EARTHQUAKES AND GROUND RUPTURE, EASTERN GULF OF CORINTH REGION, GREECE

By Ebasco Services, Incorporated

The following eye witness accounts of surface effects of recent (February 24 through March 7) earthquakes were put together by Norman Tilford and other members of the geotechnical staff of Ebasco Services Incorporated. All except Norm were in Greece engaged in a siting study for a nuclear power plant at the time of the initial quakes. Norm arrived in Greece on the second day after the initial events and remained through March.*

On February 24, 1981 at 22:57 Greece time, a destructive earthquake with a Richter magnitude of 6.7 occurred in the eastern Gulf of Corinth region of Central Greece. An aftershock with a Richter magnitude of 6.4 followed at 4:36 on February 25. One or both of these earthquakes caused ground rupture along two traces on the south side of the Gulf of Corinth at locations shown in Figure 1. Ground displacement on one of these traces is shown in Figure 2. A series of hundreds of lower magnitude aftershocks followed until March 4 at 11:58 Greece time when a Richter magnitude 6.2 event occurred in the Gulf of Corinth region, followed on March 5 by a Richter magnitude 5.2 event at 03:10 and a magnitude 5.7 event at 08:57. Aftershocks with lower magnitudes followed. Ground rupture on the north side of the Gulf of Corinth resulted from the March 4 and 5 earthquakes (Figure 1). An aerial view of one of these ruptures is shown in Figure 3.

Following the initial earthquakes Ebasco Services, Inc. established an ongoing program by geologists and geotechnical engineers, operating by helicopter and on the ground, to evaluate the earthquakes for geotechnical engineering, geological and seismic data. Norm Tilford flew from the United States on the second day after the initial earthquakes to join AEG members Robert Cannon, David Amick, Sarah Wilkinson, and other Ebasco staff already in Athens. He arrived in time to catch the first helicopter overflight of the southern epicentral region and locate the first surface rupture segment. Others along on that first exciting search were Robert Cannon, Ebasco's geology program leader in Greece, and David Amick. Norm, Robert, and Samir Khoury, Ebasco's Project Manager for Greece, overflew the second epicentral area on March 6, while Sarah Wilkinson, David Amick, Fred Snider, and Myron Temchin went into the area on the ground.

Ground investigations include detailed mapping and surveying of the rupture traces and measurements of past and continuing shoreline uplift and subsidence along the eastern Gulf of Corinth. Cooperatively with the Seismological Institute of the University of Athens, Ebasco has installed six portable MEQ 800 seismographs, an accelerometer, strain guages, tiltmeters, and water level recorders strategically located in and around the area of the earthquake swarm to gain a better understanding of seismic and tectonic activity in the area.

On March 3, Norm Tilford and Myron Techin reported the following from the area of Agios Sotira on the south side of the Gulf of Corinth: The former beach line is visible below the water surface as a line of trash and an abrupt textural change from medium to coarse-grained sand above the former beach strand to coarse sand with gravel and cobbles below the seaward of that line. A derelict sand-filled boat was found nearby, now partially submerged, but without any marine growth on the presently submerged part. The lack of marine growth demonstrates that the boat was submerged recently.

Stairs from outdoor terraces on two restaurants at this location now extend down into the water. Formerly these stairs ended on the beach above the water, as evidenced by the lack of erosion at the base of the stairs by waves and the lack of marine growth on them. The depth of submergence of the former beach strand line measured at 14:15 hours was 59 cm. At that time, the tide was probably near its low ebb or had recently turned.

On the same afternoon shortly before 15:00 Tilford and Temchin were inspecting an area of subsidence at Schinos where a road is submerged below low tide level and sea water of the rising tide was pouring inland over former dry land where boats were stored above former high tide. Observations of this rising tide crossing and covering a second road and rising around a metal stake in the ground were being made to check rate of tide rise, when the water stopped rising and began to recede. This continued for 2 to 4 minutes, by which time the water was about 1 cm lower on the metal stake than before. At about 15:04 hours an earthquake of 2 to 3 seconds duration was felt. Within 2 to 4 minutes after the shock, which was reported by the National Observatory as a magnitude 4.6 event, the water level had again risen to its former level and continued to rise and cross the road. The breeze was constant in velocity and direction during these events.

