Laying the groundwork: the 2020 survey season and community outreach programme at the Kerma Period settlement site es-Selim R4 in the Northern Dongola Reach

Elizabeth Minor, Sarah M. Schellinger, Christopher Sevara, Ahmed El-Ameen Ahmed El-Hassan (Sokhari), and Sajda Adam Omer Ahmed

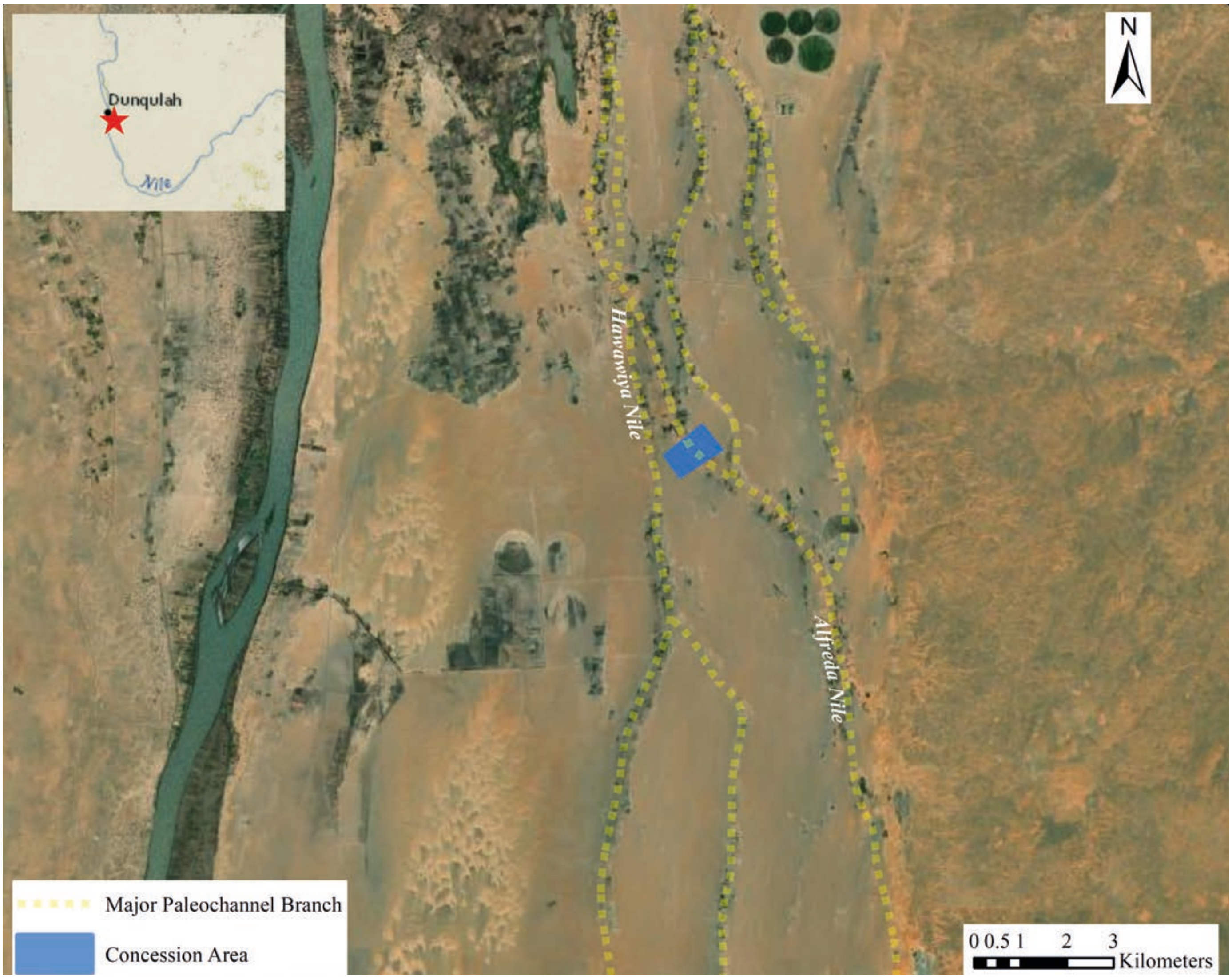

Figure 1. The ancient Sudanese settlement site of es-Selim R4 (ESR4).

Introduction

The ancient Sudanese settlement site of es-Selim R4 (ESR4) (Figure 1) is located in the Northern Dongola Reach, in which the wide floodplain was braided with Nile palaeochannels, supporting a dense network of Kerma Period settlements (Welsby 2001). The overall development of Nubian settlements during the Kerma Period is currently known through limited archaeological examples, concentrated in political centres in the Dongola region. The longest sequence of Kerma settlement development is at the city of Kerma, which captures the complexity of a religious and political capital along with residential sectors (Bonnet 2006, 2014, 2019). The ESR4 residents would have existed within a network of provincial population centres that were tied to the religio-political capital at Kerma. This Kerma settlement site presents the opportunity to investigate how factors of environmental, social, and political change intersect to affect one of the provincial population centres over the course of 1000 years.

Our initial findings presented here are based on a preliminary site survey in March 2019 and the first survey season held in January 2020. ESR4 was first documented by the Sudan Archaeological Research Society during the

Northern Dongola Reach Survey (Welsby 2001, 145). Our first site visit in 2019 confirmed evidence of occupation from at least the *Kerma Ancien* (2500-2050 BC), into the *Kerma Moyen* (2000-1750 BC), and through the *Kerma Classique* (1750-1500 BC). Occupation may have continued into the period of New Kingdom Egyptian colonisation (1500-1290 BC) or beyond. The goals of the 2020 field season focused on evaluating the preliminary interpretation of historic remote sensing imagery, deliminating features within the concession, collecting representative surface finds, and establishing relationships with members of the local community.

