THE CREMNA AQUEDUCT AND WATER SUPPLY SYSTEM
EDDIE OWENS

CREMNA (BURDUR, BUCAK, Çamlık, Girme) SU TEMİN SİSTEMİ
EDDIE OWENS

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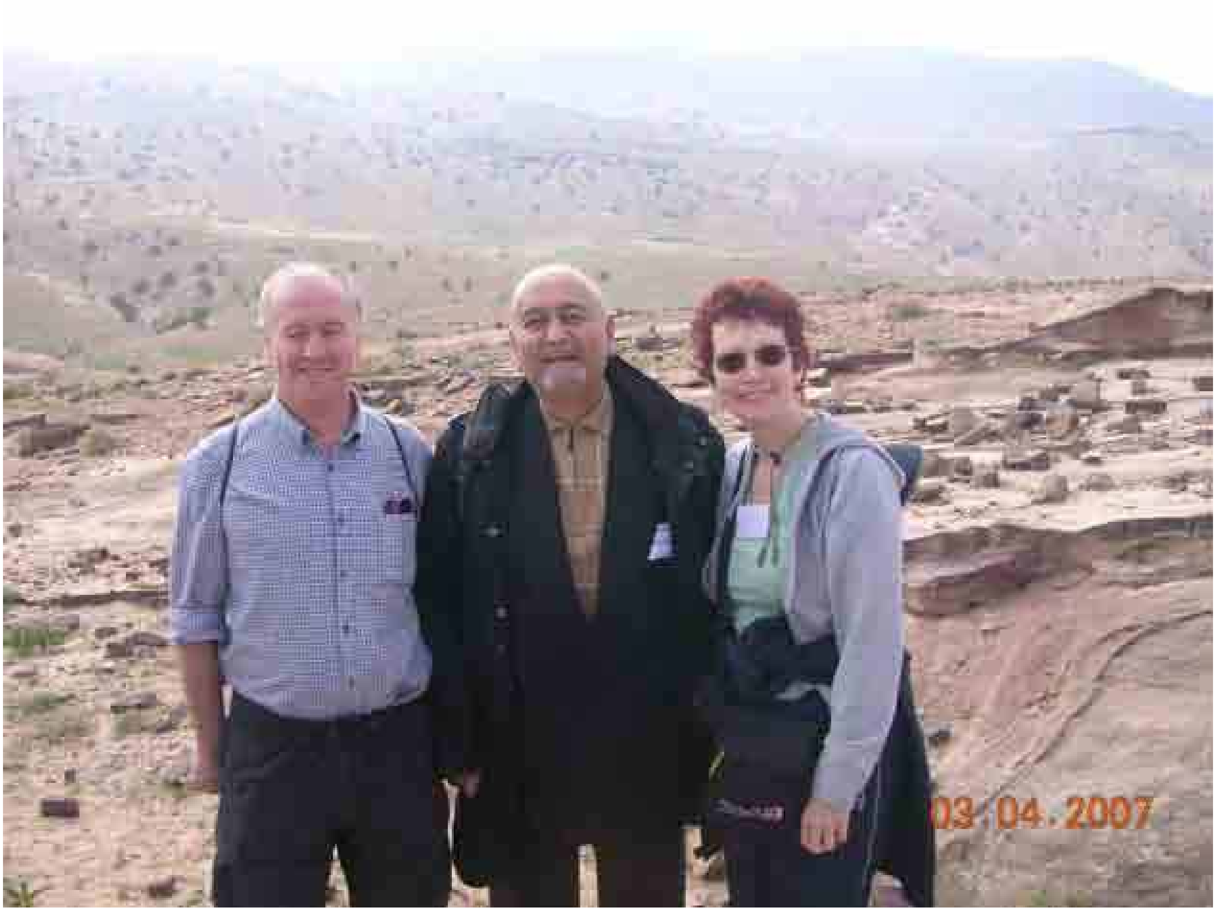

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Greece & Rome, Vol. xxxviii, No. 1, April 1991

THE KREMNA AQUEDUCT AND WATER SUPPLY IN ROMAN CITIES

By E. J. OWENS

A good supply of water was rightly regarded as one of the essential commodities for the maintenance of urban life in the ancient world.[1] One of the major problems with which city authorities had to deal was the maintenance of adequate supplies of water to satisfy the domestic, public, recreational, and industrial demands of the inhabitants. The Romans were particularly renowned for their hydraulic technology in general and the construction of aqueducts in particular, often bringing water from great distances.[2] The geographer Strabo praised the engineering skills of the Romans, maintaining that veritable rivers of water flowed by means of aqueducts through the city of Rome.[3] Close on a century later the first curator of Rome's water supply and one-time military governor of Britain, Sextus Julius Frontinus stated the same, if a little more pointedly, when he compared the achievements of the Romans in the field of water supply with the 'idle pyramids of the Egyptians or the glorious but useless monuments of the Greeks'.[4]

Such comments emphasize in the minds of the Romans their superiority over the Greeks in the construction of aqueducts.[5] The arched, high level aqueduct, striding across the countryside and negotiating river valleys is the popular, if erroneous, picture of Roman hydrological achievement.[6] Certainly a supply of running water together with a fountain house was not only considered an essential urban amenity,[7] but the means of revitalizing and rejuvenating cities which had fallen into decay. Thus Herodes Atticus the Elder revitalized the city of Canusium in Italy by providing water,[8] and according to Procopius, the emperor Justinian re-established Ptolemais in Africa, which had fallen into decay through lack of water, by constructing an aqueduct.[9]

