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Tectonic Klippe Served the Needs of Cult Worship, Sanctuary of Zeus, Mount Lykaion, Peloponnese, Greece

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ABSTRACT

Mount Lykaion is a rare, historical, cultural phenomenon, namely a Late Bronze Age through Hellenistic period (ca. 1500–100 BC) mountaintop Zeus sanctuary, built upon an unusual tectonic feature, namely a thrust klippe. Recognition of this klippe and its physical character provides the framework for understanding the coupling between the archaeology and geology of the site. It appears that whenever there were new requirements in the physical/cultural expansion of the sanctuary, the overall geologic characteristics of the thrust klippe proved to be perfectly adaptable. The heart of this analysis consists of detailed geological mapping, detailed structural geologic analysis, and close cross-disciplinary engagement with archaeologists, classicists, and architects.

Figure 1. Location of the Sanctuary of Zeus, Mount Lykaion, Peloponnese, Greece.

INTRODUCTION

In the second century AD, Pausanias authored an invaluable description of the Sanctuary of Zeus, Mount Lykaion, located at latitude 37° 23′ N, longitude 22° 00′ E, in the Peloponnese (Fig. 1). Pausanias' accounts were originally written in Greek and are available in a number of translations and commentaries, including Habicht (1999). Pausanias described the physical setting, built structures, athletic games, and nature of the cult activity taking place there in ancient times, calling attention to the presence of two distinct though linked precincts (Romano and Voyatzis, 2014, 2015). The upper level of the sanctuary resides on the summit of Agios Elias and includes an open-air ash altar, which today is represented by an ~2-m-thick blanket of bone ash surviving from animal sacrifice going back as far as the Late Bronze Age, ca. 1500 BC. The lower level comprises foundations and residual worked blocks of built structures and activity areas, including a hippodrome and stadium used for athletic games in ancient times (see Romano and Voyatzis, 2014, 2015).

In 2004, I signed on as geologist for the Mount Lykaion Excavation and Survey Project, directed by David Gilman Romano and Mary Voyatzis (see *Acknowledgments*). My objective was to evaluate, through detailed geologic mapping (Fig. 2), the ways in which the geology and archaeology of the sanctuary were interconnected. What became clear is that the geology of the sanctuary perfectly fulfills the integrated pragmatic, athletic, spiritual, and ritual requirements of the Zeus cult, which, according to Romano and Voyatzis (2014, 2015), functioned between at least as far back as 1500 BC to 100 BC.

The critical geologic emphasis here is that Mount Lykaion is a thrust klippe. Thrusting was achieved during tectonic inversion of Jurassic to early Cenozoic Pindos Basin stratigraphy (Degnan and Robertson, 2006; Doutsos et al., 1993; Skourlis and Doutsos, 2003). The 3D exposure of the thrust klippe has been achieved through erosional exploitation of the active normal faults being produced by crustal-stretching collapse of the Aegean region (Cocard et al., 1999; Goldsworthy and Jackson, 2000; Jackson, 1994; McClusky et al., 2000).

NATURE OF THRUST KLIPPEN

Thrust klippen are remnant masses of far-traveled thrust sheets, which through regional erosion become isolated from the main sheets with which they were formerly contiguous (Heim, 1922; Quereau, 1895;

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Trümpy, 2006). Low-angle regional thrust faulting places older, deeper rock formations on top of younger, shallower ones, and it is this inverted stratigraphic succession that is an essential "smoking gun" for recognizing thrust klippen.

Many large, expansive klippen have attracted historical and cultural attention, in part because they can be strikingly anomalous in topography, landscape, and aesthetics compared to their surroundings. A klippe that particularly stands out is the Mythen klippe, which overlooks Lake Lucerne (Central Switzerland) (Wissing and Pfiffner, 2002) (Fig. 3A). The bedrock of Mythen is mainly Upper Jurassic strata, which rest in low-angle thrust contact upon dominantly Cretaceous strata (Bertrand, 1887). As early as the eighteenth century the Mythen seized the philosophical, artistic, poetic, and scientific attention of Johann Wolfgang von Goethe. Goethe's passion for the Mythen influenced his friend Friedrich Schiller to use the Mythen as the backdrop of Schiller's drama, *William Tell* (1804).

Yet another example of klippen influencing history and culture is Chief Mountain, which is located along the eastern border of Glacier National Park, Montana, USA (Mudge and Earhart, 1980) (Fig. 3B). Chief Mountain is known as *Ninaistako* to the Blackfoot people. Bailey Willis (1902) identified Chief Mountain as a thrust klippe, recognizing that Precambrian basement rocks were faulted up and over Cretaceous strata along the Lewis overthrust. According to Blackfoot tradition, *Thunder* resides there, and Thunder is considered to be an agent of renewal to the Blackfoot people (National Park Service, 2006).

