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Earthquake Faulting at Ancient Cnidus, SW Turkey

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Abstract: The ruins of Cnidus, an important ancient city in southwestern Asia Minor, lie directly on an earthquake fault – the Cnidus Fault. Offset and deformed archaeological remains along the trace of the fault testify to its recent activation. The ancient city's famous Round Temple of Aphrodite is vertically offset by 0.35 m across the fault. The fault also forms the back wall to the Sanctuary of Demeter where Roman-age walls are displaced and deformed by slip on the fault. Archaeological evidence suggests multiple episodes of abrupt destruction at the site and, in the Sanctuary of Demeter, indicates past earthquake surface rupture on the Cnidus Fault. Other evidence of seismic damage is apparent at the site, most notably the parallel collapse of columns in a former stoa/row of shops, which directly overlie a destruction level dated by archaeologists to the 5th century AD.

Together, the geological and archaeological evidence points to at least two major seismic events affecting the site. The first event, around the late Hellenistic period (2nd–3rd century BC), caused the destruction of the original Round Temple and of a temple in the Sanctuary of Demeter. The second event involved surface rupture of the Cnidus Fault and was responsible for the dislocation of the replacement Round Temple and the later walls of the Sanctuary of Demeter. In both cases, the archaeological evidence is consistent with a late Roman to early Byzantine age for this second event, which, if contemporaneous with the 5th century AD destruction of the stoa, supports an historical account of the city being devastated by an earthquake in AD 459.

Key Words: Cnidus, archaeoseismology, faulting, surface rupture, earthquake

Antik Knidos Kentinde Faylanma, GB Türkiye

Özet: Küçük Asya'nın güneybatısında önemli bir antik kent olan Knidos'un kalıntıları aktif bir fay olan Knidos Fayı üzerinde yer almaktadır. Fay boyunca gözlenen deformasyona uğramış arkeolojik kalıntılar, fayın yakın geçmişteki aktivitesini göstermektedir. Antik kentin ünlü yuvarlak Afrodit Tapınağı fay tarafından 0.35 m düşey olarak ötelenmiştir. Ayrıca bu fay, Demeter Tapınağı'nın arka duvarını oluşturur ve Roma dönemine ait duvarlar fay tarafından kesilmiştir. Antik kentte ve Demeter Tapınağı'nda birbirini takip eden birçok ani yıkımın olduğunu gösteren arkeolojik kanıtlar Knidus Fayı'nın önceki depremlerde yüzey kırığı oluşturduğuna işaret etmektedir. Kentte sismik hasarı gösteren diğer kanıtlardan en önemlisi kutsal salonun stünlarının, arkeologlar tarafından M.S. 5. yüzyılla tarihlenen bir yıkım seviyesi üzerine paralel olarak direk yıkılmış olmalarıdır.

Jeolojik ve arkeolojik kanıtlar kentin en az iki büyük sismik olaydan etkilendiğini göstermektedir. Bunlardan birincisi yuvarlak Afrodit Tapınağı ve Demeter Tapınağı'nın yıkılmasına sebep olan yaklaşık geç Hellenistik zamanda (M.Ö. 2.–3. yüzyıl) meydana gelen sismik olaydır. İkincisi, yuvarlak Tapınak ve Demeter Tapınağı'nda yerdeğiştirmelere neden olan ve Knidos Fayı'nda yüzey kırıkları oluşturan depremdir. İkinci depremi arkeolojik kanıtlar geç Roma–erken Bizans dönemine tarihlemektedir. Kutsal Salon'un da M.S. 5. yüzyılda da yıkılmış olması şehrin M.S. 459 yılında bir deprem ile tamamen yıkıldığını göstermektedir.

Anahtar Sözcükler: Knidos, arkeosismoloji, faylanma, yüzey kırığı, deprem

Introduction

Cnidus (Knidos in Turkish) was an important coastal city in southwestern Asia Minor that flourished in Hellenistic and Roman times but declined into obscurity in the Byzantine period. The city lies in a seismically active area (Figure 1) and archaeologists have speculated that earthquakes may have been responsible for the final abandonment of the city. Thus far there has been no corroborating geological support for this view. In this paper, we review the published archaeological evidence

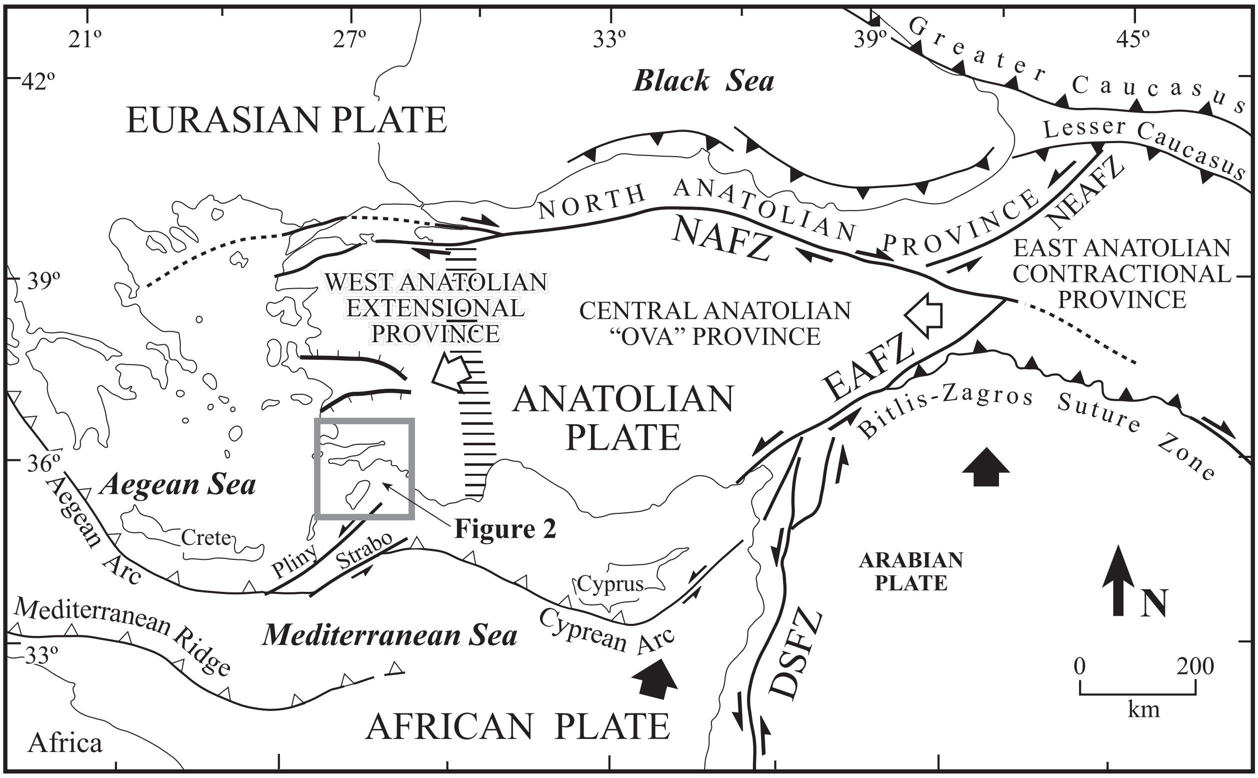

Figure 1. Simplified tectonic map of Turkey showing major neotectonic structures around Turkey (from Bozkurt 2001).

