SUDAN & NUBIA

The Sudan Archaeological Research Society Volume 27 2023

Statement concerning Sudan

The Kirwan Memorial Lecture

Reports

Studies

Darfur focus

Front cover. Block 1000.0049 from Naga (photograph courtesy Karla Kroper).
Above. Pottery jar with decoration of sorghum heads from BMC 60, Berber (photograph courtesy Mahmoud Suliman Bashir).

New work on landscapes of the Northern Dongola Reach

Christopher Sevara, Tim Kinnaird, Ahmed El-Ameen Ahmed El-Hassan (Sokhari)
and Sam Turner

Figure 1. Northern Dongola Reach, location of November 2022 Fieldwork. Red dots indicate sites tested during fieldwork, blue dots indicate sites mentioned in the text. Locations and nomenclature of sites follow Welsby 2001a. Approximate location of main Nile Palaeochannel syst-ems outlined in yellow. Channel nomenclature follows Macklin *et al.* 2013. Image source: ESRI/National Geographic.

Introduction

Environmental change can have a significant impact on the continued functioning of individuals and groups within established lifeways. For instance, management of and access to water in arid environments for communities with both agricultural/sedentary and pastoral/nomadic social structures has continually presented challenges that must be overcome if populations are to remain stable and thrive. Responses to changing climates and increasing aridity that work to secure such access for the improvement of e.g., agricultural yield or livestock by modifying approaches to how land is used (e.g., by digging wells, creating terraces for soil retention, or building complex irrigation) can be viewed as a physical manifestation of resilience in the face of such challenges (e.g., Lang and Stump 2017).

In the Northern Dongola Reach (NDR), extensive prior work has documented traces of numerous landscape infrastructure features such as wells, linear features in the base of palaeochannels, and mound features of indeterminate use, which can be indicative of significant change in the way people lived in and utilised their local environments (Welsby 2001a; 2000b) (Figure 1). They may hold key information as to how people were able to adapt and thrive in a changing landscape. However, the diffuse stratigraphy of such features combined with other environmental factors has often made it difficult to understand when they were built and how they correspond with development and resilience of local, and regional population groups.

Adaptations in Human Landscapes Along the Nile (AHLAN) seeks to better understand resilience of past and present communities in the NDR through a detailed study of these features and palaeoenvironments (Figures 2-5), and their connections to corresponding settlement and

Sevara, C. *et al.* 2023 [http://doi.org/10.32028/SN27pp86-106].

pastoral activity. In order to do so, AHLAN is using a combination of remote sensing data analyses, targeted infield integrated archaeological investigation, and geoarchaeological sampling to collect more information about the creation, duration of use and capacities of such features as well as their effect on local environments. In November of 2022, we conducted a pilot study to test a recently developed methodology, optically stimulated luminescence profiling and dating (OSL-PD), which has yielded positive results in understanding the age and duration of use of similar landscape features in other environmental contexts (e.g., Vervust *et al.* 2020; Turner *et al.* 2021).

In this paper, the results from our initial study are presented, alongside a discussion on the potential for refining current models of landscape development in the NDR and beyond. We first introduce current models for understanding the socio-environmental changes that have occurred in the NDR since the African Humid Period, which may have necessitated responses in the form of new types of landscape infrastructure. This includes observations of rapid recent changes to the local landscape as interpreted from historic and modern satellite imagery, and their potential impacts on such structures. We then present the results from our 2022 fieldwork using OSL-PD to better characterise the dates and duration of use of various landscape infrastructure features. Finally, we discuss these initial results in relationship to current chronologies of human development, and their potential for further understanding and revision of existing models of settlement development and landscape change.

The Northern Dongola Reach, climates and environments

In Saharan and sub-Saharan north Africa, populations faced significant environmental change as the African Humid Period (AHP) came to an end and aridification intensified (Manning and Timpson 2014). Changes to the annual rainfall and flow of the ancient Nile channel network over time have been demonstrated to have had a significant effect on settlements all along the Nile Valley (e.g., Dalton *et al.*

Figure 2. A N-S running linear feature in the bed of the Alfreda Nile palaeochannel, Site H22. November 2022.

Figure 3. A N-S running linear feature in the bed of the Alfreda Nile palaeochannel, Site H22. November 2022.

Figure 4. Mound features in the bed of the Alfreda Nile palaeochannel, Site H22. November 2022.

Figure 5. Section of a mound field situated on the SW bank of the Alfreda Nile palaeochannel, Site P17. January 2020.

2023; Osman and Edwards 2012, 37; Woodward *et al.* 2015; 2017). This change in the availability of water as a resource would have necessitated significant changes to local and regional landscape infrastructures. Responses to this could include adaptations in farming strategies, building of water storage and access features, and rerouting of transport from riverine to terrestrial networks.

Recent models of palaeoenvironmental landscape development, based on data from extensive archaeological survey and OSL dating, have constructed a chronological sequence for the distribution of channels in the network and, related them to land use from the Neolithic to Medieval period (Welsby 2001a; 2001b; Macklin *et al.* 2013). The palaeochannels themselves can be traced via modern aerial and satellite data (Figure 1). In the river flow modelling from Macklin *et al.*, the westernmost branch of the Nile (termed the Dongola Nile) is the branch of the river that still flows today. *C.* 45km upstream (SSE) from modern Dongola, the anabranching (palaeo)channel system splits from the Dongola Nile, with two main branches (the central Hawawiya and eastern Alfreda) and a series of sub-branches running north to coalesce into the Selim Nile palaeobranch west of the Selim Basin. All branches flowed prior to 3500BC, while the sub-branches of the Hawawiya and Alfreda became dry by *c.* 1450BC. Between *c.* 1500 and 1000BC the central Hawawiya branch dried out, and the eastern Alfreda branch ran only seasonally. By *c.* AD300 the Alfreda channel flow becomes ephemeral, and from then there is no further flow within the network. Archaeological site distribution seems to move in tandem with this model (Macklin *et al.* 2013, 696), and it is theorised that certain types of features encountered in the NDR, such as 'wadi walls' and moundfields, may be related to changing water management and land use strategies.

