Identification of Buried Normal Faults with GPR: A Case Study in the Büyük Menderes Graben, Western Turkey

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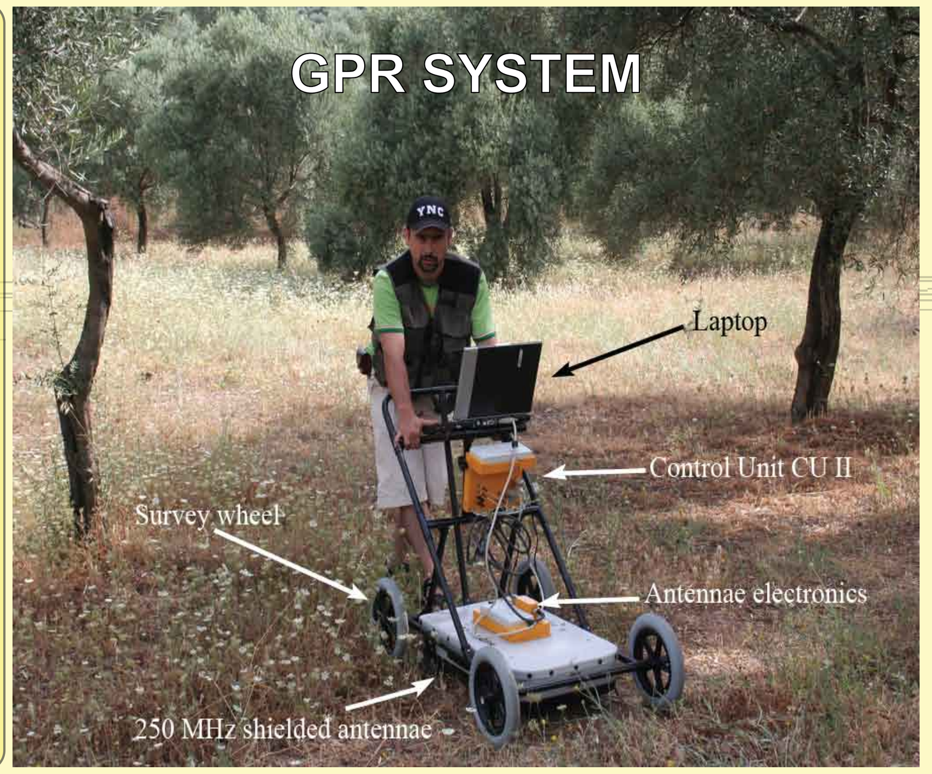
ABSTRACT

Location of a fault is important in active fault studies. Since the motion is vertical in normal faults, they are characterized by scarp in the field. However, scarps of normal faults in unconsolidated units are not resisted for a long time and are removed as a result of either geological processes (such as erosion, sedimentation) or man-made activity (such as agriculture, modification). In such environments, it becomes difficult to locate the fault on the basis of geological and geomorphological observations.

Ground Penetrating Radar (GPR) is a shallow geophysical method and this method has widely been used in active fault studies but most studies have been concerned with the location of buried structures. The GPR method works on the basis of recording of the reflections of the electromagnetic waves from the interfaces by a horizontal receiver which were transmitted to the ground with high velocity by using a horizontal antenna. Data collected is filtered to eliminate the environmental and instrumental noise by using computers and then interpreted to determine the buried structures in high resolution and sensitivity. New types of shielded GPR antennas provide more rapid and reliable results with high resolution, providing that the following parameters can be considered to get significant GPR data in paleoseismology: i – The thickness of young sediments which in general, are conductive; ii - topographic differences between the beginning and the end points of profiles; iii - the reflection characteristics from surface objects (e.g. electrical poles, vegetation, trees); iv - the GPR profiles should be perpendicular to the fault zone.

