

INVESTIGATING HUMAN-ENVIRONMENT INTERACTIONS IN THE MIDDLE NILE: THE CONTRIBUTION OF ARCHAEOMETRIC TECHNIQUES TO UNDERSTANDING LANDSCAPE USE AND SOCIAL PRACTICES IN BRONZE AGE SUDAN

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Abstract: *This paper presents case studies from our recent investigation of landscape properties in the MUAFS concession area in northern Sudan and associated material remains, including materials from Sai Island, the main urban site of this region in Upper Nubia. It tackles various geoarchaeological methods and geological techniques, including rock sampling and petrographic analysis of sandstones, highlighting the potential of these methodologies to reconstruct past landscapes and patterns of mobility. The material culture, especially ceramics, is analysed from a multi-perspective approach that incorporates a range of different scientific methods: the project integrates compositional bulk analysis (INAA) with mineralogical (XRD) and petrographic data via optical microscopy (OM) to examine the physical properties, provenance and technology of production of the ceramic samples as well as Raman spectroscopy to determine the range of temperatures reached by the ceramics during firing. Overall, this paper highlights how advances in landscape archaeology and the archaeometry of material culture are expanding our understanding of the significant ecological and social transformations in the Bronze Age Middle Nile. We argue that this combined analytical approach, applied to the case study of the Attab to Ferka region, can be successfully extended to other regions worldwide.*

Keywords: *Sudan; Bronze Age; landscape archaeology; geoarchaeology; resources; raw materials; environment; archaeometry; ceramics; material culture*

1. Introduction

The Munich University Attab to Ferka Survey Project (MUAFS) began its work in northern Sudan in 2018.¹ The MUAFS research concession (see Fig. 1) is adjacent to a cataract region and the rocky area of the Batn el-Haggat and is thus both a geological and a cultural border zone, located in the hinterland of two urban centres of the New Kingdom (1550–1070 BCE), Amara West² and Sai Island.³ Over the centuries, the area was a contact zone between different cultural groups from the northernmost (e.g., for the Kerma Empire, 2500–1500 BCE)⁴ and the southernmost sphere of influence (e.g., for the Egyptians in the early New Kingdom).⁵

The Sudanese Antiquities Authority carried out an initial survey of the MUAFS concession in the 1970s in collaboration with the French archaeological department under the direction of André Vila.⁶ They documented numerous sites from the Paleolithic to the Post-Medieval period, including settlements and burial sites as well as rock carvings, fortresses and churches.

In 2020, the ERC project *DiverseNile* was launched in the MUAFS concession between Attab and Ferka in the Middle Nile. By combining the contact space and landscape biography models, the project introduces a novel approach focusing on ‘contact space biographies’ to investigate human-landscape encounters in a peripheral borderscape, shaped by humans, human activities, technologies, materialities

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¹ BUDKA 2019, 2020a; BUDKA et al. 2025.

² On Amara West see, e.g., SPENCER 2017 with references.

³ For New Kingdom Sai see, e.g., BUDKA and DOYEN 2013; BUDKA 2020b; FRANCIGNY 2024.

⁴ See GRATIEN 2014; BUDKA 2020a.

⁵ See MORRIS 2018, 119–120.

⁶ VILA 1976a, 1976b, 1977a, 1977b.

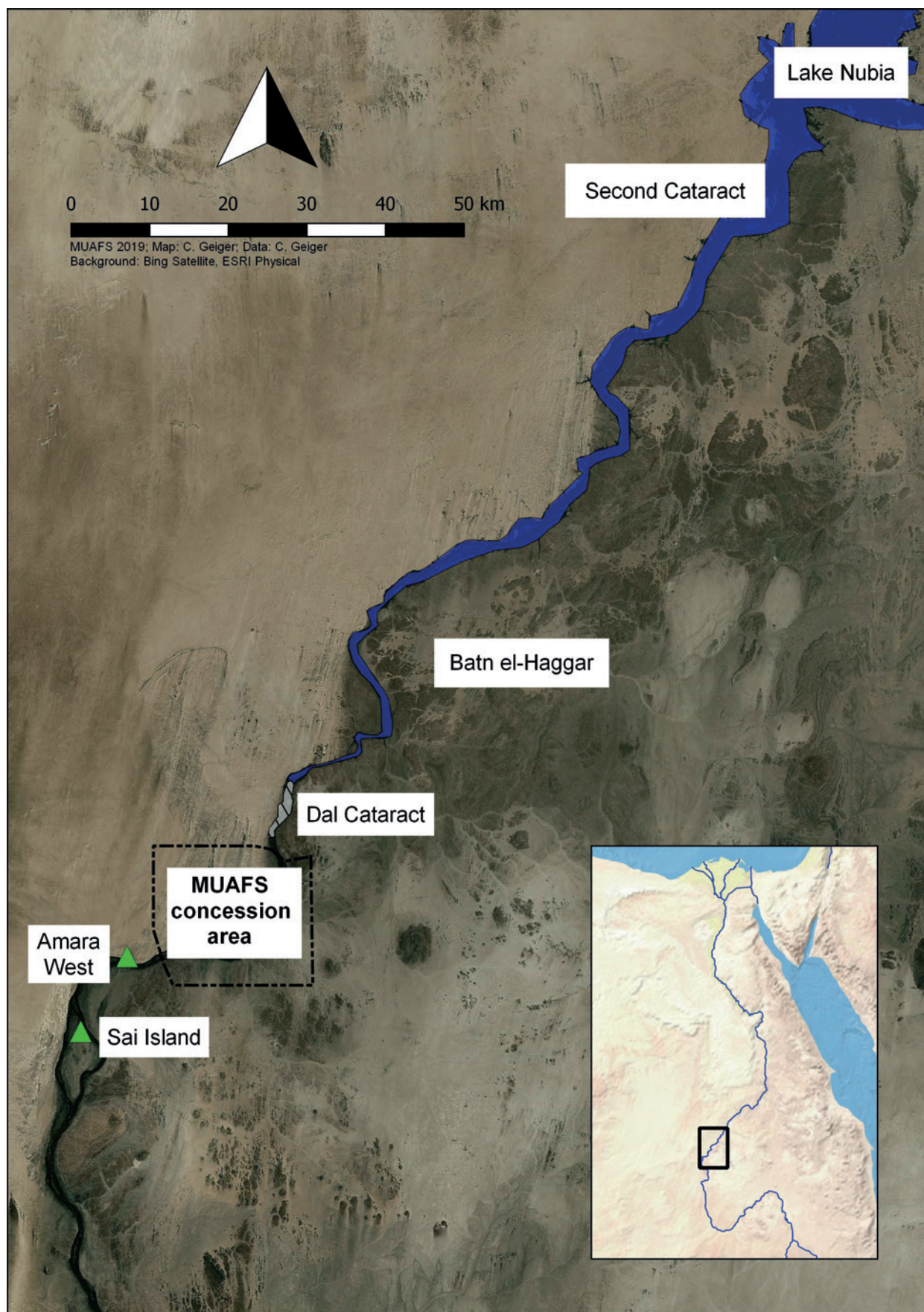


Fig. 1 Location of MUAFS concession in Sudan. Map: Cajetan Geiger ©DiverseNile project.

and animals.⁷ The primary aim of DiverseNile is to reconstruct landscape biographies of the Middle Nile beyond established but outdated and rigid cultural categories (such as Egyptian vs. Nubian but also the concept of ‘Egyptianisation’ describing the cultural situation in New Kingdom Nubia, taking a one-dimensional view of culture) and thus provide new insights into the ancient dynamics of social spaces.⁸

Using multidisciplinary methods in on-site archaeological fieldwork, the project investigates activities, their actors and cultural encounters in “contact spaces”⁹ at settlement and burial sites in the Attab to Ferka region. This includes the study of architecture, technology and material culture using a variety of techniques, including excavation, survey, photography and drone photography, mapping, a range of scientific analyses on ceramic samples, animal remains, botanical samples, human remains and geological material such as sandstone.

Moreover, the project addresses cultural diversity across a range of topics (e.g., intersocial aspects [gender, age, ethnicity, origin, social complexity and settlement patterns, etc.], subsistence strategies such as cooking practice/nutrition, religious practices, health, technologies and technology transfer, trade and contacts). This approach enables us to consider concepts beyond identity, including external factors, such as the geographic location and organisational dimensions (wherever possible), to evaluate the specific living conditions in the Attab to Ferka region during the Bronze Age, with a special focus on the Late Bronze Age, in direct comparison to local urban centres, such as Amara West and Sai Island.