The presence of such a dense network of sites and the availability of extensive survey, excavation and palaeoenvironmental data make the NDR well-suited for the diachronic study of landscape infrastructure growth and purposeful land management (Blaikie and Brookfield 1987, 9). Although greatly affected in places by erosion and other postdepositional processes (Edwards 2004, 47; Welsby 2001b, 608), significant traces such as mound fields and diversion dams (Welsby 2001a, 53, 602) still exist, dune fields cover (and uncover) sites with relative rapidity, and there is evidence of water-borne deposition and erosion that have differentially affected feature preservation (see Honegger and Williams 2015, 150; Welsby 2001b, 608-10). Some of these features, for example, may be connected to the rise of the Kingdom of Kerma (*c.* 2500–1500BC), when a rapidly changing climate and relationships to surrounding cultures spurred significant

Figure 6. 1912 Cairo Survey Department map depicting irrigation canals, proposed resectioning for agricultural redevelopment of Kerma and Es Seleim Basins. Original Title: Plan of Kerma Basins and Argo Island. (1:100k). Author: Cairo, Survey Department, 1912. Source: Sudan Archive, Durham University SAD.112/1/23[MP].

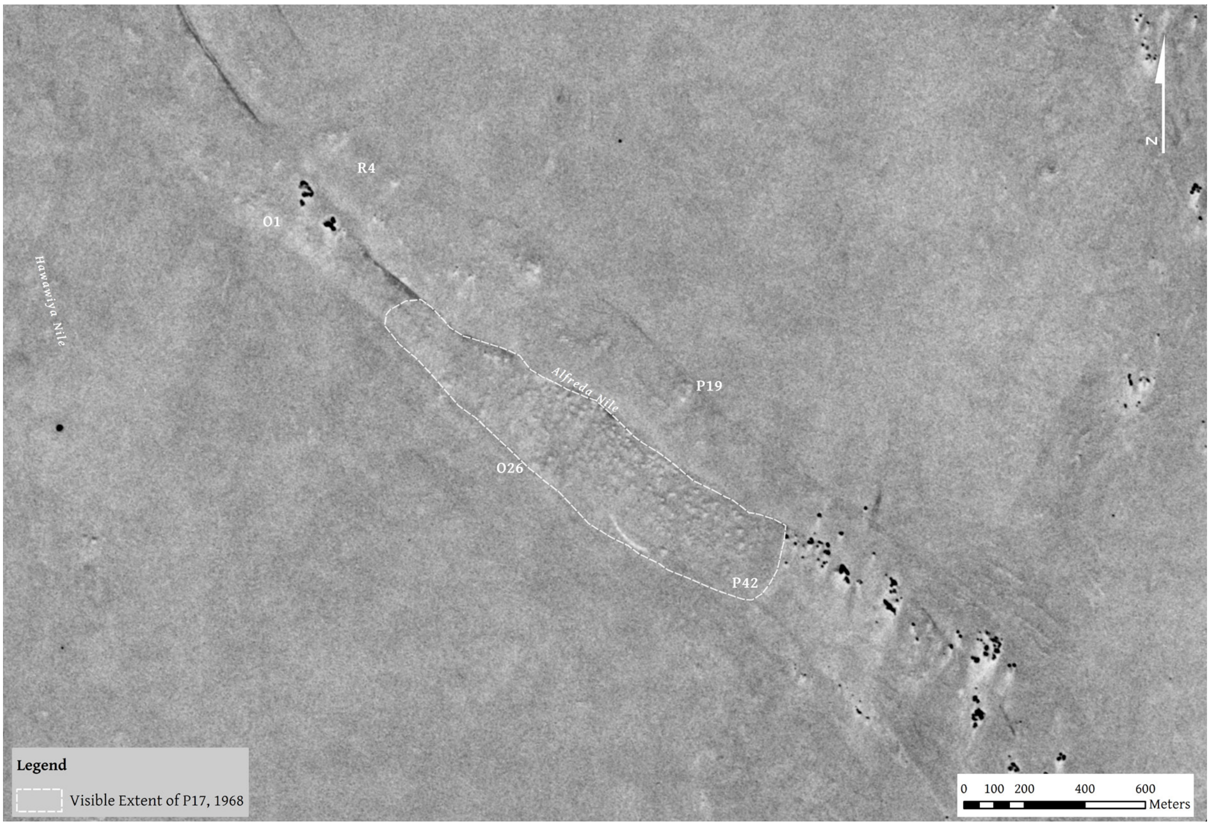

Figure 7. Historic satellite imagery showing approximate visible extent of moundfield P17 (outlined) and surrounding sites in 1968. Image: CORONA KH4B Satellite Imagery, DS1105-2219DF020.

Figure 8. Modern satellite imagery showing remaining mound superstructures at P17 (outlined in yellow) (as of November 2022). Image source: ESRI.

landscape development along the former channel system. Rural settlements may have functioned as specialised nodes of production in local to transregional networks before eventually collapsing due to social and environmental factors (Macklin *et al.* 2013, 698). The availability of such a wide range of material provides us with opportunities to enhance current models of landscape development and ask further questions in order to better understand connections between people, environment, and subsistence in all periods. While work has been conducted at several settlements in the region (e.g., Chaix 2007; D'Ercole *et al.* 2017; Minor *et al.* 2021; Porter 2019; Thomas 2014) little is currently known about the development of landscape infrastructure in relationship to settlement development.

Our understanding of these events is further hampered by ongoing efforts at agricultural redevelopment in the region. The Joint Anglo-Egyptian Condominium period saw extensive remodelling of the Kerma and Es Selim basins, patterned after models of other Nilotic basin irrigation schemes (Figure 6). That and subsequent agricultural developments have significantly affected the visibility of previous phases of land use, especially in the Kerma and northern Es Selim basins. Along the palaeobanks in the southern (upstream) segment of the anabranching palaeochannel network, recent accelerated agricultural development has also begun to have an effect on site visibility and preservation (Figures 7 and 8). Driven in part by greater access to the Nubian Sandstone Aquifer System (NSAS), which lies relatively close to the modern ground surface in the area (Mohamed *et al.* 2022; Voss and Soliman 2014), this 'regreening' of the palaeobanks of the Nile itself increases the likelihood that visible extents of former land use will be permanently erased.