In this study, we performed GPR in two sites in the Büyük Menderes Graben that is one of the most active tectonic structures of western Turkey. Boundary faults of the Büyük Menderes graben reactivated in historical times. However, in some places, surface ruptures of historical events are not visible at the surface as a result of sedimentation, erosion and modification. The GPR method was applied to locate the ruptures of historical events where they do not provide any evidence at the surface. Without performing GPR, field observations alone would not be capable of recognizing fault traces. In addition to locate the fault, we tried to identify borders of offset stratigraphic units from contrasting electrical properties, such as grain size distribution (sorting, clay content), porosity and water content that would help to estimate vertical offset on the fault. On the basis of GPR studies, trenches were conducted in these locations to compare the GPR results with exposed evidence. Comparison of trench data with the GPR results showed a good correlation especially in planar surfaces (faults) and main stratigraphic units.



OBJECTIVES

i. Determine Exact Location for Trench Studies, *ii.* Identify Displacement on the Geological Units, *iii.* Determine Optimal Survey Parameters for GPR Studies on Paleoseismology Study Sites.

BUYUK MENDERES GRABEN (BMG)

The Büyük Menderes graben is one of the principal active structures of Western Turkey (Figure 1a) which is one of the most seismically active regions of the world (Jackson and McKenzie 1988). The width of the E-W-trending Büyük Menderes graben changes between 8 and 12 km (Cohen et al. 1995, Bozkurt 2000) (Figure 1b).

Surface ruptures of historical earthquakes are partly visible along the graben (on archaeological features) but most evidence for faulting is not exposed either as a result of geological processes (erosion and sedimentation) or man-made activity. Thus, GPR method has been applied in two sites (Figures 1c and 1d) to locate faults that are not visible at the surface and to estimate vertical displacement on each faulting.

