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A Study of Ancient Well Remains in and Around Jinan City of Chu State

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Abstract

The invention of water wells enabled early inhabitants to overcome the constraint of settling along rivers. In recent years, water well remains have been continuously unearthed inside and outside Jinan City of Chu State. Through systematic collation and typological analysis of these remains, this study examines their distribution patterns, morphological characteristics, and functions. Based on the dual functions of wells for water extraction and storage, an analysis of their spatial distribution in this study reveals that ancient wells within the city were concentrated in handicraft workshop and living areas, whereas those outside the city were found in residential areas. According to differences in materials, the ancient wells are classified into earthen wells, bamboo-ring wells, pottery-ring wells, wooden wells, and tile-ring wells, revealing the technological choices of the Chu people in adapting well construction to local conditions and overcoming geological constraints. This study concludes that the widespread use of water wells drove a transition in settlement patterns from settling along rivers to clustering around wells, giving rise to the shijing (well-centered marketplace). The construction and abandonment of water wells paralleled the rise and decline of settlements, reflecting the evolutionary process of human–water relations.

Keywords

Jinan City of Chu State site; Ancient Wells Remains; Human–Water Relations

1. Introduction

The invention and emergence of water wells embodied the ingenuity of early inhabitants. This innovation enabled them to overcome the constraint of settling along rivers and lakes, holding great significance for human progress. During the Spring and Autumn and Warring States periods, science and technology flourished, and ancient wells became widespread. Numerous ancient well materials have been unearthed in the State of Chu, with existing scholarship mainly focusing on the following areas. The first area is the excavation, collation, and preliminary study of ancient well materials. Regarding the archaeological excavation and preliminary

collation of ancient wells inside Jinan City of Chu State, unearthed types include earthen, pottery-ring, wooden-ring, and bamboo-ring wells [1-5]. These finds reveal the well-ring sinking method and wooden frame structures at the well bottoms. Some wells predated the construction of city gates, while others were associated with kiln sites. They served multiple functions, including domestic water extraction, handicraft water supply, and storage. Regarding the archaeological excavation and preliminary collation of ancient wells outside Jinan City [6-10], multiple types—such as bamboo-ring, pottery-ring, and earthen wells—have been found at sites including Changdaochang and Zhangjiatai. Constructed using techniques such as sand bedding and bamboo-and-wood bracing, these wells served for water extraction, storage, and refuse disposal. Differences in well types reflected class differentiation, while their abandonment mostly resulted from warfare or natural damage. The second area is the study of the morphology and functions of ancient wells [11-15]. Over 400 Eastern Zhou water wells have been discovered inside and outside Jinan City. Scholars generally classify them into four categories: earthen, bamboo, pottery, and wooden wells. Guo Dewei adds tile-ring wells to this classification [14], noting that they were built through direct excavation or the well-ring sinking method. Most scholars argue that water wells served for water extraction, cold storage, and refuse disposal. Furthermore, the materials of the well rings likely reflected the social status of their users. Wang Chongli, however, rejects the cold-storage hypothesis and maintains that the wells were used purely for domestic and productive water supply [15]. The third area is the study of the distribution and spatial functions of ancient wells. Archaeological data indicate that the distribution of ancient wells in the Jingzhou region was closely correlated with settlement distribution inside and outside Jinan City. By comparing ancient well remains inside and outside the city, Shen Dewei examines residents' living standards, social stratification, and urban–suburban spatial functions [16].

As a major capital of the State of Chu, Jinan City maintained a close relationship with water, a fact long documented in transmitted texts. Sima Qian of the Western Han dynasty recorded in the "Huozhi liezhuan" ("Biographies of the Moneymakers") of the *Shiji* (*Records of the Grand Historian*): "Jiangling, the former capital Ying, connects to Wu and Ba in the west and possesses the abundance of Yunmeng in the east [17]." This indicates that the capital Ying was geographically situated in a land–water region. Li Daoyuan of the Northern Wei dynasty noted in the *Shuijing zhu* (*Commentary on the Water Classic*): "Northwest of Jiangling lies Jinan City... Southwest of the city is the Du watercourse, which flows northeast into the city and is named the Zixu Canal [18]." This account shows that Jinan City was a land–water architectural complex with interconnected internal and external river channels. It was a city jointly composed of city gates, water gates, moats, ancient river channels, well clusters, and extramural settlements. As the component closest to daily life within this whole, ancient wells linked the capital's overall water system with

suburban settlements and connected surface water with groundwater.

