Peace and Science in the Middle East

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The ancient cultures of the Middle East and the modern political conflicts there are shaped by a surprisingly diverse and youthful landscape. The landscape of the region is dominated by the rift valley, a 20-30 km wide valley, much of it below sea level. It is sunken between the western highlands of Israel and the Palestinian Territories and the eastern highlands of Jordan. The topographic barriers were significant enough to help create different kingdoms and cultures, yet not significant enough to prevent interaction among these cultures through commerce and war. The north-south oriented rift valley was also an important migration route for early humans, and is still a migration route for fauna, particularly birds from Africa to Eurasia.

What caused this landscape of a rift valley and the uplifted shoulders? The Dead Sea rift is a strike-slip fault, or a continental transform, that offsets the Arabian plate against the African plate. Other continental transforms, such as the San Andreas and the Northern Anatolian faults, do not exhibit a rift-like morphology. Therefore, some other forces or processes must be active here in addition to the lateral displacement of two plates. These processes could include transtensional motion along the fault, sub-lithospheric mantle flow extending northward from the Red Sea, or flexural uplift resulting from a break of a pre-stressed continental lithosphere, or transtensional motion along the fault.

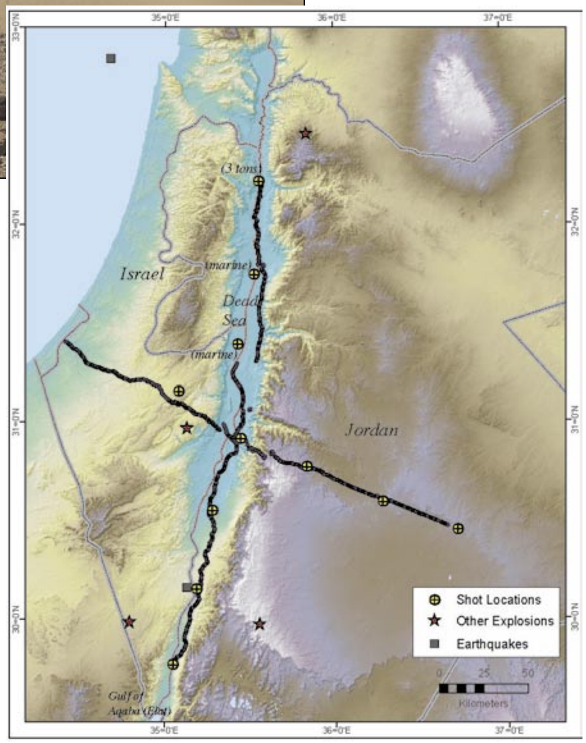
The rift geology has been studied in detail for almost a century, but the answer to this question is still elusive. Regional subsurface studies have been hampered by the political situation in the region. The peace treaty between Jordan and Israel, and the Oslo agreement between Israel and the Palestinians opened the door for scientists to cooperate on regional projects, although the security situation and the occasional conflicts still pose substantial hurdles. As part of a USAID-funded project, a plan to collect high-resolution seismic reflection profiles across the Dead Sea fault systemwas developed, but was not carried out after months of preparations because of security concerns.

THE PASSCAL EXPERIMENT

A new plan was devised and executed within four months that included using explosives instead of vibrator trucks as acoustic sources, and stand-alone seismometers instead of the Geophysical Institute of Israel's (GII) cabled multichannel seismic acquisition system. The University of Texas at El Paso (UTEP), and IRIS provided 755 seismometers, seismic recorders, and support staff on short notice. Permits were obtained to deploy seismometers along the Jordan River, a closed military zone, and within the property of the Arab Potash Company, and to transport and detonate 16.5 metric tons of explosives, in some cases in closed military zones. Commercial companies in Jordan and Israel were contracted to carry out the drilling, loading, and the detonation of the explosives.

The experiment, which took place in October 2004, consisted of two wide-angle seismic reflection and refraction profiles: a 280-km long profile along the international border between Jordan, Israel and the Palestinian Territories at the center of the Dead Sea rift, and a 250-km long profile from Gaza Strip to eastern Jordan across the Dead Sea rift. Eleven large underground explosions were detonated including a 3-ton explosion that was detonated at the bottom of a 35-meter hole in the Jordan Valley and two 750-kg explosions, each suspended at a depth of 50 meters below buoys in the Dead Sea. The 3-ton explosion was part of a US Department of Energy grant to Dr. Yefim Gitterman of GII. The marine explo- →

The lower Jordan River Valley about 10 km north of the Dead Sea. The brush-covered area is the actual river valley, which is incised within the 20-30 km wide rift valley. The western highlands rise in the background.



