Water management in the Bronze Age: Greece and Anatolia

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Abstract While the water management systems of Minoan Crete are legendary, water management on the Greek mainland in the Mycenaean period also shows a high degree of technological sophistication. Projects considered in this paper include the draining of the Kopais Lake, generally agreed to be one of the greatest engineering achievements of early antiquity; the cistern at Mycenae with its corbelled access tunnel cut deep into the bedrock of the citadel; the twin springs at Tiryns, with their underground passageways approached through the massive 'cyclopean' walls; and the North Fountain on the Mycenaean Acropolis of Athens. These Mycenaean systems are compared with the remarkable underground water supply system at Troy uncovered by the recent excavations led by Manfred Korfmann, a structure which may date to the beginning of the 3rd millennium and which appears to be invoked among the deities of Wilusa (Troy) in the early-13th century treaty between Muwattalli II of Hatti and Alaksandu of Wilusa (and which may be a precursor of the famous Persian qanats).

Keywords Kopais; Mycenae; Persia; Tiryns; Troy

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Introduction

The water management systems of Minoan Crete in the 2nd millennium BC are legendary: the water supply system, the management of wastewater and the sewerage system, all these were technologically advanced to a level that would be the envy of many societies today. But there was also a high degree of technological competence and vision in water management projects on the Greek mainland during the period immediately following the Mycenaean ascendancy over Minoan Crete. These include the draining of the Kopais Lake, generally agreed to be one of the greatest engineering achievements of early antiquity; the cistern at Mycenae with its corbelled access tunnel cut deep into the bedrock of the citadel; the twin springs at Tiryns, with their underground passageways approached through the massive 'cyclopean' walls; and the North Fountain on the Acropolis of Athens. These Mycenaean systems may be compared with the water management systems found at Troy, particularly the remarkable underground water supply system uncovered by the recent excavations led by Manfred Korfmann, a structure which may date to the beginning of the 3rd millennium and which appears to be invoked among the deities of Wilusa in the early-13th century treaty between Muwattali II of Hatti and Alaksandu of Wilusa, and which may be a precursor of the famous Persian *qanats*, known from the 1st millennium and still in use today.

The Kopais Lake drainage project

The draining of the Kopais Lake in Boeotia in the 14th century BC is the earliest drainage project in European history. Said by ancient writers to have been the work of the Minyans of Orchomenus, a rich and powerful Mycenaean kingdom on the western side of the Kopais basin, the project involved the construction of an elaborate system of canals leading to a central canal that drew off the water of the lake and emptied it into

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the sea at Larymna (see Knauss *et al.*, 1984; Lauffer, 1986). The lake was fed by the Kephissus river and by streams from Mt Helicon, and was surrounded by limestone mountains. A network of drains (*katavothrai*) in the stone, both natural and manmade, drained water from the basin into the northern part of the Euboean Gulf. The area was a shallow marsh in summer, with portions, particularly in the western part (the Kephisis), often dry enough to allow cultivation of the land. But the lake flooded periodically, to some extent annually, and apparently extensively on a more or less regular nine-year cycle.

The point of convergence of the Mycenaean drainage dykes with the artificial canal and the natural outlets (*katavothrai*) was near the location of Gla, the large Mycenean site which was apparently not a palatial centre such as Thebes, Orchomenos, Mycenae, etc., but rather an administrative outpost which served both as protection for the area and as a depository for the produce of the fertile plain that surrounded it and that was available for cultivation while the Mycenaean drainage system was operational (Figure 1). The site of Gla itself was evidently "incorporated into the complex of drainage works and fortifications that surrounded it in antiquity, and was apparently the key point of the whole system", its "main function [being] to protect the installations by which the lake was drained" (Iakovidis, 1983).

When the lake was drained again in 1886 it was over three metres deep in the area around Gla, which was consequently a true island, as the site would have been in the Mycenaean period prior to the drainage project. The method used in the 19th century drainage project reflected that of the second millennium BC: a system of dykes was constructed to hold back the waters running into the basin from the surrounding rivers, while the drainage outlets carried the lake water underground to empty into the sea.