This paper looks at the archaeometry of material culture analysed as part of the DiverseNile project and shows how this enhances our understanding of the significant environmental and social changes in the Middle Nile during the Bronze Age, in particular the period around 1500 BCE (New Kingdom colonial period of the 18th Dynasty).¹⁰

2. Materials and Methods

Our new study of landscape features and associated material remains in the Attab to Ferka region is conducted using a range of geoarchaeological methods, such as surveying, mapping and soil sampling, to determine the reasons for the distribution of sites within this contact space (Fig. 2). Geological applications such as rock sampling complement geomorphological studies of the ancient course of the Nile¹¹ and isotopic analyses of soil, water, human, animal and plant remains to reconstruct the past landscape and mobility patterns. We introduce state-of-the-art strontium isotope analysis using multi-collector inductively coupled plasma mass spectrometry (MC ICP-MS) and thermal ionization mass spectrometry (TIMS) as well as lead isotope analysis of soil, mudbricks and ceramic sherds as a new tool¹² to investigate cultural interactions. As outlined in Figure 2, due to the COVID-19 pandemic and now the war in Sudan, several analyses are still pending while others were originally not planned but conducted within a revised research strategy.

Besides novel archaeological fieldwork including 3D documentation during excavations and Geographic Information Systems (GIS) applications, we conduct various aspects of archaeometry, as the reconstruction of both the production activities and the taskscape¹³ in our study area is essential within the concept of contact space biography. Material culture is analysed from multiple angles, including scientific investigations with a focus on provenance studies and soil as an integral part of material culture (Fig. 2). Specifically, the concept of soilscape contributes to the understanding of taskscapes, as important information about how people organised their lives spatially and where activities took place becomes tangible and this in turn provides insights into social organization.¹⁴

⁷ After KOLEN and RENES 2015; see BUDKA 2019; BUDKA et al. 2025.

⁸ For similar approaches to the cultural diversity in Nubia see most recently DE SOUZA 2024; DE SOUZA and SCHRÖDER 2025.

⁹ After STOCKHAMMER and ATHANASSOV 2018; see BUDKA et al. 2025.

¹⁰ Bronze Age for Sudan is a disputed term, see most recently DE SOUZA 2023; JESSE 2025. We use it, however, to correlate

the periods of the Middle and Late Bronze Age with the ones in Egypt and are aware of regional differences (for details see BUDKA and LEMOS 2024, 10–11, fig. 1).

¹¹ See WOODWARD et al. 2015, 2017.

¹² ZIMMERMANN et al. 2019; RETZMANN et al. 2019.

¹³ After INGOLD 1993; see also BUDKA 2024a.

¹⁴ SALISBURY 2016, 17.

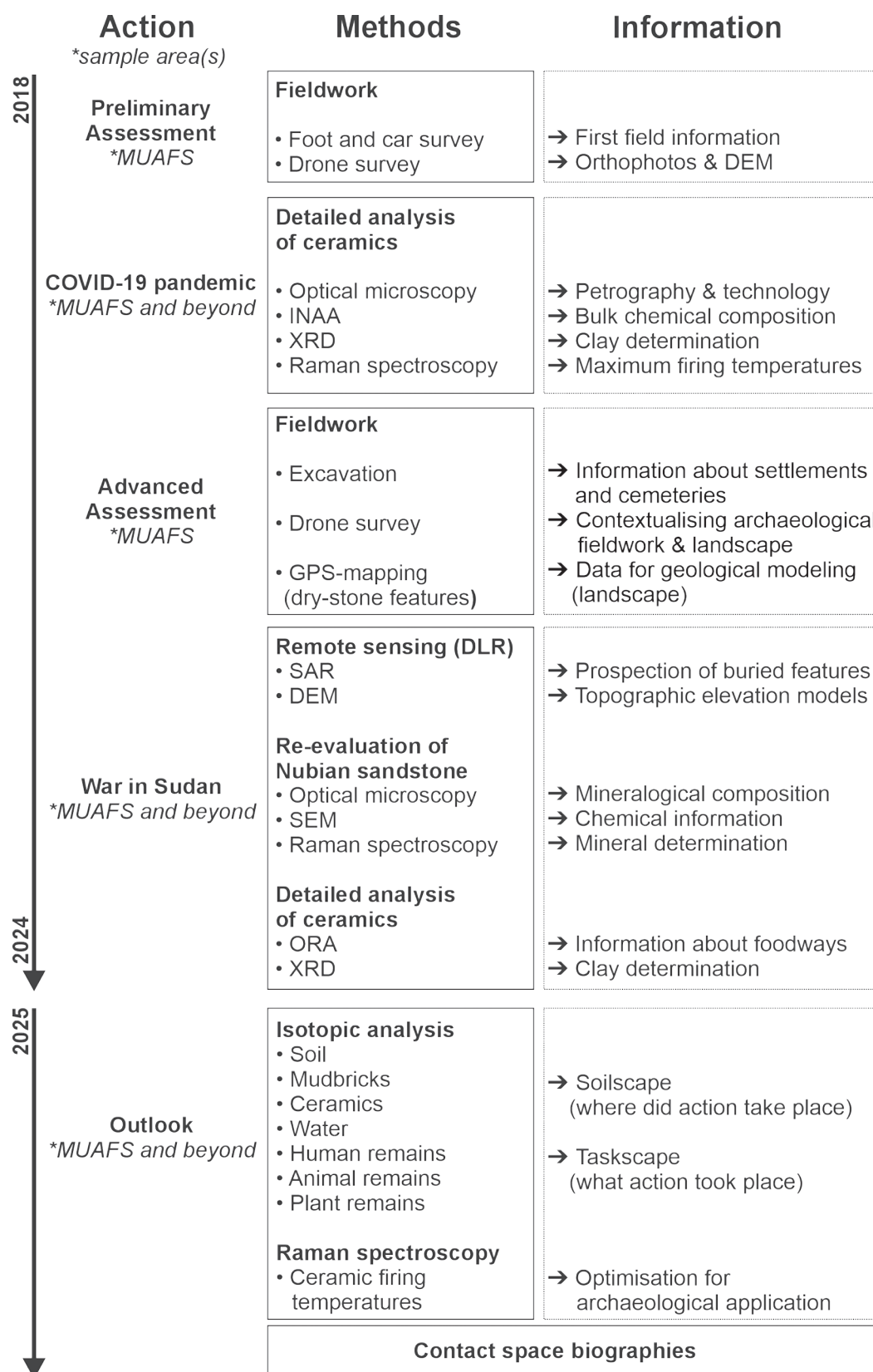


Fig. 2 Project workflow and key assessments. This figure presents the timeline of the DiverseNile project (2020–2026) within the MUAFS project (ongoing since 2018), outlining key actions, methods and outcomes. The project progressed through phases of excavation, material analysis and the contextualisation of archaeological landscapes. Future work will focus on insights into contact space biographies. Abbreviations: DEM: digital elevation model, INAA: instrumental neutron activation analysis, XRD: X-ray diffraction, GPS: global positioning system, DLR: Deutsches Zentrum für Luft- und Raumfahrt; SAR: synthetic aperture radar, ORA: organic residue analysis.

