The Hydraulic Landscape of Nimrud

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THE HYDRAULIC LANDSCAPE OF NIMRUD

Introduction[1]

Their remnants have been battered by wadi floods, meandering rivers, and the destructive actions of humans, but the canals constructed at the height of the Neo-Assyrian Empire were once central elements in its economic infrastructure (Fig. 1). Their waters sustained fields, orchards, and gardens. These products in turn sustained the towns and cities of the imperial core, and supported urbanization at sizes and densities not seen before in northern Mesopotamia.[2]

Mature Assyrian hydraulic technology of the 7th century BC, around the final capital at Nineveh, is well known to archaeology and history. The first systematic study was based around the excavations at Jerwan and Khinis.[3] Later synthetic studies by Oates and Reade have brought together the casual observations of a century of travelers and archaeologists.[4] Most recently, aerial and satellite imagery have been used as analytical tools to propose new hypotheses about form and function of Sennacherib's system.[5] With research possible again in the Kurdistan Region of Iraq, new field research on these systems is underway, and these hypotheses will finally get a rigorous test.[6]

Nimrud's landscape has, by comparison, been dramatically under-studied. The archaeology of the city, especially the citadel, is on firm ground,[7] and even some work on the lower town has been conducted.[8] With the exception of a topographic survey of a single element,[9] and a satellite remote-sensing study,[10] there has been little other than opportunistic visits to Nimrud's canal system since the time of Felix Jones.[11]

The hydraulic engineering accomplishments around Nimrud were, however, a major development in the technologies that would culminate in the extensive system behind Nineveh. Ashurnasirpal's new city would have been demographically unsustainable without the predictable and intensified agriculture made possible with a reliable water supply. With its long history of use and modification, this canal system poses more challenges than do the canals of Nineveh. With this study, we intend to provide a rich description of Nimrud's primary canal, drawing on previous research, earlier ground visits, and newly available aerial and satellite photographs and imagery. We will compare it to other known Assyrian systems, and later monumental canals in northern Mesopotamia. We will also consider the possibility that transport was a major function, and that it enabled Nimrud's flourishing by connecting it to a much greater hinterland than previously appreciated.

Sources for the Archaeology and Geography and Nimrud's Water Supply

Historical Sources

There are written records of two Assyrian kings working on the provision of water for Nimrud (ancient Calah) and its neighborhood. The first of them is Ashurnasirpal II (883-859 BC), who was responsible for transforming Nimrud from a provincial center into a major royal city or "administrative capital". The process, essentially urbanization, is first described inside a long annalistic account of the king's reign, in between the events of 879 and 878 BC.[12] It is mentioned with similar phraseology in several Ashurnasirpal texts; building continued after his death.

What may be the earliest account of a canal at Nimrud is written on a stela apparently made for display in the king's palace. The relevant passage reads in translation:[13] "I dug out a canal from the Upper Zab (and) called it Babelat Ḫegalli ('Bearer of Abundance'). I planted orchards with all kinds of fruit trees in its environs. I pressed wine (and) gave the best to Assur, my lord, and the temples of my land." Other texts

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[1] An interactive map of the landscapes and features discussed in this paper can be viewed at http://worldmap.harvard.edu/maps/nimrudlandscape. Georeferenced spatial data, including many of the satellite images and aerial photographs used in this study, are available for download online (see Ur 2015).

[2] On the dry-farming limits to urbanization in the Bronze Age, see Wilkinson 1994.

[3] Jacobsen, Lloyd 1935.

[4] Oates 1968; Reade 1978; Idem 2000; Idem 2002.

[5] Ur 2005.

[6] Especially via the Land of Nineveh Archaeological Project (LoNAP); see Morandi Bonacossi 2014; Idem 2016; Morandi Bonacossi, Iamoni 2015.

[7] Mallowan 1966; Postgate, Reade 1980; Oates, Oates 2001.

[8] Fiorina 2011.

[9] Davey 1985.

[10] Altaweel 2008, 73-75

[11] Jones 1855.

[12] Grayson 1991, 212.

[13] *Ibidem,* 252.

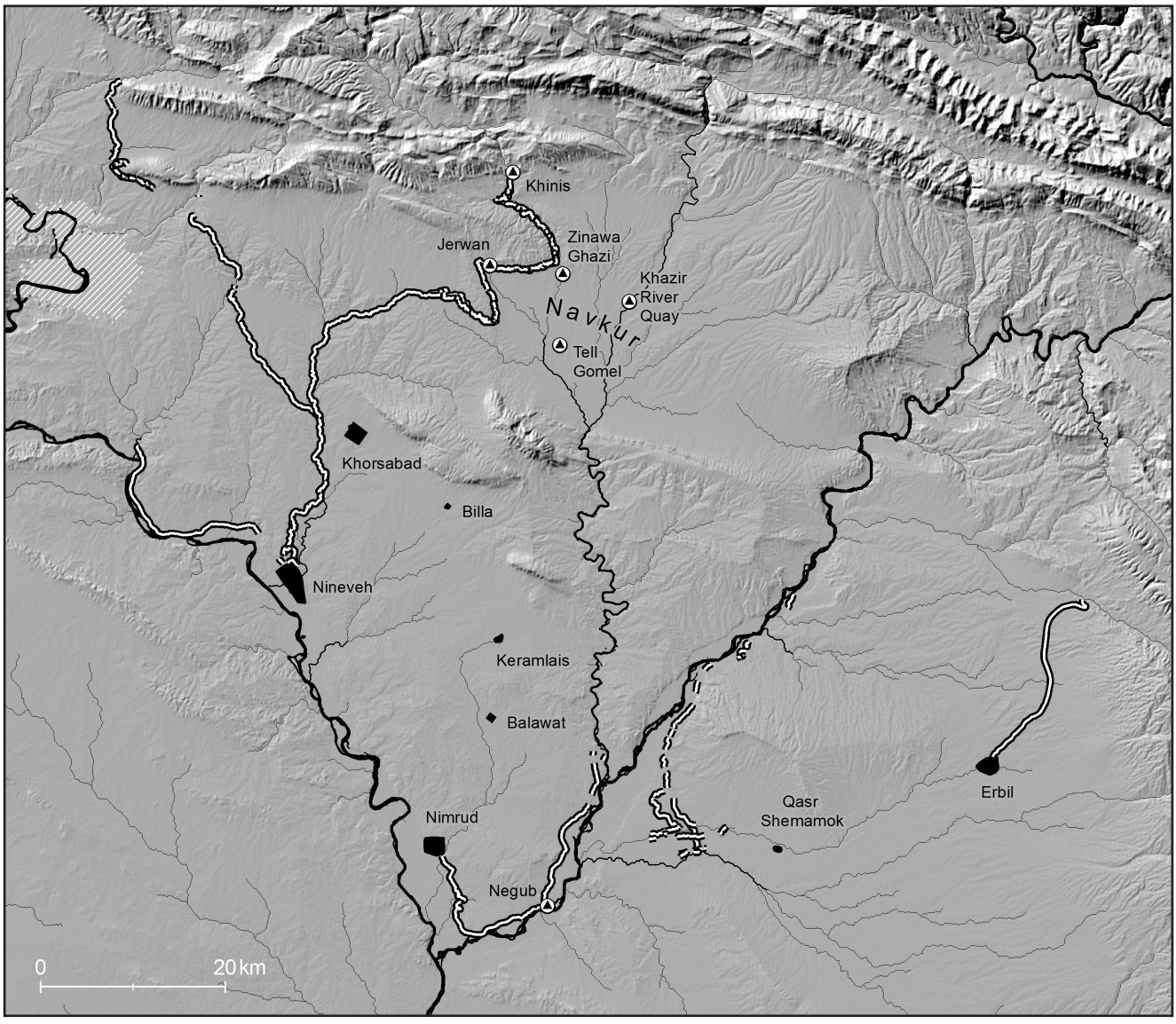

Fig. 1 - Cities and canal landscapes of northern Assyria.

use the name Patti Ḫegalli or Patti Nuḫši, "Canal of Abundance", leading Grayson to conclude that it had "no precise name."[14]

The fullest account appears on Ashurnasirpal's Banquet Stela, which can be dated by various criteria close to the end of his reign, circa 860 BC:

I dug out a canal from the Upper Zab, cutting through the mountain at its peak, (and) called it Patti ḫegalli. I irrigated the meadows of the Tigris (and) planted orchards with all kinds of fruit trees in its environs. I pressed wine (and) offered first-fruit offerings to Assur, my lord, and the temples of my land. I dedicated this city to Assur, my lord. In the lands through which I marched and the highlands which I traversed, the trees (and) plants (lit. 'seeds') which I saw were: [list of 41 types]. The canal cascades from above into the gardens. Fragrance pervades the walkways. Streams of water (as numerous) as stars of heaven flow in the pleasure garden. Pomegranates which are bedecked with clusters like grape vines ... [I,] Ashurnasirpal, in the delightful garden pick fruit like ... [...][15]

Reade[16] suggested that these gardens were represented by a broken carving on Ashurnasirpal's Rassam Obelisk.

Nimrud appears to have retained its status as major royal city until halfway through the reign of Sargon II (722-705 BC). It is likely that the canal continued

[14] Grayson 1991, 222-223.

[15] *Ibidem*, 290. Grayson's footnotes cite other slightly different translations, but none are significant for our purposes.

[16] Reade 1980, 11-13, pl. IV.

to be maintained and possibly developed throughout this period, but no relevant royal texts have been identified.[17]

The center of Assyrian royal administration moved to Khorsabad during the reign of Sargon, and subsequently to Nineveh, where it remained through the seventh century. Esarhaddon (680-669 BC), however, especially towards the end of his reign, was responsible for major building works at Nimrud. A fragmentary stone tablet of this king, recording the restoration of a canal, was found in a canal tunnel at Negub, which is located about 14 km southeast of Nimrud citadel, by the right bank of the Upper Zab, opposite the modern town of Gwer/Quweir on the left bank.

The Negub tablet, in the new standard edition of Esarhaddon inscriptions,[18] runs as follows:

"The former Tebiltu canal that Ashurnasirpal (II), a ruler who came be[fore me], had dug from the (Upper) Zab over the plain of Kalhu [...] — that canal, not turning ... [...] ... (clogged up with) loose earth, ..., path, track ... [...] was filled with sediment deposits and (thus) became level with the ground. ... [...] became [...] and turned into an abandoned plot. All of the fruit and aromatics, as many as [there are, ...] ... its tall beams ... [...] ... was devastated and ... furrow ... upon it [...] not true ... [...]."

One of Leichty's footnotes discusses the term "Tebiltu" and acknowledges that it may be an adjective, with some such meaning as "flood-prone", rather than a name.

Archaeological sources

Obvious remnants of Assyrian works connected with the supply or control of water for Nimrud and its neighborhood include many traces of canal banks on the eastern edge of the Tigris flood-plain and alongside the Upper Zab, and the Negub tunnel where the Esarhaddon tablet was found. Other remains further west also concerned with water, in the Tigris flood-plain, are considered separately below.

The first western observer to have visited Negub, in the spring of 1846, seems to have been Austen Henry Layard, the original excavator of Nimrud. As he relates,[19]

Abd-ur-rahman rode to my tent one morning, and offered to take me to a remarkable cutting in the rock, which he described as the work of Nimrod, the Giant. The Arabs call it "Negoub", or, The Hole. We were two hours in reaching the place, as we hunted gazelles and hares by the way. A tunnel, bored through the rock, opens by way of two low arched outlets, upon the river. It is of considerable length, and is continued for about a mile by a deep channel also cut out of the rock, but open at the top. I suspected at once that this was an Assyrian work, and, on examining the interior of the tunnel, I discovered a slab covered with cuneiform characters, which had fallen in from a platform and had been wedged in a crevice of the rock.

With much difficulty I succeeded in ascertaining that an inscription was also cut on the back of the tablet. From the darkness of the place, I could scarcely copy even the few characters which had resisted the wear of centuries. Some days after, others who had casually heard of my visit, and conjectured that some Assyrian remains might have been found there, sent a party of workmen to the spot; who, finding the slab, broke it into pieces, in their attempt to displace it. This wanton destruction of the tablet is much to be regretted; as, from the fragment of the inscription I copied, I can perceive that it contained an important, and, to me, new genealogical list of kings. I had intended to remove the stone carefully, and had hoped, by placing it in a proper light, to ascertain accurately the forms of the various characters upon it. This was not the only loss I had to complain of, from the jealousy and competition of rivals.