New methods for dating landscape infrastructure in the NDR

In the face of such short- and long-term changes, one of the ways in which AHLAN can contribute to a better understanding of landscape development in the region is to provide more concrete information about the abovementioned features. A short field season was conducted between November 6th-12th 2022 to identify locations and test techniques for further fieldwork. During this season, we visited several sites in the NDRS survey area to evaluate their current condition and potential suitability, including sites H22, H10, P1 and P17 (Figure 1) (nomenclature from Welsby 2001a). As part of this field season, we tested the suitability of OSL-PD to date these landscape features. The approach is multi-faceted: in the first phase of investigation, which is undertaken in the field, use is made of portable OSL equipment and gamma spectrometry to fully characterise the luminescence behaviour and dosimetry of the entirety of the sedimentary sequences revealed in test-pitting. This proxy information – in the form of net infra-red stimulated luminescence (IRSL) signal intensities, net OSL signal intensities, IRSL and OSL depletion indices – enables relative luminescence stratigraphies to be constructed in near real-time, providing an insight into environmental conditions and depositional histories. Combined with observations on the sedimentology, this is used to locate samples at strategic positions in these sequences for dating purposes. In the second phase of the investigation, samples deemed to have archaeological or geomorphological significance are progressed to OSL dating. These analyses are performed in the luminescence laboratories at the School of Earth and Environmental Sciences at the University of St Andrews, following standard sample preparation procedures and established laboratory analytical protocols (Kinnaird *et al.* 2017).

OSL-PD: Feature Locations and Testing Methodology

During the reconnaissance portion of the 2022 field season, we selected linear features (often described as 'wadi walls', e.g., as in Welsby 2001, 51 or 'river groynes' in Dalton *et. al* 2023) and mound fields at sites H22 and P17 for testing. The procedure for investigating a feature followed five main steps:

1. Opening a test-pit at a perpendicular alignment to the investigated feature;
2. Taking a series of small bulk sediment samples through this profile for OSL screening;

3. Reviewing this proxy data, then using this information to locate a sample within the stratigraphy for dating purposes;
4. Recording the sediment stratigraphy and depths of samples;
5. Back-filling the test-pit.

In step 1, a small test-pit (*c.* 0.5mx1m) is cut on a perpendicular alignment to the feature. This is immediately covered by a black opaque cover, with final cleaning taken beneath this. In step 2, a series of bulk sediment samples are collected down-profile, at regular intervals of 50-100mm. These are immediately measured in a SUERC portable OSL reader, adopting an interleaved sequence of dark count, IRSL and OSL, from which net signal intensities and depletion indices are calculated. This proxy information is reviewed and used to select sample locations for dating purposes in step 3. In step 4, the test unit and sampled profile are documented using photogrammetric approaches to create a detailed 3D model for analytical and documentation purposes. Finally (step 5), the test-pit is backfilled.

Features Tested and OSL-PD Results

Seven features were investigated at H22 and P17, five from H22 and two from P17 (Figure 9). At Site H22, the five features were explored through 74 bulk sediment samples, with four samples taken for dating purposes. At Site P17, the two features were explored through 36 bulk sediment samples, with a sample for dating taken from each feature. No cultural artefacts (e.g., ceramics, lithics) were found in association with excavated feature fills.

Site H22

H22 is a large mound field in the vicinity of several other identified settlement and funerary sites (H19-21, H23-26, H28, H30) situated near the divergence of the Hawawiya and Alfreda Nile palaeochannels (Figure 10). During the NDR survey, approx. 118 mounds of varying composition were recorded. Two mounds were identified as wells, based on the presence of distinctive materials found in association with well features at nearby Site H18. Several linear features were also observed, some of which have been identified as potential water management features ('wadi walls') as well as other linear structures. Of note are a series of linear features in the bed of the Alfreda palaeochannel, set at right angles to the channel flow (originally identified as Walls 123, 139, and 138). Wall 123 was partially excavated during the NDR survey and was found to contain a single stone-faced course with a fill of silt and pebble (see Welsby 2001a, 51-52 for a full description). While there is significant potential for certain features to have been (un)covered by shifting aeolian processes, H22 and its immediate surroundings have not experienced as much recent encroachment as areas to the north (e.g., P17 as described below). A modern well bore has recently been dug into the bed of the palaeochannel and is supporting a slowly expanding field system in the middle of the moundfield, as can be seen in Figure 10. Recent linear features, likely property markers or agricultural clearance, have also appeared at the northern edge of the mound concentration.

Five features were sampled at H22 (Figure 9). H22-22-01 is a profile of the palaeochannel bed, recently exposed, presumably when the adjacent well was excavated. This was simply cleaned back and sampled, and we hope to be able to use this material in analyses at a later date. A test trench was dug from the edge to the middle of feature H22-22-02, (Figure 11) a small mound feature that may be feature 72 as recorded in the NDR survey. Our initial impression was that the mound was constructed in at least two phases of upcast (indicated by the maxima in net OSL signal intensities observed at 250mm and 410mm depth in profile, >2.3 x 10^5 counts), and that the mound overlies a palaeosurface, potentially bleached prior to/at construction of the mound (revealed by the drop in OSL intensities from 1.5 x 10^5 to <9.6 x 10^4 counts). The sample taken for dating purposes was located in the stratigraphy beneath the mound, and as such, should

Site*	**Feature ID**	**Feature #***	**Feature Type**	**Description**	**Dims (LxW)****	**Height (above MGS)**	**Depth (below MGS)**	**OSL Sample Depth*****	**Max LP Sample Depth*****
H22	H22-22-01	n.a.	Silt Deposit	A silt deposit in the bed of the palaeochannel, exposed by recent trenching in advance of well bore.	4.10m (L)	0.00m	1.36m	n.a.	1.13m
H22	H22-22-02	72?	Mound	A small mound, part of a moundfield, whose features may be related to well digging or water management. Fill consisted of moderately compact light grey silty sand.	5.57m x 5.83m	0.395m	0.1m	0.45m	0.62m
H22	H22-22-03	123	Wall	A 'wadi wall', a linear feature running N-S across palaeochannel bed. Wall architecture consisted of a single stone course extending *c.* 20cm below the modern ground surface.	20.00m x 0.80m	0.00m	0.20m	0.20m	0.60m

Figure 9. Features sampled at sites H22 and P17.

Site*	**Feature ID**	**Feature #***	**Feature Type**	**Description**	**Dims (LxW)****	**Height (above MGS)**	**Depth (below MGS)**	**OSL Sample Depth*****	**Max LP Sample Depth*****
H22	H22-22-04	139	Wall	A 'wadi wall', a linear feature running N-S across the palaeochannel bed. Feature consists of a N-S running surficial layer of riverworn pebbles, no visible evidence of stone architecture below the surface in the section tested. Feature appears similar to adjacent Wall 138 (see below), it may have had a stone foundation or facing in the past which has been subsequently removed.	32.00m x 1.96m	0.20m	0.20m	n.a.	0.40m
H22	H22-22-05	138	Wall	A 'wadi wall', a linear feature running N-S across palaeochannel bed. Feature consists of a N-S running surficial layer of riverworn pebbles with 3 courses of rough dressed stone wall exposed in subsurface during testing. Wall is presumably sitting atop ancient palaeochannel bed.	40.90m x 1.27m	0.00m	0.345m	0.345m (1) 0.345m (2)	0.55m

FIgure 9 (cont.). Features sampled at sites H22 and P17.

