Report on KRRC Geomorphology, Summer 1997

Jay Noller[1], Lisa Wells[1], Eduard Reinhardt[2], Richard Rothhaus[3]
[1]Department of Geology, Vanderbilt University, Nashville, Tennessee
[2]Department of Earth Sciences, Life Sciences Bldg., Dalhousie University, Halifax, Nova Scotia
[3]Department of History, St. Cloud State University, St. Cloud, Minnesota

Introduction

In July 1997, a preliminary geomorphological reconnaissance investigation of the eastern Korinthia was conducted as prelude to a future archaeological survey. The geomorphic fieldwork had two goals: (1) to develop an understanding of the geologic framework of the region, and (2) to identify study sites and there make initial attempts at quantifying geologic indicators of landscape change. These data would form the cornerstone for future studies that would provide contextual information for an archaeological survey. The work was conducted by Professors Jay Noller and Lisa Wells, Dr. Eduard Reinhardt and Professor Richard Rothaus. Noller worked on soils and faults. Wells studied stratigraphic sections of recent alluvial and coastal deposits, and she ran the GPS survey. Reinhardt, Wells and Rothhaus worked on the indicators of coastline changes. Professors Noller and Wells were occasionally assisted by Ms. Kellie Townsend and Ms. Mary Plummer, both from Vanderbilt University.

Results of the 1997 Field Season

In 1997, our research group developed an understanding of the eastern Korinthia region, albeit limited, such that we generated numerous ideas and avenues to pursue for further study. Work performed during our limited stay in Korinthia provided us with enough information to submit a paper to the 1997 annual national meeting of the American Geophysical Union meeting in San Francisco (Appendix A), as well as to make what we hope will be successful attempts at raising grant funds.

Our objectives for our first, preliminary field season were

- Obtain and review previous geologic works
- Acquire topographic maps and aerial photographs
- Field Reconnaissance of eastern Korinthia
- Identify areas of rapid landscape change
- Assess tectonic setting
- Perform limited stratigraphic study
- Preliminary investigation of coastline changes
- Assess suitability of use of GPS technology in Korinthia
- Conduct initial GPS survey of areas of rapid landscape change

Prior Knowledge

Previous geologic studies of Korinthia focused on topics related to geological stratigraphy and tectonics, such as long-term structural development of the Isthmus (Sebrier, 1977; Vita-Finzi and King, 1985), stratigraphy of uplifted Quaternary marine deposits (Freyberg, 1973; Vita-Finzi and King, 1985), and seismology of historical earthquakes (Ambraseys and Jackson, 1990). Attempts to relate these physical changes in the Korinthian landscape with archaeology are limited and principally deal with earthquakes (e.g., Rothhaus, 1996). Little else seems to be known about local geomorphology of the eastern Korinthia, including soils, faults, hydrology, groundwater, and karst features, and the relationship of the landscape with human history.

Acquisition of Spatial Data Sets

The eastern Korinthia, as broadly defined, lies south of and includes the isthmus between mainland Greece and the Pelopponese, lies east of the Salomos (river), and north of Epidauvros. This large, 400 sq km region with its diverse topography, from broad marine abrasion platforms to rugged limestone peaks, requires a number of vantage points from which to understand its development during human history. Obviously, the more easily the information is obtained in a uniform manner over the entire region, the better. Thus, it is important that we identify as many broad spatial data sets as we can afford to acquire and interpret. Rothhaus has been instrumental in identifying and acquiring space-based imagery and topographic data (e.g., DEMs). During this season we obtained from the Greek government 1:50,000 topographic maps of the Korinthia region, 1:5000 topographic maps of the eastern Korinthia, and 1:10,000 aerial photographs of parts of the eastern Korinthia.

General Geomorphological Observations

We circumnavigated and criss-crossed the eastern Korinthia by vehicle. We strove to obtain vantage points from which to see the general layout of the region. We took backroads, both mapped and unmapped, across all major landscape units. Along the way we made stops for photodocumenting and describing natural and constructed cuts in Quaternary deposits and bedrock. Where exposed, soils were cursorily investigated.

At Ayios Vassilios, location and degree of pitting of the surrounding limestone, so-called micro karst, hints towards there being a soil mantle atccupation, and definitely before the construction, of the fortress. The road that leads south out of the fortress is of variable preservation; where most poorly preserved it has been eroded to a half meter or more of micro karst. Nearby terraced fields appear to have a number of ages of construction or maintenance. Lichens were investigated on the structural stones and natural outcrops. There may be a handful of lichen taxa worth measuring here as a calibration point for lichenometry, as well as for indicating relative age of stone surface exposure. The relationship of the fortress and the surrounding hillside geomorphology and soil resources would be a interesting relationship to investigate.

