42 (Confidential).

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

R B Evans
Dr D J Masson-Smith
Dr A J Burley
E M Andrew

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 34

TITLE: PHOTOGEOLOGY OF OROGENIC BELTS

LOCATIONS: Tanzania

PROJECT SIZE: 4

DATES: 1967

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Photogeological Mapping of the Mozambique Orogenic Belt through Tanzania (50,000 Square Miles.)

Assessment of the value of combined air photointerpretation and detailed ground studies in elucidating the structural history of a complex orogenic belt.

PROJECT RESULTS

Photogeological Mapping of some 50,000 Square Miles of Tanzania was accomplished and checked using ground traverses.

A Geological Map and Account of the area was published.

The study supplied a clear appreciation of the structure relationships of various segments of the orogenic belt.

OUTPUT (Reports, Papers, & etc)

Kennerley, J B. 1967. Fault Map of Tanzania 1:2,000,000 Mineral Resources Division, Tanzania.

IGS 1969. Annual Report for 1968. Details p.40-41.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr J V Hepworth
J B Kennerley

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 35

TITLE: ECONOMIC VIABILITY ASSESSMENT OF A FLUORITE-GALENA MINING PROJECT

LOCATIONS: Tunisia

PROJECT SIZE: 5

DATES: 1972

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Two IGS Geologists formed part of an ODA-led 4-man mission to Tunisia in order to assess the economic viability of a proposed Flourite-Galena mining project in the Djebilet El Kohol area for which a British Government loan had been requested.

PROJECT RESULTS

The reserve estimates, and the occurrence and composition of the ore were examined and samples collected for analysis in the UK. The proposed benefication procedure was also considered.

The results which remain confidential are contained in the internal IGS reports listed overleaf.

OUTPUT (Reports, Papers, & etc)

Davies, R G & Notholt, A J G. 1972. Preliminary report on the Djebilet El Kohol Fluorspar/Lead Mining Project, Tunisia. IGS Mineral Resources Division Internal Report (Confidential).

Bain, J A & Bland, D. 1972. Brief Laboratory Reports File Ref. GD61.25/1. Mineralogy Unit IGS (Confidential).

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr R G Davies
A J G Notholt
J A Bain
D Bland

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 36

TITLE: PHOTOGEOLOGY AND GEOPHYSICS, UGANDA

LOCATIONS: Uganda

PROJECT SIZE: 4

DATES: 1965-68

COLLABORATING ORGANISATIONS

Geological Survey of Uganda, Entebbe, Uganda

PROJECT OBJECTIVES

Two BGS staff served in Uganda on short-term technical cooperation in 1965-68. The majority of the work involved regional geological investigations of Karamoja District in NE Uganda.

PROJECT RESULTS

Photogeological interpretation of the basement rocks of the Karamoja District led to the producation of a regional phototectonic map which is of use in mineral prospecting.

Geophysical surveys of the basement rocks in the Karamoja District and a Carbonatite Complex at Bukusu were undertaken to help delineate the geological structure and mineral potential.

OUTPUT (Reports, Papers, & etc)

Hepworth, J V. 1965. Phototectonic map of Karamoja. IGS.

Statham, G A P & Evans, R B. 1965. The interpretation of geophysical profiles from Loyoro, Uganda, with recommendations for further work. Report of the Geological Survey of Uganda, No. GAPS/4, RBE/16.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr J V Hepworth
R B Evans

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

PROJECT NO: 37

FORM A3

TITLE: CARBONATITE STUDIES

LOCATIONS: Uganda

PROJECT SIZE: 3

DATES: 1968-70

COLLABORATING ORGANISATIONS

Geological Survey and Mines Department, Entebbe, Uganda (GSMD)

PROJECT OBJECTIVES

Provision of an advisor to head a small team from the Uganda Geological Survey in an assessment of the economic potential of carbonatite complexes in E Uganda.

PROJECT RESULTS

Geochemical and geophysical orientation surveys were carried at 7 complexes at Lolekek, Lokupoil Morauangeberr, Napak, Butitiku and Toror in Karamoja District and at the Sukulu Hills Complex. Some 11 000 Soil samples and 1500 stream sediment samples were collected and analysed geochemically. Results indicate anamolous concentrations of several key elements including Beryllium and Rare Earth Elements.

23,000 m of exploratory drilling for copper in the Bukusu Complex was undertaken, however the results proved disappointing.

A new unexposed carbonatite centre was discovered between the Napak and Kadam mountains.

OUTPUT (Reports, Papers, & etc)

Bloomfield, K. 1969. A Reconnaissance Survey of the Busota Grits, Southern Bugisu District. GSMD Report KB/7.

Bloomfield, K. 1969. A Preliminary examination of the South Karamoja Gravity Anomaly. GSMD Report KB/8.

Bloomfield, K. 1970. Mrima Hill Rare Earth Prospect, Coast Province, Kenya. GSMD Report KB/9.

Bloomfield, K, Reedman, J H and Tether, J G G. 1970. Geochemical exploration of Carbonatite Complexes in Eastern Uganda. GSMD Report KB/10.

Bloomfield, K. 1970. A Geochemical stream sediment survey of the Bugisu Series, Mount Nkokonjeru, Eastern Region. GSMD Report KB/11.

Bloomfield, K. 1970. A Geochemical Soil survey of the Koryet Gravity Anomaly, Pian County Karamoja District. GSMD Report KB/12.

WORKSHOPS AND PRESENTATIONS

Economic Aspects of Uganda Carbonatite Complexes Lecture and Field Excursions at 50th Anniversary of Geological Survey and Mines Department Conference 1969.

PROJECT STAFF

Dr K Bloomfield

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
TC PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 38

TITLE: GROUNDWATER MODELLING

LOCATIONS: Zambia, UK

PROJECT SIZE: 5

DATES: 1977

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Development of a model to simulate the Kakontwe limestone Aquifer near Ndola, Zambia.