The tunnel of Negoub is undoubtedly a remarkable work, undertaken, as far as I can judge by the fragment of the inscription, during the reign of an Assyrian king of the latter dynasty, who may have raised the tablet to commemorate the completion of the work. Its object is rather uncertain. It may have been cut to lead the waters of the Zab into the surrounding country for irrigation; or it may have been the termination of the great canal, which is still to be traced by a double range of lofty mounds, near the ruins of Nimroud, and which may have united the Tigris with the neighbouring river, and thus fertilised a large tract of land. In either case, the level of the two rivers, as well as the face of the country, must have changed considerably since the period of its construction. At present Negoub is above the Zab, except at the time of the highest flood in the spring, and then water is found only in the mouth of the tunnel; all other parts having been much choked up with rubbish and river deposits.

When Layard reexamined his copy of the Negub inscription in London, he thought he was able to identify the names of "the Kouyunjik king [Sennacherib], of the founder of Khorsabad [Sargon], and of his father, and perhaps even his grandfather."[20] He notes, however, that Henry Rawlinson questioned these identifications and was inclined to believe that this was a distinct series of kings.

Back in Mosul during 1849-51, Layard was able to study the fragments of the original Negub tablet in

[17] A fragmentary text of Tiglathpileser III (744-727 BC) was once thought to refer to the Patti Ḫegalli (Oates 1968, 47; Davey 1985, 49), but that attribution was in error. As restored by Tadmor and Yamada (2011, 27), in the latest edition of this king's inscriptions, the text reads as follows: "I dug out the Patti-[Enlil] canal, [which] had lain abandoned for a very long time and [...], and I made an abundance of water gurgle through it." The passage is part of an account of the king's first campaign in Babylonia, where there was a well-known Patti Enlil canal. Although the name of the god Enlil is missing from the Tiglathpileser inscription, part of the divine determinative survives in front of it. The text refers to the Babylonian canal, not to one at Nimrud.

[18] Leichty 2011, 170.

[19] Layard 1849, I, 80-81.

[20] *Ibidem*, II, 199-200.

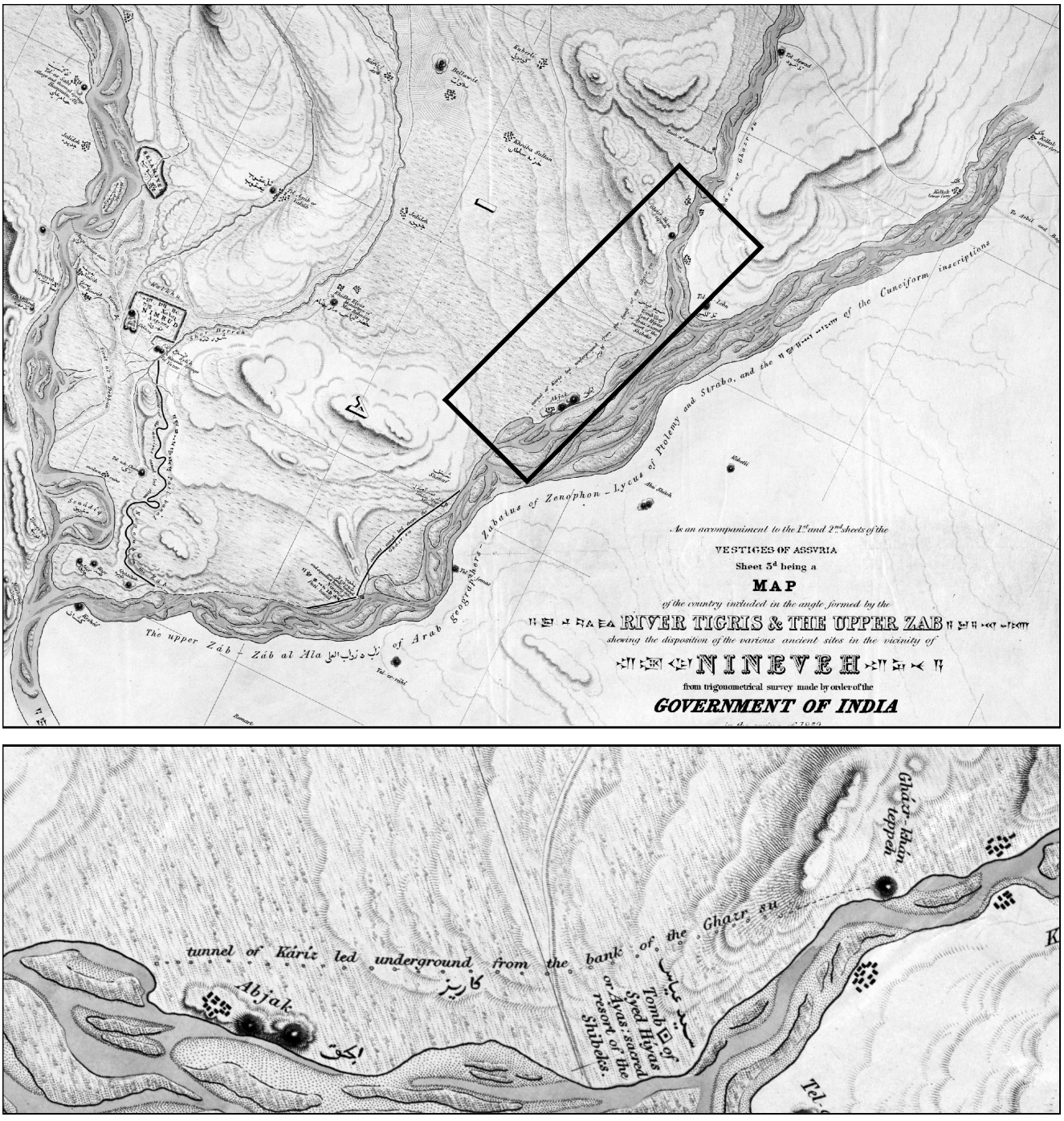

Fig. 2 - Felix Jones' map of Assyria, with the Qazakan-Abzakh underground tunnel from the Khazir river.

the convent of the Catholic missionary monks there, and could restore the greater part of the inscription.[21] For his 1853 book he consulted Edward Hincks, who confirmed the readings of Sennacherib and Sargon; the other two names were those of remote dynastic ancestors. It will have been Hincks too who recognized the gist of the inscription, which "appears to contain an account of the cutting of the remarkable tunnel through the rock in which the tablet was found, and of the canal leading from it. These great works were undertaken to convey the waters of the river Zab either to Nimroud or to the surrounding plain for irrigation." So Layard discarded his alternative idea that the water in this canal had run in the other direction, from the Tigris to the Zab.

The next relevant observations were made in dreadful weather during March-April 1852 by Felix Jones.

[21] LAYARD 1853, 616-617.

Working on behalf of the Hon. East India Company, he surveyed the countryside and created three maps. One covered the entire Assyrian plain between the Tigris and the Upper Zab; two detailed maps covered Nimrud and Nineveh and their immediate vicinities; a comparable map of Kaleh Sherkat (Ashur) was made at a different time. Jones' description of the plain and of Nimrud and Nineveh was read at a meeting of the Royal Asiatic Society in London in July 1853. This paper was published in the Society's journal in 1855, and later republished in Bombay.[22]

On the Nimrud canal, Jones[23] observed that

> ...though actually bordering on the Tigris, there is no doubt but that Nimrud latterly derived its water from the Zab or Lycus by means of a great aqueduct, ingeniously conducted from that stream to the south-east angle of the city where it borders on the Shor Derreh, a petty rivulet but boisterous winter torrent, having its source in the isolated hill of Ayn-es-safra to the north-eastward. The embankments of the great canal alluded to, where unbroken by the river, are traceable in their whole extent to the Zab; and in a subsequent age, when the famous tunnel at Negub had been left dry by the waywardness of that stream, we find an underground tunnel or Kariz connecting Nimrud with the waters of the Ghazr-Su. We have spoken of this work in the description of the general sheet of Assyria. At present the statement serves to shew the important position held by Nimrud during the latter dynasties of Assyria, for though almost within arrow's flight of the Tigris, even after its abandonment by that river, the construction of a broad canal twenty-five miles in extent, through a hard pebbly soil, was deemed indispensable to the requirements of the population.

Jones does not seem to have left any further description of the additional remains that he observed upstream of the Negub tunnel, and which he thought to be later than Negub, but his observations can be checked by reference to his map of Assyria. This map (Fig. 2) gives the undulating line of the surface canal seen by Layard running between Nimrud and Negub; Jones has restored a lost section downstream of Negub. The map then gives the slightly curving line of an upper stretch of canal that runs north-east from Negub along the right edge of the Zab flood-plain and then merges with the river. Yet further north-east the map gives the continuation of this upper stretch of canal, in the form of the slightly curving line of an underground channel which looks as if it collected water from a point, on the right bank of the Khazir, about 4 km above the confluence of the Khazir and the Zab.

Another visitor to this vicinity in 1852 was Victor Place, the excavator of Khorsabad, who hoped to find traces of an ancient bridge. He observed "une maçonnerie de pierres de taille" on the right bank of the Zab, about "une lieue" or 4 km below the Khazir-Zab confluence.[24] We do not know of any other mention of this masonry. Its age is not established, and there seems to have been at least one respectable Sasanian structure, the monastery of Dair Sarah, in this neighborhood.[25]

The Felix Jones maps of Assyria merit the high opinion expressed by Markham[26] in his account of British Indian cartography. Copies of all except the Ashur map were presumably displayed when Jones' paper was read at the Royal Asiatic Society meeting in 1853. In due course the four maps were beautifully engraved and printed. In 1994-6, when J. Reade was Hon. Librarian of the Society, its collections still included about 100 duplicate copies of two of the maps, perhaps once intended for distribution with the 1855 journal; he initiated a scheme to distribute them more widely, but did not succeed in doing so. All four maps, entitled "Turkish Empire: Vestiges of Assyria", were available for sale in London in 1870 at 6 shillings each [£0.30p in decimal currency, unadjusted], but the catalogue advertising them mainly contained maps of India.[27] Few of these "Vestiges" can have been sold, and they are now rare; a finely bound set, without the Ashur sheet, fetched £9,375 at auction (Sotheby's) on 30 September 2014.

A consequence of this obscure history is that for a long time the Felix Jones maps and the Negub canal were far less well known than they should have been; maps of Babylonia, also made for the British Indian authorities, have suffered the same neglect. Thus Jones is cited by Oppert,[28] Hilprecht,[29] and Budge,[30] but apparently not by Hormuzd Rassam[31] and George Smith[32] in the books that relate their own excavations at Nimrud and Nineveh. It is instructive to compare another map of Assyria, also based on plans made in 1852-3, that is associated with Place.[33] This map was also hidden, through publication in a book of exceeding expense and rarity. Actually the Place map has so many errors that one can only sympathize, suspecting the loss of some basic records before the final version was engraved. Yet Charles Fossey[34] wrote, with reference to Place: "faisant en quelque sorte la carte archéologique de l'Assyrie, l'ouvrage dans lequel il ra-

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[22] Jones 1855; Idem, 1857. Georeferenced versions of the three maps can be viewed online at the Harvard Geospatial Library (http://nrs.harvard.edu/urn-3:HUL.gisdata:012251491).

[23] Jones 1855, 342.

[24] Place 1867-70, II, 175.

[25] Fiey 1965, 613-615.

[26] Markham 1878, 29.

[27] Her Majesty's Secretary of State for India in Council 1870, 50.

[28] Oppert 1859.

[29] Hilprecht 1903, 66.

[30] Budge 1920, 426.

[31] Rassam 1897.

[32] Smith 1875.

[33] Place 1867-70, III, pl. 1.

[34] Fossey 1904, I, 39-40.

conte ses fouilles forme encore aujourd'hui (1904) la meilleur guide du fouilleur en Mésopotamie." Maurice Pillet,[35] in quoting Fossey with approval, demonstrates that he was unaware of Jones' work.

Carl Lehmann-Haupt also seems to have been unaware of Jones' work and, in particular, of the existence of the canal above the Negub tunnel. He does, however, give a brief but careful description of the tunnel area itself.[36] He knew the content of the Esarhaddon text, which he had seen with the Dominicans in Mosul, and distinguished two tunnels. One, which was blocked, he ascribed to Ashurnasirpal; villagers told him that there was a cuneiform inscription under the water of the Zab at its entrance, just as there was at the entrance to Sennacherib's canal from the Bastora Chai to Erbil.[37] He reckoned that this tunnel, because its position and dimensions proved unsatisfactory, had been superseded by the other tunnel, which he ascribed to Esarhaddon. This latter was still open, partly flooded by the Zab; he waded knee-deep to take what may be the first published photograph of its interior.