This sequence demonstrates that the level of the land rose over a period of a few minutes at a rate greater than the rate of rise of the tide, the earthquake occurred, then the level of the land probably subsided, allowing the tide to continue to rise to cover the road. Possibly, however, the land did not subside after the earthquake but merely

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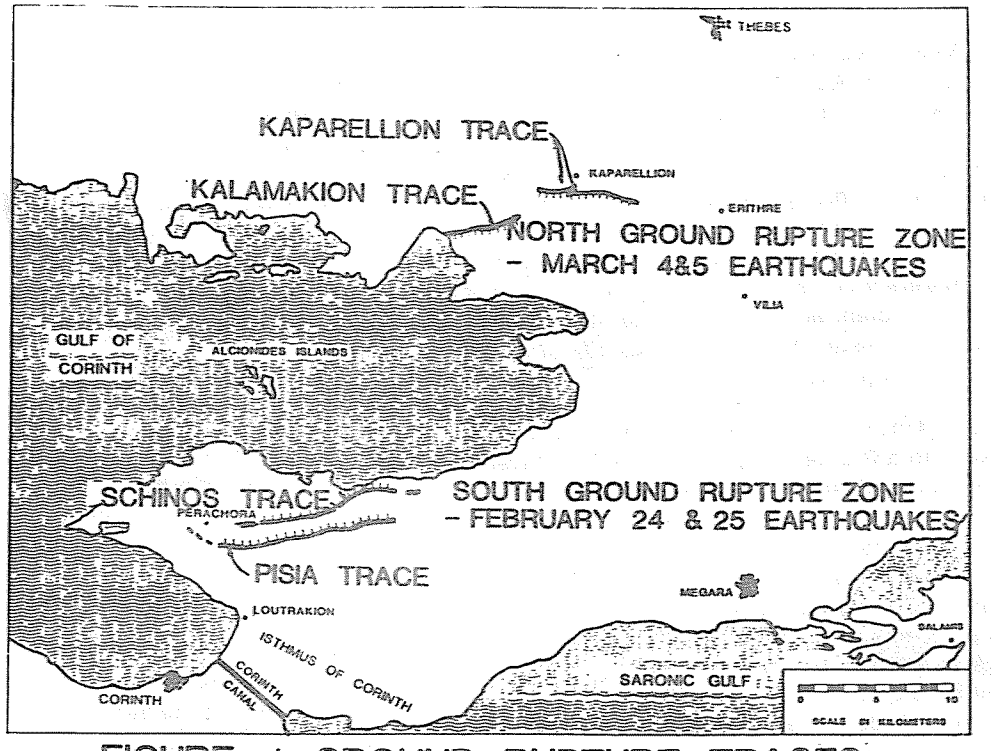

FIGURE 1 GROUND RUPTURE TRACES

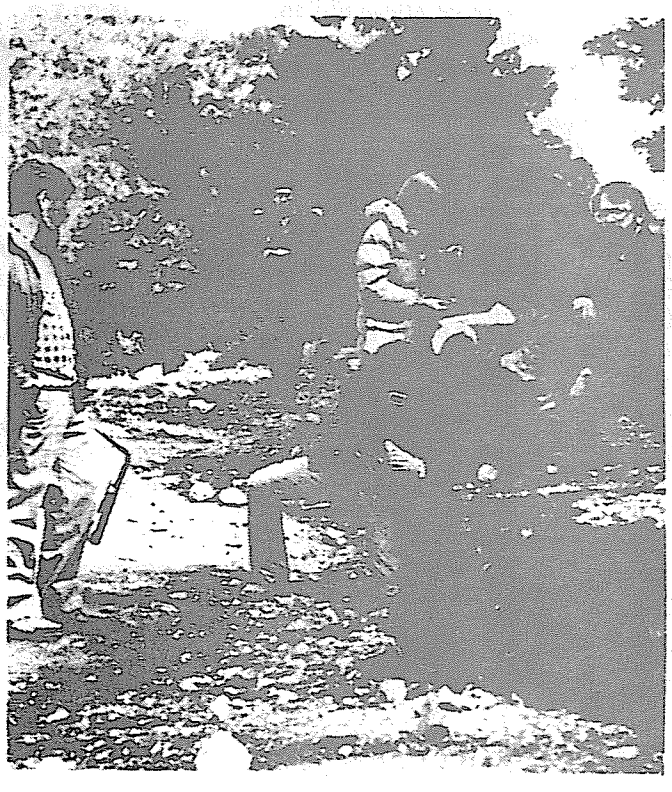

FIGURE 2. Ground displacement on the Schinos Rupture Trace. Mapping the trace are (left to right) Norman Tilford, Dr. Samir Khoury, Sarah Wilkinson, David Amick and Robert Cannon.

FIGURE 3. Aerial view of a portion of the Kaparellion Rupture Trace at a point where it crosses a narrow north-south road.

remained at its inflated level and was caught up with by the tide. This is unlikely since overall lowering of the land surface by perhaps as much as one meter (reported by local residents) was associated with the February 24-25 earthquakes. Therefore, it seems clear that whatever inflation of the land surface on the down dropped blocks precedes each shock, the net effect is subsidence.

