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Multi-centric, Marsh-based Urbanism at the early Mesopotamian city of Lagash (Tell al-Hiba, Iraq)

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ABSTRACT

Leveraging a suite of remote sensing technologies deployed over large areas, this paper presents results that challenge long-held ideas about the origin and development of the world's oldest urban centers, in southern Iraq. The standard model of third millennium BCE Mesopotamian cities presents them as nuclear, compact settlements set within an irrigated agricultural hinterland, expanding continuously from a monumental religious complex. This reconstruction holds enormous influence in the comparative global study of early urbanism. UAV photos and magnetic gradiometry data captured at Lagash (Tell al-Hiba) show dense architecture and related paleo-environmental features over c. 300 ha, revealing a city that does not conform to the standard model. Early Dynastic Lagash (2900–2350 BCE) was composed of spatially discrete sectors bounded by multiple surrounding walls and/or watercourses and separated by open spaces. The evidence is suggestive of a marshy or watery local environment, and the city sectors may have originated as marsh islands. The discontinuous, walled nature of inhabited areas would have had social and logistical ramifications for city inhabitants. A number of contemporary sites are characterized by multiple archaeological mounds, suggesting that early southern Mesopotamian cities may have frequently been spatially multi-centric.

1. Introduction

The world's earliest cities developed in the fourth-third millennia BCE between the Tigris and Euphrates Rivers in southern Iraq (Sumer, southern Mesopotamia) (Algaze, 2008; Pollock, 1999; Van de Mieroop, 1997). Founded along river channels, already-large settlements grew in the third millennium BCE Early Dynastic period (c. 2900–2350 BCE) to cover dozens to hundreds of hectares and incorporated monumental temples, residential areas, canals, and harbors. For decades scholars have described southern Mesopotamian cities as nuclear, compact, hierarchical settlements with a singular city wall (typically oval-shaped) and set within an irrigated agricultural hinterland, expanding outwards in a continuous fashion from a central religious complex. The identification of these characteristics as fundamental traits of early Mesopotamian city form traces back to Childe's (1936, 1942) definition of the "Urban Revolution", and they have remained central to widely-cited comparative discussions (e.g., Trigger, 2003: 120-131; Van de Mieroop, 1997: 63-97).

Important aspects of this standard model of third millennium southern Mesopotamian urban form have never been verified, however. Decades of conflict have limited fieldwork in southern Iraq and so archaeological knowledge has remained largely constrained to data collected by excavations in the early-to-mid-twentieth century. Many southern Mesopotamian cities were continuously inhabited for thousands of years, resulting in meters of accumulated cultural strata and therefore excavators could only expose small windows relevant to the period of initial urban growth. Further, excavations focused overwhelmingly on temples and palaces, encouraging a biased, elite-centered view of city life. The few studies of more extensive residential spaces concern neighborhoods of the second millennium BCE (Stone, 1987; Stone and Zimansky, 2004; Woolley and Mallowan, 1976), when Mesopotamian communities had already been urban for more than a millennium. With little empirical basis for a broader understanding of early city form, synthetic discussions of Mesopotamian urbanism amalgamate details from various periods, presenting an idealized picture of "the Mesopotamian city" that may not be accurate for any one period, let alone the fourth-third millennia BCE period during which cities were originally founded and greatly expanded.

A number of archaeologists have put forward alternative hypotheses concerning early southern Mesopotamian cities' origins, development, and layout, but these models have remained fundamentally speculative because spatially extensive and ground-truthed archaeological data do

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not yet exit to test their central claims. Satellite imagery analysis, geological cores, and research on sea-level, land-surface, and precipitation changes indicate that a quite different environment prevailed in far southern Iraq at various points in time 5–6000 years ago, suggesting that early cities there could have emerged within or on the edge of marshlands (Kennett and Kennett, 2006; Pennington et al., 2016; Pournelle, 2003; Pournelle and Algaze, 2014). Other types of satellite imagery analysis suggest that third millennium BCE southern Mesopotamian neighborhoods may not have been segregated by social class, but that cites were often divided into different functional sectors by watercourses (Stone, 2013, 2014, 2018). The survey and excavation of multiple fifth and fourth millennium BCE proto-urban centers in northern Mesopotamia demonstrate that those settlements had low-density spaces and intra-settlement open space, leading some to contemplate that a similar phase in development might eventually be recognized for southern Mesopotamian cities (Pournelle and Algaze, 2014: 11; Ur, 2021: 237).

New remote sensing data from Tell al-Hiba (ancient Lagash, Dhi Qar Province, Iraq) challenge some of the long-held Childean ideas about the origin and development of southern Mesopotamian cities in the third millennium BCE and provide evidence in support of some of these alternative hypotheses. UAV photos and magnetic gradiometry data show that Early Dynastic Lagash had spatially discrete, irregularly shaped, dense city sectors that incorporated multiple empty spaces and widely spaced temple precincts separated by 700–800 m (Hammer et al., 2022). The city sectors were independently bounded by walls and watercourses and had their own street plans. The discontinuous nature of the city, evidence for parts of the city having been crisscrossed by watercourses, and the presence of scattered harbor-like depressions and constructions adjacent to watercourses are suggestive of a marshy or watery local environment, a conclusion that is supported by cuneiform textual information. The city therefore was multi-centric, and it may have been originally founded on a series of individual marsh islands, some of which would have grown together over time and were walled either for flood protection or military defense. The empty spaces separating the bounded areas would have had social and logistical ramifications for city inhabitants, impeding free movement across the city but also probably allowing residents the freedom to develop separate infrastructure and neighborhood systems in each city sector. The intra-urban empty space and multiple city walls would have also offered residents and immigrants the option to maintain separate social and political identities and to mediate conflict through social distance.

Lagash's form and local environmental setting more broadly impact our reconstructions of what early cities looked like and how they internally functioned socially, politically, and economically. A number of other third millennium BCE sites in southern Mesopotamia are characterized by multiple archaeological mounds, suggesting that early cities in this region may have frequently been spatially multi-centric.

2. Background

2.1. Models of southern Mesopotamian urban form

The standard model of Mesopotamian urban form described in the introduction extends back with little modification to Childe's original definition of the "Urban Revolution" (Childe, 1936, 1942, 1950, 1952), an enormously influential and enduring model of early urbanism globally for which Mesopotamian data were key. Childe linked the development of cities to an interconnected series of changes: the emergence of powerful kings, bureaucracy, writing, and social stratification as well as important advances in the realms of agricultural intensification, technology, exchange networks, and craft specialization. While his concern was with social and institutional transformations, not with urban planning or layout, Childe's framework had implications for archaeological reconstruction of the morphology of early cities (Smith, 2009) as well as their hinterlands. The Urban Revolution "marked the establishment of totalitarian regimes under which a surplus was systematically extracted from the peasant masses and gathered into central royal or temple granaries" (Childe, 1957: 6). The spatial form of the city was therefore determined by the economic interests and building programs of the royal elite and centered on the monumental temple complex, home to both deities and a ruling "corporation of priests" (Childe, 1942: 96). The urban fabric expanded around this monumental religious complex to accommodate the tightly controlled, crowded peasant population, who were "persuaded or compelled" (Childe, 1941: 134) to provide labor for construction projects and serve as specialists for craft production, and subsistence producers whose efforts fed the specialists and the elite. The impact of these ideas on archaeological reconstructions of Mesopotamian and other early cities has been pervasive (Smith, 2003: 186-190).

Three sets of authors have proposed hypothetical alternative reconstructions of early southern Mesopotamian cities' environment and subsistence basis, degree of social inequality and internal heterogeneity, and density/nucleation. Given the hiatus in internationally collaborative archaeology in Iraq c. 1990–2015, these reconstructions often rework old data, employ satellite imagery analysis, and/or make analogies to other better-studied regions.

(1) *Wetland environments sustained early southern Mesopotamian cities*. Pournelle, Algaze (Pournelle, 2003, 2013; Pournelle and Algaze, 2014), and others (e.g., Kennett and Kennett, 2006; Pennington et al., 2016) have put forth arguments questioning the supposed riverine environmental setting and agricultural subsistence basis of the earliest southern Mesopotamian cities. A number of complex processes have caused substantial changes to the position of the Gulf coastline over the last ten millennia, including climate/precipitation change, sea level change, alluvial sediment deposition causing the aggradation of the river plain and progradation of the Tigris-Euphrates delta, and tectonic subsidence. The Gulf and its associated marshlands extended considerably northwest relative to their present location c. 8000–2000 BCE (Aqrawi, 2001; Kennett and Kennett, 2006; Potts, 1997: 30-39; Sanlaville, 1989, 2003). Global models for Holocene landscape evolution in river deltas offer an explanation for how this may have occurred. Rapid sea level rise may have caused the lower reaches of the Tigris and Euphrates to develop "large-scale crevassing" environments in which there were multiple river channel systems prone to flooding, crevassing (continual seep of a river through a break in the levee, causing the formation of multiple channels in a splay that terminates in the flood basin), avulsion (change in river course), and floodplain aggradation. These conditions resulted in the formation of wetland and swamp environments. With the slowing of sea level rise, southern Mesopotamia would have developed a more homogeneous floodplain environment characterized by fewer, meandering river channels (Pennington et al., 2016: 195-197).

Depending on the northern-most extent of the marine incursion and the exact timing of landscape evolution in relationship to ancient social and political developments, which thus far remain largely unknown, early cities in the far south of Iraq could have grown primarily within and at the edge of wetland and/or coastal environments, rather than within irrigated agricultural plains or even inland "mosaic environments" of mixed steppe, wetlands, and plain (Adams, 1981). Hunting, fishing, and gathering would have initially been as central as or perhaps much more important than agricultural and pastoral production (Pournelle, 2003). The height of the marine incursion occurred c. 4000 BCE. As the coastline retreated southeastward during the later third and second millennium BCE, as wetlands reduced and the floodplain environment emerged, southern Mesopotamians would have become more reliant on irrigated agriculture (Pournelle, 2013). Thus, individual southern Mesopotamian cities' later form, subsistence basis, and hinterland environments as reflected in excavations and in the cuneiform textual record (of the mid third-first millennia BCE) are not reflective of the situation at the time of urban foundations in the fourth-third millennia BCE.

Some have further argued that the presence of wetlands and the subsequent shift to a meandering river plain environment, as well as accompanying shifts in resource availability and agricultural and transportation potential, were decisive factors in the timing of the rise of urbanism and the later growth of territorial states in Mesopotamia and other river deltas. These scholars see wetland and coastal environments resulting from large-scale crevassing as a "nursery for civilizations," providing an abundance and variety of resources and a plethora of watercourses for low-friction transport that allowed for the initial development of high population densities (Pennington et al., 2016). Settlements located at the interface between coastal, wetland, and/or floodplain environments would have been more resilient to fluctuations in resources (Hritz and Pournelle, 2016; Pournelle and Algaze, 2014). The shifting nature of these environments would have caused increasing competition for favorable resources, locations, and territories (Kennett and Kennett, 2006). The later homogenous floodplain environment was more conducive to large-scale agriculture, and the shift to this type of environment seems to chronologically coincide with archaeological evidence at the end of the third and the beginning of the second millennium BCE for both extensive irrigation systems and the development of territorial states or nascent empires (Pennington et al., 2016: 204-205).

The importance of marshlands for some early Mesopotamian cities' economies is not in doubt (Algaze, 2008: 43-49), but more complex aspects of the above hypotheses remain speculative. Excavations at Eridu, Tell Oueli, Uruk, and other sites in the far south show the importance of fish, reeds, waterfowl, and other marsh resources as well as the existence of marsh sediment layers dating to the fifth and fourth millennia BCE (Brückner, 2003; Sanlaville, 1989). Protoliterate and later cuneiform texts of the fourth-third millennia BCE evidence the scale of fresh and saltwater fishing as well as other marsh- and coast-based activities (Englund, 1990, 1998). Cylinder seals and other artistic representations evidence the use of reeds as building materials (Pournelle, 2013: 22-23). What is in question, however, is the relative role that marsh-based versus agropastoral activities played at different points in time, the degree to which specific settlements were located within (as opposed to near) marshes (Wilkinson, 2012) at the times of their founding and later growth, and the role that marsh environments might have played in shaping urban form and other characteristics of early cities. Answering these questions requires both extensive regional and intensive site-based geoarchaeology and paleobotanical studies integrated with new surveys and excavations incorporating absolute dating techniques, multidisciplinary research programs that are only just beginning.

Since the return of internationally collaborative teams to southern Iraq, c. 2012–2015, archaeologists have begun to collect important new scientific evidence for marsh and coast environments near to early Sumerian cities (Altaweel et al., 2019). For example, sedimentological, paleontological, and paleobotanical analyses, combined with remote sensing and geomorphological analyses, have shown the existence of depositional environments oscillating between floodplain, marsh, and riverine at Uruk (Jotheri et al., 2018) and at Abu Tbeirah (near Ur) (Forti et al., 2022; Jotheri, 2019; Milli and Forti, 2019). Diatom analysis of sediments demonstrates that the Gulf never transgressed into the Uruk region or influenced it (Jotheri et al., 2018). Abu Tbeirah seems to have been located within the marine-influenced Euphrates delta in the third millennium BCE (Forti et al., 2022), and paleobotanical analyses have identified reeds, sedges, rushes, palms, and charred cereal grains, indicative of wetlands and agriculture (Celant and Magri, 2019).

Although these new data represent important advances, questions still remain concerning the chronological and causal connections between changes in the environment and sociopolitical developments, and questions still remain concerning local environment through time of other important early cities. Uruk and Abu Tbeirah were located along the Euphrates; the ancient Tigris and its delta remain largely unstudied (Hritz, 2010). In the vicinity of Lagash, surveyors and excavators have suggested that small Ubaid period (c. 5500–4000 BCE) villages, including Tell Zurghul (ancient Nigin/Nina), were founded on local geological high points ("turtlebacks") within a marsh environment (Al-Hamdani, 2014; Nadali, 2021). Archaeological finds at Ubaid-period Zurghul suggest a brackish-marine-marsh environment, including clay weights of fishing net weights, fish remains, and sickles in association with these that may have been used for cutting reeds (Nadali, 2021). However, the extent and layout of the Ubaid settlement there remains unclear, and further, geoarchaeological and radiocarbon-dated evidence of the paleoenvironment at Zurghul, al-Hiba/Lagash, Girsu, and other nearby sites is still forthcoming, both for the earlier periods and for the third millennium BCE when urban centers expanded and this region becomes especially well-documented in the textual record.[1] Archaeologists will only be able to definitively connect early urban growth and settlement form to marsh and coastline environment through future studies.

(2) *Early Mesopotamian cities were internally heterogenous*. Stone (2007, 2013) has emphasized that early Mesopotamian cities were internally divided, often by watercourses, and that they were spatially differentiated, with sectors of different functions. She has questioned the degree to which social hierarchy was expressed in the structure of early city neighborhoods (Stone, 2014, 2018). Satellite imagery allowed her to trace potential residential architecture at single period sites in southern Mesopotamia. Measurements from these digital maps suggest that neighborhoods were not segregated by house size and therefore by social status. Furthermore, early-to-mid third millennium BCE potential house sizes of the Early Dynastic period suggest a decrease in social differentiation as compared to potential house sizes of the fourth-early third millennium BCE Uruk/Jemdet Nasr periods. However, the dating of the architectural traces and house sizes have never been ground-checked, and the imagery used in the studies of city organization and division (pixel size c. 60 cm) only barely resolves house wall widths, making further verification even more necessary.

(3) *Early Mesopotamian cities incorporated spatially discrete sectors and low-density or empty spaces*. Dozens of archaeological teams carrying out extensive excavations and surveys of early cities in Syria and Turkey have revealed a northern Mesopotamian proto-urban trajectory that appears to be both different and independent of that in the south (McMahon, 2020; Ur, 2010a). Excavations and survey reveal variable concentrations of inhabitation and activity within large settlements, including spatially discrete residential areas that could have functioned to provide social distance; isolated industry, garbage, and burial areas; and low-density spaces possibly used for temporary seasonal settlement and informal economic activities (Al Quntar et al., 2011; McMahon and Stone, 2013; Ur et al., 2007). Some have posited that future fieldwork in the earliest southern Mesopotamian cities might also reveal

[1] Forthcoming studies include a dissertation-in-progress by Reed Goodman at the University of Pennsylvania, concerning the paleoenvironment and hydrology of Lagash and its surroundings.

variable concentrations of activities and possibly low-density or empty spaces (Pournelle and Algaze, 2014: 11; Ur, 2021: 237). Cuneiform textual descriptions indicate that the southern Mesopotamian city of Uruk and its wall did incorporate garden and production areas as well as districts of varied uses, and this has been partially confirmed through remote sensing (Becker et al., 2013). Further, it has been hypothesized that a marshy local environment at Uruk in the fourth millennium BCE would have resulted in discontinuous, linear inhabitation areas along the "toes" of a bird's foot delta, areas of higher land formed as a river debouches into a marsh or other standing body of water (Brückner, 2013; Pournelle, 2003; Pournelle and Algaze, 2014). But this proposed form for early Uruk has not been verified, and the possibility of variable internal city density and open spaces has not yet been investigated on the ground at other southern Iraqi sites.

These interesting ideas questioning various aspects of the standard model of early Mesopotamian urbanism remain to be tested and explained through further remote sensing and on-the-ground fieldwork.

Elsewhere in the world, the archaeology of cities has in recent years benefitted from a "geospatial revolution" (Chase et al., 2012; see also Casana, 2021; McCoy, 2020) that has enabled archaeologists to critically re-evaluate long-held models of early urbanism put forth by Childe and others. Advanced geospatial methods have revealed the structure of diverse urban spaces and landscapes, from dense urban cores to dispersed outer residential areas, road systems, fields, and waterways (e.g., Evans et al., 2013; Fisher et al., 2016; Stott et al., 2018). The resulting data have been transformative, enabling a more holistic perspective on city form and the lives and experiences of everyday citizens as well as detailed analyses of degrees of social inequality, neighborhood variability, traffic patterns, city-hinterland interaction, and more (e.g., Campana, 2017; Creekmore and Fisher, 2014; Miller et al., 2019; Vella et al., 2019).

This revolution is only just now finally beginning to impact our understanding of the "heartland of cities" in southern Mesopotamia (Darras and Vallet, 2021; Fassbinder et al., 2005; Hammer, 2019; Hammer et al., 2022; Marchetti et al., 2019; Rey and Lecompte, 2020; Van Ess and Fassbinder, 2019). High resolution aerial imagery captured during winter and spring wet seasons, in concert with geophysics and ground survey, can reveal unprecedentedly detailed street and architectural plans in this arid environment, without the need for LiDAR and other expensive data. These methodologies, especially when applied to single period sites or components of sites, will increasingly facilitate the generation and evaluation of new models of early urbanism.

2.2. *Third millennium BCE cities and Lagash*

Large settlements with significant populations, powerful institutions, and complex economies emerged in Mesopotamia in the mid-fourth millennium BCE, but enormous urban centers of several hundred hectares and competitive city-states first appeared in southern Mesopotamia during the third millennium BCE Early Dynastic period (Adams, 1981; Cooper, 1983; Matthews and Richardson, 2018). Surveys indicate that processes of settlement nucleation reached an apex in the first phase of this period, with 80 % or more of the population living in cities (Adams, 1981: 90-94, 138; Marchetti et al., 2019: 223; Ur, 2013: 140-141). Archaeology and cuneiform texts reveal that southern Mesopotamia was characterized by a network of city-states, ruled by hereditary kings, and overseen by powerful temples with priests and administrative personnel (Postgate, 1994a). Some of these city-states had a single urban core, while others included multiple urban centers, in either case surrounded by villages and hinterlands (Steinkeller, 2007; Westenholz, 2002; Yoffee, 2005).