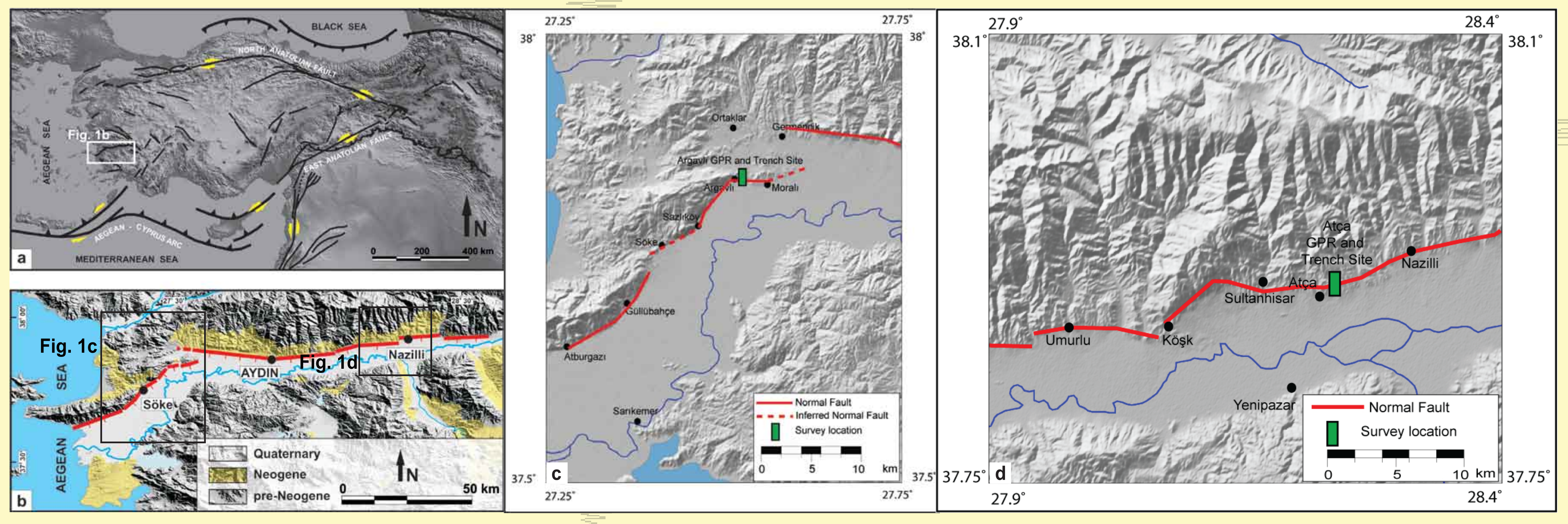


Figure 1: (a) General tectonic setting of Turkey. (b) Simplified geological map on shaded relief (SRTM) of the Büyük Menderes Graben (with the main fault in red line) showing general geological units and lithology (Altunel et. al. 2009). (c) Shaded relief image with active faults at Argavlı trench site in western part of the Büyük Menderes graben. (d) Shaded relief image shows active faults and Atça trench site in northern part of the Büyük Menderes graben.

Acquisition Parameters of GPR Survey

Antenna Freq.:	500 MHz	250 MHz
Trace Interval:	5 cm	10cm
Samples:	512	512
Sampling Freq.:	6755 MHz	2607 MHz
Time Window:	76 ns	196 ns

Processing Steps

	500 MHz	250 MHz
Move Start time:	6 ns	12 ns
Subtract-mean Dewow:	2	4
Energy Decay:	0,512	0,512
Subtracting Average:	31 / 3 ns	31 / 6 ns
Band-Pass Filtering:	200/400/600/800	100/200/300/400

ARGAVLI TRENCH SITE

Based on disturbed reflectors, we identified main faults in the studied sites. The interpreted GPR profile suggests four south-facing main faults in the Argavlı site (F1-F4 in Figure 2). Faults F1 and F2 terminate about 1 m and 70 cm below the surface respectively, while faults F3 and F4 are about 50 cm below the surface (Figure 2). Trench log shows more than four faults in the Argavlı site (Figure 2). It is worth to note here that the trench log exposed more faults but their positions in the interpreted GPR profile are consistent with the faults in the trench log.