The underground cistern at Mycenae

In the third and final building phase at Mycenae in the late 13th century, the fortification walls were extended to protect the water supply for the citadel in case of siege. An underground cistern collected water from the Perseia Spring near the Lion Gate, conveyed by

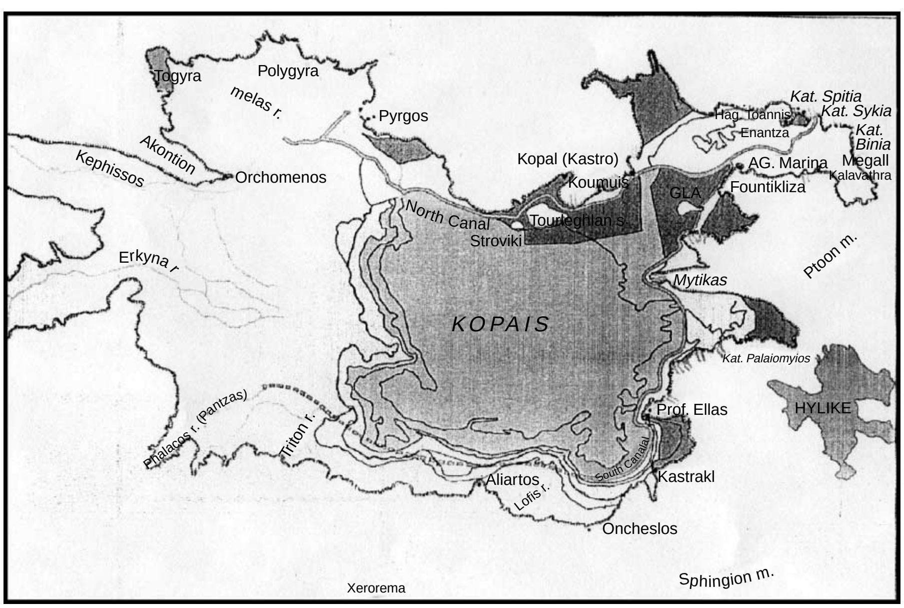

Figure 1 The Mycenaean drainage system (Iakovidis, 2003)

an underground conduit consisting of clay pipes. The problem of bringing this conduit inside the fortification wall, where it would be accessible only from within the citadel was solved by the Mycenaean engineers in what is considered to be "one of the most impressive technical achievements of the Mycenaeans" (Iakovidis, 1983), "an outstanding example of [their] architectural ingenuity and building skill" (Scoufopoulos, 1971). An underground cistern was constructed about 18 m below ground level and a roofed staircase was built leading down to it, protected by the new extension of the wall. The staircase is in three sections, with changes of direction and intervening landings (Figure 2). The first section has a corbelled ceiling, as does the remainder in part, alternating with a saddle roof. In total the staircase extends to about 40 m and includes 83 steps (Scoufopoulos, 1971). The well-shaft itself is 3.50 m deep and the level of the water it held fluctuated with the seasons and the supply from the spring. The well-shaft and the lower courses are lined with two layers of stucco for waterproofing. A row of stones acted as a filter at the point where the conduit emptied into the cistern (for fuller description, with references, see Scoufopoulos, 1971; Iakovidis, 1983).

The subterranean galleries of Tiryns

Paralleling that at Mycenae, a third and final building phase was undertaken at Tiryns toward the end of the 13th century, which doubled the total area enclosed within the fortification walls, massively increased the amount of available storage space, and, once again, guaranteed the water supply in case of siege. During the course of restoration work in 1962, two openings were found in the north-west wall, which led to two subterranean galleries (Figure 3). These were parallel to each other and extended about 20 m to the west, converging from 9 m apart inside the wall to 2.60 m apart just beyond the wall. The passageways were well built of large Cyclopean blocks and, like the descent to the underground cistern at Mycenae, they were roofed with corbel vaults, and had steps