Even the Chicago publication of the Jerwan aqueduct,[38] which has become the foundation for all subsequent surveys of the canals and irrigation systems of ancient Assyria, does not mention Jones or Negub. It is not surprising therefore that Max Mallowan, who began new excavations at Nimrud in 1949, apparently only knew of Jones' surveys through a reference to them in a British Museum guidebook.[39] He would surely have mentioned the maps themselves, if he had seen them, in his discussion of the canal mentioned in Ashurnasirpal's Banquet Stela:[40]

> The topography of this canal can still be determined from an examination of the lie of the land south of the akropolis. As we follow the old line of the canal between Nimrud and the Zab we can see that it was deliberately cut as far east as possible from the Tigris, thus extracting the maximum width of ground for cultivation between the river and the higher lying terrain to the east. The irrigable strip today is in places as much as 2 miles wide, but must have been rather less in antiquity; the river has shifted out of its Assyrian bed, since 612 B.C., towards the west. The king specifically mentions the name of the canal, Pati Hegalli, literally 'ditch of abundance', and says that he abundantly irrigated the meadow-land by the Tigris and planted gardens there. The choice crops were reserved for the god Assur and the temples, which doubtless means that this newly cultivated area was largely considered to be ecclesiastical property.

Mallowan's deductions about the course of the Tigris and land ownership are debatable, but he draws a convincing parallel between Ashurnasirpal's attempt to grow a wide range of trees in the newly irrigated land and the comparable attempts of an earlier king, Tiglathpileser I, at Nineveh; Ashurnasirpal was following a long-established tradition.

Mallowan also discusses population density in the new city, but David Oates[41] brought the study of Nimrud and its resources to a new level of sophistication, by discussing at the same time the agricultural resources needed to support an enlarged population. Oates also made a new plan of the city of Nimrud and its neighborhood,[42] and described the technical details of the tunnels at Negub, where there were two phases of construction, one possibly abortive. Oates regarded the stretch of canal above Negub as probably representing Ashurnasirpal's original work. He acknowledged a 1960 discussion of the canal with Mr. C. R. Mann of Binnie, Deacon and Gourley Ltd, the company that designed and constructed the Dokan dam. "In particular, Mr Mann pointed out to me the possible continuation of the canal in the line of the river bank upstream of the point where it is still visible."[43] Oates' reconstruction of the course therefore brings the canal not from the Khazir itself, by an underground channel as indicated by Jones, but from the Khazir-Zab confluence, by way of a lost section of canal alongside the right bank of the Zab. Oates and Mann, had they been aware of Jones' discovery, would undoubtedly have discussed it and would have clarified the situation on the ground by personal inspection.

In 1977 Christopher Davey undertook the difficult and long-awaited task of properly measuring the Negub tunnels. He followed Oates in suggesting that Ashurnasirpal had been responsible for the open canal upstream of Negub. In his paper he also cited Jones,[44] but like Oates he does not seem to have inspected any possible canal-head on the Khazir. Presumably Davey like Oates had not known of Jones at the time of his own survey. In the interval between Davey's survey and his publication, Reade discovered copies of the Jones maps freely available in the British Museum departmental library, and set about republishing them, including new interpretations and assessments of the canal's chronology.[45] Most recently, a general review of all the evidence relating to the Nimrud canal was provided by Bagg,[46] and a reassessment of the canal is included in the broad landscape study by Altaweel.[47]

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[35] Pillet 1962, 26.
[36] Lehmann-Haupt 1907, 52-4, taf. VI.
[37] Safar 1946, 1947.
[38] Jacobsen, Lloyd 1935.
[39] Mallowan 1952, 21.
[40] Mallowan 1966, 67-68. Mallowan (1956, 2) was aware of Jones; he quotes the Bombay edition of his survey, with its account of the dreadful weather in 1852. There is no indication, however, that had seen the maps themselves, which are not bound into any known editions of his report.
[41] Oates 1968, 43-49.
[42] *Ibidem*, 43, fig. 3.
[43] *Ibidem*, 46.
[44] Davey 1985, 49.
[45] Reade 1978, 62-63, 171-172. See also below.
[46] Bagg 2000, 95-104, 234-236.
[47] Altaweel 2008.

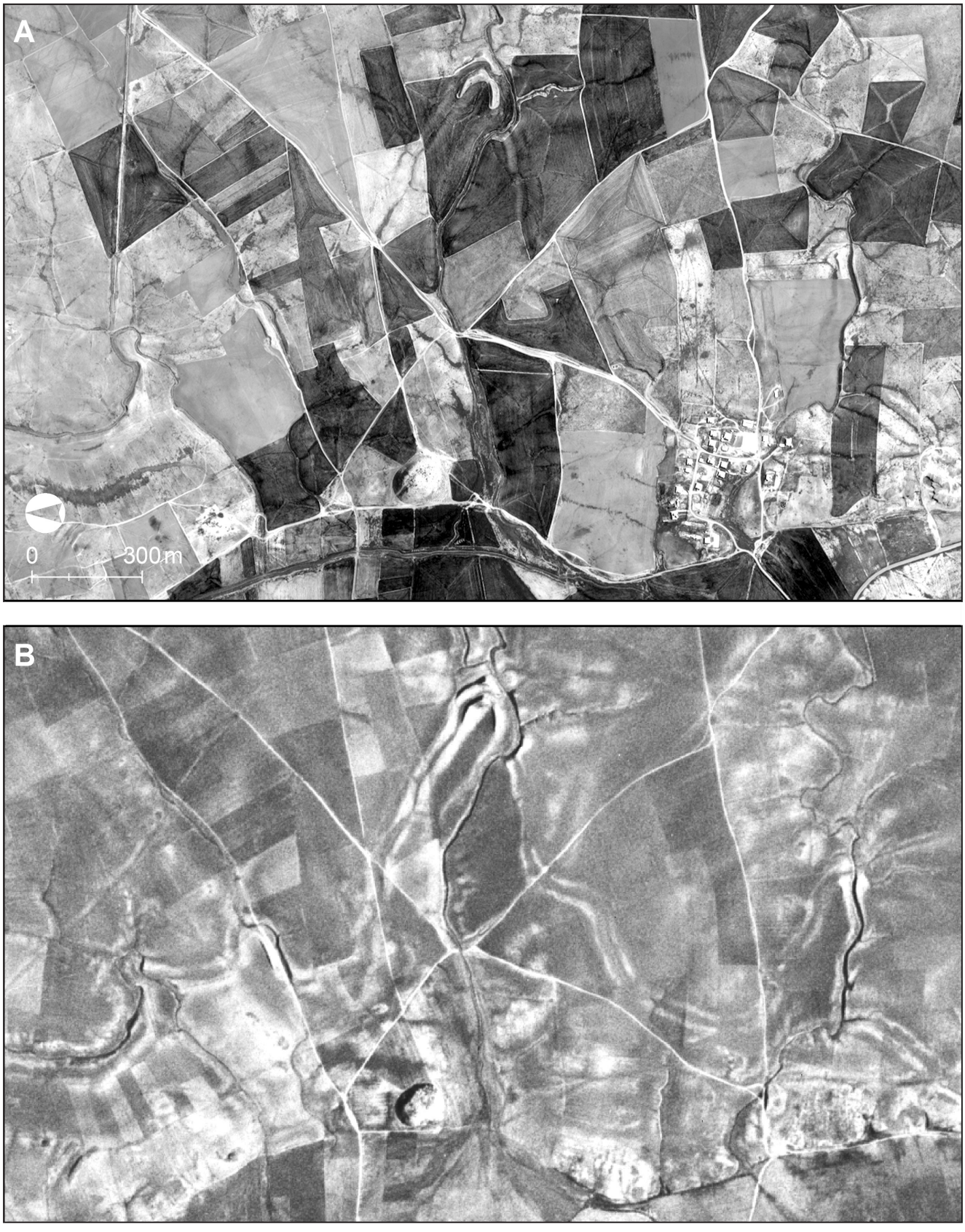

Fig. 3 - Modern commercial and historic intelligence imagery of the primary canal on the left Tigris terrace, south of Nimrud. A. WorldView-2 scene (31 March 2011, satellite image courtesy of the DigitalGlobe Foundation). B. CORONA KH-4a mission 1039 scene (28 February 1967).

Aerial and Satellite Remote Sensing Sources

The archaeological pioneers in the 19th and 20th centuries were limited to the view from the earth's surfaces. A remote perspective reveals many features that simply are not visible from the ground, including not only archaeological sites but also the subtle landscape features that extend beyond them. This reassessment of Nimrud's water system follows the recent tradition of remote sensing-driven landscape studies in northern Mesopotamia.[48] This study used a combination of modern commercial and historic intelligence imagery, including several newly available sources that have not been previously used for archaeological research.

The project used one modern image: a DigitalGlobe WorldView-2 image acquired on 31 March 2011. Late March is toward the end of the rainy season, when moisture differences in the soil are at a maximum. The enhanced moisture in low or excavated features, like relict canals, promotes plant growth; Assyrian canals in this image can be identified by the dark green growth in their beds. This image provides coverage from the village of Ibrahim al-Khalil as far as Nimrud (Fig. 3a). The high resolution (0.5 m/pixel) and true color of WorldView-2 and other modern commercial imagery make them visually attractive and easy to interpret, but they have the drawback of imaging the modern landscape. Sites and landscape features have suffered tremendously under the effects of modernization of agriculture and population expansion since the mid-20th century. Many of the features visible to Jones and Layard, and even to Oates and Reade, have since disappeared.

Near Eastern archaeologists have responded to this situation by exploiting declassified satellite photographs from the US CORONA program of 1960-1972.[49] CORONA (including the KH-4, KH-4a, and KH-4b cameras) has the benefit of moderately high resolution (1.5 to 2 m at the center of scenes captured by the latest cameras), and also the benefits of age. As a result, CORONA has been the primary dataset behind several recent studies of Assyrian landscapes.[50] The present study used a single CORONA mission from 28 February 1967 (Mission 1039, KH-4a camera), which has lower resolution than later KH-4b CORONA missions (2 m at best) but was acquired under nearly ideal ground moisture conditions for archaeological features (Fig. 3b). Elevated features such as mounds or canal banks shed moisture and therefore appear light, whereas depressed features like canal beds collect moisture and vegetation, and therefore appear dark.

CORONA missions were infrequent and often did not image the same area repeatedly. Intelligence planners solved this issue with the second generation broad-area intelligence satellite program, HEXAGON (KH-9), which ran from 1971 until 1986. Although HEXAGON's low-resolution mapping imagery has been available to the public since 2002, imagery from the high-resolution stereo cameras (1.0 to 0.6 m resolution at center) was only declassified in January 2013.[51] HEXAGON was a major advance, not only in resolution, but also in film capacity, which enabled longer missions and broader geographic capture. As a result, most geopolitically sensitive regions like the Middle East were imaged many times. The Erbil Plain, for example, was imaged 32 times on sixteen different HEXAGON missions between 1972 and 1984. Of the many missions that covered Nimrud and its eastern hinterland, the present study used scenes from five missions that flew during the wettest times of the year, which are best for landscape feature recognition.[52]

A further photographic resource, of particularly high resolution and even earlier than CORONA, are declassified photographs from the American U2 aerial reconnaissance program (code-named CHESS). In the late 1950s and into 1960, missions flew out of Adana, Turkey and over the major cities and military installations of countries throughout the Middle East; Iraq was especially well-covered. Photographs from U2 missions have been unevenly declassified, but many are now held by the US National Archives. Missions available via NARA were all flown in early morning hours, so shadows often reveal topographic details that are not apparent on CORONA, HEXAGON, or WorldView. Resolution varies between missions, but at best the photographs show objects of 0.4 m. This study used photographs from two U2 missions. Mission 8648 (30 October 1959) captured Nimrud and most of the open canal, including the Negub tunnel, on its straight line flight between Mosul and Kirkuk. Mission 1554 (29 January 1960) imaged the Qazakan-Abzakh subterranean canal before crossing the Upper Zab toward Erbil. Mission 1554 proved to be slightly out of focus but with ideal ground conditions for landscape features like canals.

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[48] Wilkinson, Tucker 1995; Ur 2003, 2005, 2010; Altaweel 2003; Idem 2008; Mühl 2013; Scardozzi 2011.

[49] For recent reviews, see Casana *et alii* 2012; Fowler 2013; Ur 2013a, c, all with earlier literature.

[50] See Ur 2005; Altaweel 2008; Mühl 2013.

[51] At present, HEXAGON imagery is held in cold storage by the US National Archives and Records Administration (NARA) and made available for viewing in the Reading Room in its College Park, MD facility.

[52] Missions 1202-1 (1 February 1972), 1208-1 (12 April 1974), 1211-1 (23 December 1975), 1214-2 (2 May 1978), and 1213-4 (14 November 1977).