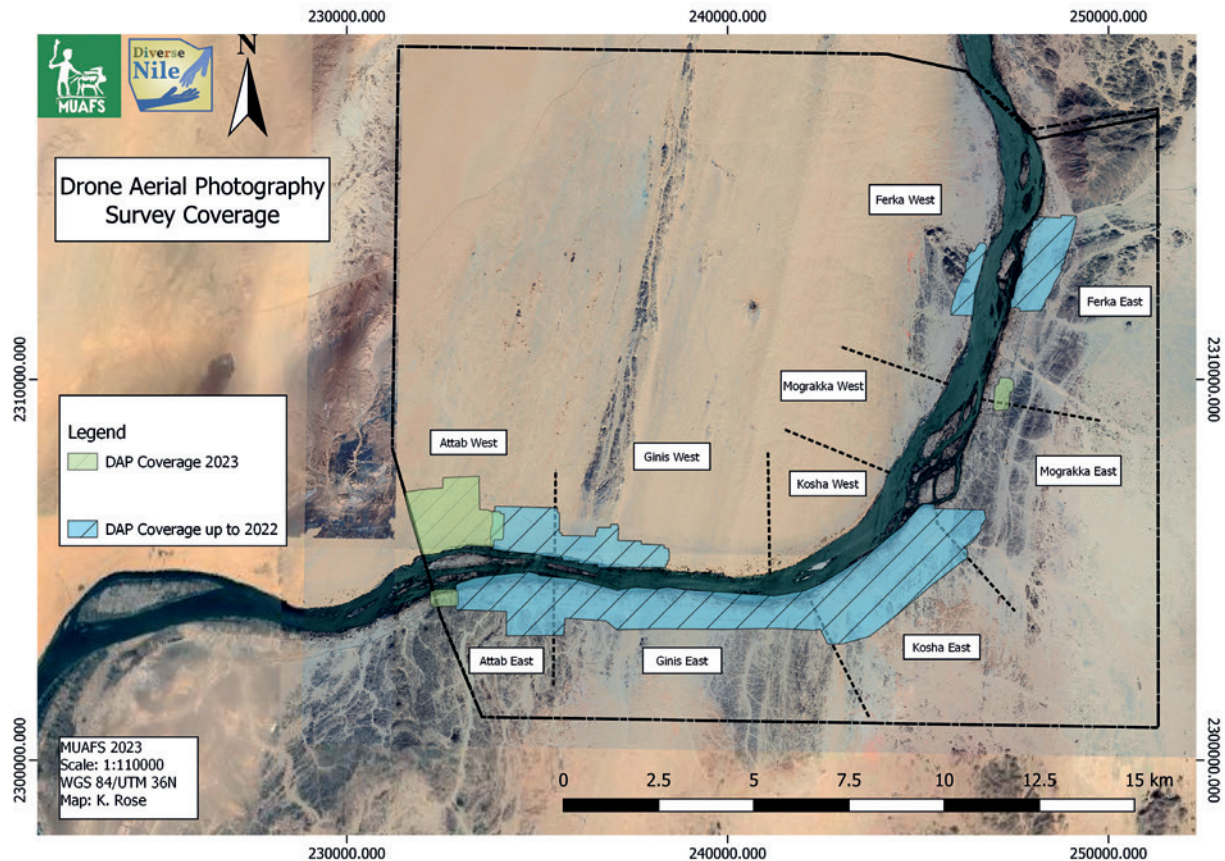


Fig. 3 Drone Aerial Photography (DAP) survey coverage in the MUAFS concession. Map: Kate Rose ©DiverseNile project.

2.1 Survey and remote sensing

The MUAFS concession area between Attab and Ferka was successfully surveyed between 2018 and 2023. The MUAFS project began with a survey on foot and by car, which was supplemented by drone recordings with a DJI Phantom 4 Pro. The initial orthophotos were calculated from the drone imagery using Agisoft Photoscan Pro and since 2023 Drone2Map (Esri).¹⁵

Most of our drone survey was conducted in the districts of Attab and Ginis, with the aim of covering the entire area (Fig. 3). The focus was on documenting paleochannels in Attab West extending westwards from the Nile into the present-day desert to understand terrain patterns and changes over time. The drone survey included detailed, low-flying (30 m) mapping of two sites we excavated in 2023, Attab West 001 (AtW 001) and Attab West 002 (AtW 002).

In the 2023 season, we also started to systematically document and precisely map dry-stone features in the landscape. Focusing on the districts of Attab West and Ginis West, we mapped approximately 300 dry-stone features.¹⁶ A total of 5 to 30 GPS points (depending on size) were recorded for each feature using a Trimble Catalyst Receiver. Special attention was given to capture the highest and lowest points of each feature, as well as the overall extent. In the district of Attab West, 114 dry-stone features were mapped, consisting mainly of walls and circular or semi-circular clusters of stones located near walls. These dry-stone walls probably date to the Kerma period. Our mapping dovetails with earlier work by Neal Spencer and his team in the Amara West district,¹⁷ which in turn builds on Vila's studies.¹⁸ Our aim here is to consider the sites in relation to natural markers in the landscape, such as the main paleo-channel in the region and the gold mine sites.

¹⁵ See GEIGER 2019; BUDKA et al. 2023, 30.

¹⁶ BUDKA et al. 2023, 2025.

¹⁷ DALTON et al. 2023.

¹⁸ VILA 1976b, 1977b.

As fieldwork was delayed in 2020 due to the COVID-19 pandemic and is on hiatus since 2023 due to the war in Sudan,¹⁹ DiverseNile has turned to more extensive remote sensing of the area. Thanks to a cooperation with the German Aerospace Center (DLR), we were able to conceptualise fieldwork ahead of going to Sudan, as well as carry out initial geological modelling based on satellite data. We also evaluated SAR (Synthetic Aperture Radar) data, which is already used extensively for archaeological prospection in other parts of the world.²⁰ The high-resolution SAR images available from the German TerraSAR-X satellite originate from a penetration depth of approximately 30cm. As some of the archaeological remains in the region are only slightly covered by sand and visible on the surface, we expect excellent results in mapping sites remotely. Especially in combination with available DEM (Digital Elevation Model) data from the TanDEM-X satellite,²¹ as well as our own drone photography.

This new type of remote sensing will expand our current knowledge of the ancient river and island systems in the Attab to Ferka region,²² as well as many other factors that are critical for assessing human-environment interactions.

2.2 Archaeometric analyses of ceramic samples

The largest group of material subjected to archaeometric analysis is pottery. Our dataset comprises over 600 ceramic samples collected over the last decade from several sites within the MUAFS concession area, as well as from the temple town on Sai Island (ERC AcrossBorders project). Additional ceramics were obtained from the sites of Dukki Gel (Kerma) and Amara West in Upper Nubia. Our sample-set also includes natural soils, unfired samples, oven fragments and experimental ceramics to serve as benchmark data and reference materials for decoding the source of archaeological pottery.²³

Within the MUAFS concession area, ceramic samples come from both settlements (AtW 001, AtW 002 and Ginis East 001) and cemeteries (Ginis East 003 and Kosha East, 3-P-7) and cover a

considerable timespan within the Bronze Age, from the Middle Kerma (c. 2050–1750 BCE) and Classic Kerma (c. 1750–1500 BCE) up to the New Kingdom period (c. 1550–1069 BCE) (and maybe even into the Iron Age, the Napatan era, c. 750–300 BCE). As such, the ceramic samples are crucial to the diachronic study of the area.

The study of these samples is extremely promising in terms of our broader objectives of understanding cultural diversity and investigating inter-regional and local social relations between Egyptian and Nubian entities. The ceramic assemblage includes a large repertoire of forms and stylistic types (dishes, bowls, beakers, cooking vessels, jars and other forms with various surface treatments, for details see Table 1) that can be attributed to the local Nubian cultural sphere (i.e., Kerma wares), the Nubian desert sphere (i.e., Pan-Grave wares) and the Egyptian sphere (i.e., various Egyptian wares, both imported and locally made). Within the dataset, our main objective was to examine subtle variations in the chemical and mineralogical composition of Nile clay ceramics in order to determine their provenance and production technology.

The geochemical homogeneity of Nile clays across the Nile has been established by various researchers.²⁴ Furthermore, the archaeological evidence indicates that local wares of both the Egyptian- and Nubian-style were commonly manufactured from similar raw materials. Accordingly, our interpretation focused on clay preparation and manufacturing, rather than solely on clay sourcing.²⁵

Macroscopic observations of pottery — which included the macro fabrics and manufacturing techniques by means of traces such as grooves from the wheel — were combined with multiple analytical approaches — namely instrumental neutron activation analysis (INAA), powder X-ray diffraction (XRD), optical microscopy (OM) and Raman spectroscopy (see Table 2) — in order to obtain a vast set of information about the concrete properties, elemental composition and production techniques of the ceramic vessels. Overall, our main archaeological objectives were the following:

¹⁹ Thanks to the support of the National Corporation for Antiquities and Museums in Sudan, a short season was possible in the MUAFS concession in February and March 2025. However, the results of this risk assessment season are not included below but will be published elsewhere (see BUDKA 2025a).

²⁰ LINCK 2013.

²¹ Cf. EGER and KARBERG 2020.

²² For Attab and partly Ginis see WOODWARD et al. 2015, 2017; DALTON et al. 2023.

²³ D'ERCOLE et al. 2017; D'ERCOLE and STERBA 2018; D'ERCOLE 2024; STERBA and D'ERCOLE forthcoming.

²⁴ CARRANO et al. 2008, 2009; D'ERCOLE and STERBA 2018.

²⁵ See also D'ERCOLE 2024.