AGIOS ELIAS KLIPPE: HOW IT MAY HAVE LOOKED TO THE ZEUS CULT

Whereas Ninaistako is home to Thunder, Agios Elias (St. Elijah), the klippe hosting the Sanctuary of Zeus, is home to Lightning. Epithets for Zeus in the ancient literature include *Lightning Wielder* and *Shepherd of the Clouds*. Agios Elias (elevation 1381 m) is technically the *second*-highest summit of Mount Lyakion proper (elevation 1421 m) (Fig. 3C). The assets of its natural setting must have been particularly obvious to the ancient peoples who frequented the site. Pausanias (8.38.7; see Habicht, 1999) recorded that on a clear day most of the entire vast expanse of the Peloponnese could be seen from the very top of the sanctuary. Moreover, Mount Lykaion and environs reside within a dynamic setting marked by rock falls, landslides, fissuring, and earthquakes (Ambraseys and Jackson, 1990, 1998; Jackson, 1994). The ancient connection of earthquake-related phenomena to the action of gods is clear in the Late Bronze Age archaeological record, from which period onward Poseidon was known as *the Earth Shaker*. The association of Poseidon and earthquakes is revealed first in the Linear B clay tablets preserved at Pylos (Budin, 2004).

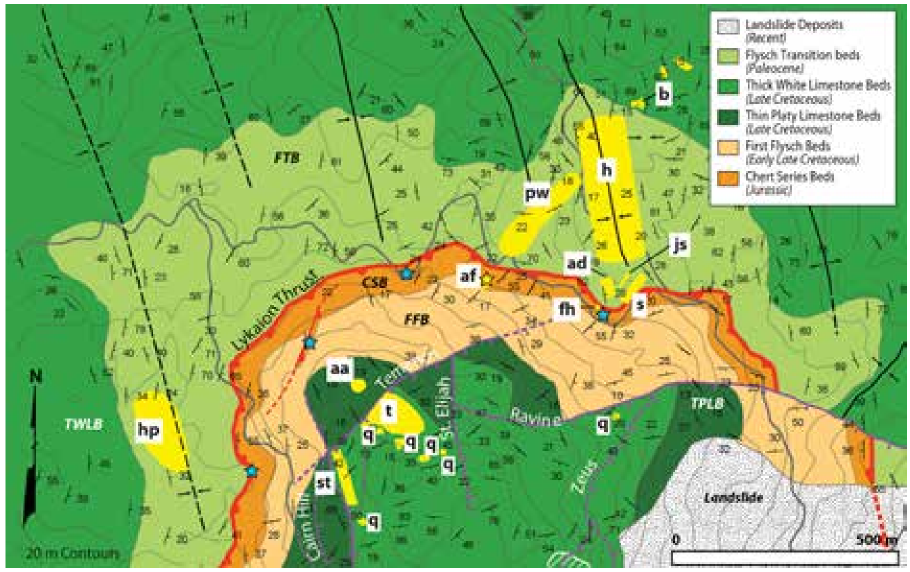

Figure 2. Geoarchaeological map of the Sanctuary of Zeus, Mount Lykaion. Archaeological features: aa—ash altar; ad—administration building; af—Agnos fountain; b—bath; fh—fountain house; h—hippodrome; hp—horse pasture; js—j-seats; pw—processional way; st—proto-stadium; q—quarry; s—stoa; t—temenos; CSB—Chert Series Beds Formation; FFB—First Flysch Beds Formation; TPLB—Thin Platy Limestone Beds Formation; TWLB—Thick White Limestone Beds Formation; FTB—Flysch Transition Beds Formation.

When Agios Elias began to be considered and/or used as a cult place in honor of Zeus, it would have appeared as a steep-sloped, smooth, 200-m-high conical mountaintop summit that gives way below to an encircling bench-like bedrock apron of more modest topographic relief (~40 m) (Fig. 4A; also see Fig. 3C). It would have been obvious that springs feed from the interface between the conical summit and bench-like platform upon which Agios Elias rests. Over time the sanctuary was expanded with the addition of built structures and activity areas (Fig. 4B). The upper level of the sanctuary was largely established between the fifteenth and seventh centuries BC, whereas the lower level was developed and used between the seventh century BC and first century BC (Romano and Voyatzis, 2014, 2015). The main archaeological features in the upper level include the open-air mountaintop ash altar, where animals were sacrificed and dedicatory objects offered to Zeus; a temenos, i.e., religious precinct where no one except priests could enter without meeting their death within a year (Pausanias, 8.38.6; see Habicht, 1999); and possibly a proto-stadium, where the earliest athletic races are thought to have been held (Romano and Voyatzis, 2015). The main archaeological elements of the lower sanctuary include the Agno fountain (a notable ancient spring), stoa (covered, detached portico with stalls), fountain house, administrative building, corridor, seats, hippodrome, stadium, baths, and a processional way (Romano and Voyatzis, 2015) (see Figs. 2 and 4B).

