BGS Technical Cooperation in the Eastern Mediterranean and Western Asia (1965–90)
TECHNICAL REPORT WC/92/1

BGS Technical Cooperation in the Eastern Mediterranean and Western Asia (1965-90)
British Geological Survey
Natural Environment Research Council

Technical Report WC/92/1

International Geology Series

BGS Technical Cooperation in the
Eastern Mediterranean and Western
Asia (1965--90)

S J Mathers (Compiler)

International Division

Cover illustration
Map of the Eastern Mediterranean and Western Asia, red dots indicate locations of host countries. Bottom left, geophysical survey in Yemen.

Bibliographic reference
## PROJECT LIST BY COUNTRY

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Introduction

This report comprises summaries of technical cooperation projects carried out by the British Geological Survey (BGS), formerly the Institute of Geological Sciences (IGS), in the eastern Mediterranean and western Asia since 1965. Most of the work described has been implemented on behalf of the Overseas Development Administration (ODA) of the Foreign and Commonwealth Office, as bilateral technical cooperation projects with the appropriate geoscience organisations of the host governments. Also included are a small number of studies carried out for multilateral aid agencies such as the United Nations (UN), foreign government departments and commercial companies.

This review covers 19 distinct projects undertaken in eight countries located in the eastern Mediterranean and western Asia (Figure 1). The region covered broadly corresponds to the area colloquially known as the "Middle East". The eight countries in which work has been undertaken are Bahrain, Cyprus, Iran, Jordan, Oman, Turkey, the United Arab Emirates and Yemen.

The main themes of the work have been hydrogeological studies, regional geological surveying and metallic mineral exploration. Other important topics include on-going studies of geothermal energy in Jordan and the installation and monitoring of a major seismic network in Turkey.

The information contained in this report, together with details of other work carried out abroad by BGS (and IGS) since 1965 are also contained in a database of past international activities held at BGS Keyworth.

Review of Projects

A brief description of the 19 projects, arranged by country, is given below.

Bahrain

Hydrogeological advisory visits to Bahrain between 1967 and 1973 resulted in the setting up of the Water Resources Board of Bahrain, the chief function of which is the systematic recording of hydrogeological data and management of the island's water resources. Recommendations were also made by the advisors to improve the efficiency of crop irrigation. Maximum abstraction rates were calculated for the local aquifers in order to avert risks of over-exploitation and the attendant problem of saline intrusion.

Cyprus

Two hydrogeological projects have been carried out in Cyprus; the first involved measurement and testing of observation boreholes sunk into a gravel aquifer on the Akrotiri Peninsula. The data collected enabled a digital model of the aquifer to be constructed which predicted the likely impact of a proposed dam development.

The second study involved the development of techniques for estimating recharge using areas of Cyprus as typical examples of semi-arid areas. Clearly such studies have widespread implications and application. A complex array of measuring and data gathering equipment was installed and drilling programmes carried out. The techniques successfully produced an accurate measurement of the downward movement of water in the surficial environment.
Iran

Following the major earthquake of August 1968 which affected the Khorassan Province of Iran, hydrogeologists and geophysicists undertook emergency studies to help detect usable sources of groundwater in the devastated area. In the Nimbaluk and Gonabad plains, studies of hydrogeological data and the use of geophysical techniques pin-pointed vital water resources and guided the well drilling programmes which formed part of the relief effort.

A major regional geological mapping and geochemical survey, involving up to 4 resident British geologists, was carried out between 1968-75 in northwest Iran. Geological maps of the area around Qasvin, Rasht and Bandar e Pahlavi were published in collaboration with the Geological Survey of Iran. Such programmes provide the essential geological framework for the subsequent detailed investigations of water, energy and mineral potential and typify the important role played by many national geological surveys.

Jordan

Between 1968-70 an IGS geologist was seconded to lead a UN-funded mineral prospecting and training project in Jordan. The project had to be terminated prematurely due to the security situation in the area.

Groundwater modelling was carried out for aquifers in Jordan including those responsible for the water supply of the important coastal port of Aqaba and surrounding areas. The studies enabled guidance to be offered for the safe development and management of the aquifers and a maximum abstraction level was recommended.

Since 1984 BGS has played an important role in developing the Natural Resources Authority (NRA) of Jordan through the presence of resident advisors, training initiatives and provision of equipment. This project is a particularly successful example of the "Institution Building" approach and has benefitted from excellent cooperation from the local authorities and the high-calibre and dedication of the Jordanian geologists assigned to the project. The NRA has developed rapidly currently employing 20 geologists and operating a cartographic and publishing department which is producing a national series of 1:50 000 scale geological maps and explanatory texts. About 40 map sheets have been surveyed and over half have already been published. Mineral deposits including oil shale, gypsum and sulphur have been located and on-going studies are assisting with the NRA's assessment of the geothermal potential of the area south of the capital, Amman, visiting specialists have provided short training courses in palaeontology, petrology, remote sensing and industrial minerals. Dr Cedric Mortimer of BGS (Project Manager 1984-89) was awarded the OBE for the key role he played in this work.