The modelling study formed Phase II of a major investigation for water supply for Ndola. Phase I consisted of field investigations and collection of data to form the basis of the digital model and was carried out by Brian Colquohoun and Partners under assignment from ODA, and reported in 4 volumes. Phase III involved an assessment of the potential of the aquifer in the light of the modeling results, and included detailed recommendations for development, the model was also used in Phase III.

PROJECT RESULTS

The model was developed and applied, special features include provision for a) soil moisture variation b) increased permeability and shortage in the karstic zone.

The model was calibrated using data collected in Phase I and used as a contribution to Phase III to predict the effects on the aquifer of various abstraction regimes.

OUTPUT (Reports, Papers, & etc)

Adams, B. 1977. A Digital Groundwater Model of the Kakontwe Aquifer, Ndola, Zambia. IGS Report WD/OS/77/13.

Adams, B & Kitching, R. 1977. The Response of the Kakontwe Aquifer Digital Groundwater Model to Varying Abstraction Regimes. IGS Technical Report WD/OS/77/24.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

B Adams
Dr R Kitching

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 39**

TITLE: ZIMBABWE MINERALS EXPLORATION PROJECT

LOCATIONS: Zimbabwe

PROJECT SIZE: 2

DATES: 1982-86

COLLABORATING ORGANISATIONS

Geological Survey of Zimbabwe (GSZ)
Institute of Mining Research, University of Zimbabwe

PROJECT OBJECTIVES

To undertake integrated geological mapping, geochemical exploration and mineral resource surveys over three priority areas of the country, covering (i) 8,500^2 kilometres in northeast Zimbabwe along the border with Mozambique (Mutoko-Rushinga-Mudzi districts) and (ii and iii) some 4,500^2 kilometres each, around the cities of Harare and Bulawayo.

To train Zimbabwean nationals in modern technqiues of geological mapping, field prospecting methods and resource evaluation through example, on-the-job training, and formal or informal courses.

To re-equip the field geological and chemical laboratory sections of Geological Survey of Zimbabwe and to ensure proper training of nationals in the use of equipment supplied.

Ensure that the resulting information (geological maps, descriptive bulletins and geochemical or mineral resource reports) would be compiled, published and disseminated to the public within a reasonable time scale.

PROJECT RESULTS

Geological mapping of 8,500^2 kilometres in northeast Zimbabwe at 1:25,000 scale led to the production of 11 field maps at 1:50,000 by three experienced BGS geologists, a counterpart geologist and supporting staff. Geochemical field exploration was carried out by national technicians with local support staff and supervised/directed by the BGS economic geologist and project manager. Some 14,000 drainage sediment samples were collected and subsquently analysed for 12 elements in the laboratories of the Institute of Mining Research at the University of Zimbabwe. Computer generated maps summarizing the data and potential mineral anomalies were compiled.

PROJECT RESULTS (Continued)

Revision geological mapping around Harare included remapping six 1:50,000 map sheets. Geochemical exploration was undertaken in areas outside the city and led to the delineation of several anomalous areas. One particularly promising target was investigated in detail by geochemical soil and geophysical surveys. Subsequently a scout drilling programme was proposed and accepted by ODA for funding. Six diamond drill holes were sunk in the closing stages of the project; at least four intersected favourable massive sulphide horizons with potentially interesting values in zinc and copper, gold is evidently present at sub-economic levels. A substantial Bulletin was prepared describing the geology, structure and mineral potential of the Harare region.

Detailed remapping of six 1:50,000 sheets around Bulawayo was undertaken and a definitive 1:100,000 geological map of very high standard was produced. The geological structure and mineral resources of the region include gold. The clear structural controls of gold mineralisation along previously unrecognised zones of high strain has generated considerable renewed interest, within the private sector, in the gold potential of the Bulawayo region.

Training of national staff included joint geological mapping surveys with the one permanent, professionally qualified counterpart available, over the first 7-month field-season, and thereafter his inclusion in all aspects of project work. From late 1985 this Zimbabwean geologist attended a one year MSc course at Leicester University, with the support of British Council Training Award. Up to 8 national technicians also received extensive on-the-job training in all stages of mineral exploration. A GSZ chemist was afforded training and work-experience in the BGS laboratories, London.

OUTPUT (Reports, Papers, & etc)

Baldock, J W. 1984. Siliceous stromatolites in the Iron Mask felsic volcanic sequence of the Harare region. Annals, Zimbabwe Geological Survey (for 1983).

Barton, C M, Carney, J N, Crow, M J & Simango, S. 1985. Geology of the Archaean cratonic margin and the Zambezi-Mozambique orogenic belt in northeastern Zimbabwe (Rushinga, Mudzi and Mutoko districts). Annals of the Zimbabwe Geological Survey, X, 1-39.

Baldock, J W. 1986. The Zimbabwe Geological Project 1982-86. Summary and final report. BGS Technical Report MP/86/34R.

Dunkley, P N. 1987. A Regional drainage geochemical exploration survey of the country between Rushinga and Nyamapanda, north-east Zimbabwe. BGS Report MP/87/16.

Dunkley, P N. 1987. A Regional drainage geochemical exploration survey of the Makaha area north-east Zimbabwe. BGS Report MP/87/17.

Baldock, J W, Evans, R B & Zhou, P. 1987. Geological, geochemical and geophysical exploration at the Selby Prospect, Harare, Zimbabwe: an exploration case history of massive sulphides in Archaean black shales. IMM African Mining Conference Vol. (pp.1-8).

Baldock, J W & Evans J. 1988. Constraints on the age of the Bulawayan Group Greenstone Belt sequence, Harare, Zimbabwe. Journal of African Earth Sciences. Vol.7, No.5/6, p.795-804.