2. Surrounding Water Systems of Jinan City and the Background of Ancient Well Distribution

Water wells are a vital component of urban hydraulic systems, supplementing surface water sources while serving for water extraction and storage. In the Eastern Zhou Chu capital of Jinan City, the hydraulic system was jointly composed of a surface water system—including natural river channels, moats, water gates, and drainage facilities—and a groundwater system centered on water wells.

The "Chengma" chapter of the Guanzi (Master Guan) records: "Whenever establishing a state capital, it must be sited either at the foot of great mountains or above broad rivers. On high ground, it should stay clear of drought so that water is sufficient; on low ground, it should stay clear of floods so that ditches and dikes are spared [19]." Consistent with this general principle of capital site selection, Jinan City was geographically surrounded by mountains on three sides and water on one. This setting not only provided a military barrier for the city site, but also ensured an ample supply of surface water for the capital. Furthermore, the city was located on the Jianghan Plain, which featured medium- and deep-level groundwater. This ensured that groundwater was easily accessible in and around Jinan City.

The moat of Jinan City connected with ancient river channels, serving both drainage and defensive functions. Water gates were constructed where river channels entered and exited the city walls to accommodate water transport, drainage, and urban defense. Two water gates have been confirmed—on the western side of the southern wall and the eastern side of the northern wall—and another may have existed at Longhuiqiao [1]. The water gate on the western side of the southern wall consisted of 40 wooden pillars arranged in four rows, forming three passageways. These water gate structures allowed vessels to pass, regulated water flow, and directed the river channels into the overall water system of Jinan City.

The intramural water system comprised four interconnected ancient river channels. The Zhu, Xinqiao, and Longqiao rivers served as the main drainage arteries of the Jinan City water system. The Zhu River flowed south from the northern wall, while the Xinqiao River entered the city through the water gate on the western side of the southern wall. The two converged at Banqiao inside the city to form the Longqiao River, which then flowed east out of the city walls. Meanwhile, the ancient river channel on the western slope of Fenghuang Hill flowed from south to north into the Longqiao River. Outside the city, the moat and other ancient river channels connected with this network, eventually flowing east into Dengjia Lake [1]. The topography of Jinan City—elevated in the north and south and low-lying in the center—created a natural elevation gradient. The Chu people ingeniously adapted to this terrain by integrating aprons (sanshui), drainage pipes, surface drainage ditches, intramural river channels, and the extramural moat. Together, these facilities

formed a comprehensive drainage system for sewage disposal, water drainage, and flood control, ultimately channeling water into the rivers.

As surface water sources, ancient river channels had inherent limitations. Their water volume fluctuated significantly by season, with water levels dropping during the dry season and facing flood pressures during the wet season. Because these channels ran through various functional zones of the capital, their water quality was vulnerable to domestic waste and handicraft effluents. Moreover, they could hardly meet the water demands of areas far from the watercourses. Consequently, inhabitants dug and utilized water wells, and the resulting ancient well clusters formed a vital component of the urban water system. Over a thousand water wells existed inside and outside Jinan City, widely distributed across palace areas, workshop zones, residential quarters, and even along the city walls. This distribution pattern not only satisfied daily water needs inside and outside the capital, but also channeled groundwater into urban functional zones and extramural settlements.

Surface water and groundwater complemented each other, together forming a system of water use. Numerous kiln sites were located near the Zhu, Xinqiao, and Longqiao rivers within Jinan City. These were areas of handicraft production, and the river water was polluted. The Jianghan Plain lies within a subsidence basin in the middle reaches of the Yangtze River. Quaternary fluvial and lacustrine deposits are widespread, reaching a thickness of 280 m in the central area. Several aquifers occur within these strata. Among them, porous aquifers are the most widespread and thickest, and groundwater resources are abundant [20]. These geological conditions allowed residents to dig numerous wells and obtain relatively clean groundwater, compensating for the vulnerability of surface water to pollution.

