FIELD TRIP GUIDE - Friday, 25 September 2024[1]

The Perachora Peninsula (EASTERN Gulf of Corinth Rift): active tectonics and interplay between earthquakes and landscape change

Topics:

- Tectonic overview of eastern gulf of Corinth Rift
- Scale, morphology and surface displacements associated with active, basin-bounding fault systems and fault terraces
- Active faulting, Palaeoseismology and landscape growth
- Interplay between tectonics and sea-level change
- Relationship of onshore to offshore rift structure and the sedimentary response

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[2] DISCLAIMER: the Field Trip Organisers and Project Geo-Inquire cannot be held responsible for the safety of any visitors to any of the sites or locations featured in the Guide.

Fig. 1 Panoramic View of the Corinth Rift (view west). Modified after https://imagico.de/earth/

Fig. 2. Google Earth of the eastern Gulf of Corinth showing field trip stops and other infrastructure.

FIELD TRIP GEOLOGY and GEOPHYSICS

The field trip is devoted to the active tectonics, seismically active faults, structure and interaction between the tectonics and landscape change in the Perachora peninsula, lying between the N-S extending (Briole et al. 2021) eastern end of the Gulf of Corinth and the less active Saronic Gulf (see Fig.1 to 3).

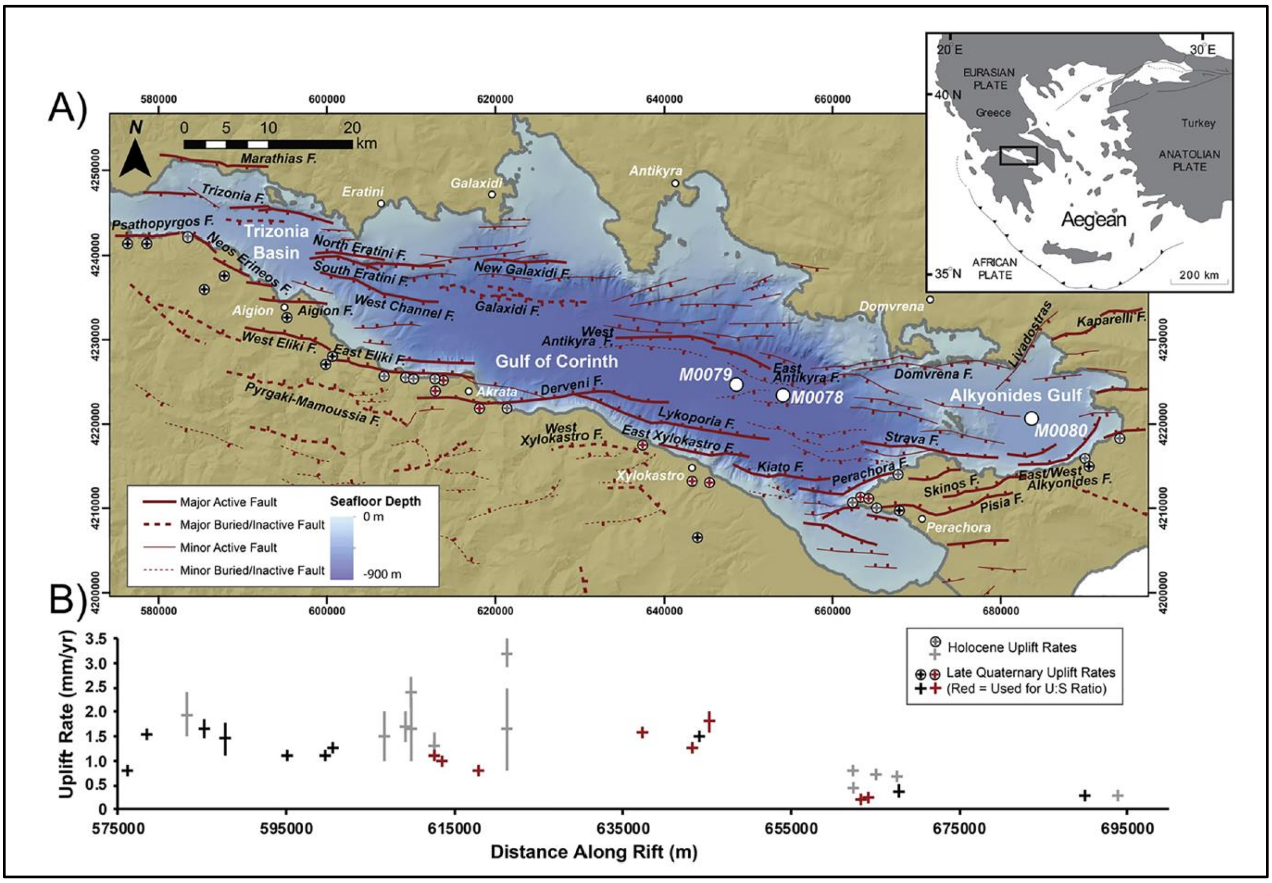

Fig 3. A) Structural map of the Corinth Rift, illustrating the onshore and offshore rift fault network and the location of three drill sites from IODP Expedition 381. Inset is a location map of the Corinth Rift within the tectonic framework of the Aegean. All major active faults offset the 129 kyr seismic horizon. B) An along rift profile of late Quaternary and Holocene uplift rates. The locations of the uplift data are shown on the structural map. After Nixon et al. (2024) and references therein.

Stop 1