Archaeologically, available data primarily come from monumental buildings. Sequences of temples demonstrate the continuity of religious institutions over millennia, and these temples are often monumental in scale compared to adjacent residential architecture (Evans, 2019: 442-447). Less is known about Early Dynastic cities' non-elite inhabitants and daily life. Only a few Early Dynastic houses and graves are known from "surface scraping" and excavations at Abu Salabikh (Matthews and Postgate, 1987; Matthews and Postgate, 1994; Postgate, 1983, 1994b), and from excavations at Nippur (McCown and Haines, 1967; McMahon, 2006) and Kish (Algaze, 1983) in southern Iraq and at Khafajah and Tell Asmar in the Diyala region of central Iraq (Delougaz et al., 1967; Henrickson, 1981, 1982). The famous Royal Cemetery of Ur revealed elite graves of the Early Dynastic, but no associated houses (Woolley, 1934).

Ground observations and some limited aerial and satellite remote sensing data suggested that these "mature" urban centers of the early-to-mid third millennium BCE were spatially differentiated: they were often walled in an oval shape, had sectors for palaces and temples separated from residential neighborhoods, incorporated harbors, and were divided by canals (Trigger, 2003: 127). The cores of cities were dense with architecture leaving little open space. Adjacent buildings and houses shared exterior walls and were accessed via narrow lanes and some larger streets up to 2–3 m wide. The street plans are not straight and seem to reflect the organic growth of settlements (McMahon, 2013, 2020; Pollock, 1999: 47-48; Stone, 2013: 168; Van de Mieroop, 1997: 84), in contrast to rectilinear planning principles often employed in later periods of Mesopotamian history and elsewhere in the world (e.g., Novák, 2004).

One of the largest of these early-third millennium BCE cities is Lagash, modern Tell al-Hiba (Fig. 1a). Tell al-Hiba's enormous size, c. 400–600 ha (Carter, 1989–90; Ur, 2013: 141; Yoffee, 2005: 57), attracted frequent archaeological attention. The site was identified as ancient Lagash on the basis of an inscription found in the 1950s by Safar and Jacobsen. Previous excavations in 1968–1976 and 1990 (Hansen, 1978, 1980–1983, 1990, 1992) and a previous survey in 1984 (Carter, 1989–90; Goodman et al., in press) demonstrate an occupation history from the early third millennium (c. 2900–2600 BCE) to the mid-second millennium (c. 1600 BCE). However, it is clear that the site achieved its largest extent in the mid-late third millennium Early Dynastic III period (c. 2600–2350 BCE). Subsequent occupation from the end of the third millennium to the mid-second millennium was mostly concentrated in the north-center of the site, near the Area B excavations. Additionally, some Isin-Larsa and Old Babylonian period material (early-to-mid second millennium BCE) was found at the site's northern edge and near the Area C excavations. Some widely dispersed sherds of the Uruk (c. 4000–3100 BCE) and Jemdet Nasr (c. 3100–2900 BCE) periods and some concentrations of sherds of other periods (Kassite, c. 1595–1155 BCE, and Islamic, c. ninth-tenth centuries CE) hint at spatially limited earlier and later inhabitation.

The previous excavations at Lagash focused exclusively on monumental architecture of the Early Dynastic period, including temples and administrative buildings (Pittman and Ashby, in press). The excavations unearthed two temples. The Ibgal temple of Inanna, goddess of love and sex, dates to the Early Dynastic III period (Area A) and the Bagara temple of Ningirsu, god of springtime thunder, rainstorms, ploughing, and war, who was also the patron deity of the Lagash city-state, dates to the Early Dynastic III through the Isin-Larsa period of the early second millennium (to c. 1800 BCE, Area B) (Ashby, 2017; Hansen, 1978, 1980–1983, 1992). Five total temples are known at Lagash from cuneiform texts (Hansen, 1992: 207). Another excavation area (Area G) exposed an area that the excavators hypothesized might also be part of a temple precinct dating to the Early Dynastic I period (c. 2900–2600 BCE) (Hansen, 1990, 1992). A fourth set of trenches (Area C) targeted an administrative building dating to the Early Dynastic period that had been destroyed by a fire (Bahrani, 1989; Hansen, 1992). A new team recommenced excavation in 2019 and 2022 and has targeted industrial and residential areas in the south part of the site (Area H) (McMahon et al., 2023 forthcoming).

Textual and archaeological information indicate that Early Dynastic

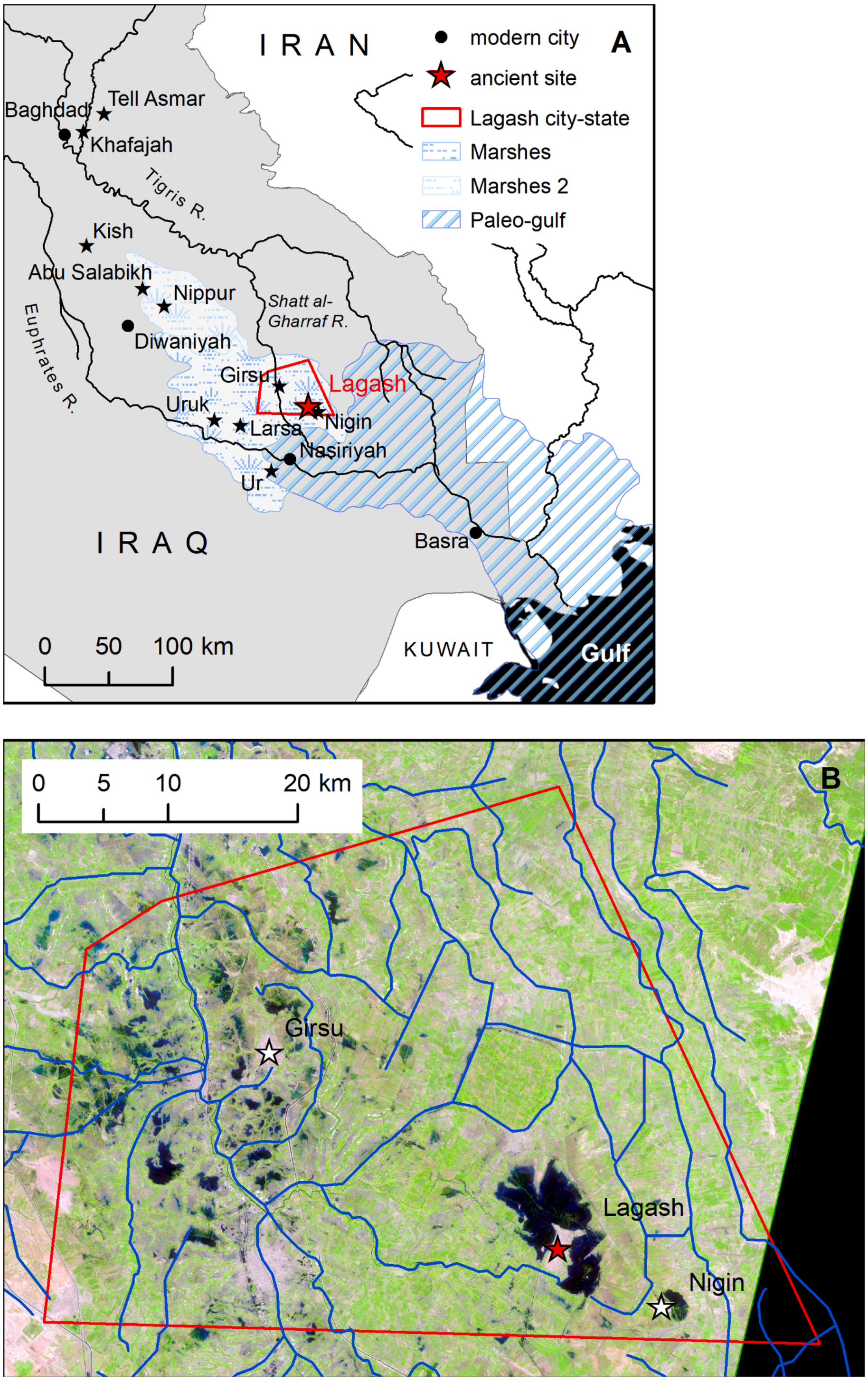

Fig. 1. A) Location of Lagash in southern Iraq in relationship to modern cities, modern river courses, other ancient sites mentioned in the text, the possible maximal northern extent of the Gulf coastline and associated deltaic marshes c. 4000 BCE (as reconstructed by Pournelle 2003), and the possible approximate boundaries of the Early Dynastic Lagash city-state (as reconstructed by Hritz (2021), after Steinkeller (2007) and Jacobsen (1969)). B) Closer view of the Lagash city-state. Base imagery is a Sentinel-2 image captured 4 April 2019, two days after the conclusion of heavy rainstorms (24 March-2 April) that resulted in extensive flooding across the Middle East, including in southern Iraq. The image thus shows the maximal extent of the modern marsh area around Lagash, witnessed during the field season.

Lagash was the capital of an eponymous city-state encompassing not only Lagash itself, but also the major cities of Girsu (Telloh), Nigin/Nina (Tell Zurghul), and other smaller settlements; that it controlled a fertile countryside; and that its location at the head of the Gulf connected it with both marsh resources and regional trade networks, which brought materials from Iran, the Indus, and Arabia (Carroué, 1983, 1986; Huh, 2008; Jacobsen, 1969; Nissen, 1975). Girsu, Lagash, Nigin, and the unidentified port city of Gu'abba were connected in the Early Dynastic and subsequent Ur III periods by a watercourse named in texts as the "Going-to-Nigin" canal. Cuneiform texts, mostly excavated and looted from Girsu, describe this canal as well as the varied environments present within the state, including marshes (Carroué, 1986; Schrakamp, 2019: 134-136, for the Early Dynastic Period; note that much more textual evidence concerning these topics is available from texts of the subsequent period, Ur III, e.g., Borrelli, 2020; Rost, 2011). Texts also indicate the importance of both agropastoral production (e.g., grain, wool, animal products) and marsh resources (e.g., fish, reeds) for the Lagash city-state in late Early Dynastic period (Beld, 2002: 5-35; Prentice, 2010: 97-125). Zooarchaeological and malacological analyses from the previous excavations at Lagash, although limited, agree with this historical reconstruction of the economy (Kenoyer, 1989–1990; Mudar, 1982).

Altogether the various types of evidence indicate that residents of Lagash had had access to agricultural fields, pastures, and marsh lands. Throughout the mid twentieth century (Ochsenschlager, 2004) and still today Lagash sits within a local marsh that is at this point disconnected from the main Tigris-Euphrates marshes further to the south (Fig. 1b), but its modern wetland location may not be reflective of the city's situation in the third millennium BCE. Swamps and marshes in southern Mesopotamia can appear, disappear, and shift not only with the regional climate and landform changes discussed above, but also with the avulsion of rivers and changes in settlement and irrigation/drainage patterns (Wilkinson, 2012).

If third millennium BCE Lagash was indeed a city set within marsh lands, this should be reflected in its urban form. As part of her hypothesis of a marsh setting for early cities in the far south of Mesopotamia, Pournelle (2003, 2013) has proposed that these early cities might have had a form not dissimilar to Marsh Arab settlements known ethnographically, which are often characterized by multiple islands of settlement separated seasonally by wetlands (Salīm, 1962; Thesiger, 1964). Stone (forthcoming) proposed this specifically for Lagash on the basis of her examination of the site in commercial DigitalGlobe imagery, and Pournelle (2013: 22, 26) proposed that Lagash was founded on an elevated "turtleback", a geologically consolidated mound within marsh lands.

Several features of Tell al-Hiba indicated that near-surface remote sensing methodologies would successfully reveal the city's structure. While many of its peer settlements were long-lived cities in which substantial populations resided for millennia, Lagash's low, flat morphology and survey results indicate its occupation was comparatively short-lived. The previous excavations and survey make clear that the strata resulting from Early Dynastic occupation are at or just below the surface, making them accessible for mapping and excavation. Analysis of high-resolution satellite and aerial imagery showed that architecture and streets appeared clearly during wet times of year (Hammer et al., 2022; Stone, 2013, 2014, in press). The resolution of the commercial satellite imagery used for some earlier analyses (0.6 m) only barely resolves house walls within southern Mesopotamia cities, as the average wall thickness is also 0.6 m (Stone, 2014: 181). Further, flooding over recent decades (Carter, 1989–90) must have erased or obscured from surface view some of the archaeological remains. Thus, higher-resolution aerial images, geophysics, and survey were required to better reveal Lagash's Early Dynastic city form.

This paper expands on a preliminary analysis of the aerial images (Hammer et al., 2022) and integrates the results of the aerial mapping with magnetic gradiometry data in order to explore the implications of the revealed city structure for models of Mesopotamian urbanism and to put forth a series of hypotheses concerning Lagash's development in a watery, possibly marshy environment.

3. Methods: Spatial archaeology and remote sensing

Surface survey, UAV photography, and magnetic gradiometry were carried out at Lagash in March-April with the goal of revealing the structure of the ancient city (Fig. 2). The field season coincided with a series of rainstorms. From 24 March-2 April, these rains were especially heavy, resulting in destructive and fatal flooding across the Middle East and the expansion of the marsh surrounding the site. The moist soil conditions improved the visibility of archaeological features in the remote sensing datasets.

3.1. Surface survey

Archaeological surveys increasingly incorporate a variety of geospatial datasets, but they are always still anchored by systematic surface collections to document artifact chronology, density, and distribution of materials and activities. The 2019 survey reinvestigated areas that were collected in 1984 (Carter, 1989–90) and also covered areas that had been flooded at that time, showing that these formerly inaccessible areas were also inhabited and dense with artifacts. The survey units were 10 × 10 m in size and spaced 50 or 100 m apart, depending on proximity to new excavation areas, similar to methodologies employed at the southern Mesopotamian city of Ur (Hammer, 2019) and the northern Mesopotamian cities of Brak and Hamoukar (Ur, 2010b; Ur et al., 2011) (Fig. 2). Surveyors collected all diagnostic ceramic and any non-ceramic artifactual material. They also recorded counts of the total number of sherds and fragments of ceramic slag.

3.2. Magnetic gradiometry

Geophysical methods are other effective tools for mapping the distribution of subsurface architecture and other features. Increasingly these methods are applied at landscape scales (Kvamme, 2003) to cover whole sites or large percentages of them (Benech, 2007; Blau et al., 2000; Branting, 2013; Casana and Herrmann, 2010; Matney, 2000). The team surveyed roughly 14 ha in four test areas across the site with a fluxgate magnetic gradiometer (Bartington Grad 601–2). Data were collected in a zig-zag pattern within 20 × 20-m grid squares with 0.5 m transect separation. Noise-reduction and image optimization processes were applied to the data using Archaeofusion software (Ernenwein et al., 2014).

The processed magnetic gradiometry data reveal a wide variety of structures in all four test areas. These structures have been digitized with vector lines and polygons for comparison with data generated from UAV photos.

3.3. UAV photogrammetry and digitization

In places with mudbrick architecture and soil salinization, like southern Mesopotamia, under moist soil conditions, UAV photography is a powerful tool for mapping buried near-surface architecture. Following rains, walls, streets, dumps, and fills absorb/shed water and precipitate salts at different rates. It is the resulting patterns of soil moisture and salinity that reveal the plan of archaeological features (Hammer, 2019: 178-179; Stone, 2014).

High-resolution UAV imagery of Lagash was captured using a DJI Phantom 4 Pro V2 Quadcopter and DroneDeploy flight planning software over a period of six weeks in mid-March to late April 2019. The UAV photography, c. 31,000 photos, cumulatively achieved complete coverage of a c. 480 ha area of the core part of the site with good archaeological surface visibility (sparsely vegetated and removed from modern villages, field systems, and active marsh areas). Multiple sets of photos were captured under variable soil moisture and lighting conditions with the UAV flying at altitudes of 80, 90, 200, and 250 m.

Each set of photos was individually processed in Agisoft Metashape to obtain orthomosaics with ground resolution of c. 3–12 cm and digital elevation models of c. 10–30 cm, depending on altitude. Following photogrammetric processing, the orthomosaics were adjusted and analyzed in ArcGIS. To facilitate spatial comparisons, the georeferencing of each dataset was fine-tuned with ground control points drawn from a single DigitalGlobe image.

The orthomosaics were processed and analyzed using methods more fully described elsewhere (Hammer et al., 2022). Most importantly, the tracing of features visible in the imagery was undertaken through the comparison of mosaic datasets, displayed in ArcGIS with dynamic range histogram stretches. The resulting digital map thus represents a composite of features visible across multiple mosaics (Fig. 3).

3.4. Integration of datasets

Magnetic gradiometry and UAV photography offer complementary information, as they reveal two different aspects of the soil, its magnetic and color/moisture retention properties. At Lagash, magnetic gradiometry does not always show ephemeral surface remains that may

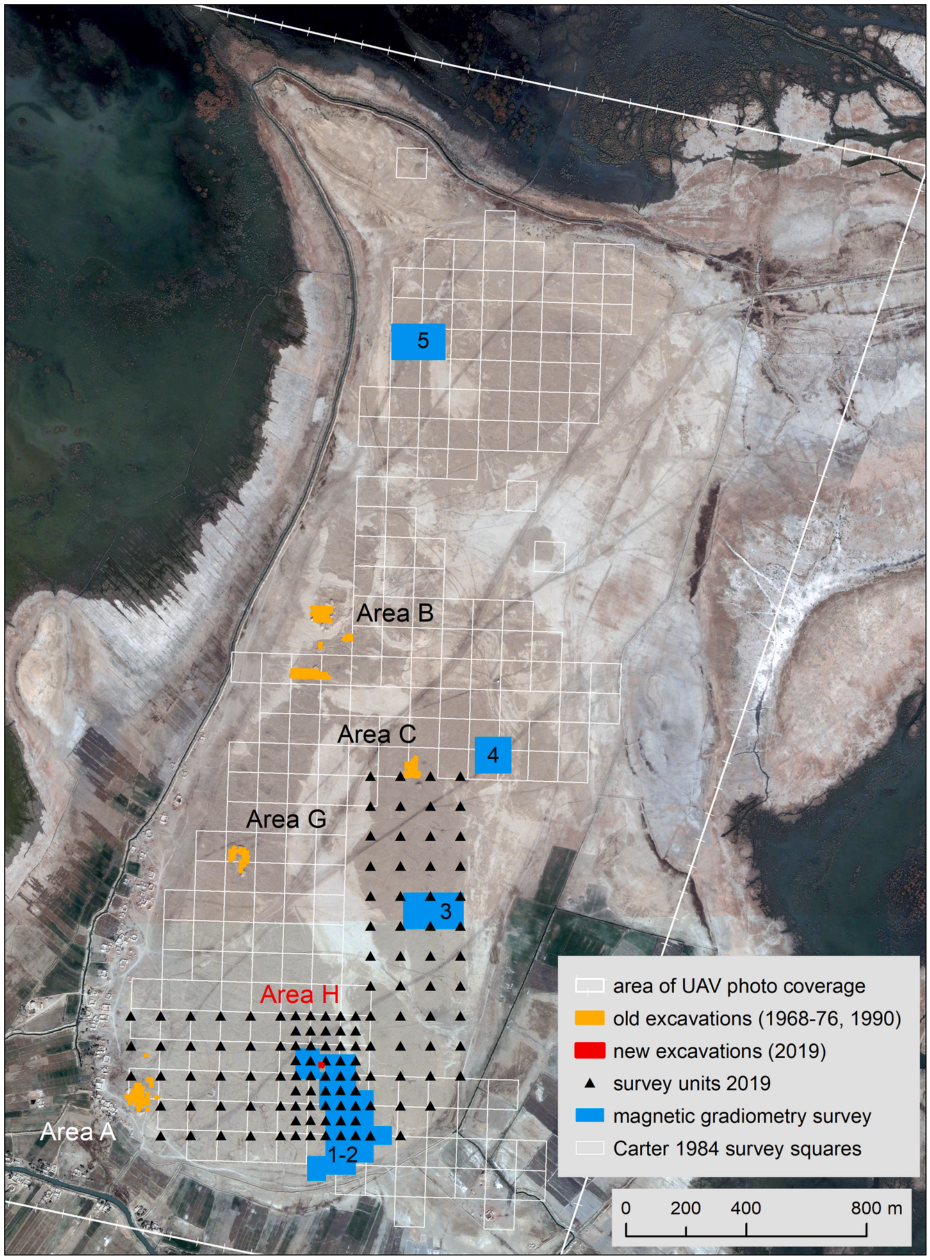

Fig. 2. Map of Lagash showing the locations of excavated trenches, squares surveyed by Carter in 1984, new survey units, and magnetic gradiometry and UAV survey areas. Base image from DigitalGlobe, 8 December 2007, displayed with a 2.5 standard deviation histogram stretch. For the best interpretation of this figure, see the color version online.

appear in UAV photos. By the same token, the magnetic gradiometry shows deeper features that may not appear in UAV photos. Ovens, kilns, and drains appear much more distinctly in the magnetic gradiometry than they do in the UAV photography since burning changes the magnetic properties of the sediment. To facilitate visual analysis of areas for which UAV mosaics and magnetic gradiometry data were available, these datasets were closely georeferenced and combined using 3-way Principal Components Analysis performed on the three bands of the UAV image and the single band of the magnetic gradiometry results, paralleling methods used for combining multiple geophysics datasets (Kvamme, 2006).