Thus, the urban water system of Jinan City comprised both surface water and groundwater. Surface river channels formed the “warp” of this system, with the Zhu, Xinqiao, and Longqiao rivers serving as its main arteries. These channels connected with the moat and, together with drainage ditches, pipes, and other facilities, provided flood control, sewage disposal, and regulation of water volume. Clusters of wells drawing on groundwater formed the “weft” of this system. Densely distributed across the functional zones within the city and extramural settlements, these wells supplied clean water and provided water storage, supplementing surface water.

3. Distribution Patterns of Ancient Wells

Numerous ancient wells have been discovered within Jinan City. Their distribution was closely related to the layout of settlements. Within Jinan City, well clusters were mainly located near water sources and workshop areas, while those outside the city were often found in areas where residents lived and worked. Together, these wells formed part of the residential areas both within and outside the city, directly reflecting production and daily life in and around the capital.

3.1. Distribution of Ancient Wells Within the City

Ancient well remains are abundant within the city. Between 1975 and 1979, 12, 12, 256, and 18 ancient wells were discovered at the northern gate of the western city wall, Songbai Foundation Platform No. 30, the western section of the Longqiao River, and the southern bank of its eastern section, respectively. In 1987, another 29 wells were discovered at the Xinqiao site [1-3,5]. To date, many well remains within the city have neither been excavated nor published. Most of the discovered ancient wells were distributed along rivers and in low-lying areas, mainly concentrated near the Longqiao River, the Xinqiao River, the ancient river channel on the western slope of Fenghuang Hill, and nearby canals. Five ancient well clusters were located near the Longqiao River and its tributaries, with one cluster near each of the two canals. Ancient wells were also distributed along both banks of the Xinqiao River, near the Xinqiao Fishpond, and along both banks of the ancient river channel on the western slope of Fenghuang Hill [1]. This pattern of clustering along rivers and near water sources was closely related to groundwater recharge from river water, which helped maintain the water supply of the wells.

Wells in Jinan City were mainly concentrated in handicraft workshop areas. Archaeological surveys indicate that the Songbai area in the southeast and the Jicheng area in the northeast were mainly occupied by palaces and other important buildings. Pottery and roof-tile workshops were concentrated along both banks of the Longqiao River, while metal-smelting and casting workshops were mainly located in the Xinqiao area in the southwest. The Xugang area in the northwest may have been a residential area for commoners [1,2,14]. Wells were found adjacent to kiln sites near the western section of the Longqiao River, the Xinqiao Fishpond, and the ancient river channel on the western slope of Fenghuang Hill. Further excavations at Songbai Foundation Platform No. 30 between 2011 and 2012 uncovered two kiln sites and five wells. Among them, wells J15 and J16 were located north of the two kiln sites, respectively, and were used to supply water for kiln operations [4]. Two well clusters were also discovered in the handicraft workshop area near the southern gate of the western city wall. These remains indicate that wells were important water-supply facilities for handicraft production in Jinan City, providing water for activities such as pottery making, roof-tile production, and metal smelting and casting.

Wells were also distributed in residential areas within the city. In 1975, excavations at Songbai Foundation Platform No. 30 uncovered 12 wells. Of these, wells J1–J11 all had their openings in the fourth layer of the rammed-earth platform and postdated the construction of the F1 platform [2]. These 11 wells were distributed around F1, and wells J6 and J11 both cut through its wall foundations. They may have been dug after F1 had been in use for some time to meet the water needs of daily production and domestic life. Wells were discovered among the earlier remains beneath the building foundations at the northern gate of the western city wall, along with

numerous ash pits and pottery sherds. These findings indicate that the area had originally been an important residential area before the city gate was built [2]. Wells could meet the daily water needs of residents in these residential areas.

Ancient wells within the city served at least two distinct functions. One group was distributed along the Longqiao River and in nearby low-lying areas, closely associated with kiln sites and handicraft production. The other was located near platform buildings or residential areas, meeting the need for domestic water. Together, these two groups formed the general distribution pattern of ancient wells within Jinan City, indicating that wells in the capital served more than one function.