Site*	Feature ID	Feature #*	Feature Type	Description	Dims (LxW)**	Height (above MGS)	Depth (below MGS)	OSL Sample Depth***	Max LP Sample Depth***
P17	P17-22-01	n.a.	Mound	A mound feature consisting of multiple, similar highly compacted silty sand layers with a riverworn pebble capping.	5.00m x 5.00m	0.60m	not fully excavated	0.74m	1.22m
P17	P17-22-02	n.a.	Mound	A mound feature consisting of multiple similar, highly compacted silty sand layers with a riverworn pebble capping.	5.60m x 4.60m	0.65m	Not fully excavated	0.94m	1.18m

* Nomenclature from Welsby 2001a

** Visible dimensions at time of sampling

*** From top of feature

n.a. = ‘not applicable’

MGS = ‘modern ground surface’

OSL = Optically Stimulated Luminescence

LP = Luminescence Profiling

Figure 9 (cont.). Features sampled at sites H22 and P17.

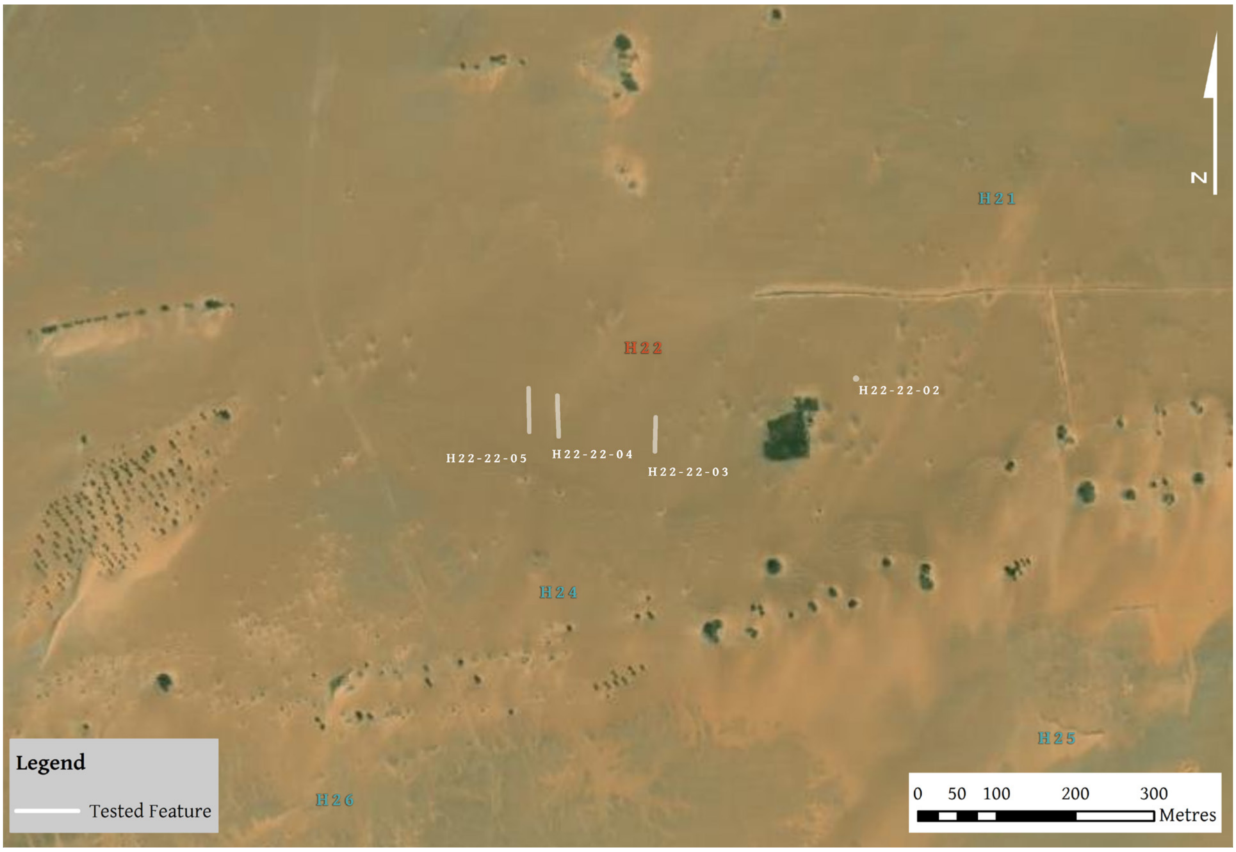

Figure 10. Site H22 and vicinity, location of tested features. Image date: 2022. Image Source: ESRI.