The tracings that result from analysis of the UAV mosaics represent sediment interfaces visible across multiple sets of UAV photos captured in slightly different soil moisture and lighting conditions. The comparison to magnetic gradiometry data results provide confirmation that many of the sediment interfaces visible in the UAV imagery mark the presence of subsurface features and therefore lend confidence to the broader mapping that is only possible with the UAV imagery. But such interfaces may mark other sorts of features that are not architectural, and also a single architectural feature can result in the formation of multiple different sediment interfaces. For example, the UAV photos may show both the edge of a wall and also a sediment interface marking the interior fill of a room, slightly removed from that wall, or only one might be visible.

4. Results

The spatial datasets allow for the mapping of near-surface architectural remains, streets, and water features across an area of c. 300 ha, revealing important aspects of the ancient city structure.

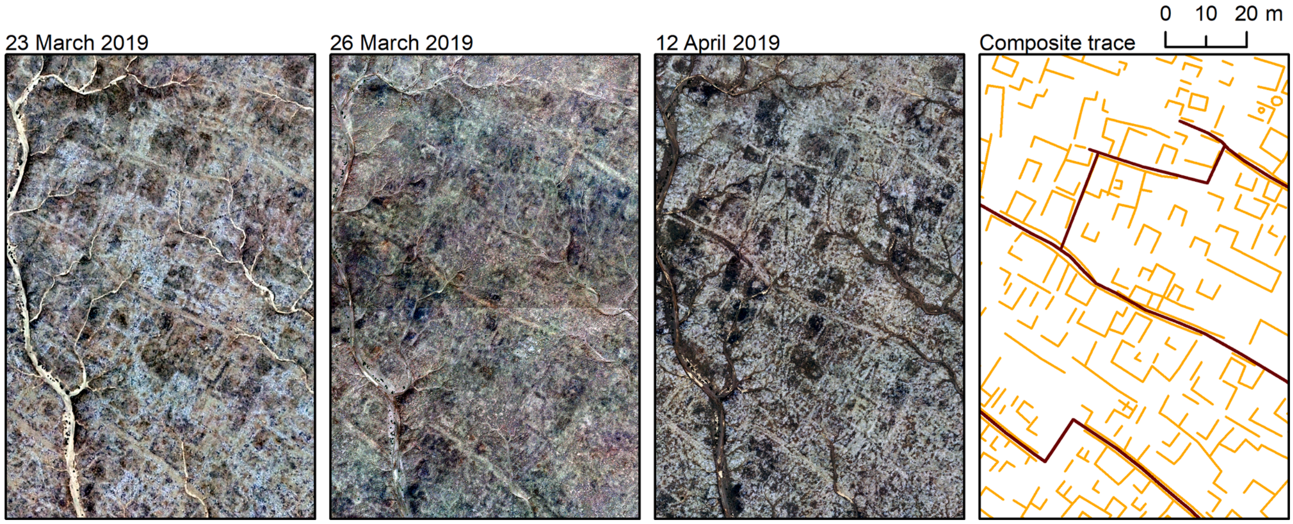

Fig. 3. Series of UAV photo mosaics captured throughout late March and early April 2019. Comparison of these mosaics led to the composite digitized map of near-surface features.

4.1. Surface survey

97 % of sherds collected from the southern part of the site date to the Early Dynastic III period. The remaining 3 % includes a few sherds of the Early Dynastic I, Akkadian, and Isin-Larsa periods, mostly clustered around the new Area H excavations.[2] The distribution of non-ceramic artifacts in the sample collection units also show areas possibly associated with the production of stone and metal objects (McMahon et al., 2023 forthcoming).

Because the new survey has not yet been extended across the site, the discussion primarily focuses on the remote sensing results. The limited survey results are crucial to the interpretation of the remote sensing insofar as they confirm earlier conclusions about the dates of the widest spread of urban habitation, and in turn suggest that much of the coherent architectural and street patterns seen in the remote sensing data likely dates to the Early Dynastic III period. The 1984 survey's documentation of later pottery in some areas, especially the central part of the site, suggests that near surface traces in those areas could be of a later date; only further survey and excavation will be able to verify this. An Early Dynastic date for near-surface patterns in the southern part of the site is far also supported by the new excavations there in 2019 and 2022, which have revealed Early Dynastic III kilns and mid-Early Dynastic domestic structures and streets (Hammer et al., 2022; McMahon et al., 2023 forthcoming).

4.2. Magnetic gradiometry

The largest of the four surveyed areas (area 1–2, c. 8.25 ha) covered the southern edge of the site and revealed a 10-meter-wide surrounding wall with 6 m square buttresses placed every 20 m (Figs. 4, 5). A gate with possible towers gives access to a main street. Parallel to the external face of the city wall and gate is a regular strip marked on the surface. This feature also appears in the UAV photos and on the ground surface, marked by lighter sediment. This could perhaps represent the outlines of a foundation ditch, moat, or depression excavated during the construction or use of the city wall. Inside the city wall are many streets aligned with rectilinear structures, kilns, and "drains"—large ceramic rings, also visible on the surface, many of which were observed to mark the locations of toilets and large storage pots. On the east edge of the surveyed area, a broad c. 18 meter-wide sinuous feature of uncertain nature appears to cut through the architecture and streets. The orientation and appearance of this feature suggest that it could be a water channel/ditch that flowed after abandonment. The UAV imagery shows straighter linear features c. 5 m in width in this area that appear similar to lengths of ditch that parallel the city wall.

Area 4 covered the site's eastern edge (c. 1.5 ha) and shows another piece of city wall, c. 10 m in width, as well as several parallel linear features that might represent ditches and/or a watercourse that followed the exterior face of the wall (Fig. 6g,h,i). Inside the city wall are some clear streets aligned with rectilinear structures. The UAV imagery significantly aids interpretation of this second area, showing more sediment interfaces than are visible in the magnetic gradiometry data. A short segment of the wall in the UAV imagery shows c. 8 meter-wide rectangular features spaced c. 8 m apart that could represent buttresses. A linear feature c. 5 m in width, marked on the surface by lighter sediment, tracks the exterior face of the wall, similar to the possible ditch in survey area 1–2. UAV imagery suggest that this feature connects to a relict watercourse to the north of area 4. There is a break in this feature in the middle of the magnetic gradiometry survey area, perhaps indicating the presence of a gate, but the streets and architecture are too faint in both datasets to confirm or refute this. Roughly 9 m east of this possible ditch is another parallel linear feature, c. 8 m in width, that is best visible in the magnetic gradiometry data. This outermost linear feature also appears to connect to the relict watercourse.

Areas 3 and 5 (c. 2.5 ha each) in the central and northern part of the site show internal city streets, buildings, and drains (Fig. 6a-f). Area 3 also shows large circular structures c. 15 m in diameter, which could perhaps represent storage structures. This part of the site is topographically low and in recent decades has been seasonally flooded (Carter, 1989–90). The combined UAV and magnetic gradiometry data show how the edges of the site have either been destroyed by erosion or have been buried by sediment deeply enough that architecture is not visible with near-surface remote sensing methods. Area 5 shows four parallel northwest-to-southeast oriented streets of equal width and spacing lined with rectilinear room blocks. On the west side of the survey area is a wider north–south oriented street. A few rectilinearly-demarcated areas marked on the surface by lighter sediments are empty of architecture.

4.3. UAV photogrammetry

The aerial photos show an astonishing density of architecture and streets spread over c. 300 ha (Fig. 7). Because Lagash is so large and flat, it had seemed possible that part—or perhaps a lot—of this inhabitation

[2] These percentages have been calculated by Sara Pizzimenti.

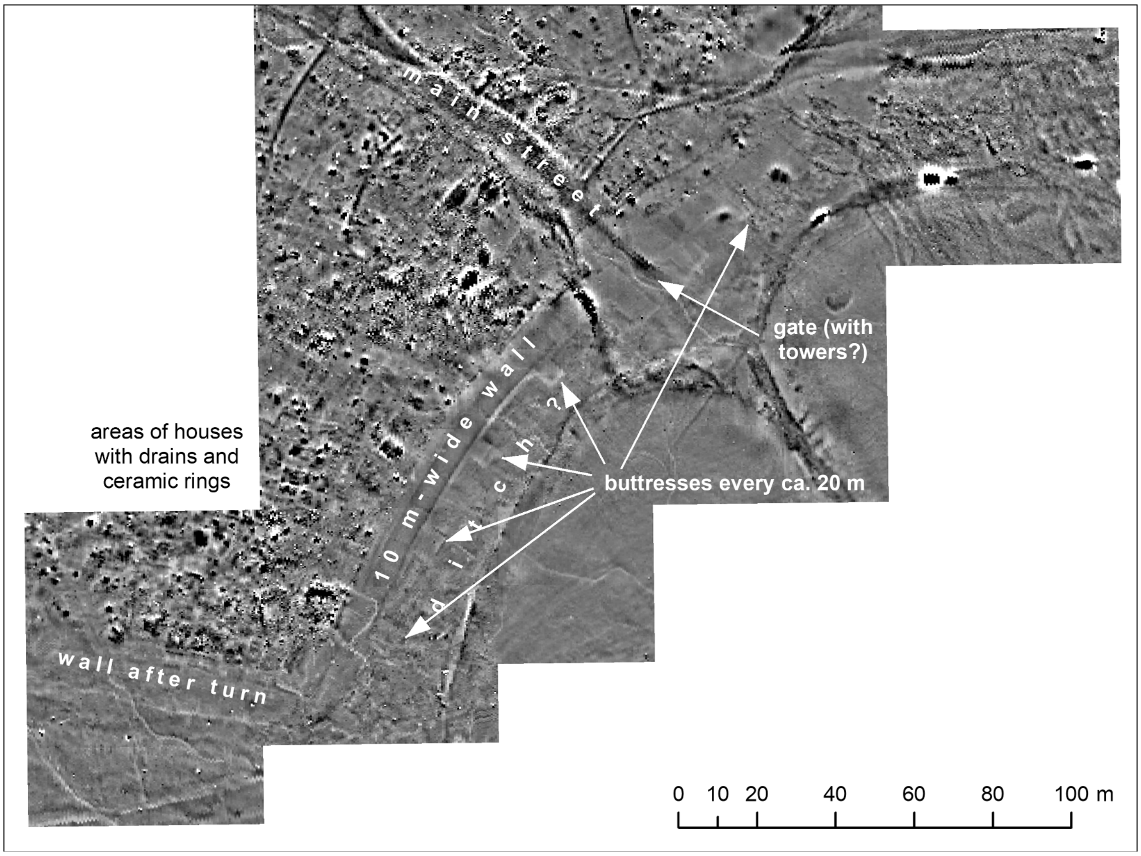

Fig. 4. Close-up of magnetic gradiometry survey results showing the buttressed city wall and south gate. Results displayed with a 2.5 standard deviation histogram stretch.

was low density. However, surface topography was not always a good indicator of architectural density. Many flat, low-lying areas are carpeted in architectural remains. Not all settlement areas show equal architectural density, however. The areas with dense architecture are discontinuous, concentrated on mounds marked by sediments that appear grey in color in the aerial photos. These mounds are separated by some spaces apparently empty of near surface architecture, often marked with lighter color sediment. The aerial photos also show some mounds at the city fringes with a lower density of architecture and possible enclosures or open spaces 15–25 m across.

The visible near surface architecture is mostly concentrated in four discrete areas collectively covering c. 200 ha (Fig. 8): two elongated mounds with their long axis oriented north–south in the southern portion of the site, south of the largest relict river course and curiously stretching away from it rather than following its course ("west ridge" c. 90 ha and "east ridge" c. 40 ha), a roughly circular area in the northern portion of the site, north of the relict river course ("north mound" c. 56 ha), and a series of five roughly circular or oval areas (4 ha or less) that appear to be individual mounds adjacent to the relict river course on both sides (Hammer et al., 2022). The southwestern tip of the east ridge is separated from the rest of the settlement area by a modern wadi that today drains the depression and empty space separating the west ridge from the east ridge. This wadi appears to cut some streets and other architectural features, suggesting that the southwestern tip was originally connected to the east ridge.

Much of the architecture can only be traced in a fragmentary way, hampering density and scale comparisons across the city's extent. Wall widths and the lengths of visible wall fragments suggest, however, that much of the visible near-surface architecture is modest in scale. There is one area, however, where wall widths and lengths indicate the presence of more substantial buildings, including temple and storage areas. This area is c. 200 m south of the previously excavated area G. It seems likely that at least some of the other textually-attested temples were located here.

The UAV images show that the city wall first recognized by magnetic gradiometry encircles the west ridge and that another city wall encircled the east ridge. In addition to the south gate, there are three other city wall lengths along the edges of the west and east ridges with clear buttresses (Fig. 9). Given the association of buttresses with a city gate in the south, it makes sense to look for other gates in these areas with geophysics. One of these areas is marked by a modern wadi, which is another piece of evidence suggestive of a gate in this location. As seen with the south gate, the break in the city wall at the gate's location conduited drainage after the site was abandoned, resulting in the formation of a wadi.

The remote sensing results have provided new spatial and environmental context for the four previously excavated areas, showing the placement of the known temples within the city fabric (Hammer et al., 2022). Two observations are important for the overall interpretation of the city structure. First, a c. 5–7 meter-wide linear feature, preserved for c. 400 m, appears to connect the southwest edge of the site near the the Ibgal temple (area A) to the area with larger architecture visible in the UAV imagery (south of area G). This suggests that a broad street/thoroughfare directly connected two temple areas separated by at least 700 m. Second, the satellite and UAV imagery suggest that the Bagara Temple (area B) was located on its own mound (perhaps island), outside of the walled portions of the west ridge.

The aerial photos also show important environmental and other non-settlement features of the site (Fig. 10). These include the paleochannels of a river, other watercourses or canals within and on the edges of the city, probable ditches along the external face of the city wall (described above), and an extensive area (c. 7.5 ha) of large rectilinear features

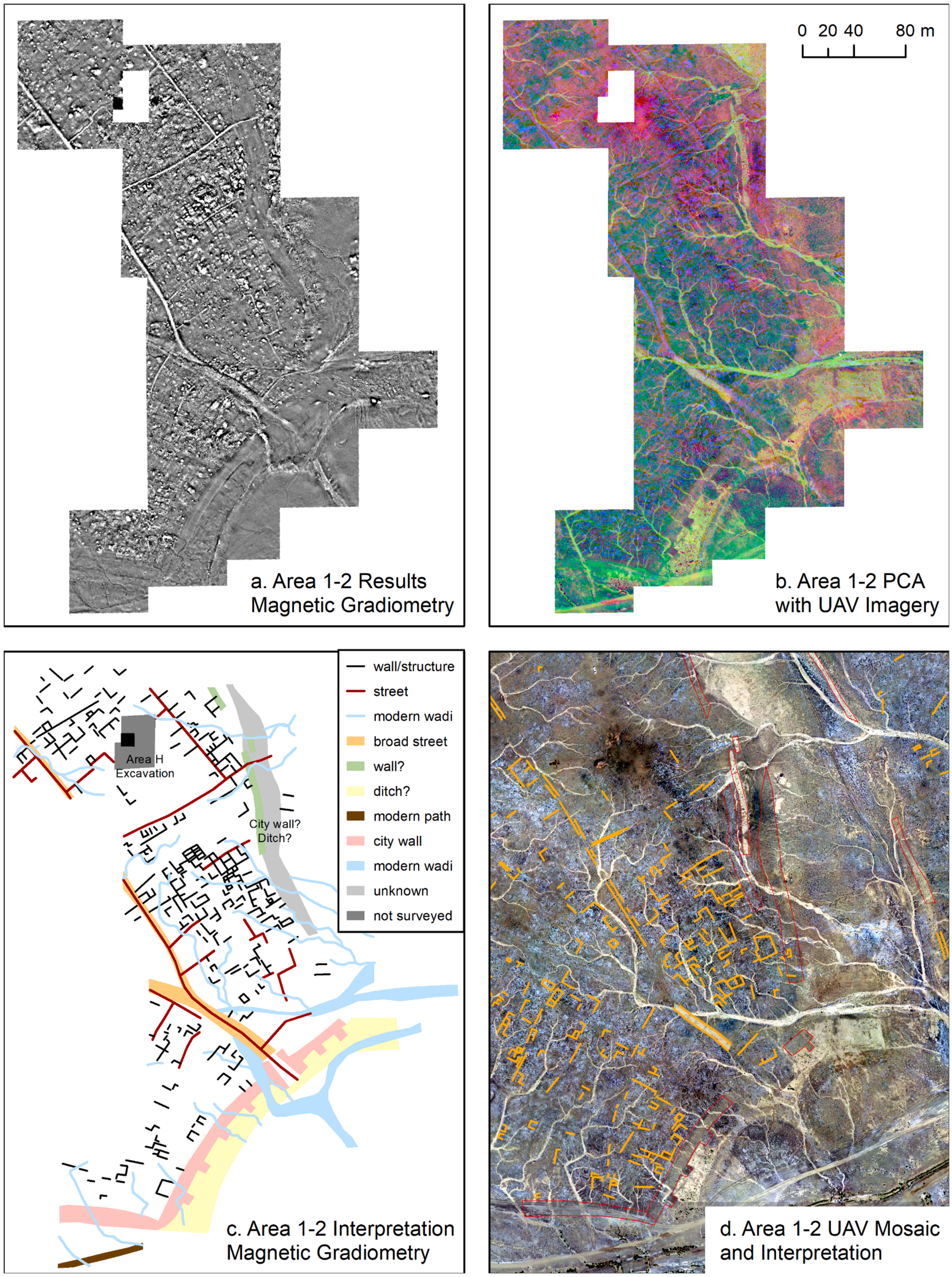

Fig. 5. Magnetic gradiometry survey results, alongside PCA analysis integrating UAV photography and interpretation, showing the city wall, gate, and structures in area 1–2. UAV photo mosaic captured 28 March and 8 April 2019. All images displayed with a 2.5 standard deviation histogram stretch. For the best interpretation of this figure, see the color version online.

possibly marking pits for the excavation of mudbrick material. These rectilinear features are located directly beside the river paleochannels, as would be expected for the construction of mudbricks. A fuller reconstruction of the path of the river is impeded on the west side of the site by the actively flooded marsh, which is bounded by modern paths that have damaged archaeological visibility through sediment compaction. The path of the river is obscured on the east side of the site by more marsh areas and irrigated fields.