3.2. Distribution of Ancient Wells Outside the City

The distribution of ancient wells in the outskirts of Jinan City was closely related to settlement patterns. These wells were mainly concentrated in residential areas and handicraft workshop areas. Shen Dewei argues that the area outside the walls of large early cities was termed jiao ("suburbs"), while the area closer to the city was called jinjiao ("near suburbs") [16]. Ancient wells discovered in the outskirts of Jinan City were mainly distributed in the southern suburbs, including the Changdaochang, Zhangjiatai, Gaotai, Yanjiatai, and Paima sites. Changdaochang was located approximately 400 meters from the southern city wall, where seven wells dating to the middle and late Warring States period were discovered. Nine pottery jars used for drawing water were recovered from well J5, while wells J2 and J7 dated to a slightly later period [6]. The high concentration of wells may have been related to the substantial demand for water in local production activities. Zhangjiatai was located approximately 700 meters from the southern city wall, where 32 wells were discovered. Everyday pottery vessels, including dou vessels and basins, were commonly recovered from the wells, suggesting that the wells were mainly used for domestic purposes [7]. Gaotai was located approximately 1,000 meters south of the city, where several hundred wells were discovered, of which 88 have been excavated [8]. Pottery jars, flasks, and a small number of iron agricultural tools were recovered. These wells may have supplied water for both domestic and agricultural use. Paima was located approximately 1,500 meters from the city. The excavated well J1 yielded numerous pottery vessels used for drawing water and was mainly used for daily water collection [10]. Two wells discovered at the Maojiashan site east of the city were both located adjacent to kiln sites and likely served as water-supply facilities for pottery workshops [21]. Overall, ancient wells in the outskirts of Jinan City supplied water for both the daily needs of residents and agricultural and handicraft production. Their distribution was closely related to the production and daily activities of suburban settlements.

Ancient wells outside Jinan City were mainly concentrated in settlements in the southern suburbs and often occurred in clusters. This indicates that production and daily life in the capital had extended beyond the city walls, forming relatively dense

settlement areas in the nearby suburbs. Within the city, ancient wells were mainly distributed along riverbanks and in handicraft workshop areas and residential areas, while those outside the city were concentrated in nearby suburban settlements. Chronologically, some wells within the city may date back as far as the middle to late Spring and Autumn period, and well use continued into the Warring States period. In contrast, well clusters outside the city mainly reflect the development of suburban settlements during the middle to late Warring States period. Differences in the distribution and dates of ancient wells within and outside the city reflect a trend toward the expansion of the capital's activity areas beyond the city walls over Jinan City's long period of use.

4. Forms and Functions of Ancient Wells

Among the ancient wells documented in published archaeological reports from within and outside Jinan City, 458 have relatively well-defined structural forms. All these wells had circular openings and can be broadly classified by construction material into earthen wells, bamboo-lined wells, ceramic-lined wells, wooden wells, and tile-lined wells. Based on their locations and excavated artifacts, ancient wells can be divided into water-drawing wells and cold-storage wells.

4.1. Analysis of Ancient Well Forms

Ancient wells discovered within and outside Jinan City were mainly classified into earthen wells, bamboo-lined wells, ceramic-lined wells, wood-lined wells, and tile-lined wells. Earthen wells, bamboo-lined wells, and ceramic-lined wells were more commonly found, while wood-lined wells and tile-lined wells were less common.

4.1.1. Earthen Wells

Earthen wells represented the most basic form of well construction, including purely earthen wells and wells combining earth and bamboo rings. These wells had no lining rings and all had circular openings, with diameters greater than those at the bottom. They used undisturbed soil directly as their walls and were the least costly to construct, but had relatively poor stability. Their users may have been commoners.

Earthen wells were most numerous near the Longqiao and Xinqiao rivers within the city. Among them, Well No. 111 (River Channel I) in the western section of the Longqiao River measured 3 meters in diameter at the top and 1.7 meters at the lower part. Excavation reached 3 meters below the original riverbed without reaching the bottom of the well [2]. Several earthen wells were discovered at the Zhangjiatai site outside the city. Among them, excavation of well J14 reached a depth of 5.7 meters before being halted because its walls were prone to collapse [7]. In addition, well J4 was 820 centimeters deep, while well J26 was 780 centimeters

deep. Although other earthen wells have not been fully excavated, the soft soil of the Jianghan Plain would have prevented ancient inhabitants from digging them to great depths. Earthen wells had limited service lives, and consistent water quality was difficult to ensure. Nevertheless, earthen wells remained the most basic water-supply facilities and continued to play an irreplaceable role during the early stages of settlement formation and in areas on the outskirts of the city.