Visit the Kenchreai archaeological ruins that are now submerged at the hanging wall of the active Kenchreai normal fault (Koukouvelas et al. 2017). The historical significance of Kenchreai is attested in the literary and archaeological records as a high importance port in Ancient Greek, Roman and Early Christian periods.

Archaeological excavations in the north sector of the port are by Greek research teams from 1904-present while the south submerged port excavated by an American team in 1963–1968 in revealing that the port was probably very busy in south Greece during the Roman Empire.

The port is founded on the hanging-wall block of the E-W-trending Kenchreai Fault which is 10.3 km long and divided into two segments, spaced apart about 0.1 km. The offshore propagation of the fault is a matter of debate.

The port is considered being subsided (Scranton et al., 1978), based on a submerged Fountain Court of the Temple of Isis, 0.80 m below the chapel level (which is currently at sea level) and the sea-level mark at a piscine (fish tank) currently at a depth of 1.60 m during three events. Onshore geological data suggest the lateral fault growth of the Kenchreai Fault was likely achieved by propagation primarily towards east, while its west end is captured by a persistent barrier. The Holocene palaeoseismic history of the fault investigated by a palaeoseismological trench and ^{14}C dating suggested four morphogenic earthquakes in the last 10 ka. Regarding the role of fault on submergence of the ancient port it is suggests it was destroyed by repetitive co-seismic offset 0.6 m per event. The Kenchreai Fault displays a Holocene slip rate in the order of 0.15 mm a^{-1} and a recurrence interval ranging between 1300 and 4700 years. The only known event on the faults is on 1885, instead the south mole subsidence and the drowning of the harbour is the result of sea level rise over a period of 2 ka, since the harbour is located at the eastern tip of the Kenchreai Fault, and possibly any coseismic deformation fades to zero.