AGIOS ELIAS KLIPPE: HOW IT LOOKS IN RELATION TO THE GEOLOGY

A draping of my geologic map and the archaeological elements of the Sanctuary of Zeus over the modern landscape (Fig. 5) creates an image that underscores the premise of this paper: the Sanctuary of Zeus exploits in a variety of specific ways the geology of the Agios Elias klippe, and especially the major thrust fault that defines the base of the klippe. In fact, it is

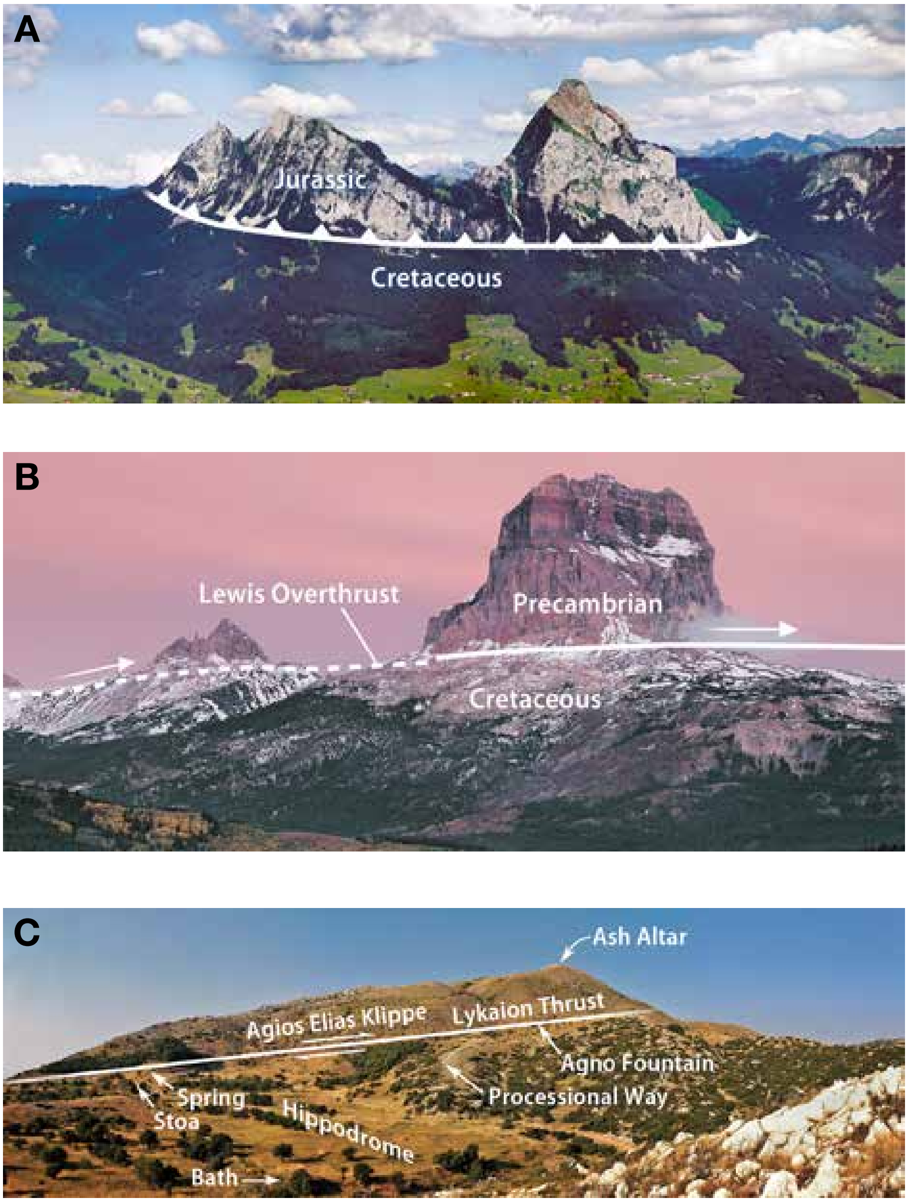

Figure 3. (A) Mythen klippe, Central Switzerland. (The author thanks H. Röst and M. Steiner for permission to reproduce their Mythen image.) (B) Chief Mountain klippe, Glacier National Park, Montana. To the Blackfoot people this mountain is *Ninaistako*. (The author thanks Marc Adamus for permission to reproduce his Chief Mountain photograph.) (C) South-directed photograph of the Agios Elias klippe, Sanctuary of Zeus, Mount Lykaion.

the trace of this thrust fault, which I have named the Lykaion thrust, that is the archaeological boundary between the upper and lower levels of the sanctuary. This thrust was identified as one among many within a regional system of thrust faults discovered during the 1:50,000 mapping carried out by Lalechos (1973) and Papadopoulos (1997).