In 1990 a brief consultancy visit to Amman was undertaken to help the NRA to design displays and demonstrations for their new museum of geology. The recommendations of the BGS consultant have been accepted and implemented by the NRA and some materials for display are being provided.

Oman

Part of the area investigated in 1965-67 by a mineral survey of the Trucial States now lies within northern Oman and was found to contain chromite and copper mineralization.

Further mineral investigations in 1972-73 in the ophiolite of northern Oman involved detailed geological mapping and geochemical sampling; a number of small chromite bodies were found.
These resources were subsequently investigated in more detail by an EC-funded study led by the British geoscience consultants Robertsons in which a BGS geologist was involved on a consulting basis in 1989. This study has delineated a large number of metallurgical grade chromite reserves.

Turkey

Mineral exploration was carried out in 1970 in conjunction with ETIBANK - the Turkish State Mining Corporation in the Maden-Elazig area. Five areas of copper mineralization were surveyed to delineate reserves, whilst geochemical studies helped identify target zones; recommendations for the development of the prospects were made.

In 1973 an exploration geochemist also provided training and advice for ETIBANK including the installation and demonstration of an Atomic Absorption Spectrophotometer which enables chemical analysis for key elements.

In a major collaborative effort spanning 18 years BGS seismologists and engineers have installed and maintained an important seismic network around the Sea of Marmara in northwest Turkey. The work has been undertaken in conjunction with the Kandilli Observatory that now forms part of the Bosphorus University. By 1983 the seismic network, MARNET, comprising 3 component base stations and 8 single component outstations, had been successfully installed. Continued support and maintenance has been made possible through funding from the ODA R&D programme and small ODA support grants.

MARNET enables the recording of earthquakes in the Marmara region and western Turkey which includes the very active Anatolian Fault System. Using the data gathered the future earthquake risk can be assessed. Without the installation and support for MARNET such crucial observations would not have been made during the severe economic difficulties experienced in Turkey in the late 1970's and early 1980's. This would have made attempts to forecast future danger almost impossible.

United Arab Emirates (UAE)

A short geophysical mission to the UAE (then within the Trucial States) was undertaken in 1966 to try to measure the extent of saline intrusion in the area and the potential sources of water supply available for the coastal capital cities. Resistivity measurements were unable to differentiate small changes in groundwater salinity, the variations measured were instead thought to be due to the clay content of the aquifer. Some useful information on the subsurface geology resulted and recommendations on other possible approaches to the problem were made.

Yemen

In 1990 the People's Democratic Republic of Yemen (PDRY/South Yemen) was amalgamated with the Yemen Arab Republic (YAR/North Yemen) to form the Republic of Yemen. The following studies have been undertaken.

In 1974-77 IGS photogeologists and hydrogeologists contributed to a land-use study of the Montane Plains and Wadi Rima' areas of Yemen. The study was organized by the Land Resources Division of ODA. Geological maps of the area were produced and exploration and production wells sited to provide water resources. Data gathered from the installation of a hydrometric network enabled safe abstraction rates to be recommended.

Project List
In 1986 a BGS Minerals Consultant visited Sana'a to review available information on mineral resources of North Yemen and to recommend measures for the development of this sector. The consultant concluded that the paucity of basic geological information about the country meant that mineral exploration policies could not be properly formulated. He recommended that the host government begin a systematic programme of geological surveying and mineral exploration which should be carried out by the Government's geological department, if necessary with international help. Only then could the mineral potential be rationally assessed and exploited.

A geophysicist visited both South and North Yemen immediately prior to their amalgamation in 1990 principally to advise on a plan to develop the mineral potential of South Yemen. The UN-funded mission led to recommendations for the provision of training and equipment for the Yemenis and a short field visit enabled a lead/zinc deposit in Tabaq to be defined by geophysics.
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 up to 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.
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<td>4</td>
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<td><strong>DATES:</strong></td>
<td>1967-73</td>
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</table>
| **COLLABORATING ORGANISATIONS** | Hydrology Research Unit, Reading  
Bahrain Petroleum Company  
Bahrain Department of Agriculture |
| **PROJECT OBJECTIVES** | To carry out an assessment of the groundwater resources of Bahrain and calculate safe abstraction rates bearing in mind the risk of saline intrusion.  
To investigate the efficiency of crop irrigation and formalise the recording of hydrogeological data for the island, by establishing a government department responsible for such activities. |
| **PROJECT RESULTS** | The Water Resources Board of Bahrain was set-up in 1970 following recommendations made during advisory visits.  
Measurements have indicated that considerable savings in volumes of irrigation water can be made without affecting agricultural productivity. |
### WORKSHOPS AND PRESENTATIONS

A paper entitled "Hydrogeology and Groundwater in Bahrain" was present at the Arab World Technology Conference, Abu Dhabi in 1983.