The dates of the city's river paleochannels are not known, but a c. 4 ha inhabitation area on the east side of the site was built on top of former channels of the watercourse and therefore post-dates them (Figs. 8, 10). The 1984 survey found an Islamic period occupation with pottery of the ninth-tenth century CE located "on the eastern edge of Area C in areas and D and L" (Carter, 1989–90: 62), which would appear to correspond with the location of this "island". If this "island" does in fact date to the Islamic period, then it remains possible that the river paleochannels were active in the Early Dynastic period at the time of the site's maximal extent.

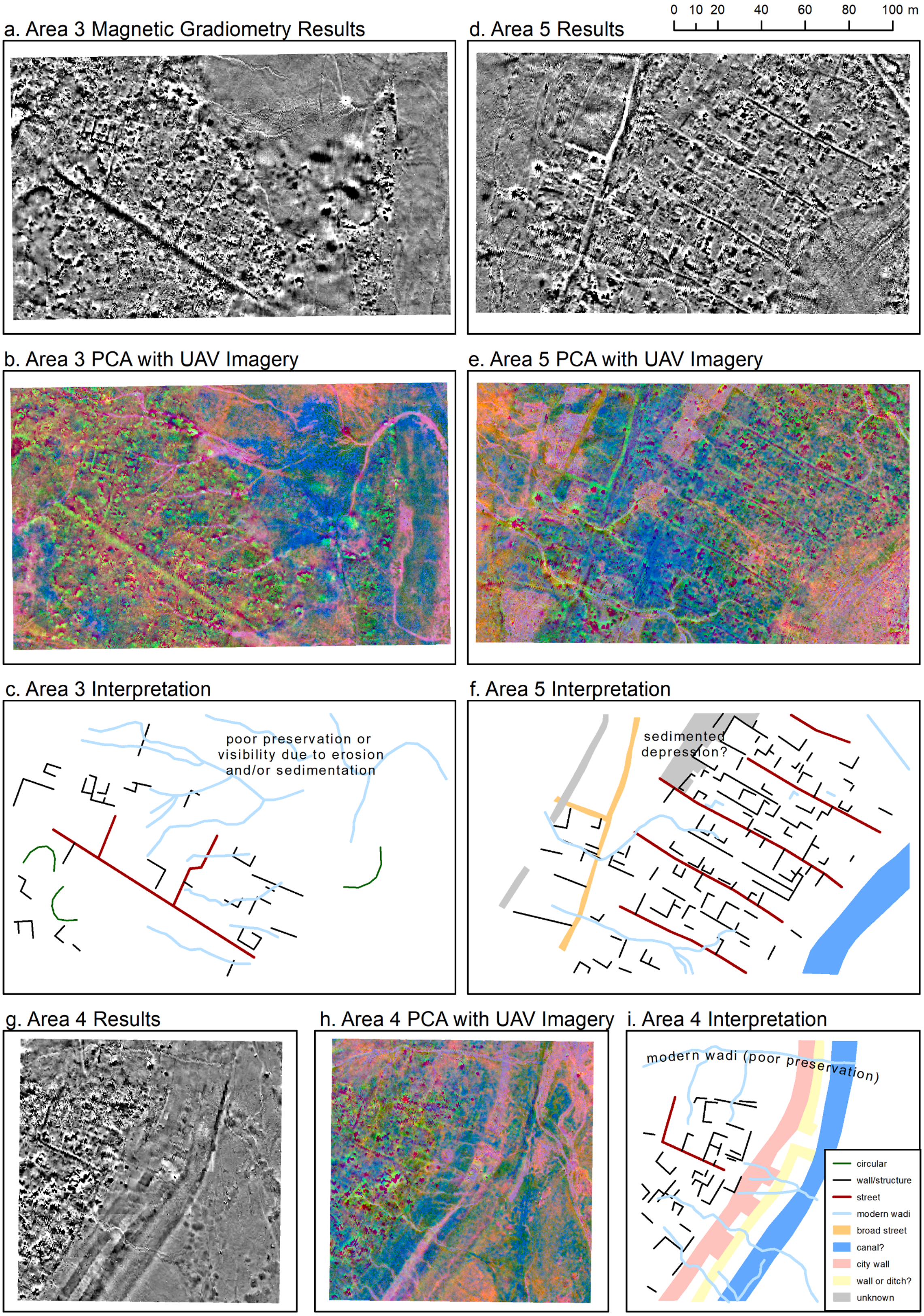

Fig. 6. Magnetic gradiometry survey results, alongside PCA analysis integrating UAV photography and interpretation, showing the interior of the city in areas 3 and 5 and the city wall with possible canal in area 4. All images displayed with a 2.5 standard deviation histogram stretch. For the best interpretation of this figure, see the color version online.

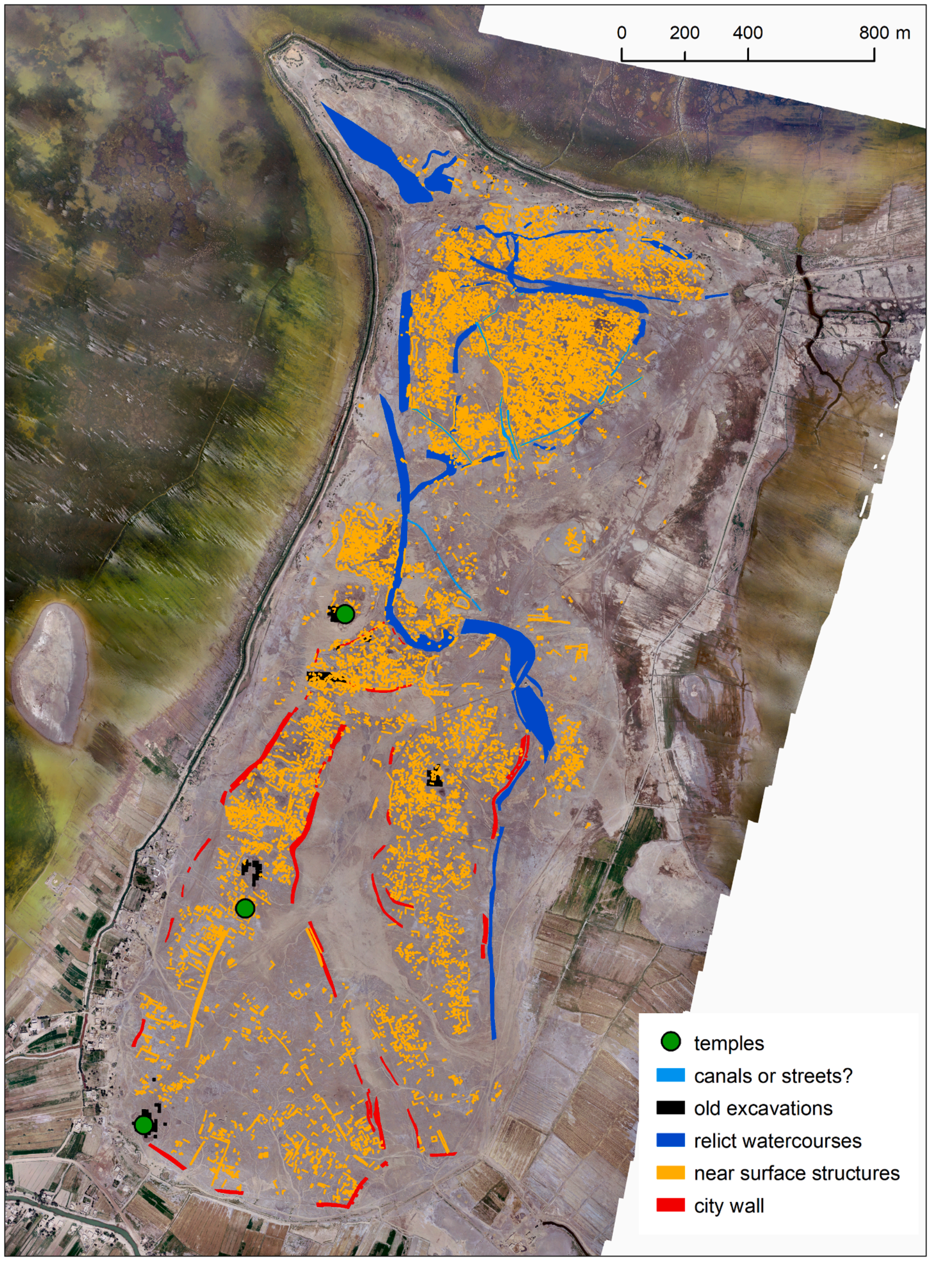

Fig. 7. Composite map of all features and sediment interfaces digitized from series of UAV imagery mosaics. Base image is a UAV photo mosaic captured 28 March and 8 April 2019, displayed with a 2.5 standard deviation histogram stretch. For the best interpretation of this figure, see the color version online.

5. Interpretation: City form and environment

The surface and subsurface mapping data indicate that Lagash was a multi-centric city of discontinuous settlement sectors separated by multiple "empty spaces", bounded by walls and/or water features. These discrete city sectors were varied in their form and function and had their own locally-oriented street plans. The city as a whole straddled a river, with settlement areas stretching up to 2 km linearly away from the river, and incorporated a significant number of intra-settlement watercourses.

5.1. Multi-centrism

The inhabited area at Lagash is discontinuous, concentrated in four dense but spatially discrete, irregularly shaped, bounded areas, separated by open spaces empty of architectural traces. The fragmentary architectural traces do not yet enable a detailed analysis of neighborhood characteristics using methods that have been especially well-honed in Mesoamerica (e.g., Garrison et al., 2019; Hutson et al., 2021; Peuramaki-Brown, 2013; Smith, 2010), but the evidence does show that the separate city sectors were variously bounded by walls and/or watercourses. The west and east ridge appear to be surrounded by at least two or possibly three separate encircling walls that are 5–10 m in width at various points. The walls clearly bound the areas in which near-surface architecture is visible and exclude an apparently empty strip of land between them that has no clear indications of architecture or paleoenvironmental features. At the northern end of the west ridge are some settlement areas adjacent to the relict watercourse which may possibly be separately walled. At some points along its length the exterior faces of the encircling walls appear to be paralleled by ditches, canals, or watercourses.

The city walls appear irregular, both in width and in geometric shape. In some places, parallel traces perhaps indicate different phases of city wall construction. The walls trace several concavities (for example along the east side of the west ridge), strongly suggesting that

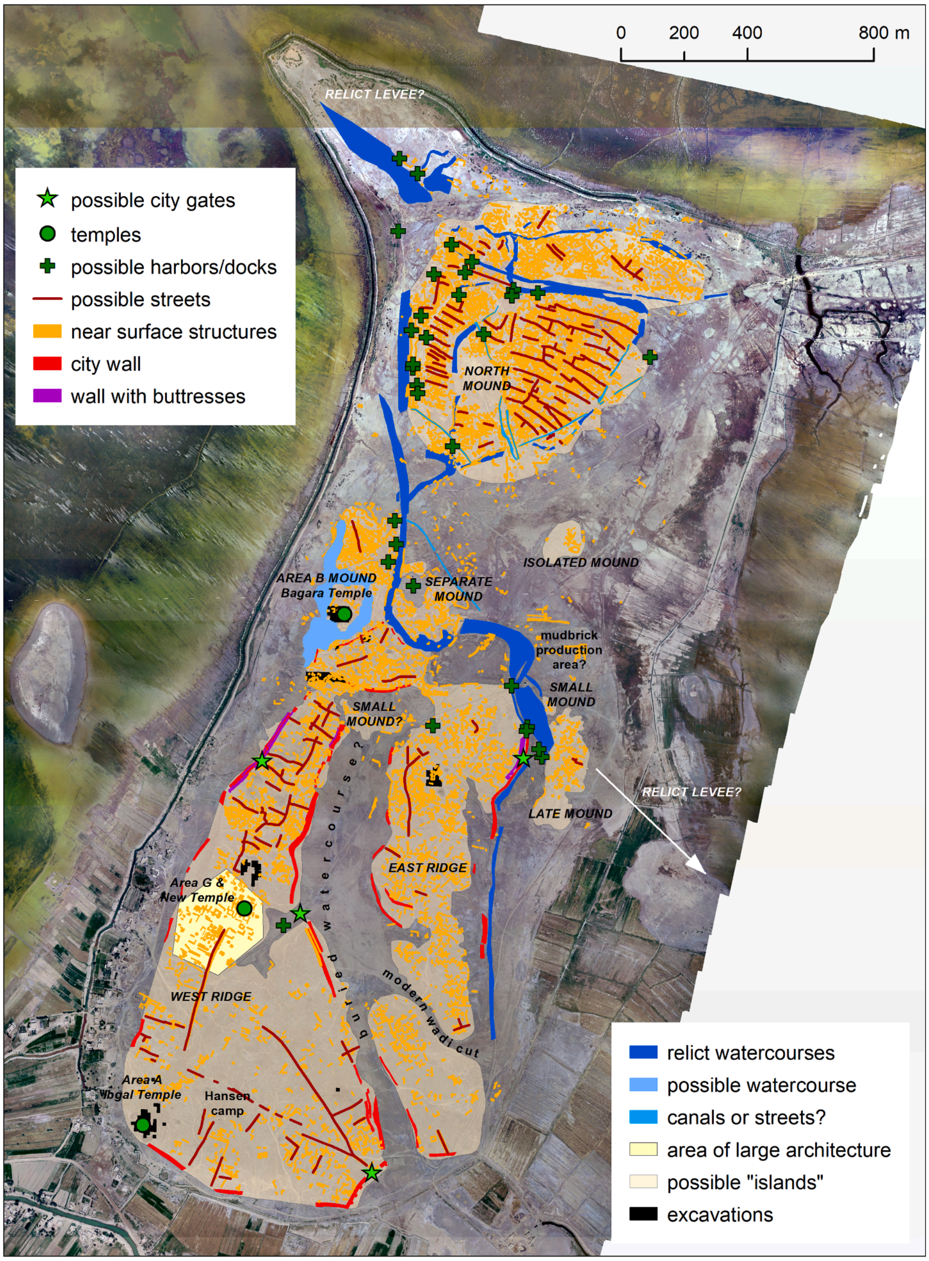

Fig. 8. Interpretive map of the results, showing the extent of settlement mounds or islands (on the basis of soil discoloration and visible near-surface features); reconstructed streets; possible gates, harbors, and water features; temples and spaces with larger architecture; and some modern features that obscure archaeological visibility. For the best interpretation of this figure, see the color version online. An interactive version of the data in this figure is available on ArcGIS Online: https://arcg.is/1LXrGO1

they followed the edges of watercourses or other existing environmental features. The reconstructed length of these walls (5 km surrounding the west ridge and 3.4 km surrounding the east ridge, 9.4 km total) and the spacing of visible buttresses (5–20 m) are comparable to the Early Dynastic period city wall at Uruk (9.5 km circumference, bastions every 9 m, (Nissen, 1972)). However, the enclosed area at these sites is very different in its topological compactness: Lagash has a linear form, and the distance from its north end to its south end (c. 3.5 km) is considerably greater than Uruk's diameter (c. 2.5 km) (Hammer et al., 2022). Various features of the Lagash city walls also seem comparable to those of the Girsu city wall, which is named in the Early Dynastic texts. Analysis of satellite imagery and ground observations suggest that Girsu had a city wall of c. 3.5 km circumference with two parts, perhaps of different phases, separated by c. 20 m: an inner mudbrick wall c. 5 m in width and an outer wall of 3–4 m, the latter perhaps fronted by ditches. At the southwestern edge of the site is a gate guarded by a tower that is c. 6 × 8 m. Parts of the Girsu inner wall were constructed from plano-convex bricks, indicating an Early Dynastic date (Rey, 2016: 20-23; Rey and Lecompte, 2020: 225).

No evidence for encircling city walls yet appears in the north mound (contra Stone, 2013: 167), which is instead characterized by intra-city water channels discussed further below. Some these channels appear to bound inhabitation areas and others cross-cut the urban fabric (Fig. 11). The west and east ridges thus had a different paleoenvironmental situation from the north mound. While it can be difficult to tell the difference between various types of linear features, there is no clear evidence for intra-city watercourses within the west and east ridges, only on their edges. The architecture of the north mound appears to sit within a quite watery environment.

These aspects of the settlement form suggest that Lagash was a multi-centric, heterogenous city, an interpretation that is further supported by the varied internal characteristics and possible functions of the city sectors. All three known temple areas, two of which were excavated, were located in a line along the western edge of the site (two within the walled west ridge and one possibly on a separate island). Two of these temples appear to be connected by a major street (the Ibgal of Inanna at

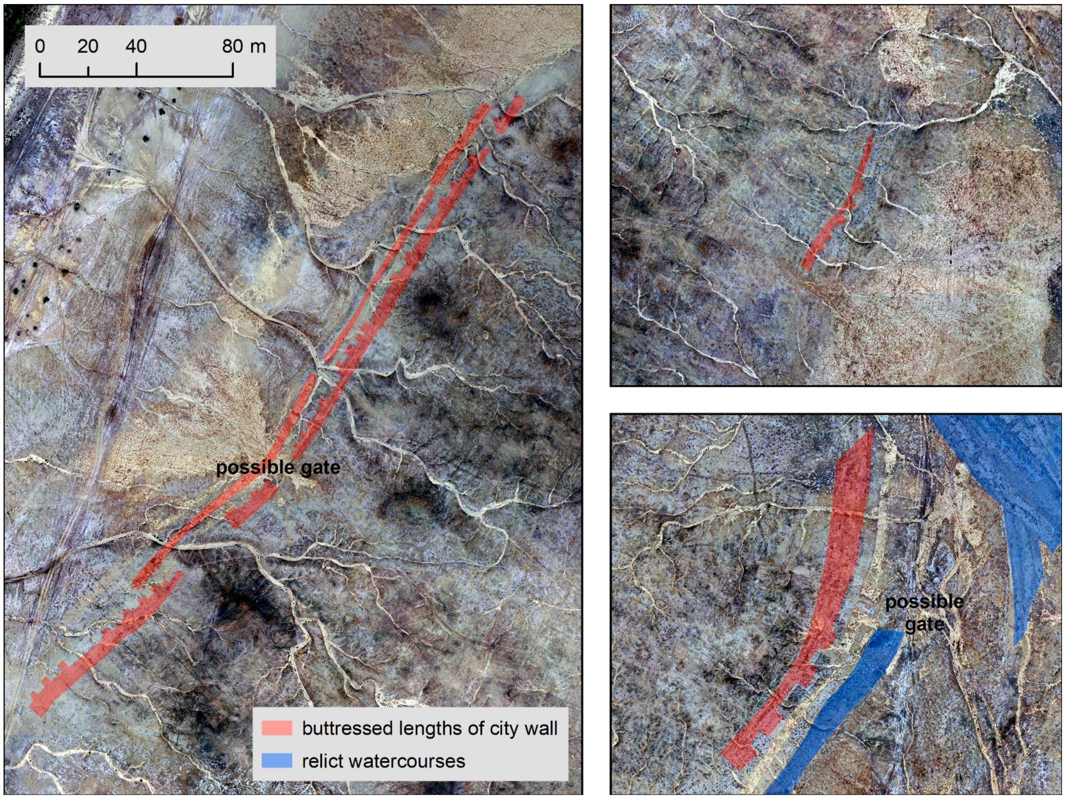

Fig. 9. Buttressed wall lengths visible in UAV photo mosaics, for comparison to the buttressed length of city wall visible in UAV and magnetic gradiometry data at the south edge of the site. Base image is a UAV photo mosaic captured 28 March and 8 April 2019, displayed with a 2.5 standard deviation histogram stretch.

the southwest edge and the temple seen in the UAV imagery south of area G) (Fig. 8). The best evidence for monumental architecture is confined to this west ridge, which also clearly contains industrial areas in its south (McMahon et al., 2023 forthcoming). The architectural traces visible on the northern mound thus far lack evidence for larger structures or major temples. This sector might have been largely limited to residential neighborhoods and industries, the latter of which were evidenced in the earlier survey (Carter, 1989–90).