Historic Remote Sensing Data Interpretation and In-Field Investigation

Prior to fieldwork, we consulted the Google Earth Professional platform, the Copernicus Open Access Hub, and the United States Geological Survey (USGS) EarthExplorer archives for historical remote sensing imagery (Figure 2).[123] Together with archaeological and paleoenvironmental information from prior work in the region (Welsby 2001; Welsby *et al.* 2002; Macklin *et al.* 2013; Woodward *et al.* 2015) the resulting data provided an overview of land use change in the region dating back *c.* 50 years as well as indications of current and historic environmental features and conditions. Within the concession, historic imagery was used to reconstruct feature boundaries, and to relocate features not visible during the 2020 field season. The visible extents of presumed settlement mound features were digitised from CORONA satellite imagery acquired from the USGS and their boundaries were checked in the field. In the case of the westernmost settlement component, it was observed that the boundary of the settlement may

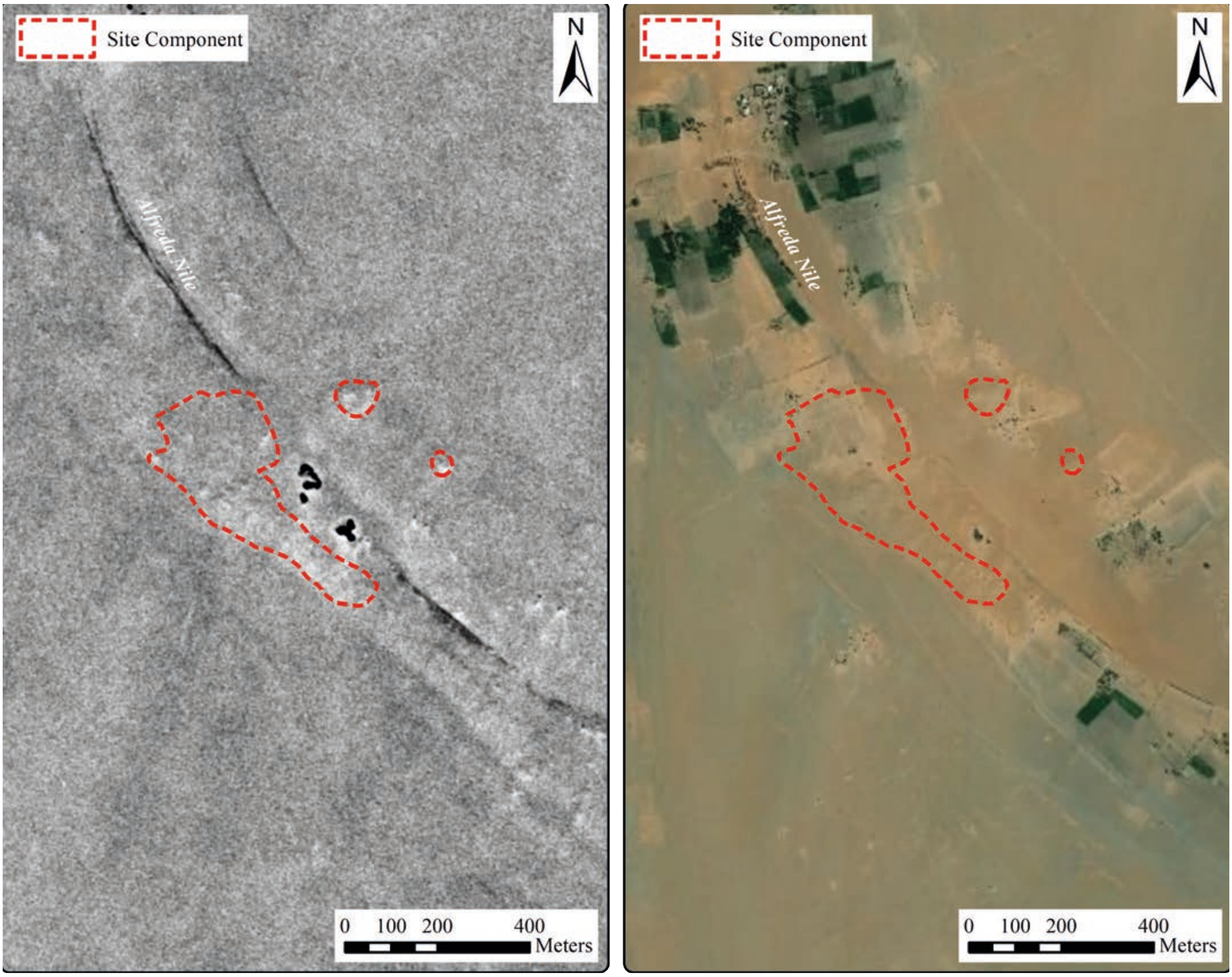

Figure 2. Satellite imagery from 1968 (Left) and 2018 (Right) showing the ESR4 concession and vicinity. Outlined high-contrast features correspond to main site components identified at ESR4 (image source: (L) USGS (R) © Google Earth, 2018).

[1] https://www.google.com/earth/ (25 May 2020).
[2] https://scihub.copernicus.eu/ (25 May 2020).
[3] https://earthexplorer.usgs.gov/ (25 May 2020).

have extended approximately 160m northwest of its current visible location, extending into a modern field system. Artefacts from periods contemporary to those recorded at the settlement component appear to corroborate the interpretation that the boundary of the settlement extends significantly to the northwest. However, it is difficult to estimate the degree to which they may have been transported during creation of the modern field system. Large linear features (C1004, detailed below) visible in the central part of the concession during a visit in 2019 had been covered by wind-blown sand, however their extents were able to be partially relocated using recent high resolution satellite imagery.

Outside of the area, a correlation was observed between high contrast features in the historic remote sensing imagery and corresponding locations visited in the field. Using archaeological data from prior work in the 1990s for morphological information about site locations, extents, and composition, several features turned out to be of historic and/or prehistoric origin. This includes a mound feature *c.* 600m southeast of the concession along the eastern bank of the Alfreda Nile palaeochannel with visible surface extents of *c.* 75m north/south and 65m east/west. Bone, ceramic and groundstone fragments were observed on the mound surface, some exhibiting little signs of weathering and in the vicinity of recent disturbance. Diagnostic ceramic material present on the surface was provisionally dated to the *Kerma Moyen*/*Classique* Periods.