for earthquake damage in the light of new geological and geomorphological field observations to show firstly that the city lies directly on an active fault, and secondly that rupture on this fault is a likely cause of at least some of the damage recorded at the site. Furthermore, from the peculiar setting of the main cult sites, we argue that the active fault itself, or at least specific points along its trace, may have represented sacred sites to the local population.

Geographical and Historical Setting

The ruins of ancient Cnidus lie at the western end of the Datça Peninsula, a 65-km-long, E–W-trending strip of mountainous terrain (Figure 2). The mountains rise in places to over 1000 m, but towards the western end of the peninsula they give way to considerable patches of well-watered land along the southern shores. The ruins of the settlement itself sprawl for several kilometres over this southwestern area, although the area delimited by the city walls is confined to the steep terraced slopes of the rocky Tekir Promontory and of the adjacent islet of Cape Krio (or the 'Camel's Hump'), which form the westernmost tip of the peninsula.

The original site of Cnidus was established in the early 7th century B.C. in the centre of the Datça Peninsula, near the modern town of Datça (Newton 1865; Bean & Cook 1952; Grant 1986) (Figure 2). However, probably to exploit the Tekir Promontory's strategic position as a stopping-off point for maritime traffic along the Asia Minor coast, the city 'moved' west to its present position around 360s B.C. and quickly flourished into an important commercial, cultural and artistic centre. The temples of the new city were constructed by the leading sculptors of the time (Skopas and Bryxias) and adorned with important artwork, most famously the statue of Aphrodite by Praxiteles, for which the town became particularly famous in the ancient world.

Archaeological excavations show that the Hellenistic economic and cultural prosperity of Cnidus continued into Roman times and up to early Byzantine times. Excavations reveal that the bulk of the buildings at the site are Hellenistic or Roman, but numerous Byzantine

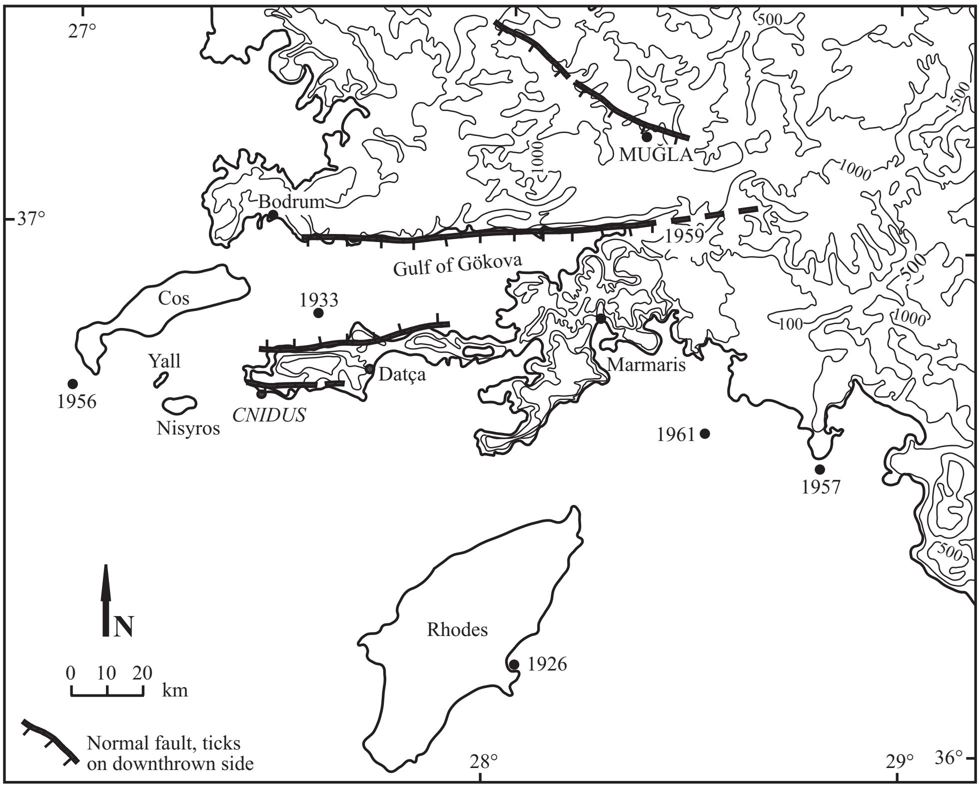

Figure 2. Structural and morphological setting of the Datça Peninsula. Bold lines show exposed active fault scarps in limestones, short lines on downthrown sides. Map also shows distribution of earthquakes with M ≥ 6 around Cnidus during the 20th century (Earthquake information taken from Ambraseys 1988 and McKenzie 1972).

structures still attest to a prestigious position and a substantial population, with ubiquitous houses and fortifications as well as at least seven churches. By the 6th or 7th century AD, however, the city appears to have been in decline. Arabic inscriptions in some of the churches testify to attacks by Arab raiders who also sacked other coastal cities in Anatolia in the mid-7th century AD. A key outstanding question at Cnidus relates to whether the city suffered gradual decline in the Byzantine period or whether it experienced a more dramatic demise as a result of earthquakes or human action.

Archaeological investigation of Cnidus began in 1812 when the ruins were studied on behalf of the Society of the Dilettante, who published the first plan and drawings of the site in 1840. Shortly afterwards, in 1857–1858, Sir Charles Newton made the first significant excavations at the site (Newton 1865). There was no further detailed examination of the site for more than a century. Then, between 1967 and 1977, systematic excavations and survey work were carried out under the direction of Professor Iris Love (Love 1968, 1969, 1970, 1972a, b, 1973, 1976); many of the buildings were uncovered during this excavation campaign. Current excavations at the site started in 1988 under the supervision of Professor Ramazan Ozgan (Selçuk University in Konya); the results are summarised in Mellink (1991, 1992, 1993) and Gates (1994, 1995, 1996).