In each of the city sectors, there are generally consistent orientations for streets and buildings, though these orientations are not uniform between the sectors. The dense, better-preserved street pattern in the north mound is dominated by NNW-SSE streets placed at somewhat regular intervals and sometimes incorporating dog-leg bends. In the north, this street pattern crosses areas that appear to be separated by the intracity watercourses. In the west and east ridges, the major street patterns are oriented roughly parallel and perpendicular to the longest axis of the irregular shape enclosed within the city walls. Each separately walled area has its own street pattern oriented to the geometry of the inhabited area (Hammer et al., 2022).

5.2. Local environmental setting and hydrology

The UAV images indicate that Lagash straddled a river that entered the site at its northwestern edge, flowed along the west side of the north mound, took a sinuous course between the north mound and the west and east ridges, and exited the city in the center of its east side. North and east of excavated area B, visible architectural traces appear to directly abut the relict channel of the river, suggesting that the watercourse must have at some point been canalized in this area to constrain changes in its flow (Fig. 10). This stretch of the watercourse would be the ideal location for bridges or other means of crossing. There is an expansive clearly bounded area without visible architecture, located adjacent to the river's course and marked by lighter sediments. This area could be an infilled lagoon or harbor. Downstream (east) of this area, the presence of numerous channels scars indicate that the river frequently shifted its course, and few architectural traces are visible close to the channels. This could have been because the city inhabitants chose not to canalize this length of the river and therefore did not construct buildings in this area or because movement of the river erased constructions (including any reinforcements for attempted canalization) that had stood in this area.

The river appears to have fed a number of intra-city watercourses visible in the north mound. The orientation and preserved path of these intra-city watercourses suggests that they took their water from the river near the settlement's northwestern edge. Recent surveys, magnetic gradiometry results, and geoarchaeological studies at the southern Mesopotamian sites of Uruk, Larsa, and Girsu (Darras and Vallet, 2021; Rey and Lecompte, 2020; Van Ess and Fassbinder, 2019) indicate that intracity watercourses, including peripheral canals that encircled some settlement areas, were a common feature of third and second millennium BCE Mesopotamian cities. However, the intra-city watercourses at crossing the north mound at Lagash seem far more numerous than those evidenced at other sites (Hammer et al., 2022). Beside these water channels or even built into them are rectangular-shaped areas of lighter sediment that could possibly represent the location of smaller "harbor"-like features: boat slips or small docks. Where they occur in pairs, these also could alternatively mark the footings of bridges for foot and cart traffic across watercourses (Fig. 11).

6. Discussion

6.1. Lagash as a city of organically expanded marsh islands?

Many of the visible features of Lagash are suggestive of settlement located within a marshy or watery environment. However, the new data suggest revisions to earlier hypotheses that Lagash was a single or series

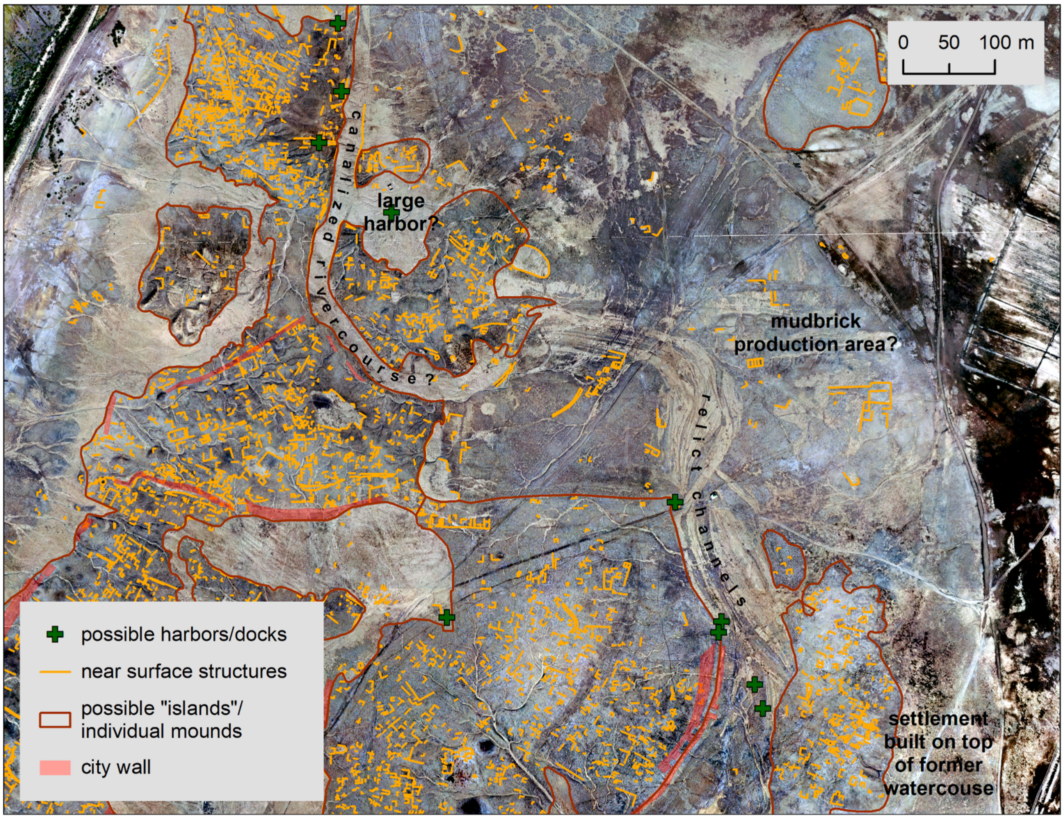

Fig. 10. Paleoenvironmental and non-settlement features visible in a UAV photo mosaic captured 28 March and 8 April 2019, displayed with a 2.5 standard deviation histogram stretch. The features include a possibly canalized river bed, channel scars along a possibly un-canalized length of the river, possible harbors, an area of in-filled linear pits possibly marking the location of an area used for the excavation of mudbrick material, and a later settlement mound constructed on top of the former watercourse. For the best interpretation of this figure, see the color version online.

of marsh islands. On the basis of her evaluation of much lower resolution commercial imagery, Stone (forthcoming) believed that the city consisted of around thirty-three islands of varying size, many rather small, with empty watery or marshy spaces between them, perhaps used as harbors. It is now clear that that the majority of the dense inhabitation is in three large contiguous clusters, perhaps islands or toes of a bird's foot delta, of c. 90 ha (west ridge), 40 ha (east ridge), 56 ha (north mound), one of which in the north is possibly cross-cut by internal watercourses. Many of the areas that Stone interpreted as "empty" watery spaces are in fact full of dense architecture that is simply not visible in commercial satellite imagery, which is lower resolution and not always captured under ideal soil moisture conditions (Hammer et al., 2022).

Here I propose a series of processes, some combination of which could have led Lagash to evolve into its final, discontinuous form as documented in the UAV mosaics. These can be divided into settlement evolution processes, environmental changes, and taphonomic processes.

Settlement evolution processes: If a marshy or watery local environment existed at Lagash during the beginning of the Early Dynastic period, inhabitants may have settled upon scattered local high points that were generally protected against seasonal flooding ("turtlebacks") or on the linear levees ("toes") of a bird's foot delta (as has been proposed, but not verified, for Uruk (Pournelle, 2003; Pournelle and Algaze, 2014)). These high points would have been separated by watercourses, marsh areas, and/or lakes whose path/extent were progressively shaped by human intervention and anthropogenic topography. Long-term settlement would have encouraged the expansion of these high points, as the accumulation of mudbrick, reed, and other building materials raised the local land surface. As the settlement mounds grew upwards, watercourses and canals would have been relatively lower and lower, eventually leading them to be abandoned and infilled, either deliberately or otherwise. In these ways, some of the original high points could have merged, forming continuous dry land. Environment and subtle topography could have shaped the irregular form of the city walls, as they enclosed the organically expanding settlement areas and perhaps even protected them against flooding. A combination of natural and human-directed water flow could result in the intra-city water courses seen in the north mound.

Environmental changes: Alternatively, or in addition to the above settlement evolution processes, third millennium BCE sea level change, specifically the southeastward retreat of the Gulf coastline, would have shaped Lagash's discontinuous form, though in uncertain ways that remain to be clarified. Pournelle (2013) argues that a marine incursion caused the Lagash area to be flooded or marshy and unsuitable for inhabitation before the late fourth millennium BCE, that another sea level rise (to one meter above present levels) occurred during the Early Dynastic III, at the height of Lagash's power, and that afterwards the Gulf head retreated southward, causing a broad shift in southern Mesopotamia from a marsh to a steppe environment. However, the exact timing, extent, and effects of the transgression and retreat of the Gulf head in southern Mesopotamia remain unverified in this region and cannot yet be correlated with specific developments at Lagash. If higher sea levels coincided with the city's founding or expansion, city settlement may have been confined to the few remaining high points suitable for occupation. If lowered sea levels coincided with the city's founding or expansion, more extensive and continuous areas of dry land, nonetheless still separated by remaining watercourses and any remaining wetland areas, would have formed and allowed for more extensive occupation.

Taphonomic processes: Post-abandonment processes can heavily shape the appearance of any site, and in a wetland environment, geoarchaeological work is necessary to determine whether sites developed in such an environment or whether they developed in dry areas that

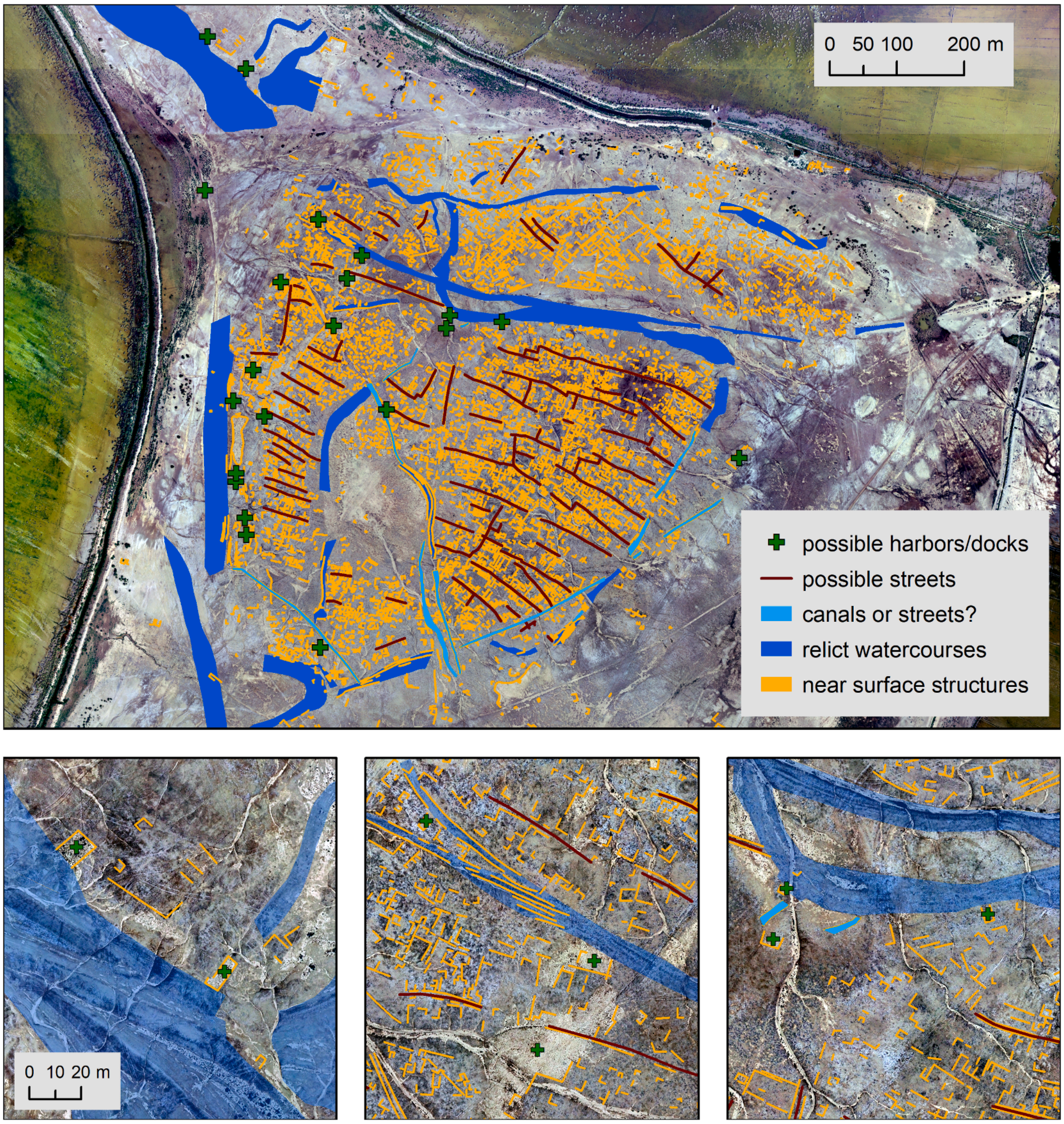

Fig. 11. Map of possible dock/boatslip/harbor features built into or beside watercourses in the north mound of Lagash, with close up maps of three examples. Base image is a UAV photo mosaic captured 28 March and 8 April 2019, displayed with a 2.5 standard deviation histogram stretch. For the best interpretation of this figure, see the color version online.

were subsequently flooded (Wilkinson, 2012: 130-132). Given the active marsh in the area in recent times and possibly during other periods over the last four millennia, we cannot without further excavation and sediment coring rule out the possibility that post-abandonment taphonomic processes have not in some cases resulted in a false appearance of discontinuous "islands" of settlement at Lagash bounded by water courses. This would occur as repeated marsh expansion and retreat caused the infilling of low-lying settlement areas with water and sediment, erasing some archaeological traces and burying others to a depth at which they are not visible in near-surface remote sensing, leaving only some high areas with preserved near-surface remains visible. The topography and streets of the formerly inhabited areas could work as conduits for draining water into specific paths and channels, forming water courses that cross-cut and follow the edge of settlement mounds.

Regardless of the local environmental conditions during the Early Dynastic period, this set of taphonomic processes definitely affected the surface appearance of the site to some degree. The magnetic gradiometry data from survey areas 1–2 and 3 as well as the UAV mosaics (for example at the south end of the east ridge) preserve some evidence of this. However, in many other areas of the site, the preserved architectural traces are clearly bounded by the city wall and watercourses do not appear to cut through architectural traces. This suggests that the concentrations of settlement are truly separate city sectors reflective of the Early Dynastic situation and therefore that the reasons for the discontinuous city form are more likely to be primarily found in settlement evolution processes and sea level changes.

The hypothetical developmental process of Lagash as a city of marsh islands outlined above could offer a possible explanation for the dispersed pattern of temple precincts seen at Lagash. The Bagara temple in area B appears to be located on its own mound, possible island, surrounded by a watercourse, ditch, or lagoon (Hammer et al., 2022). Although the Ibgal temple in area A and the newly identified temple south of area G appear to be located in a continuously inhabited area, it could be that their distance from each other (c. 700 m) has to do with their original foundation on separate islands, mounds, or high points that eventually expanded and grew together. This suggestion is purely hypothetical; we have no topographic or remote sensing evidence that these other temples occupied different pre-existing high points (the form and ancient rebuilding of these temples has produced local topographic peaks at the temples' locations on the modern surface). But the idea is a plausible one worth testing and nonetheless serves as a reminder that the palimpsest form of the city as visible in the remote sensing data and imagery might not reflect its form at the time of its original founding.

The Early Dynastic was several centuries long, and it could be that the discontinuous form of Lagash also reflects city sectors inhabited at different points in time (horizontal statigraphy). The spatial distribution of the known temples and visible paleoenvironmental features at Lagash suggest some hypotheses about relative differences in age among the various city sectors. Excavated Mesopotamian temple sequences are typically very long, indicating that these institutions anchored neighborhoods and cities over centuries and even millennia. Their presence may be a proxy for neighborhood age, indicating that the west ridge and area B island hold the most ancient parts of the city, which later expanded to the other areas. The watery nature of the north mound suggests that it might be the youngest of the city sectors. Over time, intracity canals like those seen in the north probably would have tended to dry up and be converted to streets (Van de Mieroop, 1997: 78), so their presence only in the north mound could indicate that it had a shorter inhabitation history. The west and east ridges could represent older areas of the city that had time to grow and evolve street patterns, while the north mound could represent a younger expansion of the city where parallel streets still reflect the former areas of fields. A similar sort of process has been hypothesized for steppe-based northern Mesopotamian cities, with former field boundaries being incorporated into the expanded city plan (Ur, 2020). The major streets traced in the Lagash north mound align with relict watercourses, as one would expect if their path represented former field boundaries.

6.2. Implications of a multi-centric urban form

Regardless of the local paleoenvironmental situation and the exact habitation history of the different city sectors, Lagash's discontinuous and bounded form surely reflects social and political factors of early urban life. At this point, however, it is only possible to speculate which of these factors were most important. The city walls could have been constructed to formalize and defend the organic growth of intentionally separate city sectors, at a time when city populations must have grown and been maintained via local rural and foreign in-migration (Algaze, 2018; Bernbeck, 1999; Emberling, 1999) and at a time when early cuneiform texts and art depictions evidence organized battles between Lagash and nearby city-states (Cooper, 1983; Winter, 1985). The scale and elaboration of early Mesopotamian city walls like the 10 + meter-wide buttressed walls at Lagash cannot be fully explained by warfare or its threat, however. City walls served as highly visible markers of the power of kings and the stability and political independence of their cities, intended to impress both citizens and potential enemies (Pollock, 1999: 47-8, 178; Postgate, 1994a:74-76; Richardson, 2015; Trigger, 2003: 125). Separate city sectors could have developed in part as separate residential areas for Lagash city inhabitants of different geographic origins or sociopolitical affiliations. Archaeologists have hypothesized that the dispersed nature of residential areas of the earlier northern Mesopotamian city of Brak may have functioned to provide social distance, a means of reducing intra-group conflict (Ur, 2014; Ur et al., 2007). The spatial separation of inhabitation areas at Lagash could have helped mitigate the social, political, and logistical difficulties that the community would have faced in becoming larger. In the coming years, the excavation and theorization of the empty spaces between separate urban inhabitation spaces like those at Lagash will be an important key to understanding early Mesopotamian urbanism (Smith, 2008).