In carrying out geological mapping of the sanctuary and its surroundings (1:2500-scale), I expanded the four-unit Pindos Group stratigraphy of Lalechos (1973) and Papadopoulos (1997) into the five formations shown in the map explanation (Davis, 2009) (see Fig. 2). The oldest Pindos Group formation (Chert Series Beds Formation, Jurassic) rests in thrust-fault contact atop the youngest (Flysch Transition Beds Formation, Paleocene). The Jurassic Chert Series Beds serve as a décollement into which the Lykaion thrust soles, which is also the case for most parts of the Pindos fold and thrust belt (Degnan and Robertson, 1998; Skourlis and Doutsos, 2003). Décollement favorability of the Chert Series Beds derives from its inherent quasi-plastic mechanical character, composed of very thin radiolarian chert beds intercalated with soft claystone and mudstone. Beneath the Lykaion thrust fault the rocks are marked by a system of large upright to slightly overturned anticlines and synclines, which control the geologic map relationships (Davis, 2009, 2014) (see Figs. 2 and 5).

Limestone and interbedded siltstone of the Flysch Transition Beds Formation (Paleocene) crop out immediately below the klippe and have eroded to an open, relatively smooth landscape forming the bedrock bench. Directly beneath is the Thick White Limestone Beds Formation (Late Cretaceous), composed of resistant, sharp weathering, brush- and bush-surmounted limestone. In combination with the underlying Thin Platy Limestone Beds Formation (Late Cretaceous), the Thick White Limestone Beds Formation supports the steep imposing cliffs that mark the west and north faces of Mount Lykaion. Moreover, the Thick White Limestone Beds Formation has been heavily attacked by karst processes as revealed in the more than 150 sinkholes within its map-area distribution of just 10 km^2. Today it is difficult to overstate the impenetrability of some of this karst-modified terrain where not agriculturally terraced.

The cone-shaped, smooth-weathering klippe landscape above the thrust is much different from that below because of the presence of relatively soft sandstones of the First Flysch Beds Formation (early Late Cretaceous) and the mudstones and radiolarian chert layers of the Chert Series Beds Formations (Jurassic) (see Fig. 5). Normal faults conspicuously cut and offset the bedrock within the klippe (see Figs. 2 and 5), and this faulting has had a particularly profound effect on the landscape character of the top of the klippe (Davis, 2009). The normal faulting postdates the late Cretaceous to Eocene folding and thrusting. The clearest expression of this faulting marks the eastern margin of the Agios Elias klippe, where major, *active*, east-dipping, NNE-striking normal faults of the “Zeus” active fault system have cut into the plateau-like upper surface of the Agios Elias klippe, producing structural platforms that step down to the east. The edge is so precipitous that rock falls are frequent, and a very large landslide complex has accrued on the eastern flank of the klippe (see Figs. 2 and 5). Closely associated with the trace of this normal fault system is an active fissure field marked by hummocky, disrupted landscape.

On Agios Elias proper there are three normal fault zones that intimately connect to the geoarchaeology. The Cairn Hill fault strikes north-south, dips eastward, and cuts and offsets the Lykaion thrust fault at the south end of the klippe (see Fig. 2). The north end of the trace of this fault coincides with the location of the proto-stadium. A second normal fault trace (the Temenos fault) trends east-west close to the very summit of the klippe, and separates the ash altar area from the temenos. A third normal fault (the Ravine fault), striking northwest/southeast, dips eastward, and cuts and offsets the Lykaion thrust fault near the northeastern “corner” of the klippe.

CONNECTIVITY OF THE ARCHAEOLOGY, GEOLOGY, AND TECTONICS

Upper Level of the Sanctuary

On the Agios Elias summit (see Figs. 2 and 5), the normal-fault displacements have resulted in Thin Platy Limestone Beds being perched, as a faulted block, at the very top, structurally above the stratigraphically younger Thick White Limestone Beds Formation. The Thin Platy Limestone Beds Formation weathers to smooth grassy slopes, creating a landscape conducive to carrying out ceremonial functions, and for which the Thick White Limestone Beds would have been completely unsuitable. Moreover, the combination of bed thickness and joint spacing in the Thin Platy Limestone Beds Formation delivers nearly perfectly sized and shaped portable limestone blocks (resembling cinder blocks), which could readily be moved around, piled, and shaped into built structures, such as walls and ascent ways, for ritual purposes.

The northern boundary of the temenos trends east-west and was located at the very base of the ash altar summit “cone,” at the break in slope from nearly 30° to flat. Thus the northern boundary of the temenos lies right along the trace of the Temenos fault, which appears to be active (see Fig. 2). One of the best upper-level examples of the *hand-in-glove* fit of the geology and archaeology is the location and orientation of the proto-stadium. It trends north-south, and is located on the trace of the Cairn Hill fault (see Fig. 2). This trace is marked by an 8-m-wide fault-growth deposit of alluvium (clay and silt) that accumulated at the intersection of westerly back-tilted limestone beds on the hanging-wall, and the east-dipping Cairn Hill fault. Thus this straight and alluvium-padded swath of ground was an obvious choice for competitive racing.