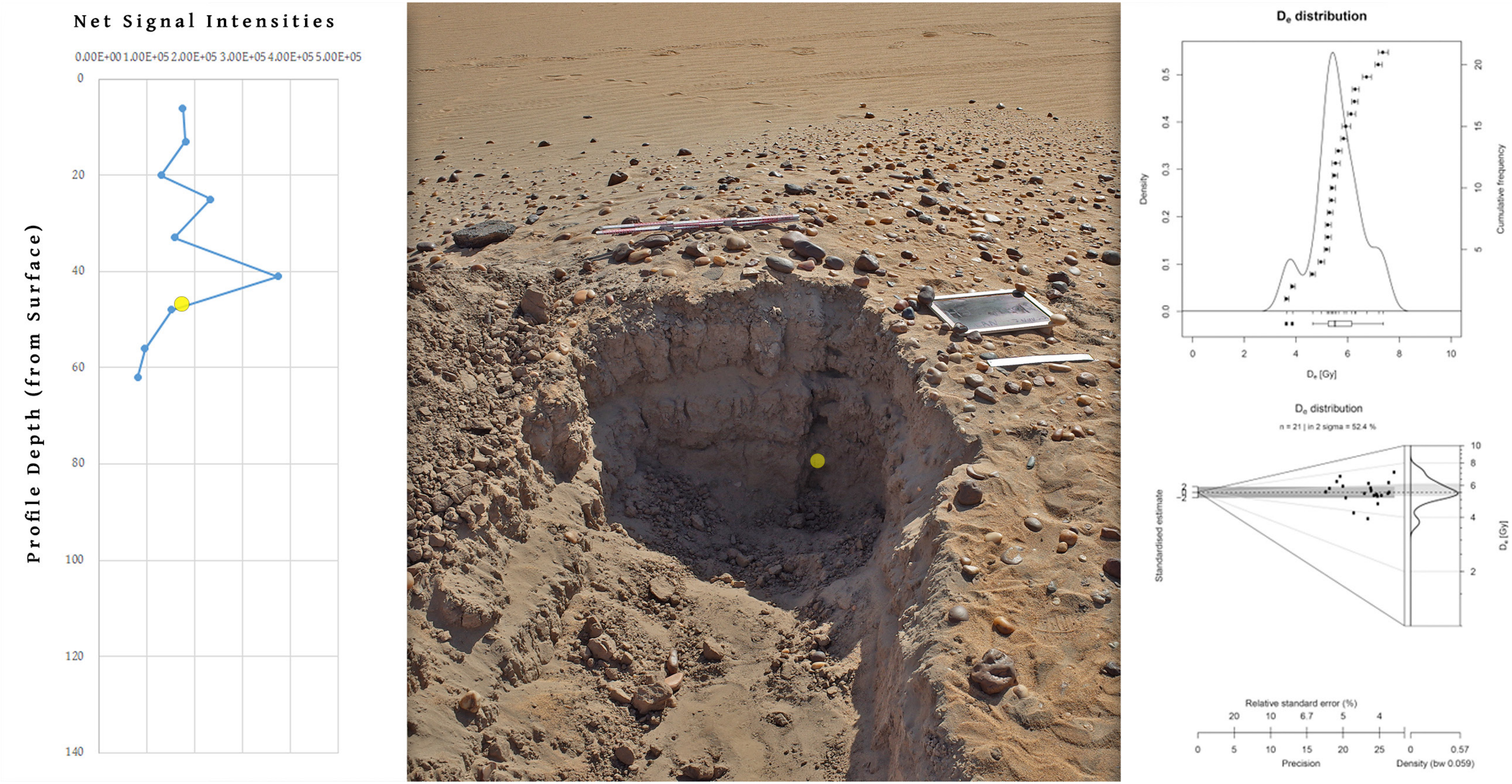

Figure 11. Profile of mound feature H22-22-02, corresponding net signal intensities for luminescence profile, and dose rate distribution. Small divots seen in profile are locations of luminescence samples and correspond to points plotted on the graph. Yellow dot indicates location of OSL sample.

CERSA #	Field ID	Burial dose /Gy	Total effective dose rate* / mGy a-1	Age / ka	Calendar years†
1173	H22-22-02 OSL1	5.27 ± 0.23	1.82 ± 0.10	2.89 ± 0.2	870 ± 200BC
1174	H22-22-03 OSL1	5.48 ± 0.31	2.02 ± 0.11	2.71 ± 0.21	690 ± 210BC
1175	H22-22-05 OSL1	8.00 ± 0.56	2.48 ± 0.12	3.23 ± 0.28	1210 ± 280BC
1176	H22-22-05 OSL2	6.40 ± 0.37	2.25 ± 0.12	2.84 ± 0.23	830 ± 230BC
1177	P17-22-01 OSL1	4.53 ± 0.23	2.12 ± 0.10	2.14 ± 0.15	120 ± 150BC
1178	P17-22-02 OSL1	6.64 ± 0.13	1.91 ± 0.12	3.48 ± 0.22	1460 ± 220BC

Figure 12. OSL sample results. Burial doses, total effective environmental dose rates and corresponding depositional ages for features sampled at H22 and P17.

provide *terminus post quem* (TPQ) for construction: the quartz SAR OSL depositional age of this sample was 870 ± 200BC (Figure 12).

The three linear features set across the palaeochannel (Welsby's 123, 139, and 138) were also investigated (Figures 13, 14). H22-22-03 (123), the easternmost feature, was bisected at a point where the stone facing was interrupted. Three parallel profiles were taken from beneath the 'wall': all show a progression in signal intensity with depth, from 1.5-1.6 x 10^4 counts immediately beneath the wall to ~5.5 x 10^5 counts at depth. An OSL sample taken at the base of the feature returned an OSL age of 690 ± 210BC, providing TPQ for construction. H22-22-05 (138), the westernmost feature, was found to have multiple courses of stones below the ground surface, suggesting that the silty-pebbly rubble which demarcates the surface of the feature might be the remains of the core of former courses. Sample trenches were dug on both sides of the feature, with the samples taken for dating positioned under the western face of the feature. As observed at H22-22-05, signal intensities increase with depth in the sequence, from 1.3-1.6x10^5 to >2.4x10^5 counts at depth, consistent with a normal age-depth progression. Two samples were positioned for dating purposes, at similar positions in the stratigraphy, returning OSL depositional ages of 1210 ± 280BC and 830 ± 230BC.

The synchronicity across the depositional ages obtained for the mound (H22-22-02) and wadi wall (H22-22-05) suggest that these features might have been constructed during the same period of water management; the weighted combination of the two dates suggest this occurred at 850 ± 150BC.

Site P17

P17 is the remainder of a large mound field located in the vicinity of several settlement sites on the southwest bank of the Alfreda Nile palaeochannel (P42, O26, O1). P17 is characterised by numerous mounds, comprised of densely packed silts covered by riverworn pebbles. During the NDR survey in the mid-1990s, approximately 290 mounds were noted in what remained of the field at the time, along with several other types of features. The original date range suggested for P17 was *Kerma Ancien* – New Kingdom (Welsby 2001a, 130). Much of P17 has been subsumed by recent agricultural expansion, which was already impacting the site when the NDR survey took place. Visual inspection of recent satellite imagery suggests