- Analyses and differentiations of clay raw materials and ceramic technologies across various sites and time periods within the MUAFS concession area;
- Investigation of the technological characteristics of local pottery production which follows both Nubian and Egyptian traditions, while noting similarities between hand-made (Nubian tradition) and wheel-thrown techniques (Egyptian tradition) as well as comparing these characteristics to non-local productions such as the Pan-Grave tradition;
- Identification and documentation of the recipes used in the production of different ceramic wares and types;
- Examination of the type of temper added to the clay to achieve specific performance;
- Gaining insights into the firing processes used for different ceramic wares, focusing on firing atmospheres and temperature variations.

Organic residues analyses (ORA) for the Bronze Age Middle Nile are an urgent desideratum as there is only one published case study from Askut.²⁶ While the results of the analysis of organic remains in cooking pots from Amara West were very limited,²⁷ a proof of concept of ORA for six cooking pots from Sai (unpublished) and the analysis of six samples from Attab West in the MUAFS concession were successful.²⁸

2.2.1 Instrumental Neutron Activation Analysis

INAA was performed at the Center for Labelling and Isotope Analysis, TRIGA Center Atominstitut in Vienna²⁹ on 237 samples collected between 2022 and 2023 in the MUAFS concession area (districts of Attab, Ginis and Kosha). In addition, as part of the DiverseNile project, we analysed 43 samples from Dukki Gel and 33 samples from Amara West for comparative purposes.

For this analysis, resulting in the bulk chemical characterization of the ceramic pastes, samples were either drilled or ground down to uniform particle size using an agate mortar to avoid contam-

ination. After powderisation and homogenisation of up to 1 g, about 100 mg of powdered ceramic was dried for approximately 12 h in the oven at 95°C, then weighed and sealed into SuprasilTM glass vials for irradiation in the TRIGA Mk II research reactor.

Overall, the elemental compositions in µg/g of 28 elements were quantified. In one measurement run, 43 samples were irradiated together with five internationally certified reference materials, one in-house quality control sample and the Bonn Standard.³⁰ After irradiation, all samples were measured twice with a high-purity Germanium gamma detector with a preloaded digital filter and a Loss Free Counting system. Multivariate statistical data analysis was done using a modified Mahalanobis distance measure³¹ to calculate distances in the multi-dimensional space between samples and established groups from the combined Bonn/Vienna database.

2.2.2 Optical microscopy

The ceramic petrography of representative specimens from various sites was investigated within the MUAFS area. For this purpose, 50 thin sections (~25µm) were manufactured. An additional 21 thin sections include ceramic samples from Dukki Gel (Table 1). The petrographic observations were conducted with a Zeiss Axio Lab.A1 polarised light microscope at the Department of Earth and Environmental Sciences, LMU Munich.

The analyses adhere to a previously established protocol, which includes information on the ground-mass (clay matrix), non-plastic inclusions, plastic inclusions, porosity, and organic inclusions. Furthermore, the firing regime of the ceramic sample (oxidation/reduction state of ceramic body visible under the petrographic microscope and with the naked eye) is indicated. The objective is to establish a correlation between the microfabric or petrographic group and the macroscopic evidence, which includes various groups of Egyptian-style Nile clays (e.g. Nile B and C) and Nubian fabrics 1-4.³²

²⁶ SMITH 2003, 113–124; 2024, 177–178, figs. 2–3.

²⁷ SPENCER 2014, 55.

²⁸ BUDKA 2024b, 107–108.

²⁹ STERBA 2018.

³⁰ MOMMSEN and SLÄRBERG 2007.

³¹ BEIER and MOMMSEN 1994.

³² As reported in BUDKA 2017, 122–124.

Table 1 Samples analysed by optical microscopy within the DiverseNile project from the MUAFS concession area and from the site of Dukki Gel, Kerma.

Sample No.	Find no.	Site, Location	Period	Tradition	Shape	Macro Ware and Fabric
3	MUAFS 011-3/2022	AtW 001, WP 653	New Kingdom	Egyptian	Zir	var. Nile clay C2UC
8	MUAFS 011-6/2022	AtW 001, WP 653	New Kingdom	Egyptian	Dish	var. Nile clay B2RPall
11	MUAFS 011-11/2022	AtW 001, WP 653	New Kingdom	Egyptian	Bowl	var. Nile clay B2RPall
17	MUAFS 011/2022	AtW 001, WP 653	New Kingdom	Nubian	Cooking pot	Nubian 2, Black-top and basketry
20a	MUAFS 420/2022	AtW 001, T1, SU 1200	New Kingdom	Nubian	Beaker	Nubian 1, Black-top fine, Kerma
22a	MUAFS 184/2022	GiE 003, T1, F4, SU 1001	Classic Kerma	Nubian	Beaker	Nubian 1, Black-top fine, Kerma
25a	MUAFS 212/2022	GiE 003, T1, F10, SU 1011	Classic Kerma	Nubian	Beaker	Nubian 1, Black-top fine, Kerma
25c	MUAFS 212/2022	GiE 003, T1, F10, SU 1011	Classic Kerma	Nubian	Cooking pot	Nubian 2, Basketry
27a	MUAFS 323/2022	GiE 003, T1, F20, SU 1048	Classic Kerma	Nubian	Beaker	Nubian 1, Black-top fine, Kerma
30a	MUAFS 431/2022	AtW 001, T1, SU 1202	mid-18th Dynasty	Egyptian	Dish	var. Nile clay B2RWallRPin
30e	MUAFS 431/2022	AtW 001, T1, SU 1202	mid-18th Dynasty	Egyptian	Zir	var. Nile clay C2WW
30h	MUAFS 431/2022	AtW 001, T1, SU 1202	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2-3, Coarse
31g	MUAFS 429/2022	AtW 001, T1, SU 1201	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2, Basketry
31i	MUAFS 429/2022	AtW 001, T1, SU 1201	mid-18th Dynasty	Nubian	Bowl	Nubian 2, Red polished, Impressed
33a	MUAFS 441/2022	AtW 001, T1, SU 1204	mid-18th Dynasty	Egyptian	Dish	var. Nile clay B2RWallRPin
33d	MUAFS 441/2022	AtW 001, T1, SU 1204	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2, Basketry
34d	MUAFS 447/2022	AtW 001, T1, SU 1205	mid-18th Dynasty	Egyptian	Zir	var. Nile clay B2WW
34e	MUAFS 447/2022	AtW 001, T1, SU 1205	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2, Basketry
34h	MUAFS 447/2022	AtW 001, T1, SU 1205	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2, Coarse
38a	MUAFS 127/2022	GiE 001, T4, SU 100	Napatan?	„Egyptian“	Jar	var. Nile clay B2RW
38b	MUAFS 127/2022	GiE 001, T4, SU 100	Napatan?	„Egyptian“	Dish	var. Nile clay B2UCRW
38e	MUAFS 127/2022	GiE 001, T4, SU 100	New Kingdom	Nubian	Storage vessel	Nubian 2, Red polished
41	MUAFS 502/2023	AtW 002, SU 1408	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry
43a	MUAFS 517/2023	AtW 002, SU 1414	18th Dynasty	Egyptian	Cooking pot or jar	var. Nile clay RWout
43c	MUAFS 517/2023	AtW 002, SU 1414	18th Dynasty	Egyptian	Globular jar	var. Nile clay B2RWout (burned)