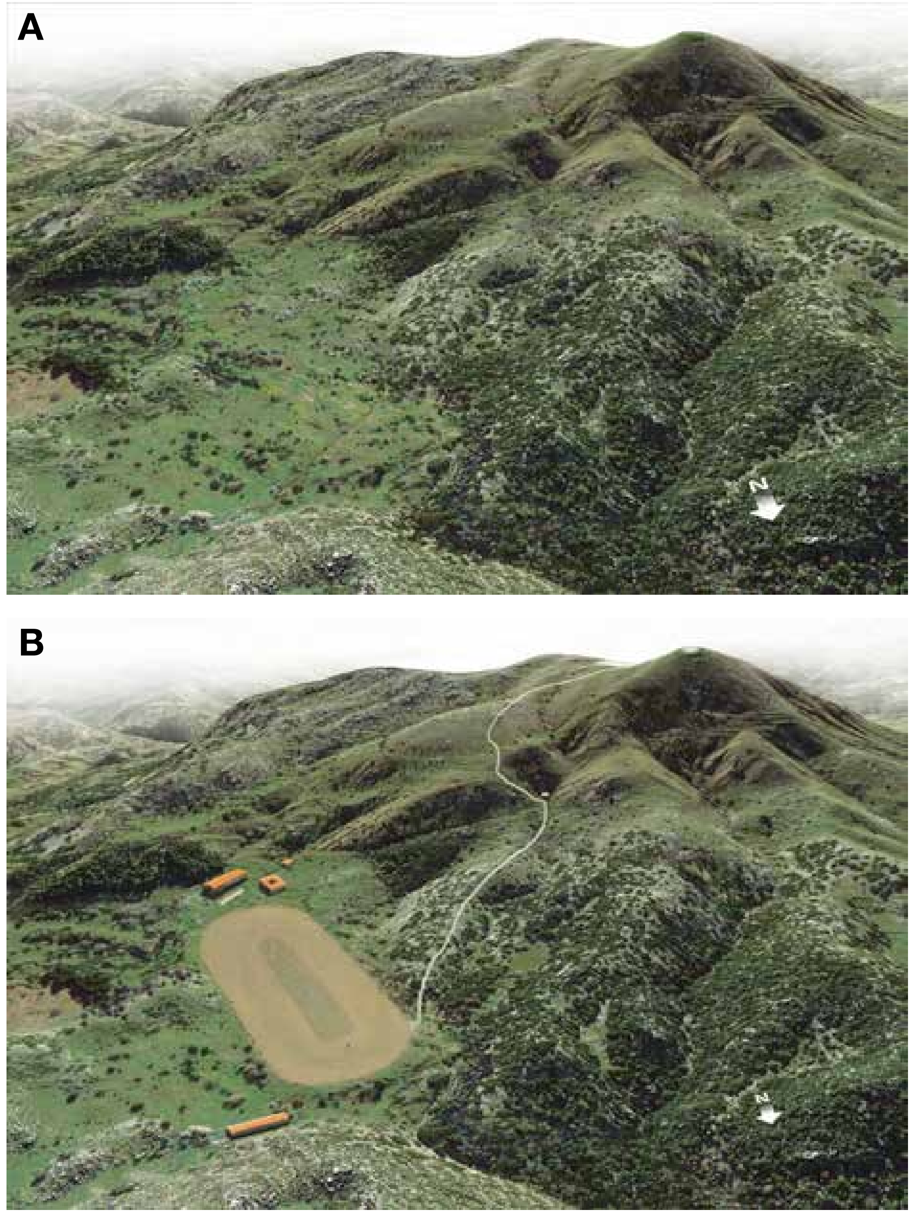

Figure 4. South-directed interpretive renderings of the landscape of Agios Elias, imagining the way the landscape may have appeared (A) in ca. 3000 BC before the Zeus cult exploited the resources of this landscape, and (B) in ca. 300 BC when built structures and activity areas were prominent additions to the landscape. Bath building and hippodrome are in foreground. Path ascends processional way, passes next to Agno foundation, and then may have continued as shown, entering the temenos just below the ash altar on the summit. At south end of Hippodrome are stoa (largest), seats (white), administrative building (square), and fountain house (small).

