The Sanctuary of Zeus, Mount Lykaion, is located in the Peloponnesus of Greece. It lies 14 km west of Megalopolis and 33 km southeast of Olympia (Fig. 1).

From at least as far back as the fifteenth century B.C., and extending into first century B.C., this sanctuary was the site of Zeus-cult activities, details of which are described in the ancient literature and in the findings of early twentieth-century excavations carried out by archaeologists associated with the Greek Archaeological Service (Romano and Voyatzis, 2014, 2015). Since 2004, this sanctuary has been the focus of detailed and comprehensive inquiry by the Mount Lykaion Excavation and Survey Project, a joint effort of the American School of Classical Studies (Athens), the Greek Archaeological Service, and the University of Arizona (see Acknowledgments below). As project geologist I have carried out detailed geological mapping of this site, with the primary goal of describing the influence of the geology and tectonics on site selection for this uncommon mountaintop Zeus-cult sanctuary, and for interpreting the distribution of its built structures and monuments. Mapping and analysis have revealed that the archaeological elements of the sanctuary were positioned and/or exploited where landscape, bedrock, and/or geologic structures were amenable to intended function (Davis, 2017).

COMPONENTS OF THIS CONTRIBUTION

This GSA Map and Chart Series contribution has five components: (A) summary; (B) Geologic Map; (C) Geoarchaeological Map; (D) Map of Field Stations; and (E) spreadsheet of formation identification and bedding readings.

STRATIGRAPHY

The basic stratigraphy of the region was established by Lalechos (1973, 1974) and Papadopoulos (1997). They framed the stratigraphic column shown in Figure 2D. They recognized that these four bedrock formations belong to the Pindos Unit. Each author mapped areas of ~500 km² at 1:50,000-scale mapping. I carried out geologic mapping at a much larger scale (1:2000) and for a much smaller area (~15 km²). I split the “Limestones” into two distinctive limestone-dominated formations (Fig. 2E), and I assigned informal names to each of five formations. (1) The Chert Series Beds formation (Jurassic to Lower Cretaceous) is composed of multicolored radiolarian chert layers in alternations with fine-grained sandstone in the lower part. Upwards, coarse-grained sandstones prevail with interbeds of...
radiolarian chert, red marl, and fine-grained limestone. (2) The 
First Flysch Beds formation (Cenomanian to Lower Turonian) 
is a sequence of brownish or greenish, fine-grained to coarse-
grained sandstones with some interbeds of red marls (clayey 
limestones). (3, 4) The Limestone Beds formation (Turonian to 
Maastrichtian) consists of platy to bedded, multicolored lime-
stone with layers or nodules of red-black chert. In the upper 
parts, clayey limestone (marls) and red mudstone are interstrati-
fied, as well as minor sandstone. (5) The Flysch Transition Beds 
formation (Maastrichtian and Paleocene) consists of alternations 
of thin-platy to bedded limestone, with layers or nodules of 
chert and clayey limestone (marl) and red marl in the lower part. 
Detailed descriptions and photographs of the map units may be 
found in Davis (2009, 2014).

The Pindos Unit was deposited in a deep, narrow, oceanic 
basin adjacent to Apulian and Pelagonian (African microplate) 
rift shoulders, on which shallow-water carbonate platforms were 
deposited (see Fig. 2A). Sediments deposited in the Pindos Basin 
from Late Triassic to Early Cretaceous were radiolarian cherts 
and other siliceous pelagic deposits interlayered with arrivals of 
turbidity-current-derived siliciclastics (Degnan and Robertson, 
1991, 1998). During the Late Cretaceous, there was a shift to 
deposition of pelagic and hemipelagic carbonates and carbonate 
turbidites (Degnan and Robertson, 1998). In Late Cretaceous and 
Paleocene, the Pindos Basin was tectonically inverted (Degnan 
and Robertson, 1991, 1998, 2006; Piper, 2006; Skourlis and 
Doutsos, 2003).

**STRUCTURAL GEOLOGY**

The Sanctuary of Zeus occupies Agios Elias (~1400 m), the 
second highest peak of Mount Lykaion. The upper part of Agios 
Elias is a thrust klippe. The regional thrust fault (Lykaion thrust), 
which defines the base of the klippe, dips 10°E and discretely 
separates the upper and lower levels of the Sanctuary of Zeus 
(Davis, 2009). The lower plate of the Lykaion thrust is marked 
by a number of large, northerly trending, gently plunging, up-
right to slightly overturned anticlines and synclines. The upper 
plate of the Lykaion thrust is largely homoclinal and gently 
dipping, although conspicuously broken by high-angle nor-
mal faults. Evidence for active faulting is clear along the eastern 
margin of Agios Elias, where Agios Elias is stepped down 
and ground-rupture fissuring is abundant, and a major ac-
tive landslide has been accumulating. Details of the nature of

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Figure 2. Pindos Basin formations and ages. (A) Carbonate platform sediments deposited on rift margin of basin. (B) Pindos Basin formations and (C) members, from Degnan and Robertson (1998). Stratigraphic nomenclature of (D) Lalechos (1973, 1974) and Papadopoulos (1997), and (E) Davis (2009). (F) The approximate thicknesses of formations in Mount Lykaion area. Overall figure adapted from Degnan and Robertson (1998, their figure 16, p. 66).
the structural geology of the map area are available in Davis (2009, 2014).