### PROJECT STAFF

Dr E.P. Wright

### FUNDING

ODA Technical Cooperation
<table>
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<td><strong>COLLABORATING ORGANISATIONS</strong></td>
</tr>
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<td>Cyprus Water Development Department, Nicosia, Cyprus</td>
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**PROJECT OBJECTIVES**

To direct drilling and testing programmes in a gravel aquifer on the Akrotiri Peninsula. The aquifer is used for irrigation of agricultural produce and its yield might be adversely affected by a proposed dam construction.

**PROJECT RESULTS**

Pumping tests and water-level measurements were made on a network of observation boreholes, the results enabled a digital model of the aquifer to be constructed. The model enabled predictions to be made for the appropriate development of the groundwater resources of the area.

A member of the Cyprus Water Development Department visited the UK to learn how to operate the model and it was subsequently installed on computer in Nicosia, Cyprus.
### OUTPUT (Reports, Papers, & etc)


### WORKSHOPS AND PRESENTATIONS


### PROJECT STAFF

Dr R. Kitching

### FUNDING

ODA Technical Cooperation
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<td>Royal Engineers (Lysimeter Installation)</td>
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<td><strong>PROJECT OBJECTIVES</strong></td>
<td>Development of techniques for measuring aquifer recharge in semi-arid areas; Measuring recharge is often difficult in many overseas groundwater studies.</td>
</tr>
<tr>
<td><strong>PROJECT RESULTS</strong></td>
<td>Various types of lysimeter, an automatic weather station, raingauges and soil moisture measurement stations were installed to gather data for the study. Drilling programmes on the Akrotiri Peninsula and in S E Mesaoria enabled detailed studies of the chemistry in the unsaturated zone above the water table to be performed, confirming a downward velocity by piston movement of 0.68 m/year.</td>
</tr>
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### OUTPUT (Reports, Papers, & etc)


### WORKSHOPS AND PRESENTATIONS

### PROJECT STAFF

Dr R. Kitching  
W.M. Edmunds  
T.R. Shearer  
N.R.G. Walton

### FUNDING

ODA Technical Cooperation
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**COLLABORATING ORGANISATIONS**

**PROJECT OBJECTIVES**

Hydrogeological and geophysical studies to help mitigate the effects of a major earthquake disaster (August 1968) in Khorassan Province, Iran. Location and advise on extraction of groundwater in the Nimbalux, Gonabad and Firdaus areas. Monitoring of aftershocks from the earthquakes.

**PROJECT RESULTS**
**OUTPUT (Reports, Papers, & etc)**


**WORKSHOPS AND PRESENTATIONS**


**PROJECT STAFF**

Dr S. Crampin  
S. Anderson  
Dr E.P. Wright  
Dr J.B.W. Day  
Dr J.W. Sutcliffe (IH)


**FUNDING**  
UNESCO/ODA Emergency Relief
**TITLE:** REGIONAL GEOLOGICAL SURVEY, NW IRAN

<table>
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**COLLABORATING ORGANISATIONS**

Geological Survey of Iran

**PROJECT OBJECTIVES**

Geological mapping and economic assessment of the Bandar-e-Pahlavi and Qazvin-Rasht areas of the Alborz Mountains, NW Iran involving field traverses, geochemical sampling and photogeological mapping.

Two distinct phases were mounted covering:
1) Bandar-e-Pahlavi Area (1968-71) 3 Geologists
2) Qazvin-Rasht Area (1972-75) 4 Geologists

**PROJECT RESULTS**

The geological surveying of the two areas was completed satisfactorily and the results published as coloured geological maps and explanatory memoirs (details overleaf). Counterpart geologists of the Geological Survey of Iran were trained in geological mapping methods.
OUTPUT (Reports, Papers, & etc)

Geological Maps

1:250 000 Map of the Bandar-e-Pahlavi area
1:100 000 Map of the Masuleh Sheet
1:250 000 Map of the Rasht-Qazvin Quadrangle
1:100 000 Map of the Shakran (No.6162) area with marginal notes

Reports


WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr R.G. Davies
Dr C.R. Jones, OBE
Dr G.C. Clark
P.G. Greenwood
Dr R.A. Bazley
Dr R.N. Annells
R.S. Arthurton

FUNDING  ODA Technical Cooperation
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<td><strong>COLLABORATING ORGANISATIONS</strong></td>
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<td><strong>PROJECT OBJECTIVES</strong></td>
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<tr>
<td>An IGS geologist was seconded to the UNDP to lead a mineral prospecting project in Jordan.</td>
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<tr>
<td><strong>PROJECT RESULTS</strong></td>
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<tr>
<td>The mineral prospecting project was curtailed in 1970 due to hostilities in the region. The IGS geologist provided training and management for the project for two years.</td>
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OUTPUT (Reports, Papers, & etc)


WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr J.A.E. Bennett

FUNDING  United Nations Development Programme (UNDP)
**PROJECT COMPLETION FORM**

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<td>DATES:</td>
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| COLLABORATING ORGANISATIONS | Raikes & Partners (Consultants), UK.  
Jordanian Water Ministry |
| PROJECT OBJECTIVES | To gather data to construct a digital model of the groundwater resources of Wadi Dhuleil in NE Jordan.  
Water levels in the area have been declining and salinity increasing leading to a need for guidance on a safe maximum abstraction rate for the aquifer.  
To assess a groundwater model developed by Raikes & Partners (Consultants) for the Qa' Disi area which is an important source of groundwater for the city of Aqaba and regional agricultural development. |
| PROJECT RESULTS | An existing groundwater model was reviewed and a new model was constructed.  
Recommendations were made for the phased development of the aquifer with an initial upper abstraction limit of 35 million cubic metres/year. |
## OUTPUT (Reports, Papers, & etc)


## WORKSHOPS AND PRESENTATIONS

## PROJECT STAFF

Dr D.K. Buckley  
Dr R. Kitching

## FUNDING

ODA Technical Cooperation
**TITLE:** GEOLOGICAL MAPPING, TRAINING AND GEOTHERMAL STUDIES

**LOCATIONS:** Jordan  
**PROJECT SIZE:** 2

**DATES:** 1984 - On Going

**COLLABORATING ORGANISATIONS**
Natural Resources Authority (NRA) Ministry of Energy and Mineral Resources, Amman, Jordan

**PROJECT OBJECTIVES**
- Systematic geological mapping, compilation, editing and publication of a 1:50 000 scale map series of the geology of Jordan together with accompanying sheet descriptions.
- Appraisal of deeper geology from hydrocarbon exploration data.
- Supervision and training counterpart staff in geological mapping, mineral assessment, map compilation, report writing and cartography is an important objective of this project.
- Assistance in archiving geological information.
- To train and advise NRA staff in their programme of geothermal evaluation (from 1989 onwards).

**PROJECT RESULTS**
The geological mapping programme resulted in several major publications by BGS staff and the publication by NRA of a considerable number of 1:50 000 geological map sheets and explanatory memoirs by Jordanian geologists reflecting the success of the training and the high-calibre of the NRA staff.

Based on this project the NRA has rapidly expanded to employ 20 local geologists and a cartographic and publishing department have been formed. The progress made by NRA is a fine example of institution building and has been augmented by the donation of considerable amounts of cartographic equipment and the provision of 5 British Council scholarships for Geology MSc courses plus several training visits to the Ordnance Survey, Southampton and BGS Keyworth for cartographic staff to receive instruction.

Resources of oil shale, tar sand, feldspar, gypsum and sulphur have been located.

The on-going geothermal studies involving residential and visiting BGS staff have located a widespread region of low temperature thermal waters probably suitable for commercial development south of Amman.

Dr C Mortimer (Project Manager 1984-89) was awarded the OBE for the outstanding success of the project in developing the NRA.
OUTPUT (Reports, Papers, & etc)

The NRA have published about 20 1:50 000 Geological maps and explanatory memoirs, a further 20 are in progress.


WORKSHOPS AND PRESENTATIONS

Workshops up to 6 weeks duration given by BGS specialists at NRA, Amman, Jordan.

1986 Petrology & Petrography (Dr J. Aspden)
1988 Palaeontology (Dr C.R. Jones)
1990 Photogeology (Dr J.P. Berrangé)
1992 Industrial Minerals (Dr D.J. Morgan)

PROJECT STAFF

Dr C. Mortimer OBE (Project Manager 1984-89)
T.J. Charsley (Project Manager 1989-present)
Dr W.J. McCourt
Dr J.H. Powell
Dr I.J. Andrews
D.J. Allen
W.G. Darling
R.B. Evans

FUNDING  ODA Technical Cooperation
BGS help Jordanians survey their mineral resources

The Kingdom of Jordan will have more known mineral resources to draw on and may soon gain energy from hot water thanks to an imaginative ODA project which has seen excellent cooperation between the Jordanian Natural Resources Authority and the British Geological Survey, writes project leader, Dr Cedric Mortimer, of BGS.

The project began in 1984 and is based at headquarters in Amman, but with field surveying throughout the country. It has two principal aims:

- In-service training in geological mapping and mineral resources assessment.
- Compilation and publication of maps and reports.

The ultimate aim is to give firm direction and continuity in the systematic geological investigation of Jordan. About 150 maps should eventually be produced and these with associated bulletins containing in-depth comment on the geology and mineral deposits of each area, are an ordered and cumulative database of the natural mineral wealth of Jordan.

As a result these resources can be carefully and fully exploited. Drilling for water and oil provided information for Phase II of the project which began in the Spring. As part of this Jordan’s famous hot water springs will be investigated in a search for geothermal energy. There will be a resident team of British experts and a series of consultancy visits by others.

The geological mapping of the central Jordan desert is taking place in broad areas of chalca, marls and phosphatic limestones mostly of the Cretaceous age.

The rocks form a windswept plateau often mysteriously hidden in clouds of dust. A brown desert pavement of strewn flints — many of them worked by ancient man — is underfoot.

Evaporation

Phosphate deposits are extensively exploited in remote mines, and the marls contain deposits of oil shales which are being investigated for economic viability.

To the west of the plateau is the Jordan Valley and the Dead Sea where brines are exploited for minerals by solar evaporation.