Even if social reasons were not the primary factors resulting in separate city sectors, these sectors certainly would have had a number of social and logistical ramifications for city inhabitants. The separately walled nature of these sectors and the empty spaces between them would have hindered cross-city traffic patterns, enabled potentially exclusionary access to different city spaces, and facilitated a greater freedom for separate city sectors to have their own characteristics like the differently oriented street plans seen in the UAV mosaics. Encircling walls limit movement and exclude outsiders but they also simultaneously can foster links and solidarity among people and institutions contained within them; the separate city walls could have promoted different affiliations among residents of different city sectors. Similarly, the watercourses that border parts of the city and that cross-cut the north mound would impede free movement between habitation areas on either side, limiting traffic to areas where bridges or boats could provide dry access. On the other hand, intra-settlement transport by boat, which is suggested by the inward-facing orientation of many of the harbor or boat slip features (Hammer et al., 2022), would have helped to connect the far edges of city sectors that are separated by kilometers. The important advantage of regional boat traffic in southern Mesopotamia's riverine environment has been well-discussed (Algaze, 2001; 2008: 50-62); many of these advantages would also apply at a smaller scale in terms of the connections and integrating force that waterways could have held within an individual city as large as Lagash, allowing people with access to boats the ability to more easily move goods and stay in contact with residents of other city sectors.

The urban structure of Lagash appears to run counter to the standard model of third millennium BCE cities in southern Mesopotamia as dense, nuclear, bounded cities growing outward in a continuous fashion from a central religious complex, positioned within an agricultural hinterland. In drawings and textual descriptions, early Mesopotamian cities are reconstructed with a prominent geographic center (the main religious complex), an oval-shaped city wall, one or two intra-city canals, and one or two harbors at their edges. Lagash instead seems to have had discontinuous occupation areas with spatially separate city sectors bounded by irregularly shaped (occasionally concave) walls that stretch linearly far away from the city river course. The city has no clear geographic center, widely spaced temple complexes, many intracity watercourses, and dozens of features scattered throughout that appear to be harbors, docks, and/or boatslips.

While Lagash is now the most obvious example, a number of other large southern Mesopotamian cities consist of multiple mounds. The massive early city of Uruk seems to have originally been two settlements in the fifth and fourth millennia BCE, the earlier Kullaba (founded 4500–3500 BCE) and the later Eanna (founded 4000–3500 BCE), which developed their own differently organized temple complexes. Although newer, the Eanna temple complex eventually grew in size and importance faster than the older complex at Kullaba. These sanctuaries were later connected and merged to form a single centralized sanctuary at Uruk from the Jemdet Nasr period (3100–3000 BCE) onward. Later in its history, Uruk had multiple settlement mounds (Nissen, 1972: 793-795). Kish provides another example of an early "twin city": it has two major mounds separated by 2 km, Ingharra and Uhaimir, ancient Kish and Hursagkalama (Yoffee, 2005: 57). These were originally independent villages established in the Uruk Period (4000–3100 BCE) that expanded towards one another in the Early Dynastic period. Further, the whole site has multiple mounds of various sizes, heights, and settlement histories that maintained separation for millennia, perhaps due to the presence of intervening canals and watercourses (Gibson, 1972; Ur, 2021). The core areas of Nippur and Ur have two halves separated by ancient city canals (Gibson, 1993; Woolley, 1930). Several earlier settlements of the fourth millennium BCE whose plans are partially visible in satellite imagery appear to have consisted of at least two or three mounds (Stone, 2013: 158-159). Recent work at the other two urban centers in the city-state of Lagash, Girsu and Nigin, has highlighted that these are also multi-mounded sites. At Girsu, satellite imagery shows that the main complex of archaeological mounds (c. 115 ha) was separated by watercourses from two clusters of "peripheral mounds" to the west and east (c. 15 ha). The main complex of mounds consists of a northern tell of 35 ha, four other tells, and a broad flatter southern area of c. 80 ha; at least part of this complex was walled (Rey, 2016: 17-21; Rey and Lecompte, 2020: 216). At Nigin, the site consists of two mounds (Nadali and Polcaro, 2016) that appear from satellite imagery to have at some point in their history been located along a watercourse (Hammer et al., 2022). The smaller Early Dynastic center of Abu Salabikh had mounds divided by watercourses and may possibly have had city walls separately encircling the individual mounds (Stone, 2013: 167), although only one walled mound was evidenced in excavation (Postgate, 1990: 106).

Multi-mounded early cities like Lagash might provide evidence extending the paleoenvironmental and archaeological arguments made for the significance of earlier wetland and later floodplain environments in the timing and form of early urbanism and later territorial states in Mesopotamia. As discussed earlier, paleoenvironmental changes around the end of the third and the beginning of the second millennium BCE may have reduced the size of wetlands and transformed multiple river channels to fewer meandering channels in the lower reaches of the Tigris-Euphrates system. Pennington et al (2016) argue that in response to these changes, the settlement pattern in far southern Mesopotamia evolved at a regional scale from settlements of roughly equal size distributed across the landscape at river avulsion nodes to larger settlements located at the apex of distributary river channel networks. At the intra-settlement scale, these paleoenvironmental changes may have additionally transformed discontinuous settlements (situated on high points within wetlands or between multiple water channels, as may have been the case at third millennium BCE Lagash) to continuous settlements in which previously empty space could be infilled (resulting in the apparently continuous cities recovered archaeologically). Thus, regional paleoenvironmental and resource changes could have resulted in the spatial reorganization of the Mesopotamian landscape *and* the internal structure of Mesopotamian cities.

The traditional archaeological focus on temples, limited knowledge of broader city form, and the confounding effects of complex post-abandonment processes have resulted in monocentric reconstructions of early Mesopotamian cities as spatially contiguous settlements. The form of sites like Lagash and its neighbors suggests that archaeologists need to move more explicitly to a multi-centric model of early Mesopotamian cities and take seriously the possibility that many early cities consisted of separate occupation areas, some of which grew together and others of which preserved intervening empty spaces. Even when early cities seem continuous in their inhabitation areas, this could be due to subsequent millennia of occupation, and archaeologists should be careful about reconstructing early city extent and form without geospatial evidence linked to occupation levels associated with the initial phases of urbanization. Now that fieldwork is possible again in southern Iraq, spatial archaeology methods, remote sensing, and strategically placed excavation can facilitate the investigation of potentially separate city sectors, what they indicate about early city life and the nature of early urban communities, and how their existence shaped citizens' experiences.

7. Conclusion

Archaeologists now recognize a diversity of ancient urban forms, both globally (e.g., Cowgill, 2004; Creekmore and Fisher, 2014; Farhat, 2020; Marcus and Sabloff, 2008) and throughout antiquity in the Middle East, with particular attention devoted in recent years to the dispersed, low-density form of fifth-fourth millennium BCE northern Mesopotamian proto-cities (Al Quntar et al., 2011; McMahon, 2020; Oates et al., 2007). Yet Childe's "Urban Revolution" model of a dense, compact, bounded city with a nuclear temple center and continuously occupied plan is still thought to describe well the "mature" southern Mesopotamian cities of the third millennium BCE (e.g., Trigger, 2003; Ur, 2014). With geospatial revolutions in archaeology, we are gaining the tools and spatially extensive datasets to suggest, beginning with Lagash, that this model may never have been never truly accurate even for the "classic" third millennium BCE cities. The idea of marsh-based early Mesopotamian urbanism has been proposed for decades, contradicting Childe and others (Oates, 1960; Pournelle, 2003), and historians have long discussed textual evidence for the proximity of early Mesopotamian cities to marsh areas (e.g., Carroué, 1986), but remote sensing data from Lagash offer the first convincing evidence of the settlement form and intra-settlement hydrology implied by such an environment.

An integrated analysis of UAV image mosaics, magnetic gradiometry data, and ground observations indicates that Early Dynastic Lagash had dense yet discontinuous occupation areas separated by significant empty spaces and contained widely-space temple precincts. Irregularly shaped sectors had their own street plans and were separately bounded by walls and watercourses. The form of the city suggests that it might have grown and/or persisted in a marshy environment. The reasons for separately walled sectors and apparently empty spaces require further investigation and verification via excavation and geoarchaeology, as does the "natural" or anthropogenic nature of the intracity water channels in the north. The apparent differences between the north and the south parts of the city suggest that there could have been multiple evolving ways for Lagash to be a "city of marsh islands", adapting to changing water levels and flow patterns and changing topography as human occupation and environmental change reshaped the landscape.

The discussion above has put forth a series of interconnected hypotheses about Lagash's physical and social evolution as a city that can only be approached through future excavation and further landscape, environmental, and geoarchaeological work. The disentanglement of site formation and post-abandonment processes is a difficult but necessary next step to confirm aspects of the local environmental situation at Lagash and city form specifically in the Early Dynastic period. The complex taphonomic processes that have been at work on southern Mesopotamian sites over millennia will make finding definitive answers to many questions very challenging, as will the enormous size of Lagash. However, the data and analyses presented here already make an important advance in our understanding of early Mesopotamian city plans and urban diversity and point to exactly where excavators may be able to obtain data to answer various archaeological and paleoenvironmental questions. Future analyses with the data from UAV imagery will be possible, especially as this work is ground-truthed. In particular it should be possible to generate interesting information about variations in building size and layout, variable urban density, and traffic patterns. Much is known about Lagash's temples and administrative areas from the prior excavations. Archaeologists of course need balanced excavations of industrial and residential areas, following research trends in the archaeology of early cities in northern Mesopotamia and elsewhere in the Middle East. But it will be impossible to understand Lagash without dedicated excavation and sampling of these empty areas, streets, watercourses, and harbors. These empty areas will doubtless provide essential clues for understanding not only Lagash's city form, but also its economic and social foundation.

The Lagash results impact our broader understanding of early urbanism in a number of ways. A marsh environment would imply that early city growth could have been driven by an economic basis and urban landscape that are significantly different from those that Childe and others envisioned (Pournelle, 2003). A plethora of intra-urban waterways implies that low-friction intra-urban circulation of people, goods, and waste would have been possible by boat; water transport could have helped to integrate parts of the city that are separated by kilometers. The separate city sectors and multiple bounding walls and features could imply a very different distribution of social and political power than the simplistic model of control and hierarchy flowing unidirectionally and centrally from palaces and temples. The incorporation of significant intra-urban empty spaces and separately walled areas could have been part of active strategies not only to live in a watery environment but also to help mitigate the social and political challenges of living in larger settlements. Given the shifting paleoenvironmental situation in southern Mesopotamia in the fifth to third millennia BCE, other southern Mesopotamian sites could have looked as Lagash did at certain points in their history, incorporating spatially discrete inhabitation areas and significant empty space within a watery environment. Overall, the Lagash results suggest that early city spaces were much more heterogenous than even Childe's harshest critics have argued

(Smith, 2003), fundamentally challenging old models of early urbanism and pointing towards exciting avenues for future research.

CRediT authorship contribution statement

Emily Hammer: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Review

Response to Emily Hammer's article: "Multi-centric, Marsh-based urbanism at the early Mesopotamian city of Lagash (Tell al Hiba, Iraq)"

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ABSTRACT

Remote-sensing techniques play an important role in the resumption of archaeological research in southern Iraq. These tools are especially powerful when ground-truthed through excavation and survey, and when informed by local environmental histories. This response engages with propositions put forward by Hammer (2022): "Multi-centric, Marsh-based urbanism at the early Mesopotamian city of Lagash (Tell al-Hiba)." Using a mix of UAV photography and magnetic gradiometry data, Hammer argues that Lagash was a marsh-based city toward the end of the Early Dynastic period in Mesopotamia (c. 2,900-2,292 BCE), and that on-site habitation had previously been restricted to points of high elevation because of excess water. Fundamental geoarchaeological and chronometric data, however, are absent. Based on evidence from previous excavations and general conditions of site preservation, we review Hammer's interpretations, including the validity and reliability of the data that the paper uses to advance its arguments. Ongoing work at that site has the potential substantially to enhance our understanding of ancient urbanism. Ultimately, this response seeks to rectify basic principles of chronology, taphonomy, and paleoenvironment at Lagash, and to highlight the importance of verifiable representation in the presentation of remotely-sensed datasets.

1. Introduction

Lagash was an important Mesopotamian city during the 3rd-millennium BCE, when most of Sumer's population consolidated around major political, religious, and economic forces, a process that brought about large and densely concentrated settlements organized through highly articulated institutions of extended households. At a still unknown point in the Early Dynastic (hereafter "ED") III period (ca. 2600–2,292 BCE), the city joined two neighboring sites, Girsu and Nigin, to form the Lagash city-state, one of the first states in southwest Asia (Huh, 2008; Rey, 2016). A series of cuneiform inscriptions dating to around this same time detail an intergenerational conflict between the state of Lagash and the state of Umma to its north, in which pitched battles were fought over access to a shared and especially fertile border region (Cooper, 1983). The Lagash Archaeological Project is seeking to move beyond hypotheticals of decades past through a robust, multi-scalar research program that articulates the city's role within its eponymous city-state, the nature of some of its earliest social institutions, and the relationship between urban development and environmental change.

The Lagash Archaeological Project's first season in March and April 2019 exploited the opportunities provided by remote sensing technologies for targeted ground-truthing in later seasons while off-site geoarchaeological study began. On-site remote sensing methodologies included UAV (drone) photography and magnetometry combined with systematic walking survey and limited excavation. Three additional seasons (Fall, 2021; Spring, 2022; Fall, 2022) have continued to employ and expand these techniques. Dr. Emily Hammer, of the University of Pennsylvania, served during the first season as the Lagash

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Archaeological Project's survey specialist. We limit the following critique to the methods, data and interpretations offered by Hammer (2022), based on previously published or readily accessible datasets.

2. Overview

Hammer (2022), Hammer et al. (2022) proposes a model of late ED (c. 2,600-2,292 BCE) urban organization by mapping time-averaged architectural features that are of value for current and ongoing work. However, the article draws several significant conclusions that are questionable for the site of Lagash. Specifically, Hammer(2022) argues that settlement at Lagash was restricted to topographic rises in ED I (2900–2700 BCE) because of excessive, on-site water; that by ED III, a less watery environment allowed marsh-based urbanism to take shape; that the site's western ridge supported a processional way connecting a series of religious precincts, including a newly identified temple; and, finally, that intracity interaction took place predominantly by watercraft. These conclusions rely on the article's reconstruction of several intracity watercourses, in particular a primary canal or river that transits the site from northwest to southeast; the identification, classification and presumed dating of architectural traces at site-wide scale; and a literature review on regional paleoenvironmental change. Hammer's interpretations depend on significant assumptions, most fundamentally that remotely sensed features are accurately characterized and that they are contemporary. These interpretations are at odds with what we know of the site's chronology, and several of the illustrated architectural reconstructions are unlikely given what is known from prior excavations.

Below we argue that Hammer (2022) mischaracterizes the dataset as deriving from a single period; wrongly identifies an ED temple; reconstructs ED intracity watercourses that are in fact modern water-formed features, at least in the forms presented; and misunderstands fundamental stratigraphic evidence as it relates to ED urban occupation. Finally, we will discuss how issues of spatial control and poor data presentation further complicate the paper's model of marsh-based urbanism.

We recognize that Hammer (2022) works only with remote-sensing data collected over a short period. We also want to make clear that we are not dismissing the possibility that settlement and marsh overlapped at Lagash before the site developed into a city. In fact, this scenario seems likely for the 4th-millennium BCE, as first proposed by Jennifer Pournelle (2003, 2013), and continues to be borne out by accumulating geoarchaeological evidence (see Goodman and Giosan, in press). However, the arguments and framing devices that Hammer (2022) offers all relate to a millennium later, during the Early Dynastic period, a time of full-blown urbanization in the Lagash region.

3. Background

Robert Koldewey first excavated Lagash in the winter of 1887, exposing public architecture and residential areas of Isin-Larsa and Old Babylonian date across three elevated mounds in the north-central region of the site (Ashby, 2018: 72–75; von Haller, 2008; Koldewey, 1887). More systematic investigations, sponsored by NYU/Metropolitan Museum and led by Donald P. Hansen from 1968 to 1990, focused on monumental religious architecture (Areas A and B), an administrative craft production center (Area C), and a large architectural complex surrounded by an oval wall (Area G). Much of that material dates to the ED period (for an overview, see Ashby and Pittman, 2022). Elizabeth Carter undertook a site-wide walking survey in 1984 (Carter, 1985, 1989–1990; Goodman et al., 2022). Following the untimely passing of Hansen, the current project director and archaeological research permit holder, Holly Pittman, oversaw the analysis and preparation of the legacy data for publication (Pittman and Ashby, 2022). At the same time, she returned to the site to renew investigations by asking research questions that complement previous results, and to take advantage of new methodologies that extend the quantity and quality of data available for analysis and interpretation.

4. Chronology

Hammer's (2022: 17) statement that the "Early Dynastic was several centuries long" downplays the fact that the ED period extends over 600 years of Mesopotamian history. We know from texts that major social and political changes occurred between ED I (2900–2600 BCE) and ED III (ca. 2600–2292 BCE) (Porada et al., 1992: 103-113), changes that certainly affected the organization and function of urban settlements throughout southern Mesopotamia. The article's premise, which relies on time-averaged features from UAV photography and magnetic gradiometry, requires a shortened timeline that does not recognize documented radical change. Not only is the ED timeline long, the ceramic corpus, which Hammer (2022) relies on to date architectural features seen in remote-sensing, does not allow clear differentiation between ED I, ED III, and the subsequent Akkadian period (Renette, 2021: 149). In another place in the article, Hammer (2022: 6) states that occupation at Lagash was "comparatively short-lived." This claim is as unsupported as the abbreviated chronology. Lagash was continuously occupied throughout the 3rd- and into the early 2nd-millennium, BCE. Previous excavations and survey show that its surface record represents a mix of architectural features over this whole span. Some quite central areas are indeed dominated by Isin-Larsa and Old Babylonian material on the surface (Ashby, 2017: 75), others with Ur III (Huh, 2008: 240), and still others with Parthian/Islamic (Carter, 1985: 222). Further, the southern area of the site, where Hammer's magnetometry and walking survey were primarily focused, has greatly suffered from recent wind and water erosion (see taphonomy, below).