Geological and Seismotectonic Setting

The Datça Peninsula is located in one of the most geologically restless parts of southwest Turkey (Figure 1). To the south of the peninsula, the northward-moving African Plate is subducting below the southwest-moving Aegean block. This movement generates large, deep subduction-zone earthquakes below the peninsula and more shallow but equally damaging earthquakes along the transcurrent fault system (Pliny-Strabo transform) bordering the eastern edge of Rhodes island (Figure 1). Several major destructive earthquakes have struck this segment of the plate boundary, most notably the damaging events of 412 BC (Ambraseys & White 1997), c. 227 BC, 199–198 BC (Guidoboni *et al.* 1994), 24 BC (Ambraseys & White 1997), AD 142–144, AD 344, AD 474–478 and AD 554–558 (Guidoboni *et al.* 1994). West of the peninsula lie the active volcanic centres of Nisyros and Yali (Figure 2), ash deposits from which crop out in patches around the Cnidus area and provided building stones for some of the city's buildings (e.g., Lower Theatre, Odeion). Major eruptive activity has occurred on Nisyros in recent times (AD 1887, 1873 and possibly around 1422) and these violent volcanic events may have been associated with intense seismic activity (Stiros 2000 and references therein). Immediately north of the peninsula lies the Gulf of Gökova, an E–W-trending tectonic trough (half graben) defined by major active normal faults that border the Gökova coastline, the northwestern edge of the Datça peninsula and the southwestern seaboard of Cos island. The 1933 (M=6.2) earthquake, which completely destroyed the town of Cos, is the most recent in a long history of damaging shocks in the vicinity of Cnidus, most notable among them being the seismic events that struck Cos in 412–411 BC, c. 27 BC, 34–335 AD and 554–558 AD (Guidoboni *et al.* 1994). Only one historical earthquake is documented specifically to have struck Cnidus: an earthquake in 459 AD, which, according to the Syrian scholar Evagrius (536–600 AD), affected much of Aegean Turkey and "...was so severe that Cnidus and, among the islands, Cos were completely destroyed." (Guidoboni *et al.* 1994).

In addition to these potential earthquake sources in the surrounding region, the site of Cnidus itself lies directly on an active fault (Figures 3 & 4). This fault, here called the Cnidus Fault, is the westernmost strand in an en-echelon array of major ESE–WNW-trending normal faults that cut obliquely across the western Datça Peninsula. The structural and geomorphic characteristics of these faults have not been studied in detail, and their geometry and kinematics are poorly resolved. The eastern faults are characterised by deeply embayed limestone escarpments and strongly dissected, abandoned alluvial fans, features that would suggest low fault activity. By contrast, the western fault in this array forms a sharp linear limestone mountain front against which thick scree deposits are actively accumulating, indicative of high fault activity. The Cnidus Fault is the westernmost segment of this prominent tectonic mountain front, extending for around 8 km from the village of Yazıköy to the Tekir Promontory.

The Cnidus Fault

The Cnidus Fault comprises two principal fault strands (upper and lower) separated by a prominent stepover zone. The ruins of Cnidus occupy the broad sloping stepover zone between the two strands, with the limits of the city being physically bounded by the imposing fault escarpments (Figure 3).

The upper fault strand can be traced from the western harbour eastward as a NE–SW-trending limestone scarp, 6–10 m in height, which forms a natural bluff on which the city walls were built (Figure 3). A few hundred metres east of the harbour the city walls continue upslope but the bedrock scarp swings abruptly to an ESE–WNW trend (Figures 3 & 4). Here the fault strand branches into three parallel traces: a higher scarp separating bedrock from Quaternary talus and two lower and less distinct scarps cutting the talus slope. While the higher bedrock scarp passes upslope of the Upper Theatre, the two colluvial fault scarps can be traced through the ruined amphitheatre (2 in Figure 3), and link with the main bedrock/Quaternary fault contact further east at the Sanctuary of Demeter (3 in Figure 3). In the Sanctuary of Demeter, the upper fault strand is spectacularly exposed as a near-vertical rock face several tens of metres high, which forms the back wall of the sanctuary. Eastwards of the sanctuary the height of the scarp becomes reduced as the fault trace dies out among bedrock limestones and fault activity switches a few hundred metres south to the lower fault strand.

The lower fault strand forms a prominent limestone escarpment that bounds the coast east of Cnidus (Figure 4). The eastern part of the former city lies in the uplifted footwall of this fault. A few hundred metres east of the city wall, the fault emerges onshore as a prominent bedrock fault scarp, which in places has been erosionally exhumed to again reveal a dramatic decametre-high, near-vertical fault surface. A few hundred metres west of this point, the bedrock scarps marking both the upper and lower fault strands die out as metre-scale bluffs in a small valley that marks the drainage divide with the neighbouring fault segment.