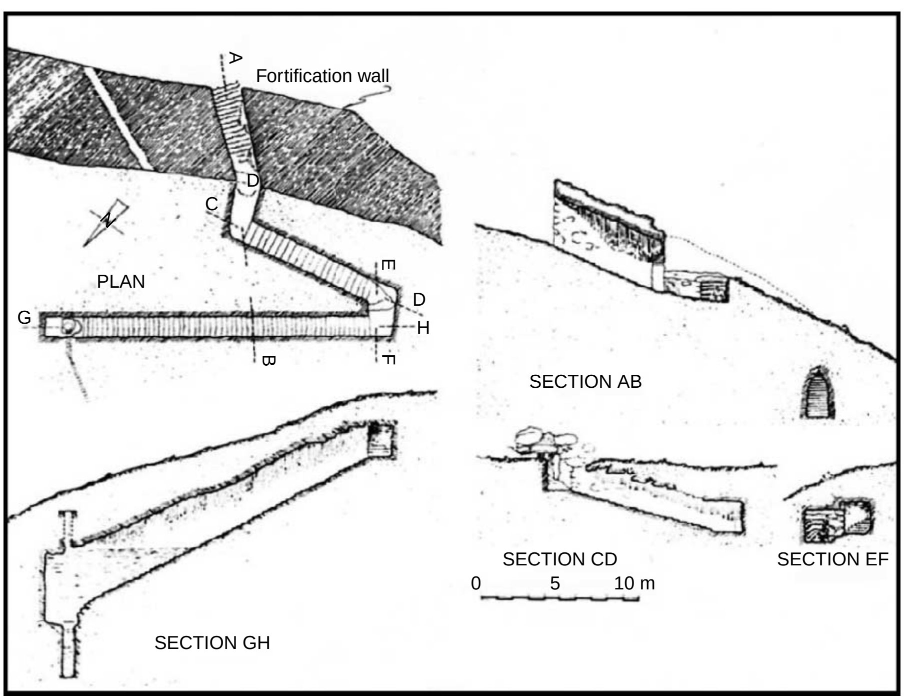

Figure 2 Underground cistern at Mycenae (Iakovidis, 1983)

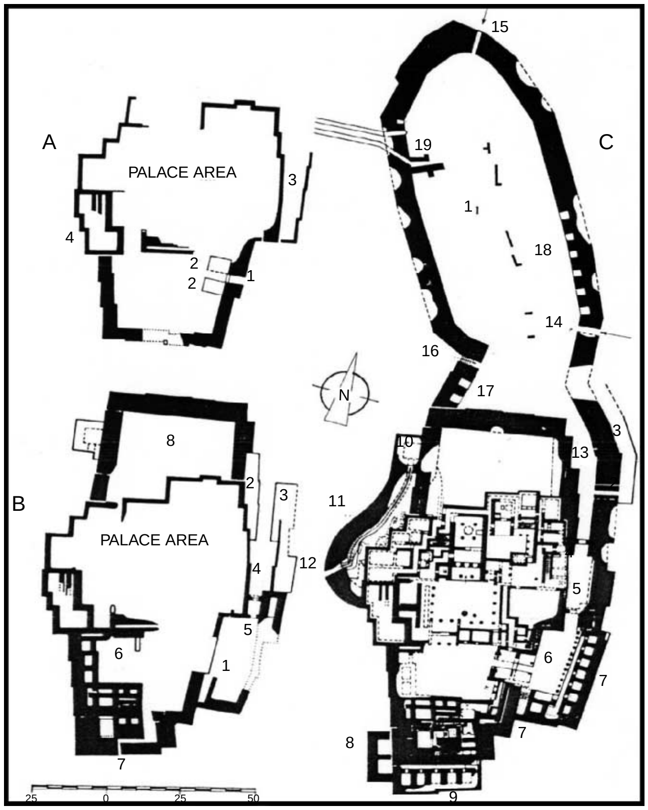

Figure 3 Tiryns Citadel (Iakovidis, 1983)

cut into the rock, along with (presumably) wooden steps, which were not preserved. Scoufopoulos (1971) has recorded that "the thick wall of the southern entrance had a cross-wall forming two rooms beyond it [which] may have served as small guard-rooms protecting the entrance", and the north entrance has what was apparently a small retaining wall, below which "ran a section of an elaborate drainage system which passed diagonally across the reservoir entrance and kept that area free and clear of water running from the higher area in the center of the Lower Citadel". Water from the surrounding hills collected in the area west of the citadel, where there was a spring with water seeping through the rock, and the galleries drew upon this supply, functioning as cisterns. As Iakovidis (1983) observes of their state on discovery in 1962, even "32 centuries after they were constructed, there was enough water at the bottom of them to leave no doubt whatsoever as to their original purpose".