4.1.2. Bamboo-lined Wells

Bamboo-lined wells were wells with cylindrical linings woven from bamboo, willow twigs, and similar materials directly against the well walls. Their construction may have involved first excavating a well pit and then placing relatively stiff bamboo and willow strips vertically along the well walls as the warp. Softer strips were woven as the weft from bottom to top to form the well lining [2]. The size of the bamboo lining depended on the diameter of the well shaft. The lining served to filter water and stabilize the well walls. Bamboo was abundant and readily available in the Chu region. Well linings made from bamboo had good air permeability but were prone to decay and had relatively short service lives. Their users may have been commoners.

Well I69 in the western section of the Longqiao River within the city was constructed using the warp-and-weft weaving technique. The warp consisted of 12 strands, each twisted from six or seven bamboo or willow strips, while the weft was formed by interweaving individual strips [2]. Some wells outside the city walls also use the warp-and-weft weaving method. The bamboo well linings discovered within the city and in its suburbs were made using the same technique, namely warp-and-weft weaving. The remains in the western section of the Longqiao River within the city may date back as far as the early Spring and Autumn period. In contrast, the ancient well remains at Gaotai outside the city first appeared in the early Warring States period, flourished in the later part of the middle Warring States period, and continued to be used into the Qin and Han periods. Chronologically, this weaving technique appears to have been used earlier within the city than outside it and was likely to have gradually spread from the city to its suburbs. This may have been related to the outward expansion of residential and activity areas in Jinan City at that time. The *Xinlun* describes the dense population of Ying, the Chu capital, with the phrase “clothes were new in the morning but worn out by evening [22].” The population of approximately 300,000 estimated by some scholars based on the area of the city site further suggests considerable pressure on the space within the city [23]. Taken together, these two pieces of evidence may suggest that the space within Jinan City was approaching its capacity at that time, making the outward expansion of residential and activity areas possible. Well-construction techniques also spread from within the city to areas outside it and continued to be used during the Qin and Han periods.

4.1.3. Ceramic-lined Wells

Ceramic-lined wells emerged after earthen wells and bamboo-lined wells. They were constructed by stacking cylindrical ceramic rings, each approximately 75 centimeters high, with earth or pottery sherds packed between the rings and the well walls [24]. The ceramic rings were generally made using the coil-building technique. Based on the structure of their well walls, these wells can be divided into three types: wells lined entirely with ceramic rings, wells combining ceramic rings and bamboo, and wells combining ceramic rings and earth. Ceramic-lined wells were relatively costly to construct, but offered better water purification and longer service lives. They may have been used by ordinary landowners and wealthy merchants.

Wells lined entirely with ceramic rings were constructed by stacking ceramic rings throughout the well shaft. Such wells may have been constructed using the ring-sinking method [3]. When excavation reached the quicksand layer near the groundwater level, a ceramic ring was placed in the well, and the soil and sand inside it were removed, allowing the ring to sink gradually. Additional ceramic rings were then stacked on top. This method could prevent the well walls from collapsing, facilitate deeper excavation, and increase the water yield.

In the other two types of composite wells, wooden frames were installed beneath the lowest ceramic ring to support and secure the upper structure. Ceramic–bamboo composite wells had ceramic rings in the upper section and woven bamboo linings in the lower section, as seen in well J1 at Zhangjiatai. The well was 7.25 meters deep. The upper 4.9 meters consisted of 7 stacked ceramic rings, while the lower 2.35 meters had a woven bamboo structure, mainly serving to filter water and prevent silt accumulation [7]. Ceramic–earth composite wells had ceramic rings in the upper section and retained earthen walls in the lower section, as seen in Well No. 80 (River Channel II) in the western section of the Longqiao River. Two ceramic rings were installed in the upper section and supported from below by two wooden planks embedded in the well wall [2]. Below the wooden supports was an earthen pit, with footholds left in the well wall. Some composite wells also used wooden frames shaped like the Chinese characters “二” (two horizontal bars), “十” (a cross), or “井” (a grid) to support and secure the upper well rings.