The geological mapping presented here was used as a basis for developing a three-dimensional (3D) structural model for Mount Lykaion and the Sanctuary of Zeus (see Acknowledgments). Figure 3A shows one of six geological cross sections that were constructed as a control for the 3D model proper (Fig. 3B). The cross section reveals the major thrust fault (Lykaion thrust) that demarcates the base of the Agios Elias klippe. The upper level of the Sanctuary of Zeus occupies this klippe. Beneath the Lykaion thrust are macroscopically folded Jurassic through Paleocene strata. The geological cross section captures just one of the several high-angle normal faults that cut and extend the thrust relationships. Note that this fault, the Cairn Hill normal fault, cuts and offsets the Lykaion thrust fault.

Figure 3. (A) Geologic cross section of the Sanctuary of Zeus, which identifies the location of the Lykaion thrust fault, the Cairn Hill normal fault, and the Agios Elias klippe. Formations are Chert Series Beds formation (orange), First Flysch Beds formation (tan), Thin Platy Limestone Beds formation (dark green), Thick White Limestone Beds formation (medium green), and Flysch Transition Beds formation (light green). (B) True 3D model of the structural geology of the Sanctuary of Zeus, constructed by Midland Valley Exploration, Ltd. based on G.H. Davis ArcMap GIS data. Same color coding as in A.
As referenced above, the regional thrusting and macroscopic folding related to the Agios Elias klippe occurred as a result of inversion tectonics, when the Jurassic to early Cenozoic Pindos Basin was closed and uplifted. Since the mid-Cenozoic, the Agios Elias klippe and the sanctuary overall have been impacted by normal faulting associated with tectonic extension and stretching of Greece and the Aegean region. In fact, geological mapping revealed that the Sanctuary of Zeus is marked by normal faults that cut and displace the Lykaion thrust. Moreover, the sanctuary contains an active fault and fissure field, which helps feed a large landslide below. The nature of the interplay of faulting and folding is revealed in Figure 3B, which captures the 3D properties of the stratigraphy and structure.

GEOARCHAEOLOGY

The very earliest evidence for Zeus-cult activity is found in the upper level of the sanctuary, which includes the ash altar, temenos, proto-stadium, and some quarries (Romano and Voyatzis, 2015). The lower sanctuary reveals built structures (stoa, administration building, fountain house, corridor, seats, bath) and activity areas (hippodrome, processional way, horse pasture) that appear to have been initiated in the seventh century B.C. (Romano and Voyatzis, 2014). Quite a number of geological factors favored the Zeus-cult placement of built structures and activity areas in close relationship to Agios Elias (Davis, 2017), including the plentiful natural springs emanating from the Lykaion thrust fault. The singularly most important geoarchaeological control is the Agios Elias klippe, which indeed ‘rides on’ the Lykaion thrust (Davis, 2017). In Figure 4, I present a geoarchaeological column, which shows the relationships of the individual archaeological elements and activity areas to the stratigraphy and structure of Mount Lykaion and the Sanctuary of Zeus (Davis et al., 2009; Similox-Tohon et al., 2009, 2011).

AIDS TO EXPLORING THE MAPS

The Geologic and Geoarchaeological Maps for this site can be actively scaled (reduced, enlarged) as they are examined. As I explore these maps at large scale, I find it useful to also have small PDF versions of each map available, so that I have a reference in migrating to targets of interest. For this reason I have included small versions of the Geologic Map (Fig. 5) and the Geoarchaeological Map (Fig. 6), herein.

Figure 4. Geoarchaeological column created to underscore the relation of archaeological elements to the geology. Colors correspond to explanation on maps (Figs. 5 and 6). Position of Lykaion thrust fault is shown (note white arrow). Abbreviations are as follows: aa—ash altar; af—Agnos fountain; as—administration building and seats; b—bath; cb—column bases; ff—fissure field; h—hippodrome; hp—horse pasture; p—proto-stadium; pw—processional way; q—quarry; s—spring; sfh—stoa and fountain house; t—temenos. CSBs—Chert Series Beds formation; FFBs—First Flysch Beds formation; TPLBs—Thin Platy Limestone Beds formation; TWLBS—Thick White Limestone Beds formation; FTBs—Flysch Transition Beds formation.
Figure 5. Smaller version of Geologic Map. Based on mapping and fieldwork carried out from 2004–2016. ASTER GDEM—Advanced Space-borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model.
Figure 6. Smaller version of Geoarchaeological Map. Based on mapping and fieldwork carried out from 2004–2016. 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. White capital letters refer to folds; see Figure 5 for explanation.
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