Evidence for Damaging Historical Earthquakes at Priene, Western Turkey

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Abstract: The ancient city of Priene was one of the earliest Ionian settlements within the western part of the Büyük Menderes valley (the ancient Maeander River) and was first founded about 8 km in the east of the present site. The old Priene was probably destroyed by a destructive earthquake in the 350s BC and the city was shifted to the existing place in 350 BC. The new city contains an abundance of evidence related to earthquakes. The following evidence indicates that damaging earthquakes, occurred in the Büyük Menderes graben, caused great damage to the new Priene. (1) Part of the Sacred Stoa is offset by about 5 cm dextrally and about 50 cm vertically; (2) in the western end of the Sacred Stoa, stair blocks are displaced and tilted; (3) block stones of a N-S- trending street wall are displaced and tilted about 16˚ to north; (4) floor blocks of the agora are displaced and broken; (5) block stones of a semicircular building and two adjacent columns, near the northwestern corner of the agora, are tilted up to 16˚ to north and (6) the lower column-shafts in the Temple of Athena broken all the way around on their bottoms. In addition, restoration of some public buildings (such as the agora, the theatre, street walls and water reservoirs) in the city centre in different times and renovation of the cult statue and the altar in the Temple of Athena indicate that the city was affected by damaging earthquakes at various times after it was rebuilt.

Introduction

Large earthquakes occurred in western Turkey and involved surface ruptures in various scales in the historical period and during the 20th century. Earthquakes also damage man-made structures as a result of both rupturing along a fault or fissures, and widespread ground shaking. Modern towns in western Turkey have been affected by large earthquakes in the 20th century. For example, the 1 October 1995 Dinar earthquake (M=6.3) caused great damage in the town of Dinar and the 16 July 1955 Söke-Balat earthquake (M=6.8) destroyed the town of Balat (ancient Miletus). Likewise, historical earthquake have affected ancient cities and besides causing damage to man-made structures they played important role in the history of cities. The environs of the Büyük Menderes graben, which is one of the most tectonically active structures of western Turkey, are rich in well exposed archaeological sites (e.g. Miletus, Priene, Nysa, Hierapolis) at where destructive historical earthquakes should have left evidence of ancient damage. Recent studies (e.g. Stiros, 1988; 1996; Altunel and Barka, 1996; Hancock and Altunel, 1997) showed that archaeological data in tectonically active regions is valuable in estimating historical impacts of ancient earthquakes. Historical
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This paper reviews the history of Priene from a tectonic perspective and examines deformed man-made structures in the city centre of Priene that display evidence for damaging historical earthquakes.

**Neotectonic and Seismic Setting of Priene**

The Büyük Menderes graben bounded by active normal faults is one of the main active structures of western Turkey (Fig. 1a) (McKenzie, 1972; 1978; Şengör, 1982; 1987; Roberts, 1988; Şaroğlu et al., 1992). The graben makes a major change in strike from E-W inland to NE-SW in its western end, and Priene is located in the northern side of this NE-SW-trending part of the graben (Fig. 1b). The city is sited on a hill which is about 100 m above the flat floor of the graben (Fig. 2). Overlooking the city to the northwest is mountain bounded to the southeast by the 250-m-high steep topographic feature (Fig. 2) which expresses a weathered fault plane according to Roberts (1988). A topographic feature also bounds the southeastern side of the city (Fig. 2). Although this southeast-facing escarpment is also very weathered it reflects the location of an active normal fault (Roberts, 1988; Şaroğlu et al., 1992).

The Büyük Menderes graben contains normal fault geometric segments that have ruptured during major earthquake events in the historical period and during the 20th century. For example, the 1653 (I0=IX) and 1899 (I0=IX) earthquakes involved surface ruptures for about 70 km and 50 km, respectively, along the northern boundary of the Menderes graben (Ergin et al., 1967; Ilhan, 1971; Allen, 1975; Soysal et al., 1981; Ambraseys and Finkel, 1987; Ambraseys and Finkel, 1995). The 16 July 1955 Söke-Balat earthquake (M=6.8) took place near the western end of the Büyük Menderes graben (Öcal, 1958). McKenzie (1972) has provided a fault-plane solution indicating that there was normal downthrow southeast combined with subsidiary right-lateral motion.