Whilst the aqueduct with its supply of running water became one of the obvious marks of Roman urban life, few cities either could or did rely solely on water supplied by aqueducts. In the first place they were expensive to build and maintain. Cities had to attract the necessary resources, for which even the emperor himself was directly concerned.[10] Pliny records the enormous sums of money that the citizens of Nicomedia expended on two abortive attempts to build an aqueduct.[11] The construction of the aqueduct supplying Alexandria Troas in Asia Minor, requested by the elder Herodes Atticus, cost seven million drachmas, more than double the original estimate much to the annoyance of other cities in the province and the emperor Hadrian himself.[12] The construction of the Lyon aqueduct in Gaul must have cost an enormous sum of money in the supply of lead alone.[13]

Secondly, there was the problem of maintaining the supply of water itself. Like rivers, most aqueducts, fed by gravity and with only small header tanks at the source, were prone to fluctuations in the rate of flow due to variations in the quantity of water at the source.[14] In addition, arched aqueducts in particular must have been prone to damage and disruption through uneven settling across unsuitable ground. Pliny draws attention to the problem of the unsuitability of the terrain to support an aqueduct when describing the attempts of Sinope to build an aqueduct.[15] Similar difficulties are illustrated by the *Aqua Claudia* at Rome. In all, its construction took fourteen years to complete and then it was out of service for repair for nine years of its first nineteen years of use.[16]

Thirdly, there were military dangers. As the military situation within the Empire deteriorated from the middle of the third century A.D. onwards and cities had to endure either hostile attack or investment by Roman troops, reliance on external sources of water became more precarious. Not only could the aqueduct be cut, but also the dry channel might even provide access into the city.[17] The siege of Naples by Belisarius, Justinian's general, admirably illustrates the dangers.[18] First he cut the aqueduct to the city, although in the case of Naples this had only a minimum effect on the inhabitants, because there were sufficient wells within the city walls to provide drinking water and so reduce the impact of the loss of the aqueduct.[19] However, Belisarius did send four hundred troops into the city through the aqueduct, who, after some difficulty in getting out of the channel, effected its capture. Belisarius learned from the siege of Naples and, when later he himself was besieged by the Goths in Rome, he ordered that all of Rome's aqueducts should be blocked.[20] Although for drinking purposes the Romans could rely on the river Tiber and many wells throughout the city,[21] one of the more serious effects of Belisarius' action was to bring to a halt the water-powered grain mills, until water wheels to drive the mills were constructed on the river Tiber itself.[22] Rome and Naples probably reflect the pluralistic approach to the problems of water supply which many cities of the Empire had. This approach, in which public and private efforts were harmonized, is further confirmed by the building inscription from Pergamon. The text required property owners to clean and maintain their house cisterns, even though by the Roman period the city was supplied with numerous aqueducts.[23]

The problems of maintaining adequate supplies of water for domestic, industrial, and recreational needs at Kremna in Pisidia were particularly acute. The city of Kremna, which became a colony at the time of Augustus, is situated on a high southward-sloping plateau in the mountainous region of south-western Turkey. The plateau itself is triangular in shape with its apex pointing to the east. The northern and southern sides rise sheer from the surrounding valleys, and access to the site is only possible from the west and south west. Whilst the nature of the location offered admirable defensive qualities it presented problems for the maintenance of adequate supplies of water.

There are no natural springs on the plateau itself and the geology of the site is not conducive to the retention of water. The declivity of the plateau, together with the porosity of the limestone rock, means that water falling on the site tends to seep through cracks and crevices in the southern cliffs in the form of small springs and rivulets.

Two such springs are still active today. One is situated immediately below the south-western corner of the city next to the road which ran below the southern cliffs and led to the southern gate. Another meagre spring is situated on a narrow path below the cliffs to the east of the southern gate. Along this path evidence of the efforts of the citizens of Kremna to capture these valuable sources of water abound in the form of tanks, channels, and runnels.