OUTPUT (Reports, Papers, & etc)

Carney, J N, Treloar, P J, Barton, C M, Crow, M J, Evans, J A & Simango, S. 1991. Deep-crustal granulites with migmatitic and mylonitic fabrics from the Zambezi Belt, northeastern Zimbabwe. Journal of Metamorphic Geology, 9, 461-479.

Baldock, J W. In press. The geology of the Harare Greenstone Belt and surrounding granitic terrain. Bulletin of the Geological Survey of Zimbabwe. No.84. 1 map.

Barton, C M, Carney, J N, Crow, M J, Dunkley, P N & Simango, S. In press. The geology of the country around Rushinga and Nyamapanda. Geological Survey of Zimbabwe Bulletin No.92. (with 2 1:100,000 scale maps).

Barton, C M, Carney, J N, Crow, M J, Evans, J A & Simango, S. In press. Geology and structural framework of the Zambezi Belt, Northeastern Zimbabwe.

WORKSHOPS AND PRESENTATIONS

Institute of Mining and Metallurgy African Mining Conference 1987

PROJECT STAFF

Dr J W Baldock (Project Manager)
Dr P Dunkley
Dr M J Crow
Dr J N Carney
Dr C M Barton
Dr M S Garson (ODA contract)
Dr J Ridgway
P Sandon
J Evans
R B Evans
P Turner (Cartographer)
G Wood (Cartographer)

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 40**

TITLE: MIDLANDS GOLDFIELD PROJECT

LOCATIONS: Zimbabwe

PROJECT SIZE: 3

DATES: 1989-On going

COLLABORATING ORGANISATIONS

Zimbabwe Geological Survey

PROJECT OBJECTIVES

To study the structural controls of Archaean Gold mineralization in the Midlands Greenstone Belt with a view to locating further concealed gold deposits.

The Midlands Goldfield is the principal gold providing area in Zimbabwe, Exploration targets will be identified for follow-up by the commerical sector.

PROJECT RESULTS

Landsat (TM) Imagery and Aerial Photography coupled with field observations have enabled the structural framework of the area to be defined and criteria controlling the distribution of gold have been identified.

Follow-up geochemical field testing of soils has been successful in identifying mineralized areas predicted from the structural studies, three areas have significant gold showings.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

Research Council of Zimbabwe Symposium 1990

Two two-week training workshops for emergent small-scale miners were held in Bulawayo and Chegutu respectively. These courses, which are organised in collaboration with the Small-Scale Miners Association of Zimbabwe and the Intermediate Technology Development Group, are designed to give intensive practical training in basic geology, gold prospection, surveying, sampling, orebody evaluation, business and financial planning as well as covering mining law, mine engineering and beneficiation methods. Each course catered for up to 25 English-speaking participants for which basic items of surveying and mineral separation equipment were provided. These course in part disseminated results of ODA R&D project Archaean Goldfields.

PROJECT STAFF

P E J Pitfield
Dr S D G Campbell

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 41

TITLE: ASCENSION ISLAND DESK STUDY

LOCATIONS: Ascension Island (UK)

PROJECT SIZE: 5

DATES: 1989

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

To compile a brief desk study on the geology and mineral potential of Ascension Island for the Foreign and Commonwealth Office.

PROJECT RESULTS

A short brief on Ascension Island has been prepared and circulated, it contains details of the geology and mineral potential of Ascension Island (guano phosphate and aggregates) and the adjacent seafloor (possible managanese nodules and metalliferous deposits).

Onshore the potential is very limited; although a seabed survey for metalliferous deposits around the island might be considered.

OUTPUT (Reports, Papers, & etc)

Walshaw, R D. 1989. The economic mineral potential of Ascension Island and the surrounding seafloor. BGS Technical Report WC/89/31R.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr R D Walshaw

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 42

TITLE: GIBRALTAR GROUNDWATER INVESTIGATION

LOCATIONS: Gibraltar

PROJECT SIZE: 4

DATES: 1979-85

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

An assessment of the groundwater resources of the Jurassic Limestone aquifer of Gibraltar involving drilling of exploratory wells.

PROJECT RESULTS

A drilling programme was implemented to investigate the resources of a shallow lens of freshwater overlying seawater within the Karstic limestones which comprise the Rock of Gibraltar.

Drill holes were sited along faults and karstic zones where high permeabilities are expected. Recharge has been assessed to help develop guidelines for safe future extraction rates.

OUTPUT (Reports, Papers, & etc)

Murray, K H & Wright, E P. 1980. Interim Report on the Gibraltar Groundwater Investigation. Report No. WD/OS.80/14.

Wright, E P. 1981. Gibraltar Groundwater Supply: Groundwater Studies - Review and Progress Report. Report No. WD/OS/81/23.

Shedlock, S L. 1982. Pump Testing of the North Face Borehole and Data Logging. Report No. WD/OS/82/10.

Wright, E P & Shedlock, S L. 1983. Gibraltar: Groundwater Resource Study Progress Report - April 1983. Summary Review 1982 - 1983. Report No. WD/OS/83/4.

Shedlock, S L & Wright E P. 1985. Drilling Programme in the Isthmus of Gibraltar (Interim Report). Report No. WD/OS/85/12.

Shedlock, S L. 1985. Deep drilling programme in the Isthmus of Gibraltar, September 1985. Report No. WD/OS/85/21.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr E P Wright
K H Murray
S L Shedlock
D Oliver

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 43

TITLE: POZZOLAN AND MINERALS STUDY

LOCATIONS: Mauritius

PROJECT SIZE: 5

DATES: 1967

COLLABORATING ORGANISATIONS

Building Research Station, Garston, Hertfordshire

PROJECT OBJECTIVES

To investigate the availability of pozzolanic materials on Mauritius, the work was extended to include a survey of raw materials for cement and a geochemical reconnaissance by obtaining panned concentrates from rivers aimed at detecting possible diamond occurrences.

