Ophiolites are slices of oceanic crust that have been pushed up on to the continents when tectonic plates collided. A study by the BGS and its partners is revealing new information about the formation of these exotic rock sequences, and as **Michael Styles, Richard Ellison, David Greenbaum, Emrys Phillips & Andrew Farrant** explain, it will help to establish their economic potential.

Mapping ancient oceans

In 2002, the BGS was awarded a contract from the Federal Government of the United Arab Emirates (UAE) to carry out a multidisciplinary programme of geological mapping, airborne geophysics and deep seismic surveys across the mountainous region and adjacent desert of the Northern Emirates. This programme is being carried out on behalf of the Petroleum and Minerals Sector of the Ministry of Energy, and represents the largest international project presently being undertaken by the BGS.

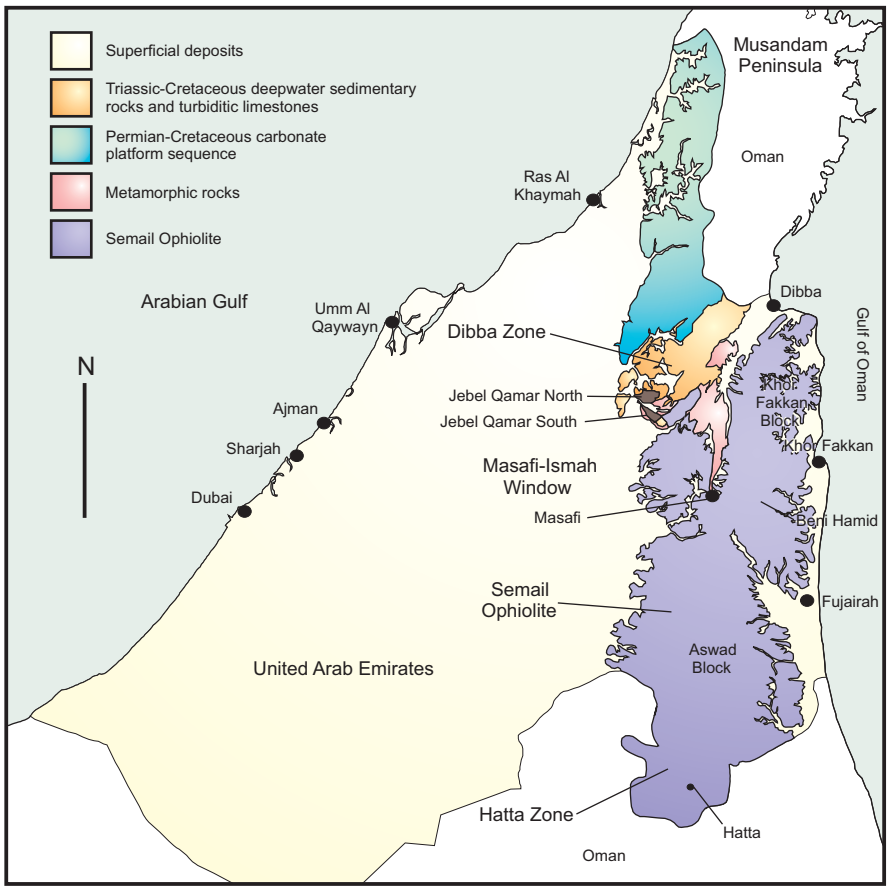
The mountainous Northern Emirates area is one of significant worldwide geological interest and includes the northernmost section of the Semail ophiolite (continuing from the Oman Mountains to the south). This is the world's largest and best-preserved example of an exposed ophiolite thrust complex. Whereas the greater part of the ophiolite occurs within Oman, the lesser known UAE section is believed to contain important variations which will help to resolve the controversy over the genetic and tectonic evolution of this region. This in turn will have significance for minerals potential.