On March 7, Robert Cannon and Myron Temchin were sketch mapping the rupture traces to the north of the Gulf of Corinth, preparatory to establishing scales and criteria for detailed leveling. In the early afternoon, they were working in a recently planted field. At that location, the vertical offset was 35 to 40 cm and the fracture was open 10 to 15 cm, except where wedge-shaped blocks had broken from one side of the fracture to close it up. At 13:35, an earthquake reported later to have a Richter magnitude of 5.7 occurred in the region. At the instant of onset, Robert and Myron were both standing by the open fracture. Myron looked down to see the fracture closing and opening, so in fear of liquefaction of the wet soil, he began to run toward the road. Robert stood still to make observations. The first sensation of the earthquake was motion, without sound. It gave Robert the feeling of stumbling, but without having moved his feet. Then Robert immediately felt the soil beneath his feet turn to "putty" and a small fracture beneath his foot started to pulse and open. He stepped away as the tremor continued and spread his feet to maintain balance. To avoid sinking in the soil, he had to continue "treading." Robert observed that the fracture was opening and slamming shut repeatedly and within the first second, a deep but quiet rumbling noise was heard along with a muffled, slapping sound as the sides of the fracture hammered together. Looking up the field in a direction parallel to the plowed rows and parallel to the rupture, he observed the individual rows of soil heaving and rolling so that the entire plowed surface appeared to be in disharmonic motion. Blocks of soil in and near the fracture zone were being tipped steeply from side to side. Myron observed similar motion as he ran the first 10 m, with his feet getting stuck in the soil. He also observed many small cracks opening parallel to the plowed furrows. The ground shaking was estimated to last only 4 to 5 seconds, followed by two loud "thunder" blasts about 8 to 10 seconds after the commencement of ground shaking.

Approximately 20 minutes after the earthquake, Robert and Myron drove to a lookout over the Gulf of Corinth and observed a newly formed silt plume extending out about 0.5 km in the water along the projection of the fracture trace. The plume obviously resulted from pumping of water and bottom sediments as the subaqueous fracture opened and closed during the earthquake. Reports from local residents indicate that a "geyser" occurred offshore in the area during that earthquake.

Dr. Samir Khoury was also on the surface rupture that Sunday about 7 km from Robert and Myron's location. Here is his story:

"I had noted from the helicopter on Friday, March 6, 1981, that the northern trace of the surface rupture terminated just north and west of the town of Platea. The eastern termination of the surface rupture died out in cultivated and recently plowed fields and did not reach the western-most main road heading north out of Platea. I drove there on March 7, 1981, with my family and a Greek neighbor. We observed the extensive damage in the towns of Erithrea and Platea and the town people explained that most of the serious and extensive damage had been caused by the recent March 4 earthquake. The towns were shaken by the February sequence with some resulting damage, but most buildings had remained intact.

Once out of Platea, we had no problem locating the closest approach of the surface rupture to the road. A large number of visitors were all driving in the same direction. We stopped a couple of kilometers north of Platea at the eastern entrance to a secondary road heading west. We were at this point about 500 to 700 meters from the trace of the surface rupture, which displaced the secondary road.

We decided to have lunch first and as we were standing around the back of the car, an earthquake struck. The onset was very sudden. We all felt while standing a very distinct up and down vertical displacement. It felt like jumping off the ground a couple of centimeters several times. This vertical motion lasted for perhaps 3 to 4 seconds. My daughter, who was running in a field to the east, did not feel this first motion. As we called her and she was beginning to come towards us, we all, including her, felt another jolt and vibrations lasting for a few more seconds. We all felt that there was a distinct gap between the first up and down motions and the following vibrations. The up and down motion was very distinct and very different from all earthquake shakings I had ever felt before. None of the numerous visitors appeared to panic although all of them felt and recognized the shaking as an earthquake. It was about 13:30 local time.

After lunch, we all walked towards the surface rupture and decided to split into two groups. Since I was most interested in studying the termination of the rupture within the cultivated field, I headed with my son and neighbor towards the southeast. We followed the surface displacement across a stream which it has displaced south side down. The displacement at that spot created a small water fall of 30 to 50 cm vertical drop. The width of the cracked and disturbed zone at this point was about 5 meters.

As we followed the displacement further east the vertical drop became noticeably smaller, on the order of 15 to 25 cm. I stopped to photograph and measure a section close to a deflection point. I was then standing on the down side of the fault zone in silty ground when another earthquake struck. I felt very distinctly the ground liquify under my feet and for a split second I had the impression that I was going to fall in the fault zone. It felt also like the down side dropped a couple of centimeters, but this may have been a side effect of the liquefaction I felt. The event lasted only a few seconds and I noted that the time was around 14:00 hours. After that I continued to work with no further excitement."

That sums up our first first-hand report from the field. Look for more in coming issues of the AEG Bulletin.