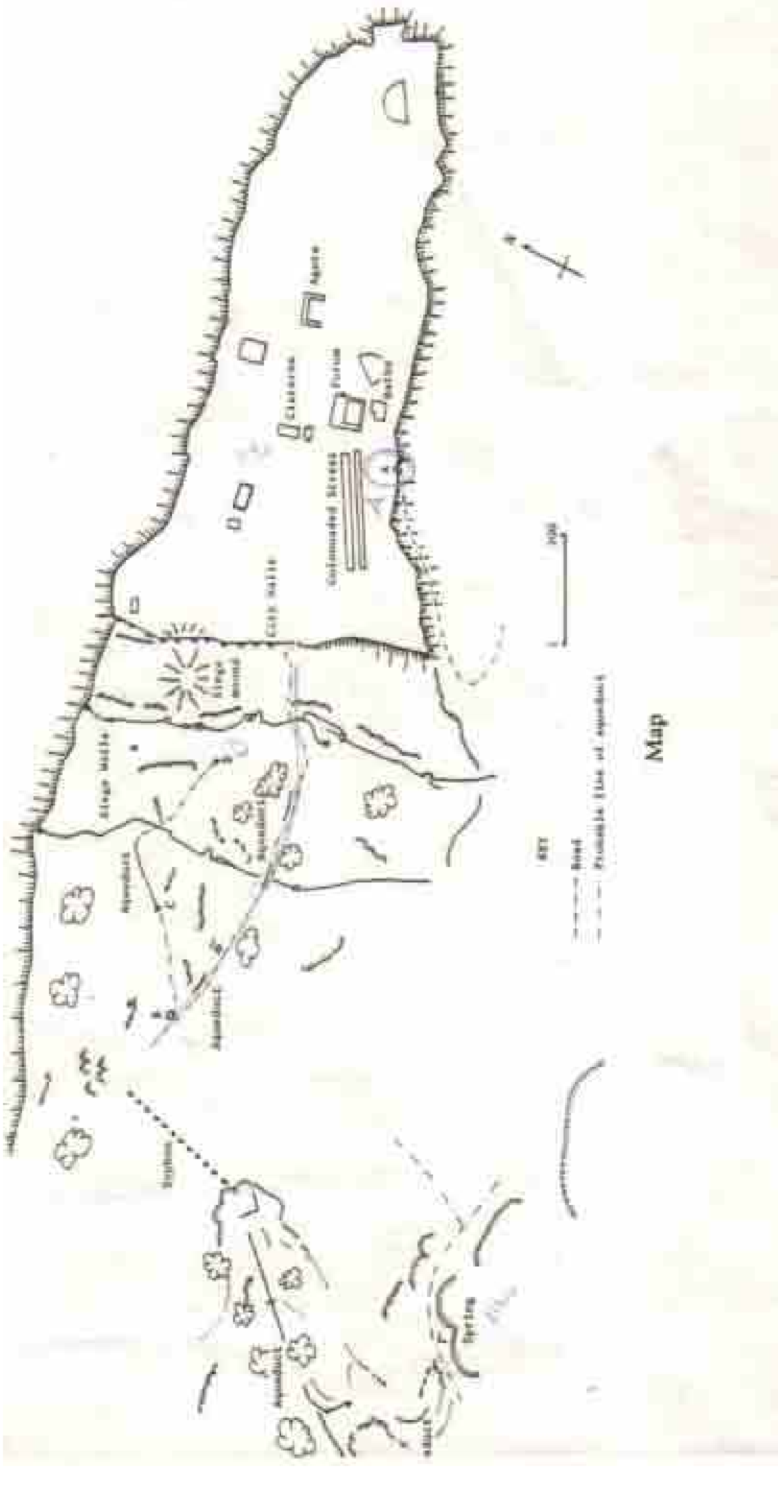
In addition to the small tanks and runnels along the southern cliffs, there was in antiquity a spring house ca. 40 m. to the west of the southern gate on a terrace above the southern approach road (A on map).[24] The spring house consisted of two adjoining tanks which were situated in a cavern hollowed into the cliff face (Plate 1). The rear of the cavern was cut deeply into the rock to improve the supply.

The water was collected in two adjoining shallow basins, constructed of large, squared limestone blocks. The rear basin measured 1.24 × 2.07 m. Pieces of waterproof plaster remained *in situ* on its walls and floor. The front tank, from which the water was drawn, was an elongated rectangle, measuring 3.05 × 0.84 m.

The front of the roof of the cave above the tank was roughly squared, obviously to receive a stone façade. Indeed the lowest courses of the façade were still *in situ* between the right-hand side wall of the front tank and the side wall of the cavern. In the area of the spring house small pieces of marble revetment were found, which possibly came from decorative features on the stone façade.

On the plateau itself there were no natural springs and only two domestic wells were located. Both were situated in the residential area overlooking the civic centre. For personal and domestic purposes the

Plate 1



Map

citizens of Kremna relied heavily on rainwater storage cisterns. Almost every house possessed a cistern which was located in the courtyard and was fed by collecting rainwater from the surrounding roofs of the house. The most common cistern was flask-shaped, a type which is ubiquitous throughout the ancient world. There were also two types of square cistern. One was a simple square or rectangular tank set below the level of the courtyard floor and roofed with limestone blocks. The other was larger and had a central pier supporting the roof of limestone blocks. The walls were usually coated in waterproof cement.

Besides the numerous domestic cisterns there was also a large public reservoir comprising sixteen interconnected tanks arranged in four parallel rows of four. They were situated under a large limestone slabbed piazza, which occupied a small shallow valley above the main civic centre. The two easternmost longitudinal rows have collapsed (Plate 2). The two western rows on the other hand are almost complete, thus allowing detailed examination of the whole reservoir system.

Each tank consisted of a rectangular vaulted chamber, measuring approximately 9.24 × 3.40 m. with a maximum height of 3.83 m. The end walls, side walls, and vaulting of the chambers were constructed with small roughly cut stones, and were covered with three coats of hydraulic cement. The vaults were capped with five rows of elongated rectangular blocks. Either two or three small, square openings were let into the roof of each tank to allow air to escape as the chambers filled. These holes were covered with limestone grids cut in the shape of a spoked wheel.