Table 1 *cont.*

Sample No.	Find no.	Site, Location	Period	Tradition	Shape	Macro Ware and Fabric
43d	MUAFS 517/2023	AtW 002, SU 1414	18th Dynasty	Egyptian	Cooking pot/ globular pot	var. Nile clay B2 (chaffy)RWout
43h	MUAFS 517/2023	AtW 002, SU 1414, Str. 1	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry
47b	MUAFS 319/2023	GiE 003, T3, Feature 42, SU 1502	Classic Kerma	Nubian	Storage vessel	Nubian 2
52b	MUAFS 343/2023	GiE 003, T3, Feature 39, SU 1505	Classic Kerma	Nubian	Jar or globular bowl	Nubian, variant desert fabric
54	MUAFS 351/2023	GiE 003, T3, Feature 39, SU 1505	Classic Kerma	Nubian	Cooking pot	Nubian 3, Basketry
56	MUAFS 390/2023	GiE 003, T3, Feature 40, SU 1518	Classic Kerma	Nubian	Bowl	Nubian 2
61a	MUAFS 442/2023	GiE 003, T4, SU 1608	Classic Kerma	Nubian	Storage vessel	Nubian 2, Black-top
65	MUAFS 372/2023	GiE 003, T5, SU 1701	Pan-Grave	Nubian/Pan-Grave	Bowl	Nubian, Pan-Grave, Herringbone, see PG.2/De Souza-Ownby 1
66c	MUAFS 475/2023	GiE 003, T5, SU 1706	Pan-Grave	Nubian/Pan-Grave	Bowl	Nubian, Pan-Grave, Black-top, see PG.2/De Souza-Ownby 1
66d	MUAFS 475/2023	GiE 003, T5, SU 1706	Pan-Grave	Nubian/Pan-Grave?	Beaker	Nubian, Pan-Grave?, Black-top, see PG.5/De Souza-Ownby 2
66h	MUAFS 475/2023	GiE 003, T5, SU 1706	Middle Kerma	Nubian	Jar	Nubian, Black-top, Fabric to check
66l	MUAFS 475/2023	GiE 003, T5, SU 1706	Middle Kerma	Nubian	Jar	Nubian, variant of Nubian 3
66n	MUAFS 475/2023	GiE 003, T5, SU 1706	Middle Kerma	Nubian	Cooking pot	Nubian 3, Geometric incisions and basketry
66p	MUAFS 475/2023	GiE 003, T5, SU 1706	Pan-Grave	Nubian/Pan-Grave	Bowl	Nubian, Pan-Grave, Black-top, Slipped and polished
71h	MUAFS 527/2023	KoE, 3-P-7, WP 825	Classic Kerma	Nubian	Storage vessel	Nubian 2/3, Burnished out
71i	MUAFS 527/2023	KoE, 3-P-7, WP 825	Classic Kerma	Nubian	Storage vessel	Nubian 2, Impressed
74c	MUAFS 026/2023	AtW 001, T2, SU 1253	18th Dynasty	Egyptian	Bread mould	var. Nile clay C2 (chaffy)
81c	MUAFS 059/2023	AtW 001, T2, SU 1259	18th Dynasty	Nubian/Pan-Grave	Beaker	Nubian (sim. Pan-Grave), Black-top, see PG.4/De Souza-Ownby 3
81d	MUAFS 059/2023	AtW 001, T2, SU 1259	18th Dynasty	Egyptian	Dish/plate	var. Nile clay C2UC (chaffy)
83	MUAFS 082/2023	AtW 001, T2, SU 1263	18th Dynasty	Egyptian	Cooking pot	Hybrid type, var. Nile clay B2 sandy
86	MUAFS 114/2023	AtW 001, T2, SU 1268	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry
88a	MUAFS 186/2023	AtW 001, T2, SU 1283	18th Dynasty	Egyptian	Jar	var. Nile clay B2UC (overfired)

Table 1 *cont.*

Sample No.	Find no.	Site, Location	Period	Tradition	Shape	Macro Ware and Fabric
92c	MUAFS 283/2023	AtW 001, T2, SU 1324	18th Dynasty	Egyptian	Bread plate	var. Nile clay B2/C2 (chaffy)
93a	MUAFS 287/2023	AtW 001, T2, SU 1325	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry
94a	MUAFS 290/2023	AtW 001, T2, SU 1326	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry
DG-12	DG.04.01-15	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Jar	KERMA-II, Fine polished
DG-17	DG.04.01-23	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Large bowl	KERMA-IV, Fine polished
DG-18	DG.04.01-24	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Cooking pot	KERMA-V, Basketry
DG-19	DG.04.01-25	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Cooking pot	KERMA-V, Basketry
DG-20	DG.04.01-27	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Unidentified	KERMA*, Common
DG-22	DG.08.36-05	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Jar	KERMA-IV, Roughly Polished/Wet-smoothed
DG-23	DG.08.36-06	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Cooking pot	KERMA-IV, Common
DG-24	DG.08.36-08	Dukki Gel, Sector 1/36	early 18th Dynasty	Nubian	Jar	KERMA-IV, Roughly Polished/Wet-smoothed
DG-26	DG.11.23D-17	Dukki Gel, Sector 23D	early 18th Dynasty	Nubian	Cooking pot	KERMA-V, Common
DG-29	DG.11.23D-Unnamed-1	Dukki Gel, Sector 23D	early 18th Dynasty	Nubian	Unidentified	KERMA*, Fine polished
DG-30	DG.11.23D-Unnamed-2	Dukki Gel, Sector 23D	early 18th Dynasty	Nubian	Unidentified	KERMA*, Fine polished
DG-31	DG.11.23D-Unnamed-3	Dukki Gel, Sector 23D	early 18th Dynasty	Nubian	Unidentified	KERMA*, Common
DG-35	DG.10.45C-24	Dukki Gel, Sector 45C	early 18th Dynasty	Egyptian	Bowl	var. Nile B1-III, Red slipped, Burnished
DG-36	DG.10.45C-25	Dukki Gel, Sector 45C	early 18th Dynasty	Egyptian	Bowl	var. Nile B1-I, Red slipped, Burnished
DG-40	DG.10.45C-Unnamed-2	Dukki Gel, Sector 45C	early 18th Dynasty	Egyptian	Bread mould	var. Nile B*, Uncoated
DG-41	DG.10.45C-Unnamed-3	Dukki Gel, Sector 45C	early 18th Dynasty	Nubian	Cooking pot	KERMA*, Basketry
DG-48	DG.03.79-46	Dukki Gel, Sector 79	mid-18th Dynasty	Nubian	Jar	KERMA-IV, Roughly Polished/Wet-smoothed
DG-49	DG.03.79-53	Dukki Gel, Sector 79	mid-18th Dynasty	Nubian	Bowl	KERMA-V, Common
DG-57	DG.04.03-70	Dukki Gel, Sector 3	mid-18th Dynasty	Nubian	Jar	KERMA-IV, Roughly Polished/Wet-smoothed
DG-58	DG.04.03-71	Dukki Gel, Sector 3	mid-18th Dynasty	Nubian	Globular pot, spouted vessel	KERMA-III, Common, Red slipped
DG-59	DG.04.03-72	Dukki Gel, Sector 3	mid-18th Dynasty	Nubian	Cooking pot	KERMA-V, Common

Table 2 Samples analysed by X-ray diffraction within the DiverseNile project.

Sample No.	Site, Location	Period	Tradition	Shape	Macro Ware and Fabric	Performed Analyses
30a	AtW 001, T1, SU 1202	mid-18th Dynasty	Egyptian	Dish	var. Nile clay B2RWallRPin	OM, INAA
30e	AtW 001, T1, SU 1202	mid-18th Dynasty	Egyptian	Zir	var. Nile clay C2WW	OM, INAA
33a	AtW 001, T1, SU 1204	mid-18th Dynasty	Egyptian	Dish	var. Nile clay B2RWallRPin	OM, INAA
33d	AtW 001, T1, SU 1204	mid-18th Dynasty	Nubian	Cooking pot	Nubian 2, Basketry	OM, INAA
34d	AtW 001, T1, SU 1205	mid-18th Dynasty	Egyptian	Zir	var. Nile clay B2WW	OM, INAA
38e	GiE 001, T4, SU 100	New Kingdom	Nubian	Storage vessel	Nubian 2, Red polished	OM, INAA
41	AtW 002, SU 1408	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry	OM, INAA
43a	AtW 002, SU 1414	18th Dynasty	Egyptian	Cooking pot or jar	var. Nile clay RWout	OM, INAA
43d	AtW 002, SU 1414	18th Dynasty	Egyptian	Cooking pot/globular pot	var. Nile clay B2 (chaffy) RWout	OM, INAA
43h	AtW 002, SU 1414, Str. 1	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry	OM, INAA
46	GiE 003, T3, Feature 41, SU 1504	Classic Kerma	Nubian	Jar	Nubian 2, Black-top	INAA
47b	GiE 003, T3, Feature 42, SU 1502	Classic Kerma	Nubian	Storage vessel	Nubian 2	OM, INAA
54	GiE 003, T3, Feature 39, SU 1505	Classic Kerma	Nubian	Cooking pot	Nubian 3, Basketry	OM, INAA
56	GiE 003, T3, Feature 40, SU 1518	Classic Kerma	Nubian	Bowl	Nubian 2	OM, INAA
65	GiE 003, T5, SU 1701	Pan-Grave	Nubian/ Pan-Grave	Bowl	Nubian, Pan-Grave, Herring-bone, see PG.2/De Souza-Ownby 1	OM
66c	GiE 003, T5, SU 1706	Pan-Grave	Nubian/ Pan-Grave	Bowl	Nubian, Pan-Grave, Black-top, see PG.2/De Souza-Ownby 1	OM, INAA
66d	GiE 003, T5, SU 1706	Pan-Grave	Nubian/ Pan-Grave (?)	Beaker	Nubian, Pan-Grave?, Black-top, see PG.5/De Souza-Ownby 2	OM, INAA
66n	GiE 003, T5, SU 1706	Middle Kerma	Nubian	Cooking pot	Nubian 3, Geometric incisions and basketry	OM, INAA
66p	GiE 003, T5, SU 1706	Pan-Grave	Nubian/ Pan-Grave	Bowl	Nubian, Pan-Grave, Black-top, Slipped and polished	OM, INAA
74c	AtW 001, T2, SU 1253	18th Dynasty	Egyptian	Bread mould	var. Nile clay C2 (chaffy)	OM, INAA
81c	AtW 001, T2, SU 1259	18th Dynasty	Nubian/ Pan-Grave	Beaker	Nubian (sim. Pan Grave), Black-top, see PG.4/De Souza-Ownby 3	OM, INAA
81d	AtW 001, T2, SU 1259	18th Dynasty	Egyptian	Dish/plate	var. Nile clay C2UC (chaffy)	OM, INAA
83	AtW 001, T2, SU 1263	18th Dynasty	Egyptian	Cooking pot	Hybrid type, var. Nile clay B2 sandy	OM, INAA
86	AtW 001, T2, SU 1268	18th Dynasty	Nubian	Cooking pot	Nubian 3, Basketry	OM, INAA
87b	AtW 001, T2, SU 1273	18th Dynasty	Egyptian	Beer jar	var. Nile clay B2/C2 (chaffy)	INAA