Land use along both sides of the modern Nile channel has intensified since the 1960s, when the CORONA imagery captured the beginnings of what appears to be large-scale modification of the es-Selim basin. A steady increase in modern field system development along the Alfreda and Hawawiya palaeochannels appears to accelerate from the mid-1980s, with the excavation of a large canal system to the south of the concession bringing water for large scale industrial agricultural development starting in the early 2000s. The increase in scale and intensity of agricultural production at this time represents a significant change to the land surface in the area of the former Nile channels. The impacts of these changes were observed when visiting other previously identified archaeological sites outside of the concession, where modern agricultural encroachment has either partially or fully impacted visible remains of archaeological resources.

GNSS Survey and Aerial Photography Methodology and Results

All survey location recording was done using a handheld GNSS receiver (Leica Zeno 20). The horizontal and vertical accuracy was stored for each shapefile and averaged 70cm horizontal and 1m vertical accuracy. For each of the major site components mapped, the outline of the area and at least two intersecting transects were recorded. Components were then outlined by walking the defined perimeter with a GNSS sensor set to automatically record waypoints at 0.5m intervals.

Aerial photography was carried out with the goal of creating orthophotos, photogrammetric 3D models, and DEMs (Digital Elevation Models). A modified carbon-fibre extendable fishing pole with attached Ricoh GR 2 camera was used for detail imaging of component C1006. A DJI Phantom 4 Pro drone was used to collect imagery to generate a high resolution orthomosaic and 3D model of the concession. We used the automated flight management application DroneDeploy[4] to ensure rapid, consistent, and seamless coverage of the project area. Ground control points made from 30cm wide plastic circles with Quick Response (QR) codes adhered to them for automated identification were distributed around the concession area. Processing of all aerial imagery was carried out using Agisoft Metashape,[5] yielding an orthomosaic and corresponding DEM at a ground resolution of 0.1m. The resulting orthoimage was enhanced using a local contrast enhancement algorithm (CLAHE) (Zuiderveld 1994) to improve visibility of features (Figure 3).

In-Field Survey: Site Component Descriptions

Six main site components were identified (Figure 4): three occupation areas on the higher adjacent *geziras* and three architectural features lower in the dry palaeochannel that runs along a southeast to northwest axis. Each area was assigned a C (component) number beginning with 1001.

Site Component C1001 (Mound A) (Figures 4 and 5) is the smallest settlement mound located in the eastern corner

[4] https://www.dronedeploy.com/ (24 May 2020).
[5] https://www.agisoft.com/ (24 May 2020).

Figure 3. Contrast enhanced orthoimage mosaic created from drone imagery collected during the 2020 field season.

of the concession. It is distinguished by a concentration of pebbles, dark rocks, pottery sherds, and a few areas of decayed animal bone. The dark rocks may be evidence of underlying stone architecture (Welsby 2001, 145), but they are no longer *in situ* to determine wall layouts from surface survey.

Site Component C1002 (Mound B) (Figures 4 and 6) is a double-peaked settlement mound located *c.* 200m northwest of C1001. This mound is more prominently visible on the landscape as it is closely bounded by the sandy palaeochannels to the south and north. Similar to Mound A, the surface has a concentration of pebbles, dark rocks, pottery sherds, and decayed animal bone. The top of Mound B offers the best view of the surrounding area, particularly of any movement coming along the palaeochannels. In terms of preservation, Mound B sustained prior superficial damage from a motorised scoop, possibly related to the construction of a track along the northwest edge of the concession, and subsequent field development could expand to this area and impact the stability of the site.

Site Component C1003 (Settlement Area C) (Figures 4 and 7) is a long, oblong area with evidence of settlement and production zones. This component is notable due to its large size and amount of surface material visible. The highest point of C1003 is almost directly to the southwest of C1002 and also provides a vantage point for observing all activities in the area. The perimeter outline presented here may slightly overestimate the confines of the ancient settlement, especially in the northeast corner due to newly planted watermelon fields hindering survey.

The north-eastern end of this settlement area appears to have extended into what is now an active field system. The middle section of the urban area also has significant surface damage from the start of field clearing as evidenced by hundreds of small mounds. Despite these disturbances, the underlying occupation layers are probably still intact in both of these areas. The southern end of the settlement area was not disturbed and the presence of pebbles, black rocks, and occasional pot sherds suggests that the occupation is preserved here at deeper levels. An area of note in the urban sector is locus C1003-L1004. This area has a high concentration of surface sherds, a triangle of mudbrick walls, and another section of mudbrick that is reddened from burning activity. Some of the sherds are also scorched, possibly suggesting that this was a pottery production zone. The prevailing winds blow to the southwest in this area, which would have redirected all

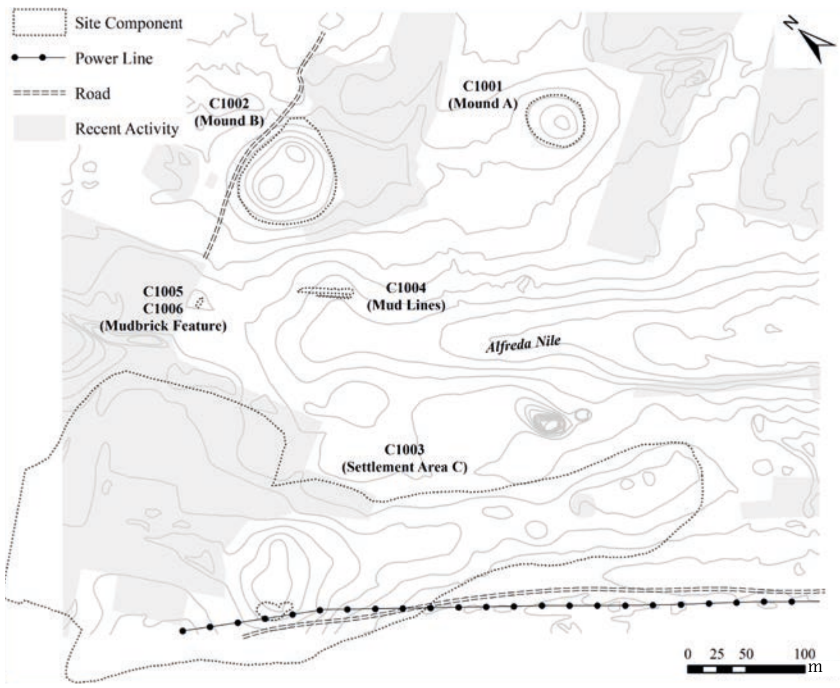

Figure 4. Topographic map of principal site component locations and modern activities at ESR4. Contour interval: 0.5m.