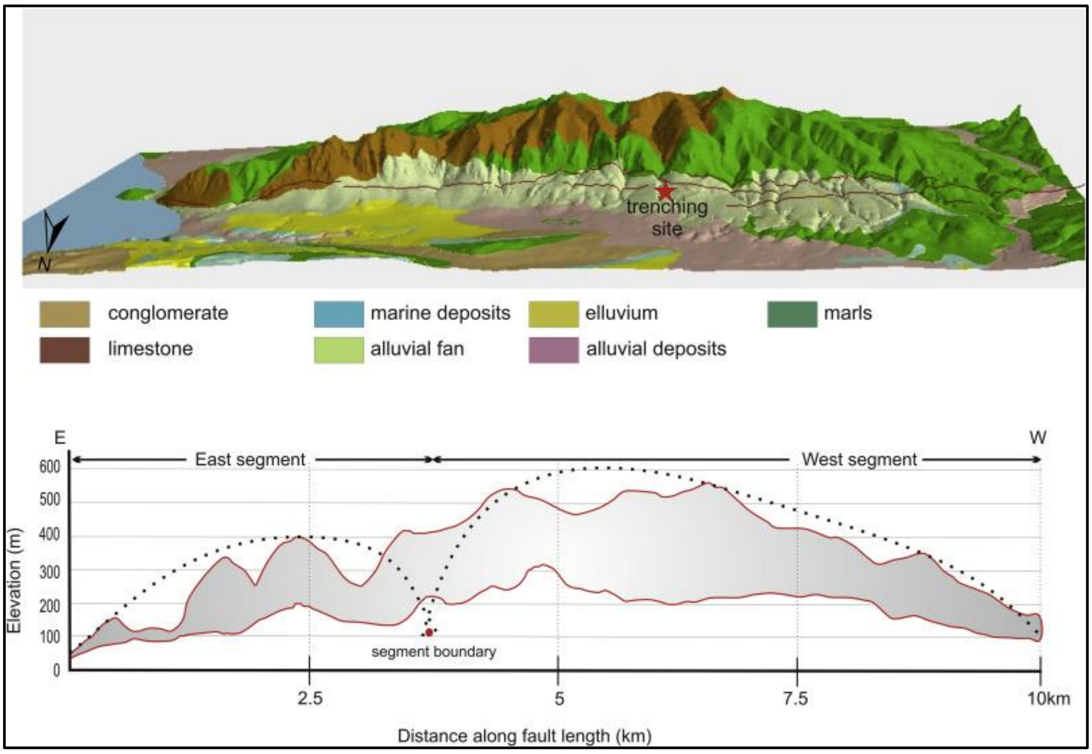

Fig. 4. (a) 3D-map showing the Kenchreai Fault, showing the location of the excavated palaeoseismological trench (indicated with a red star). (b) Hanging-wall and footwall topographic profile versus distance along strike.

Stop 2

At a short distance from Loutraki, we will encounter the cape of Heraion of Perachora. The cape stands alongside the important relics of the early Corinthian Civilization discovered in the sanctuary of the goddess Hera (Hera Akraia-Limenia). Humphry Payne, Director of the British School in Athens, conducted the site's first excavations from 1930 to 1933. The research continued until 1964-1965 when most of the site was unearthed. Cape Heraion is a perfect place to examine the interaction between eustatically-driven sea-level fluctuations in the Quaternary and fault activity. Several marine terraces, in the form of wave-cut platforms, have been mapped in the near vicinity; the car park is on one of them, now at c. 40 elevation. Coastal notches and other landforms testify to the Upper Holocene uplift (Evelpidou et al. 2023).

A E–W striking, S-dipping normal fault scarp forms the wall of the archaeological sanctuary (Fig. 5). In the scarp is also exposed the etched fault plane by slickenlines, compatible with faults showing normal kinematics. The scarp is part of the South Alkyonides Fault Zone (SAFZ; Roberts, 1996). The SAFZ ruptured in the 1981 Gulf of Corinth earthquake sequence, including two M> 6+ shocks and metre-scale surface ruptures to the east of Heraion. No clear evidence of rupture occurred at the archaeological site (Jackson et al., 1982). However, recent evidence for fault's activity comes from a series of marine notches in the limestone sea cliffs in this area (Boulton and Stewart, 2015). The highest and best-defined notch is dated at around 6.4 kyr BP, at an elevation of +3.2 m above sea level (asl) in the sea cliff to the west of the harbour (Pirazzoli et al., 1994, Pirazzoli and Evelpidou, 2013), another notch occurs at +2 m within the harbour (Kershaw and Guo, 2001). The Heraion Fault separates the two, with the higher notch level cut into the uplifted footwall of the fault, indicating a 1.2 m vertical offset of this mid-Holocene marker and implying relative movement across the fault during the last few millennia.