These three types of ceramic-lined wells differed in their materials and structures. Ceramic–bamboo and ceramic–earth composite wells used fewer ceramic rings while still providing support for the well walls and meeting water-drawing needs. This reflects how well construction in the Chu region was adapted to local conditions and made flexible use of materials.

4.1.4. Wood-lined Wells

Very few wood-lined wells have been discovered. Most known examples were constructed either by joining two semicircular wooden sections or by hollowing out a single log. These wells had stable structures and were complex and costly to

construct, but had long service lives and provided clean water.

Well I167 in the western section of the Longqiao River within the city was constructed by joining two wooden troughs to form an oval well lining. The structure was reinforced with supporting timbers, vertical posts, and mortise-and-tenon braces, while the lower section consisted of an earthen pit [2]. Well J1 in the Paima ancient well cluster south of the city was mainly constructed from a hollowed-out log, with additional curved wooden planks inserted and secured using mortise holes and wooden wedges to form a circular well lining [10]. Small holes were made in the bottom of the well for inserting bamboo poles, which likely extended into the underground aquifer. This allowed groundwater to enter the well while preventing collapse caused by excessive excavation depth. Well J77 at Gaotai had a double lining of wood and bamboo. The inner wooden lining was secured with bamboo poles and wooden blocks, while the outer bamboo lining served as a filter [8]. Such wells may have been constructed using the direct excavation method. Their wood processing, joining techniques, and supporting structures were relatively complex, reflecting a relatively high level of well-construction technology.

4.1.5. Tile-lined Wells

Tile-lined wells were wells that used roof tiles to form their well linings. Among the published archaeological findings from Jinan City, only one tile-lined well has been reported, at Huangjiamiao. The well opening was 0.5 meters below the ground surface and measured 0.8 meters in diameter. The well wall was constructed with semi-cylindrical roof tiles laid horizontally, with their surfaces facing inward. The tiles were arranged in staggered, overlapping courses to form a circular lining [14]. As the well has not been excavated, its lower structure remains unknown. Tile-lined wells were also discovered at the Warring States workshop site at Changling Station in Xianyang. They were divided into two types: wells with tile bands and wells with upper tile bands and lower tile rings [25]. The former were constructed using broken roof tiles and pottery sherds, while the latter combined semi-cylindrical roof tiles, flat roof tiles, and ceramic rings, showing greater structural diversity. In comparison, the tile-lined well outside the western city wall was constructed with semi-cylindrical roof tiles set on their sides and laid horizontally to form circular rings. Its construction materials were uniform, with no evidence of the mixed use of flat roof tiles, broken tile rings, or pottery sherds. There was also no indication of tile bands constructed in separate sections. In contrast, tile-lined wells in the Xianyang region showed greater variation in form and used a mixture of materials, including various combinations of tile bands and tile rings. Although the lower structure of the Huangjiamiao well remains unknown because it has not been excavated, the horizontal arrangement of semi-cylindrical roof tiles to form well rings, as seen in its exposed section, is relatively rare among known tile-lined wells.

In a broader comparison, relatively few tile-lined wells have been discovered in the Jingzhou region, while more have been found in northern China. In 1965, 36 tile-lined wells dating to the Eastern Zhou period were discovered in the Beijing region, and similar wells have also been found in Hebei [26,27].

4.2. Analysis of Ancient Well Functions

In terms of their distribution, ancient wells within and outside Jinan City were mainly located in residential areas and near handicraft workshop areas. Based on the artifacts recovered from these wells, the Warring States-period wells within and outside Jinan City were used mainly for drawing water and cold storage.

Drawing water was the most basic function of ancient wells. Wang Zhen of the Yuan dynasty wrote: "A well is a hole dug in the ground from which water emerges. The Shuowen states that it means 'clear.' Thus, the Yijing says, 'The well is clear, and its cold spring is fit to drink.' When lined with stone, it remains clean and free of mud; when water is drawn with vessels, it provides sustenance without being exhausted. ... As for springs emerging from rock cavities and openings, they flow without end and do not run dry when water is drawn. These are natural wells [28]." Wells can thus be understood as deep pits excavated to draw groundwater to meet the needs of daily life and production.