Table 2 *cont.*

Sample No.	Site, Location	Period	Tradition	Shape	Macro Ware and Fabric	Performed Analyses
88b	AtW 001, T2, SU 1283	18th Dynasty	Egyptian	Cooking pot	var. Nile clay B2UC (part. burned out)	INAA
88d	AtW 001, T2, SU 1283	18th Dynasty	Egyptian	Cooking pot	var. Nile clay B2RW, Rope impressions (part. burned out)	INAA
88e	AtW 001, T2, SU 1283	18th Dynasty	Egyptian	Cooking pot	var. Nile clay B2UC	INAA
92c	AtW 001, T2, SU 1324	18th Dynasty	Egyptian	Bread plate	var. Nile clay B2/C2 (chaffy)	OM, INAA
ABRI Nile clay	Abri	Modern	Replica	Small vessel	Modern Nile clay, Abri village	OM, Raman Spectroscopy

2.2.3 X-ray diffraction analysis

XRD analyses were performed at the clay laboratory of the Chair of Engineering Geology at TUM, Munich, to complement INAA and optical microscopy analyses and increase our knowledge of the composition and production technology of the Nile clay samples. XRD provided information on those mineral phases (i.e., clay minerals) which are typically not distinguishable under the optical microscope. This technique also gives useful insights into the firing process that the ceramic body has undergone. This is based upon the understanding that specific minerals are susceptible to degradation, disappearance or alteration (mineral neoformation) at specific temperatures due to the collapse of their crystalline structure through the process of dehydroxylation.³³

For this analysis, we selected 30 ceramic samples from Nubian- and Egyptian-style sherds that are representative of the corpus data from excavations at the sites of Attab West and Ginis East. To this, we added a replica in modern Nile clay from Abri in Sudan (Table 2).

About 1 g of the ceramic bodies was homogenised and ground using an agate mortar. The XRD analyses were performed on side-loaded powder mounts of ~0.5 g using a BRUKER D8 Advance Eco X-ray diffractometer (CuK α , 40 kV, 25 mA, 2°–75° 2 Θ , 0.01° step size, 1 s/step, 15 mm irradiated length, 2.5° primary and secondary sollers and a LynxEye XE-T detector). The phases in the bulk ceramic powders were then identified using their characteristic diffraction lines, the DIFFRAC.EVA software (BRUKER), the ICDD pdf2 and the

crystallographic open databases. To identify clay minerals, we prepared semi-oriented mounts by pipetting an aqueous suspension of the powder on glass slides and drying them overnight. These were X-rayed in an air-dried state and an ethylene-glycolated state following heating to 550°C.

2.2.4 Raman spectroscopy

The Raman spectroscopic analyses, applicable to reveal differences in the manufacturing technique and firing temperatures of Late Bronze Age ceramics from Nubia,³⁴ were conducted on 20 thin sections at the Mineralogical State Collection in Munich (MSM) with a HORIBA JOBIN YVON XploRA ONE system. All ceramic thin sections have organic inclusions within the matrix intentionally added as temper material, which turned to charcoal due to the manufacturing temperature conditions. Raman spectroscopy offers a reliable method for quantifying the internal structure of charcoal,³⁵ which is highly temperature-dependent up to 1200°C.³⁶ Three specific bands can be characterised for carbon: the defect band (D-band) at ~1350 cm⁻¹, the Valley region (V-region) at ~1450 cm⁻¹, and the graphite band (G-band) at 1580 cm⁻¹ (see below, Fig. 9e). Their apparent intensities can be quantified as heights (HD, HV, HG). For the study presented in section 3.3, four samples from Dukki Gel were compared to six samples from Sai Island.

2.3 Archaeometric analyses of sandstone samples

As the DiverseNile project is concerned with the Bronze Age use of raw materials and resources,

³³ See MAGGETTI 1982; RICE 1987; HEIMANN et al. 2014.

³⁴ DELLEFANT et al. 2023.

³⁵ DELLEFANT et al. 2023.

³⁶ McDONALD-WHARRY et al. 2013; DELDICQUE et al. 2016, 2023; GUIZANI et al. 2017a, 2017b; LAMBRECHT et al. 2021.

the origin and mineralogical properties of Nubian sandstones from Sai Island near the MUAFS region were investigated, building on an earlier study by the ERC AcrossBorders project. This project documented various types of Nubian sandstone, the island's most common rock type.³⁷ A key result was identifying the source of the stone used for New Kingdom structures on Sai, particularly the 18th Dynasty Temple A. In 2016, Dietrich and Rosemarie Klemm identified seven sandstone quarries near the New Kingdom town using lithologically processed Landsat TM images and on-site research.³⁸ Two quarries, sites 1 and 2, located just east of the town wall, were the most accessible for building materials.

The recent investigation aims to determine whether Nubian sandstones from Temple A on Sai Island were locally sourced and how they were selected for building purposes. This was conducted using the following techniques.

2.3.1 Optical microscopy

Uncovered and polished thin sections (~25µm) of 19 samples were prepared from the samples and investigated (Leica DM2700 P) at the Department for Earth and Environmental Sciences, LMU Munich, using both reflected and transmitted polarised light. Photomicrographs were taken with a Leica MC170 HD camera and processed with the Leica Application Suite X 3.08.19082 software. Petrographic information, such as phase determinations and their chemical compositions were ascertained using Raman spectroscopy and SEM, respectively.

2.3.2 Raman spectroscopy

To investigate the combination of chemical composition and its crystallographic structure, Raman spectroscopy provides a fast and easy-to-use approach. Phase determinations of 19 thin section samples were confirmed at the MSM with a HORIBA JOBIN YVON XploRA ONE system.

2.3.3 Scanning electron microscopy

To obtain detailed information about the chemical compositions of specific phases in thin sections, we employed scanning electron microscopy (SEM), which produces high-resolution backscattered

electron (BSE) images. BSE imaging effectively highlights compositional contrasts, with heavier elements appearing brighter, making it essential for distinguishing between different minerals and phases. For this study, six thin section samples were analysed using a Hitachi SU5000 SEM in the Department of Earth and Environmental Sciences at LMU Munich.

3. Results

3.1 Landscape archaeology and the Bronze Age riverscape

In order to understand the landscape and riverscape during the Bronze Age in the MUAFS concession area, the site AtW 001 is particularly relevant. The site is located on a small mound, directly west of what could be a second, smaller mound. Slightly south-east of the site is a large dry-stone wall. A possible paleochannel runs west to east, directly north of the site, which is supported by the low elevation of this area recorded in the Digital Elevation Model achieved with drone photos (Fig. 4).