Figure 5. Site Component C1001 (Mound A).

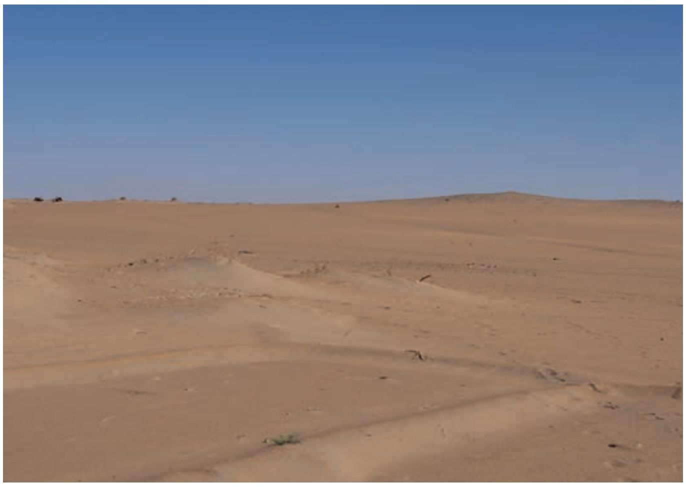

Figure 6. Site Component C1002 (Mound B).

of the smoke away from the settlement.

Site component C1004 (Figures 4 and 8) consists of two parallel mud lines, perhaps walls, in the palaeochannel between C1002 and C1003. The mud line features are designated as locus C1004-L1001. Both linear features run parallel to the course of the palaeochannel, from northwest to southeast. The larger feature is 3m in thickness, while the thinner feature is *c*. 0.75m, with a distance of 4.8m between them. Both mud features have consistent widths and distinctly vertical side surfaces, but no outlines of bricks or mortar are observable. A 2m wide section of both the thick and thin features was brushed to remove the windblown sand. Some reddening of the mud was visible on the southwest face of the thicker feature. More pronounced reddening and a hardened sloped surface with a round footprint was found on the thinner feature. These are either mudbrick walls or are carved out from the natural palaeochannel Nile mud embankment. The regularity of the linear features and the evidence of burning activities makes it certain that they are human-made or -modified.

Site component C1005 (Figure 4) is an area with possible mud or mudbrick features that is now overlaid with windblown sand, cow dung, and goat pellets. Preliminary brushing did not produce any identifiable mudbrick features. The overburden in the area made it difficult to investigate further during this short survey season. Two fragments of a groundstone and a grinder were recovered from this area.

Site component C1006 (Figures 4 and 9) is a symmetrical mudbrick feature made up of four rounded rectangles. A gap of approximately 200-300mm separates each half of the feature, which is made of two rounded rectangles in a T-shape. The walls are a single brick thick and curved handmade bricks are used for the corners. The largest brick dimensions are 320mm long, 120mm wide, and 120mm high, which is notably similar to some brick dimensions at Doukki Gel (Bonnet 2019, fig 60). Preliminary brushing uncovered a high concentration of goat pellets around and within the wall features. The north-eastern central cell was full of windblown sand and this was removed by brushing and a shovel to a depth of 100mm. This uncovered a small patch of hardened mud that may extend to the full size of the cell at a lower depth. Large black rock blocks are located within the cells and along the northwest edge of the feature. No pottery was recovered. This feature warrants further investigation to determine if it was constructed during ancient occupation, and therefore could be a type of architecture related to the rounded style found at Doukki Gel (Bonnet 2019, figs 35 and 60), or if it is from historical site uses. If this area is more recent in date, it can provide an interesting point of connection for modern area residents and local oral history.

In-Field Survey: Surface collection

Surface collection was carried out in order to recover diagnostic material from each of the main site components (Figure 10). For C1001 (Mound A) and C1002 (Mound B) their smaller sizes allowed for more comprehensive surface collections. For C1003 (Settlement area) we were highly selective in collection due to its large size and our small team for this initial season. Site component areas C1004, C1005, and C1006 had little to no visible surface finds due to the thick sand overburden. This initial surface collection focused on diagnostic sherds with the goal of initial characterisation of site chronology, and find locations were recorded with the GNSS receiver for incorporation into

Figure 7. Site Component C1003 (Settlement Area C).

Figure 8. Site Component C1004, parallel mud features.

future large scale survey analysis. Overall, the ceramic material was consistent with the generally *Kerma Moyen* to *Kerma Classique* pottery types first identified by Welsby's team (2001, 145) and by the current mission in 2019 (Figure 11). Preliminary analysis shows that area C1003 has the highest observable concentration of *Kerma Classique* beakers, especially in the northern section that is now under a new field.

Community outreach

The final goal of the ESR4 2020 season included community outreach and establishing collaboration through community-based participatory research. As archaeologists working in the modern community of es-Selim, we seek to situate ourselves to promote 'entangled' collaboration through the model of community-based participatory research (Atalay 2012; Fushiya and Radziwiłko 2019; Minor *et al.* 2021). We recognise that our team's ideas of heritage and the values placed on the material remains of past actions may not always coincide with those of people living in the landscape today (Kleinitz and Merlo 2014), and that community engagement may help to align diverse interests.

Figure 9. Site Component C1006, rounded mudbrick feature.

While undertaking the research goals outlined above, this project seeks to build formal and informal community relationships that will inform the research agenda undertaken in subsequent seasons.

Our initial community outreach was designed to set a foundation for positive collaboration for the duration of the project. We found that community members were readily willing to participate in meetings, and the fact that many were familiar with Welsby's work at Kawa helped facilitate relationship building. Community meetings involved introducing ourselves, the specialised equipment we used, and opening a conversation about the project research goals.