These biblically famous locations occupy a trough which formed in recent geological times as the whole of Jordan and Arabia moved more than 100 km northwards. The depression is the deepest normal hole in the world. Waves break on the shore of the Dead Sea at about 400m below normal sea level. Fringes of old levels reach 200m higher, indicating that the Dead Sea is shrinking.

A boat was used to map and study otherwise inaccessible tracts of the rugged east coast where oil seeps are a feature. Blocks of pitch were encountered in the sea. These are recorded historically as ‘coming from the depths’ and are sometimes ‘as large as houses’.

Hot springs in the Jordan Valley indicate usable geothermal energy and BGS will be investigating this possibility.

In the sandy desert of southern Jordan, near Aqaba, is a series of Precambrian granites. Ores are known to occur locally and further study is required. In this area are the ancient copper mines of Wadi Araba, which some say belonged to King Solomon.

Mapping

Maps are to a scale of 2cm to 1km (1:50 000) and each geologist maps a 650sq km area. From 1984 to 1989 Mr Bassam Sunna, NRA Director of Geology, increased the strength to 20 geologist with a maximum of five UK experts in post. So far 19 maps have been completed and 20 more are in progress.

The format of the maps is that which has been developed in previous ODA geological projects in Asia, Africa, and South America. The coloured sheets include column and cross sections with the legend and main map and there is also a concise description of the geology and resources, in Arabic and English.

Cartographic work and printing is carried out in Jordan under the guidance of Mr David Royce, the Map Production Manager. Britain has given the cartographic equipment to help the NRA produce their maps and publications, and amplify their knowledge of geology, and the mineral resources upon which Jordan depends.

Training

In-service training of geologists and cartographers goes on as a routine part of the programme. Specialist courses have been given in Amman, and others are planned.

Five young Jordanians have so far been awarded scholarships for MSc degrees in the UK. Others have been training at the Ordnance Survey in Southampton and the BGS in Nottinghamshire.

As a result of the survey, in which the Jordanians are now becoming their own experts, resources of oil shale, tar sand, feldspar, gypsum and sulphur have been revealed and the knowledge gained has been fundamental in the search for groundwater and hydrocarbons.
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<thead>
<tr>
<th><strong>TITLE:</strong> MUSEUM DEVELOPMENT</th>
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<table>
<thead>
<tr>
<th><strong>LOCATIONS:</strong> Jordan</th>
<th><strong>PROJECT SIZE:</strong> 5</th>
</tr>
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<tbody>
<tr>
<td><strong>DATES:</strong> 1990</td>
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<table>
<thead>
<tr>
<th><strong>COLLABORATING ORGANISATIONS</strong></th>
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<tbody>
<tr>
<td>Natural Resources Authority (NRA), Ministry of Energy and Mineral Resources, Amman, Jordan.</td>
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<thead>
<tr>
<th><strong>PROJECT OBJECTIVES</strong></th>
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<tbody>
<tr>
<td>A brief consultancy visit to Amman, Jordan was undertaken to advise the NRA on the equipping of their new Geological Museum with displays and demonstrations suitable for both the professional and the general public.</td>
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<table>
<thead>
<tr>
<th><strong>PROJECT RESULTS</strong></th>
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<tbody>
<tr>
<td>The consulting visit was undertaken and detailed plans and recommendations for the development of the museum were made (in the report listed overleaf), and approved by the NRA. Photographic material and some geological samples have been provided for the museum displays.</td>
</tr>
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</table>
OUTPUT (Reports, Papers, & etc)


WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr B.J. Taylor

FUNDING  ODA Technical Cooperation
<table>
<thead>
<tr>
<th>TITLE: TRUCIAL STATES MINERAL SURVEY</th>
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<tbody>
<tr>
<td>LOCATIONS: Oman and United Arab Emirates (UAE)</td>
</tr>
<tr>
<td>PROJECT SIZE: 4</td>
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<tr>
<td>DATES: 1965-67</td>
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**COLLABORATING ORGANISATIONS**

**PROJECT OBJECTIVES**

To undertake a preliminary geological and economic appraisal of non-hydrocarbon mineral resources in the Trucial States (now United Arab Emirates and part of Oman) and to report on the desirability of further mineral exploration.

**PROJECT RESULTS**

The region was studied using rapid field traverses and geochemical sampling was undertaken in areas with reported mineral wealth, scintilometer readings were taken to try and locate any phosphorite deposits.

Deposits of Asbestos, Cement Raw Materials, Copper and Iron Minerals, Ochre, Gypsum, Magnesite, Phosphates and Talc were detected and reported on.

A more detailed follow-up study of 2,000 sq miles of northern Oman was also undertaken identifying chromite and copper occurrences as the chief economic potential. Some 16,000 m tonnes of chromite resources was found.
### OUTPUT (Reports, Papers, & etc)


### WORKSHOPS AND PRESENTATIONS

### PROJECT STAFF

J.E.G.W. Greenwood  
P.E.Loney (Contract Officer)

### FUNDING

ODA Technical Cooperation/TRUCIAL STATES COUNCIL
TITLE: MINERAL INVESTIGATIONS, OMAN

LOCATIONS: Oman

PROJECT SIZE: 4

DATES: 1972-73

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

Mineral investigation of three areas within the ophiolite-terrain of the Oman Mountains involving the examination of old mines and known mineral occurrences together with geological surveying and geological mapping.