PROJECT RESULTS

The main raw materials readily available in Mauritius for the manufacture of pozzolana and Portland cements are unconsolidated and consolidated coral beach sands, raised coral reefs, trachyte and basalt. Total estimated reserves of consolidated coral sand and raised coral reef material are placed at 1 million metric tons, reserves of unconsolidated coral sand at 14 million metric tons, and of trachyte at 13 million metric tons, while basalt is present in unlimited amounts. Imported gypsum will be required to regulate the setting of the final cement product and imported fuel oil for the kiln burners. The most suitable site for a cement plant is in the Belle Mare area.

Two samples of clay proved promising brick-making raw material and a reconnaissance survey showed estimated reserves of about 15 million metric tons of ordinary brick-making material in the La Nicolière area and about 5 million metric tons of refractory clay in the Mare au Vacoas area, both calculated on a wet basis.

The heavy mineral concentrates obtained by panning about forty major rivers showed no significant concentration of economic minerals and furthermore contained none of the diamond indicator minerals.

A radiometric survey of natural gamma activity was carried out over a traverse distance of approximately 300 miles and indicated that no economic concentrations of uranium or thorium were present.

OUTPUT (Reports, Papers, & etc)

Wright, P C. 1967. Reports on the raw materials available for cement and brick manufacture in Mauritius, together with the results of mineral reconnaissance and radiometric surveys 22 May - 18 July 1967. IGS Mineral Resources Division Report No.76.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr P C Wright

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY **FORM A3**
PROJECT COMPLETION FORM **PROJECT NO: 44**

TITLE: GROUNDWATER INVESTIGATIONS, ST HELENA

LOCATIONS: St Helena

PROJECT SIZE: 5

DATES: 1987

COLLABORATING ORGANISATIONS

Water Authority, St Helena

PROJECT OBJECTIVES

Advisory visits to implement and monitor progress of ODA-funded drilling programme for groundwater resources.

Design of extraction plan and technology needed. Recommendations for safe extraction rates and aquifer management.

PROJECT RESULTS

Recommendations made include:

Continued drilling for groundwater resources in the west of the island, this can be achieved within the ODA-Budget.

Continued investigation of springs should continue to develop a better understanding of the groundwater system.

Routine monitoring of groundwater quality needs to be undertaken, the necessary equipment was identified.

A small diameter windpump should be installed to test their feasibility on the island for pumping water.

OUTPUT (Reports, Papers, & etc)

Lawrence, A R. 1983. Groundwater Resources of St Helena. BGS Technical Report WD/OS/83/12.

Lawrence, A R and George, C. 1987. A review of the Groundwater Investigation Programme on St Helena. BGS Technical Report WD/OS/87/13.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

A R Lawrence
C George

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 45

TITLE: STUDY OF ROCKFALLS IN JAMES VALLEY

LOCATIONS: St Helena

PROJECT SIZE: 5

DATES: 1975

COLLABORATING ORGANISATIONS

Public Works Department, St. Helena

PROJECT OBJECTIVES

To assess the stability of the sides of James Valley, St. Helena; to determine the reasons for rockfalls occurring; to recommend cost effective remedial measures.

PROJECT RESULTS

The valley sides were zoned in terms of their susceptibility to rockfall hazard.

Causes of instability were identified and relate to geology, stripping of vegetation and rainfall.

Alternative remedial measures were proposed that could be implemented locally at reasonable cost (there was, and is, no airport so anything from outside has to be shipped in at great inconvenience).

OUTPUT (Reports, Papers, & etc)

Culshaw, M G. 1975. Report on a reconnaissance survey to assess the causes and extent of rockfalls in James Valley, St Helena and to recommend possible courses for remedial action. IGS Engineering Geology Unit Report 75/14, 2 volumes.

Culshaw, M G. 1975. The rockfalls of James Valley, St. Helena. A preliminary report giving a summary of recommendations. IGS Engineering Geology Unit Report 75/10.

Culshaw, M G & Bell, F G. 1992. The rockfalls of James Valley, St. Helena. In: Proceedings of the 6th International Symposium on Landslides, Christchurch, New Zealand, Feb 1992. In Press.

WORKSHOPS AND PRESENTATIONS

6th International Symposium on Landslides, Christchurch, New Zealand, 1992.

PROJECT STAFF

M G Culshaw

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 46

TITLE: SEYCHELLES GROUNDWATER STUDY

LOCATIONS: Seychelles

PROJECT SIZE: 5

DATES: 1974

COLLABORATING ORGANISATIONS

Public Works Department, Mahé, Seychelles

PROJECT OBJECTIVES

A request for an assessment of the groundwater potential of the principal Seychelle Islands was made by the Public Works Department, Mahé in May 1974.

An IGS hydrogeologist visited the Seychelles to assess the potential and made recommendations for development trials.

PROJECT RESULTS

Potable groundwater resources capable of development were identified in the plateau sands on the granitic islands and also as lenses on the sandy cays, thin lenses are also likely to exist on the raised-reef islands.

Most present water supply is met from impounded storage of streamflow, however on La Digue where dry weather shortages are most common groundwater abstraction could be developed.

Trial wells need to be drilled to establish aquifer thickness and water quality. Pumping tests are necessary to examine yields and resources.

Recommendations were made for a more detailed follow-up survey of selected areas.

OUTPUT (Reports, Papers, & etc)

Buckley, D K. 1974. Assessment of the Groundwater Resources of Seychelles with recommendations for their development. IGS Technical Report WD/ST/74/24.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

D K Buckley

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 47

TITLE: GRAVITY SURVEY, SEYCHELLES

LOCATIONS: Seychelles

PROJECT SIZE: 5

DATES: 1973

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

In 1973 The Seychelles were visited by a BGS geophysicist to establish gravity base stations using an internationally calibrated La Coste and Romberg gravity meter.