Lower Level of the Sanctuary

In the lower level of the Sanctuary of Zeus there is an intimate relationship between the archaeological elements and the trace of the 10°E-dipping Lykaion thrust. Immediately above the trace of the thrust is the Agno fountain, which was described by Pausanias as flowing like the Danube (i.e., year-round) (Book 38, see Habicht, 1999), and a second spring marked by the location of the ancient fountain (spring) house. These springs, and others (see Figs. 2 and 5), coincide with locations just above the outcrop trace of the clay-gouge smear of quasi-plastic Chert Series Beds Formation, which formed

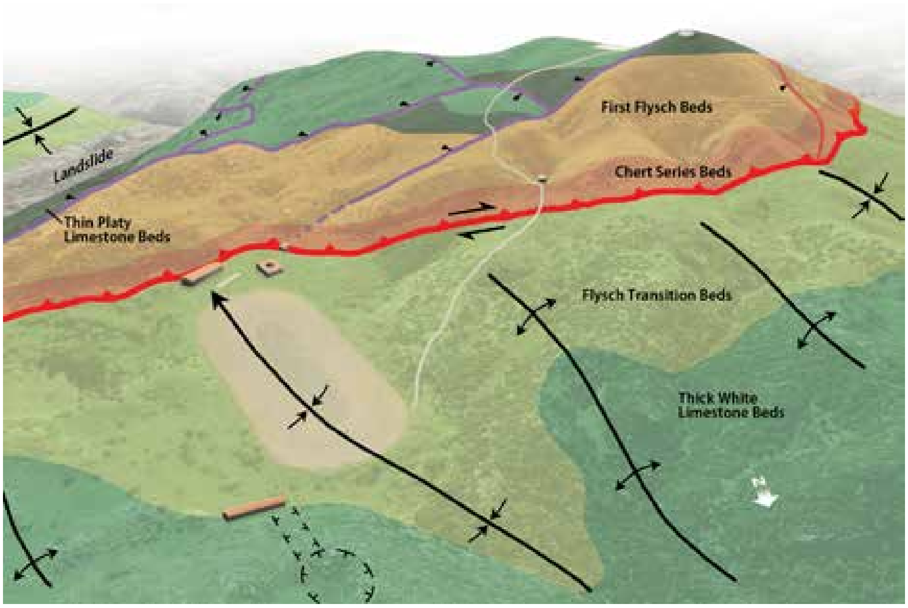

Figure 5. A draping of the author's geologic map of Mount Lykaion onto the modern landscape of Agios Elias. The archaeological elements are pictured stylistically, for only the excavated remains of foundations and spilled building blocks can be seen today. The exact location of the pathway above the Agno fountain is speculative.

along the base of the upper plate of the Lykaion thrust. Precipitation falling on the upper reaches of the Agios Elias klippe creates meteoric water that seeps into the underlying porous, permeable bedrock, including both the fractured, karst-attacked limestone and the jointed sandstone. Upon encountering the clay seal, the flow of this descending meteoric water is forced to shift laterally, "day-lighting" just meters above the trace of the Lykaion thrust.

The stoa was placed immediately adjacent to the trace of the Lykaion thrust (see Figs. 2 and 5). The long dimension of the stoa (70 m) is not only oriented perfectly parallel to the trace of the Lykaion thrust, but the back wall of the stoa physically abuts against the fault. The limestone blocks for the back wall of the stoa are set against a scarp-like face that was excavated through easily removed clayey-gouge materials (sheared Chert Series Beds Formation) in the uppermost part of the lower plate of the thrust fault. The limestone-block foundation of the stoa was placed just a few meters below the trace of the Lykaion thrust, and built upon a limestone bedrock foundation of the flat-lying Flysch Transition Beds Formation, the uppermost unit of the lower plate of the thrust.

The hippodrome (for horse racing and chariot races) and stadium (located within or just next to the hippodrome) constitute another illustration of the tight connection between archaeology and geology (see Figs. 2 and 5). The hippodrome of the sanctuary measures ~250 m × 100 m, with its long dimension oriented 348° (Romano and Voyatzis, 2015). The flat space it occupies is starkly anomalous to the steep slopes and cliffs of the overall sanctuary and environs! Mapping and analysis discerned that the flat space owes its existence, geologically, to a fortuitous intersection of structural geology and stratigraphy. The hippodrome resides along a broad, open, 12°-plunging syncline whose hinge line is oriented *exactly* parallel to the trend of the hippodrome. Moreover, the landscape surface of the hippodrome coincides with the interface between the Thick White Limestone Beds Formation (below) and the Flysch Transition Beds Formation (above) (see Figs. 2 and 5). The strata of the relatively thin-bedded and incompetent Flysch Transition Beds Formation has been almost entirely eroded away at the hippodrome site, thus creating a stripped structural platform along and/or near the top of the Thick White Limestone Beds Formation. The added touch was partial infilling of the shallow synclinal basin by runoff-derived silt and clay alluvium eroded from the flanks of the Agios Elias klippe to the immediate south. The fine-grained alluvial blanket imparted softness to the track, amenable for the horse racing and running races. Of course none of these interpretive geological details would have been known to the local people in charge of the site, but it would have been obvious that this soft flatland would have been perfect for the athletic games envisioned.