AtW 001 is part of the larger site 2-T-62 recorded by André Vila in the 1970s.³⁹ The results from our 2022 and 2023 excavations suggest that this rural settlement site is probably related to gold exploitation.⁴⁰ The finds from the site include grindstones, stone tools such as pounders as well as quartz flakes, testifying to grinding and crushing activities, presumably connected with gold working.⁴¹ Substantial layers of mud brick collapse were found as well as several potential phases of poorly preserved mud brick structures. The domestic character of the site is evident from many ashy deposits and rubbish deposits including frequent animal bones, charcoal and pottery sherds, as well as a surprisingly large number of (almost) intact vessels. These vessels, which are of primarily Egyptian tradition but also have a strong Nubian component and hybrid forms, allow a dating of the site to the 18th Dynasty. In addition, several round and oval-shaped storage pits were documented, some of them with traces of firing/ash which could be connected with heating or cooking.

³⁷ DRAGANITS 2014; BUDKA 2020b, 42–52.

³⁸ BUDKA 2020b, 27–28, with references therein. See now DELFANT et al. 2025.

³⁹ VILA 1977b, 88–89, fig. 10.

⁴⁰ BUDKA 2022; BUDKA et al. 2023, 2025; WARD et al. 2025.

⁴¹ BUDKA 2022; BUDKA et al. 2025.

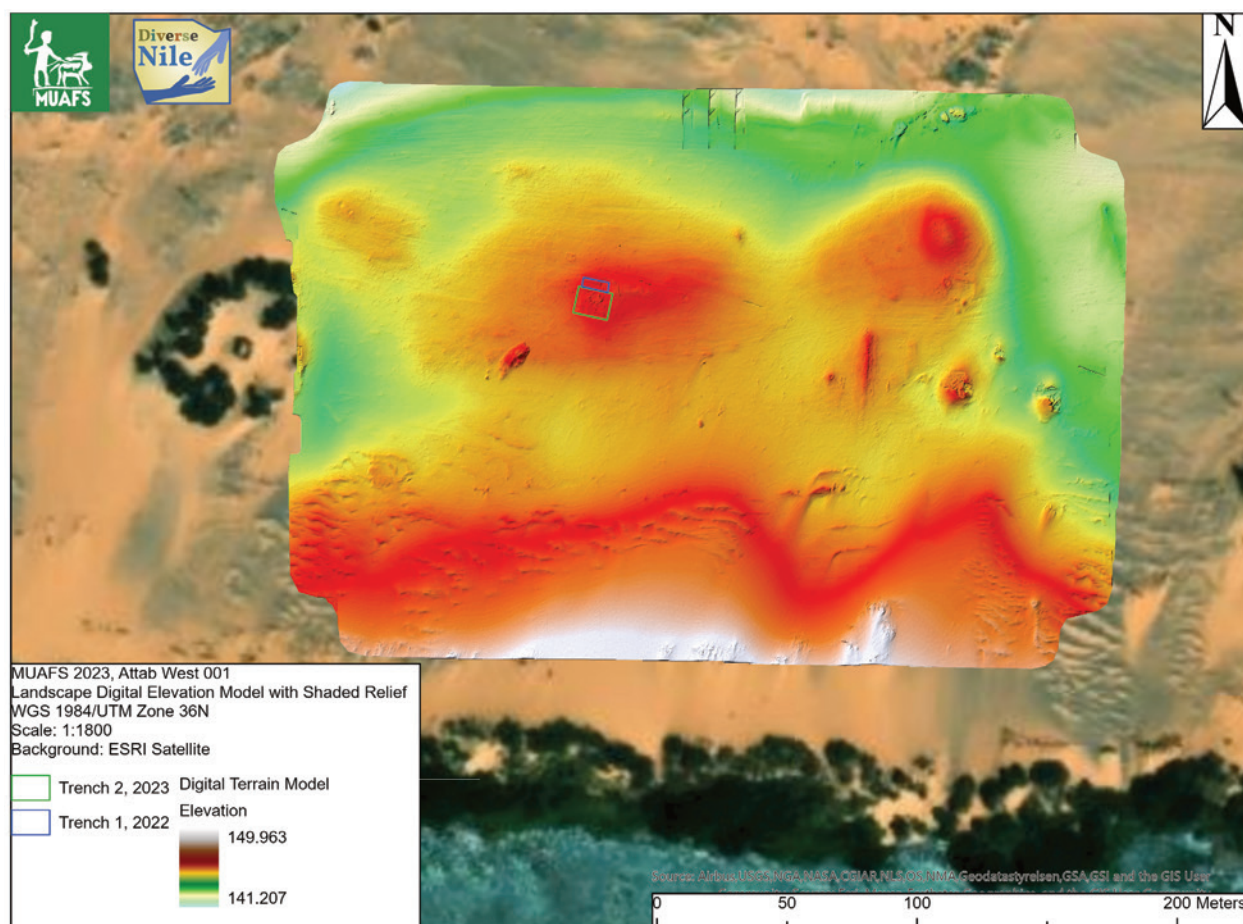


Fig. 4 Landscape Digital Elevation Model with Shaded Relief achieved from drone photos showing the area around Attab West 001. Map: Kate Rose ©DiverseNile project.

3.2 Ceramics: Petrographic and mineralogical data

Based on diagnostic clay mineral phases recognised in the XRD spectra, we distinguished three distinct groups of samples, namely (Fig. 5):

- Group A (9 samples: 43h, 54, 66c, 66d, 66n, 81c, 81d, 86, Abri)
- Group B (8 samples: 30a, 38e, 43a, 43d, 74c, 83, 88b, 92c)
- Group C (13 samples: 30e, 33a, 33d, 34d, 41, 46, 47b, 56, 65, 66p, 87b, 88d, 88e)

These groups show similar primary phases, such as quartz, feldspar (mostly K-feldspar), micas (biotite, muscovite/illite), amphiboles, pyroxenes, zeolites (probably mordenite) and Fe-Ti-oxides (ilmenite, hematite, anatase) which are present in comparable amounts across all samples and are typical of

clayey sediments from the Nile River and its tributaries in Sudan.⁴² All three types also occasionally contain small amounts of secondary, low-temperature (<100°C) phases, such as gypsum or goethite. The main differences observed were in the presence or absence of clay minerals, specifically chlorite, smectite and kaolinite.

Samples from group A are characterised by the presence of chlorite (identified by its 001 reflections at 14.3, 7.07 and 4.71 Å), Ca-smectite in a dehydrated (~9.6 Å) or hydrated state with approximately one water layer (~12 Å), and in part kaolinite (7.15 Å).

Samples from group B also contain smectites but are generally devoid of 14.3. and 7 Å reflections related to kaolinite or chlorite. They do contain a minor peak at 13.9 Å that is related to de-

⁴² See GARZANTI et al. 2015; MARITAN et al. 2023; MOHAMMED-NOOR et al. 2024.