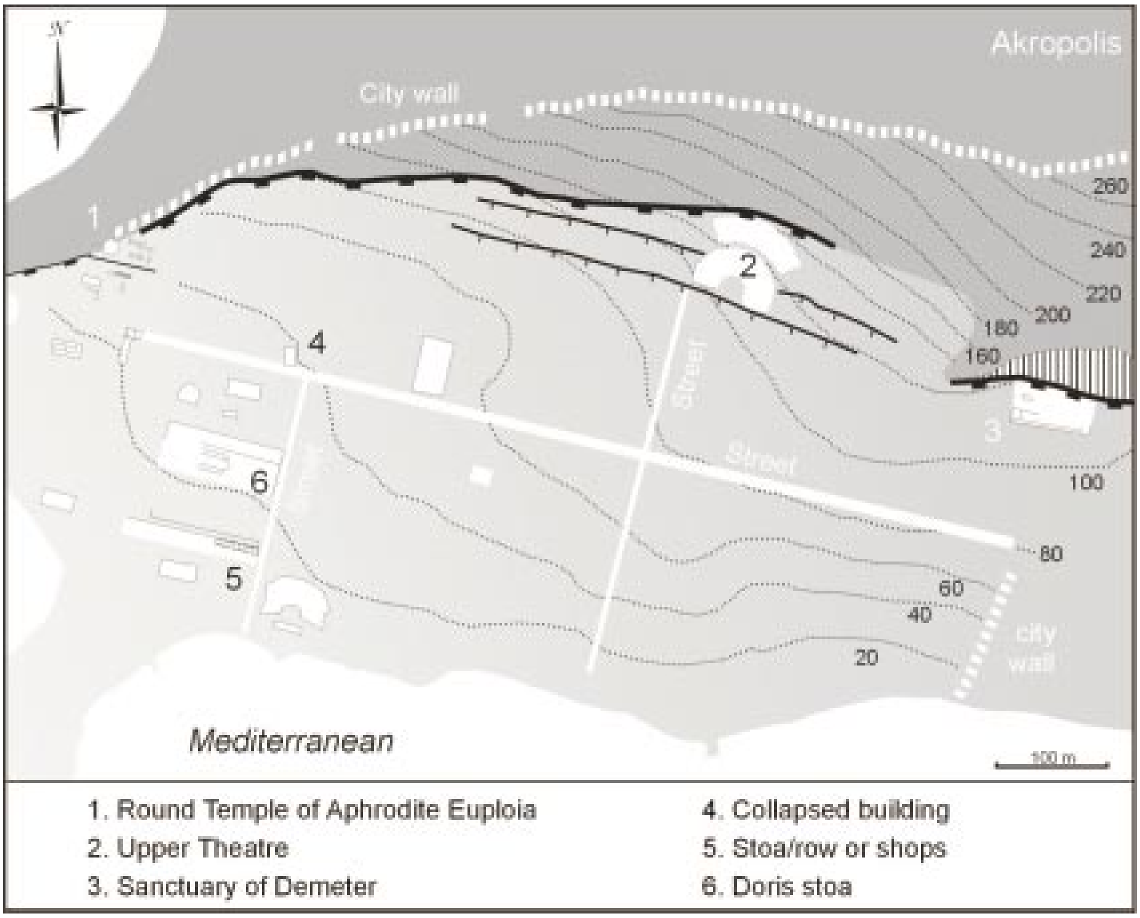

Figure 3. Plan view of key ruins at Cnidus. The bedrock limestone/Quaternary contact that marks the main trace of the Cnidus Fault is shown by the solid black line with boxes on the downthrown (south) side. Lines with barbs indicate the trace of prominent morphological scarps cutting Quaternary scree deposits downslope of the bedrock fault scarp. Hashed ornament shows the decametre-high exhumed fault plane that forms the near-vertical back wall to the Sanctuary of Demeter.

Geological and Archaeological Evidence for Recent Rupture of the Cnidus Fault

At several points along the Cnidus Fault, ruins of the former city lie on or close to the fault trace. Often these constructions are too intensely destroyed or too indistinct to give any detailed indication of the sense or amount of deformation or displacement on the fault. For example, although the fault trace cuts directly through the Upper Theatre (2 in Figure 2) this was stripped of almost all its masonry some time between the 1812 visit of the Society of the Dilettante and Newton's arrival in 1857 (probably robbed out when Cnidus was used as a quarry by Mehmet Ali Pasha in the 1840s). Consequently, the barren amphitheatre provides no clear evidence of fault displacement beyond a morphological step on both its western and eastern flanks.

However, two of the most important constructions in the city, which lie directly on the trace of the Cnidus Fault, do show evidence of recent fault movement: the Round Temple of Aphrodite Euploia and the Sanctuary of Demeter.

The Round Temple of Aphrodite Euploia

The Round Temple, which is believed to have housed Praxiteles' renowned statue of Aphrodite Euploia, is located in the highest, most western terrace of the city, a location with excellent vistas over the city and its

Figure 4. Panorama of the Cnidus Fault, with the ruins of the ancient city on the slopes below. Numbers denote the location of key buildings: 1– Round Temple of Aphrodite Euploia; 2– Upper Theatre; 3– Sanctuary of Demeter.

harbours. The ruins of the temple itself were progressively uncovered by archaeological excavations in the period 1969–1972. The excavations revealed a circular podium (monopteros) with inscriptions that appear to date the structure to the 3rd or 2nd century BC although there appear to have been at least three building phases (Love 1972a, b). The present marble podium is from the second building phase since it contains fragments of earlier Corinthian column drums that Love (1972b) speculates may be from an earlier original round building near or on the present site; the third phase occurred after the structure was damaged and repaired, attested to by mortar infilling cracks in the podium. To the northeast of the podium, a Byzantine wall contains a step block from the podium and therefore must have been constructed after the destruction of the monopteros (Love 1972b, p. 405).

The podium has clearly been strategically placed; its northern side is set into bedrock while its southern side is laid on artificial terrace packing (Love 1972b). Love's excavation of the podium revealed a prominent NE–SW-trending crack that splits the circular structure precisely in two (Figure 5a), downthrowing the southeastern half (Figures 5b & c). Similar NE–SW cracks were observed cutting Byzantine structures (houses?) northeast of the podium. Love (1972a) recognised that the crack coincides with a bedrock fault and speculated that the subsidence was the result of an earthquake. Supporting evidence for seismic destruction was an associated destruction layer within the ruined temple itself. Excavations had revealed large rocks and stone rubble overlying a cache of several hundred terracotta statuettes (Love 1972b). Some of the statuettes showed slight traces of burning and they lay on a thin horizon of fine grey soil containing flecks of carbonised wood, which in turn lay directly on a hard reddish virgin soil and degraded bedrock.

Our geological investigations confirm the archaeological finding that the displaced podium of the Monopteros of Aphrodite Euploia lies directly on a bedrock fault which juxtaposes basement limestones against artificial terrace fill (Figure 5d). The fault itself strikes NE–SW, dips steeply south, and bears striations that indicate a slip vector aligned N185º. Structural mapping confirms that the fault is the surface trace of the main Cnidus Fault, being readily traced for several hundred metres east and west of the podium. West of the podium, the fault offsets a high terrace wall (the back wall of the Temple of Apollo [2nd century BC] on the terrace below), and continues as a prominent (c. 5-m high) limestone bedrock scarp to the coast, where it is obscured below rockfall debris. East of the podium, the crack can be traced across Byzantine constructions; a vertical section through one wall within the Byzantine complex shows the fault trace marked by a 40-cm fissure in the heavily shattered bedrock directly below and infilled by debris, including ceramic fragments. The crack then joins the bedrock fault scarp that forms the back wall of the sanctuary site and continues northeastwards upslope, forming the base of the city wall.

The displaced podium itself remains clearly evident. Although the horizontal trace of the crack on the podium floor is now obscured by debris, the centre of the podium