PROJECT RESULTS

Preparation of 3 geological maps and 3 accompanying maps with results of stream sediment geochemical survey.

In the Wadi Wa’al - Wadi Laquerc region, Tawi Ubaylah and Luzva; concentrations of quartz veins with chalcopyrite and brochantite mineralisation were found. Gabbro terrain in the Wadi Jizi area showed high background copper valves in stream sediment samples.

A number of small chromite bodies were found. The largest, Farfar 1, has been investigated by exploration companies but no follow up was done by BGS.
OUTPUT (Reports, Papers, & etc)


WORKSHOPS AND PRESENTATIONS

PROJECT STAFF

Dr J.N. Carney
Dr M.J.P. Welland
Dr A.H.G. Mitchell

FUNDING ODA Technical Cooperation
| **TITLE:** CHROMITE RESOURCES, OMAN OPHIOLITE |
| **LOCATIONS:** Oman | **PROJECT SIZE:** 4 |
| **DATES:** 1989 |

**COLLABORATING ORGANISATIONS**
Robertstons Group PLC (International Division)

**PROJECT OBJECTIVES**
A BGS geologist was assigned as consultant in geological mapping under a short-term commercial arrangement to assist a British company contracted by the sultanate to undertake geological mapping and exploration for chromite in the Oman ophiolite.

**PROJECT RESULTS**
Regional geological and prospect location maps at 1:25 000 and a geological report were completed for the exploration phase. A large number of metallurgical-grade chromite bodies, some with significant economic potential, were found during this intensive helicopter-assisted work, which also refined the geological mapping of the ophiolite. Omani government geologists were trained in the techniques used, and the results of this rapid exploration programme were judged highly successful by both parties to the contract.
<table>
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<tr>
<th><strong>OUTPUT (Reports, Papers, &amp; etc)</strong></th>
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<th><strong>WORKSHOPS AND PRESENTATIONS</strong></th>
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<tr>
<th><strong>PROJECT STAFF</strong></th>
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<tbody>
<tr>
<td>Dr R.N. Annells</td>
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</table>

| **FUNDING** European Community (EC) |
**TITLE:** GEOLOGICAL MAPPING AND MINERAL EXPLORATION, MADEN-ELAZIG AREA

**LOCATIONS:** Turkey

**PROJECT SIZE:** 4

**DATES:** 1970

**COLLABORATING ORGANISATIONS**

Turkish State Mining Corporation (ETIBANK)

**PROJECT OBJECTIVES**

Mineral Investigation and Geological Mapping in the Maden-Elazig area of Turkey to assist ETIBANK with its programme of mineral exploration and copper-mining activities in the area.

**PROJECT RESULTS**

After preliminary investigation it was decided to concentrate on the mineral exploration aspect of the project.

Mineral occurrences at Kisabekir, Zahoran, Kundukan, Davudan, Putyan and YK Baru were mapped and examined in detail to delineate reserves and future exploration strategies, geochemical sampling and analysis helped define target zones.

Recommendations for the development of the prospects was made.
## OUTPUT (Reports, Papers, & etc)


## WORKSHOPS AND PRESENTATIONS

## PROJECT STAFF

Dr J.A.E. Allum  
Dr D.R. Workman  
J.W. Arthurs

## FUNDING

ODA Technical Cooperation
# MARNET Seismic Network Installation and Monitoring

**Title:** MARNET Seismic Network Installation and Monitoring  

**Locations:** Turkey  

**Project Size:** 2  

**Dates:** Intermittent 1971-1989  

**Collaborating Organisations**  

Kandilli Observatory, Bosphorus University, Istanbul  

**Project Objectives**  

To install and maintain a seismic network in the area of the Sea of Marmara, Turkey.

To monitor seismic activity in the area which lies astride the Anatolian Fault System, to attempt to assess the likelihood and frequency of further strong earthquakes in the region.

**Project Results**  

The MARNET radio-linked seismic network was established, covering the Marmara Sea region of northwest Turkey, over the period 1976 to 1983. It comprises a 3-component base station and 8 single component outstations. Over the same period, local staff were trained to enable them to undertake routine maintenance and repair of the network, and to enable them to deinstall and reinstall stations to take account of changing circumstances. Over this period, Turkey suffered a period of intense economic depression; MARNET staff assisted in the maintenance of the entire Turkish national seismograph network and in the execution of a variety of related studies.