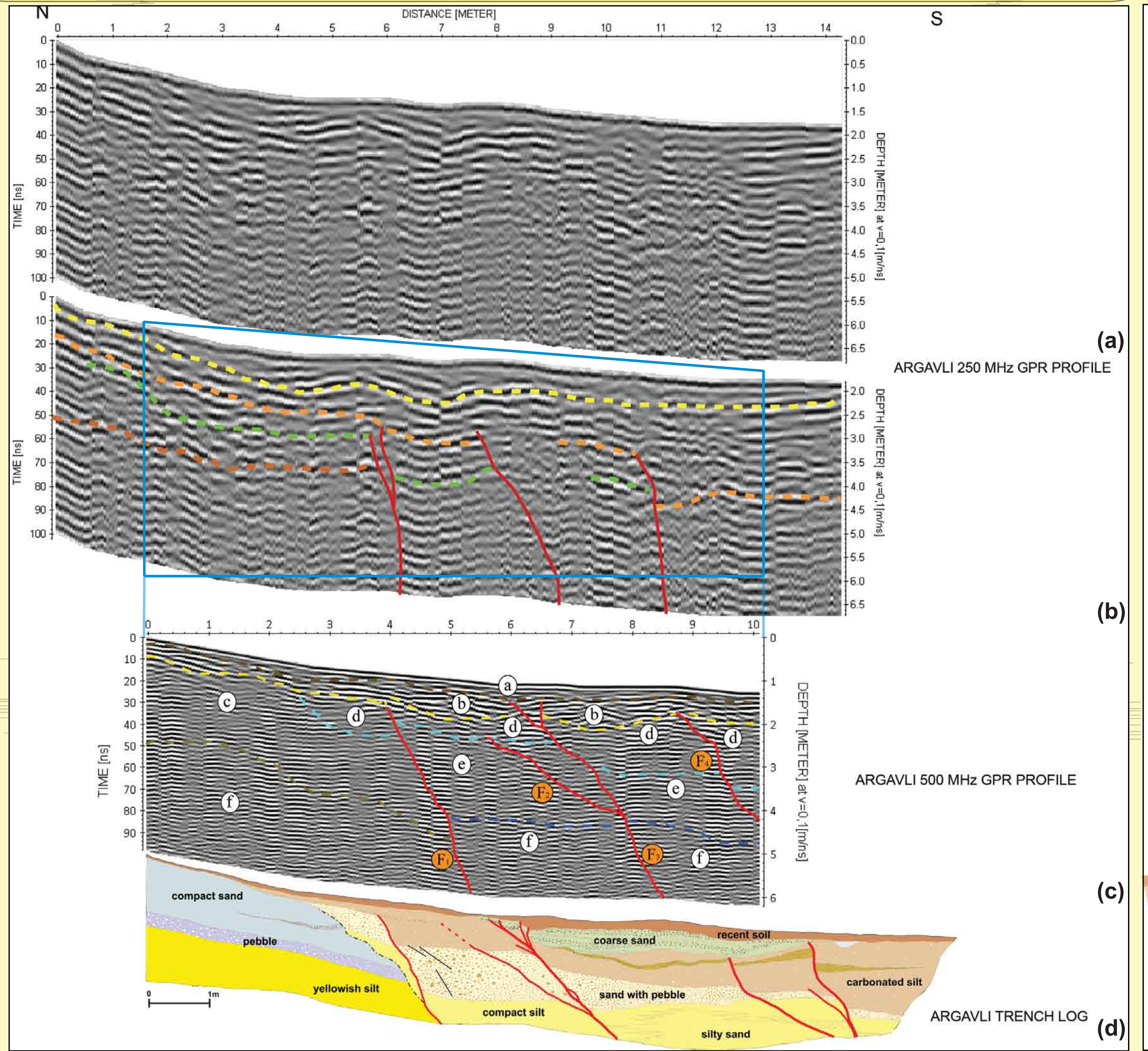


Figure 2: Comparison of the 250 MHz and 500 MHz GPR profile with the trench log in the Argavlı trench site. (a) 250 MHz processed profile, (b) 250 MHz interpreted profile. Dashed lines represent the interfaces; red lines represent possible faults. (c) Interpreted 500 MHz GPR profile. Dashed lines and letters from "a" to "f" represent the interfaces; red lines and letters from "F1" to "F4" represent possible faults. (d) Trench log. All figures are in the same scale and there is no vertical exaggeration.

ATCA TRENCH SITE

In the Atça site, the interpreted GPR profile suggests two south-facing main faults (Figure 3). The fault F1 is a single line and it terminates about 1,5 m below the surface, while the fault F2 is branching upwards and both branches terminate about 50 cm below the surface (Figure 3). The trench log also shows two faults in the same places (Figure 3). The faults positions are in harmony with the GPR interpreted profile. Furthermore, the log showed that fault F2 is a 70 cm wide fault zone including more than one fault plane.