Nevertheless, Hammer (2022: 4, 8) suggests that the dataset represents Lagash as a single-period site at the end of the ED period. Hammer supports this assumption in a footnote (Hammer, 2022: 8, footnote 2) citing Sara Pizzimenti, who served as the Lagash Archaeological Project's ceramicist during the 2019 season. In the footnote, Hammer asserts, but gives no source, that Pizzimenti reported that 97% of the 2019 survey pottery dates to the ED III period.[1]

5. Dating and characterization of architectural features identified through UAV photography and magnetometry

NYU's excavations established that the two temple complexes on the western topographic ridge (Ibgal Temple [Area A] and Bagara Temple [Area B]) date at the latest from the ED III period and extended into the first half of the second millennium BCE. Between these areas, Hansen's excavations uncovered another possible temple precinct in Area G with large-scale architecture that dates to ED I, a fact that Carter's survey also supported (1989–1990: 61). Hammer (2022: 13, figs. 8, 14, 16) identifies a "new temple" just to the south of Area G, based solely on an "area of large architecture" visible in drone photography (though no imagery is provided). Carter (1984: 5), who surveyed this area on the ground, noted the presence of large-scale architecture but suggested that its configuration as a large open square could represent a caravanserai-like complex. Indeed, 3rd-millennium temples in Mesopotamia have a particular form (Ashby, 2017: 8-9). The identification of a new temple, whose existence Hammer (2022:9) invokes to support the broader multicentric argument based on this monumental architecture's alignment with a hypothetical "broad street/thoroughfare," is based solely on drone photography. Such an identification seems premature at best. Following Hammer's submission of the JAA article for publication, magnetic gradiometry by the Lagash Archaeological Project has demonstrated that this feature appears as an open space with four

[1] It is possible that this date comes from a powerpoint slide prepared by Pizzimenti for a ceramic conference held shortly after the season at the Penn Museum.

unrelated walls that give the appearance of a large and unified square in aerial photos. This information can be reviewed on the Lagash Archaeological Project's website: https://web.sas.upenn.edu/lagash/current-excavations/2022-fall-season/ accessed February 26, 2023.

It is important to highlight similar issues with urban perimeter walls that Hammer reconstructs throughout the site (see especially Hammer, 2022: 12, figs. 7 and 13, fig. 8). For instance, a major stretch of wall is traced running roughly east–west directly south of excavated trenches in Area A. In the north of Area A, Hansen uncovered three building levels of an ED III temple precinct dedicated to the goddess Inana (Hansen, 1970, 1973). The central and southern parts of the complex could not be excavated because of erosion from a modern wadi, and also because they extended into modern agricultural fields (Ashby, 2017: 101, 108; Ashby and Pittman, 2022: 97). This raises a basic question: how could the heart of a major ED temple complex intersect with and crossover a contemporary city wall? It is impossible to see the color variability on which Hammer depends to reconstruct the wall in this location; however, based on the earlier excavations in Area A (including the noted wadi), an explanation should be offered for an otherwise improbable scenario. Indeed, it would help if Hammer had reconstructed architecture (or any interpreted features) in a way that allows the reader to see for themselves the UAV color variability.

6. Taphonomy

The fundamental challenge for understanding the occupational history of Lagash is the extensive erosion by both wind and water that has profoundly affected the current appearance of the site. One particular pattern that is striking in the remote-sensing data, and which speaks to the complex taphonomy affecting the site, is the disjunction between the hundreds of drains and the traces of architecture visible in the magnetic gradiometry data. That the two often do not line up suggests that the drains were infrastructure for architecture that has subsequently eroded away, a point already recognized by Carter (1989–1990: 61). Further, the packing around those drains, which consisted of large collections of broken up late pottery to facilitate drainage, now blanket the site, further biasing the surface's ceramic record. These disjunctions were apparent in the 2019 survey and remote-sensing studies. At the same time, we also cannot assume that ED I architecture, where it is preserved, was originally covered by ED III architecture that has since eroded. Robert Adams observed that the period of greatest urban occupation in southern Mesopotamia was toward the end of ED I, in the first half of the 3rd-millennium BCE (Adams, 1981: 94). Finkbeiner more recently concluded that ED I is also the most extensive period at the site of Uruk (Boehmer, 1991: 468; Finkbeiner, 1991).

One of the major limitations of Hammer's chronological and ecological proposition that ED Lagash was a marsh-based city relies heavily on the reconstruction of a primary intrasite watercourse (Hammer, 2022: 9-10, 12-15, 17-18; figs. 7, 8 and 11). There are three primary assumptions that the paper makes on this point, using the remote-sensing data alone: first, that the mapped water-formed feature was indeed an intracity watercourse; second, that that intracity watercourse was contemporary with late ED period settlement; and third, that the existence of a watercourse or water channels indicates marsh-based living conditions.

We will first discuss the watercourse itself. The article reconstructs an ED intracity watercourse (Hammer, 2022: 14) from a system of scour lines that runs roughly northwest-southeast with a series of east–west meanders. These are clearly visible across aerial imagery datasets. Hammer dates the watercourse by asserting that the feature's scour lines disappear beneath a topographic rise on which Carter's survey found Islamic pottery, thereby implying that Carter identified the rise as strictly late (Hammer, 2022: 10). However, Carter's survey simply notes an unusual late presence in an area with an otherwise mixed surface ceramic record (Carter, 1989–1990: 62). Perhaps more clearly, satellite imagery shows that the water feature Hammer identifies is redirected west and south by the "late mound" (see especially Hammer, 2022: 13, fig. 8), where the water entered and then quickly spread into a low depression. The scour lines therefore do not run beneath a mound with later settlement as illustrated in Fig. 1. In fact, Hammer illustrates (2022: figs. 7 and 8, pp. 12 and 13, respectively) the continuation of that same watercourse west and south of the "late mound," not under it, and at the same time aggregates individual meander scars into a single, and rather large, canal (assuming, but not demonstrating, that these meander scars do not represent water channel switching or channel reoccupation over time). The article's fig. 8 (Hammer, 2022: 13) also indicates the possibility of a "relict levee" running east of the "late mound." A zooming out on the satellite imagery makes it clear that this is unlikely to be a levee, certainly based on the information at hand, since it is one of the first areas to disappear under modern marsh when water levels increase.

Additional evidence pertaining to Hammer's reconstructed watercourse appears on the same page of Carter's survey publication where an Islamic presence is discussed, and where Carter mentions a "recent earthen dam" (Fig. 2) running north–south across the low-lying depression that divides Lagash into northern and southern zones (Carter, 1989–1990: 62). This dam was likely established to redirect water away from agricultural fields that then lay due east of Area B and which had encroached upon the site throughout the recent past. The force of that water stream, increased through its redirection by the dam, sent water over a topographic high near Area B before carving its way south to encircling rises across the site, especially the more erosion-resistant mounds that are consolidated by large quantities of ceramic slag.

This water-formed feature could have been active as early as the 1920s, after the government built a water regulator at the town of Bada'a along the Shatt al-Gharraf, just west of Lagash, to pump water directly into the Lagash area for the local rice-growing industry (Cotha Consulting Engineers, 1959). The regulator resulted in a semi-permanent lake around the site for much of the 20th-century. Elevation data visualized in Fig. 3 clearly indicate the large crevasse-splay that resulted from the introduction of the regulator, with levees running perpendicular from the Shatt al-Gharraf and branching eastward toward Lagash. This excess water rushed its way to the lowest lying area at the site, the east–west depression that Carter (1989–1990: 62) first suggested might signal an old canal bed, and which is the first area to flood when left undammed, or when the earthen dams collapse (Figs. 4a, b).

Indeed, the large, rectilinear and grid-like features that Hammer (2022: 9-10; 15, fig. 10) identifies as possible pits for ancient mudbrick extraction near the "possibly un-canalized length of river" are more credibly understood as recent scours working around elevated areas before meeting linear feeder canals from modern fallow fields (Fig. 5). We confirmed this by inspection of the area on foot. Ultimately, the relatively marked development of the watercourse that Hammer identifies as late ED in date can be more parsimoniously described as the effects of recent on-site flooding and damming. Test pits located in the cross-section of the watercourse in the Fall 2022 season revealed monumental architecture of ED III date beneath later water-lain deposits (https://web.sas.upenn.edu/lagash/current-excavations/2022-fall-season/test-pits accessed February 26. 2023).

If we recognize that this water feature formed later than the ED III city, we must also re-evaluate Hammer's characterization of the site's northern zone as marshy and the "youngest of the city sectors"(Hammer, 2022: 17). In fact, the paleo-channel system that the article identifies as contemporary with the ED settlement is more easily explained by the same recent water phenomena described above. Carter's survey notebook records "rivulets" in both areas where Hammer reconstructs ancient watercourses. These rivulets are recorded differently than wadis and paleochannels in that notebook because these streams were active during the 1984 survey season. As seen most clearly in Hammer (2022: 16, fig. 11), these water features were sourced from the same general direction that led to Hammer's (2022) misidentification of a primary

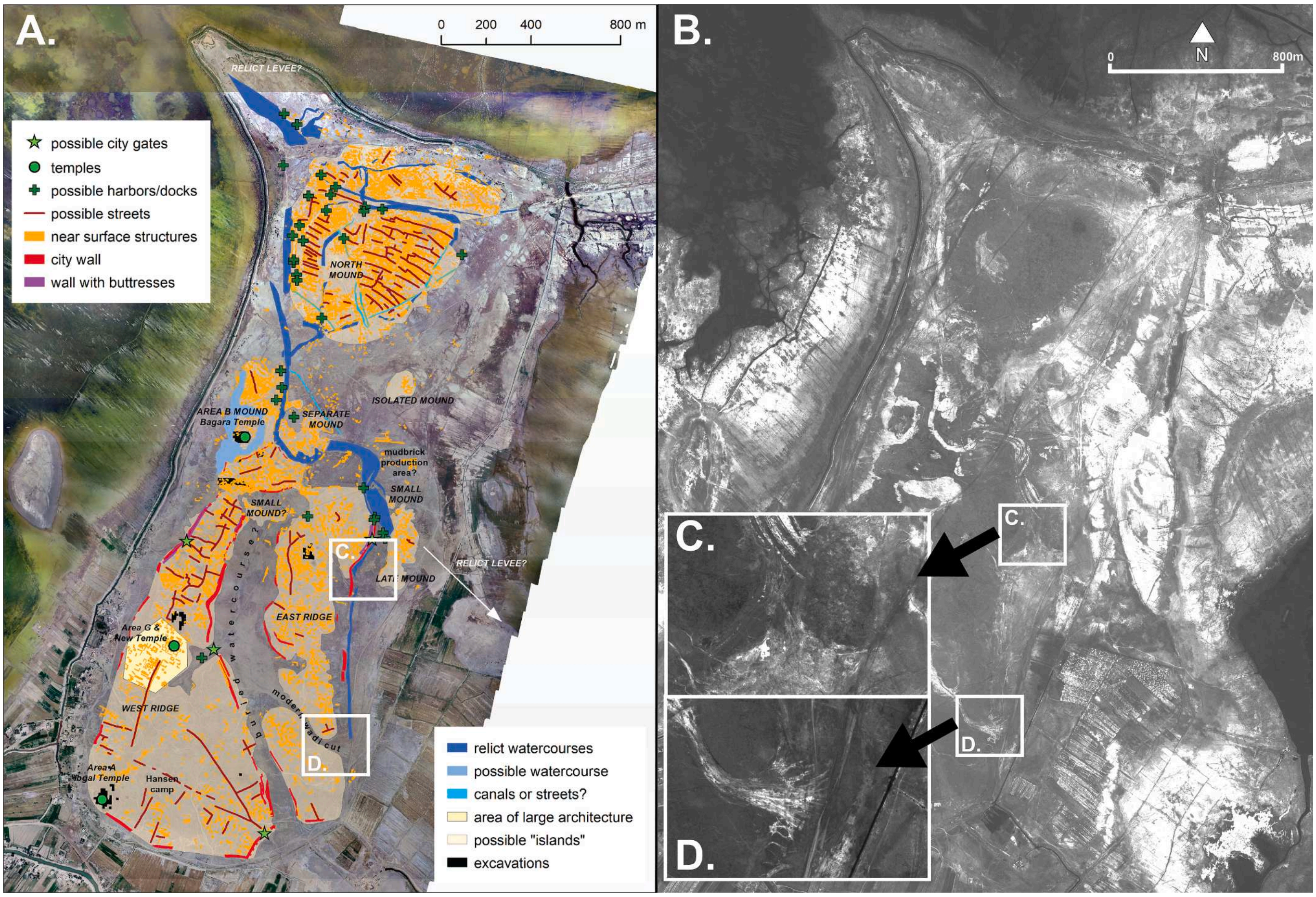

Fig. 1. (A) Hammer, 2022: 13, fig. 8 compared with (B) georeferenced DigitalGlobe image of Lagash taken in June 2009. (C) represents the point at which Hammer, (2022) argues that an ED watercourse is covered over by a "late mound" despite tracing the continuation of that very watercourse west and south of the "late mound." The enlarged crevasse-splay areas—(C) and (D)—represent points where recent channel flow met low topography and standing water, explaining the crevasse patterning. Based on remote-sensing imagery, there is no continuation of a water course on the other side of Hammer's "late mound."

watercourse. We also point out in the same figure the clear overlap in certain instances of architecture overlying the reconstructed watercourses (not to mention Hammer's reconstruction of architecture that is drawn over spoil heaps from legacy excavations, especially those in Area B). The linearity of the watercourses or water channels across Lagash's northern end, as Hammer (2022:16) points out, could be explained by recent water being channeled by ancient roads, or by any number of other plausible scenarios given the dynamic taphonomy. But it likely also explains why, in Hammer's own geophysical results in the north (see Hammer, 2022: 11, Fig. 6d), modern wadi scours have clearly washed away earlier architecture.

However, even the data as presented contradict the conclusions reached. If Hammer (2022) had correctly identified an ancient water feature, we would expect certain prerequisites of form, especially given Lagash's precarious downstream position vis-à-vis powerful settlements like Umma. First, as Hammer (2022:14) recognizes, the watercourse must have been channelized, protecting installations and architecture along its borders from natural or anthropogenic flood and erosion. Yet there is, as of now, no evidence for canalization along any part of the feature, while there is clear evidence for uncontrolled channel switching, especially east of Area B and northeast of Area C. Hammer (2022: 14) notes, referring the reader to fig. 10, "North and east of excavated area B, visible architectural traces appear to directly abut the relict channel of the river, suggesting that the watercourse must have at some point been canalized in this area to constrain changes in its flow." However, these architectural traces only appear to abut the watercourse because those are the features that remain after erosion. Hammer (2022: 14) posits that the city's ED inhabitants could have left this stretch of the primary watercourse unconstrained—why or how we do not know, as an intracity river that is canalized must be canalized in full—even as it abuts and has scoured away parts of major archaeological mounds. Finally Hammer (2022: 9) remarks that the primary intracity watercourse is "curiously stretching away from [the site's southern ridges] rather than following its course…". This situation is much less curious when we recognize that the water- formed feature is a result of recent flooding.

We still must deal with the implicit assumption that the presence of an intracity waterway—and any number of offtakes, real or not—-translates to a comprehensive paleoenvironmental situation that pertained to all 400-plus hectares of the site, and further that this waterway could be chronologically understood against urban processes within even the most general ED timeframe. Of course, drone photography cannot meet this demand; but it also bears stating that watercourses through a city, ancient or modern, do not indicate marsh-based urbanism. Many of today's cities in southern Iraq are bisected by a river or crisscrossed with water channels. Duwaya, the nearest modern-day city to Lagash, is no exception; and the same is seen with larger examples, such as Nasiriyah and Basra. None of these locations represent marsh-based urbanism (in which water transport is the primary mode of intracity movement, or a primary determinant of spheres of social interaction), or a developmentally later stage of a former marsh-based settlement adaptation.

Ultimately, the primary metric that Hammer uses to characterize and date urban form at ED Lagash—an intracity ED watercourse and its

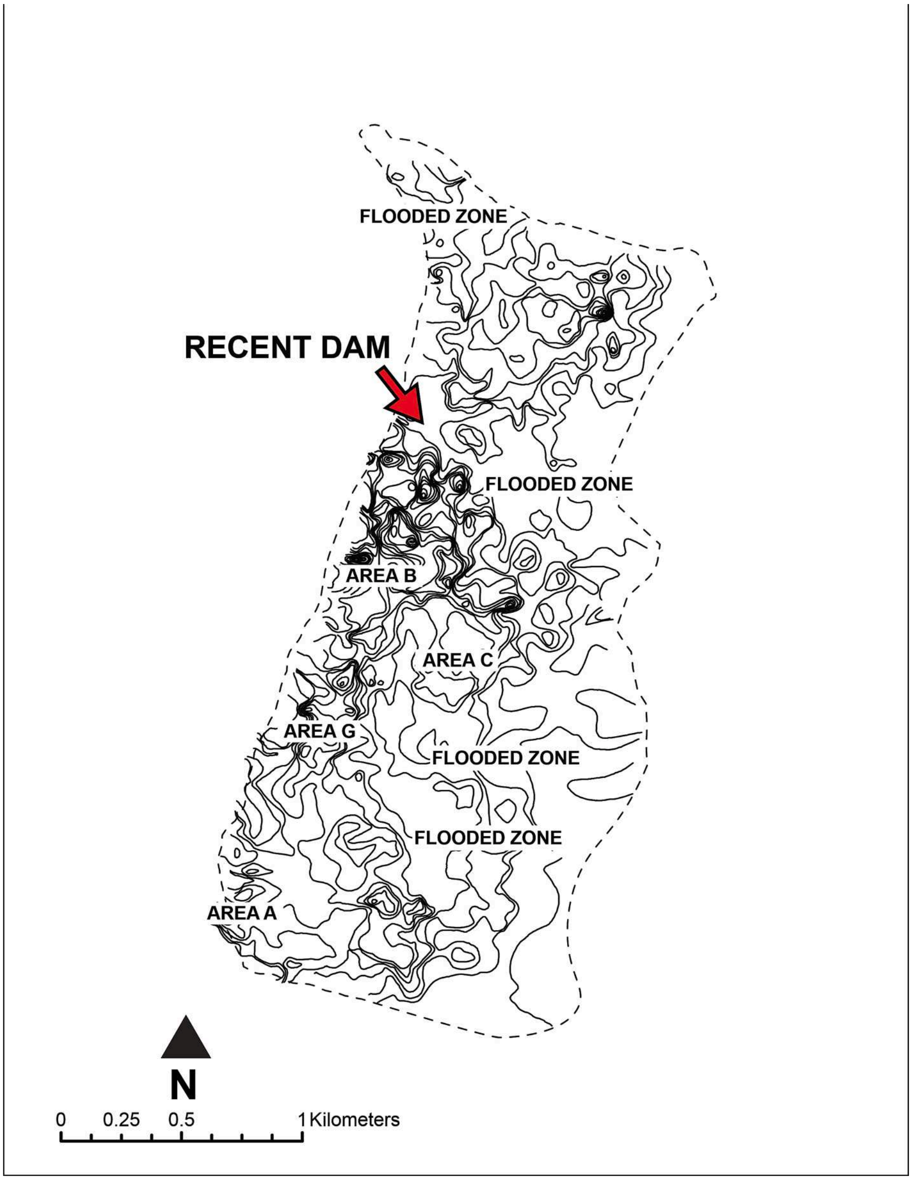

Fig. 2. Topographic map redrawn from Elizabeth Carter's 1984 survey (Carter, 1989–1990: 75, Fig. 1). Note the location of a "recent earthen dam," along with areas of active flooding on-site in 1984. The locations of Hansen's four excavation operations (A, B, C and G) have been added for reference.

various manifestations across the northern tip of the site—is incorrect, based on the data and methods employed. So too is the characterization of a late "island" east of Area C. Not only was this area of mixed date, Carter's survey notebook describes late occupation across a series of hills, not islands. Finally, the certainty of the north's "early" (we assume the article means early in the sense that it predated the occupation of the two ridges identified in the south) dating, based on its "watery nature" (Hammer, 2022: 17) is entirely unconvincing.