Nimrud and the Tigris

It may seem odd to be concerned about water for Nimrud when the city sat close to the Tigris River. The issue is, of course, about the elevation of water, which is costly to raise in bulk. Assyrian water lifting technology is a subject of some contention,[53] and is still ambiguous at the current state of debate. Quantities of water sufficient for drinking and cleaning can be transported efficiently over small distances by containers and animal traction. Larger quantities, sufficient for field and garden irrigation, probably required gravity flow irrigation in the Iron Age, and indeed still do throughout the Middle East, where the principles have not changed since the Sumerians.[54]

Nonetheless, it is likely that there were attempts to divert the Tigris toward the city in Assyrian times. The river has moved frequently within its valley in the last century, and while today it flows against the western limits of the floodplain (and has since the time of Felix Jones), it must have flowed just below the citadel in the early first millennium BC. Max Mallowan's excavations recovered a ten-meter high quay wall constructed of cut stone blocks, with a 6 meter wide upper surface.[55] If interpreted correctly, this feature would have afforded easy movement of bulky products from the river into the city, and particularly the adjacent citadel area. Such shipping would have effectively expanded the sustaining area to include all agricultural areas of the Tigris valley upstream of the city.[56]

It would, therefore, be of particular interest to keep the Tigris flowing adjacent to the citadel, in the face of its tendency to migrate within its floodplain. The most likely form for such an effort would be a diversion within the floodplain that would keep water flowing against the eastern edge of the floodplain (i.e., directly beneath the city). One such diversion has been known since Felix Jones at Awai (or Awaiyeh), 1.5 km northwest of Nayfa village.[57] Via a combination of WorldView imagery and U2 photographs, a slightly curved segment of almost 600 m can be reconstructed (Fig. 4). Its elevation and the terrace below the citadel are at approximately identical heights (191 m ASL). Although could have served to fill a branch of the river that flowed along the base of the city, along the quay.

The Awai dam could not, however, have fed a canal that flowed *into* the city, not without water lifting.[58] The citadel rises as high as 213 m ASL; the elevation of the lower town is variable,[59] but even at its lowest, it is still more than 5 m above the Awai dam height. A canal capable of watering Nimrud's lower town without lifting devices would have to originate at least 15 km upstream from Nimrud, in the region of Qara Quyunli Sufla village. No traces of any canal exist in our imagery datasets for a left-bank Tigris canal above Nimrud.

Archaeological Evidence for the Khazir-Upper Zab Canals

A detailed review of the archaeological evidence for the canals is worthwhile, for several reasons. At the most basic, they remain poorly described, despite the fact that they have been known since the middle of the 19th century. Jones[60] devoted a single page, and Oates' description[61] was not much longer. Davey's excellent topographic survey[62] was unfortunately limited to Negub. At the same time, the surviving elements of the system are still at risk from human transformations and the actions of the Upper Zab itself. Many of its features may not survive for future field archaeologists to investigate.

A further necessity involves dating the system's components. Only the tunnels at Negub have inscriptional evidence for dating by association; the rest of the system must be dated by association with these features and by their morphological similarity to other known Assyrian canals. The Assyrians were not the only premodern irrigators of the Zab terraces,[63] so it is important that the reconstruction of the early first millennium system has a firm empirical basis.

Our reassessment of the Khazir-Upper Zab canals (Fig. 5 and foldout map, Pl. A) has revealed the remaining traces to be far more complicated than have been previously portrayed. It is certain that the surviving traces described here are a palimpsest of three or more phases of use, not all in use simultaneously, although all probably to be dated to the time of the Neo-Assyrian empire. We therefore separate the straightforward description of the remains (this section) from their more contentious chronological interpretation (the following section). This description proceeds vertically, from the uppermost elements to the canal's terminus at Nimrud.

Possible Canalheads on the Upper Zab and Khazir Rivers

The right-hand bank of the Upper Zab River, for some distance north-east of the village of Abzakh (Fig. 8, lower right-hand corners of all three images), fol-

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[53] See Dalley, Oleson 2003.
[54] Wilkinson 2013.
[55] Mallowan 1966, 76-81.
[56] Barbanes 1999; Wilkinson 2003, 128-130.
[57] Jones 1855, 343, where he notes that Jean Tavernier may have also crossed this feature.
[58] Reade 1978, 170-171.
[59] See Ur 2013b, fig. 3 for a profile of Nimrud.
[60] Jones 1855, 342.
[61] Oates 1968, 46-47.
[62] Davey 1985.
[63] Ur *et alii* 2013; Ur, Osborne 2016.

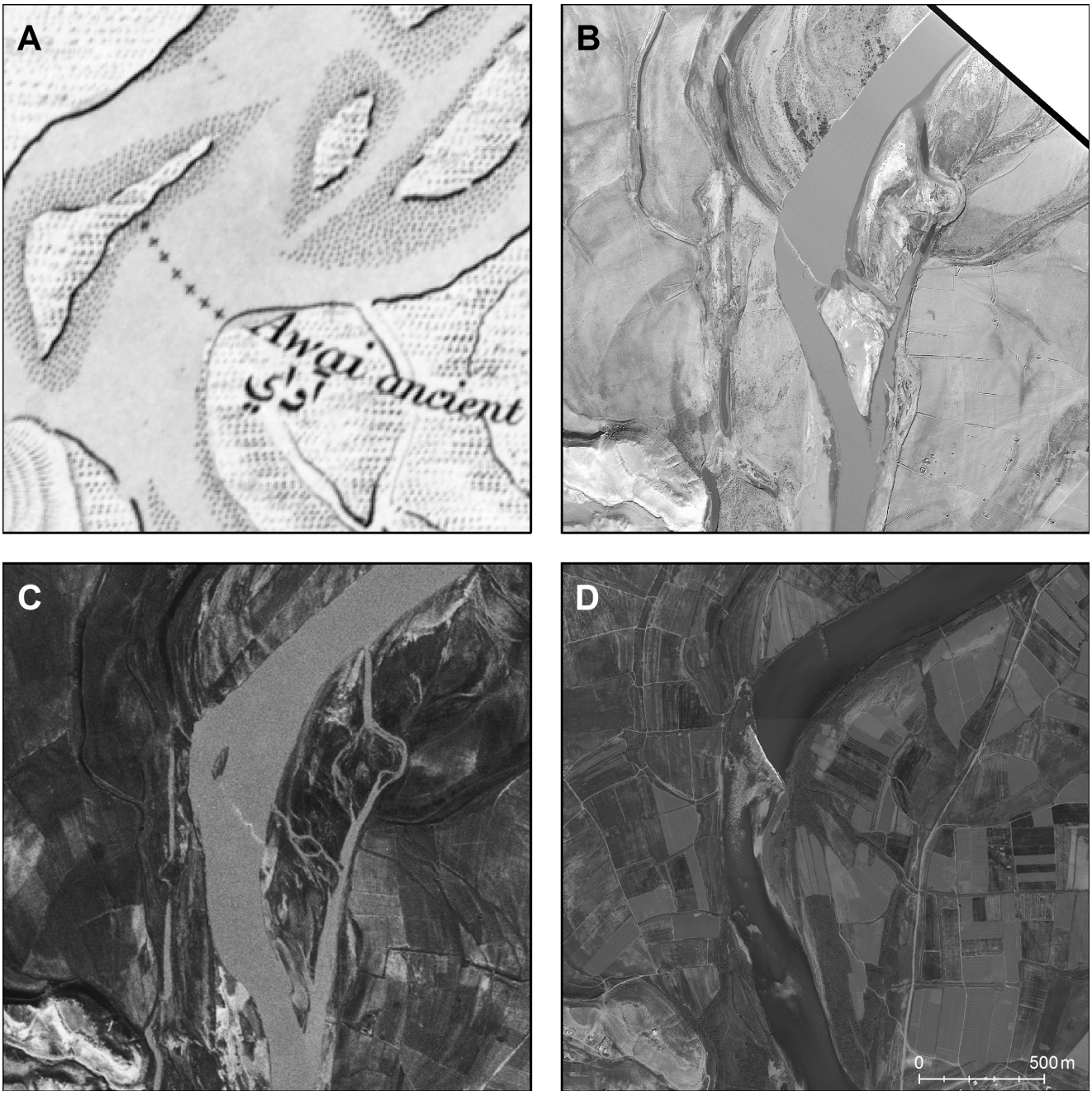

Fig. 4 - The diversion feature at Awai. A. The map of Felix Jones. B. U2 mission 8648 (30 October 1959). C. CORONA mission 1039 (28 February 1967). D. WorldView-2 (31 March 2011, satellite image courtesy of the DigitalGlobe Foundation).

lows a remarkably straight line. It seems possible that this is a remnant of an open canal which took off from the Upper Zab just below its confluence with the Khazir, and which has been otherwise destroyed by the Zab. It could additionally, or alternatively, be a remnant of the open canal adjoining the Khazir that is represented further upstream by the Wardak canal segment (see below).

The uppermost traces of the Nimrud canal itself are associated with the Khazir River, not far above its confluence with the Upper Zab. In this region, two parallel segments can be identified from satellite and aerial imagery.

The first segment is a conventional open canal on the Khazir's right bank. It begins one kilometer north of the village of Wardak and directly across the river from Tell Leban; its preserved traces can be followed for 550 meters along the edge of the Khazir's uppermost terrace. On a U2 photograph (Fig. 7), it appears to have very little relief left, but its spoil banks appear to span roughly 30 meters. The canal bed is around 230 m ASL, about six meters above the present level of

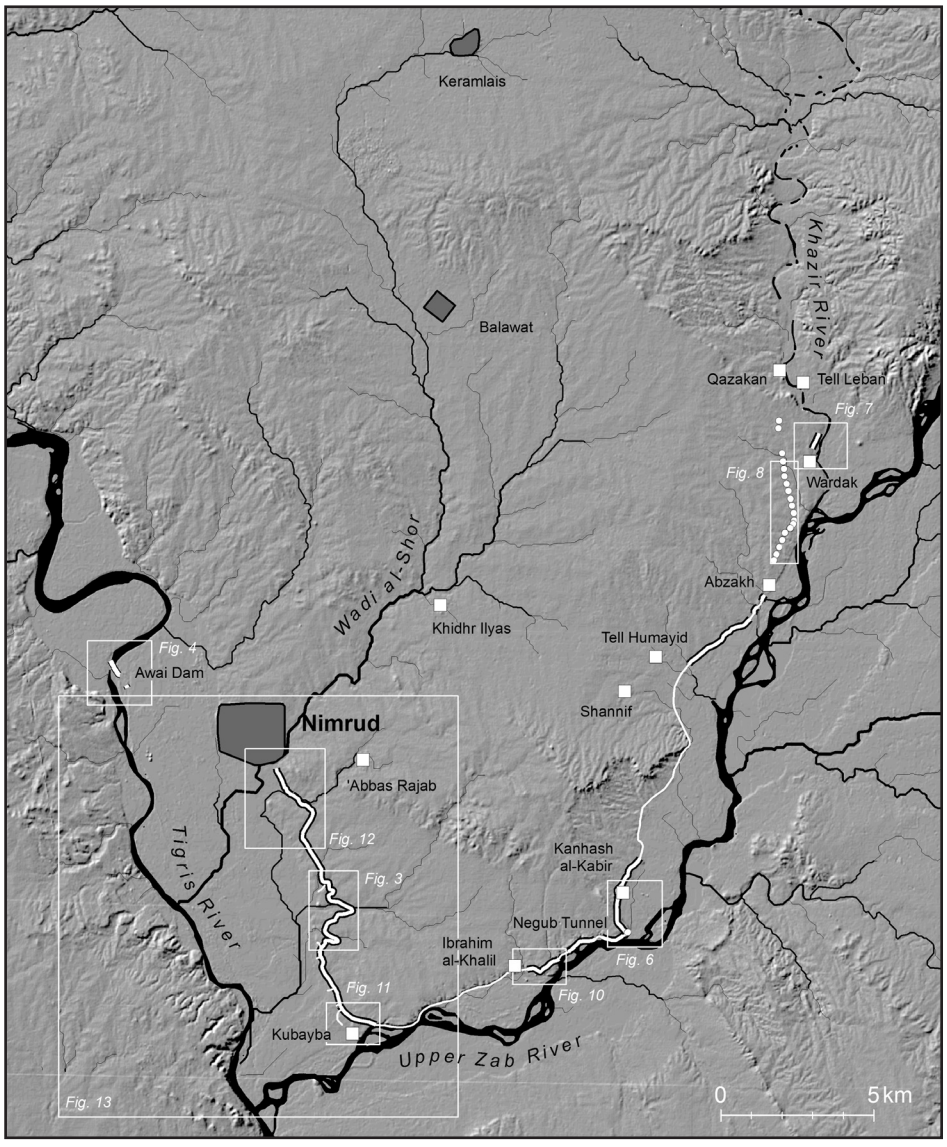

Fig. 5 - The Khazir-Upper Zab canal.

the Khazir. There is little else that can be said for the Wardak open canal segment; any direct traces above or below it have been removed by the Khazir.