In 1988 the information was made publically available due to hydrocarbon exploration in the Seychelles.

PROJECT RESULTS

A gravity base station and observation of 26 regional gravity stations was accomplished in 1973 on the two main islands of Mahé and Praslin.

The data was published in 1988 using funds from an ODA/BGS R&D programme (publication overleaf).

OUTPUT (Reports, Papers, & etc)

Evans, R B & Gibberd, A J. 1988. Gravity measurements on Seychelles. BGS Technical Report WK/88/20.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

R B Evans
A J Gibberd

FUNDING ODA Technical Cooperation

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 48

TITLE: OSAS WORK IN BOTSWANA

LOCATIONS: Botswana

PROJECT SIZE: 1

DATES: 1968-On going (as Key Cadre)

COLLABORATING ORGANISATIONS

Geological Survey of Botswana (host)
Leeds University, UK
Canadian International Development Authority (CIDA)

PROJECT OBJECTIVES

BGS Geologists have been seconded to the Geological Survey of Botswana under the OSAS arrangements with a continuous but declining presence since 1968, two staff presently serve in Key-Cadre posts. Prior to 1968 Britain had provided non-BGS geologists also on OSAS terms.

A total input of about 110 staff years of BGS effort has been deployed, with a maximum presence of 7 geologists. Staff are seconded with the objective of strengthening the administrative and scientific capacity of the host organisation and advising the Botswana Government on geology-related matters.

PROJECT RESULTS

Regional geological surveying using air photography and field checking was carried out in areas of Precambrian shield terrain, the Limpopo Mobile Belt, Proterozoic Fold Belts and Karoo Supergroup. Principal maps and reports produced are listed overleaf.

Minerals studies included an Industrial Minerals inventory of Botswana and investigation of copper-nickel, gold, diamond, iron-ore, semi precious stones and coal deposits. Private sector mineral exploration was monitored and advice was given on mining law and granting licences.

Regional geophysical seismic, magnetic and gravity studies were implemented to assist in identifying mineral potential and elucidating deep structure.

Hydrogeological work involved well siting and drilling supervision, emergency drought relief operations and regional resource appraisals A geotechnical survey was conducted of the Serowe Township.

BGS staff filled several senior posts included those of Director and Deputy Director within the Geological Survey of Botswana advising on new mining legislation, editing and publishing reports and maps, and representing Botswana on international committees and at conferences. Several Botswanan geologists received British Council scholarships for UK study and others received 'in service' training in field geology.

OUTPUT (Reports, Papers, & etc)

Much of the output from OSAS work in Botswana is published in the Bulletins, Reports and Maps of the Geological Survey of Botswana. Other important references include:

Bennett, J D. 1970. Craton-mobile belt relations with particular reference to the Mosetse-Matsitama area, north-eastern Botswana. Geological Magazine, Vol.107, (2), 113-123.

Bennett, J D. 1971. Annotated bibliography and index of the geology of Botswana, 1967-70. Report Geological Survey Botswana.

Bennett, J D. 1971. The gneisses and granitoid rocks of eastern Botswana. (Paper prepared for "Granite 71" Symposium, Salisbury, Rhodesia, 1977). Geological Society South Africa Special Publication No.3.

Key, R M. 1974. Some aspects of the geochemistry of the metavolcanic rocks of the Tati schist belt, NE Botswana. 18th ann. Report research Institute African Geology, University Leeds, 44-49.

Litherland, M & Key, R M. 1974. A preliminary interpretation of the field mapping of the Eastern Geotraverse of Botswana. 18th ann. Report research Institute African Geology, University Leeds, 39-43.

Key, R M & Hutton, S M. 1976. The tectonic generation of the Limpopo Mobile Belt and a definition of its western extremity. Precambrian Research, 3, 79-90.

Key, R M, Litherland, M & Hepworth, J V. 1976. The evolution of the Archaean crust of northeast Botswana. Precambrian Research, 3, 375-413.

Key, R M. 1977. The geochronology of Botswana. Transactions Geological Society South Africa 8D, 31-42.

Ermanovics, I F, Key, R M & Jones, M T. 1977. The Palapye Group, central eastern Botswana. Transactions Geological Society South Africa, 81, 61-73.

Key, R M. 1979. Statiform manganese mineralisation in the Palapye Group, Central Eastern Botswana. Transactions Institution Mining Metallurgy, 88, B139-144.

Key, R M. 1979. Primary Manganese mineralisation in the Palapye Group, Central Eastern Botswana in Proceedings of the 5th IAGOD Symposium, Salt Lake City, 1978.

Key, R M & Rundle, C C. 1981. The regional significance of new isotopic ages from Precambrian windows through the 'Kalahari Beds' in N.W. Botswana. Transactions Geological Society South Africa, 84, 51-66.

Key, R M. 1982. 'Cold Spot' tectonics during the late Archaeon of Southern Africa. Revista Brasiliera de Geosciencias, 12, 183-186.

Key, R M & Wright, E P. 1982. The genesis of the Gaborone rapakivi granite complex in southern Africa. Journal Geological Society London, 139, 109-126.

OUTPUT (Reports, Papers, & etc)

Barton, J M & Key, R M. 1983. Rb-Sr ages and geological setting of certain rock units from the Central Zone of the Limpopo Mobile Belt, near Zanzibar, eastern Botswana. Special Publication Geological Society South Africa, 8, 19-25.

Key, R M, Ermanovics, I F & Skinner, A C. 1983. The evolution of the southern margin of the Limpopo Mobile Belt in Botswana. Special Publication Geological Society South Africa, 8, 169-174.

Aldiss, D T, Benson, J M & Rundle, C C. 1984. Early Jurassic pillow lavas and palynomorphs in the Karoo of eastern Botswana. Nature, 310, 302-304.