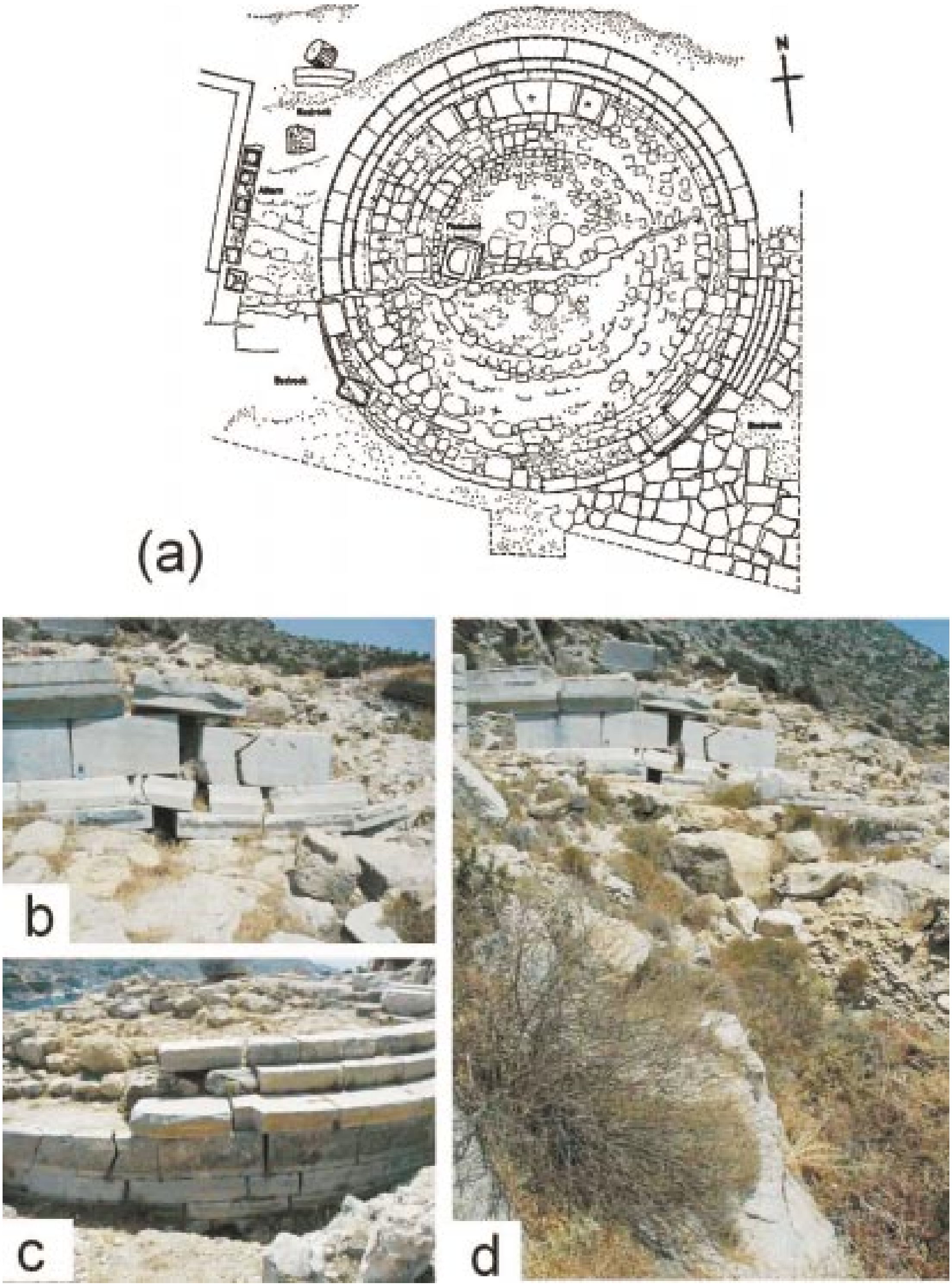

Figure 5. (a) Plan view of the podium of the Round Temple of Aphrodite Euploia showing the trace of a crack that bisects the structure, from Love 1972b, figure 6). (b) Close-up view of the southwest side of the podium showing vertical offset and dilated blocks that accommodate a net 0.5-m downthrow of the southern side. (c) Close-up view of the northeast side of the podium. (d) View to the northeast showing the bedrock fault that juxtaposes limestones with alluvial terrace materials and cuts directly through the podium.

is pierced by an about 50-cm large circular hole and the crack passes exactly from this small well and is visible on its walls. More distinct are the gaping vertical fractures that cut both the southwest and northeast walls. On the southwest side, cumulative displacements of multiple tilted and offset blocks indicate a net vertical southward downthrow of the structure by around 0.35 m (Figure 5b); many of the blocks showed a small (1–2 cm) right-lateral offset (also discernible in Love's sketch of the podium floor; Figure 5a). On the opposite side of the podium the vertical offset is less distinct, with the deformation being distributed across a broader zone of fractured and tilted blocks (Figure 5c). Measurements of the dilation direction of the displaced alter blocks on both sides reveal a consistent opening direction, corresponding to a N–S direction.

An important question is whether displacement of the podium is the result of seismic rupture along the Cnidus Fault or is simply due to differential ground movement between the bedrock and the artificial (terrace) fill. Two lines of evidence support the former. First, the slip vector of the fault striations and the opening direction of the blocks are parallel and do not correspond to a pure downslope translation. Secondly, newly developed shear fractures cutting the alter blocks have orientations parallel to the underlying fault and at least one of these nascent fractures exhibits striations. Since it seems unlikely that fracturing by ground subsidence would be sufficiently energetic to generate striae, dynamic rupture of the podium is preferred.

Sanctuary of Demeter

Generally, places associated with the worship of Demeter, goddess of fertility, were located away from the centre of cities, and this is the case at Cnidus, where the Sanctuary of Demeter is located on the upper slopes of the easternmost side of the city. According to its excavator, Sir Charles Newton (1865), the sanctuary ('temenos') was probably a private site and was dated by a dedication to around 350 BC. Little of the sanctuary remained at the time of Newton's excavation (probably because it did not have the same chance of being repaired and renewed as often as the public temples of Cnidus; Newton 1865) and today only its retaining walls are evident.

The sanctuary is defined by massive masonary retaining walls on its western, southern and eastern sides; the northern side is defined by a sheer rock-face "...sloping at an angle of 79º with such regularity as to suggest that it has been scarped by the hand of man" (Newton 1865). Three votive niches carved into this rock-face, believed to have contained the statues of Demeter, Persephone and Hades, led Newton to excavate at the base of the rock-face in 1858 (T in Figures 6b & d). In doing so, however, the excavation destroyed much of the structures therein, leaving only a few foundation walls. Newton stated that a foundation wall constructed out of Hellenistic materials and aligned parallel to the southern boundary wall was offset, with the level of the ground being higher on the northern platform Newton (1865, p. 408) speculated that "...the want of care and regularity in laying of the foundation..." implied either that it was not genuine Hellenistic craftsmanship or that the foundations had been dislocated by an earthquake.

Newton records other signs of earthquake damage. The litter of Hellenistic remains suggests that a small temple of that period once stood on the site but both the temple and its statues appear to have been subsequently thrown down and dispersed, "...either from an earthquake or by human action". Even after its destruction, however, the sanctuary continued to be sacred because rough enclosures built thereafter continued to accrue votive objects until the 2nd–3rd century AD. The enclosures constructed nearest the rock-face were found by Newton to be deformed, "...forced out of the perpendicular so that each group leans to the south". On the basis of this evidence, Newton (1865, p. 412–413) concludes:

"I am disposed to think that this inclination was caused by an earthquake. I would here note the fact that in one place near the centre of the escarp the strata of soil were curiously contorted, and among them was a layer of ashes, lamps and other human remains so twisted and intermixed with other strata, as to suggest that some violent convulsion of nature had occurred here."