Sunken fields appear to be a new enterprise in the Sofiko area (Fig. 1). These fields are of recent excavation because of the non-eroded nature of the spoil piles adjacent to them. The fields are excavated to the ground water table in the enclosed basin of Zaramas, northeast of Sofiko. Corn was being grown in the sunken fields. The excavation areas afford a good opportunity to document and sample three or more meters of exposed basin sediments. It was not immediately apparent whether buried soils were present in the section or not. The Zaramas basin is internally draining, probably due to its being bounded on the north side by a bedrock scarp with evidence of Holocene activity.

Figure 1. Sunken fields and their spoil piles are present in the Zaramas basin.

Investigation of Active Faults

Greece is seismically active due to its position at the southern edge of Eurasian plate. As such, tectonic activity may well be one of the most rapid and significant agents of landscape change. Thus, this season we set out to assess the potential impact of tectonism on the landscape and human records. We performed a reconnaissance investigation of active faults in the eastern Korinthia. Specific faults investigated included those near Kiras Vrisi, including the Poseidon fault, the Korinth fault, faults near Kechries, faults near Sofiko, faults in and near Korfos, faults near Athikia and Ryto. Other regional faults were briefly visited. As discussed below, there are many active faults in the region that most certainly moved during earthquakes during the period of human occupancy.

Poseidon Fault

The Poseidon fault, heretofore unnamed, is a 4-5-km-long, west-northwest-striking normal(?) fault that shows 5-10 m of surface offset and minimum of about 15 m of down-dip displacement (Fig. 2). This fault was previously mapped by Freyberg (1973) as an inactive structure in the subsurface with limited exposure. However, west of the OSU compound the fault appears to cut late Quaternary soil, making it a surface fault and possibly active. Because of this the fault was further investigated and was found to trend through the southwest corner of the Temple of Poseidon at Isthmia. There is no readily apparent offset of the temple structures or grounds, although bedrock is deformed and the surface forms about a 5m scarp (as can be seen where the fault is crossed by the nearby road through Kiras Vrisi). The Hexamilion, the stone wall that crosses the Isthmus, lies along the fault, following the top of the scarp for much of its length. The fault scarp provides several meters of topographic relief at the base of this wall.

The location of these structures along and above the fault has implications for their survivability during an earthquake. First, surface fault rupture along the fault would have led or, in the future, could lead to significant direct destruction. Second, faults are known to occasionally “bounce” or “absorb” energy from an earthquake on a different fault, leading to a concentration of damage in its vicinity.

Fig. 2. The Poseidon fault is crossed in several locations by the Hexamilion, and underlies much of the central extent of this ancient fortification. Here we see the offset in the surface caused by the fault.

Korinth Fault

The Korinth fault is a 15+-km-long, west-striking normal fault present along the base of the escarpment formed by the Oneion Range and Akrokorinth. Reconnaissnce of nearly the entire length of the fault was made, and several sites were studied in some detail. At Loutro Eleni the fault enters the Saronic Gulf and forms the basis for the cold fresh water spring there (Fig. 3). Subsidence of Kechries Bay must be associated with the presence of this fault along its southern shore. It is interesting to note that subsidence of the bay and its harbor were heretofore unrelated to this fault by previous workers. We described a 1.5 to 2-m-high fault scarp in colluvium near Xilokeriza, the first such documentation of an active fault in the eastern Korinthia.

Figure 3. The Korinth fault is exposed in the roadcut along the highway between Kechries and Almiri, just to the west of Loutro Eleni. The fault, which intersects the road at the position of the front of the white car, juxtaposes limestone bedrock (left) against a thick sequence of consolidated colluvial sediments and interbedded red soils (right).

Sofiko Fault

The Sofiko fault, heretofore unnamed, is a 6-km-long, northeast-striking normal fault that shows more than 15 m of maximum late Quaternary surface offset. The fault lies at the foot of a 200-280-m-high escarpment in limestone bedrock. The most recent offset, i.e., surface fault rupture during an earthquake, on this fault is preserved as a 20-40-cm-wide “nastri-di-faglia” or fault ribbon along an exposed fault face underlain by limestone (Fig. 4). Such fault ribbons are common along faults in Greece (Stewart, 1996).