The inner side walls of the adjoining tanks rested on a row of large, well-cut limestone blocks. In turn the blocks were supported by a series of free-standing, upright monolithic blocks which allowed the free flow of water laterally across adjoining tanks. The flow of water longitudinally between adjacent rows of reservoirs was much more restricted. A single section of terracotta piping, set at the height of the beginning of the vault was the only means by which the water could pass longitudinally between adjacent tanks.[25]

The restriction in the longitudinal flow of water between adjacent rows of tanks ensured that the whole system never emptied. Once the water fell below the level of the terracotta pipe section, the water ceased to pass longitudinally to the next adjoining rows of tanks.

The total storage capacity of the reservoirs was in the region of 1622.1 m^3 (1052 m^3 up to the beginning of the vaulted roof). Although such a volume of water was relatively small to satisfy all the demands of a city the size of Kremna, it seems unlikely that the tanks

could have been supplied by rainwater alone. First, the piazza did not offer a sufficiently large catchment area to ensure that the tanks remained full. Secondly, there is no evidence of extensive channelling, which would have been necessary to bring water from the surrounding buildings. Moreover, in the residential area to the east of the reservoir much of the rainwater was already being collected by individual householders.

Instead, the tanks were fed by means of an aqueduct which brought water from springs ca. 2 kms. to the south west of the city which still supply the modern Turkish village immediately to the west of the site. The aqueduct is short in comparison to other aqueducts in southern Turkey. Nevertheless, it is an impressive example of Roman hydraulic technology. Although the spring is clearly visible from Kremna, the intervening valley was too deep for the aqueduct to take a direct route to the city.[26] Like many Roman aqueducts it followed an indirect but easier route, taking advantage of the gentler terrain to the west of the city. That this spring was the source of water for the aqueduct is certain. Not only were there remains of ancient, dressed limestone blocks in the immediate vicinity of the spring but the aqueduct itself was traced up to the spring. However, the whole question of the relationship between the spring, the aqueduct, the public tanks, and the city in general was complicated by the fact that much of the city, including the public reservoirs (elev. 1190 m.), was at a higher level than the springs (elev. 1160 m). Thus if the water in the aqueduct was intended for the reservoirs, it had to be lifted mechanically.

From the spring to a point on the outcrop of rock, which overlooks the modern village of Hacibağ, the water was carried in a single pipeline of jointed terracotta sections abundant fragments of which were found along the route. The pipeline was supported on a solid stone wall (Plate 3). Over two hundred and thirty metres of the foundations were traced along the top of a low spur of hill which overlooks the western end of the modern village. The foundations were approximately 1.00 m. in width and were constructed of roughly squared limestone boulders forming an inner and outer face. This foundation supported a series of limestone blocks in the top of which a small U-shaped channel was cut to receive the terracotta pipeline. One such block with a U-shaped depression cut into it was found on the line of the aqueduct.

Between the spring and the above spur the aqueduct crossed two narrow but rocky gulleys and here the pipeline was carried on arched structures. Except for the solid squared stone foundations either side of the gulley, nothing now remains of the first bridge, although on

Plate 3

the ground there were abundant fragments of terracotta pipe. On the far side of the first gulley a thirty-metre section of the foundation wall was discovered.

The second gulley was wider and probably spanned by two arches. Indeed one of the arches has been preserved in the top soil where it had fallen (Plate 4). The span was ca. 4.00 m. and the height to the centre of the arch was ca. 3.50 m. Although it is feasible that the water was carried across the two gulleys by means of gravity, it is possible that the actual spans which crossed the lowest points of the gulleys utilized the technology of the inverted syphon. In the first place the fragments of terracotta water pipes associated with the bridges were appreciably thicker than those pieces found in the vicinity of the solid wall on the spur and could conceivably have come from a pressurized section of pipeline. Secondly, on the outcrop of rock between the two gulleys there were the remains of a rock-cut structure together with a large, squared limestone block. It is possible that this was in fact a rock-cut tank which collected the water from one part of the pressure system before delivering it to the next section. Such a pressure pipe was certainly employed to carry the water across the valley which separated the spur from the site.[27]

The valley, in which the modern Turkish village is situated, presented a more serious obstacle. It could not be circumvented because the terrain levelled out to the west and so it would not have been possible for the aqueduct to maintain the necessary height. It was, however, relatively deep and so a high level bridge, maintaining the flow of water by gravity, would have been both unnecessarily high and expensive to construct. Instead a low-level, pressurized system was constructed utilizing a low-level bridge supporting a syphon pipe.

From the rock outcrop, which forms the end of the spur to a point on the opposite side of the valley above the north-western corner of the village the aqueduct was carried on a series of narrow pillars. The foundations of thirteen of the piers of the bridge, properly called a *venter*, have come to light.[28] Traces of the header tank have not been found, but such a tank need not be large and it probably lies in the remains of the collapsed building which occupies the end of the outcrop.

