Locate Shallow Fault with Seismic and Resistivity Tomograms, S-wave tomogram, and Surface Waves Common-offset Gathers

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Abstract

2D geophysical methods are used to detect the presence of the buried Qademah fault near King Abdullah Economic City (KAEC). The fault location is confirmed by several geophysical methods including 2D resistivity tomogram, 2D refraction traveltime tomogram, and 2D reflection image. A 3D seismic data set is conducted at the same location, where surface waves are used to find the S-wave phase velocity of the shallow layers. The S-wave velocity tomogram shows a large velocity gradient across the interpreted fault.
The common-offset gather constructed from the recorded active-source data show a large delay in the surface wave arrival times which is associated with the location of the fault.

Field Example

The Qademah fault is Quaternary in age or younger than 1.8 Ma as some of the sea shells on the fault scarp still retain traces of original color (Roobol and Kadi, 2008). This fault is very poorly exposed as it cuts unconsolidated Tertiary and Cenozoic sediments of the coastal plain, so that the fault scarps are often eroded or represented by low gravel banks. This fault can be traced along a north-south distance of 25 km on geological maps (Roobol and Kadi, 2008), however, it is shown on these maps as an inferred fault. A geophysical study is needed along the fault to map its extension.

Further studies are required to verify or prove that the Qademah fault exists south of its exposed portions. This can be achieved by geophysical studies and trenching through the expected location of the fault. The Qademah fault is one of the Red Sea coastal plain faults, which have formed due to the opening of the Red Sea. As this process continues today one cannot say that these faults are inactive. A paleoseismicity study is required to demonstrate the age of the movement history of the fault.

Two sites are selected for the current study located at the northern and southern parts of the fault (Figure 1). In the northern site we conducted 2D seismic and 2D resistivity surveys, while in the southern site we conducted only 2D seismic survey.

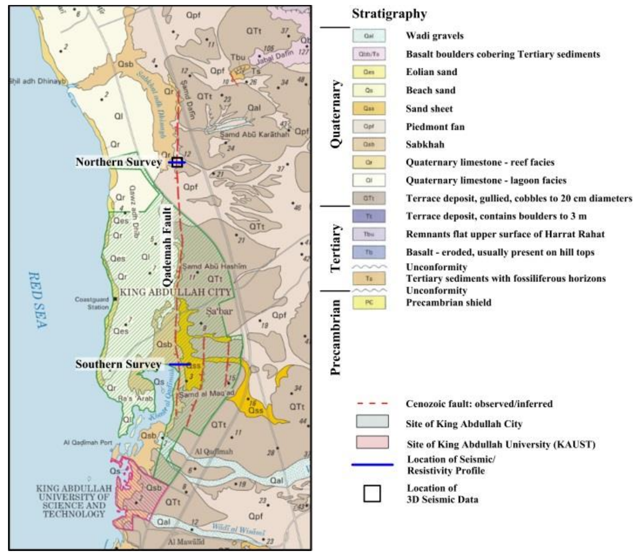

Figure 1: The surface geology map of the study area shows the location of the northern and southern sites, after Roobol and Kadi (2008).

The result from the northern survey is shown on Figure 2, where Figure 2a shows the resistivity tomogram, Figure 2b shows the refraction traveltime tomogram, and Figure 2c shows the reflection stacked section. The location of the Qademah fault is shown on both seismic and resistivity tomograms (Figure 2a and 2b) and on the reflection stacked section (Figure 2c). For more details on the northern survey see Hanafy (2012). We selected a small area at the northern location of the Qademah Fault to collect a small 3D seismic data set. Vertical component 40-Hz geophones were deployed inside the black rectangle in Figure 1b, where 288 receivers are arranged in 12 lines with 24 geophone/line, here the inline offset is 5 m and the crossline is 10 m. We collected 288 CSGs using a 40 kg accelerated weight drop as the seismic source.

The 3D seismic data set is used to find the S-velocity from the surface waves. The S-velocity estimated from the surface waves corresponds to the average S-velocity to a depth of about one wavelength. The S-wave phase velocity tomogram is shown in Figure 3, and the location of the Qademah fault is shown at the eastern side of the tomogram at the offset = 90 m. Another possible fault runs in a North-South direction and parallel to the Qademah fault at offset = 50 m as shown by the dashed line on the tomogram. The interpreted colluvial wedge due to the Qademah fault is shown as a low velocity anomaly located between the two faults, while the low velocity anomaly at the western side of the tomogram corresponds to the Sabkha deposits (Figure 1).