An element of support was continued as a component of the ODA sponsored R&D project on Earthquake Prediction Research. Further small support grants were provided in 1986-89 to refurbish some of the older equipment and to provide a pair of minicomputers for data acquisition and analysis.
OUTPUT (Reports, Papers, & etc)

The principal output of the MARNET programme was the catalogue of earthquakes in the Marmara region and western Turkey. This dataset is of fundamental importance to any assessment of earthquake hazard (and so also of earthquake risk) in this region. Kandilli has published (and continues to publish) the earthquake catalogues generated from MARNET annually in the Bulletin of the Earthquake Research Department of Turkey, in its own independent publications, and in computer-readable form through the Bulletins of the International Seismological Centre. MARNET is also the basis of an information service offered to government, press and public by the Observatory.

Staff of Kandilli Observatory regularly publish technical papers on MARNET data and results in Turkish technical journals; a number of PhD theses have been based on data from the network. Several joint papers have been produced under joint BGS-Kandilli authorship describing the system and its results, including:


WORKSHOPS AND PRESENTATIONS

MARNET is the showpiece of the Observatory; it is exhibited on a daily basis to distinguished Turkish and foreign visitors. In 1980, the biannual World Conference on Earthquake Engineering, and in 1989 the 25th Assembly of the International Association of Seismology and Physics of the Earth's Interior were held in Istanbul. In each case, a display was assembled at the conference site. In 1989, this took the form of a complete, working duplicate of the MARNET base station operating in the foyer of the conference hall. Delegates were able to inspect earthquake data as it was being recorded and see the analyses being conducted in 'real time'.

PROJECT STAFF

Dr S. Crampin
Dr J.R. Evans
A. Miller
S.N. Morgan
D.L. Petrie

FUNDING ODA Technical Cooperation
<table>
<thead>
<tr>
<th><strong>TITLE:</strong></th>
<th>EXPLORATION GEOCHEMISTRY ADVISOR</th>
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<tbody>
<tr>
<td><strong>LOCATIONS:</strong></td>
<td>Turkey</td>
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<tr>
<td><strong>DATES:</strong></td>
<td>1973</td>
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</table>

**COLLABORATING ORGANISATIONS**

Turkish State Mining Corporation (ETIBANK)

**PROJECT OBJECTIVES**

To provide training and advise for ETIBANK staff on techniques of geochemical exploration, sampling and data presentation.

**PROJECT RESULTS**

Methods of drainage and soil surveys were demonstrated including sample collection and preparation, assessment of geochemical data and map preparation. An atomic absorption spectrophotometer was installed and instruction given in its use.
**OUTPUT (Reports, Papers, & etc)**


**WORKSHOPS AND PRESENTATIONS**

**PROJECT STAFF**

Dr R.D. Walshaw

**FUNDING**  ODA Technical Cooperation
**TITLE:** GEOPHYSICAL STUDIES FOR WATER RESOURCES

**LOCATIONS:** United Arab Emirates  
(then part of the Trucial States)  
**PROJECT SIZE:** 5

**DATES:** 1966

**COLLABORATING ORGANISATIONS**

Trucial States Water Resources Survey

**PROJECT OBJECTIVES**

At the request of the Trucial States Council resistivity and magnetic surveys were carried out in selected areas over a 3-month period in order to detect and indicate the quality of groundwater resources and assess the usefulness of these geophysical techniques in such a context.

Groundwater is found at shallow depth beneath the gravel plains and desert foreland, which lie between the Central Mountains and the western coast of the Trucial States. The aquifer is recharged by the surface flow of rainwater from the Central Mountains, and, consequently, there is a change from relatively freshwater beneath the gravel plains to saline water near the coast. Groundwater is required both for irrigation and for domestic supplies to the coastal capitals. For domestic purposes, the acceptable maximum of total dissolved solids is 2000 p.p.m.

The primary object of the surveys was to test the effectiveness of the resistivity technique in outlining areas where the average groundwater salinity is less than 2000 p.p.m. total solids, and in determining the depth of the water-table and the thickness of the aquifer.

**PROJECT RESULTS**

A geophysical survey employing mostly the resistivity method, but with some magnetic traverses, was made over selected areas of the United Arab Emirates (formerly the Trucial States) to provide hydrogeological information for a water resources survey. The resistivity technique was found to be most suitable for these desert conditions. It proved impossible to detect small salinity variations in the buried aquifer by geophysics. The variations in aquifer resistivity found, were thought to be due to varying clay content, which could be related to aquifer yield. Specific borehole sites were used to test this supposition. A number of subsurface structures relevant to the hydrology were located. Recommendations on further necessary geophysical work were made.
### OUTPUT (Reports, Papers, & etc)


### WORKSHOPS AND PRESENTATIONS

### PROJECT STAFF

R.B. Evans

### FUNDING

TRUCIAL STATES COUNCIL AND ODA Technical Cooperation
## Title: Montane Plains and Wadi Rima' Project

<table>
<thead>
<tr>
<th>Locations: Yemen</th>
<th>Project Size: 4</th>
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<tr>
<td>Dates: 1974-77</td>
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</table>

### Collaborating Organisations
ODA, Land Resources Division (LRD)

### Project Objectives
IGS Photogeologists and Hydrogeologists contributed to this study organised jointly with ODA's Land Resources Division.