The Zhu, Xinqiao, and Longqiao rivers formed the main arteries of the Jinan City water system, flowing through palace areas, workshop areas, and residential areas. In workshop areas, wells were located near kiln sites and ash pits, and some wells supplied water for production activities. Wastewater discharged from pottery workshops and metal-smelting and casting workshops inevitably entered the river channels, making it difficult to ensure that the natural water was suitable for residents' daily drinking needs. Under these circumstances, wells drew on groundwater and provided residents with clean drinking water through the natural filtration of underground aquifers and the filtering effect of well linings.

The water-drawing function of wells is also supported by archaeological excavation evidence. Most ancient wells discovered within and outside Jinan City were earthen wells and bamboo-lined wells. These two types were clearly used for drawing water, with their structures mainly designed to facilitate groundwater seepage. Some ceramic-lined wells also had openings at the bottom that allowed groundwater to enter the wells. The artifacts recovered from the wells consisted mainly of high-necked jars and long-necked pots. Their necks were often decorated with incised horizontal grooves to increase friction with the ropes [11]. Wear marks on the necks may have resulted from daily water-drawing activities. Similar rope marks were also found on the necks of pottery jars recovered from ancient wells at the Taixi site in Gaocheng, Hebei [29]. These findings further confirm the use of such vessels for drawing water and reflect the water-drawing function of these ancient wells.

Cold storage was an additional function of wells, allowing food to be stored and preserved. The climate was warm from the Yangshao period to the Yinxu period, with mean annual temperatures approximately 2 degrees Celsius higher than today. The climate became cooler during the early Western Zhou period but warmed again by the Spring and Autumn period, entering a second warm period [30]. Higher temperatures made food more prone to spoilage, so ancient inhabitants used the cooler environment at the bottoms of wells to store food. Ceramic-lined Well II·J89 was discovered on the southern bank of the Longqiao River in Jinan City. The well contained a large, intact pottery jar with a capacity of approximately 0.14 cubic meters, capable of holding 145.5 kilograms of water. Based on this evidence, archaeologists suggest that the well was used for cold storage [3]. Similar cold-storage wells have also been discovered in the underground palace structures at Gelaofen in Xinzheng, the capital of the Han state [31]. These wells were similar to the "treasure wells" and "cold wells" recorded in historical texts, which were used to preserve food in the cooler underground environment.

Ancient wells within and outside Jinan City were primarily used for drawing water to meet the domestic and production needs of nearby residents. Ancient inhabitants also used wells to store and preserve food by taking advantage of the cooler underground environment. The coexistence of water-drawing and cold-storage functions reflects how residents at that time made practical use of wells.

5. Human–Water Relationships as Reflected in Ancient Wells

Water is the source of life and an essential natural resource for daily life and production. As important evidence of human–water relationships, wells not only served the daily needs of ancient inhabitants but also fostered a settlement pattern centered on wells. This gradually enabled people to move away from living near natural water sources and instead settle around wells. Over a long historical period, wells and urban settlements coexisted and were closely interconnected. The distribution and use of wells were embedded in the spatial structure and social life of cities. The gathering of people gradually gave rise to "shijing" (marketplaces).

Early inhabitants lived near water sources and established settlements close to surface water. As settlements expanded, some residential areas inevitably became distant from surface water sources. Under these circumstances, digging wells to obtain water became an essential part of settlement life. More than 1,000 ancient wells have been discovered within and outside Jinan City, and their distribution was closely related to settlements both inside and outside the city. The wells discovered beneath the building foundations at the northern gate of the western city wall of Jinan City were dug before the gate was constructed and were used by residents of the earlier settlement for their daily water needs. The wells were subsequently abandoned when the city gate was constructed. Settlements outside the city did not have access to the ancient river channels that supplied water within the city and

relied almost entirely on wells for their daily water needs. One or several suitably located wells with sufficient water supply were often a prerequisite for the establishment of a settlement.