The north fountain at Athens

A large cleft in the rock on the north side of the Acropolis functioned as a natural reservoir, which was accessible only from the summit of the hill. The Mycenaean engineers dug into this cleft, which varies in width from 1 to 3 m, to a depth of 34.50 m and constructed an underground fountain, 4 m in diameter, reached by eight flights of stairs (Figure 4). A settling-pit in the middle of the reservoir acted as a filter to collect mud and other impurities. Iakovidis reports that "even in summer the water level was high enough for it to be drawn, by means of a bucket tied to rope, from the bottom step of the staircase" (Iakovidis, 1983). The descent opens underneath the fortification wall and is thought to have consisted

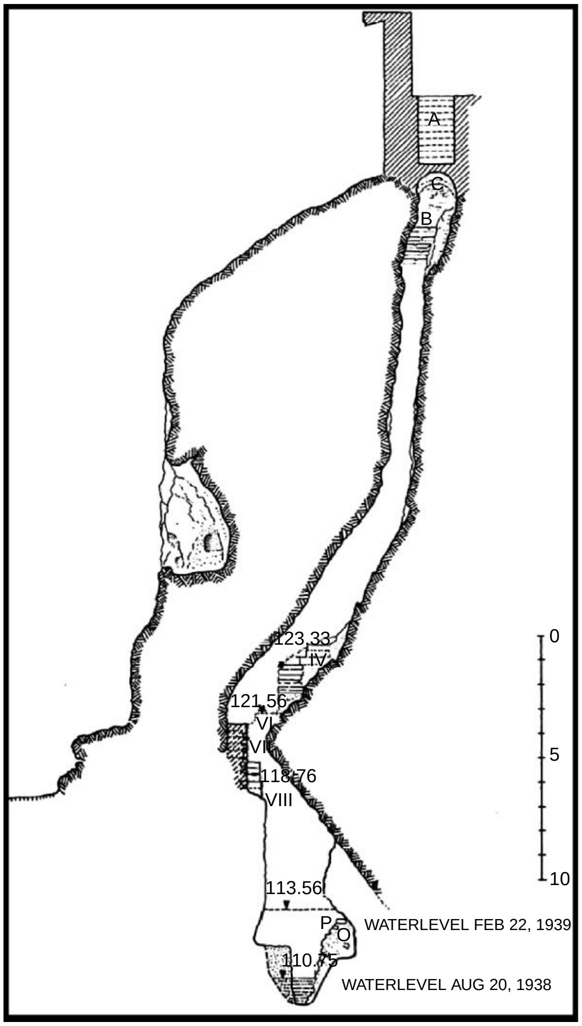

Figure 4 Athens: North Fountain, vertical section (Iakovidis, 1983)

of a corbelled gallery of the sort found also in the access passageways to the secured water supply at Mycenae and Tiryns. The first two flights of stairs ended at a "natural opening in the cleft which leads outside, to the cave of Aglauros" (but cf. Dontas, 1983 on the location of the Aglaurion). According to Broneer (1939), the fountain was in use for only about a quarter century, when presumably the threat that led to the securing of an enclosed water supply, along with strengthening of the fortifications in the latter half of the 13th century, was no longer felt to require such precautions. Athens is the only major Mycenaean citadel which did not suffer destruction at the end of the Bronze Age, and the construction and subsequent abandonment of the North Fountain might be thought to indicate a concern for increased security at the time of widespread destruction elsewhere, which in the end was not required for the defence of the Acropolis.

The underground water supply system at Troy

During the recent excavations at Troy, led by the late Manfred Korfmann, a particularly exciting discovery was made in the 1997 and 1998 seasons. In the lower town a deep cave was found, cut into the hill, with (as described by Latacz, 2004) "one broad main

