ILP TASK FORCE on SEDIMENTARY BASINS

2009 International Workshop

December 6th-11th, 2009, Abu Dhabi (United Arab Emirates)

CRUSTAL STRUCTURE of the UAE - EVIDENCE from DEEP SEISMIC REFLECTION DATA

Tim Pharaoh, Andy Chadwick, John Rowley.
British Geological Survey, Keyworth, Nottingham, NG12 5GG
tcp@bgs.ac.uk

Regional deep seismic reflection lines were acquired for the Ministry of Energy, UAE, in 2003. The lines were acquired and processed by WesternGeco, with quality control of these operations carried out by BGS. Subsequently special processing operations (including pre-stack depth migration, Gardner-style refraction processing and section balancing) were carried out by IFP.

Two lines (D1 and D4) are regional dip lines, crossing the country from the coast of the Arabian Gulf in the west to the coast of the Gulf of Oman in the east, and up to 90 km long. They cross sequentially the foreland basin, the overthrust mountain front, the telescoped Mesozoic continental margin, the Semail Ophiolite and its metamorphic substrate. The northernmost line (D4) also crosses the 'Hawasina'-type melange. Two further lines are shorter strike lines crossing the foreland basin (D3) and the ophiolite (D2), which tie the dip lines.

In the west, the deep seismic lines clearly image the internal structure of the Permian-Mesozoic carbonate platform overlying the Arabian shield. These strata are correlative with those exposed in the Musandam mountains further north. The base of the sedimentary sequence is imaged at 5.5 s TWTT (about 11 km depth). A reflective lower crust overlies the reflection Moho at 15 s TWTT (about 42 km depth). These figures are estimates due to poor velocity control. The Moho deepens eastwards across the platform. Although a velocity pull-down effect may be present due to the eastward thickening pile of the Late Cretaceous foreland basin, flexure of the crust beneath the basin, resulting from lithospheric loading by the obducted Semail Ophiolite, also contributes. In the mountain front area, the carbonate strata are involved in at least two antiformal ramps at the eastern edge of the foreland basin. These form important traps for hydrocarbons migrating into the foreland, e.g. the Sajaa field. The detachment for these relatively thick-skinned parautochthonous nappes lies within, or close to the base of, the Permian sequence. The inferred displacement at this level observed on line D1 is of the order of 10km. Reflections continuing beneath the ophiolite show that the carbonate platform may perhaps extend as far east as line D2.

On line D4, the involvement of the entire Musandam sequence in a major antiformal ramp, is demonstrated. This is interpreted as an out-of-sequence structure, probably generated during the Zagros Orogeny, with a further translation of at least 10 km. The rear of the structure is truncated by the Dibba Zone, inferred by BGS to represent the telescoped early Cretaceous margin of the platform. The structural complexity of this zone is known from the surface mapping and its components are rather poorly reflective, so the present seismic interpretation is necessarily schematic.

The major part of the Hajar mountains are composed of the Semail Ophiolite, and metamorphic rocks across which it was obducted. There is an active and ongoing debate on the origin of the latter. Do they represent allochthonous components of the Arabian Shield, or even more exotic microcontinental relics? Unfortunately the seismic data do not resolve this issue, and indeed are of rather poor quality to the east of line D2. In this area, the lower crustal reflectivity and reflection Moho are offset to a higher level, about 14 s TWTT, and possibly even shallower levels approaching the eastern coast. Better velocity control is required to evaluate the role of velocity pull-up (due to the presence of the ophiolite and metamorphic rocks at shallow crustal level) and possible extensional thinning of the crust associated with development of the Gulf of Oman.

On the other hand, the deep seismic data do provide valuable information on the present thickness of the ophiolite and possible emplacement mechanisms. Special processing by IFP has revealed that the ophiolite is presently less than 1.5 km thick along the wstern part of line D1, and thins to 700 m across a structural culmination in the vicinity of line D2. As the culmination mirrors the eroded surface of the ophiolite, overlain by Miocene strata, it is inferred that the structure represents an expression of uplift during and after the Zagros Orogeny. The present morphology of the ophiolite resembles that of a glacier, with segments of compressional and extensional flow, driven by gravitational spreading. Some compression appears to have affected the overlying Miocene strata, and it thus appears that the ophiolite may have suffered spreading since the Zagros orogenic uplift. The glacier analogy represents an attractive mechanism for the generation and deformation of the ophiolitic part of the melange as a continuum process, at least at high crustal levels.

The ophiolite (and the mountains) are truncated at the eastern coast by the faulted margin of the sedimentary basin underlying the Gulf of Oman, filled with Oligocene and younger strata. Unfortunately the deep seismic reflection lines do not extend across this margin and so cannot contribute to the debate concerning the evolution of this basin, the origin of its basement or the magnitude of crustal attenuation.

It is hoped that further reprocessing of the deep seismic reflection lines in the near future may provide an even sharper focus on the processes involved in the obduction of the Semail Ophiolite, the evolution of its foreland basin and subsequent uplift history.