The pressure pipeline was constructed in terracotta.[29] Three complete sections were found in the garden of a house directly on the line of the piers. The lengths of the sections varied from 0.39 m. to 0.42 m. With an external diameter of 24 cms. and an internal diameter of only 8.2 cms., the walls of the pipe were almost 16 cms. thick, necessary to withstand the pressure of the water (Plate 5).[30]

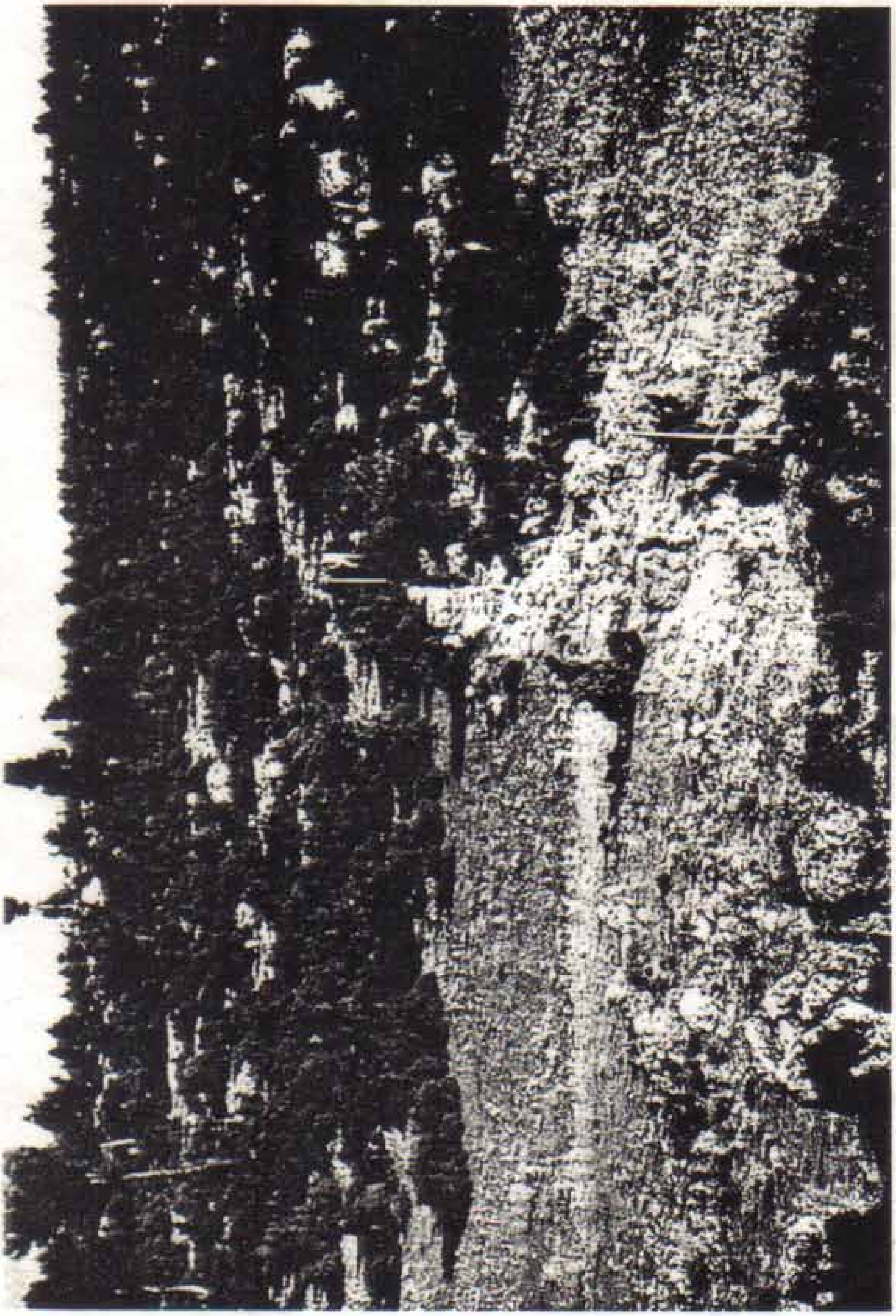


Plate 4

Plate 5

One end of each section was recessed and there was a corresponding flange at the other end for jointing. In the three preserved sections the flange was missing but in the recess there was *in situ* the flange of the adjoining section of pipe. The joints were crudely but effectively sealed with waterproof cement. With such a small diameter and the relative crudity of the jointing the amount of water delivered through the pressure pipe could not have been great.[31]

On reaching the northern side of the valley the aqueduct turned eastwards to run towards Kremna. Unfortunately, all traces of the aqueduct and the receiving tank from the pressure system to the north west of the village have been lost through stone robbing and quarrying, although extensive pieces of broken terracotta piping indicate its general direction.

Closer to Kremna two aqueducts were discovered. The lower one ran directly eastwards, following the line of the road which approached the city from the west, and was traced as far as the ridge which overlooks the western side of the city. Its remains consisted of a solid stone foundation, several sections of which were preserved, together with fragments of terracotta piping. But, as its elevation remained below that of the spring, it was only able to supply water to the south-western corner of the city.

The second aqueduct, slightly more substantial in construction than the lower one, climbed the side of the valley (Plate 6). The preserved section ran for over 140 m., curving in a north-easterly direction towards a cement lined tank which was positioned on the ridge to the west of the city (D on map). This tank certainly had the elevation to deliver water to the public cisterns, but the difference in height between the spring and the tank was close to 30 m. Thus the water needed to be lifted mechanically.