The other segment originates further upstream and is subterranean. Although first noted by Jones,[64] it has not received much attention in subsequent discussions of Nimrud's canal system, perhaps because no subsequent visitors have identified it on the ground. Several segments are, however, visible on January 1960 U2 photographs and several CORONA[65] and HEXAGON missions. The canal weir must have been located near Qazakan village, where there is a prominent tell. Today the Khazir flows at 227 m ASL at this spot. No trace of a diversion feature or associated open canal can be found in the image sources at hand, but such a canal probably ran west of the tell and entered the subterranean canal at the bluffs 400 m to its south. The uppermost recognizable segment is visible 1.3 km south of the tell, where it appears as a series of dark spots on most image sources (Fig. 8). At this point the tops of the shafts are at 248 m ASL, meaning that the shafts could be as deep as 20 m to the canal itself. The shafts, and associated clean-out heaps surrounding them, are 12-15 m in diameter, and the shafts themselves were dug at regular 20 m intervals.

The shafts of the subterranean canal are visible again 900 m west of Wardak village, and can be reconstructed in its entirety for the next 3.5 km, where

[64] JONES 1857, 342, where he labels the feature the "Ghazir-su karez." See also the discussion above.

[65] ALTAWEEL 2008, 74-75 and fig. 29.

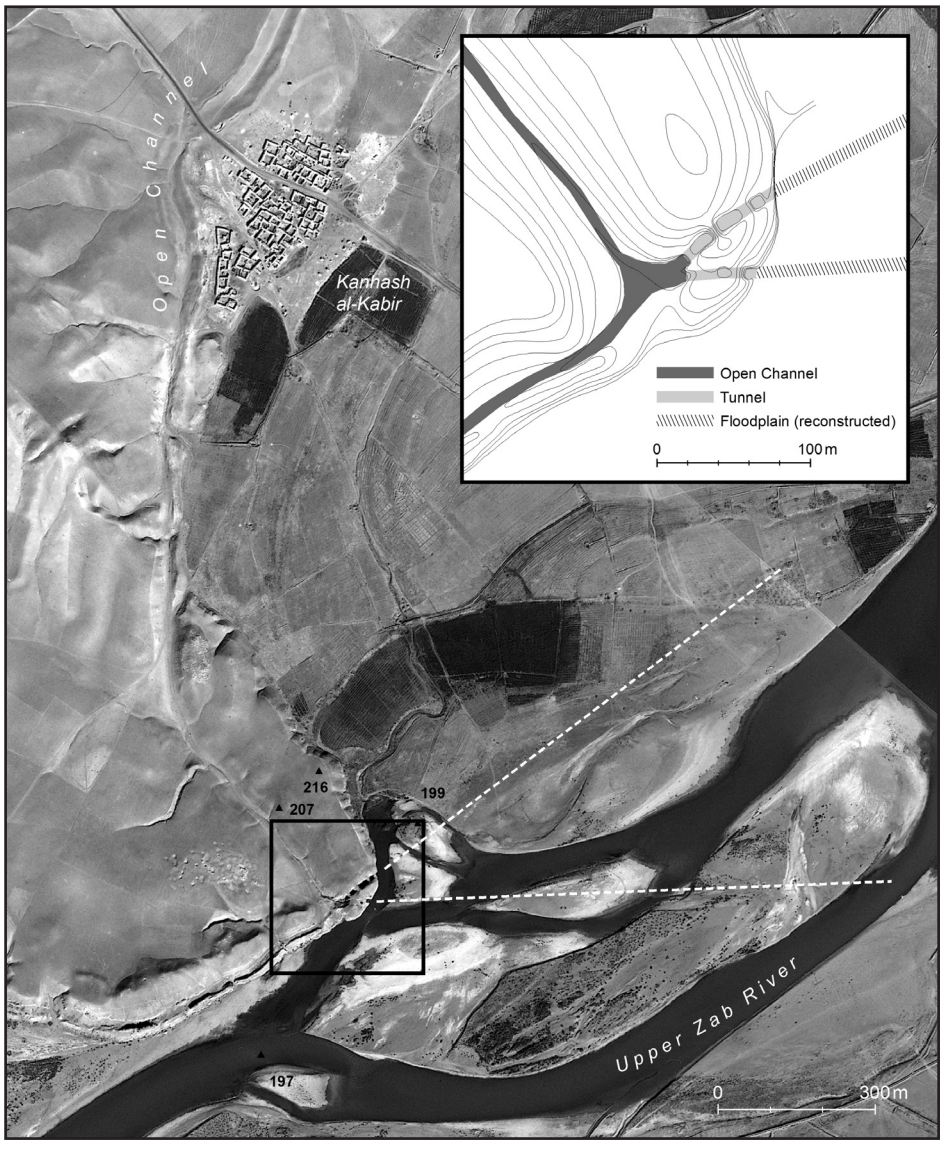

Fig. 6 - Canals, tunnels, and hypothesized weirs at Negub (background image U2 mission 8648, 30 October 1959). Dashed lines show the extension of the tunnel angle into the Upper Zab floodplain. Elevation heights in meters above sea level. Inset: detail of the Negub tunnel based on the topographic survey of Davey 1985, fig. 1. Contours at 2 m intervals.

it disappears under the village of Abzakh. West of Wardak, the shafts run parallel to a deep ravine that drains into the Upper Zab valley. Along this stretch, the channel itself is probably about 10 m below the ground surface. In total, the subterranean channel ran approximately 7.2 km from Qazakan to Abzakh village; 4.0 km (55%) can be reconstructed from a combination of CORONA, HEXAGON, and U2 imagery.

The question of the antiquity of this feature can be raised. *Karez* or *qanat* features in the adjacent Erbil Plain are associated predominantly with Medieval archaeological sites, and continue in use in the Kurdistan Region to the present,[66] although nearly all were abandoned in the course of the 20th century AD.[67] The Qazakan-Abzakh feature differs from these *karez* in several ways. Morphologically, its shafts of this feature were dug at 20 m intervals, compared to around 30 m intervals for *karez* on the Erbil Plain. In all image sources, the Qazakan-Abzakh shafts are retaining moisture and appear dark; medieval and modern karez all have light signatures because their upcast soils are light and shed moisture. The reasons for this discrepancy are difficult to propose; it may be because the Qazakan-Abzakh shafts have long since collapsed and have had longer time for soils to form within them.

[66] Ur *et alii* 2013.
[67] Lightfoot 2009.

Fig. 7 - U2 aerial photograph of the Wardak canal segment on the right bank of the Khazir River (Mission 1554, 29 January 1960).

On the other hand, soil formation atop the collapsed shafts looks remarkably similar to the identifiable portions of the Bastora-Erbil subterranean water channel that can be attributed to Sennacherib.

At the macro scale, the Qazakan-Abzakh canal also behaves differently from medieval and later *karez*. It is fed by diverted surface water (the Khazir), rather than by tapping the water table, and therefore is technically not a *karez*. Its trajectory runs perpendicular to the natural drainage of the landscape, whereas the medieval and later *karez* generally run in parallel to it. In other words, the Qazakan-Abzakh canal behaved like a conventional surface channel. Indeed its closest parallel is the subterranean Bastora-Erbil canal, which can be attributed firmly to the reign of Sennacherib. Ground observation is badly needed, but on the present state of the evidence, the best hypothesis is that the Qazakan-Abzakh channel is Neo-Assyrian in date.

Right Bank Channel South of Abzakh

At some point near (or under) Abzakh village, the canal emerged and continued in an open channel. Only a short segment can be identified immediately south of the village, but just over a kilometer to the southeast begins a well-preserved 2.5 km segment that runs on the very edge of the uppermost river terrace. The bed of the canal is approximately 218 m ASL, about 3 m above the next-lowest terrace and 7 m above the current level of the adjacent Upper Zab river. The channel cut is broad along this stretch, as much as 45 m between the tops of the spoil banks, where both are preserved.

Fig. 8 - The Qazakan-Abzakh subterranean channel, visible by the alignments of collapsed access shafts (dark spots). A. U2 mission 1554 (29 January 1960). B. HEXAGON mission 1213 (14 November 1977). C. HEXAGON mission 1214 (2 May 1978). See also Fig. 2 for Jones' map of this feature.

At the end of this segment, near the villages of Tell Humayid and Shannif, the valley broadens into a wide embayment to the west. River movement into this embayment appears to have removed the course of the canal, and for over 7 km, no unambiguous trace of the surface canal is preserved on U2, CORONA, or HEXAGON photographs.

Canals and Tunnels around Negub

The surface channel reappears 1.2 km northeast of Kanhash al-Kabir village, and can be traced 2.8 km to the point where it arrives at the Negub tunnel complex. Both banks of the canal are well preserved in this segment, and the channel is approximately 40 m wide between the tops of the banks. The canal bed is 210 m ASL at the start of the segment, 4 m above the adjacent terrace and 8 m above the adjacent Upper Zab.

The tunnels at Negub (Fig. 6) cut through a conglomerate bluff that extends out into the Upper Zab valley. Two tunnels were cut: a narrower 40 m-long tunnel to the south on an east-west axis, and a wider 70 m tunnel on a northeast-southwest axis. Both are accessible by broad open shafts from the surface of the bluff. The brief descriptions by Layard, Jones, Lehmann-Haupt, Oates, and Reade have been superseded by the detailed topographic map of Christopher Davey,[68] which appears highly accurate when compared with U2 aerial photography. These tunnels were fed by canals or weirs across the Upper Zab that no longer survive. The Kanhash al-Kabir open channel segment arrives at Negub at a point *below* these two tunnels, however. In other words, the open channel below Negub was fed at various points by one of three different sources. The bottleneck at Negub reveals the complex history of Nimrud's water system; it poses a serious challenge to a remote sensing-based reconstruction and will be discussed in detail below.

Below Negub, the canal can be followed running tightly against the edge of the valley. In the 3.5 km between Negub and the village of Ibrahim al-Khalil,

[68] DAVEY 1985.

over 90% of the channel can be identified. Immediately below Negub, Assyrian engineers cut the right edge of the channel into the valley edge (Fig. 9). The canal itself can be measured precisely on U2 aerial photographs to about 20 m wide.

At the end of this segment, 1.3 km east of Ibrahim al-Khalil, the canal cuts through another bluff jutting out into the river valley (Fig. 10). Unlike at Negub, the canal runs through a deep and open cut through the bluff. The upcast from the excavation rises 3 m over the surface of the bluff, casting shadows on the imagery. The width of the cut, between the tops of the upcast banks, is over 100 m. In the intervening millennia, the upcast material has eroded back into the channel at its center (211 m ASL) but the canal itself was closer to 203 m, the preserved bed elevation at the start and end of this cut feature. At this point, the canal ran about 10 m over the current level of the Upper Zab River. It is likely that some of the elevation of this bluff is artificial; this point is the terminus of a half dozen "hollow way" trackways arriving from the north and west, suggesting the presence of a previously-unrecognized archaeological site, mostly likely of the Early or Middle Bronze Age. At Ibrahim al-Khalil village, the banks have been disturbed and are ambiguous on all image sources; below the village, river action has removed approximately 5.5 km of the canal.

Canals on the Tigris Terrace between Kubayba and Nimrud

Eight hundred meters northeast of Kubayba village, the canal can be identified again, as it cut through the terrace that separates the Upper Zab and Tigris River valleys. From this point the primary canal can be mapped in its entirety up to a point 400 m south of Fort Shalmaneser, totaling 12.1 km of canal excavation.

The start of this long segment, near Kubayba, is similar to the bluff cut at Ibrahim al-Khalil: a deep and wide cut into the high terrace, almost 70 m between the tops of the spoil banks (Fig. 11). The preserved base of the channel is 204 m at its start, now 8 m over the adjacent floodplain terrace.

The Tigris Terrace segment has the two distinct characteristics of Assyrian open canals that have been recognized elsewhere in the imperial core:[69] sinuosity and monumentality. In northern Mesopotamia, monumental scale alone is not sufficient to identify Assyrian waterworks; Sasanian and Abbasid engineering projects were equally massive and labor intensive. These later projects did not, however, allow the local contours of the terrain to dictate the course of water channels in the manner that the Assyrian canals did. In this manner, Assyrian canals behave similarly to the late 20th century canal systems visible on historical aerial and satellite photographs, only at much larger scale and proportions. The combination of monumental scale and topographically-imposed sinuosity distinguishes Assyrian canals from either Sasanian-Abbasid or recent systems.[70]

In two places, the canal takes major diversions to the east to accommodate natural drainages (see Figs. 3 and 6). The first is 2.4 km north of al-Jaif village. The canal turns abruptly nearly 90° to the east and runs 400 m up the wadi, before crossing it and returning another 500 m down the opposite site, where it resumes the original canal alignment, only 300 m from the initial 90° turn and at an addition of 600 m to the length of the canal. The second diversion is 700 m further to the north, where it makes a similar accommodation to the largest wadi between Kubayba and Nimrud. This diversion adds over 1 km to the length of the canal. These diversions may be diagnostic of early Neo-Assyrian canal engineering. In later times, similar impediments were dealt with by Sennacherib's engineers via aqueducts, most famously at Jerwan[71] but less dramatically at many other points along the Khinis-Khosr canal.[72] Along this sinuous stretch, the canal bed is around 198-199 m ASL and routinely 40 m wide between upcast banks.