Key, R M. 1986. Discussion of "The Chronological significance of the Pre-Transvaal Sequence dolerite dyke swarm in southern-eastern Botswana" by D T Aldiss. Transactions Geological Society South Africa, 89, 419-420.

Key, R. M. 1986. Sedimentation along the eastern margin of the Bushveld Basin S.E. Botswana. In 'extended abstracts of Geocongress, 1986' Geological Society.

Aldiss, D T. 1986. The chronological significance of the pre-Transvaal Sequence dolerite dyke swarm in southeastern Botswana. Transactions Geological Society South Africa, 89 (3), 325-334.

Aldiss, D T. 1991. The Motloutse Complex and the Zimbabwe Craton/Limpopo Belt transition in Botswana. Precambrian Research, 50, 89-109.

Aldiss, D T & Carney, J N. 1992. The regional significance of the Proterozoic Okwa Inlier, western Botswana. Precambrian Research, 56.

WORKSHOPS AND PRESENTATIONS

Presentations at:

"Granite 71" Symposium, Salisbury Rhodesia 1977
Limpopo Mobile Belt Seminar, Lobatse, Botswana 1977
Workshop - Photogeology, Lobatse, Botswana 1979
5th IAGOD Symposium, Salt Lake City 1978

PROJECT STAFF

Dr C R Jones (Awarded OBE for his work as Director of the Geological Survey of Botswana)

Dr J D Bennett	R A Smith
Dr R N Crockett	C D G Black
Dr M Litherland	I N Gale
Dr J V Hepworth	A C Skinner
Dr D Gould	R J Peart
Dr J W Baldock	Dr C Mortimer
Dr R D Walshaw	I T Williamson
Dr R M Key	D P Piper
Dr G C Clark	R Hargreaves
J F T Houston	Dr D T Aldiss
Dr J N Carney	Dr E P Wright

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 49

TITLE: OSAS WORK IN KENYA

LOCATIONS: Kenya

PROJECT SIZE: 4

DATES: 1968-70 and 1984

COLLABORATING ORGANISATIONS

Mines and Geological Department, Nairobi, Kenya (host)

PROJECT OBJECTIVES

A BGS Geologist was seconded to serve with the Mines and Geological Department from 1968-70, ammounting to a total input of 2 years staff time.

The objective of the secondment was to strengthen the capacity of the host organisation especially in the field of mineral exploration.

PROJECT RESULTS

The economic mineralized breccia zones of the Kinagoni Lead-Silver deposit were outlined, the reserves beneath a thick overburden were calculated from 4000 m of drilling and mining was subsequently undertaken (A short ODA-funded consultancy was also undertaken in 1984 to estimate further reserves for the mine).

A bentonite deposit was evaluated for use in drilling mud.

A reconnaissance structural survey of the Taita Hills (650 km^2) was undertaken to provide the background for mineral exploration.

OUTPUT (Reports, Papers, & etc)

Clarke, M. C. G. 1970. The Kinangoni Hill Lead/Silver Deposit, Coast Province, Kenya. Internal Circular of Mines and Geological Department of Kenya No 6.

Clarke, M. C. G. 1984. 1984 Estimate of Ore Reserves at Kinangoni Lead Mine (Kenya). BGS Overseas Directorate Report 85/2 (Restricted).

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr M. C. G. Clarke

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 50

TITLE: OSAS WORK IN MALAWI

LOCATIONS: Malawi

PROJECT SIZE: 1

DATES: 1965-87

COLLABORATING ORGANISATIONS

Geological Survey Department, Zomba, Malawi (host)
United Nations Development Programme (UNDP)
University of Malawi

PROJECT OBJECTIVES

BGS geologists were seconded to serve with the Geological Survey Department of Malawi under OSAS arrangements on a continuous basis from 1965 until 1987 when the last post was localized.

A total input of 60 staff years was deployed with the objective of strengthening the administrative and scientific capacity of the host organisation and advising the Malawi Government on geology-related matters.

PROJECT RESULTS

Regional geological surveying was undertaken in the Malawi Rift and the basement terrain of Central Malawi, local staff received 'on the job' training during this work. Some of the key reports and maps produced are listed overleaf.

Exploration was undertaken for economic minerals deposits of copper, chromium, nickel, lead, gold, coal, glass sand, vermiculite, marble, kaolin and fertilizer and cement raw materials.

Water supply studies were mounted for urban needs and agricultural projects, wells were sited and irrigation canals routed.

A geotechnical study was undertaken for the construction of the International Airport at Lilongwe.

Geophysical surveys were conducted to help identify mineral potential and to elucidate the structure beneath Lake Malawi.

For many years BGS geologists occupied senior positions, including that of Director, with the host organisation. New mining legislation was promulgated and Malawi was represented at international conferences and on committees.

OUTPUT (Reports, Papers, & etc)

1965 Photogeological compilation map 1:100 000 of 1300 Miles^2 Karonga-Chisenga area.

Clark, D, Stephens, E A and Coryndon, S C. 1966. Pleistocene fossiliferous Lake Beds of the Malawi (Nyasa) Rift American Anthropologist, Vol 68/2.

Carter, G S and Bennett, J D. 1973. The geology and mineral resources of Malawi (with 1:100 000 Geological Map) Bulletin of the Geological Survey of Malawi No 6.

Carter, G S, Haslam, H W & Smith, S H. 1973. Regional geochemical reconnaissance of Malawi. Bulletin of the Geological Survey of Malawi, No.43, 45pp.

Haslam, H W. 1975. A geochemical investigation of the Chimwadzulu Hill ultrabasic body. Records of the Geological Survey of Malawi, 8, 37-47.

Haslam, H W, Harding, R R & Tresham, A E. 1976. Chromite-chlorite intergrowths in peridotite at Chimwadzulu Hill, Malawi. Mineralogical Magazine, 40, 695-701.