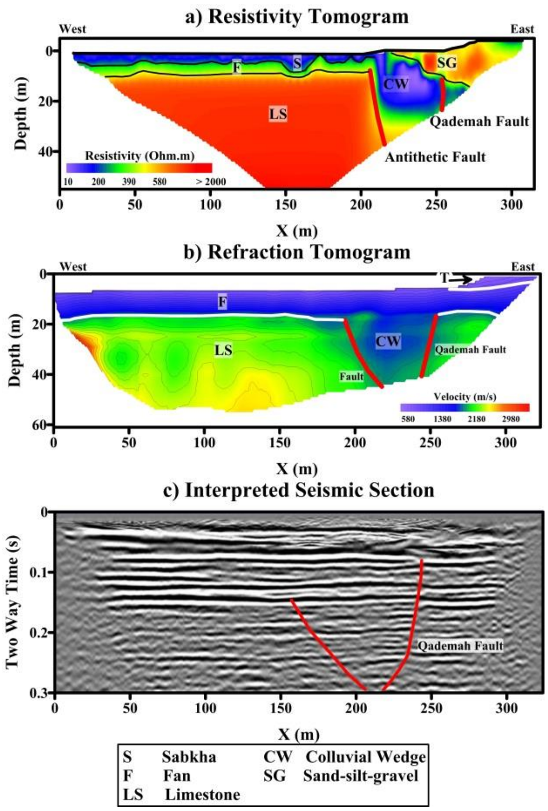

Figure 2: a) The resistivity tomogram, b) the refraction tomogram, and c) the reflection stacked section of the northern site. The Qademah fault is shown on both tomograms and on the reflection stacked section.

To map the extension of the fault toward the south we selected a couple of locations where seismic data was recorded; in this work we will show only the most southern part (Figure 1). Figure 4a shows the refraction traveltime tomogram, here, the Qademah fault is clearly shown on the tomogram at offset X = 270 - 300 m. Figure 4b shows the common-offset gather with source-receiver offset of 50 m, the gradual increase in the surface-waves arrival times between X = 100 m and X = 270 m is associated with the low velocity anomaly shown on the refraction traveltime tomogram (Figure 4a) at the same offset range. The Qademah fault is located at the SE end of this low-velocity anomaly (Figures 4a and 4b).

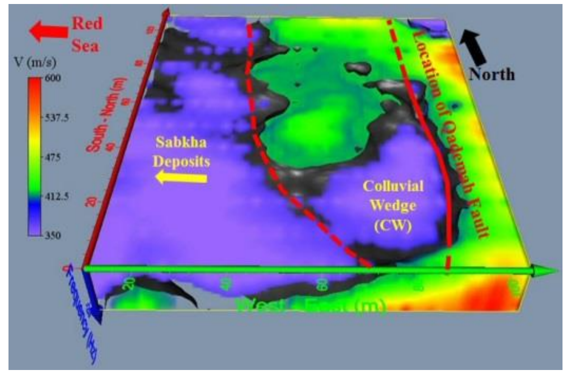

Figure 3: The S-wave phase velocity tomogram.

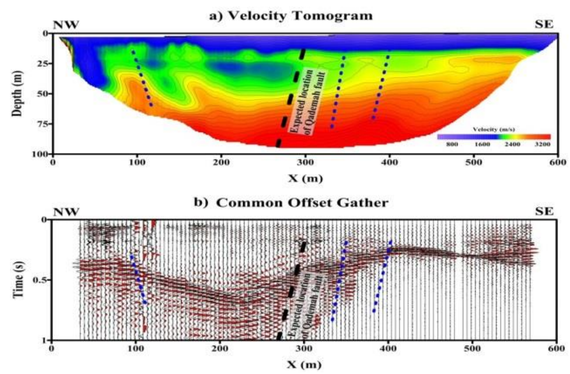

Figure 4: a) the refraction tomogram and b) the common-offset gather with source-receiver offset of 50m.

Summary

We used 2D and 3D seismic data and 2D resistivity images to find the location of a hidden-shallow fault known as Qademah fault. The 2D traveltime tomogarm and the 2D resistivity images show the location of the interpreted colluvial wedge associated with the Qademah fault. The seismic stacked section and common-offset gather image show a discontinuity in the seismic events at the location of the fault.

References

Hanafy, Sh. 2012. Subsurface fault and colluvial wedge detection using resistivity, refraction tomography and seismic reflection. EAGE meeting, Copnhagen, Denemark.

Roobol, M. J. and Kadi, K. A., 2008. Cenozoic faulting in the rabigh area, central west saudi arabia (including the sites of king Abdullah economic city and king Abdullah university of science and technology. Saudi Geological Survey, SGS-TR-2008-6, 1–12.