Beyond these two diversions, the canal takes on a stronger linearity in the last 5 km before arriving at Nimrud's outer wall. At several points, it appears that the canal's designers were strengthening the right bank of the canal, to protect it from dangerous run-off and to channel seasonal wadi flow into the canal, which by this point may have been depleted by extraction for terrace irrigation (see below).

The end of the canal, as far as can be determined via aerial and satellite imagery, is 220 m south of Fort Shalmaneser, at the top of the left bank of the Wadi al-Shor (Fig. 12). It is tempting to assume that water from the canal would have flowed over the wadi and into the city itself; however, no evidence exists for an aqueduct on any image sources, and ground survey will be required to determine whether one existed. Even if it did, elevation challenges would have been substantial. The canal terminus is approximately 196 m ASL. The open space west of the main Fort Shalmaneser building is a full 10 m higher, as is the surface of the citadel (206 m ASL). Other parts of the town are lower; for example, one proposed location of intramural gardens adjacent to the citadel[73] is only 197 m ASL. Any such connection between this inner zone of the city and the terminus of the Khazir-Upper

[69] Ur 2005.

[70] See discussion in Ur *et alii* 2013, 106-107.

[71] Jacobsen, Lloyd 1935.

[72] Morandi Bonacossi 2016; Morandi Bonacossi, Iamoni 2015.

[73] See Ur 2013b, 14 and fig. 2.

Fig. 9 - The canal below Negub. Photograph by Julian Reade, ca. 1966.

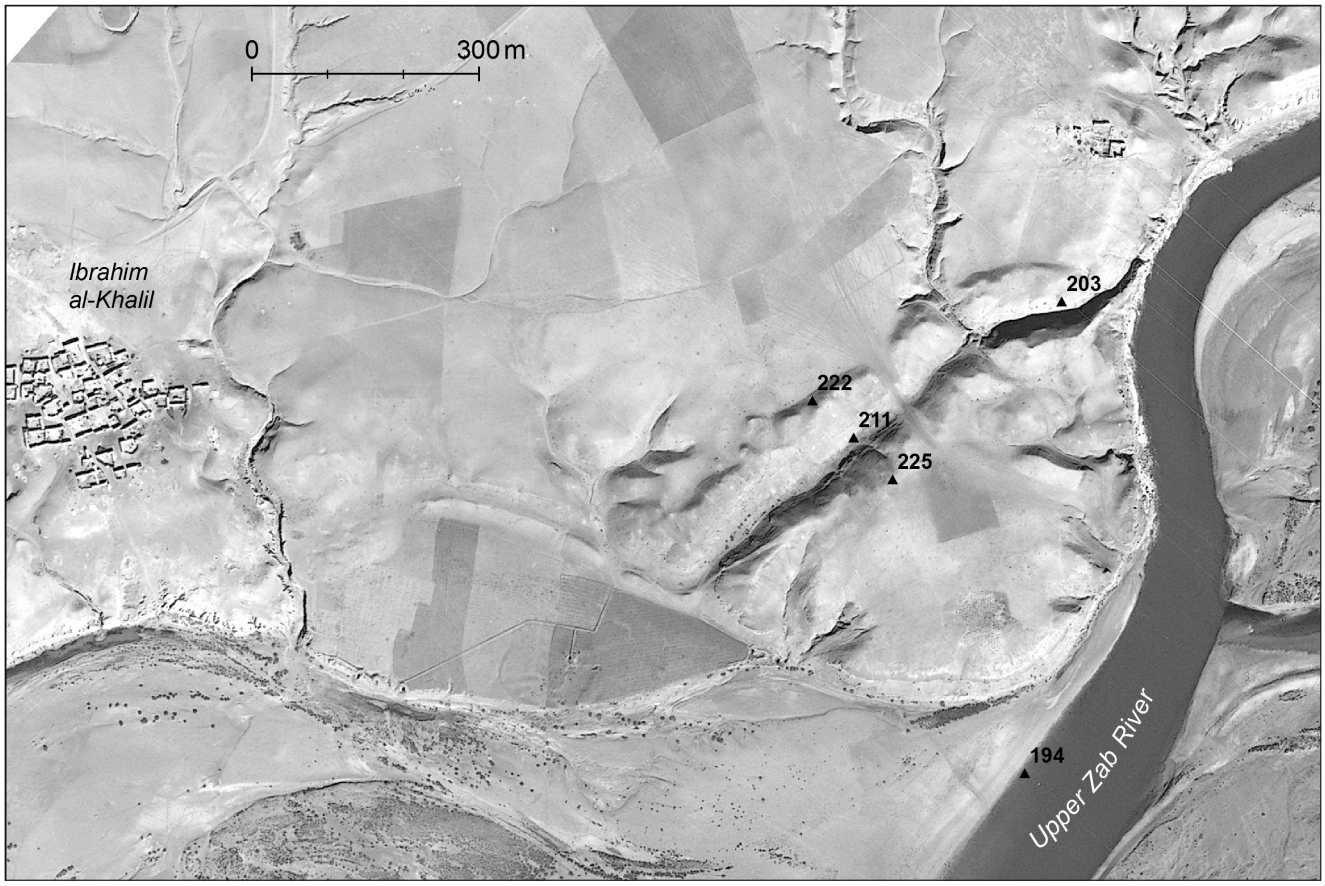

Fig. 10 - U2 mission 8648 (30 October 1959) image of the canal cut through a bluff east of Ibrahim al-Khalil village. Elevations in meters above sea level.

Fig. 11 - Primary canal and secondary canal near Kubayba village (CORONA mission 1039, 28 February 1967).

Zab canal is invisible on available aerial and satellite photographs, and will probably require ground-based geophysical survey to detect (if it existed).[74]

Secondary Canals and Irrigation on the Upper Tigris Terraces

Since its first systematic treatment by David Oates,[75] the Khazir-Upper Zab canal has been treated as part of the staple economy of the city. Oates included calculations of irrigable areas of the terraces and floodplains adjacent to the city. The primary canal from Kubayba to Nimrud is fully reconstructable, but any secondary canals from it are far more challenging to identify. Secondary canals are smaller and more likely to be entirely built of earth, and therefore much easier to remove via erosion or cultivation. Furthermore, offtake cuts on the left bank of the canal present weak points for subsequent surface runoff and wadi formation. Because they are low points in canal upcast banks, modern tracks and roads use them to traverse the former canal beds, disturbing their signatures on satellite and aerial images.

Nonetheless, there are several likely secondary canals preserved at the start of the Kubayba-Nimrud segment, close to the villages of Kubayba and al-Jaif (see Fig. 11). The primary canal cuts through the high bluff at Kubayba and runs 1.2 km to its other side, where the land slopes down toward the Tigris valley. At this point on the opposite side of the bluff, an offtake leads off to the southwest before curving

[74] J. Reade repeatedly inspected the relevant areas while walking across them during 1962-3, and noticed no signs either of an aqueduct crossing Wadi al-Shor or of any artificial watercourse in the area between the citadel and Fort Shalmaneser.

[75] Oates 1968.

Fig. 12 - The terminus of the canal near Fort Shalmaneser (HEXAGON mission 1202, 1 February 1972). Elevations in meters above sea level.

around again to the southeast, along the southern edge of the bluff. The canal itself appears to be roughly 10 m wide. Two hundred meters further is another more ambiguous offtake, and 700 m beyond it is yet another, also somewhat ambiguous on 1967 CORONA imagery. These secondary canals may have carried water to fields and settlements on this narrow spur of terrace that juts out 2 km into the floodplain where the Tigris and Upper Zab join.

Closer to Nimrud itself, there are other linear features at right angle to the primary canal, but most have been captured by recent surface flow and have become wadis; they are impossible to identify as canals with any confidence. Other linear features are more likely to be hollow ways rather than canal features. The plain north and east of Nimrud is covered with these linear trackways, which articulate with both Nimrud's gates but also with the Bronze Age tell landscape.[76]

Chronology of the Khazir-Upper Zab Canal System

The Nimrud water system probably functioned for more than two centuries, perhaps with fluctuating degrees of efficiency. Over such a time span, environmental changes would be expected; large floods would have damaged or destroyed canals and weirs, and shifted rivers within their floodplains. Based on observations on the adjacent lower Erbil plain, it is likely that the Upper Zab began to incise into its floodplain during this time, creating challenges to keep water flowing through terrace canals whose basal levels were increasingly higher above the river.

[76] Altaweel 2008; Ur 2013b.

Throughout its life, the Tigris terrace stretch of the canal between the village of Kubayba and Nimrud appears to have been maintained in its original position; there are no visible signs of major redesigns in the available imagery. The situation at Negub and above, however, is far more complex and shows signs of multiple stages of construction and redesign. Two parallel channels tapped the waters of the Khazir River, one open and poorly preserved, the other subterranean and largely reconstructable via its access shafts. These two upper channels may have been alternative ways of supplying the open channel below Abzakh village.

The complex feature at Negub (Fig. 6) shows evidence for at least three stages of use. The two tunnels would have accommodated water from either an Upper Zab terrace or directly from the river itself, whereas the large open cut through the bluff can be traced to the north. Describing the shift in use between these three stages, without recourse to excavation and canal bed elevation data, is a major challenge. We present here two possible reconstructions of the canal's historical development: one favored by Reade, and based largely on the original reconstruction of Oates, and an alternative favored by Ur.

Oates-Reade Reconstruction

David Oates[77] assumed that Ashurnasirpal's original canal was entirely open, and originated somewhere near the Khazir-Upper Zab confluence. In this earliest upper stretch, the bed of the canal could be identified by a particularly straight branch of the Upper Zab, which had taken it over. This canal continued into the open north-south cut through the bluff at Negub, and then proceeded to the Tigris terrace and Nimrud itself. This long stretch of open canal above Negub was exposed to the meanderings of the river; later kings abandoned segments above Negub in favor of using the spur as "a natural breakwater"[78] that would force water into the lower canal system with little effort even if the river did move. In Oates' reconstruction, the southern tunnel at Negub was the work of Tiglath-pileser III, followed by Esarhaddon's cutting of the eastern tunnel, in which Layard found his inscription. Tiglath-pileser need not be implicated here; it is just as plausible, and more likely, that the two tunnels are sequential attempts by Esarhaddon's engineers at solving the same water access problem.

Oates did not include the Wardak open channel or the Qazakan-Abzakh subterranean channel in his reconstruction. Both would, however, be elegant solutions to a meandering Upper Zab river, which gradually removed all traces of the open canal, with the possible exception of the small segment above Wardak village. The subterranean channel could deliver water from the Khazir into the existing Patti-ḫegalli, but while protected from damaging floods and migrations of the Upper Zab. A possible commissioner of the subterranean channel would be Tiglath-pileser III, who was engaged with building at Nimrud itself, and who may have encountered similar subterranean earthworks in his campaigns in Urartu. Earlier studies have assumed that Tiglath-pileser mentioned this canal repair work in a royal inscription, but it now appears that language refers to work done in Babylonia, not on Ashurnasirpal's old Patti-ḫegalli.[79] Nonetheless, for the reasons above, he would be a strong candidate for the builder of the subterranean canal.

This scenario posits an initial lengthening but ultimate shortening of the overall length of the canal; the original 9th century canal ran approximately 35 km from the Khazir-Zab confluence to Nimrud; it was first lengthened to 38 km from the Wardak canalhead, and then to 43 km from the Qazakan canalhead, but was finally replaced in the 7th century by a 21.9 km canal from Negub to Nimrud. If, as is quite likely, the river was moving laterally and vertically (i.e., downcutting), the repair work undertaken at Negub by Esarhaddon (and possibly Tiglath-pileser III before him) may have involved the deeper excavation of the canals below that feature, to accommodate the lower level of the source.

Alternative Reconstruction

An alternative reconstruction emphasizes the likely vertical movement of the Upper Zab. As the river has moved within its floodplain, it has also begun to cut back into it. While its lateral movements have taken away the canals on the adjacent terraces, its vertical movements have dropped its water level. Proper geomorphological studies have yet to be conducted, but it is reasonable to speculate that this situation resulted from a corresponding drop in the level of the Tigris. The drop in the level of the Upper Zab subsequently has caused the rivers and wadis of the adjacent Erbil Plain to cut down, to the point that several likely Neo-Assyrian canals are today many meters above their likely canal heads.