The main focus of our work is on the geological mapping of the Northern Emirates, and an assessment of the mineral potential. There is also a parallel programme of regional geophysical surveys, including deep seismic reflection and airborne magnetic and radiometrics. The geophysical work is being carried out by commercial contractors overseen by the BGS. In addition to these primary data-gathering surveys, we are also undertaking reviews of the hydrogeology and the seismic and geological hazards of the whole of the country. The geoscientific data brought together in this project form an important part of the national information base needed to assist the rapid development currently taking place in the UAE.

The Hajar mountains in the east, which include virtually all the exposed rocks in the Emirates, are being mapped at a scale of 1:25 000. The desert area to the west, largely sand dunes with very limited areas of exposed rock, is being mapped at 1:50 000. A team of eight geologists have spent four months each winter for three years to carry out the geological mapping. Two years into the project they have already mapped an area of 13 000 square kilometres, with observations made at over 17 000 locations, and over 4500 samples collected.

The largest part of the mountain area is formed by the UAE–Oman ophiolite, a huge slice of Indian Ocean crust that was pushed up on to the margin of the Arabian shield during Late Cretaceous

The grey Mussandam Limestone Group overlying the orange ferruginous Ghalilah Formation.



Simplified geological map of the United Arab Emirates.

times (90 to 95 million years ago). The ophiolite extends from the UAE southwards for 400 kilometres into Oman and is the largest and best preserved example in the world. The detailed mapping is supported by petrographical and geochemical studies undertaken by the BGS and Cardiff University. This has enabled the scientific aspects of the project to be extended beyond the scope normally possible under a commercial contract. The work is revealing important data about the evolution of the ophiolite. It was initially formed at a mid-ocean ridge, but as time progressed, this setting changed to one where the continually developing oceanic crust was located above an ocean trench (supra subduction zone). This exciting new information about the formation of the ophiolite has been well received when presented at several prestigious international conferences.

The northern part of the area is an extensive platform carbonate sequence that formed on the margin of the Arabian shield during Mesozoic times. These rocks are a thrusted mass that has been extensively folded and faulted. Between the ophiolite and the platform carbonate sequence is an area of complex geology known as the Dibba zone. This zone comprises a highly deformed sequence of turbiditic limestones, alkaline volcanic rocks and siliceous mudstones and cherts which have been thrust towards the north-west during the later stages of the ophiolite emplacement.

> " this is the world's largest and best-preserved example of an exposed ophiolite thrust complex "

These sedimentary and volcanic rocks originally formed in an offshore deepwater setting and were scraped up off the ocean floor in front of the advancing ophiolite as the ocean basin closed during the collision of Arabia and Asia. The ocean crust of the ophiolite was very hot during the earliest parts of the emplacement resulting in the metamorphism of the sedimentary and volcanic rocks caught beneath the ophiolite. The highest metamorphic grades (upper amphibolite to possibly granulite facies) are found immediately below the sole of the ophiolite. The major thrust zone separating the base of the ophiolite from its metamorphic sole has been strongly modified during the later stages of ophiolite emplacement and subsequent uplift. As a result the very high-grade metamorphic rocks are now found as dissected slivers along this major tectonic boundary.

The western part of the project area is largely covered by desert sand and alluvial fan deposits emanating from the mountain front. They overlie a sequence of Cretaceous and Tertiary rocks formed in a new foreland depositional basin that developed after the emplacement of the ophiolite. This sequence of rocks hosts some important hydrocarbon resources and the new work will help to improve understanding of the regional setting.

Recent (Quaternary) deposits cover most of the country, and detailed mapping of these deposits is crucial. The coastal strip, alluvial fans and the desert hinterland are the location of most of the country's infrastructure and the alluvial fans are also an important source of aggregate as well as a major aquifer. The alluvial fan and dune deposits provide a detailed record of climate change associated with changes in the track and intensity of the Indian Ocean summer monsoon. They indicate a trend for increased aridity over the past several thousand years.

All the information collected during the project will be fully integrated into a large database and geographical information system, which will enable comparison between, and spatial analysis of, all the different data types. A range of traditional printed maps and reports will also be produced.

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