Haslam, H W. 1977. Kaolinite derived from weathering of anorthosite in Malawi. Transaction of the Institution of Mining and Metallurgy (Section B, Applied earth sciences), 86, B47-49.

Brewer, M S, Haslam, H W, Darbyshire, D P F & Davis, A E. 1979. The petrology and geochronology of hypersthene granites in the Mchinji area, Malawi. Report of the Institute of Geological Sciences No.79/1, 18pp.

Haslam, H W, Brewer, M S, Davis, A E & Darbyshire, D P F. 1980. Anatexis and high-grade metamorphism in the Champira Dome, Malawi: petrological and Rb-Sr studies. Mineralogical Magazine, 43, 701-714.

Haslam, H W. 1980. Grandidierite from a metamorphic aureole near Mchinji, Malawi. Mineralogical Magazine, 43, 822-823.

Haslam, H W, Brewer, M S, Darbyshire, D P F & Davis, A E. 1983. Irumide and post-Mozambiquian plutonism in Malawi. Geological Magazine, 120, 21-35.

Haslam, H W. 1983. An isotropic alteration product of cordierite. Mineralogical Magazine, 47, 238-240.

Haslam, H W. 1989. Charnockites at Mchinji, Malawi: the nature and origin of igneous charnockites. Journal of African Earth Sciences, 8, 11-18.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr R L Johnson
T J Charsley
J R P Bennett
Dr J D Bennett
Dr J H Bean OBE
Dr H W Haslam
Dr P N Mosley
Dr M J Crow
D P Piper

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 51

TITLE: OSAS WORK IN SWAZILAND

LOCATIONS: Swaziland

PROJECT SIZE: 1

DATES: 1970-81

COLLABORATING ORGANISATIONS

Geological Survey and Mines Department, Mbabane, Swaziland (host)

PROJECT OBJECTIVES

BGS geologists were seconded to serve with the Geological Survey and Mines Department of Swaziland between 1970 and 1981, comprising a total deployment of about 25 years of staff time.

The work undertaken was mainly related with the development of energy, mineral and water resources.

PROJECT RESULTS

Detailed geological surveying, geophysics and drilling was undertaken to assess coal resources in the Karoo sediments as a source of energy for a thermal power station.

Other mineral resources evaluated included Ironstone, Gold, Clays, Kaolin, Talc and Tin, several of the deposits were developed commercially.

A new updated national geological map of Swaziland was compiled and published at 1:250 000 scale with an accompanying explanatory text.

An analysis of the groundwater potential of Swaziland was made. The possible geothermal potential of the thermal springs was evaluated. The water well drilling programme was nationalised and integrated with detailed geophysical surveys to assist borehole site selection.

OUTPUT (Reports, Papers, & etc)

Robins, N S & Bath A H. 1979. Assessment of the thermal springs of Swaziland. IGS Report No. WD/OS/79/16.

Robins, N S. 1980. A review of groundwater resources and well yields in Swaziland. Transactions of the Geological Society of South Africa. 83:1, 1-4.

Wilson, A C. 1982. 1:250 000 Geological Map of Swaziland (with accompanying notes) Government of Swaziland.

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

M C McKeown
Dr M C G Clarke
Dr A C Wilson
N S Robins

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 52

TITLE: OSAS WORK IN UGANDA

LOCATIONS: Uganda

PROJECT SIZE: 3

DATES: 1965-70

COLLABORATING ORGANISATIONS

Geological Survey of Uganda, Entebbe, Uganda (host)
Royal School of Mines, Imperial College, University of London, UK

PROJECT OBJECTIVES

BGS geologists were seconded to serve with the Geological Survey of Uganda between 1965-70 amounting to a total deployment of about 5 years of staff time.

The work undertaken was principally involved with studies to help identify Uganda's mineral potential.

PROJECT RESULTS

Exploration for beryl pegmatites was carried out and included an evaluation of geochemical methods for their detection. Evaluation of various tin, tungsten and rare earth deposits in SW Uganda was also carried out.

Assistance was given in organizing the 50th Anniversary Conference of the Geological Survey of Uganda at which several presentations were made.

A geochemical atlas covering 26.000 km^2 of Uganda was compiled utilizing data from 17.000 samples recovered from water supply boreholes.

OUTPUT (Reports, Papers, & etc)

Reedman, A J. 1969. The Prospection and Evaluation of Beryl-bearing pegmatites in Uganda. Proceedings 50th Anniversary Conference Geological Survey and Mines Department Uganda.

Reedman, A J & Gould, D. 1970. Low sample-density stream sediment surveys in geochemical prospecting: an example from northeast Uganda. Transactions of the Institute of Mining & Metallurgy Section B 79, 246-248.

Reedman, A J & Lowenstein, P L. 1971. Economic Geology of the beryl-bearing pegmatites of southwest Uganda. Transaction of the Institute of Mining & Metallurgy Section B 80, 4-18.

Reedman, A J. 1973. Geochemical Atlas of Uganda - folio 10p and 32 plates, Geological Survey of Uganda, Entebbe, Uganda.

Nixon, P H, Reedman, A J & Burns, L K. 1973. Sapphirine-bearing granulites from Labwor, Uganda. Mineralogical Magazine, 39, 420-428.

Reedman, A J. 1973. Partly Remobilised Syngenetic Tungsten Deposit at Nyamaliho Mine. Overseas Geology & Mineral Resources, 41, 101-106.