In order to address community priorities in our future research, we asked a set of questions to get input on the project's research programme. When asked which of our research themes they were the most interested in learning about first, community members responded that their priority is to know more about the ancient climate and environment, especially how it relates to their region today. When asked how they would like to receive updates about our research results, women said they preferred a projected video to be watched as a group, and men wanted pamphlets because they can be shared with others in the area even when the team is not there. We all agreed that perhaps yearly updates as pamphlets, and then a video after a few years is the best compromise. When asked what they would like international audiences to know about Sudan and their community, the men said 'What you see with your own eyes', and the women said 'Our way of dressing (*tob*)'. We ended the meeting with an invitation to bring any concerns or questions to us as the project progresses. During the course of the survey season, we spoke with other landowners and farmers in the area and held similar informal conversations. We hope that this model of community engagement has set a strong foundation to both stop agricultural encroachment and to build into a deeper collaboration for our research.

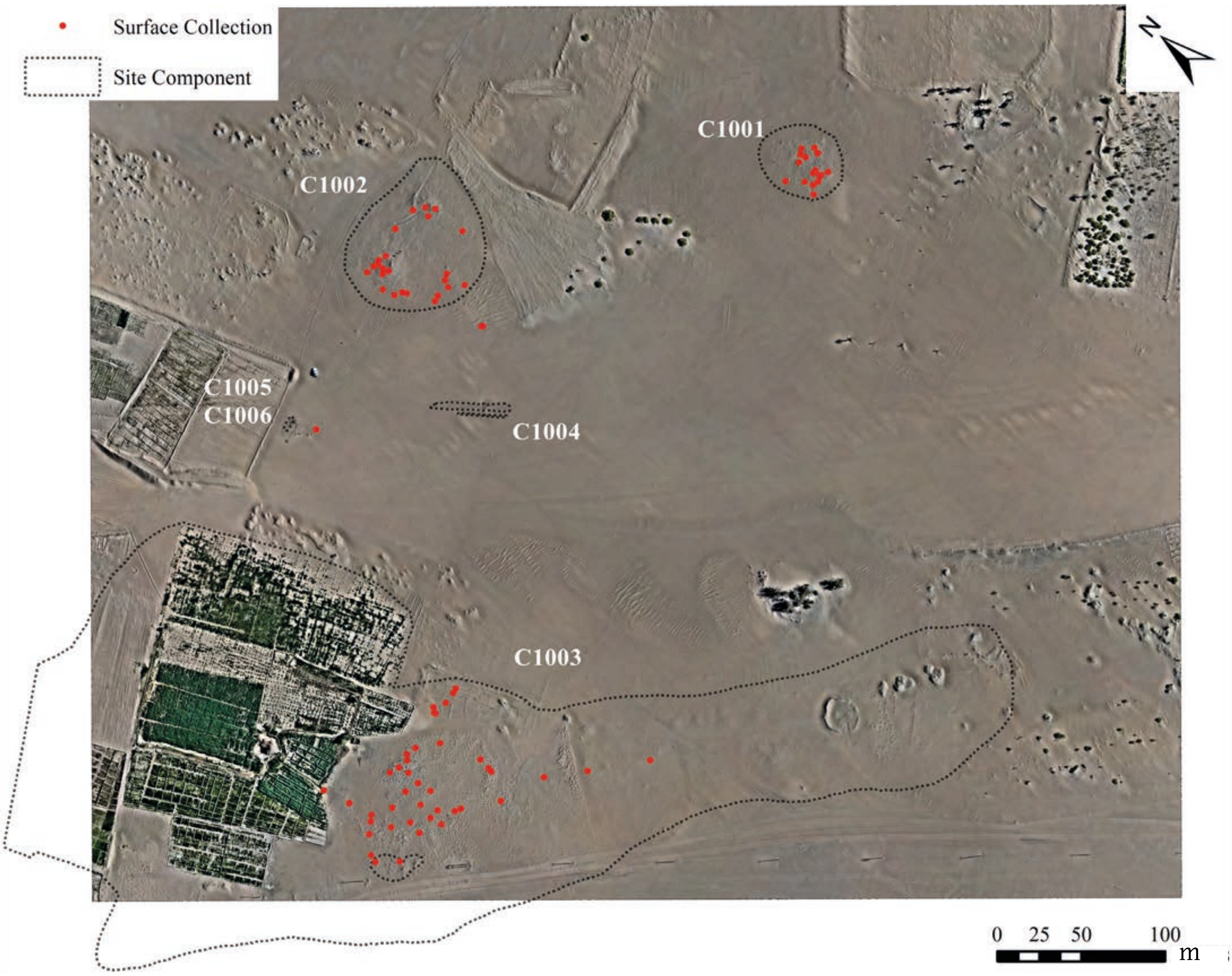

Figure 10. Location of surface finds collected during survey.

Figure 11. Selection of *Kerma Classique* pottery from C1003.

Discussion

Historic Remote Sensing Data Interpretation

Preliminary results from our fieldwork support our initial estimations of the added value of incorporating historic and modern remote sensing data analysis into our research design to understand the direct and indirect human and environmental impacts on preservation and visibility of archaeological features at local (i.e. ESR4) to regional scales. The extensive information already provided by previous survey and paleoenvironmental reconstruction work in the region (Welsby 2001; Welsby *et al.* 2002; Macklin et al. 2013; Woodward *et al.* 2015; Herbich 2019), will also help to calibrate interpretations of remote sensing data.

Significant agricultural development around Dongola/es-Selim between 1968 and the late 1990s, when Welsby (2001) and his team were in the field, and in the subsequent 20+ years has greatly affected archaeological resources in some areas. We are faced with the challenge of recovering as much information as possible about prior activity in the area while respecting current occupants' needs. Incorporating a suite of minimally invasive approaches that include historical imagery will also be helpful in this regard. Site and landscape components can be reconstructed through interpretation and 3D modelling, providing us with the ability to acquire further metric information about prior visible extents of archaeological resources and quantify recent changes to the landscape (Sevara *et al.* 2018; Orengo *et al.* 2015; Sevara 2013). If substructure material still exists, it may be detectable through geophysical prospection, coring, and targeted sampling. Identifying these in a minimally invasive way will help us to develop strategies that can allow for the investigation of any remaining features with minimal impact on current agricultural practice.