Roman hydraulic engineers certainly had both the technology and the ability to raise the water this distance. Before the construction of the aqueducts at Pompeii, water for the Stabian baths was lifted ca. 25 m. from underground sources.[32] The Roman colony at Lincoln faced a similar problem. Here the source of water for the settlement was ca. 23 m. below the site itself.[33] A stone-built foundation was located at the source of the Lincoln aqueduct which, in view of the large quantity of nails that were found in the vicinity, is possibly the base of a wooden lifting tower.[34]

The Romans had available several mechanical devices for lifting water,[35] although how the water at Kremna was lifted remains unclear. However, just above the water tank which serves the modern Turkish village and approximately at the point where the projected lines of the two aqueducts met there were the remains of a substantial building (B on map). Its foundations were partly cut into the rock to

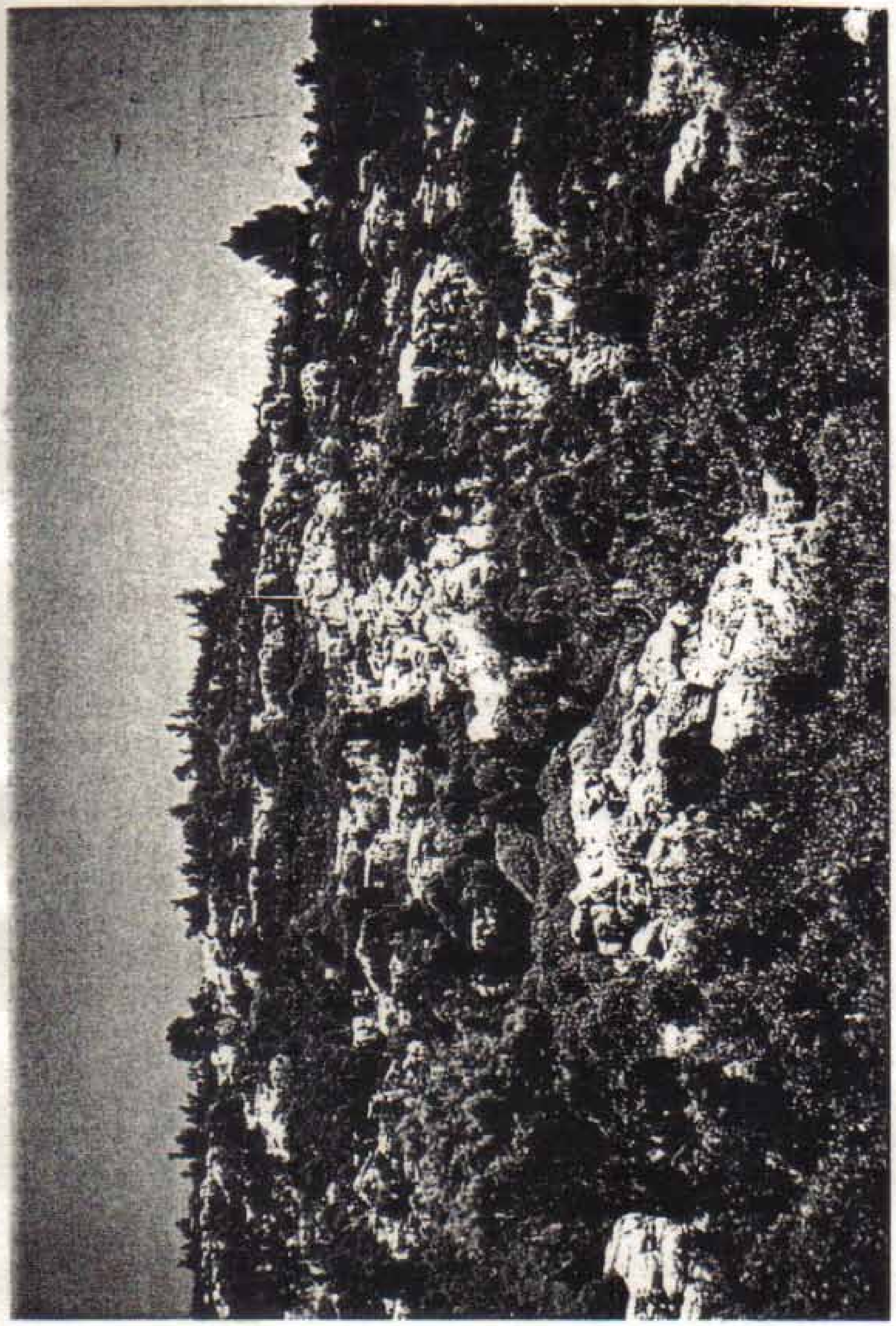


Plate 6

the north, whilst to the south they were constructed of large, roughly-cut limestone blocks. The maximum dimensions of the foundations were 14.40 m. × 12.50 m. The foundations supported a substantial limestone structure. Much of it has disappeared although the walls were particularly thick and constructed in large limestone blocks, some of which, especially on the southern and eastern sides, remained *in situ*. In addition, inside the building there was extensive evidence of mortared rubble and cement *in situ*.