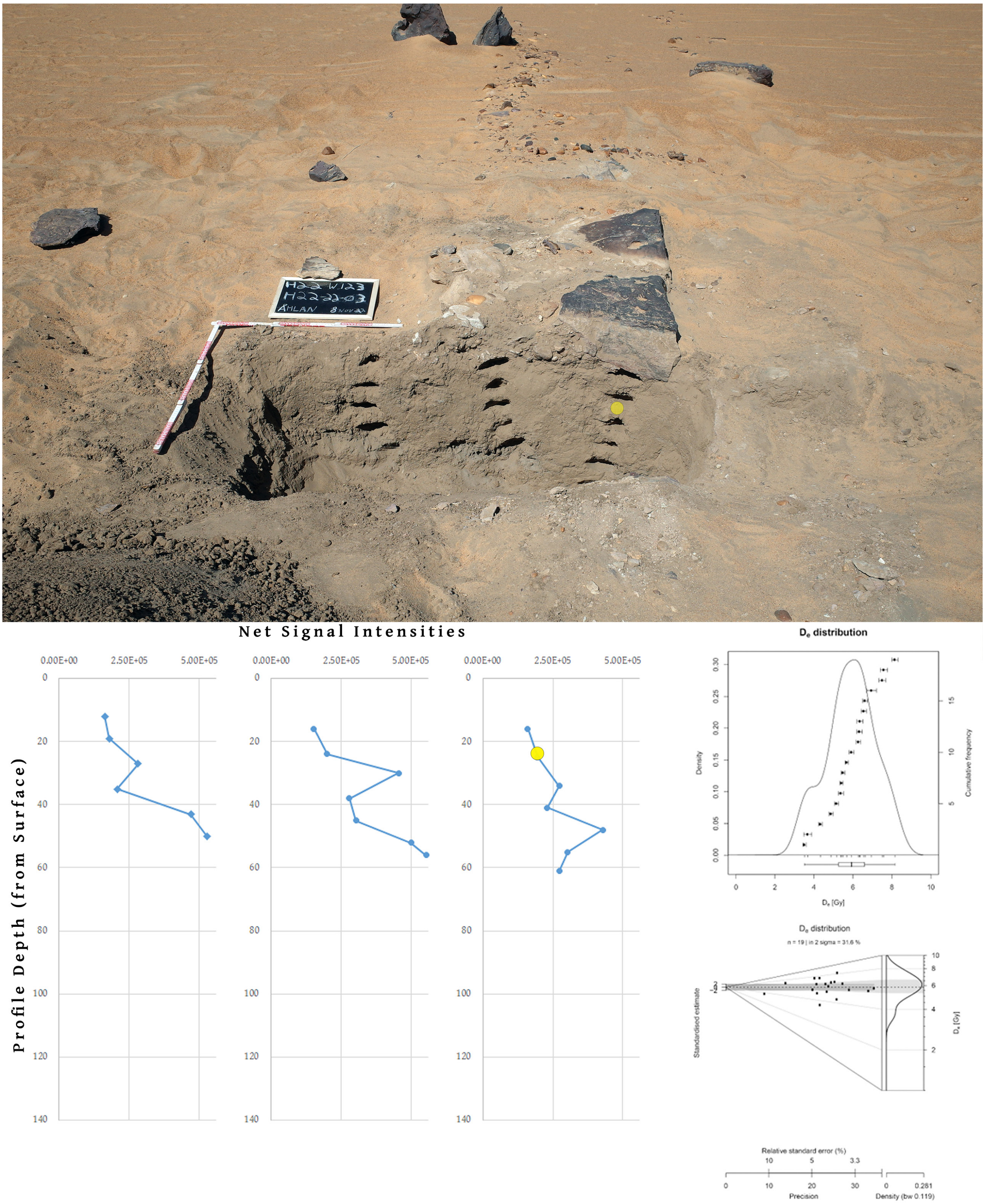

Figure 13. Profile of linear feature H22-22-03 (Wall 123), corresponding net signal intensities for luminescence profile, and dose rate distribution. Yellow dot indicates location of OSL sample.

60-70 mound superstructures remain, scattered in pockets between the fields that occupy the palaeobank. This translates to a visible loss of roughly 84% of the moundfield (see Figures 7 and 8 above).

Two mound features (referred to as ‘tumuli’ in the NDRS reports) were partly excavated in 1994, prior to their destruction as a result of agricultural activity. Feature 251, a mound approx. 8.5x8.2m standing 0.31m, contained two pit cuts, one in the centre of the mound and another to the north-eastern edge.

Figure 14. Profile of linear feature H22-22-05 (Wall 138), corresponding net signal intensities for luminescence profile, and dose rate distribution. Yellow dot indicates location of OSL sample.

The central cut contained loose grey sand, gravel and pebble fill and was approx. 0.8m deep. The second cut contained loose grey sand, ash and charcoal and was excavated to a depth of 0.5m. The excavation report indicates rubber was found in some part of the fill, which may indicate that the mound was partially disturbed at some point in the recent past. Feature 257, a mound approx. 7.8x5.5m standing 0.1m, contained a subsquare pit approx. 0.10m below the surface with loose sand and pebble fill down to a depth of *c.* 0.70m. Below that the fill became more compact and it was difficult to determine the terminus of the feature. The feature was half-sectioned and a single sherd of pottery was found at a depth of approx. 2.8m (summarised from Welsby 2001a, 205). We were, unsurprisingly, unable to relocate these during the 2022 field season.

Our sampling focused on two of the mound features in the largest remaining pocket of features at P17 (Figure 15). For both features P17-22-01 and P17-22-02, small trenches were dug from the edge to the midsection of the feature (Figure 9). Both were dug to a depth of *c.* 1.2m, and the narrow face of each trench was profiled and sampled. Feature fill was comparatively uniform in both cases, and moderately to densely compacted. No substructures were encountered. Luminescence profiling (Figures 16 and 17) suggests at least 5-6 phases of construction, evidenced by the multiple deviations down-profile from the normal signal-depth trend. Both features appear to have been constructed episodically, similarly to H22-22-02 (Figure 12). It appears that both P17-22-01 and P17-22-02 were revisited/refreshed seasonally. P17-22-01, situated closer to the palaeochannel, returned a date of 120 ± 150BC at 740mm depth in profile. P17-22-02, situated further away and slightly higher on the bank, returned a date of 1460 ± 220BC at 0.94m depth. These dates constrain phases of construction of the mound. At H22-22-02 it was possible to identify the palaeosurface at the base of the mound and the disturbed/'bleached' sediment beneath, this is not so at either P17-22-01 and P17-22-02, so it might be that these test-pits did not penetrate the base of these features; therefore, the date of 1460 ± 220BC should be viewed as *terminus ante quem* for construction of these mounds. It is important to note that the sample located in P17-22-02 at 0.94m depth corresponds

Figure 15. Site P17 and vicinity, location of tested features. Image date: 2022. Image Source: ESRI.