Fig. 5. The Heraion site from Steward and Picardi (2017).

Stop 3

The Pissia fault is an E-W striking, c. 15-km- long, north-dipping, basin-bounding fault. It is a seismically active fault, which ruptured during the 1981 Alkyonides earthquake sequence, which caused 22 casualties and extensive damage to the nearby population centres including the capital, Athens. The 1981 sequence comprised three main rupture events (Jackson et al. 1982; Fig. 6). The first two occurred during the night of the 24th to 25th February 1981 (M: 6.7 and 6.4, respectively); the former event is linked to the Pissia fault, with a mean co-seismic displacement of 0.9 m (maximum 1.5 m). The latter is attributed to the Schinos fault which runs parallel and partially overlaps the Pissia fault, spaced c. 2 km apart. The third event (M=6.4) occurred a week later and ruptured the south-dipping Kaparelli Fault, on the northern side of the Alkyonides gulf. Exposure dating (Mechernich et al. 2018) through cosmogenic 36Cl and Terrestrial Lidar Scanning (TLS) on exposed fault surfaces showed that the Pissia fault has been reactivated six to eight times in the Holocene. The Pissia (and Schinos) fault has been suggested to rupture with non-characteristic earthquakes.

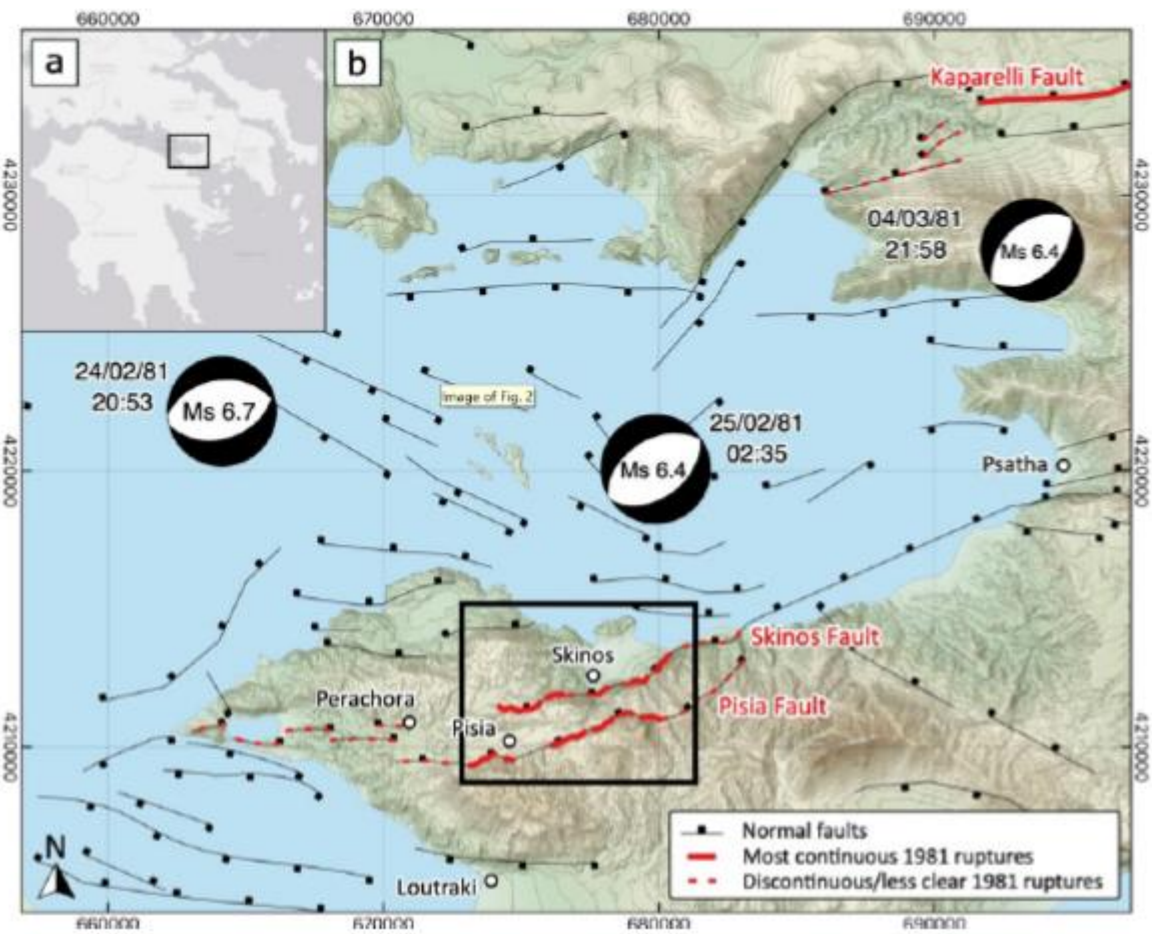

Fig. 6. Locations of the 1981 coseismic ruptures on the Pissia and Schinos faults, after Mitchell et al. (2024).

Stop 4

At the Vamvakies Fan, palaeoseismological trenches dug across the 1981 earthquake rupture that crosses the fan, gave evidence of up to six previous events, analogous to the 1981 earthquake. Radiocarbon trench analysis revealed vertical displacements in the range of 0.4-1.3 m, with an average recurrence interval of 330 yrs, an average throw-rate of 0.7–2.5 mm/yr for surface-breaking events on the Schinos Fault (Fig. 6), comparable to the displacements produced during the 1981 earthquakes (Collier et al., 1998). Based on these results, a major part of the N-S extension across the basin is taken up by this fault system.