The purpose of this structure is not known. Further along the road to the east there are the remains of built tombs. Yet the building has no obvious entrance and, unlike the tombs, has neither decorated architectural fragments nor roof tiles. Furthermore, the fact that it is directly on the line of one of the aqueducts and is orientated approximately towards the other suggests that it might be connected with the water supply and could conceivably be a water tower or tank used in the raising of the water. Higher up the slope, at the point where the preserved remains of the upper aqueduct began, there was a ruinous and much weathered pile of rubble (C on map). This was possibly a similar water installation. It is possible that both of these structures were water towers and the water was raised mechanically, possibly by means of a bucket and chain system in the towers, whence it flowed by gravity to the next lifting station.[36]

Immediately to the west of Kremna all traces of the aqueduct have disappeared. Presumably this was due to the actions of the emperor Probus, who laid siege to Kremna in A.D. 278, after the city had been captured by Isaurian bandits.[37] Similarly, within the city itself remains of the aqueduct were not found, although it is likely, because of the configuration of the terrain, that the water was conveyed to the tanks by means of an underground channel.

If the archaeological evidence has been correctly interpreted, the aqueduct was undoubtedly an impressive engineering achievement. Nevertheless, the amount of water that was actually delivered by the pipeline could not have been great. The water itself was carried only in a single terracotta pipeline with a diameter of ca. 11 cms. which in the pressure sections of the pipeline was reduced to ca. 8 cms. In addition the friction generated by the water as it passed through the pipeline, especially through the pressurized sections, which were only crudely jointed, would have reduced the flow further.[38] Ultimately, if the reconstruction of the aqueduct is correct, the amount of water which was delivered to the public cistern was dependent upon the rate at which it could be lifted. The citizens of Kremna had made great efforts and incurred great expense to deliver a relatively modest amount of water to the city. Why?

A nymphaeum has not come to light at Kremna; and it is likely that if the water from the reservoirs had been used to supply a public fountain house the demand would have outstripped the capacity of the system to refill the tanks. Furthermore, although each individual tank had three small breather holes to allow air to escape as the reservoirs filled, the openings were covered with spoked grids and it was not possible for the public to reach the water in the tanks directly. Moreover, the inconvenience of obtaining water would have increased when the water level dropped below the terracotta pipe sections which united the tanks longitudinally and in consequence the four lateral tanks effectively became independent reservoirs.

Although the aqueduct was not constructed to provide water for domestic purposes it is likely that it supplied water for the public baths. Bath houses needed large supplies of water and there was a large public bath house situated below the piazza which covered the reservoirs. There was no storage capacity in its vicinity and its location near the edge of the southern cliffs and close to the theatre did not allow space for the storage of large quantities of water.[39] It would, however, have been reasonably easy to conduct water from the cisterns to the public baths by means of gravity. That the water was for the use of the public baths also explains the appearance of the two aqueducts. When it became necessary to top up the reservoirs, the water was lifted mechanically up the higher channel, otherwise it was allowed to flow along the lower channel to other parts of the city.

The correlation between the construction of aqueducts and bath houses in the Roman world is increasingly being realized.[40] Indeed during the siege of Rome by the Goths Belisarius banned the use of the bath houses in order to preserve water.[41] The relationship has been recognized in the civil aqueducts of Britain.[42] Closer geographically to Kremna, the appearance of aqueducts in Asia Minor has been associated with the rise in popularity of the Roman habit of public bathing.[43]

The aqueduct of Kremna is small in comparison with other known aqueducts in the Roman world. It is, nevertheless, a highly sophisticated piece of Roman engineering, which utilizes a range of Roman hydraulic technological skills to deliver a modest amount of water to the reservoirs supplying the baths. The effort, which the citizens of Kremna made to provide water for the baths, is further proof of the relationship between bath buildings and aqueducts, and confirms the importance of the bath house in Roman provincial life.

In a more general sense, the evidence for the water supply to the city of Kremna probably reflects the attitudes to water in the majority of cities in the empire. There was no single solution to maintaining adequate supplies of water to satisfy the public, domestic, and industrial demands of an ancient city. As at Rome, Naples, and Pergamon, public and private efforts at Kremna were complementary in an effort to maintain sufficient supplies.