Environmental Conditions

Identified as an area of primary interest to the neighbouring community, initial results confirm that targeted excavation at ESR4 will yield significant data about subsistence strategies in the face of changing environmental conditions. In the 1000 years under investigation, the climate of the Sahel changed from semi-arid to hyper-arid conditions (deMenocal and Tierney 2012). Human subsistence strategies adapted in response, and in ways that intersected with social and political contexts. In particular, the zooarchaeological and palaeobotanical data set within the settlement occupation sequence will provide key evidence for these social changes (Thompson *et al.* 2008; Monroe 2020; Shahat forthcoming). The Northern Dongola Reach Survey found a concentration of *Kerma Ancien* to *Classique* sites in the region, demonstrating that environmental change made the area inhospitable for prolonged human occupation after *c.* 1550 BC (Welsby 2001; Macklin and Woodward 2001; Honegger and Williams 2015; Macklin and Lewin 2015). Sites closer to the Nile, such as Amara West, underwent a long-term process of adjustment before abandonment due to climate change (Woodward *et al.* 2017; Spencer *et al*. 2012). The community at ESR4 could have faced similar slow-acting environmental changes, as the water table in the Nubian Sandstone Aquifer experienced a delayed drop to an equilibrium level following the cessation of the humid period (Voss and Soliman 2014), and residents would have sought resilient subsistence strategies, as seen in later Nubian periods as well (Herrick 2018).

Kerma regional relationships

The Kerma settlement at es-Selim R4 has the potential to supply new evidence that addresses provincial and interregional relationships. The connections between provincial Kerma communities with the political/religious centre of Kerma is primarily, and only partially, understood through a comparison of regional Kerman mortuary practices (Akasha (von Känel 1980), Sai Island (Gratien 1986), Mirgissa (Vila 1970), and Ukma West (Vila 1987)).

Detailed cultural sequences for Kerma settlement sites are less represented, and include Sai Island (Gratien and Olive 1981; Hesse 1981; Hildebrand and Schilling 2016; D'Ercole *et al.* 2017) and Gism el-Arba (Gratien 1999; 2003; Chaix 2007). Understanding interregional connections through a provincial lens also holds great potential to answer questions about the nature of the political relationship between the Kerma Kingdom and polities to the North (Egyptians and Hyksos) and South (Sub-Saharan Africa). Nubian states, especially Kerma, are not often considered as active participants in Bronze Age 'world systems,' despite archaeological evidence demonstrating deep political and economic connections (Smith 2003a; Hafsaas-Tsakos 2009; Minor 2012, 199). The site also holds potential for a regional perspective on the nature of socio-economic interactions between Kermans and Egyptians at the end of the *Kerma Classique* Period and start of New Kingdom Egyptian occupation. Located in the region beyond the Egyptian temple-town colonial system and the fluid cultural entanglements of Tombos (Smith 2003a, 2003b; Buzon *et al.* 2016), ESR4 has the potential to add to the evidence of complexities of colonial experiences.

Community Engagement

Our initial community engagement has provided insight into how people living in the area relate to past remains of human activity in the landscape and what they would like to better understand about past human occupation and environmental conditions. This was evident when people described their encounters with archaeological resources in the area: using their own toponyms that incorporate their perspectives and interpretations of past land use or naming things in relationship to family or agricultural practice. Continuing to understand and incorporate these perspectives into our research is a key goal as the project progresses.