Figure 4. A 30-40-cm-wide “nastri-di-faglia” is present along the base of the Sofiko fault scarp. Note the contrasting smooth and chatter-marked textures of the fault face.

Ayios Vassilios Fault

The impressive structure and fortress of Ayios Vassilios is a dramatic vantage point that owes most of its 200 meters of topographic relief to the Agios Vassilios fault (previously unnamed) that lies at the foot of the escarpment. The recency of activity along this fault, most certainly Holocene, is not known. Historic earthquakes, fault sources unknown, have added to the decay and destruction of the Frankish structures.

Coastline Changes

We performed preliminary surveys of modern and ancient submerged coastlines in and around Kechries Bay and the bay of Korfos. We identified four or more submerged shoreline notches in bedrock at three locations between Isthmia and Loutro Eleni. We used in tandem Global Positioning System (GPS) and theodolite leveling methods to measure depth below Mean Sea Level (MSL)

Figure 5. Survey of representative shoreline sites, such as this site near Acro Sofia, involved the use of theodolite and GPS survey techniques. Drs. Reinhardt and Wells (two figures at left) are standing on the modern shoreline notch. A GPS antenna is stationed to the right.

GPS Survey

We used a pair of Trimble LS4600 GPS antennae to perform a post-processed topographically and leveling survey of parts of the study region. A base station was established on the roof of the main building of the OSU compound at Kiras Vrissi. A number of baseline surveys were attempted to extend the GPS network to the furthest regions of the survey area. A topographic survey was made of the wetlands in the bay of Korfos. Survey readings were made at Lechaion and Acro Sofia. For successful future GPS surveys, we identified the need for data from an established Greek GPS base station and known topographic survey benchmarks within the study region.

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APPENDIX A

Paper Presented at *Fall 1997* ***American Geophysical Union Meeting, San Francisco***

Subsidence of the Harbor at Kenchreai, Saronic Gulf, Greece, During the Earthquakes of AD400 and AD1928

Jay Noller, Lisa Wells, Eduard Reinhardt, and Richard Rothaus

The ancient port of Kenchreai, one of two ports for Corinth, the premier city of Roman and Early Byzantine Greece, was traumatically damaged and submerged during an earthquake in the late 4th - early 5th century. The moles, piers, warehouses, and an early Christian basilica today rest submerged 0.5-1.5 m below MSL. Based on archaeological chronology of damage sustained by the port facilities and structures in Corinth and Isthmia, this event is thought to have occurred c. AD 400. We attribute the source of this event to the Corinth fault, a 15+-km-long normal fault, that marks the southern extent of the broad, low-lying topography of the Isthmus between the Gulf of Corinth and the Saronic Gulf. The fault scarp forms the precipitous southern shore of Kechries Bay within which rests the harbor at Kenchreai. Abundant geologic evidence of late Holocene activity is present along the base of a 200-300-m-high faceted, oversteepened escarpment in limestone, including offset stream terraces and colluvium and submerged shorelines. The most recent event on the fault is evident as an up to 2-m-high scarp which we attribute to surface rupture during the destructive Corinth earthquake of AD 1928.

The submerged shorelines provide compelling evidence of hanging-wall subsidence in association with surface-rupturing events on the Corinth fault. The modern shoreline is benched into limestone bedrock along the shore of Kechries Bay. At least four shorelines are traced below sea level. Depths to these submerged shorelines were measured on the hanging-wall block at two locations: 200 m north of the fault at Loutro Eleni and 4 km away at Acro Sophia. Measured depths to each bench are similar at both sites and lie, top to bottom, 0.50 +/- 0.25m, 1.25 +/- 0.5m, and 1.75 +/- 0.25m below the modern shoreline. Although dating of these shorelines is in progress, we tentatively correlate the first submerged bench with the AD 1928 event. We associate the second submerged bench to subsidence during the c. AD 400 event. Depth to this second bench and the submerged port facilities match well.

Our investigation suggests that (1) the ancient port of Kenchreai has undergone perhaps two episodes of submergence, one c. AD 400 and another in AD 1928, (2) the c. AD 400 and AD 1928 earthquakes occurred on the Corinth fault, (3) earthquakes on the Corinth fault subsided 4-km-wide Kechries Bay by 50 to 75 cm during each of the last three events.