Love's excavations in the early 1970s were unable to uncover all of the specific walls described by Newton, but many of the sanctuary walls that were excavated were found to be deformed from their original rectangular plan "...due no doubt to the action of earthquakes" (Love 1972b, p. 102). In addition, the excavations reveal two major periods of construction, the outer retaining walls belonged to the earlier (undated) period, whilst the inner walls are characterised by mortar rubble construction of the Roman period, probably from the 1st–3rd century AD.

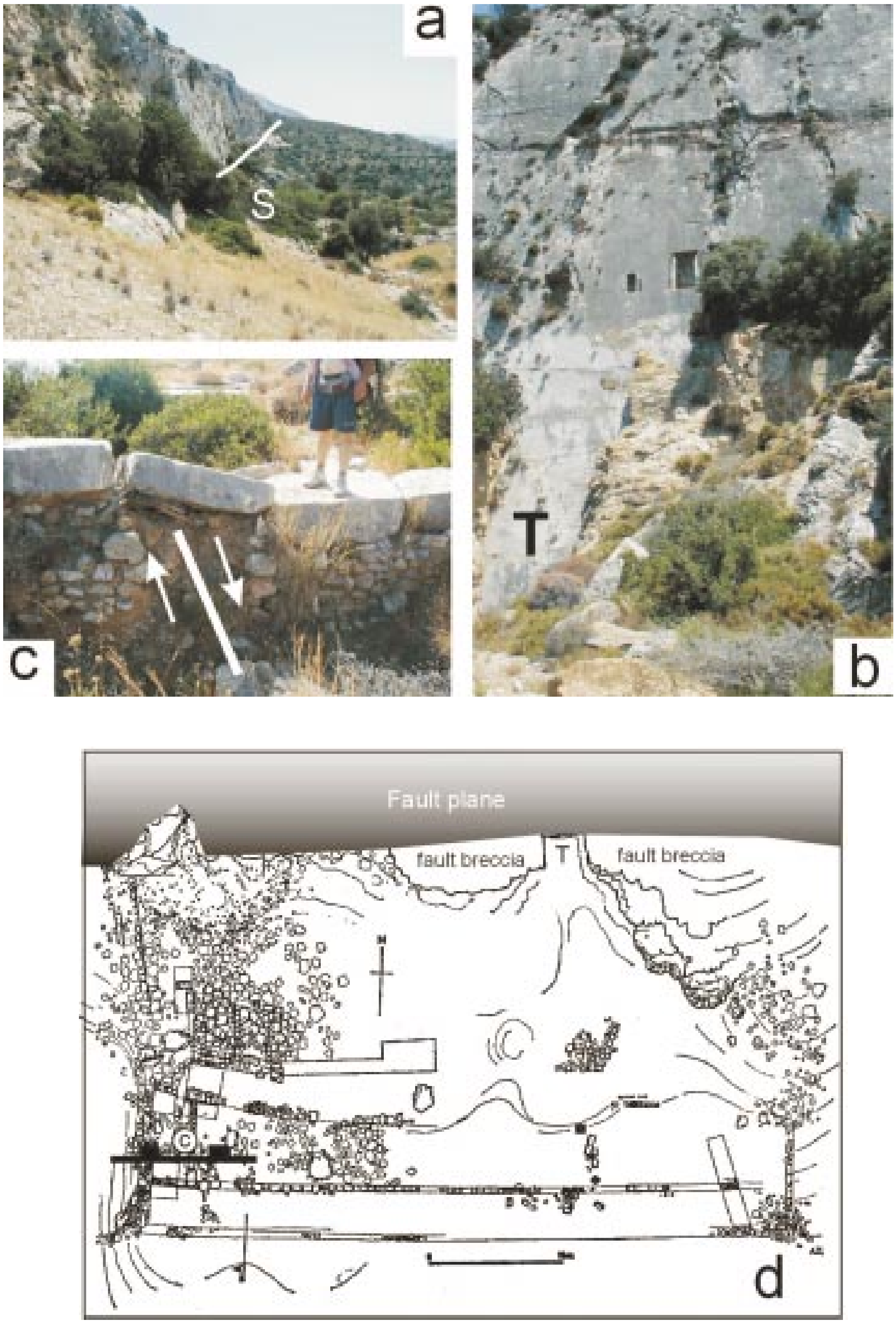

Figure 6. (a) View east showing the prominent limestone fault scarp that forms the back wall to the Sanctuary of Demeter (S). (b) The smooth rock-face that defines the northern edge of the sanctuary and corresponds to a near-vertical limestone fault plane. Rock-carved niches in the fault plane would have displayed statues associated with a former Hellenistic temple at the site. Excavations by Newton removed much of the scree cover at the locality and blasted a trench (T) open to artificially exhume the lower whitish part of the fault plane. (c) View of dislocated N–S-trending wall near the southwestern corner of the sanctuary (location c in d). (d) Plan view of the Sanctuary of Demeter following the excavations of Love (1972b, figure 5). The graduated shaded area denotes the fault plane, T marks the site of Newton's trench, the solid line with barbs shows the position of the faulted wall shown in (c).

Our geological investigations reveal that the sheer rock-face referred to in the archaeological reports of Newton and Love is in fact an exhumed slip plane of the Cnidus Fault. The fault plane itself strikes ESE–WNW and bears well-preserved striations that indicate a slip vector of N185º. It is noteworthy that the three votive niches carved into this fault plane would, prior to Newton's exhumation, have lain a metre or so above the former ground surface precisely at the bedrock/Quaternary contact.

The deformation of the sanctuary's retaining walls also remains evident. For example, a N–S-trending inner (Roman) wall described by Love (1972b) is clearly tilted and offset by 0.5 m, with downthrow to the north (Figure 6c). This would be consistent with a displacement on an E–W-trending minor normal fault that is parallel but antithetic to the main bedrock fault plane a few tens of metres to the north (Figure 6d). Conceivably, the main fault trace downthrowing to the south may be where Newton located the offset foundation walls and 'contorted soil', although confirmation of this must await re-exhumation of the overlying scree and excavation debris pile.

Archaeological Evidence for Seismic Shaking

Published archaeological studies report several locations where earthquake damage is found at Cnidus. Love (1972a, b), for example, suggests that there is evidence for repairs to several prominent buildings (Doric stoa, Temple of Apollo Karneios and the Alter of Aphrodite) during the latter part of the 1st century BC*.