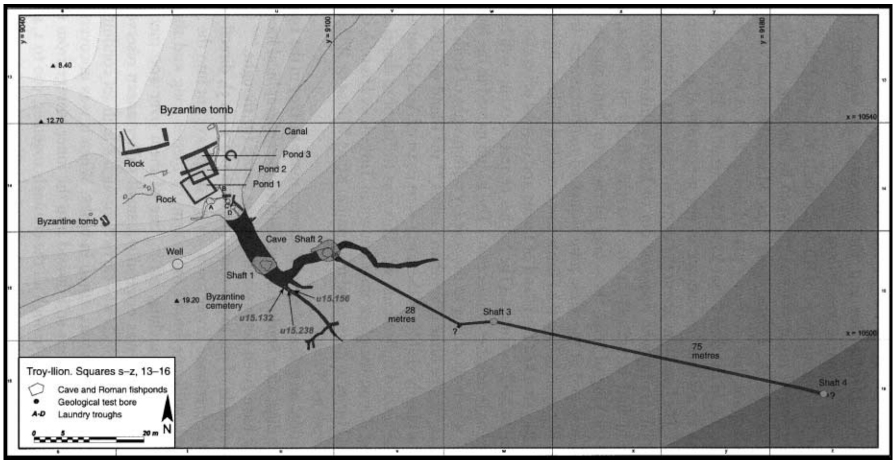

Figure 5 The water supply system uncovered in Wilusa/Troy in 1997 (Latacz, 2004)

arm 13 m long and three narrow channels branching off it, one of them over 100 m long" (Figure 5). This was originally a small subterranean reservoir, built perhaps as early as the beginning of the third millennium BC; even today up to 1,400 L/d still flow through this system. Most remarkably, in a 13th century treaty between the Great King of the Hittites and Alaksandu of Wilusa (Troy), among the gods of Wilusa invoked to guarantee the treaty is included the 'Underground Watercourse of the Land of Wilusa', evidently referring to this very installation. The plan of this subterranean system, with extended arms branching off to sources from which water is brought via underground conduits to a central reservoir may be a precursor of the Persian *qanat* sytem, known from the first millennium BC.

The Persian qanats

It is reported that in 714 BC Sargon II of Assyria discovered in the kingdom of Urartu, just north of the Zagros Mountains, a system of underground conduits that had been constructed to channel snowmelt. He is said to have admired and imitated these irrigation channels and two centuries later, Cyrus the Great had this type of system used throughout his empire. Eventually the system was expanded to cover 250,000 square miles on the Iranian plateau alone, producing ten million gallons of water a minute. The French geologist Henri Goblot regarded it as "one of the greatest civil engineering projects in the history of the world" (Khansari *et al.*, 1998). The system is still in use today, although its use is increasingly diminishing due to the drop in the level of the water table caused by extensive construction of dams and wells. These underground channels, or *qanats*, while simple in concept, are extremely labour-intensive, both to build and to maintain. As shown in the diagrams (Figures 6 and 7), a master shaft is sunk to the water source, typically at the base of mountains to tap the snow-fed subterranean water. A tunnel then runs on an incline from the source to the destination, which may be many miles away; where necessary the tunnel is lined with ceramic rings.

At intervals of from 15 to 60 feet additional shafts are sunk to allow for removal of the excavated dirt and the provision of air for the workers; on completion these shafts provide access for ongoing maintenance work. As Khansari *et al.* (1998) point out, the Iranian desert is "laced with lines of these shafts", which look from the air like giant molehills (Figure 8). From its original homeland in Persia, the technique of *qanat*

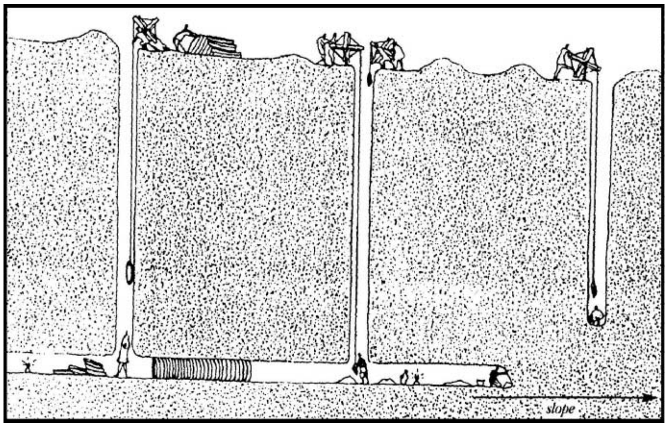

Figure 6 Method used to construct a qanat and its access shafts (Khansari *et al*., 1998)