NOTES

1. Aristotle, *Pol.* 7. 1330 b.
2. E.g. Rome (50–90 m.), Cologne (75 m.), and Carthage (132 m.), see A. T. Hodge, 'Aqueducts', in I. M. Barton (ed.), *Roman public buildings* (Exeter, 1989), pp. 129–30; Fréjus (40 m.) and Nimes (50 m.), see A. Grenier, *Manuel d'archéologie gallo-romaine IV* (Paris, 1960), pp. 41–45, 88–97.
3. Strabo, 5.3.8.
4. Frontinus, *De Aqueductibus* 1.16.
5. J. J. Coulton, 'Roman aqueducts in Asia Minor', in S. Macready and F. H. Thompson (eds.), *Roman architecture in the Greek world* (London, 1987), pp. 72–73 points out that it was not through lack of the requisite technology that the Greeks did not make extensive use of long aqueducts but the unstable military situation. The siege of Syracuse by the Athenians during the Sicilian expedition illustrates the dangers. One of the actions taken by the Athenians was to cut off the water supply to the city (Thuc. 6.100). In Greece water was brought to Olynthos from springs about 6 miles from the city, see D. M. Robinson and J. W. Graham, *Excavations at Olynthus VIII* (Baltimore, 1938), p. 307, D. M. Robinson, *Excavations at Olynthus XII*, pp. 103–14. Similarly in Sicily Akragas and Syracuse tapped external sources of water, see A. Burns, 'Ancient Greek water supply and city planning: a study of Syracuse and Acragas', *Technology and Culture* 15 (1974), 389–412.
6. Despite the obvious spectacular structures such as the Pont du Gard, and the aqueducts of Segovia, Lyon, and Rome, in general less than 10% of an aqueduct was usually carried on arched bridges, see N. Smith, 'Roman hydraulic technology', *SciAm* 238.5 (1978), 154; Hodge, op. cit., p. 129.
7. Pausanias, 10.4.1, includes running water at a fountain head as one of the essential amenities which characterized an ancient city.
8. Philostratus, *Vitae* 2.1 (551).
9. Procopius, *De Aedific.* 6.2.
10. See Philostratus, *Vitae* 2.1 (548); Pliny, *Epist.* 10.38, 90.
11. Pliny, *Epist.* 10.37.
12. Philostratus, *Vitae* 2.1 (551).
13. G. R. Stephens, 'Civil aqueducts in Britain', *Britannia* 16 (1985), 198–9.
14. Hodge, op. cit., pp. 130–2.
15. Pliny, *Epist.* 10.90–91.
16. Smith, op. cit., 154–5.
17. See Coulton (n. 5 above).
18. Procopius, *De Bello Gothico* 5.9–10.
19. Procopius, op. cit., 5.8.44.
20. Procopius, op. cit., 5.19.18.
21. Procopius, op. cit., 5.19.28–29. Rome relied on wells before the construction of the first aqueduct, see Frontinus, *De Aqueductibus* 1.4. Although in general river water was considered unsuitable for drinking purposes (see Palladius, *De Re Rustica* 1.17), during a siege water from any source would be used.
22. Procopius, op. cit., 5.19.27.
23. Dittenberger, *OGIS* 483 lines 203–32.
24. To refresh travellers, see the Dipylon fountain house at Athens, R. E. Wycherley, *The stones of Athens* (Princeton, 1978), p. 19. See also Olynthos for a fountain house at a gate on the southern hill, D. M. Robinson, *Excavations at Olynthus II* (Baltimore, 1928), pp. 11–14.

25. Only one instance of the interconnecting pipe was found *in situ* but the partial collapse of the party walls between tanks, at the point where such pipes were located, indicates that all the internal partition walls were so pierced.

26. Vitruvius, *De Architectura* 8.6.5.

27. The Romans were fully conversant with the technology of the syphon and it was probably utilized more extensively than has been supposed, see A. T. Hodge, 'Syphons in Roman aqueducts', *PBSR* 38 (1983), 174–221, esp. 220–1. The Kremna syphon was less than 300 m. in length, compare Aspendos (0.8 km.) and Les Tourillons, supplying Lyon (ca. 6 kms), see Hodge, ibid., 185–9. Hodge, ibid., 220, calculates that the total length of the syphons in the Lyon area comes to 16.6 kms!

28. Vitruvius, op. cit., 8.6.5.

29. Vitruvius, op. cit., 7.6.8–10 recommends the use of clay pipes because they are cheaper, easy to construct and maintain, and because water carried in clay pipes remains pure. Terracotta pressure pipes were used in aqueducts in Spain, Hodge, op. cit., 175. Lead, stone, and terracotta encased in masonry were also used, e.g. see Hodge, ibid., 181–2, 189 (lead), Coulton in Macready and Thompson (eds.) (1987), p. 74 (stone), Thompson, 'The Roman aqueduct at Lincoln', *ArchJ* 111 (1954), 119 (terracotta sheathed in concrete).

30. Vitruvius, op. cit., 8.6.8 recommends a minimum thickness of two digits. As far as the author is aware the Kremna pipes are the thickest yet found.

31. See Hodge, *PBSR* 38 (1983), 195–202 for discussion of the hydrology of pressure pipes.

32. See J. Oleson, *Greek and Roman mechanical water lifting devices* (Toronto, 1984), pp. 242–8, 355.

33. Thompson (1954), 120–5. J. Wacher, *The towns of Roman Britain* (London, 1974), pp. 126–32 questions whether the accepted source for the aqueduct is correct.

34. See Hodge, ibid., 192. The original excavator suggested a force pump might have been used.

35. Vitruvius, *De Architectura* 10.4.1–7.5. J. Oleson (n. 32) has catalogued the available documentary and archaeological evidence for water lifting devices.

36. J. G. Landels, *Engineering in the ancient world* (London, 1978), p. 74 calculates for a height of 16 m. a theoretical rate of lift of 13.63 litres of water per minute for one man, using a bucket and chain system.

37. Zosimus 1.69–70; S. Mitchell and M. Waelkens, 'Cremna and Sagalassus 1987', *AS* 38 (1988), 57–58. As already discussed, cutting the water supply would have been one of the first actions of any besieging force.

38. See above n. 31.

39. Twelve interconnecting tanks stored water for the Helena baths at Rome, see E. Nash, *A pictorial dictionary of ancient Rome II* (London, 1962), pp. 454–7. The baths of Caracalla had sixty-four interconnecting chambers, see Nash, op. cit., p. 434.

40. Hodge in Barton (ed.), op. cit., p. 128.

41. Procopius, *De Bello Gothico* 5.19.27.

42. Stephens, op. cit. (n. 13), 197–8, 201, 203.

43. Coulton, in Macready and Thompson (eds.), op. cit., p. 82.