Our geological field surveys across the wider Cnidus site reveal several localities where there are tilted, offset or rotated structures, although these occurrences are often isolated or minor, and consequently are difficult to distinguish from the deformations expected from natural physical decay. One noteworthy example is a collapsed house located to the northeast of the Corinthian Temple and immediately north of the main E–W street (locality 4 in Figure 3). The northern, southern and western walls of the house are rubble but a section of the eastern wall

Figure 7. Collapsed building north of the main E–W street.

* Love speculates that the causative event could be the earthquake that struck nearby Cos in c. 27 BC.

remains, although it lies rotated and tilted against the stone debris (Figure 7). Its semi-intact preservation implies that this eastern wall collapsed inward onto the rubble of the adjacent and opposing walls. However, two particular localities exhibit characteristic features of earthquake destruction.

Stoa/Shop Buildings

In the lower terrace of the city, close to the harbours and the adjacent agora, Love's archaeological excavations revealed a row of shops belonging to a stoa or colonnaded street running in an E–W direction (Figure 8a). The stoa appears to have been constructed in the 2nd century BC. A rock-cut cistern below the shops was found filled with a vast amount of ceramics and statuettes and other Greek and Roman objects, complete and fragmentary. The absence of stratification in the deposit suggests that all the objects were deposited at one time. The cistern was found closed by blocks at its opening and then sealed by a thin plaster floor as well as a burnt layer containing carbonised wood (Love 1973). The current excavations have uncovered pottery, glass and a coin of Theodosius II indicating that these shops were destroyed by fire in the 5th century AD (Gates 1994).

The new excavations have also uncovered the floor of the stoa/shop buildings thereby revealing a series of fallen columns at its eastern end (Figure 8a). These fallen columns display a variety of fractures and breaks, but they are arranged broadly in parallel and aligned in a NNE–SSW direction (Figure 8b). The excavation has carefully exposed and preserved the deposits on which the individual column barrels lie, so that they presently rest on raised *in situ* sediment 'plinths'. The stratigraphy of these plinths exhibits a chaotic assemblage of rock debris, broken terracotta and bone material and at the

Figure 8. (a) View west along the 2nd century BC stoa and line of shops on the lower terrace. Recent excavations at the eastern end have uncovered seven fallen columns that are aligned in a NNE–SSW direction. (b) Close-up view of the fallen columns. (c) The columns rest on sedimentary plinths that show a destruction layer of rock debris, broken terracotta and bone material showing evidence of burning.

base show a distinct burnt horizon (Figure 8c). A sample of bone collected from this apparent destruction horizon is currently being radiometrically dated by ^{14}C assay.

Doric Stoa

Love (1972a) describes the excavation of a Doric colonnade or portico which, owing to its great size, is interpreted as the famous stoa built by the renowned Cnidian architect Sostratos. Following clearance of the overlying debris, a detailed plan of the preserved blocks was made (Figure 9). This plan appears to support a general preferred orientation in the direction of the fallen columns of the colonnade since most of the columns are aligned NE–SW; the arrangement of the columns suggests that they toppled to the northeast. The evidence must be viewed with caution, however, firstly because today the column barrels no longer lie in their original positions described, and secondly because there is a possibility that some of the column barrels were robbed out (Love 1972a).

Fallen Columns as Seismic-Shaking Indicators

Parallel fallen columns are commonly employed as diagnostic indicators of earthquake damage (e.g., Stiros 1996); alternatively, a non-aligned (chaotic or radial) arrangement of fallen columns can help support a human-induced destruction of a temple or stoa (cf. Miller 1988). Nur & Ron (1996) argue that it is possible to infer from the direction in which columns fell the ground motion during the earthquake that overthrew them. Drawing on examples from archaeological sites along the Dead Sea Fault Zone, they suggest that, assuming that more or less free-standing columns fall in a direction opposite to the initial horizontal strong ground motion, their orientation can be an indicator of the direction of fault-rupture propagation.

At Cnidus, the orientation of column collapse appears to be SSW directed in the stoa/shop buildings and SW directed in the Doric stoa. This direction is roughly parallel to the slip vector of the bedrock fault and with the opening direction of the displaced podium blocks in the Round Temple of Aphrodite.

Discussion and Conclusions

The main conclusion of this study is that the ancient site of Cnidus lies directly on an active normal fault, the Cnidus Fault. An indication of its recent activity can be gleaned from the fresh geomorphic expression of the bedrock scarp defining the bedrock limestone/Quaternary contact which is comparable in continuity and appearance to other active limestone fault scarps in the Aegean region (e.g., Stewart & Hancock 1988, 1991; Stewart 1993). However, it is the archaeological evidence for recent fault movement that demonstrates unambiguously its Late Holocene activity.

The published archaeological accounts indicate that since its original establishment in early Hellenistic times,

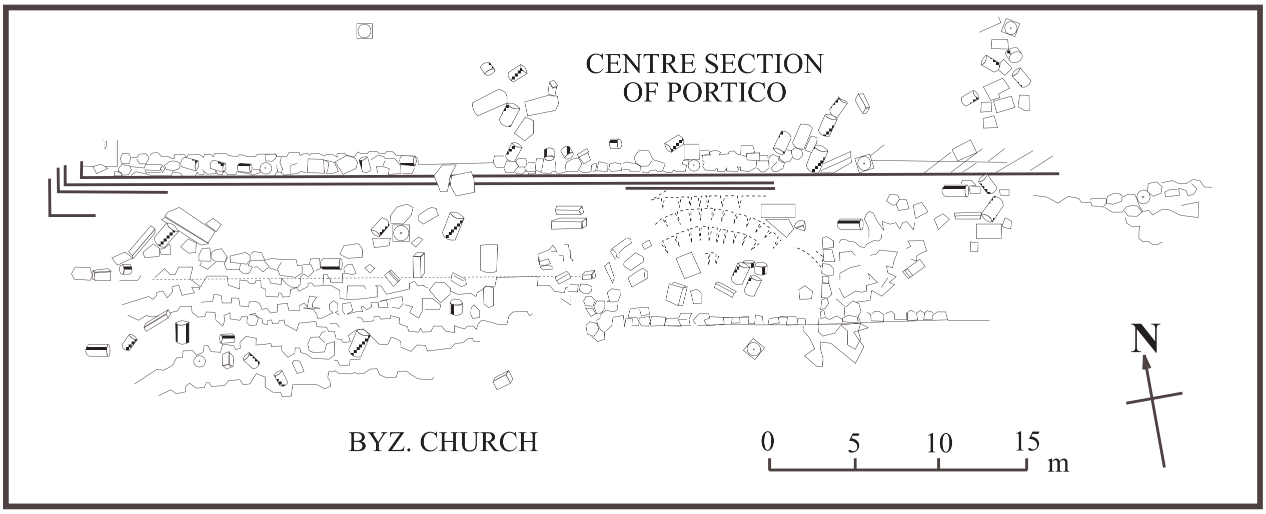

Figure 9. Plan view of the Doric stoa showing an apparent NE–SW alignment of fallen column barrels (simplified from Love 1972a).