Stop 5

Psatha bay, is located at the eastern end of the Corinth Gulf, in the Alkyonides Gulf. The bay is bounded by active neotectonic structures that have affected its evolution. Karkani et al. (2023) studied the coastal sediments of Psatha Bay and beachrock outcrops to reconstruct the coastal evolution of the area and RSL changes. Corings took place in the marshy area in the landward part of Psatha coastal area and beachrocks were mapped and dated with OSL. According to Karkani et al. (2023) the new beachrock index points indicate a sea level that has fallen by 0.64 ± 0.13 m since 2200 ± 210 years BP and by 0.95 ± 0.13 m since 4160 ± 320 years BP, as a direct result of their location close to the uplifting footwall of the north-dipping Psatha fault, further suggesting a tectonic uplift rate of ~0.26 mm/yr for the late Holocene. This rate is in good agreement with other studies in the wider area (e.g. Leeder et al., 2005). Conversely, the coring site at the coastal marshy area lies in the hanging wall of Psatha fault and is directly related to the subsidence of the hanging wall.

References

Briole, P., A. Ganas, P. Elias, and D. Dimitrov, 2021. The GPS velocity field of the Aegean. New observations, contribution of the earthquakes, crustal blocks model, Geophys. J. Int., 226(1), 468-492, http://doi:10.1093/gji/ggab089.

Evelpidou, N., A. Ganas, A. Karkani, E. Spyrou, and G. Saitis, 2023. Late Quaternary Relative Sea-Level Changes and Vertical GNSS Motions in the Gulf of Corinth: The Asymmetric Localization of Deformation Inside an Active Half-Graben, Geosciences, 13 (11), 329 https://doi.org/10.3390/geosciences13110329

Jackson, J. A., J. Gagnepain, G. Houseman, G. C. P. King, P. Papadimitriou, C. Soufleris, and J. Virieux, 1982. Seismicity, normal faulting, and the geomorphological development of the Gulf of Corinth (Greece): the Corinth earthquakes of February and March 1981, Earth Plan. Sci. Let., 57(2), 377-397, doi:10.1016/0012-821X(82)90158-3.