In this alternative scenario, Ashurnasirpal's Patti-ḫegalli started at Negub. In his "banquet stele" inscription, the origin of the canal is explicitly said to be "from the Upper Zab,"[80] not one of its tributaries. Neo-Assyrian royal inscriptions are capable of great geographic specificity, particularly with regard to otherwise obscure geographical names, and it seems unlikely that the Upper Zab would be mentioned when the composer meant the Khazir. The only element of

[77] Oates 1968, 46-47.
[78] *Ibidem*, 47.
[79] See discussion above, under Historical Sources.
[80] TA ÍD *za-ba* AN.TA (Grayson 1991, A.0.101.30 line 36b).

the upper system that connects unambiguously with the Upper Zab is the eastern tunnel at Negub. Its east-west orientation is well situated to receive water from a floodplain diversion positioned to its east. If it were to cross the entire floodplain, such a diversion could handle small lateral movements, and be easily replaced in the event of large flood damage.[81]

This floodplain weir arrangement would not, however, be able to handle vertical movements, and it is certain that at some point after initial canal construction, the Upper Zab incised itself significantly. The canal engineers could respond to the lowering of the source in one of two ways: they could lower the canal as well so water could continue to flow at the new lower elevation, or they could construct a new intake further upstream at an elevation above the level of the existing canals. The former option, favored by the Oates-Reade hypothesis, would only require the deeper excavation of the existing primary canal, if the target of the system were still at a lower elevation than the canal head (i.e., royal gardens in Nimrud itself). However, the satellite imagery interpretation and Ashurnasirpal himself agree that the system was used to water fields and orchards on the Tigris terraces, in addition to whatever uses the water might have been put to within the city (itself a challenge, given the elevation of the canal at its end in the Wadi al-Shor). Lowering the primary canal would have necessitated the lowering of secondary canals and the fields and orchards throughout the system. Lowering the main canal might have kept water flowing to Nimrud itself, but it would have forced the abandonment of the irrigated terraces.

The common response to a lower water source is to extend the primary canal upstream to a suitably high elevation. Evidence of such strategies is the open canal near Wardak and the subterranean Qazakan-Abzakh canal.[82] It may be that Assyrian engineers had decided that the Upper Zab was simply too dynamic to divert, and opted to extend as far as the Khazir, a smaller and presumably more manageable tributary. While both actions would necessitate a great deal of new canal cutting, the engineers may have determined that this investment[83] was worth it to keep water flowing into the secondary canals on the Tigris terrace. Although speculative, it seems likely that the Wardak open canal was the first to be built, diverting Khazir water from somewhere above the Khazir-Upper Zab confluence, but then it too fell afoul of a laterally migrating Upper Zab. Rather than attempt to restore the right bank canals, the engineers might have installed the subterranean canal from Qazakan, which would have been impervious to the destructive Khazir-Zab confluence.

In this alterative reconstruction, the shift from an Upper Zab source to a Khazir source would have corresponded to a shift at Negub from the eastern tunnel to the northeastern tunnel, the alignment of which was better suited to accommodate a canal on a river terrace. This new arrangement was, however, still threatened by the lateral movement of the river in flood, and the spur at Negub may have been a prominent target where it juts into the path of floods. The engineers responded as they did upstream, by moving the canal inland, by excavating the deep and open north-south cut through the bluff, west of the tunnels. In this scenario, the sequence at Negub rotated in a counter-clockwise manner from the eastern tunnel to the northern open channel. Each rotation shifted the canal further from the destructive power of the Upper Zab, and each probably received water from a higher source.

This relative chronology appears to accommodate the available evidence, but an absolute chronology is exceedingly challenging. The short Patti-ḫegalli must have originated with Ashurnasirpal II. However, the hypothesized lateral and vertical shifts in the Upper Zab, and the corresponding engineering adjustments, could have happened at any time after initial construction. Because of the language of decay and abandonment in the inscription of Esarhaddon, it is tempting to assume that as much as a century had passed, perhaps culminating with the removal of the capital to Khorsabad and then Nineveh. It is also tempting to associate the subterranean channel from Qazakan with Esarhaddon. The only parallel for such a lengthy underground canal is the Bastora-Erbil canal, which can be securely dated to the reign of his father Sennacherib. Indeed it is possible that the same engineers who designed the Bastora channel were still active when his son and successor commissioned a similar feature on the other side of the Upper Zab.

These hypothesized historical moments are even more speculative than the relative chronology of the system's development. We can only hope that at some time in the future, these two hypothetical developmental sequences will be able to be tested via ground observation, as is now happening with Assyrian hydraulic works on the Navkur and Erbil plains.[84]

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[81] It is likely that early weirs and dams were designed to give way in the face of strong floods, rather than send high energy waters into the canal, thereby causing system-wide damage. The most prominent such example is the roughly contemporary Marib dam in Yemen; see Brunner, Haefner 1986.

[82] As initially hypothesized by Jones 1855, 342.

[83] Minimally 20 km, from the start of the Wardak canal to the point where it joined the canal at Negub.

[84] For Navkur, see Morandi Bonacossi 2014; Idem 2016; Morandi Bonacossi, Iamoni 2016; for Erbil, see Ur *et alii* 2013; Ur, Osborne 2016.

Function of Nimrud's Khazir-Upper Zab Canal System

It has been argued that the canals of the Neo-Assyrian empire were one pillar of a durable plan to mold the landscape of the imperial core that was consciously carried out by royal planners over several centuries, alongside demographic engineering via forced deportation and urban planning, in contrast to the preceding urban landscapes of the Bronze Age, which were largely unplanned, although not unstructured.[85] Water systems can serve many functions, and it is likely that the system above Nimrud was intended to serve several, possibly evolving over the course of its long span of use.

The system undoubtedly fed irrigation systems. On one hand, the water may have been used for royal gardens, access to which was available only to the elite.[86] Within Nimrud, one of the authors[87] has proposed that the mostly likely location for textually-known royal gardens is at the base of the citadel to the east, where satellite imagery and topographic survey show a depression that appears to be vacant of collapsed mudbrick architecture.[88] This location has roughly the same elevation as the last identifiable segment of the canal to the south of Fort Shalmaneser, meaning that it would have been possible to bring water from the canal into the city without raising its level. To accomplish this task, engineers would have had to install an aqueduct over the Wadi al-Shor and a further two kilometers of canal, either through the city or along its southern wall. The available satellite and aerial imagery does not show any evidence for such a segment, which could have been relatively narrow, and therefore more easily effaced, than the upper parts of the system.

With the challenges to irrigation now revealed, it is probably preferable to seek the main royal gardens outside the city-wall to the south. The Khazir-Upper Zab canal was presumably finished by Ashurnasirpal II before his son Shalmaneser III built Fort Shalmaneser, and possibly before it had even been decided to locate the arsenal at the south-east corner of the city. The line of the city-wall in this area is unusually angular, and the defensive arrangements may have evolved. Later, in the reign of Esarhaddon, Area R of Fort Shalmaneser incorporated a postern-gate, approached by a corridor which probably featured paintings showing the king returning from a hunt.[89] So it seems not unlikely that there was a royal garden and hunting-ground south of Fort Shalmaneser, in the area close to Wadi al-Shor and the termination of the canal.

The same topographic challenges would have applied to the use of the canal water within the city for human use, whether through consumption, washing, or ritual use. If the canal was to be a source, it would have required the people of the city to come to it with water containers, rather than water flowing into the city.

Less ambiguous is the system's role in the irrigation of orchards and fields. Evidence comes from the inscriptions of Ashurnasirpal, but also from the canal itself, which acts to maximize the downslope (i.e., irrigable) area to its left by following the contours closely. Further evidence comes from the slight traces of secondary canals on the Tigris terraces. The alimentary potential of the canal, and its implications for the sustainable population of Nimrud, were the subject of Oates' initial study, from which he concluded that even with the addition of the floodplain and terrace irrigated lands, the city still would have required import of staple crops.[90] Our reassessment of the course of the canal adds increased spatial accuracy to its reconstruction (Fig. 13), and reveals it to be a far smaller area of irrigated terrace than was assumed by Oates. Far from challenging his conclusions, the reassessment offers greater support to his conclusion that the canal's irrigated area alone was insufficient to sustain the population of the new city.

It may, however, be a mistake to consider the economic role of the canal only with reference to the fields that it watered. It is possible that the canal's transport role may have been just as significant, if not more so. Scholars have assumed that the Tigris valley and immediately adjacent alluvial plains upstream from Nineveh were the source of the crops that sustained its population.[91] The flow of the river would bring products from producer areas to the city of consumers. Nimrud certainly took advantage of this flow, but it may have also exploited the broad and reliably rain-fed plains in its northeastern hinterland.

The Navkur plain is fifty kilometers north-northeast of Nimrud; it is broad and relatively flat, with the multi-period site of Tell Gomel at its center (see Fig. 1). The various tributaries of the Khazir River flow through it and join together at its southern limit.[92] The plain receives a much higher annual rainfall than the Tigris Valley, and therefore is a more reliable source of cereal crops. It is most famous for being the likely location of the defeat of the Persians by Alexander at Gaugamela. Centuries earlier, at the time of Sennacherib, Assyrian engineers dammed the Gomel, and channeled its waters into a canal that flowed along the northern fringes of the plain, ultimately to Nineveh.[93] This canal fed secondary channels that irrigated the

[85] Ur in press-a, b; Ur, Osborne 2016.
[86] Reade 1978, 1980.
[87] Ur 2013b, 14.
[88] Fiorina 2011, fig. 3; Ur 2013b.
[89] Reade 2013, 358.
[90] Oates 1968, 47-49.
[91] E.g., Wilkinson 2003, 128-131.
[92] Reade, Anderson 2013.
[93] Jacobsen, Lloyd 1935.

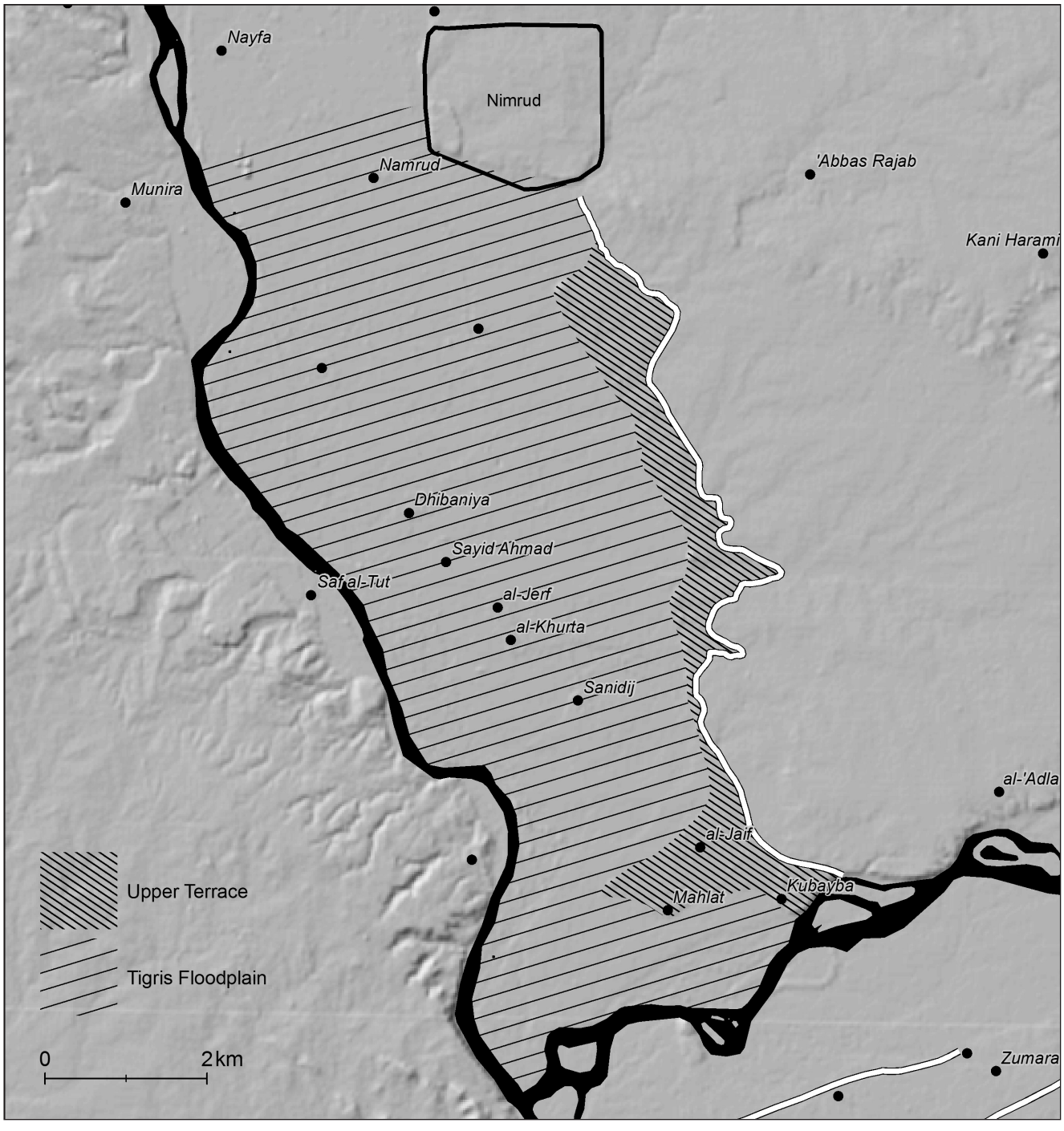

Fig. 13 - Potential areas irrigated from the canal on the Tigris floodplain and upper terraces below Nimrud. The size of the floodplain irrigation zone depends on the position of the Tigris, which was probably closer to the left terrace in the past.

plain and sustained its dense population in the Neo-Assyrian period.[94]

Most recently, the picture of Assyrian settlement and land use has gotten more detailed with the addition of two landscape features.[95] The first is a limestone quay on the right bank of the Gomel River, close to the village of Zinawa Ghazi. The cut-stone blocks are faced at the top and rusticated at the bottom; a few paving stones survived on top. The blocks themselves are similar in almost all ways to the stones of the aqueduct at Jerwan, with the exception of inscriptions. The second feature is a scattered heap of ashlar blocks, very similar in size to the Zinawa Ghazi

[94] Ur 2005; Morandi Bonacossi 2016.
[95] Morandi Bonacossi 2014.

feature, found on the left bank of the Khazir River near the Hasaniyeh bridge. The surveyors interpret these blocks as the remains of a similar quay feature that had been destroyed by recent gravel mining.