A bath complex lies just beyond the northeast corner of the hippodrome. This location is remote from the built structures of the lower level (see Figs. 2 and 5). Yet mapping reveals that its positioning is perfectly suited to tapping a local water source. A sinkhole lies 120 m upslope from the baths, and a collapse sinkhole corridor connects the sinkhole to the back of the baths. Outcrops between the back of the bath and the sinkhole are marked by conspicuous solution fluting.

DISCUSSION

On the tectonic scale, the geology, seismology, and geomorphology of Mount Lykaion combine to exert grandeur and power to the sanctuary. Its elevation is a testimony to the residual crustal buoyancy achieved through the presence of anomalously thick crust fashioned by tectonic inversion and crustal shortening of the Pindos basin. Its topographic relief is a product of the active normal faulting that is causing collapse of basins and severe downcutting by drainages. Its earthquake activity, active faulting, fissuring, and landsliding are derived from contemporary crustal stretching. On the scale of the Agios Elias klippe, there is an intimate relationship between archaeology, structural geology, stratigraphy, and geomorphology.

I introduced and framed this article with an emphasis on tectonic klippen, even though the salient cult-suited geologic resources of Agios Elias can be presented without much reference to klippen (Davis, 2009, 2014). But recognizing Agios Elias as a klippe, i.e., as an *outlier*, is fundamental to understanding the *provenance* of the Sanctuary of Zeus. Provenance can be defined as "the beginning of something's existence."

Interpreting the beginning of the existence of the Late Bronze Age Zeus-cult worship on Mount Lykaion is very challenging, because so many factors and variables must be taken into consideration. I simply wish to add another consideration to that list. From a regional tectonic perspective, I believe that Agios Elias likely attracted attention for ritual activity in honor of Zeus because it departed substantively from the "standard" landscape of the region. I think of Goethe's fascination with the Mythen klippe as an analogue. Like the worshippers of Zeus, Goethe was well-traveled regionally and challenged himself in trying to understand natural phenomena in a way grounded in direct experience (Miller, 1995; Seamon and Zajonc, 1998). Goethe wrote: "Natural objects should be sought and investigated as they are … not to suit observers, but respectfully as if they were divine beings" (Matthaei, 1971, p. 57; Seamon and Zajonc, 1998). In a similar manner, Ninaistako stood out to a well-traveled Blackfoot people who were intimately connected to the land and who undoubtedly recognized that Ninaistako was exotic when viewed in the overall backdrop of the larger Cordillera. Such a perspective may have played a part in Agios Elias being chosen as the sanctuary for homage to and celebration of Zeus. This landform would have been recognizable as an outlier, for it is an exception to the rule of north-south–trending mountain ridges forming the Pindos backbone of Greece. After all, an *outlier* is "a thing detached from the main body or system"; "a thing differing from all other members of a particular set." There *must* have been a sense that Zeus would not have settled for the norm.

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REFERENCES CITED

Ambraseys, N.N., and Jackson, J.A., 1990, Seismicity and associated strain of central Greece between 1890 and 1988: International Geophysical Journal, v. 101, p. 663–708, https://doi.org/10.1111/j.1365-246X.1990.tb05577.x.

Ambraseys, N.N., and Jackson, J., 1998, Faulting associated with historical and recent earthquakes in the Eastern Mediterranean: Geophysical Journal International, v. 133, no. 2, p. 390–406, 10.1046/j.1365-246X.1998.00508.x.

Bertrand, M., 1887, Ilot triasique du Beausset (Var): Analogie avec le bassin houiller Franco-Belge et avec les Alpes de Glaris: Bulletin de la Société Géologique de France, v. 3, no. XV, p. 667–702.

Budin, S.L., 2004, The ancient Greeks: An introduction: Oxford, Oxford University Press, 468 p.

Cocard, M., Kahle, H.-G., Peter, Y., Geiger, A., Veis, G., Felekis, S., Paradissis, D., and Billiris, H., 1999, New constraints on the rapid crustal motion of the Aegean region: Recent results inferred from GPS measurements (1993–1998) across the West Hellenic Arc, Greece: Earth and Planetary Science Letters, v. 172, p. 39–47, https://doi.org/10.1016/S0012-821X(99)00185-5.

Davis, G.H., 2009, Geology of the Sanctuary of Zeus, Mount Lykaion, southern Peloponessos, Greece: Journal of the Virtual Explorer, v. 33, 58 p.

Davis, G.H., 2014, Quasi-flexural folding of pseudo-bedding: Geological Society of America Bulletin, v. 126, p. 680–701, https://doi.org/10.1130/B30963.1.

Degnan, P.J., and Robertston, A.H.F., 1998, Mesozoic-early Tertiary passive margin evolution of the Pindos ocean (NW Peloponnese, Greece): Sedimentary Geology, v. 117, p. 33–70, https://doi.org/10.1016/S0037-0738(97)00113-9.