**Historical Background**

Priene was one of the earliest Ionian settlements founded in the 10th century BC (Duyuran, 1948) but its present location is not the site where it was first founded (Duyuran, 1948; Baran, 1965; Bean, 1979; Akurgal, 1995). According to Bean (1979) and Akurgal (1995), it has not so far been possible to ascertain the exact site where it was founded. However, Aksu et al. (1987) stated that it was located on the coast about 8 km to the east of the present location. In 350 BC, the new city of Priene was built on its present site with the financial help from Athens (Duyuran, 1948; Baran, 1965; Akurgal, 1995).
The new Priene was also on the coast when first founded but the alluvial deposits brought down by the Menderes River (the ancient Maeander River) gradually increased the distance between Priene and the Aegean Sea coast. For example, Strabon (travel writer lived in 63 BC-21 AD) states that when he visited Priene, the city was about 6 km far from the sea, and at the present time Priene is about 13 km far from the present coast line. According to Akurgal (1995), Priene was subject to the influence and rule of Athens at first, then it passed first to the Kingdom of Pergamon and finally to Rome, which begun to govern it about the middle of the 2nd century BC. It was the centre of an important diocese during Byzantine period. After the end of the 12th century the city was abandoned (Bayrak, 1982).

Priene was constructed on a plan in which streets intersect at right angles (Fig. 3a). In this account, only major buildings that display evidence of either offset by faulting or damage by earthquake shaking, are described. History of major man-made structures in Priene was summarised from Akurgal (1995). The Temple of Athena at Priene was constructed in two stages. The eastern part of the temple was completed in the third quarter of the 4th century and the western part was completed in the middle or the second half of the 2nd century BC when the cult statue and the altar were renovated. The Agora which formed the city centre was built in the 3rd century BC and was enclosed on three sides by stoas. The Sacred Stoa was added in the second half of the 2nd century BC. The Bouleuterion and Prytaneion were built in about 150 BC. The Theatre was built in the second half of the 4th century BC but it was renovated at the beginning of the 2nd century BC, in the middle of the 2nd century BC and finally in the 2nd century AD. Priene possessed two gymnasia: the upper Gymnasium and Stadium were built in the 4th century BC and underwent extensive alterations in Roman times; the lower Gymnasium was built in 130 BC. Priene was supplied with water from the mountains via an aqueduct leading to the water reservoirs in the northeast of the city. These reservoirs had been existence since Hellenistic times but mortared walls of the reservoirs are of the Byzantine period. After the establishment of the new Priene in 350 BC, it was enclosed by a city wall which was built of local marble and preserved in an excellent state of repair.

Description of Damage At Priene

At Priene, evidence that can be used to assess archaeoseismicity are fractured, dilated and collapsed walls, rotated wall blocks, rotated and broken columns, and fractured and offset floor blocks. Most damaged archaeological relics are sited within a NE-SW-trending damage corridor (Fig. 3b) within which some historical buildings are either offset in various scale by right-lateral oblique normal faults or ruptured by dilational fissures. Damage related to shaking, such as tilted or toppled walls, and rotated block stones, is also existing within this corridor.