The overall objective was to carry out comprehensive surveys of the land and water resources of two areas of the Yemen Arab Republic, and prepare proposals for development. The Montane Plains area covers 2,800 km² in the central mountains and the Wadi Rima' study area lies on the Tihama coastal plain.

### Project Results
Photogeological mapping of the Montane Plains area was accomplished to provide a geological map as background for the study of land and water resources.

Supervision of drilling of exploration and production wells in the Montane Plains, and in Wadi Rima' on the Tihama coastal plain.

A Hydrometric network was established to try and obtain accurate measurements of water balance and thereby provide guidelines for safe abstraction rates. A digital strip model for the Wadi Rima' aquifer system was developed in the UK at the end of the study to guide future water management.

Test pumping was carried out of the production wells. Water quality was also studied, detailed surveys were carried out of existing groundwater abstraction.

Geological investigations were also performed.
**OUTPUT (Reports, Papers, & etc)**


Contributions were also made to:


**WORKSHOPS AND PRESENTATIONS**

**PROJECT STAFF**

J.E.G.W. Greenwood
F. Habgood
P.J. Chilton
B.L. Morris
N.S. Robins
J. Toombs
K.E. Rollin

**FUNDING** ODA Technical Cooperation
<table>
<thead>
<tr>
<th>TITLE: MINERALS CONSULTANT, YEMEN</th>
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<tbody>
<tr>
<td>LOCATIONS: Yemen</td>
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<tr>
<td>PROJECT SIZE: 5</td>
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<tr>
<td>DATES: 1986</td>
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**COLLABORATING ORGANISATIONS**

Geological Survey Authority, Ministry of Oil and Mineral Resources, Sana'a, Yemen

**PROJECT OBJECTIVES**

A short Mission to Sana'a was undertaken with the following terms of reference:

- to make a review and appraisal of all studies of mineral potential which have been previously undertaken for the Government of the Yemen Arab Republic;
- to make recommendations on whether a further more specialised consultancy is required and if so to draw up the terms of reference of such a consultancy;
- to make recommendations to the Government of the Yemen Arab Republic on the steps it might take to further identify evaluate and develop its mineral resources.

**PROJECT RESULTS**

The Consultants principal findings were as follows:

Mineral exploration is in its infancy in the Yemen Arab Republic and much needs to be learnt about the basic geology and the mineral and underground water potential of the country. Information available at present suggests that the most favourable area for mineralisation is in the north.

Development in the mines and minerals sector is currently inhibited by the absence of clear government policy towards the sector. Arising from this situation the Geological Survey Authority programme has no obvious strategy. In particular there has been no systematic programme leading to the publication of geological maps and accompanying reports and to the building up of expertise within the country.

The Government of the Yemen Arab Republic should recognise that:

- (a) The basis for all substantial developments in the mines and minerals sector and in the assessment of underground water resources is a systematic programme of geological mapping and mineral reconnaissance which is best carried out by a Government Geological Survey.
- (b) The intermediate and later stages in the evaluation of major mineral deposits and, in particular, the proving of ore bodies and mining feasibility studies are best funded by mining companies as potential investors. The Geological Surveyor Authority may, however, have to undertake the later stages in the case of industrial minerals and small deposits of metallic minerals which are not of interest to outside mining groups but may be profitably worked by local entrepreneurs.
### OUTPUT (Reports, Papers, & etc)


### WORKSHOPS AND PRESENTATIONS

### PROJECT STAFF

Dr R.L. Johnson

### FUNDING

ODA Technical Cooperation
TITLE: GEOPHYSICS ADVISOR

LOCATIONS: Yemen

PROJECT SIZE: 5

DATES: 1990

COLLABORATING ORGANISATIONS

PROJECT OBJECTIVES

The purpose of this consultancy was to review all the available geophysical information for Peoples Democratic Republic of Yemen (PDRY-South Yemen) as well as the geophysical facilities (personnel, equipment, drafting and processing) of the PDRY Department of Geology and Mineral Exploration (DGME) of the Ministry of Energy and Minerals in Aden. The Government of the former PDRY was interested in preparing a long term Mineral Plan which would include programmes, projects and recommendations regarding priorities for minerals to be used as a base for a five year plan (1991-95) which would include training, equipment and fund requirements with a work plan and a time schedule.

These plans have now to be viewed in the light of the unification of the former PDRY (Southern Yemen) with the former Yemen Arab Republic (Northern Yemen) to form the Republic of Yemen in May 1990. This unification was part of the reason for visiting Sana'a at the request of the UN at the end of the Yemeni UN consultancy.

PROJECT RESULTS

Recommendations have been made to the UN with regard to

a) Training Yemeni staff.
b) Provision of key geophysical equipment, computing facilities and software packages for data processing.
c) New exploration strategies and application of techniques.

Measurements of magnetic susceptibility carried out during the visit have helped define the extent of Pb/Zn mineralization in Tabaq.
**OUTPUT (Reports, Papers, & etc)**


**WORKSHOPS AND PRESENTATIONS**

**PROJECT STAFF**

R.B. Evans

**FUNDING** United Nations Development Programme (UNDP)