(left) Two vehicles mark the location of shotpoint 3, 50 km south of the intersection of the two profiles shown below. (below) Seismic refraction experiment location map. Black dots are seismometer locations. The various sources used in the experiment are identified in the legend.

sions were recorded on the permanent GII seismic network as the equivalent of earthquakes with local magnitude of 3.2 and 3.0. The study was augmented in 2005 by a survey of the gravity and magnetic fields along the seismic lines.

Miniature stand-alone seismic recorders (Texans) attached to single vertical 4.5 Hz geophones recorded the acoustic signal. Both the geophones and the recorders were buried a few inches below the surface to improve the signal quality and to prevent vandalism. The instruments were sent to the Middle East, (169 to Israel, and 598 to Jordan), and were deployed in the field, generally at distance intervals of 650 m with occasional larger intervals. At total of 409 instruments were deployed along a north-south line within the rift valley in Jordan and the remaining 334 instruments were deployed along an east-west line crossing the rift at the south-central part of the Dead Sea basin.

Instruments could not be left in the field for more than a week because of limited battery power. Eight teams worked simultaneously to speed the deployment and collection of this large number of instruments. Each team consisted of two people, and occasionally a soldier. Deployment lasted one to two days and the collection took another day. Local Bedouin guards were hired in a few places to prevent theft and vandalism. Nevertheless, five instruments were lost and four could not be found. Jackals carried one instrument into a minefield where it remains today because it is too dangerous to retrieve. Jackals also pulled up geophones of several other instruments, but only a handful of recorders had electronic problems.

For security reasons, all 11 explosions were detonated during daylight hours. Jordanian boreholes also had to be shot on the same day they were loaded, while Israeli boreholes could be loaded a day or two in advance. All 11 shots were detonated in two consecutive days making for a tight schedule. Time windows for shots were assigned to the Israeli and Jordanian shooting teams. Additionally, natural earthquakes and commercial mining explosions were recorded during this time period. The entire dataset of explosions, earthquakes, and mine shots is being used to obtain 2-D models of P-wave velocity along and across the Dead Sea rift, as well as 3-D tomographic images of the sediment and crust of the area.

INITIAL RESULTS

First results from the seismic profile across the rift show the Dead Sea basin fill to extend to between 6.5 and 8 km depth, with a low P-wave velocity (5.4-6.3 km/s) under the basin extending to 17 km depth, which may include pre-rift sediments and upper crustal rocks. However, there is no effect of either the basin or the plate boundary on the crustal structure between 17 and 30 km depth. As expected, there is significant difference in the structure of the upper crust between the east and west shoulders of the rift. Shallow P-wave velocity within 20 km east of the rift is high because uplift and erosion have brought crystalline basement close to the surface. Interestingly, the deformation involved with the uplift of the rift shoulders may not extend deeper than 15 km or farther than 100 km from the rift. These results may indicate a stratified rheology of the continental crust and may be significant in understanding lower crustal deformation in strike-slip regimes. ■

ACKNOWLEDGEMENTS

The project was funded by USAID Middle Eastern Regional Cooperation Program grant M21-012. Matching funds and encouragement by the USGS, Al-Balqa' University (Jordan) and the Geophysical Institute of Israel are gratefully acknowledged. We thank USGS administration and the President of Al-Balqa' University for their support. We appreciate the support of the head of the Military Intelligence, Jordanian Army, and his staff in facilitating the logistical aspects of the experiment. David Simpson and Jim Fowler from IRIS provided administrative help. We thank Ilan Nixon, Gal-Yam Co., Israel, Dr. Bassam Fakhouri, Chemical and Mining Industries Co. of Jordan, Kobi Shimon, Arad Mineral Ltd., Israel, and Shabat Drillers, Ltd., Israel, for their work. Special thanks are given to Tip Meckel, Galen Kaip, and Matt Averill for their help in the field and to the Jordanian field assistants and security personnel who worked long hours in scorching heat during the Fast of Ramadan.