Figure 16. Profile of mound feature P17-22-01, corresponding net signal intensities for luminescence profile, and dose rate distribution. Yellow dot indicates location of OSL sample.

Figure 17. Profile of mound feature P17-22-02, corresponding net signal intensities for luminescence profile, and dose rate distribution. Yellow dot indicates location of OSL sample.

to one of the minima in intensities down-profile, it therefore represents the true depositional age of this layer, and is not an age overestimate as might have been obtained if the sample had been located in one of the upcasts.

Discussion

The initial findings presented here have provided interesting results from landscape infrastructure features that have historically proven difficult to reliably date. Although we currently have no further direct evidence that these features were used for water or agricultural management, their construction during a time when the Nile palaeochannels in the Dongola Reach were beginning to run more infrequently paired with their placement in/near the channel systems strongly suggests this, as do the results of recently published studies focusing on the construction and use of similar features in other parts of the Nile valley (Dalton *et al.* 2023, 19). Through further testing of infrastructure features and eventual connection to contemporary settlements, we will better understand how agricultural and other landscape infrastructure systems functioned. In turn, this will allow us to evaluate societal resilience (Lang and Stump 2017, 397 and see e.g., Bradtmöller *et al.* 2017) and how development affected social and ecological systems in the short and long term.

At H22, the four investigated features were constructed during a comparatively short time period, from 870 ± 200 to 690 ± 210BC, in agreement with earlier evidence that the Alfreda palaeochannel became more ephemeral during this period. These features may have been in use simultaneously, at least for a time. In the case of the walls (H22-22-03 to 05), perhaps these may have been for channel bottom farming, silt accumulation or water retention/diversion to field systems or reservoirs. If the mound feature sampled is the result of periodic upcasts from well digging, then the wells would have provided water in dry periods. The OSL dates suggest a later period than those suggested in the original survey report, this does not imply that people were not utilising the area in the Kerma period, though the palaeochannel itself would likely have been full of flowing water. There is more work to be done to better understand how these features present, their duration of use, and what purposes they served. Additionally, investigation of other anthropogenic and palaeoenvironmental features, including those that exhibit some superposition (e.g., the linear Feature 143 that seems to run under Mound 137) would probably provide much useful insight. H22's status in relationship to the other recorded sites in its immediate environment also needs to be determined. It is probable H22 is related to one or more of these other localities, or perhaps has further components that are now covered by aeolian deposits on the southern banks of the palaeochannel. Given the sequence of occupation at nearby H25 (Thomas 2014, 67; Porter 2019, 77), H22 could conceivably be a component of later-phase occupation.

Results from P17 suggest a longer period of cultural activity that fits with the current model of a progressive drying of the Alfreda palaeochannel. Our evidence shows that individual features were revisited and 'refreshed' periodically: if these are water-related, they may indicate seasonal use when there was no channel flow. The date range for the two features suggests the moundfield was long-lived, possibly more than 1300 years (*c.* 1460–120BC). Further excavation is required to determine whether the base of the mounds at P17 were reached; notwithstanding this, the pronounced temporal span for samples taken at near equivalent depths in profile, suggests that these features were not in use simultaneously, and that the site was long-lived. The early date of P17-22-02, 1460 ± 220BC is interesting as it falls at the end of the Kerma period, toward the end of when water may have still been running constantly in the Alfreda palaeochannel. Welsby *et al.* (2001b) have noted that some of the mound features here may have exhibited signs of water-related erosion. Although this was not noted for the particular feature we sampled (P17-22-02), it does lend further weight to the suggestion that, if water related, these features may have begun to be exploited as the river became seasonally-ephemerally active, that there was perhaps some overlap of water availability. In that case, the (river)waterworn features observed at P17 could be of a similar age or even older. The wide age range between the two features sampled and their close proximity would suggest that these features may have been dug opportunistically, perhaps moving closer to the channel as it ceased to run continuously and as the water table dropped. Testing of further features and a more detailed reconstruction of the palaeotopography is needed here to gain a clearer view of the sequence, pattern (if any) and duration of use. It should not be assumed that all features in the moundfield are of the same type. Figure 7 gives an indication of the former extent of the moundfield. Given its size, potential duration of use, and proximity to other settlements such as R4/O1, which could have seen at least partial contemporaneity (Minor *et al.* 2021, 101), it is possible that the moundfield could have been accessed as a seasonal resource by contemporary settlements.

It was noted that approximately 2100 mounds with broadly similar characteristics to those at H22 and P17 were found at locations along the banks and in the beds of the Hawawiya and Alfreda palaeochannels during the NDR survey, and only in a comparatively few instance could those investigated be positively identified as wells by their structure (e.g., the presence of a well-shaft below/adjacent to the upcast) (Welsby 2001b, 606). A comparison was drawn between these structures and modern and historic seasonal well-fields in other parts of Sudan. Our initial findings indicate that earlier suggestions of the general time period into which these features might fit are reasonable (see Welsby 2001b, 607). The same holds for the linear features in the base of the palaeochannel at H22. Such fields may have been accessed by dwellers in nearby settlements as water resources in the palaeochannels became less reliable, and/or by pastoralists as settlements ceased to be permanently occupied. Regardless, the success of the OSL-PD methodology in this context means that questions as to the absolute duration of these systems can now be addressed more fully.

Outlook and next steps

Testing the applicability of OSL-PD in the environmental context of Sudan has allowed us to better estimate how to deploy it as part of a larger scale research project in the region. We propose an expanded programme to connect elements of infrastructure to local settlements and regional activities through further environmental sampling, integrated archaeological prospection and community engagement. Active remote sensing platforms such as Synthetic Aperture Radar may help us to further delimit palaeoenvironmental and even anthropogenic features lying under aeolean deposits (e.g., Linck *et al.* 2013) In addition to more comprehensive remote sensing studies, future fieldwork will include more widespread testing at additional locations on different palaeobranches of the channel network, and in the channel bed itself. A combination of data from spaceborne and in-field geophysical survey can assist with identification of further features for sampling and delimitation of palaeoenvironmental features, as well as assessment of subsurface preservation for features that may have been partially destroyed by modern development.

Accelerated development in the region threatens archaeological resources and significantly impacts water and soil availability. It is our responsibility to work with local communities to help find a balance between unmitigated erasure of the archaeological record and sustainable land use. At meetings for the ESR4 Archaeological Project near Es-Selim in 2020 (Minor *et al.* 2021), people expressed interest in sharing their experiences of modern/historical landscape development and their relationships to past land use. There is significant scope for collaboration with local communities, which presents us with opportunities to evaluate sustainability in modern land use practices, carry out collaborative community mapping and develop models for future land use and stewardship of archaeological resources.