Karkani, A., Evelpidou, N., Saitis, G., Tsanakas, K., Drinia, H., Vassilakis, E., Karymbalis, E., & Batzakis, D. 2023. Coastal Evolution and Relative Sea Level Changes at Psatha (Alkyonides Bay, Greece). Journal of Marine Science and Engineering, 11(1), 199. https://doi.org/10.3390/jmse11010199

Koukouvelas, I. K., V. Zygouri, G. A. Papadopoulos, and S. Verroios 2017. Holocene record of slip-predictable earthquakes on the Kenchreai Fault, Gulf of Corinth, Greece, J. Struct. Geol., 94, 258-274, doi: https://doi.org/10.1016/j.jsg.2016.12.001.

Leeder, M.R., Portman, C., Andrews, J.E., Collier, R.E.L., Finch, E., Gawthorpe, R.L., McNeill, L.C., Pérez-Arlucea, M., and Rowe, P. 2005. Normal Faulting and Crustal Deformation, Alkyonides Gulf and Perachora Peninsula, Eastern Gulf of Corinth Rift, Greece, J. Geol. Soc. Lond., 162, 549–561.

Mechernich, S., S. Schneiderwind, J. Mason, I. D. Papanikolaou, G. Deligiannakis, A. Pallikarakis, S. A. Binnie, T. J. Dunai, and K. Reicherter 2018. The Seismic History of the Pisia Fault (Eastern Corinth Rift, Greece) From Fault Plane Weathering Features and Cosmogenic 36Cl Dating, Journal of Geophysical Research: Solid Earth, 123(5), 4266-4284, doi: https://doi.org/10.1029/2017JB014600.

Mitchell, S., G. P. Roberts, J. P. Faure Walker, F. Iezzi, C. Sgambato, J. Robertson, Z. K. Mildon, A. Ganas, I. D. Papanikolaou, and E. J. Rugen 2024. The relationship between kinematics and fault geometry for surface coseismic ruptures on across-strike faults: New observations of slip vectors and displacements along the Pisia and Skinos faults from the 1981 Eastern Gulf of Corinth, Greece earthquakes, J. Struct. Geol., 182, 105117, doi: https://doi.org/10.1016/j.jsg.2024.105117.

Nixon, C. W., L.C. McNeill, R. L. Gawthorpe, D. J. Shillington, G. Michas, R. E. Bell, A. Moyle, M. Ford, N. V. Zakharova, J. M. Bull, G. de Gelder, 2024. Increasing fault slip rates within the Corinth Rift, Greece: A rapidly localising active rift fault network, Earth Plan. Sci. Let., 636, 118716, doi: https://doi.org/10.1016/j.epsl.2024.118716.

Pirazzoli, P.A., Stiros, S.C., Arnold, M., Laborel, J., Laborel-Deguen, F., Papageorgiou, S. 1994. Episodic Uplift Deduced from Holocene Shorelines in the Perachora Peninsula, Corinth Area, Greece. Tectonophysics, 229, 201–209.

Pirazzoli, P.A. and Evelpidou, N. 2013. Tidal Notches: A Sea-Level Indicator of Uncertain Archival Trustworthiness. Palaeogeogr. Palaeoclim. Palaeoecol., 369, 377–384.

Roberts, G.P. 1996. Noncharacteristic Normal Faulting Surface Ruptures from the Gulf of Corinth, Greece. J. Geophys. Res., 101, 25255–25267.

Scranton, R.L., Shaw, J.W., Ibrahim, L., 1978. Kenchreai: Eastern Port of Corinth, Results of Investigations by the University of Chicago and Indiana University for the American School of Classical Studies at Athens, I. Topography and Architecture, Leiden.