7. Spatial control

Although Hammer (2022:6–7) describes the process for combining UAV and magnetometry data, flaws in the spatial control of the magnetometry data call into question the effectiveness of the application of those methods and the accuracy of their results. This is especially significant if we are to understand them as offering "complementary information" in the construction of the paper's arguments (Hammer, 2022: 6).

Following the 2019 season, the completed GeoTIFF maps of Hammer's 2019 magnetometry survey were consulted to plan the locations of future trenches (e.g., Hammer, 2022: 10, Fig. 5a). A variety of features visible in the imagery—kilns, walls and streets—were not found when tested through excavation in Spring 2022. While at the time we thought that Hammer's imagery was difficult to interpret for any number of taphonomic reasons, Zimmerman's Fall 2022 magnetometry results at Lagash matched excavation results exactly, leading us to resurvey an area that Hammer had previously covered (Fig. 6). There was no correlation between the two datasets, so rather than rely any longer on GeoTIFFs generated by Hammer, we opted to re-plot Hammer's original data. In doing so, it became clear that the magnetometry data had been collected incorrectly, resulting in a displacement that Dr. Hammer only rectified for final publication, though residual issues inevitably persist.[2]

Given the lack of ground truthing available to check the results of the magnetometry data in 2019, Hammer's errant spatial control might be understandable. However, two weeks later, when the 2019 survey reached the southeast corner of the tell, a type of ground truthing was

[2] See the Lagash Archaeological Project website for a full elaboration of the correction https://web.sas.upenn.edu/lagash/magnetometry-2022/.

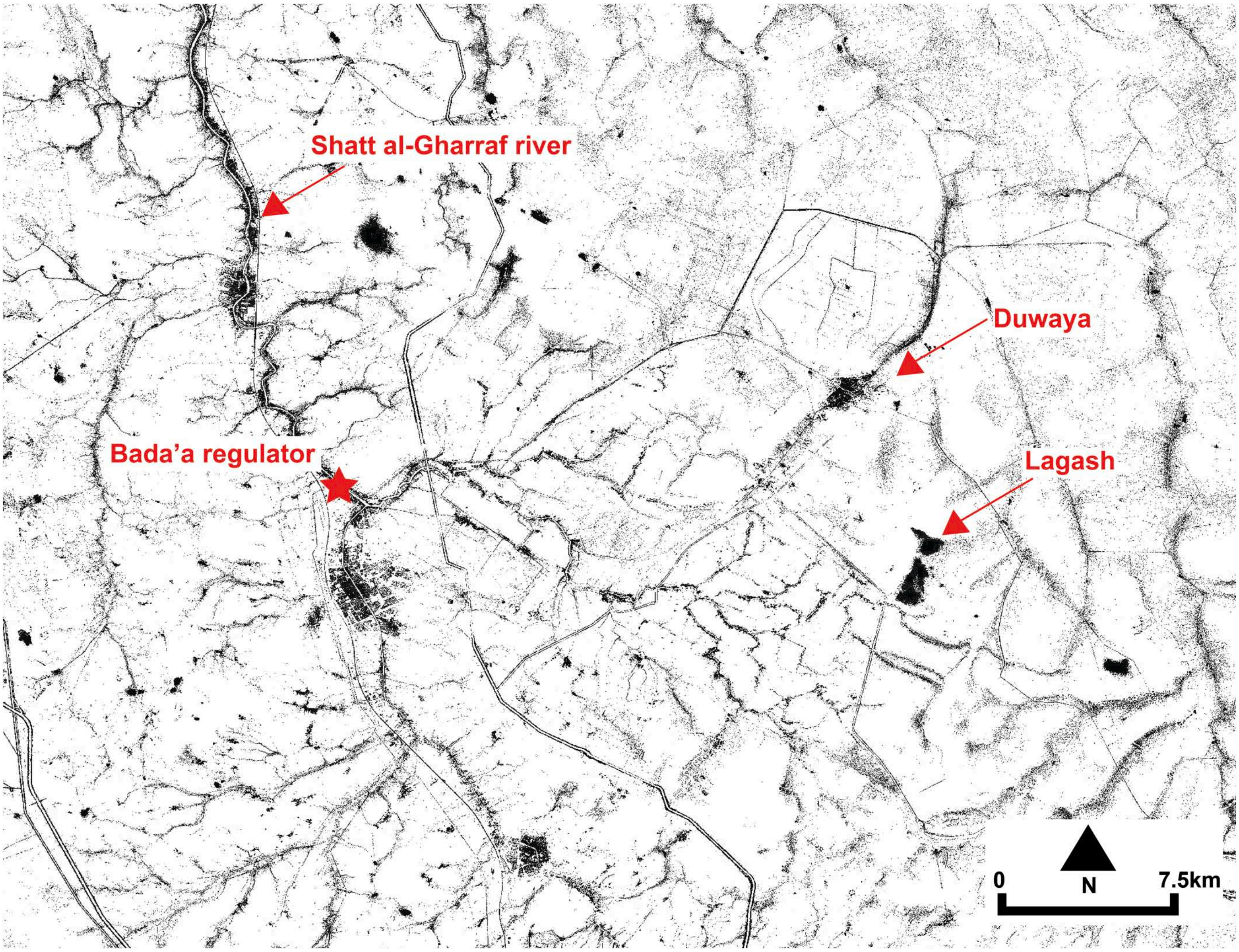

Fig. 3. Multi-surface relief model (MSRM) using Copernicus elevation data. Black lines (and their intensity) denote raised relief. Note the levees extending from the Shatt al-Gharraf river and running west to east into the Lagash basin. The west-east levees formed from a crevasse-splay that began to build in the 1920's after the installation of water control devices at the town of Bada'a. The devices, described in the literature as a "regulator," pumped water into the low-lying relief around Lagash for five decades to support the local rice growing industry.

provided by the massive city wall that appears clearly in both drone footage and magnetometry. Hammer then attempted to reconcile the magnetometry with the aerial imagery with a flawed geo-rectification that introduced a severe skew to the magnetogram's overall plan. From that point forward two sets of magnetometry images are presented somewhat interchangeably: those with correct geometry but incorrect spatial registration (which are always presented without contextual clues from other imagery), and those with the distorted geometry from faulty geo-rectification. Critically, the misalignment of the magnetometry and aerial imagery means that they could not have been used in the complementary fashion reported. Furthermore, these georectified images evolved as Hammer revised various articles,[3] but given that the author's conclusions were not affected by this modification to one of the paper's primary datasets, it must be acknowledged that the changes were made largely for cosmetic purposes and that a deliberate obfuscation of problems in initial spatial control undergirds a paper that is fundamentally about spatial organization.

8. Conclusion

As far as current evidence takes us, Hammer's fundamental suggestion, namely that urbanism at Lagash was "marsh-based" during the ED III period, is untenable. What was happening beyond the city walls is an entirely other, though equally important, story. Indeed, 3rd-millennium texts clearly discuss and situate the "marsh of Lagash" beyond and to the north of the city (Rey 2017: 45, fig. 19). We might say the same for the problematic interpretation of Lagash's "multicentric" nature. The limits of the ancient city are obscured on all sides by a village, modern marsh, and agricultural fields. For example, one very large rise (at least 10 ha) to the west of Lagash's modern (but arbitrary) limits and which was separated from the site by water during the 1984 survey was found to be covered with pottery of late ED date (Carter, 1989–1990: 62). This continuation of the tell, which is just one case in point, does not figure into any of Hammer's reconstructions of the ED III city, even though the mound is near two known monumental areas (Areas B and G).

However, there is an even larger problem with the paper's developmental scheme and framing. Significantly, Hammer (2022: 16) misrepresents the impact of taphonomic processes on the remote-sensing

[3] These skewed images have appeared in multiple circulated versions; by final publication they have been greatly improved although these published versions still have artifacts indicating that they were adjusted after the fact in software rather than by correcting the underlying spatial registration of the source data (compare for example Hammer, 2022 Fig. 5a and 5b).

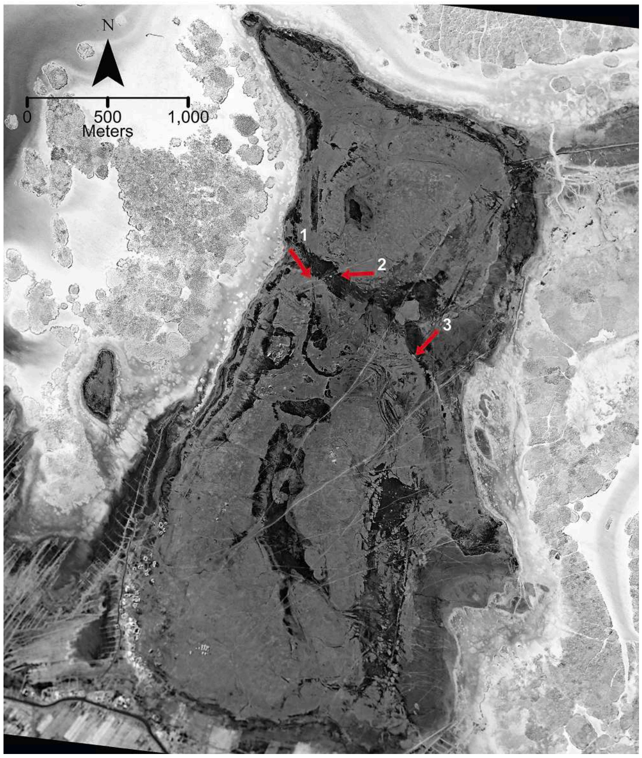

Fig. 4a. Hexagon satellite image dated to October 1972 shows: 1: the direction of water flow when the on-site dam is active, 2: the location of the earthen dam that would redirect water from the lowest-lying area onto the site itself during times of flood, especially in spring, and 3: linear meander scars from recent flow divergences before the water-formed feature had matured. Note that water had not yet fully eroded sediment that connected Hammer's "late island" to the raised areas just to the west.

Fig. 4b. Google Earth Historical Image dated to December 1988. The dam identified by Carter in 1984 has collapsed, allowing water to bisect the northern zone of the site unimpeded.

data. While Hammer (2022) acknowledges that the surface appearance was impacted by erosion in "survey areas 1–2 and 3," the article goes on to state that in other areas of the site, "the preserved architectural traces are clearly bounded by the city wall and watercourses do not appear to cut through architectural traces." However, the only other two areas subject to magnetometry by Hammer, namely 4 and 5, clearly reveal washed out architecture (see Hammer,2022: 11, Fig. 6). Further, when walls are correctly identified in the remote-sensing imagery, we have no way to constrain their date. In the 5th season (1978) of excavation under Hansen, the team excavated part of a large intracity wall south of Area B. That wall was faced with unbaked brick, a poor material for a water-rich environment, especially if water ran along its outside face.

In Hammer's (2022: 15) picture of urban evolution, excess water restricted habitation at ED I Lagash to high points, or turtlebacks. As sea level rise slowed and water levels dropped, newly emerged spaces between highpoints could be infilled through anthropogenic and natural processes, approaching a more continuous settlement pattern (Hammer, 2022: 15, 18). To advance this interpretation, Hammer cites but does not quote Pournelle (2013: 19), who in fact states that sea levels "remained stable throughout the Uruk and Jemdet Nasr, regressed slightly at the beginning of the Early Dynastic, and then returned to their high stand." Pournelle (2013: 26) further notes that this high stand, which is consistent with the proposed 1 m rise in sea level above present, is consonant with a paleo-shoreline beach ridge, located far south of Lagash in Kuwait (see Hritz et al., 2012: 45). While Pournelle's data (which are based on a review of the literature) are admittedly theoretical and regionally non-specific, they argue for a drop in water levels during the early ED period, contrary to what Hammer claims.

A brief review of the earlier excavation reports should dissuade even the most resolved observer from positing that settlement at Lagash during the ED I period was restricted to highpoints or determined by a watery environment, more generally. Two deep soundings were executed during the NYU excavations, the first in Area A, the other in Area G. In Area A, excavators reached and continued to dig 2.8 m below an ED III surface, capturing eight building levels of ED architecture—including ED I—before the water table was struck (Ashby, 2017: 87-95; Ashby and Pittman, 2022). None of the exposed soil horizons from that deep sounding, the deepest lower than current plain level, reflected a marsh-like environment (see section photo, Ashby, 2017: 247, Pl. 10; Ashby and Pittman, 2022: 89, Fig. 2). Relict marsh soil horizons are preserved throughout the region and have been noted in geological (Buringh, 1960), geoarchaeological (Brückner, 2003; Goodman and Giosan, in press; Jotheri, et al. 2018: 61; Wilkinson, 1990) and archaeological contexts (Safar and Lloyd, 1981; Woolley, 1955).

In Area G, during the 4th season of work, excavators exposed 7 m of ED I deposits before encountering the water table (Hansen, 1980–1983: 426). Again, no marsh horizons were documented, despite depths reached which were much lower than other ED I contexts at Lagash. In both instances ED I material clearly continued below the water table (Ashby and Pittman, 2022) so that the earliest ED levels tested at Lagash sit well below the site's highest mounds—including ridges with ED I occupation—and must have been relatively low lying at their time of habitation in the earlier centuries of the 3rd-millennium BCE.

Overall, neither the evidence cited by Hammer, nor the readily available reports or legacy data, indicate that Lagash was a marsh-based city during the first half of the 3rd-millennium BCE. If anything, they point to the deeply stratified nature of ED I Lagash. There is now a need to investigate those strata through archaeological and geoarchaeological methods to characterize and constrain the socio-natural environment over timescales that can be associated with other sites for cross-comparative study. While it is of course possible that urban form at ED Lagash was influenced by a marshy environment, a hypothetical model whose debt we owe to Elizabeth Stone (in press), any further proof requires chronostratigraphic evidence from geoarchaeological and archaeological investigation.

Our purpose here is not only to express disagreement with the

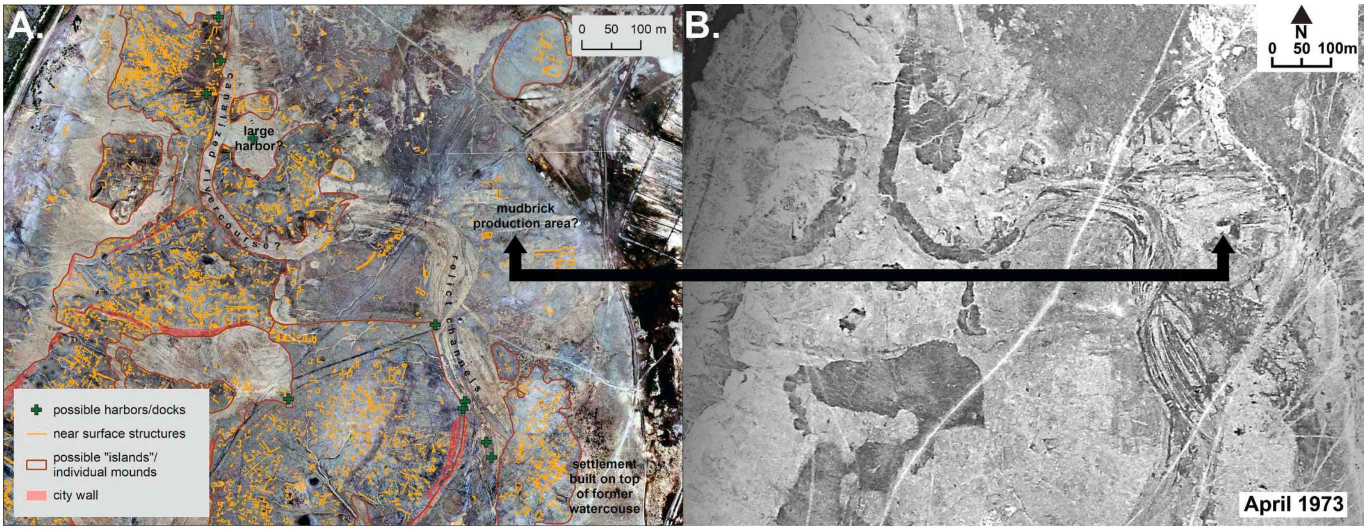

Fig. 5. Comparison of (A) Hammer, 2022: 15, fig. 10 that designates a “mudbrick production area?” where “large rectilinear features” mark “pits for the excavation of mudbrick material (Hammer, 2022: 9–10)” with (B) the same georeferenced area as seen in a Hexagon spy photograph from April 1973. The black arrows designate the putative mudbrick excavation area in both Hammer’s figure and the Hexagon imagery. As seen in the Hexagon imagery (B), rectilinear features are more plausibly understood as superimposed meander scars meeting traces of modern agricultural fields.

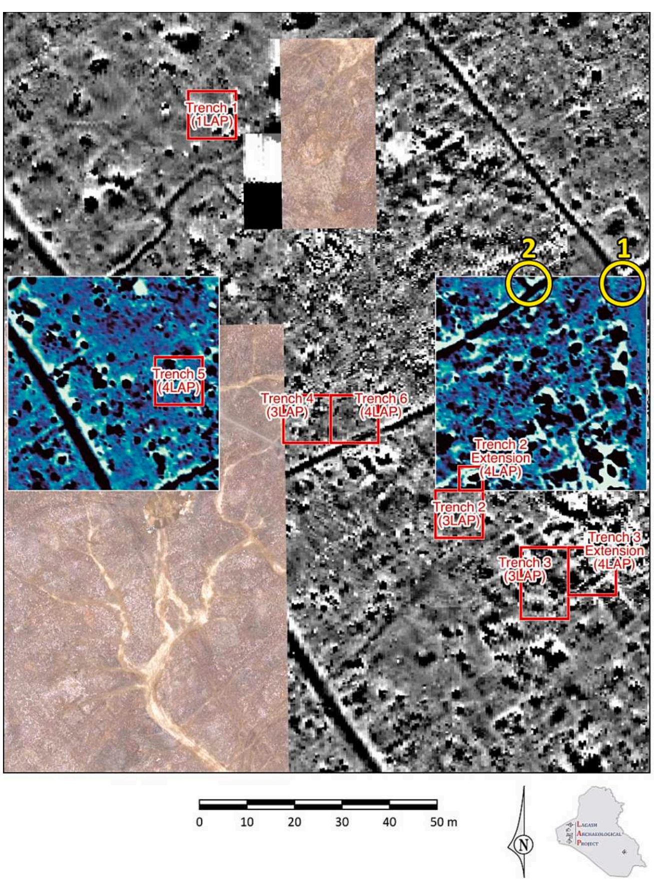

Fig. 6. Visualization of poor spatial control of the 2019 magnetometry data in area H. Magnetometry collected in 2019 (grey) is 20 m off when compared to the ground-truthed magnetometry collected in fall 2022 (blue). Note the location of the circled intersection: (1) indicates it in the 2019 data, whereas (2) shows its correct position in the 2022 data.

various interpretations and framing devices that Hammer (2022) has employed. It is, more generally, to set the record straight so that the archaeological and larger anthropological community interested in early urbanism can understand the extent to which we currently understand the actual conditions under which Lagash may have evolved and under which the site has been extensively altered over more than four millennia since its heyday. It has always been clear to members of the Lagash Archaeological Project that for a site like Lagash, which consists of well over a thousand years of occupational history, remote sensing techniques cannot be used in isolation. Moreover, models based on remote-sensing should provide raw signatures next to illustrated reconstructions, so that their veracity can be checked. The Lagash Archaeological Project is looking forward to sharing results in the near future derived from integrated methodologies that can help us better understand the evolution and structure of this important urban center.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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