Conclusion

Results from our study indicate that there is sufficient scope to further the understanding of landscape development in the Dongola Reach through application of new dating methods and remote sensing data analysis, and that there is an additional urgency in facilitating the investigation of former landscape infrastructure features due to rapid changes in land use that are altering the current landscape. Findings from OSL-PD analyses indicate the features tested were established as the ancient palaeochannels of the Nile began to dry, and provide support for the argument that they were created as responses to environmental change. At Site H22, we tested 3 linear features and a mound feature in the bed of the ancient Alfreda Nile palaeochannel. These appear to have been constructed at the same or in a relatively brief period of time during the early-middle part of the 1st millennium BC, at a point at which current models indicate the palaeochannel was flowing only intermittently. At Site P17, the remains of a large moundfield on the southern bank of the Alfreda Nile, we have observed a much longer duration for feature construction. Based on the results from two mound features tested there, it seems these features were being created over a period of more than 1000 years, beginning in the mid-2nd millennium BC. These dates correspond to active phases at nearby investigated settlements, and it will be interesting to see how and if these relationships develop as further work is carried out. A larger project, including future field seasons and close cooperation with local collaborators and other teams working in the region, will enable us to better understand landscape management techniques and establish correspondence between these features, settlement development and environmental change in the Northern Dongola Reach.

Acknowledgements

We would like to thank NCAM and Dr Abdelhai Abdelsawy for allowing us to undertake this work and for facilitating permissions for the 2022 fieldwork, and SARS for their continued support of the project and permission to operate within the NDR concession. We also thank Saleh Mohammed Saleh Wed Alsafir for essential operational support, The Dongola Ministry for Tourism and Wildlife, Dr Elizabeth Minor and Dr Sarah Schellinger (Directors, ESR4 Archaeological Project) for their continued support in development of AHLAN, and Ahmed Farah and the Farah family in Es-Selim. We are grateful for advice from Dr Derek Welsby and Dr David Edwards regarding potential areas of interest for investigation and project scope, and to Dr Loretta Kilroe for information about excavations at Site H25. Thanks also to CERSA luminescence and the School of Earth Environmental Sciences, University of St Andrews for providing sample analysis. Newcastle University School of History, Classics and Archaeology and the Centre for Landscape provided financial support for this research.

References

Blaikie, P., and H. Brookfield (eds). 1987. *Land Degradation and Society*. London.

Bradtmöller, M., S. Grimm, J. Riel-Salvatore. 2017. 'Resilience theory in archaeological practice – An annotated review' *Quaternary International* 446, 3–16.

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.

Dalton, M., N. Spencer, M. G. Macklin, J. C. Woodward and P. Ryan. 2023. 'Three thousand years of river channel engineering in the Nile Valley' *Geoarcheology*, 1-23 [https://doi.org/10.1002/gea.21965].

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.

Edwards, D. N. 2004. *The Nubian Past: An Archaeology of the Sudan*. London.

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.

Kinnaird, T., J. Bolòs, A. Turner, A, and S. Turner. 2017. 'Optically-stimulated luminescence profiling and dating of historic agricultural terraces in Catalonia (Spain)' *Journal of Archaeological Science* 78, 66–77.

Lang, C. and D. Stump. 2017. 'Geoarchaeological evidence for the construction, irrigation, cultivation, and resilience of 15th-18th century AD terraced landscape at Engaruka, Tanzania' *Quaternary Research (United States)* 88, 382–399.

Linck, R., T. Busche, S. Buckreuss, and J. W. E. Fassbinder. 2013. 'Possibilities of Archaeological Prospection by High-resolution X-band Satellite Radar – a Case Study from Syria' *Archaeological Prospection* 20, 97–108.

Macklin, M. G., J. C. Woodward, D. A. Welsby, G. A. T. Duller, F. M. Williams and M. A. J. 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.

Manning, K., and A. Timpson. 2014. 'The demographic response to Holocene climate change in the Sahara' *Quaternary Science Reviews* 101, 28–35.

Minor, E., S. Schellinger, C. Sevara, A. El-Hassan and S. Ahmed. 2021. 'Laying the Groundwork: 2020 Survey Season and Community Outreach Program at the Kerma Period Settlement Site Es-Selim R4 in the Northern Dongola Reach' *Sudan and Nubia* 24.

Mohamed, A., E. Ahmed, F. Alshehri and A. Abdelrady. 2022. 'The Groundwater Flow Behavior and the Recharge in the Nubian Sandstone Aquifer System during the Wet and Arid Periods', *Sustainability* 2022, 14, 6823.

Osman, A., and D. Edwards. 2012. *The Archaeology of a Nubian Frontier*. Bristol.

Porter, S. 2019. 'Excavations at H25 in the Northern Dongola Reach', *Sudan and Nubia* 23, 77-80.

Thomas, R. 2014. 'El-Eided Mohamadein (H25): a Kerma, New Kingdom and Napatan settlement on the Alfreda Nile', *Sudan & Nubia* 18, 58-68.

Turner, S., T. Kinnaird, G. Varinlioğlu, T. Şerifoğlu, E. Koparal, V. Demirciler, D. Athanasoulis, K. Odegard, J. Crow, M. Jackson, J. Bolos, J. C. Sanchez-Pardo, F. Carrer, A. Turner and D. Sanderson. 2021. 'Agricultural terraces in the Mediterranean: Medieval intensification revealed by OSL profiling and dating.' *Antiquity*, 95(381), 773-790.

Vervust, S., T. Kinnaird, P. Herring and S. Turner. 2020. 'Optically stimulated luminescence profiling and dating of earthworks: the creation and development of prehistoric field boundaries at Bosigran, Cornwall', *Antiquity*, 94(374), 420-436.

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. 2001a. *Life on the Desert Edge: Seven thousand years of settlement in the Northern Dongola Reach, Sudan, Volume I*. Oxford.

Welsby, D. A. 2001b. *Life on the Desert Edge: Seven thousand years of settlement in the Northern Dongola Reach, Sudan, Volume II*. Oxford.

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.

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 and M. Binder (eds), *Nubia in the New Kingdom: Lived Experience, Pharaonic Control and Indigenous Traditions*. Leuven, 225–255.