WORKSHOPS AND PRESENTATIONS

Presentation on Beryl Pegmatites and Field Excursions at 50th Anniversary Conference of the Geological Survey of Uganda. 1969

PROJECT STAFF

Dr A J Reedman
R S Seal

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 53

TITLE: OSAS WORK IN ZAMBIA

LOCATIONS: Zambia

PROJECT SIZE: 1

DATES: 1970-79

COLLABORATING ORGANISATIONS

Geological Survey Department Zambia (host)

PROJECT OBJECTIVES

BGS geologists were seconded to serve with the Geological Survey Department of Zambia under OSAS arrangements between 1970-79. Britain has also provided contract geologists also on OSAS terms. A total input of 35 years of BGS staff time was deployed in order to strengthen the scientific capability of the host organisation and advise the Zambian Government on geoscience related matters.

PROJECT RESULTS

Regional geological surveying and geochemical studies were performed widely including important studies on the basement rocks in the NW of Zambia and the Karoo Basalts of Western Zambia. The geological reports and maps produced are listed overleaf.

Industrial mineral deposits were assessed including Dimension Stone, Limestone, and Quartz and the coal potential of the Luano Valley was investigated.

New national metamorphic, metallogenic and geological maps were produced.

Advice was given geotechnical aspects for the Kafue Gorge Hydroelectric scheme.

A short ODA Consultancy Visit was undertaken in 1990 to examine the large backlog of maps and reports which remain unpublished from OSAS work. Recommendations have been made to resolve this problem.

OUTPUT (Reports, Papers, & etc)

Drysdall, A R, Johnson, R L, Moore, T A & Thieme, J G. 1972. Outline of the geology of Zambia Geologie en Mijnbouw, 51 (3), 265-276.

Appleton, J D. 1973. Catalogue of decorative and ornamental stones in the Lusaka area. Economic Report, Geological Survey of Zambia. No 36.

Appleton, J D. 1973. Geology of the Kabompo Gorge area: Explanation of Degree Sheet 1225, NW Quarter. Report Geological Survey of Zambia.

Appleton, J D. 1973. Geology of the southern half of the Ntambu Sheet. Geological Survey of Zambia Records.

Appleton, J D. 1973. 1:250,000 Geological map of the Ntambu Sheet (SD- 35-1) with explanatory notes. Geological Survey of Zambia.

Appleton, J D. 1973. Geology of the Ntambu Sheet. Geological Survey of Zambia Records.

Arthurs, J W. 1973. The Geology of the Solwezi area: Geological Survey of Zambia Report No 37

Edwards, R A. 1975. The Geology of the West Lunga River area: Geological Survey of Zambia Report No 43.

O'Connor, E A. 1976. The Geology of the Lumezi River Area, Geological Survey of Zambia Report.

O'Connor, E A. 1976. The Geology of the Lundazi Area, Geological Survey of Zambia Report.

Klinck, B A. 1977. The Geology of the Kabompo Dome Area. Geological Survey of Zambia Report No.44.

Ramsay, C R & Ridgway, J. 1977. Metamorphic patterns in Zambia and their bearing on problems of Zambian tectonic history. Precambrian Research, 4, 321-327.

Ramsay, C R & Ridgway, J. 1979. Metamorphic patterns in Zambia and their bearing on problems of Zambian tectonic history: a reply (to S. Vrana). Precambrian Research, 8, 130-135.

Rechwalder, P & Brandon, A. 1980. The Geology of the Luano Valley Area, Geological Survey of Zambia Report No 61, 85p.

Ridgway, J & Money, N J. 1981. Karoo basalts from Western Zambia and geochemical provinces in central and southern Africa. Geologische Rundschau 70, 868-873.

Thieme, J G & Johnson, R L. 1981. Geological Map of the Republic of Zambia. 1:1 000 000 Zambia Government.

Ridgway, J & Ramsay, C R. 1986. A provisional metamorphic map of Zambia - explanatory notes. Journal of African Earth Sciences Vol 5, 441-446. 1 map (1:500 000)

WORKSHOPS AND PRESENTATIONS

Represented Zambia at Intergovernmental Conference of Experts for IGCP Paris 1971

PROJECT STAFF

Dr J D Appleton
Dr B A Klinck
Dr R A Edwards
J W Arthurs
Dr R L Johnson
Dr J Ridgway
T R Marshall
Dr E A O'Connor
Dr A Brandon
P N Mosley

FUNDING ODA OSAS

ODA/BRITISH GEOLOGICAL SURVEY
PROJECT COMPLETION FORM

FORM A3

PROJECT NO: 54

TITLE: OSAS WORK IN ZIMBABWE

LOCATIONS: Zimbabwe

PROJECT SIZE: 3

DATES: 1987-On going (as Key Cadre)

COLLABORATING ORGANISATIONS

Geological Survey of Zimbabwe, Harare, Zimbabwe (host)

PROJECT OBJECTIVES

Since 1987 BGS has provided staff seconded under Key Cadre arrangements to the Geological Survey of Zimbabwe, to-date amounting to an input of about 5 years of staff time.

The staff have been involved with economic geology, editing and cartography.

PROJECT RESULTS

To date:

Institutional strengthening of the Geological Survey of Zimbabwe.

Training of local geologists.

OUTPUT (Reports, Papers, & etc)

WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

P L Lowenstein
M Armstrong
P Turner (Draughtsman)
G R Wood (Draughtsman)

FUNDING ODA OSAS

INDEX OF PARTICIPATING COUNTRIES

Country	Project Numbers
Angola	1
Ascension Island	41
Botswana	2,3,4,48
Cameroon	5
Chad	6
Egypt	7,8,9,10
Ethiopia	11
Gambia	12
Ghana	13
Gibraltar	42
Kenya	14,15,16,17,18,19,20,49
Lesotho	21,22
Libya	23,24
Malawi	25,26,50
Mauritius	43
Morocco	27
Niger	28,29
St Helena	44,45
Senegal	30
Seychelles	46,47
Sierra Leone	31
Sudan	32
Swaziland	33,51
Tanzania	34
Tunisia	35
Uganda	36,37,52
Zambia	38,53
Zimbabwe	39,40,54