About 15 m to the northeast of Prytaneion street walls are ruptured. The western part of the approximately 5-m-high east-west trending street wall exhibits an entirely different and later style of ornamentation (Fig. 4a). Towards the southwest of this location, block stones of the north-south trending street wall are displaced and tilted up to 16˚ to north (Fig. 4b). About 15 m further southwest, side blocks of the Sacred Stoa are displaced and blocks are disturbed (Fig. 5b). In
this location, the level-placed blocks of the stoa are offset by about 5 cm dextrally (Fig. 5c [i]) and about 50 cm vertically (Fig. 5c [ii]). Although there is no space between undamaged floor blocks, up to a centimetre spacing is obvious in the deformed part (Fig. 5c). The Sacred Stoa is 116 m in length and its southern side is entirely enclosed with six stairs which led up to the stoa (Fig. 3b). Near its western end stair blocks are displaced and tilted (Fig. 6a). A few metres to the southeast of this location, there is a semicircular building with two columns in its western and eastern sides (Fig. 3b). The block stones of this semicircular building are tilted up to 16° to north. Adjacent columns on its eastern and western sides are also tilted up to 10° to north and the latter is shifted on its base block (Fig. 6b).

The Agora and its western side wall are ruptured. Floor stones of the Agora are displaced, tilted and broken (Fig. 7a). The western wall of the agora is dilated and fractured (Fig. 7b). There are numerous other damaged relics in the city centre. For example, walls of houses are collapsed, numerous columns are toppled,
cracked and broken. A fissure trending NE-SW ruptures the eastern wall of the upper gymnasium and the floor blocks of the church and upper gymnasium are cracked and displaced. One of the most common damage that observed at Priene is that in columns, especially in the Temple of Athena, the lower column-shafts broken all the way around on the bottom (Fig. 8).

Discussion and Interpretation

Impact of earthquakes on the history of Priene

Archaeological data provides useful information for the identification of historical earthquake damage. Before discussing damage on relics at Priene is of archaeoseismic origin, it is important to consider the impact of earthquakes on the history of Priene. As outlined above, the history of Priene extends back about 3 000 years but the period of its first foundation date and 350 BC is almost a blank (Table 1). The exact site of the old Priene is not known yet but according to Aksu et al. (1987) and Akurgal (1995), the old Priene was on the coast in the east of the new Priene. The reason for shifting the city about 8 km westwards is not clear in the archaeological

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<th>DATE</th>
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<tr>
<td>1100</td>
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<tr>
<td>500</td>
<td>Restoration in water reservoir</td>
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<tr>
<td>400</td>
<td>Renovation of the theatre</td>
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<td>300</td>
<td>Major restoration in the upper gymnasium</td>
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<td>Sacred Stoa, Lower gymnasium and stadium, Major restoration in the agora, The western part of the Temple of Athena was completed, Bouleuterion and Prytanion, Renovation of the theatre, and the cult statue and the altar were renovated</td>
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<td>100</td>
<td>Agora and the Temple of Zeus</td>
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<td>Eastern part of the Temple of Athena</td>
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<td>200</td>
<td>Upper gymnasium</td>
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<td>1000</td>
<td>Foundation of the old Priene</td>
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Table 1. A review of construction and reconstruction of major buildings at Priene.
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There are two possible reasons for transferring the city westwards. The first reason is that, as Akurgal (1995) pointed out, the coast line was gradually drawing away as a result of alluvial deposition by the Menderes River and the old Priene which was a port city gradually lost its significance, thus the old city was abandoned and the new city was built. However, Strabon writes that when he visited the new Priene, it was about 6 km far from the Aegean coast and even later (during the Byzantine time) the distance between the city and the coast line should have been much bigger. Thus, if the increased distance between Priene and the Aegean Sea coast was the reason for transferring the city, it should have been shifted westwards several times after 350 BC. In addition, the old Priene was on the coast in 500 BC (Bean, 1979; Aksu, 1987; Akurgal, 1995) and it seems unlikely that the coast line drew back about 8 km in 150 years. Furthermore, if the reason for transferring the city of Priene was the increased distance between the city and the coast, Priene could have coped with shifting without the financial and other help from Athens. Therefore, it is improbable that the increased distance between the city and the Aegean Sea was the main reason to abandon the old Priene.

The second and likely reason for shifting the city westwards is that, the old Priene was completely destroyed by an earthquake in early 350s BC and the city was rebuilt in the present site after this earthquake. Although Ambraseys (1971) and Stiros (1996) pointed out that earthquakes should not be regarded as an easy solution for the exhumation of civilisation and cultural gaps observed in certain regions, it is well documented.