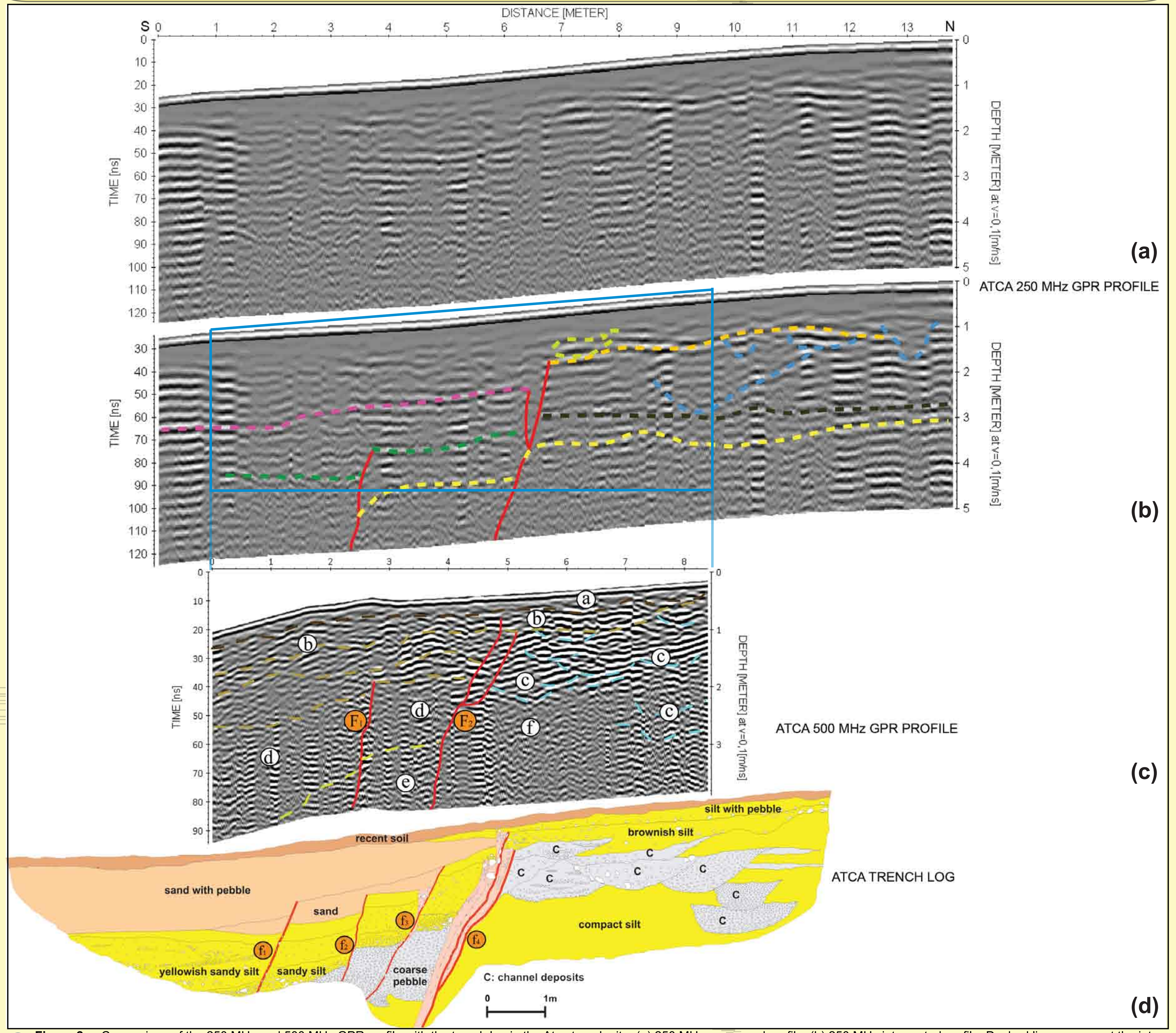


Figure 2: Comparison of the 250 MHz and 500 MHz GPR profile with the trench log in the Atca trench site. (a) 250 MHz processed profile, (b) 250 MHz interpreted profile. Dashed lines represent the interfaces; red lines represent possible faults. (c) Interpreted 500 MHz GPR profile. Dashed lines and letters from "a" to "f" represent the interfaces; red lines and letters from "F1" to "F2" represent possible faults. (d) Trench log. All figures are in the same scale and there is no vertical exaggeration.

CONCLUSIONS

In this study, we have used GPR prospecting in some locations along the northern flank of the Büyük Menderes Graben where the main fault is not visible at the surface due to erosion, sedimentation and human activity. Trenching was conducted on the basis of GPR studies that helped to locate faults precisely. GPR and trench studies gave striking results in the Büyük Menderes graben, especially in regions with suitable geological (dry and clay-free) and geomorphological (low inclination) conditions. Therefore, GPR has considerable contribution to trench studies. In addition, in regions where trench excavations are not possible, GPR surveys might provide important information for active faults.

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