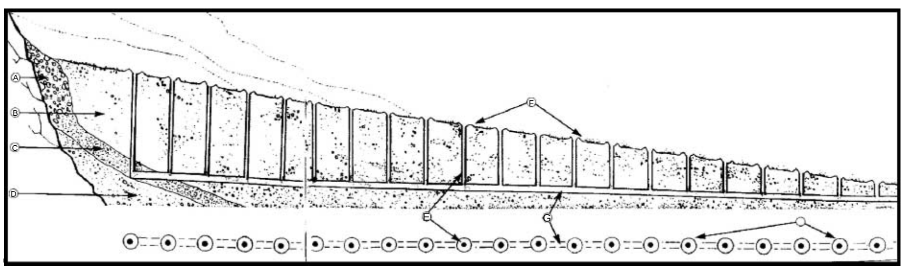

Figure 7 Cross section of a qanat (Khansari *et al*., 1998)

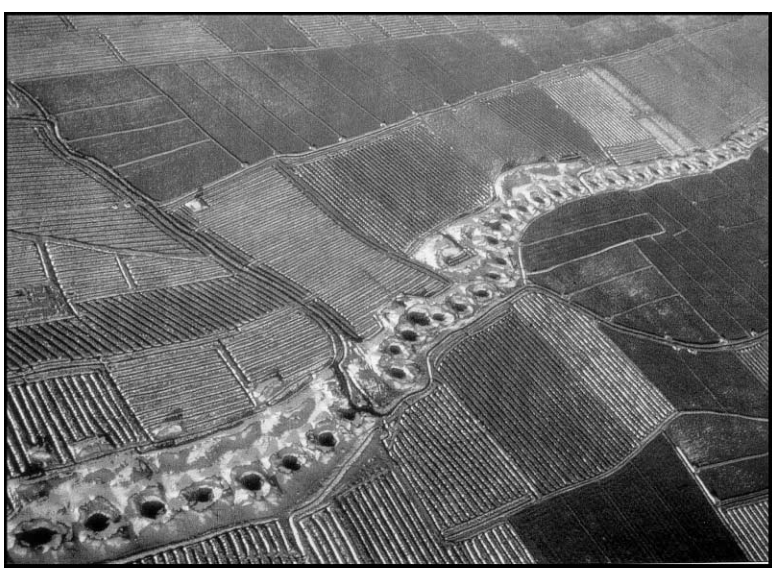

Figure 8 Aerial view of a qanat near Yazd (Khansari *et al*., 1998)

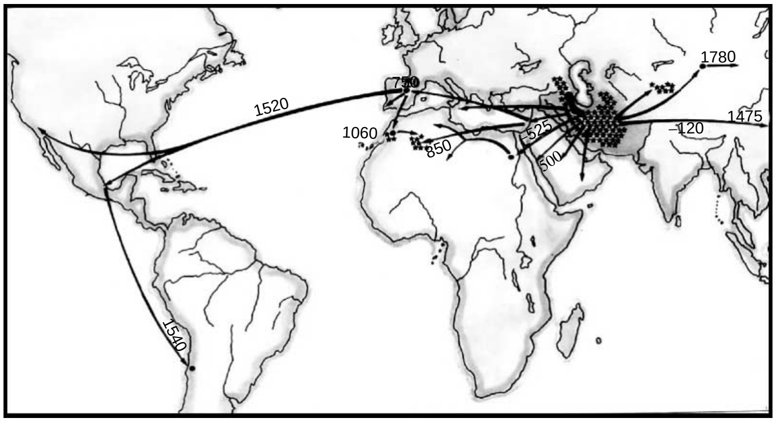

Figure 9 Spread of the technique of the qanat system (Khansari *et al*., 1998)

construction spread to Oman and Egypt, and subsequently to Europe and other parts of Africa and eventually to the Americas and other parts of Asia (Figure 9).

Conclusions

The water management projects on the Greek mainland in the mid-2nd millennium BC show a remarkably high level of technological competence and vision. The hydraulic engineering achievements of the Mycenaeans, especially the draining of the Kopais Lake and the securing of the water supply at the citadels of Mycenae, Tiryns, and Athens, are sophisticated achievements by any standards. Even more extraordinary is the underground water supply system recently discovered at the site of ancient Troy, dating to the 3rd millennium BC, a structure which may have led to the Persian system of underground conduits or *quanats*, in continuous use from at least the 1st millennium BC to the present day.

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