Figure 5. a) Sketch of displaced blocks in the northeast corner of the Sacred Stoa (see Fig. 3b for location). b) Sacred Stoa (see Fig. 3b for location). Note deformation in the floor. c) Sketch of the base of the Sacred Stoa. (i) plan view, (ii) profile view.
by both historical (e.g. Stiros, 1996; in press; Hancock and Altunel, 1997) and modern records that earthquakes play a certain historical role in tectonically active regions. Attempting to attribute abandonment of the old Priene to a destructive earthquake in early 350s BC is not speculative comparing with the following examples. The 464 BC earthquake that destroyed Sparta triggered a revolt of slaves and oppressed tribes, and a war that could have ended with the disappearance of the Spartan state (Stiros, 1996). Stiros (1996) also stated that the important town of Gortyn in Crete survived the earthquake around 620 AD probably due to the financial and other assistance from the central government but when this support dried up, Gortyn disappeared after the later earthquake around 670 AD. The 60 AD earthquake destroyed Hierapolis in western Turkey and with help from the Emperor Nero, the city was rebuilt in its present form (Bean, 1989). Likewise, the 16 July 1955 Söke-Balat earthquake (M=6.8) ruined Balat (ancient Miletus located about 15 km southwest of Priene) and the town was rebuilt about 5 km in the south. The town of Gediz in western Turkey was shifted about 5 km southwestwards after the 28 March 1970 Gediz earthquake (M=7.2). As a recent example, the 1 October 1995 Dinar earthquake (M=6.3) caused great damage in the town of Dinar (western Turkey) and the town was rebuilt with help from the government. Similarly, since the new Priene was built with the financial help from Athens, it can be concluded that the old Priene was completely destroyed by an earthquake in early 350s BC and the new Priene was built in the present site.

**Historical earthquake Damage**

Two types of historical earthquake damage can be observed at Priene. These are phenomena associated with ground rupture and damage related to ground shaking. The most characteristic examples for the ground rupture are the foundations of the collapsed walls (Fig. 4a), tilted wall blocks (Fig. 4b), destroyed stoa (Fig. 5), fractured and displaced floor blocks (Fig. 7a), and tilted and broken columns (Fig. 6b) within a NE-SW-trending damage corridor (Fig. 3b). According to Stiros (1988; 1996), Altunel and Barka (1996) and Hancock and Altunel (1997), such phenomena is characteristic criteria for historical earthquakes. The NE-SW-trending damage corridor (Fig. 3b) is roughly parallel to the northern...
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Figure 7. a) Scaleless sketch plan of the floor of the Agora (see Fig. 3b for location). Note that blocks are displaced, tilted and fractured along a NE-trending zone.
b) Scaleless sketch profile of the western wall of the Agora (see Fig. 3b location). Note dilation between blocks.

margin of the Büyük Menderes graben (Fig. 1b). As Fig. 5(b) shows, the Sacred Stoa was offset by about 50 cm vertically and about 5 cm dextrally. This slip sense is consistent with that of the 16 July 1955 Söke-Balat earthquake that McKenzie (1972) has provided a faulplane solution indicating normal downthrow southeast combined with subsidiary right-lateral motion. Downthrowing the western part of the Sacred Stoa (Figs 5b and c) indicates that the fault faces northwest which is different direction from that McKenzie (1972) estimated. Thus, it can be concluded that the NE-SW-trending damage corridor is a product of earthquake and it reflects the location of antithetic fault to major fault system. This NE-SW-trending damage corridor probably formed during more than one event. The principal evidence for this conclusion is that, as Fig. 6(b) shows, a column within the damage corridor is both tilted up to 10° to north and shifted on its base. This may indicate two different earthquake events.