The area outside the southeastern corner of the city, where the Gaotai ancient well cluster was located, was a transitional zone between suburban residential areas and water-supply areas. The Gaotai well cluster and the settlements of Jinan City showed a clear pattern of development and abandonment in parallel. The history of the well cluster closely followed the development of the capital. The Gaotai well cluster remained in use for almost the entire period of Jinan City's development. It was already in use during the later part of the early Warring States period, when Jinan City was first established, and appeared at the same time as the city. During the middle Warring States period, as the capital reached its peak, its population increased sharply, and the urban area expanded, the use of the well cluster also reached its peak, reflecting the prosperity of the settlement. By the early part of the late Warring States period, Jinan City had entered a phase of continued occupation. Although the number of artifacts from the well cluster declined slightly, their types remained stable, and the wells continued to be used. This indicates that the wells were not abandoned after the city's peak but remained in use alongside the settlement. The Zhangjiatai site was an ordinary residential area for commoners in the near suburbs of Jinan City. No substantial architectural remains were found in the excavated area, and most of its occupants were associated with production activities. The site had 26 wells for domestic use in its earlier phase, but this number fell sharply to seven in the later phase. This change occurred after the later part of the middle Warring States period. The sharp decline in the number of domestic wells coincided with a significant decrease in the overall frequency of use of the site, directly reflecting a reduction in its residential function. The possibility of population loss in the area surrounding the site cannot be ruled out. A decline in population or out-migration was likely the direct cause of the reduced demand for wells [16] . Whether considering the Gaotai well cluster and the settlements of the capital or the Zhangjiatai well cluster and the settlements outside the city, the construction and abandonment of wells corresponded to the rise and decline of the associated settlements.

In addition, well clusters were an archaeological feature formed on the basis of individual household courtyards [9]. As household units grew larger, the demand for wells also increased, and several well clusters would develop within a large village. Wells could not remain in use indefinitely and might eventually be abandoned due to deteriorating water quality, falling groundwater levels, or the relocation or decline of the settlements themselves. When a new well was dug at a particular location, it often indicated that a new settlement was taking shape.

Wells became places that residents visited daily to draw water, and these regular gatherings gradually gave rise to shijing (marketplaces). Zhang Shoujie wrote in the

Shiji Zhengyi: "In ancient times, there were no markets. When people gathered at wells in the morning to draw water, they would bring goods to sell beside the wells. This is why the term shijing came into use" [17]. In ancient times, before the availability of piped water, places where people drew water served as gathering places. Residents gathered around wells to draw water and also brought their surplus goods to exchange with others. Over time, the areas surrounding wells became established trading places. Markets and wells were closely connected in spatial terms. Wells did not exist as isolated structures but, like markets, were concentrated in designated areas. Both shared the characteristics of "public spaces". These characteristics of public space not only promoted the prosperity of shijing but also determined the choice of locations for early settlements.

Wells served as social links between households and settlements, and their construction and abandonment corresponded to the rise and decline of settlements. The shijing spaces that emerged from gatherings around wells gradually became embedded in the social order of early cities. All of these developments reflect human–water relationships in ancient times.

6. Conclusion

This study of ancient well remains within and outside Jinan City has followed two lines of inquiry: the relationship between wells and settlements, and human–water relationships. An analysis of relevant literature shows that the distribution of wells was closely related to the functional divisions within settlements. This distribution helped residents shift from living along rivers to settling around wells and gradually gave rise to shijing spaces. The construction and abandonment of wells were linked to the rise and decline of settlements. Their functions, including drawing water, storing water, and cold storage, reflected how ancient inhabitants understood and used groundwater resources.

In terms of the relationship between wells and settlements, ancient wells within Jinan City were mainly distributed in handicraft workshop areas and residential areas, while those outside the city were concentrated in residential areas. This distribution was closely related to the functional divisions within settlements. Areas with dense well clusters were often places where production activities and daily life were most active. Wells linked surface water and groundwater and compensated for the limitations of surface water resources. They enabled settlements to move beyond the constraints of rivers, shifting from riverside locations to areas centered around wells.

From the perspective of human–water relationships, wells were not only facilities for drawing water in daily life but also social links that connected household courtyards and helped organize settlement space. The construction, use, and abandonment of well clusters were closely related to the rise and decline of the settlements in which they were located. Gatherings around wells gave rise to shijing,

trading places that had the characteristics of public spaces. Markets arose around wells, while markets in turn helped secure the place of wells. Both became deeply embedded in the spatial structure and social order of early cities. From settling near water to living around wells and then to the emergence of markets around wells, changes in the role of wells reflected the deepening of human–water relationships in ancient times. These changes also offer an indispensable perspective for understanding the evolution of settlement forms and early urban society.

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