Geological studies commissioned to support the United Arab Emirates' rapid urbanisation are also providing insights into ancient environments. **Andrew Farrant[1], Adrian Parker[2], Ashley Parton[2],** and **Richard Ellison[1]** describe some of the techniques and findings.

Arabian adventures

The United Arab Emirates (UAE) is one of the world's most rapidly urbanising countries. Despite the recent downturn in the economy, the region continues to undergo rapid development, particularly around Abu Dhabi and Dubai. Consequently the country is host to many major civil engineering projects including the world's tallest building, artificial offshore islands, new international airports, metro systems and high-speed rail networks.

Development of this sort requires a sound geological understanding of ground conditions and potential geohazards. In addition, the enormous quantities of raw materials needed require local sustainable resources of industrial minerals such as hard rock aggregates and high-purity limestones. The government of the UAE has recognised that it must have high-quality baseline geological data to aid planning and development, as previous geological maps, produced largely from remotely sensed imagery in the 1970s have proved inadequate for today's needs. The Federal Government commissioned the British Geological Survey to undertake a major geological, strategic mineral assessment and airborne survey project in the UAE. This began in 2002 with a contract to map the eastern emirates, including the UAE–Oman ophiolite. This initial contract was completed in 2006 with the publication of a suite of geological maps at 1:50k and 1:100k scale and comprehensive geographical information system (GIS).

The success of this first contract was followed in 2008 by a new contract to complete the geological mapping of the country at 1:100k scale. This project is focused on mapping the younger Neogene and Quaternary deposits that underlie most of Abu Dhabi emirate, and includes the acquisition and interpretation of geophysical and seismic data that will complement the mapping work. A nationwide programme of geophysical data acquisition using airborne remote sensing systems is being flown especially for the project. The data from this survey has been merged with legacy data from both onshore and offshore to provide full magnetic and gravity coverage for the entire country. In addition, the UAE has a wealth of seismic data derived from oil exploration held by the national oil company so a national network of seismic line data of different vintages is being reprocessed and interpreted, and then integrated with the mapping work. Our aim is to provide the first 3D geological framework for the whole of the country.

The UAE government has also asked the BGS to undertake strategic mineral resource surveys of limestone, industrial minerals, platinum group elements, and dimension stone. Good reserves of high-quality limestone and dolomite suitable for cement production and the chemical industry occur in the northern Emirates, and these are being exploited particularly around Ras al Khaimah. Extensive outcrops of gabbro and basalt associated

Sand dunes migrating across gravel plains, south-western UAE.

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Wind-eroded zeugen of cemented Quaternary palaeodunes near Abu Dhabi.

with the UAE–Oman ophiolite form good reserves of hard rock aggregates, some of which are suitable for future development.

We are due to complete the mapping in 2012, but it has already provided new insights into the geological history of the UAE over the past 50 million years. In particular it has clarified the Neogene stratigraphy of the foreland basin that developed during the uplift of the Zagros and Hajar Mountains. However, it is perhaps the Quaternary that has proved the most fascinating. Much of the UAE is covered by extensive wind-blown (aeolian) dune sands forming low-lying sandy deserts that extend south to the Rub al-Khali or 'Empty Quarter'. However, this epithet belies the complexity of dune forms that occur, and these have now been mapped for the first time. We have also mapped older cemented palaeodunes that represent several phases of early dune development, interspersed by wetter climatic events. In places near the coast, these older dunes have been eroded to form spectacular zeugen, locally capped by raised marine sediments. These provide insights into local and eustatic sea-level change.

The mapping of the Quaternary deposits has provided us with a better understanding of the past climate of the Arabian Peninsula. Quaternary wind-blown, alluvial fan and wadi sediments can be used as proxy indicators for the changing climate over the past few hundred thousand years. As Arabia is situated at the nexus of three continents, its location makes it susceptible to changes in global weather systems, particularly shifts in the position of the intertropical convergence zone (ITCZ) and the varying influence of the Indian Ocean monsoon and the Atlantic westerlies.

The current geological mapping has identified extensive alluvial fan, wind-blown and lake deposits that indicate significantly wetter periods have occurred at various times during the Quaternary. We are investigating one particular exposure near Al Ain in detail through collaboration with Oxford Brookes University. We have used geochemical analysis and dating of the interbedded alluvial fan and aeolian sediments to develop a framework of landscape evolution and environmental change through the late Quaternary. The resulting palaeoclimate record from Al Ain can be correlated with other proxy records from marine sediments and ice core records. Analysis of these sediments depicts a dramatically changing environment, which while predominantly arid, is punctuated by much wetter periods, notably during Marine Isotope Stages 5 and 6 (around 150 000 to 74 000 years ago).

The timing of these arid and humid phases is important to the history of human migration. Arabia has played a critical role in the dispersal of human populations out of Africa over the course of the Late Pleistocene (128 000 to 12 000 BP) when the climate of Arabia periodically oscillated between hyperarid and humid conditions. During the wetter periods, reactivation of the wadi and alluvial fan networks created corridors of fresh surface water, allowing humans to occupy and migrate through the region.

This international, multidisciplinary project is an excellent example of how geological mapping can be used not only to underpin national infrastructure development, resource evaluation and planning, but can also help answer more fundamental research questions.

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Burj Khalifa, the world's tallest building nearing completion, Dubai.