Stewart, I.S., Piccardi L., 2017. Seismic faults and sacred sanctuaries in Aegean antiquity. Proceedings of the Geologists' Association, 128, 711-721.

IMPORTANT NOTICES

A. SAFETY IN THE FIELD

• Each individual must take responsibility for their own safety.
• Drivers will, most likely, NOT stop if you are at the side of the road waiting to cross, even at pedestrian crossings. DO NOT JUST WALK INTO THE ROAD EXPECTING THE CAR TO STOP.
• The roads you may stand on looking at geological features can be narrow and windy.
• Beware of unstable outcrops. Avoid all cliff-like outcrops during rainstorms or high winds.
• If you are vertigo-prone, avoid cliff edges and elsewhere.
• Beware of the sun: use sunscreen and wear a hat
• Have plenty of water with you. The water in the hotel is potable.

B. Logistics, accommodation, food and procedures.

• The hotel accepts credits cards
• We will aim to have breakfast at 07:30 and leave for the field at 08:.30.
• We will aim to return to the hotel by 18:00.
• you will be provided with a picnic lunch for the field, and drinks.

C. Health and first-aid issues

• Participants should inform the trip leader before departure (in confidence by email) or on arrival in Athens (as a note) of any physical or mental condition which may affect performance in the field (e.g. asthma, diabetes, epilepsy, vertigo, heart condition, back or joint problem, ear disorder, lung disease, allergies etc.). If any medication is required to respond to any of the indications above, please inform the field trip leader of the location of this medicine in case it is required.
• The Field Trip organisers may not provide drugs to participants. If you have any medical drug needs, (e.g. painkillers, drugs for allergic reaction to bites etc) then it is the individual participant's responsibility to have these with them.

D. Weather conditions:

Late October - early November weather is expected to be calm in the field trip area, with max temperatures in the mid-20s, but may be significantly cooler (or windier). Expect occasional showers, so bring clothing for different types of weather.

E. On the road:

There will be no alcohol during the day due to Greek Law policy in operation whilst on the trip.
All participants should be aware of moving vehicles and pedestrians at outcrops. As a rule, do not stand on the tarmac road surface – stay on the grassy verges.
We may spend some of the time off the tarmac road and on dirt tracks.

F. Earthquakes:

The Gulf of Corinth is a seismically active area that has hosted recent earthquakes, so a few lines of caution are deemed necessary, in the case of an earthquake:

If indoors:

• DROP to the ground and take COVER by getting under a table, or other piece of furniture, or use a doorway, if you know, it is a strongly supported, load-bearing one. HOLD ON until the shaking stops. If there isn't a table near you, cover you face and head with your arms and crouch in an inside corner of the building.

• Stay away from glass, windows, outside doors and walls and anything that could fall one you, such as lighting fixtures or tall furniture.

• Stay inside until the shaking stops and it is safe to go outside. Research has shown that most injuries occur when people inside buildings attempt to move to a different location inside the building or try to leave.

• DO NOT use elevators, even if they are working. There may be aftershocks and power cuts.

If outdoors:

• Move away from buildings, (even stone fences), streetlights and utility wires

• Once in the open, stay there until the shaking stops. The greatest danger exists directly outside the buildings, at exits and alongside exterior walls

• Move away from steep cliffs and rockfaces (rockfalls happen!)

G. Photography.

Never photograph a military installation or associated items (including airplanes). Never photograph a policeman.

H. Rock Samples.

Do not attempt to bring any samples out of Greece. You may be apprehended at the airport and may be imprisoned for attempting to remove antiquities. A permit is needed to bring rock specimens out of the area.

I. Emergency Numbers:

European emergency service line **112**

Police **100**

Fire Service **199**

Medical Emergency **166**

Corinth General Hospital: +**30 2741 361400**

END of FIELD TRIP GUIDE

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