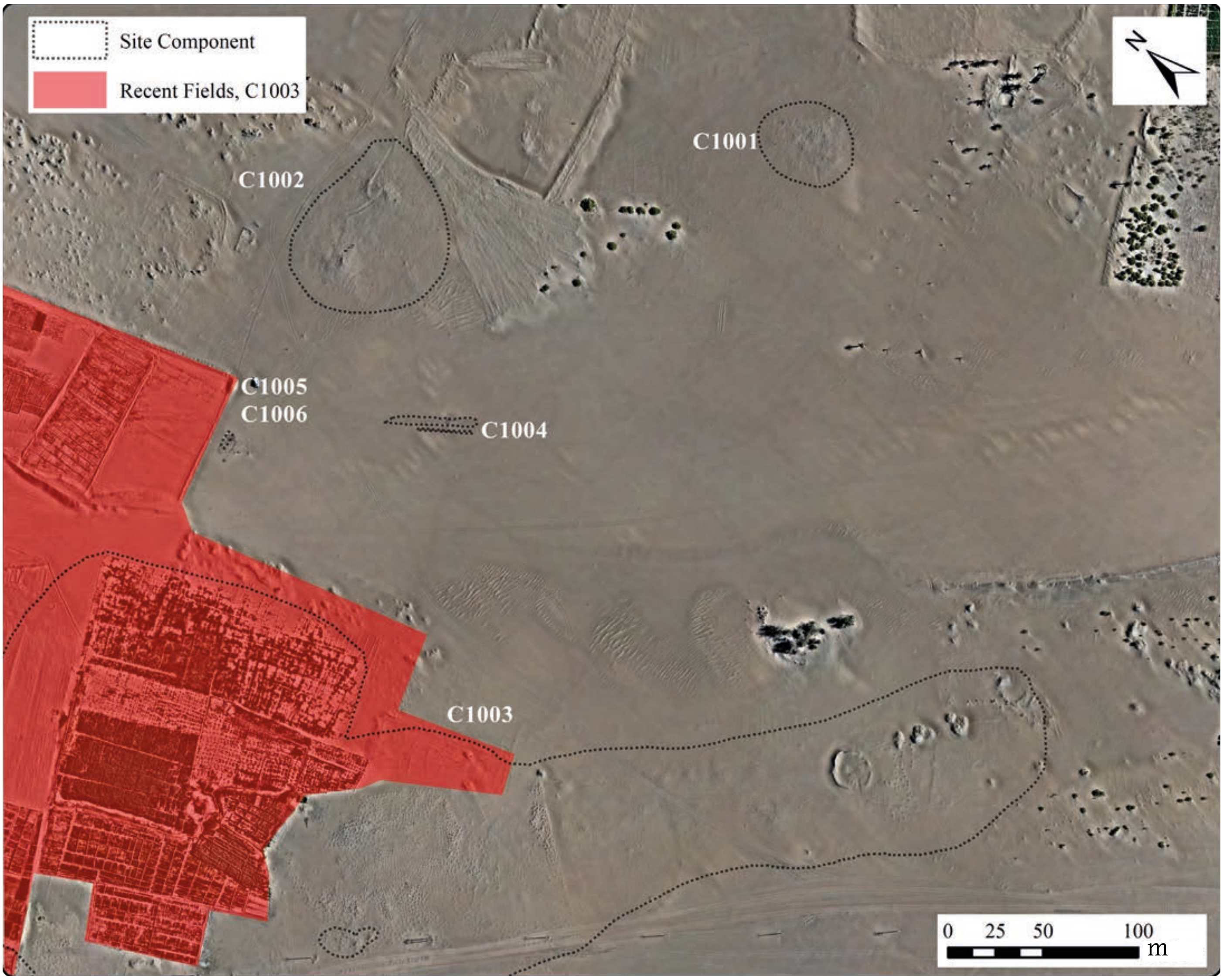

Figure 12. Visible impacts of recent agricultural activities on site components of ESR4. New field construction (outlined in red) near C1003 has the potential to significantly impact the settlement area in the near term.

Conclusions and Future Work

Recent acceleration of agricultural practice has had a direct impact on surface conditions at ESR4; while mounds to the east of the palaeochannel are so far largely untouched by agricultural development, the westernmost settlement area has seen significant encroachment. Therefore, the most critical site conservation issue is the building of new fields along the northern edge of the site. Fields are now within a few metres of what appears to be the central portion of the settlement area and have subsumed portions of possible activity zones on outlying edges (Figure 12). Discussion with local landowners and land users has resulted in a verbal agreement to temporarily halt agricultural activity in the area so that we may focus on investigation of this portion of the site in the next field season (Figure 12). Ultimately, we aim to build a more coherent picture of past rural development at ESR4 and the wider Northern Dongola Reach, and to work with present stakeholders at all levels in order to develop awareness of archaeological resources and plan for future sustainable development in the region.

Acknowledgements

The goals of the 2020 field season at ESR4 were largely achieved through a collaborative effort between all groups involved. We were able to document the current conditions at the site, perform initial data collection and analysis of surface materials, and engage with land owners and land users to open dialogues about how best to proceed with future activities in the region. We would particularly like to thank: Al-Hassan Ahmed and the National Corporation for Antiquities and Museums, Sudan for their project support; the Farah Family and the Nahla Awlad el-Farah Community for their participation and welcome; Saleh Mohammed Saleh Wed Alsafir for operational support; Martin Fera for loan of the pole and Ricoh equipment; Geoff Emberling and Kate Rose for loan of drone and support; Laurel Bestock for the use of the URAP digital field recording form system; Wellesley College for their financial support; and to the reviewer for their insightful comments.

References

Atalay, S. 2012. *Community-based archaeology: research with, by, and for indigenous and local communities.* Berkeley.

Bonnet, C. 2006. 'Les établissements de cultures Kerma', in I. Caneva and A. Roccati (eds), *Acta Nubia, Proceedings of the X International Conference of Nubian Studies (Rome, 2002)*. Rome, 15-20.

Bonnet, C. 2014. *La ville nubienne de Kerma. Une capitale nubienne au sud de l'Egypte*. Lausanne.

Bonnet, C. 2019. *The Black Kingdom of the Nile*. Cambridge.

Buzon, M., S. T. Smith and A. Simonetti. 2016. 'Entanglement and the Formation of the Ancient Nubian Napatan State', *American Anthropologist* 118(2), 284-300.

Chaix, L. 2007. 'New data about rural economy in the Kerma culture: the site of Gism-el-Arba (Sudan),' *Studies in African Archaeology* 9, 25-38.

D'Ercole, G., J. Budka, J. H. Sterba, E. A. Garcea, and D. Mader. 2017. 'The successful 'recipe' for a long-lasting tradition: Nubian ceramic assemblages from Sai Island (northern Sudan) from prehistory to the New Kingdom,' *Antiquity* 91(355), 24-42.

Fushiya T. and K. Radziwiłko. 2019. 'Old Dongola community engagement project: preliminary report from the first season', *Sudan & Nubia* 23, 172-181.

Gratien, B. 1986. *Saï I: la nécropole Kerma*. Paris.

Gratien, B. 1999. 'Some rural settlements at Gism el-Arba in the Northern Dongola Reach,' *Sudan & Nubia* 3, 10-12.

Gratien, B. 2003. 'L'habitat 2 de Gism el-Arba. Rapport préliminaire sur un centre de stockage Kerma?,' *Cahier de Recherches de l'Institut de Papyrologie et d'Egyptologie de Lille* 23, 29-43.

Gratien, B. and M. Olive. 1981. 'Fouilles à Saï: 1977-1979,' *Cahier de Recherches de l'Institut de Papyrologie et d'Egyptologie de Lille* 6, 69-169.

Hafsaas-Tsakos, H. 2009. 'The kingdom of Kush: An African centre on the periphery of the Bronze Age world system', *Norwegian Archaeological Review* 42(1), 50-70.

Herbich, T. 2019. 'Efficiency of the magnetic method in surveying desert sites in Egypt and Sudan: Case studies', in R. Persico, S. Piro, and N. Linford (eds), *Innovation in Near-Surface Geophysics*. Elsevier Inc., 195-251. [https://doi.org/10.1016/b978-0-12-812429-1.00007-6]

Herrick, H. M. 2018. *85Sr/86Sr Analysis as a Method to Explore Human Ecology and Forest Resilience in Ancient Meroe, Sudan.* Master's Thesis. University of Arizona, Tucson.

Hesse, A. 1981. 'L'enclos SAV2 de l'île de Saï (Soudan) in Etudes sur l'Egypte et le Soudan anciens,' *Cahier de Recherches de l'Institut de Papyrologie et d'Egyptologie de Lille* 6, 7-67.

Hildebrand, E. A. and T. M. Schilling. 2016. 'Storage amidst early agriculture along the Nile: perspectives from Sai Island, Sudan', *Quaternary International* 412, 81-95.

Honegger, M. and M. Williams, 2015. 'Human occupations and environmental changes in the Nile valley during the Holocene: The case of Kerma in Upper Nubia (northern Sudan)', *Quaternary Science Reviews* 130, 141-154. [https://doi.org/10.1016/j.quascirev.2015.06.031].