Damage related to ground shaking at Priene is characterized by rotated columns, collapsed, tilted and toppled walls, and cracked and displaced floor blocks. Similar damage has also been reported by Karcz and Kafri (1978) from Israel, Stiros and Pirazzoli (1995) and Stiros (1996) from Greece, and Altunel and Barka (1996) and Hancock and Altunel (1997) from Hierapolis (Turkey). One of the most characteristic examples for ground shaking observed at Priene is that in columns of the Temple of Athena, the lower column-shafts broken all the way around on the bottom (Fig. 8). Similar deformation has been observed (during author’s survey in 1992) in water tank at Landers, California, damaged
by the June 28 earthquake (M=7.3). The metal water tank which is about 8 m in height and 10 m in diameter was deformed as a result of ground shaking. In addition to the deformation at the top of the tank, the tank bulges outward all the way around on the bottom (Fig. 9a), called “elephant’s foot”. Similarly, marble columns at Priene were deformed by ground shaking but because they are brittle their bottoms were broken instead of bulging (Fig. 9b).

According to the earthquake catalogues (e.g. Dikmen, 1952; Öcal, 1958; Ergin et al., 1967; Sipahioğlu, 1979) destructive earthquakes near the western end of the Büyük Menderes graben include events in 26 (or 25) BC, and in 68, 238, 244, 262, 1891 and finally in 1955 AD. As Fig. 10 shows, earthquakes occurred in the western end of the Büyük Menderes graben have affected Priene. Earthquake effects after the 12th century AD were not repaired at Priene because the city had already been abandoned by that time. Therefore, it can be concluded that damage observed in the Sacred Stoa, the agora, the Temple of Athena and the N-S-trending street wall is indicative of deformation after the 12th century AD. However, earthquake effects on such public buildings before 12th century AD should have been repaired because those buildings were in use. As Table 1 summing-up there have been major reconstruction and restoration at Priene in the 4th century and 2nd century BC and in the 2nd century AD and during the Byzantine period. Fig. 4(a) shows that the western part of an E-W-

Figure 8. Lower column-shaft of the Temple of Athena. Note that it is broken all the way around on the bottom. Also note that base blocks are broken.

Figure 9. a) Sketch of water tank at Landers, California. (i) before deformation (28 June 1992 earthquake), (ii) after the earthquake. Note that the tank bulges outward all the way around on the bottom. b) Column and its base at Priene. (i) before deformation, (ii) after deformation.
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A trending street wall exhibits an entirely different and later style of ornamentation which indicates that the wall was repaired. The water reservoirs had been existence since Hellenistic times but the Byzantine type mortared walls indicate that they were repaired during the Byzantine period. The cult statue and the altar in the Temple of Athena were renovated in the middle of the 2nd century BC and the city wall was repaired in different times. As Stiros (in press) concluded in somewhere else, presence of restoration in man-made structures is indicative of earthquake damage. Thus, on the basis of the above observations at Priene and Stiros’ (in press) account, it can be concluded that the city was also affected by earthquakes in the period of 350 BC and the 12th century AD.

Remains at Priene display evidence for historical earthquakes but problems arise in connection with the dating of certain events. All that can be said at the present day is that destructive earthquakes occurred at Priene in its 3 000 years history. Considering with heavy reconstruction and renovation in the city centre, it can be concluded that destructive earthquakes include events in the 4th century and 2nd century BC, in the 2nd century AD, during the Byzantine period and after the 12th century BC.

Conclusion
The present site of Priene is not the first place where it was first founded. Initially, the city was founded about 8 km in the east of the present location and probably after a destructive earthquake in 350s BC it was shifted westwards to the present site. Major restoration of public buildings in the new Priene indicates that the new city was affected by earthquakes several times between 350 BC and the 12th century AD. The agora, Sacred Stoa and street walls in the city centre were ruptured by a NE-SW-trending damage corridor that shows clear evidence for displacements since the 12th century AD.

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References


Şaroglu, F., Emre, O. and Boray, A. 1992. 1: 1 000 000 Türkiye diri fay harti (1: 1 000 000 active fault map of Turkey) (unpublished). MTA, Ankara, Turkey.