Degnan, P.J., and Robertson, A.H.F., 2006, Synthesis of the tectonic-sedimentary evolution of the Mesozoic–early Cenozoic Pindos Ocean; evidence from the NW Peloponnese, Greece: Geological Society, London, Special Publication 260, p. 467–491, https://doi.org/10.1144/GSL.SP.2006.260.01.19.

Doutsos, T., Pe-Piper, G., Boronkay, K., and Koukouvelas, I., 1993, Kinematics of the central Hellenides: Tectonics, v. 12, p. 936–953, https://doi.org/10.1029/93TC00108.

Goldsworthy, M., and Jackson, J., 2000, Active normal fault evolution in Greece revealed by geomorphology and drainage patterns: Journal of the Geological Society, v. 157, no. 5, p. 967–981, https://doi.org/10.1144/jgs.157.5.967.

Habicht, C., ed., 1999, Pausanias' guide to Ancient Greece: Berkeley, California, University of California Press, 233 p.

Heim, A., 1922, Geologie der Schweiz, v. II, part 2: Leipzig, C.H. Tauchnitz, 541 p.

Jackson, J., 1994, Active tectonics of Aegean region: Annual Review of Earth and Planetary Sciences, v. 22, p. 239–271, https://doi.org/10.1146/annurev.ea.22.050194.001323.

Lalechos, N., 1973, Geologic map of the Greece Kato Fighalia sheet (1:50,000): National Institute of Geological and Mining Research, Athens, Greece.

Matthaei, R., 1971, Cautions for the observer, *in* Matthaei, R. (ed.), Goethe's color theory: New York, van Nostrand Reinhold, 275 p.

McClusky, S., Balassanian, S., Barka, A., Demir, C., Ergintav, S., Georgiev, I., Gurkan, O., Hamburger, M., Hurst, K., Kahle, H., Kastens, K., Kekelidze, G., King, R., Kotzev, V., Lenk, O., Mahmoud, S., Mishin, A., Nadariya, M., Ouzounis, A., Paradissis, D., Peter, Y., Prilepin, M., Reilinger, R., Sanli, I., Seeger, H., Tealeb, A., Toksoz, M.N., and Veis, G., 2000, Global positioning system constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus: Journal of Geophysical Research, v. 105, B3, p. 5695–5719, https://doi.org/10.1029/1999JB900351.

Miller, D. (trans. ed.), 1995, Goethe, Volume 12: Scientific Studies: Princeton, New Jersey, Princeton University Press, 344 p.

Mudge, M.R., and Earhart, R.L., 1980, The Lewis thrust fault and related structures in the Disturbed Belt, northwestern Montana: U.S. Geological Survey Professional Paper 1174, 18 p.

National Park Service, 2006, Ninaistako (Chief Mountain): Resource Bulletin, Crown of the Continent Research Learning Center, U.S. Department of the Interior, https://www.nps.gov/glac/learn/nature/upload/Chief%20Mtn.pdf (last accessed 12 Sept. 2017).

Papadopoulos, P., 1997, Geologic map of the Megalopolis sheet (1:50,000): National Institute of Geological and Mining Research, Athens, Greece.

Quereau, E.C., 1895, On the cliffs and exotic blocks of North Switzerland: The Journal of Geology, v. 3, no. 7, p. 723–739, https://doi.org/10.1086/607329.

Romano, D.G., and Voyatzis, M.E., 2014, Mt. Lykaion excavation and survey project, part 1, the upper sanctuary: Hesperia, v. 83, no. 4, p. 569–652, https://doi.org/10.2972/hesperia.83.4.0569.

Romano, D.G., and Voyatzis, M.E., 2015, Mt. Lykaion excavation and survey project, part 2, the lower sanctuary: Hesperia, v. 84, no. 2, p. 207–276, https://doi.org/10.2972/hesperia.84.2.0207.

Seamon, D., and Zajonc, A., eds., 1998, Goethe's way of science: A phenomenology of nature: Albany, New York, State University of New York Press, p. 213–232.

Skourlis, K., and Doutsos, T., 2003, The Pindos fold-and-thrust belt (Greece); inversion kinematics of a passive continental margin: International Journal of Earth Sciences, v. 92, no. 6, p. 891–903, https://doi.org/10.1007/s00531-003-0365-4.

Trümpy, R., 2006, Geologie der Iberger Klippen und ihrer Fysch-Unterlage: Eclogae Geologicae Helvetiae, v. 99, p. 79–121, https://doi.org/10.1007/s00015-006-1180-2.

Willis, B., 1902, Stratigraphy and structure, Lewis and Livingston Ranges, Montana: Geological Society of America Bulletin, v. 13, p. 305–352, https://doi.org/10.1130/GSAB-13-305.

Wissing, S.B., and Pfiffner, O., 2002, Structure of the eastern Klippen nappe (BE, FR): Implications for its Alpine tectonic evolution: Eclogae Geologicae Helvetiae, v. 95, p. 381–398.

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