Von Känel, F. 1980. 'III. Catalogue des Tombes', in C. Maystre, *Akasha I*. Geneva, 67-199.

Kleinitz, C. and S. Merlo 2014. 'Towards a collaborative exploration of community heritage in archaeological salvage contexts: participatory mapping on Mograt Island, Sudan', *Der antike Sudan. Mitteilungen der Sudanarchäologischen Gesellschaft zu Berlin* 25, 161-175.

Macklin, M. G. and J. Lewin. 2015. 'The rivers of civilization', *Quaternary Science Reviews* 114, 228-244.

Macklin, M. G. and J. C. Woodward. 2001. 'Holocene Alluvial History and the Palaeochannels of the River Nile in the Northern Dongola Reach', in D. A. Welsby (ed.), *Life on the Desert Edge. Vol. I.* Sudan Archaeological Research Society Publication No. 7. London, 7-13.

Macklin, M. G., J. Woodward, D. Welsby, G. Duller, F. Williams, and M. Williams, 2013. 'Reach-scale river dynamics moderate the impact of rapid Holocene climate change on floodwater farming in the desert Nile', *Geology* 41, 695-698. [https://doi.org/10.1130/G34037.1]

deMenocal, P. B. and J. E. Tierney. 2012. 'Green Sahara: African humid periods paced by earth's orbital changes', *Nature Education Knowledge* 3 (10), 12.

Minor, E. 2012. *The Use of Egyptian and Egyptianizing Material Culture in Nubian Burials of the Classic Kerma Period*. PhD dissertation, University of California, Berkeley. [Ann Arbor: ProQuest/UMI. (Publication No. AAT 3555826)]

Minor, E. P. Favela, M. Morris, K. Oliver, G. Oppenheim, and R. Tao. 2021. 'Digital Engagement Strategies for Community Based Archaeology: Crowdsourcing Excavation Planning and Gamification to Share Research Results for the Wellesley College Hall Archaeology Project', in E. Watrall and L. Goldstein (eds), *Digital Heritage and Archaeology in Practice*. Gainesville, forthcoming.

Monroe, S. L. 2020. *Colonizing Cattle: The Zooarchaeology of an Egyptian Military Frontier in Nubia*. PhD dissertation. UC Santa Barbara. Berkeley.

Orengo, H. A., A. Krahtopoulou, A. Garcia-Molsosa, K. Palaiochoritis, and A. Stamati. 2015. 'Photogrammetric re-discovery of the hidden long-term landscapes of western Thessaly, central Greece' *Journal of Archaeological Science* 64, 100-109. [https://doi.org/10.1016/j.jas.2015.10.008]

Sevara, C. 2013. 'Top Secret Topographies: Recovering Two and Three-Dimensional Archaeological Information from Historic Reconnaissance Datasets Using Image-Based Modelling Techniques', *International Journal of Heritage in the Digital Era* 2, 395-418.

Sevara, C., G. Verhoeven, M. Doneus and E. Draganits, 2018. 'Surfaces from the Visual Past: Recovering High-Resolution Terrain Data from Historic Aerial Imagery for Multitemporal Landscape Analysis' *Journal of Archaeological Method and Theory* 25, 611-642. [https://doi.org/10.1007/s10816-017-9348-9]

Shahat, A. Forthcoming. 'Biomolecular isotope and 14 carbon dates of Ancient Egyptian food offerings: case study from non-elite cemetery of Deir el Ballas', *Proceedings of the BAE-ISAAE 10-13 January 2019*. Cairo.

Smith, S. T. 2003a. *Wretched Kush. Ethnic identities and boundaries in Egypt's Nubian Empire*. London and New York.

Smith, S. T. 2003b. 'The University of California Dongola Reach Expedition, West Bank Reconnaissance Survey: 1997-1998', Kush 18, 157-172.

Spencer, N., M. Macklin and J. Woodward. 2012. 'Re-assessing the Abandonment of Amara West: The Impact of a Changing Nile?', *Sudan & Nubia* 16, 37-43.

Thompson, A. H., L. Chaix and M. P. Richards. 2008. 'Stable isotopes and diet at ancient Kerma, Upper Nubia (Sudan),'*Journal of Archaeological Science* 35(2), 376-387.

Vila, A. 1970. 'Le cimetière Kerma', in J. Vercoutter (ed.), *Mirgissa. Volume I.* Paris, 223-305.

Vila, A. 1987. *Le cimetière Kermaïeue d'Ukma Ouest.* Paris.

Voss, C. I. and S. M. Soliman. 2014. 'The transboundary non-renewable Nubian Aquifer System of Chad, Egypt, Libya and Sudan: classical groundwater questions and parsimonious hydrogeologic analysis and modeling', *Hydrogeology Journal* 22 (2), 441-468.

Welsby, D. A. 2001. *Life on the Desert Edge: Seven thousand years of settlement in the Northern Dongola Reach, Sudan, Volume I.* Sudan Archaeological Research Society Publication No. 7. Oxford.

Welsby, D. M. Macklin, and J. Woodward, 2002. 'Human responses to Holocene environmental changes in the northern Dongola reach of the Nile, Sudan', in R. Friedman (ed.). *Egypt and Nubia: Gifts of the Desert*. London, 28-38.

Woodward, J., M. Macklin, L. Fielding, I. Millar, N. Spencer, D. Welsby and M. Williams. 2015. 'Shifting sediment sources in the world's longest river: A strontium isotope record for the Holocene Nile', *Quaternary Science Reviews* 130, 124-140. [https://doi.org/10.1016/j.quascirev.2015.10.040]

Woodward, J., M. Macklin, N. Spencer, M. Binder, M. Dalton, S. Hay, and A. Hardy. 2017. 'Living with a changing river and desert landscape at Amara West', in N. Spencer, A. Stevens, M. Binder (eds), *Nubia in the New Kingdom: Lived Experience, Pharaonic Control and Indigenous Traditions*. British Museum Publications on Egypt and Sudan 3. Leuven, 225-255.

Zuiderveld, K. 1994. 'Contrast limited adaptive histogram equalization', in P. S. Heckbert (ed.), *Graphics gems IV*. Boston, 474-485.