the Round Temple of Aphrodite has been rebuilt and/or repaired at least twice; at least one of these events is marked by a destruction level in which there are traces of burning. The first destructive episode appears to have occurred prior to the present marble podium being dedicated in the 3rd or 2nd century BC. Thereafter, the new podium would seem to have survived intact at least until after its notorious depiction in pseudo-Lucian's 'Affairs of the Heart'. The dating of this account, however, is problematic; while some modern scholars now attribute the account to Lucian himself, which places it in the second half of the 2nd century, the traditional view has been that the work is of an unknown later (3rd or even 4th century) writer (see Jones 1986). Whatever its date, the second destructive episode caused the 0.35 m displacement of the podium by rupture on the active fault that underlies it. Following this second event, the damaged podium was temporarily patched up with mortar, although at some later stage marble blocks from the podium were incorporated into new Byzantine buildings.

The Sanctuary of Demeter also implies at least two destructive events. After its construction at the beginning of the Hellenistic period (c. 350 BC), the small temple that probably occupied the site was destroyed. Rough enclosures were then built, apparently in the 1st–3rd century AD, to house votive offerings and these continued to accrue at least up until the 2nd–3rd century AD. At some point during this period, a second destructive event was responsible for the displacement and deformation of the enclosure walls, which caused the sanctuary's abandonment. The contorted soil and associated destruction horizon reported by Newton (1865) within a few metres of the bedrock fault plane is consistent with surface rupture of the Cnidus Fault, although it is not clear to which of the two destructive events it might relate.

Archaeological excavations provide other insights. The repairs to several prominent buildings (Doric stoa, Temple of Apollo Karneios and the Alter of Aphrodite) during the latter part of the 1st century BC suggest a destructive event around that time. Many of the Roman buildings at the site show evidence of burning consistent with a later destructive event, in late Roman or early Byzantine times. The strongest evidence for the Byzantine period is the recent indication that the stoa and shops constructed around the 2nd century BC were destroyed by fire in the 5th century AD.

In summary, there would appear to be physical evidence for at least two separate destructive earthquakes at the site. At this point, it is customary to pluck events from historical earthquake catalogues that fit the archaeological chronology of the site. However, the site chronology remains poorly resolved, with both the structural and literary clues being very loosely dated. More importantly, there remains the possibility (indeed likelihood) that the site was affected by numerous damaging shocks, each of which independently instigated rebuilding and repair. With these two caveats in mind, we draw inferences from the historical catalogue with caution.

The first earthquake event, responsible for the destruction of the original (Classical) round temple and the Hellenistic temple of Demeter, would seem to have occurred during the latter part of the Hellenistic period. This conceivably occurred in the 2nd century BC, necessitating the repair to many of the public buildings and the rebuilding of the marble podium and encouraging the construction of new buildings such as the stoa. Certainly there is a substantial collection of inscriptions from Rhodes and across Caria (the region in which Cnidus was located) that refer to an earthquake in the 2nd century BC; the event, however, is difficult to date precisely (Guidoboni *et al.* 1994). Inscriptions may refer to the earthquake of 199–198 BC for which damage was reported as far away as Samos island in the north and Thera (Santorini) island in the west. Another possibility is the disastrous earthquake of c. 227, most famous because it caused the collapse of the Colossus of Rhodes (one of the seven wonders of the ancient world), but which according to Pausanias also caused major destruction to the north on nearby Telos island and across the mainland cities of Caria and adjacent Lycia (Guidoboni *et al.* 1994). However, perhaps because of the loss of the great Colossus, the 227 BC shock seems to have been particularly felt in Rhodes. In both these cases the extent of reported damage is far wider than that which would be expected from rupture on the Cnidus Fault. However, none of the archaeological evidence for this shock requires rupture of the Cnidus Fault – seismic shaking from a more distant earthquake source is equally possible.

Surface rupture of the Cnidus Fault is strongly suggested, however, for the second destructive event. This rupture displaced the new (Hellenistic) Round

Temple of Aphrodite and caused deformation and offset to the Roman-age enclosing walls of the Sanctuary of Demeter. Again the timing of this event is poorly constrained by archaeological remains at these two localities. The age of the youngest votive objects at the Sanctuary of Demeter indicates that the event occurred after the 3rd century AD. The rebuilt Round Temple appears to have lasted at least until the late 2nd century AD and possibly as late as the 4th century AD; hence the event that destroyed it must be later than this. Some Byzantine structures close to the Round Temple bear cracks similar to that affecting the podium, while other buildings incorporate marble blocks from the destroyed podium and so must postdate the destruction. Together with the evidence for the destruction and burning of the stoa and shops in the 5th century AD, an early Byzantine destruction seems likely. The most likely culprit would seem to be the event of 459 AD, the only earthquake for which damage is specifically attributed to Cnidus (Guidoboni *et al.* 1994).

The earthquake history outlined above for ancient Cnidus is tentative in that it explains the reported and observed damage at the site in the simplest way. It is hoped that the history of the site will be refined by ^{14}C dating of the destruction horizons and by a more precise archaeological chronology as new finds emerge from the ongoing excavations. Palaeoseismic investigations are also needed to confirm surface rupture on the fault and to constrain the timing of this. If surface rupture did occur on the Cnidus Fault in 459 AD, however, it is clear that the earthquake did not directly cause the complete abandonment of the city; the inclusion of blocks from the damaged round temple into later Byzantine buildings clearly demonstrates continued occupancy of the site. However, it is likely that seismic rupture of the Cnidus Fault would have had devastating local effects, particularly in terms of rockfalls and landslides on the steep slopes of the Tekir Promontory, and so it could have marked the end of the city as a viable commercial and strategic staging post, and thereby ushered in its ultimate economic demise.

Arguably the most significant conclusion of this study is the finding that the two most important temples in the city appear to have been deliberately positioned directly above the trace of an active fault, and rebuilt in the same position after a destructive earthquake. Such a correspondence between sacred sanctuaries and active fault traces is not an isolated case: it has been observed at other ancient sites (Piccardi 2001), the most famous being the Oracle of Apollo at Delphi (Piccardi 2000). Such a positioning supports the view that the sacred nature of these sites may be directly due to the peculiar and unusual natural phenomena often attributed to earthquakes, and may be symptomatic of a wider association between sacred sanctuaries and earthquake faults across the ancient world.

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