Daniele Morandi Bonacossi interprets these opportunistic finds as part of a network of river navigation on the Gomel and Khazir, across the Navkur Plain.[96] His assessment emphasizes their potential in transport of building materials, possibly for subsequent overland transportation to the northwest for the construction of the Jerwan aqueduct; most textual and art historical assessments of Assyrian river transport have also emphasized the movements of lamassu and the like.[97]

Although Navkur is more spatially proximate to Nineveh and especially Khorsabad, the position of these quays on the Gomel and Khazir Rivers actually connects them more closely to Nimrud, especially when one takes into consideration the Khazir-Upper Zab canal (Fig. 1). If one imagines that these two quays were only two of many points across the plain, where its produce could be loaded onto barges or *kelek*s for low-friction transport downstream, then the Navkur plain suddenly becomes the agricultural hinterland of Nimrud. The canal could have been simultaneously irrigating the left bank terraces of the Tigris while transporting the harvests of the rain-fed Navkur plain to consumers in Nimrud. This system would connect Nimrud to an extensive area of reliable agricultural production but would involve relatively little overland movement. This might help account for the known associations between Nimrud and Kurbail, a major provincial center generally thought to lie on or within reach of the Khazir.[98] Furthermore, the lower stretch of the canal is close to the lower Erbil Plain (Kilizu province in Neo-Assyrian times), another region that was probably heavily irrigated at the height of the empire.[99]

Such an interpretation raises a lot of issues, especially about the navigability of the Gomel and Khazir rivers as well as the Khazir-Upper Zab canal. Could water transport have navigated the subterranean segment at Qazakan? Today these rivers are highly seasonal, which would have had a great impact on navigability, if the same circumstances applied in the past. These issues will require dedicated research at some future time when it is possible to conduct ground-based investigations along the canal itself; remote sensing alone will not be sufficient.

This interpretation also raises questions of chronology. Were all of the functions of the Khazir-Upper Zab canal part of the original design of Ashurnasirpal's engineers? The Khinis-Jerwan irrigation zone was articulated elegantly with shipment points at Zinawa Ghazi and probably elsewhere; does this suggest that only under Sennacherib's son and successor Esarhaddon did the Navkur plain and Nimrud become economically integrated? Or might it suggest that this integration was already in place in the 9th century, when Ashurnasirpal urbanized Nimrud and commissioned the earliest version of the canal? If so, could the Khinis-Jerwan canal also have been of greater antiquity than previously appreciated, and perhaps was only rehabilitated by Sennacherib, despite his larger-than-life presence in the reliefs at Khinis? On present evidence, it is not possible to do more than pose these questions.

Conclusions: Nimrud's Water System in Context

A methodological conclusion involves the value of early observations by European observers. The observations of Felix Jones have proven to be remarkably accurate, and indeed his maps show a level of accuracy not matched before the availability of GIS and satellite remote sensing.

We can consider the Khazir-Upper Zab canal in comparison to other known Neo-Assyrian canal systems. In many ways, it fits comfortably among them, particularly in its scale and design. Its engineers sought to keep the canal at a constant gradient by following the contours of the terrain, which often resulted in considerable lengthening when a canal met a wadi; in this sense, the Tigris terrace segments show a close similarity to the canals near Faida and Jerwan, north of Nineveh. On occasion, the designers created deep cuts through watersheds; the cut near Kubayba has similarities to the earthworks near Maltai, Bandwai, and Tell Uskof in Sennacherib's "third stage".[100] Short distance tunneling through stone, such as we see at Negub, is similar to tunneling known from the Khinis canal head,[101] and possibly also near Bandwai.[102] Even the subterranean segment between Qazakan and Abzakh is paralleled by Sennacherib's channel between the Bastora Chai and Erbil.[103]

What is unique, however, is the degree to which all of these elements appear in the same canal system, and that is probably due to the great age and use life of the canal. Indeed the Khazir-Upper Zab canal is the longest-lived Assyrian canal in the imperial core, potentially in operation for nearly three centuries.[104]

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[96] Morandi Bonacossi 2014 and personal communication.

[97] See reviews in Fales 1993; Idem 1995.

[98] Reade, Anderson 2013, 47; Radner 2006.

[99] Ur *et alii* 2013, 106-108 and especially fig. 13; Ur, Osborne 2016.

[100] Reade 2000, 2002; Ur 2005, 327-333.

[101] See Jacobsen, Lloyd 1935-1949.

[102] Reade 2002.

[103] Safar 1946, 1947.

[104] Other systems in the Tigris Valley and Makhmur plains are not yet firmly dated (Altaweel 2008; Mühl 2013). A longer-lived canal may be the Khabur system associated with Dur-Katlimmu (see Kühne 1990; Idem 2010; Idem 2012), but its Middle Assyrian use phase is debated.

This situation is unsurprising, given Nimrud's enduring cultural and political significance in the Neo-Assyrian state.

The Khazir-Upper Zab canal also testifies to the dynamism of the landscape, not only since the Neo-Assyrian Empire, but during it. The isolated surviving segments, especially along the Upper Zab, took their present disjointed form as a mobile river scoured its terraces and removed some canal traces. The elevation of these surviving segments, high above the current level of the Upper Zab, seems to attest to substantial down-cutting by the river, which may be the result of a changing climate. If the canal were short-lived, it would not be possible to determine when these environmental shifts had occurred. The Khazir-Upper Zab canal had a long life, however, and its various repairs and extensions could be interpreted as responses by its engineers to environmental changes taking place during its use life.

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[105] See footnote 1 above.

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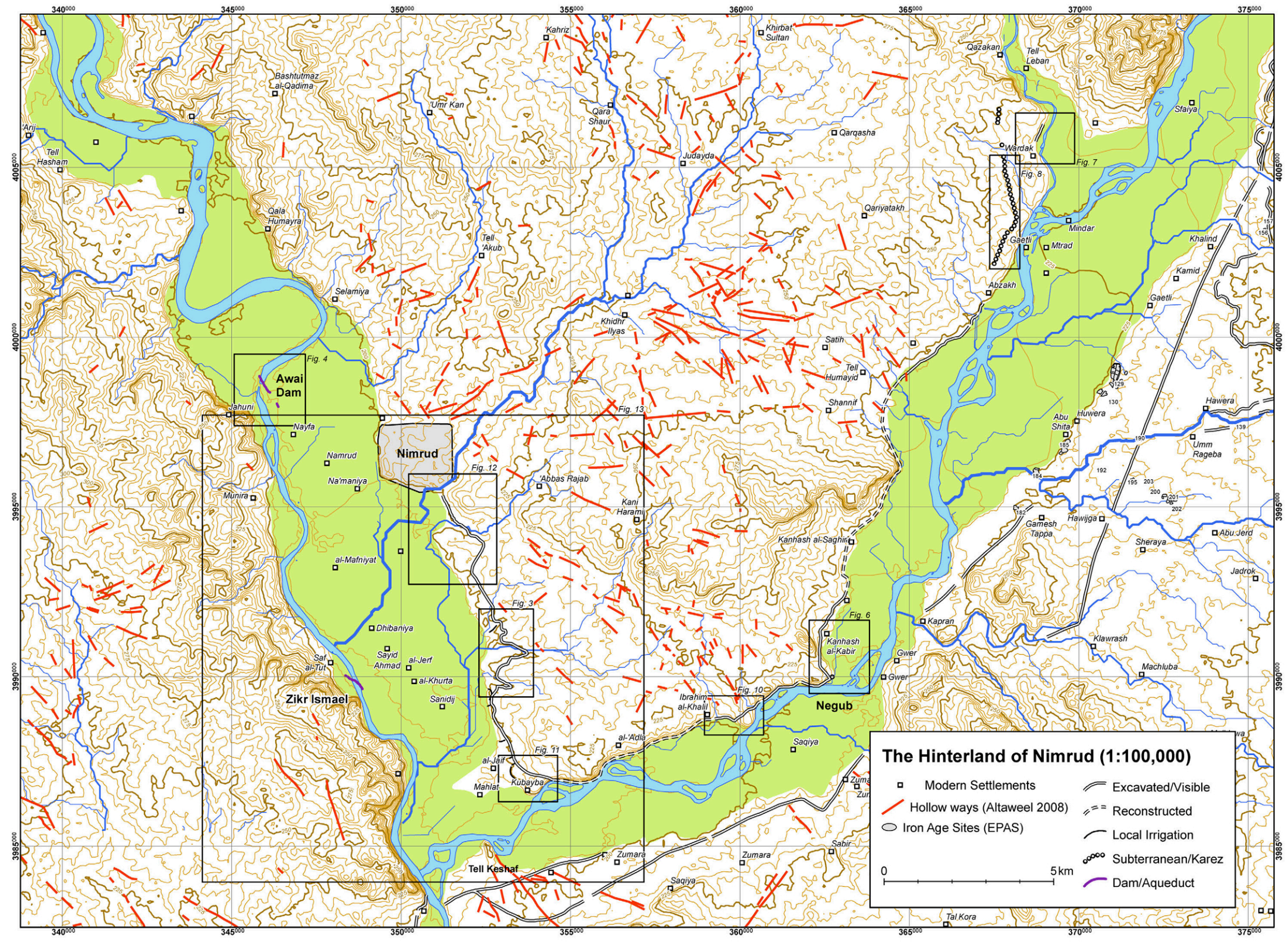
The Hinterland of Nimrud (1:100,000)
Modern Settlements
Hollow ways (Altaweel 2008)
Iron Age Sites (EPAS)
Excavated/Visible
Reconstructed
Local Irrigation
Subterranean/Karez
Dam/Aqueduct
0
5 km
Awai Dam
Nimrud
Zikr Ismael
Tell Keshaf
Negub
Fig. 3
Fig. 4
Fig. 6
Fig. 7
Fig. 8
Fig. 10
Fig. 11
Fig. 12
Fig. 13
Kahriz
Khirbat Sultan
Qazakan
Tell Leban
Sfaiya
Bashtutmaz al-Qadima
'Umr Kan
Qara Shaur
Qarqasha
Judayda
Wardak
Qariyatakh
Mindar
Gaetli
Mtrad
Khalind
Kamid
Abzakh
Qala Humayra
Tell 'Akub
Selamiya
Khidhr Ilyas
Satih
Tell Humayid
Shannit
Hawera
Huwera
Abu Shita
Umm Rageba
Jahuni
Nayfa
Namrud
Na'maniya
Munira
'Abbas Rajab
Kani Harami
Gamesh Tappa
Hawijga
Abu Jerd
Sheraya
Jadrok
Kanhash al-Saghir
al-Mafniyat
Kapran
Kanhash al-Kabir
Klawrash
Gwer
Machluba
Dhibaniya
Sayid Ahmad
al-Jerf
Saf al-Tut
al-Khurta
Sanidij
Ibrahim al-Khalil
al-'Adla
Saqiya
al-Jaif
Kubayba
Mahlat
Zumara
Sabir
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Impaginazione a cura di Stefano Rolle

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NEL MESE DI LUGLIO 2016
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