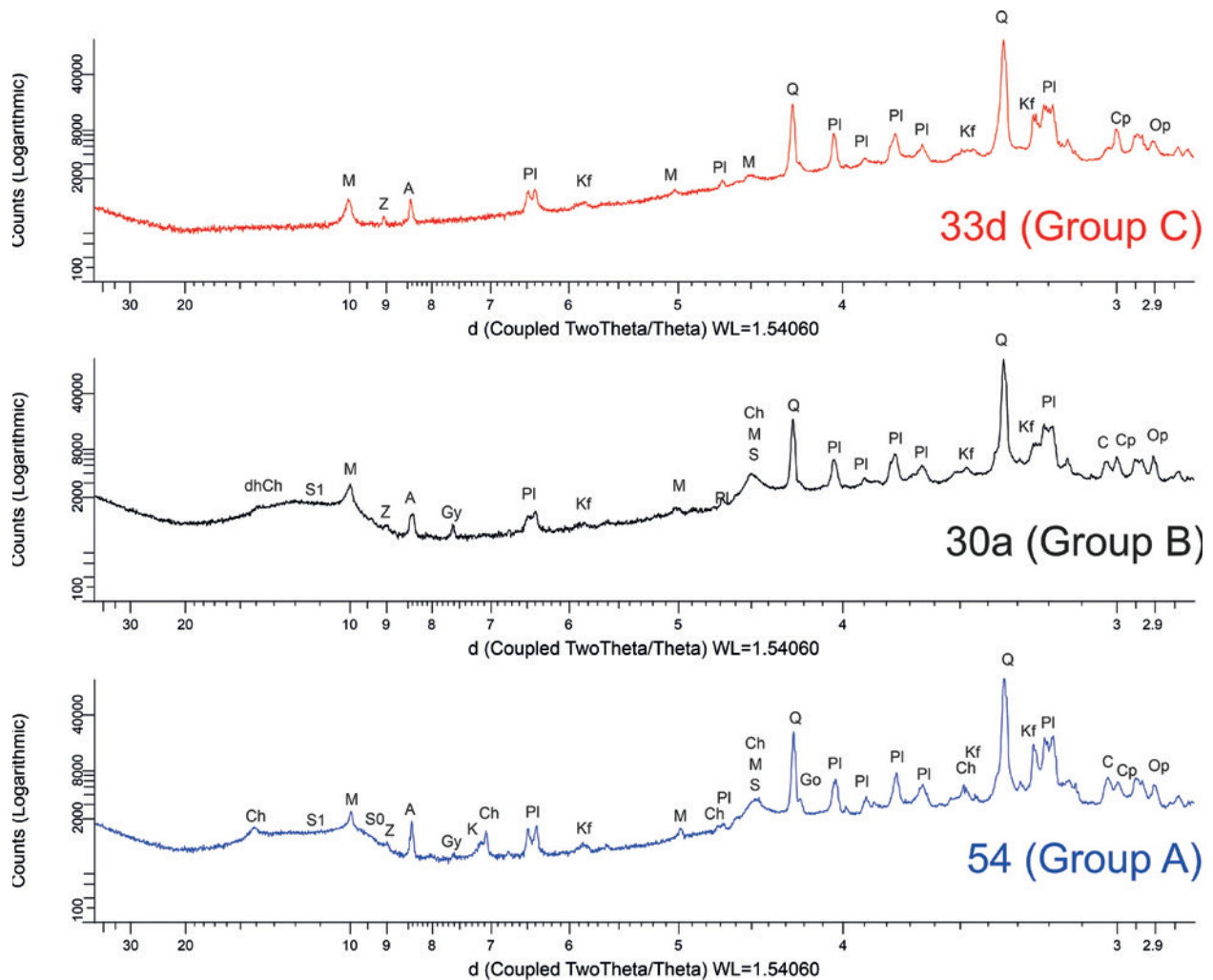


Fig. 5 Representative X-ray diffractograms of the three main groups (A, B, C) of ceramics based on observed clay mineral contents. Abbreviations: A: amphibole, C: calcite, Ch: trioctahedral chlorite, Cp: clinopyroxene, dhCh: dehydroxylated chlorite, Go: goethite, Gy: gypsum, K: kaolinite, Kf: K-feldspar M: muscovite/illite, Op: orthopyroxene, PI: plagioclase, S0: dehydrated smectite, S1: smectite with ~1 water layer, Z: zeolite (mordenite).

hydroxylated chlorite probably indicating firing temperatures above 550°C,⁴³ but probably below the dehydroxylation temperature of the cis-vacant dioctahedral smectites.⁴⁴ Ethylene glycol treatment shows expansion of the smectites to 15 to 17 Å.

Samples from group C lack smectite, chlorite and kaolinite, but exhibit the presence of variable proportions of muscovite/illite. Cross-referencing the petrographic, mineralogical and macroscopic data enabled the identification of certain patterns, as described below (Table 3).

Samples from group A, except sample 81d (Egyptian-style dish/plate, Nile clay C2UC chaffy,

similar to a petrographic fabric from Sai Island)⁴⁵ and the modern Abri sample from Nile clay of the region are all Nubian (Kerma or Pan-Grave) in tradition. They are composed of fired Nile clay and typically contain monocrystalline quartz, polycrystalline quartzite, feldspar, amphibole, iron oxides, biotite and muscovite inclusions, with calcite (micrite) being a common to abundant component. They exhibit a unimodal texture (average grain size in the very fine to fine sand: dominant grain size of ~60–120 µm up to ~250 µm) and are characterised by a high abundance of organic inclusions, which may include herbivore dung, ash, straw and chaff

⁴³ BRINDLEY and ALI 1950; MOORE and REYNOLDS 1997.

⁴⁴ DRITS et al. 1995.

⁴⁵ D'ERCOLE and STERBA 2018; D'ERCOLE forthcoming.

Table 3 Characteristics of the XRD groups, including references to the macroscopic fabrics of the analysed MUAFS samples.

XRD Group	Samples	Main mineral phases	Characteristic features	Tempering	Tradition	Function	Fabric	Firing	Sorting
Group A	43h, 54, 66c, 66d, 66n, 81c, 81d, 86, Abri	Quartz, K-feldspar, micas, amphiboles, pyroxenes, zeolites & Fe-Ti-oxides	Chlorite, smectite (dehydrated/hydrated), kaolinite	Organics & calcite (?)	Mainly Nubian & Pan-Grave	Mainly Cooking pots	Mainly Nubian 3 & Pan-Grave fabrics	Patched reduced/oxidized	Good/Moderate
Group B	30a, 38e, 43a, 43d, 74c, 83, 88b, 92c		Smectite & partly dehydroxylated chlorite	Feldspathic sand	Mainly Egyptian	Mainly Cooking pots	Mainly var. Nile clay B2	Oxidized	Seriate/Slightly Bimodal
Group C	30e, 33a, 33d, 34d, 41, 46, 47b, 56, 65, 66p, 87b, 88d, 88e		Muscovite and illite, NO smectite, chlorite & kaolinite	Organics	Nubian, Pan-Grave & Egyptian	Multiple shapes/functions	Nubian 2, Nubian 3 & var. Nile clay B2	Reduced with narrow Ox	Moderate

remains. The firing process occurred in a reduced atmosphere resulting in a fully black or patched black/red ceramic body with oxidised margins. The presence of non-dehydroxylated trioctahedral chlorite and kaolinite indicates that firing temperatures were less than 500°C.⁴⁶ The presence of dehydrated smectites implies temperatures above about 250°C and that the smectites did not form by a rehydroxylation process⁴⁷ but are rather residual phases consistent with the low firing temperatures.⁴⁸ The gypsum- and goethite-bearing samples do not contain dehydrated but partly rehydrated smectites.

Petrographically, these samples mostly resemble the Sai Island Nubian fabric 3 which is tempered with common (54, 66n) to abundant (43h, 86) organic inclusions (Fig. 6).⁴⁹ The Nubian/Pan-Grave samples 66c (Black-top bowl) and 66d (Black-top beaker) show other affinities respectively with the de Souza's types PG.2 (dung temper) = de Souza/Ownby Petrofabric Group 1 and PG.5 (sand temper) = de Souza/Ownby Petrofabric Group 2. Finally, sample 81c (Black-top beaker) resembles de Souza's type PG.4 (straw temper) = de Souza/Ownby Petrofabric Group 3.⁵⁰

Samples from group B are mostly Egyptian in tradition, with the exception of sample 38e (hand-made storage vessel of unknown date, Nubian fabric 2). They are typically fully oxidised and appear rich

in fired biotite and potassium feldspar while they are generally poor in calcite and organics. They often show amphibole and might contain grog. Sorting is generally good to fair and the grain size is in the range of the very fine to fine sand (~60–120 µm up to 250 µm) (Fig. 6). Only sample 83 shows a coarser grain size and a bimodal/hial texture. These ceramics might have been fired at slightly higher temperatures than samples from group A (see Table 3).

The samples from group B are mostly from cooking wares. Among these, the bread mould (74c) contains traces of pristine clay minerals (i.e., non-dehydroxylated chlorite) and does not show the large amounts of chlorite; thus, it could have been fired at lower temperatures than the other samples of the same group. The same stands for the bread plate 92c. Sample 83 is from a hybrid cooking pot⁵¹ made in a sandy and gritty fabric similar to that of Egyptian cooking pots, with the likely addition of a deliberate quantity of feldspathic sand from the breakdown of granite. It also contains organic inclusions.

Samples from group C are petrographically similar to those from group A (Fig. 6). Samples 30e, 33a and 34d show the highest amount of hematite. These samples are from vessels in either the Nubian- (33d, 41, 46, 47b, 56), Nubian/Pan-Grave (65 and 66p) or Egyptian-style (30e, 33a, 34d, 87b, 88d

⁴⁶ BRINDLEY and ALI 1950; MOORE and REYNOLDS 1997.

⁴⁷ See, e.g., SHOVAL et al. 1991.

⁴⁸ See, e.g., DRITS et al. 1995.

⁴⁹ For this fabric see D'ERCOLE and STERBA 2018; D'ERCOLE forthcoming; also BUDKA 2025b.

⁵⁰ Cf. DE SOUZA 2019; DE SOUZA and OWNBY 2022.

⁵¹ See BUDKA 2024b, 107, fig. 3; 2024c, 26.

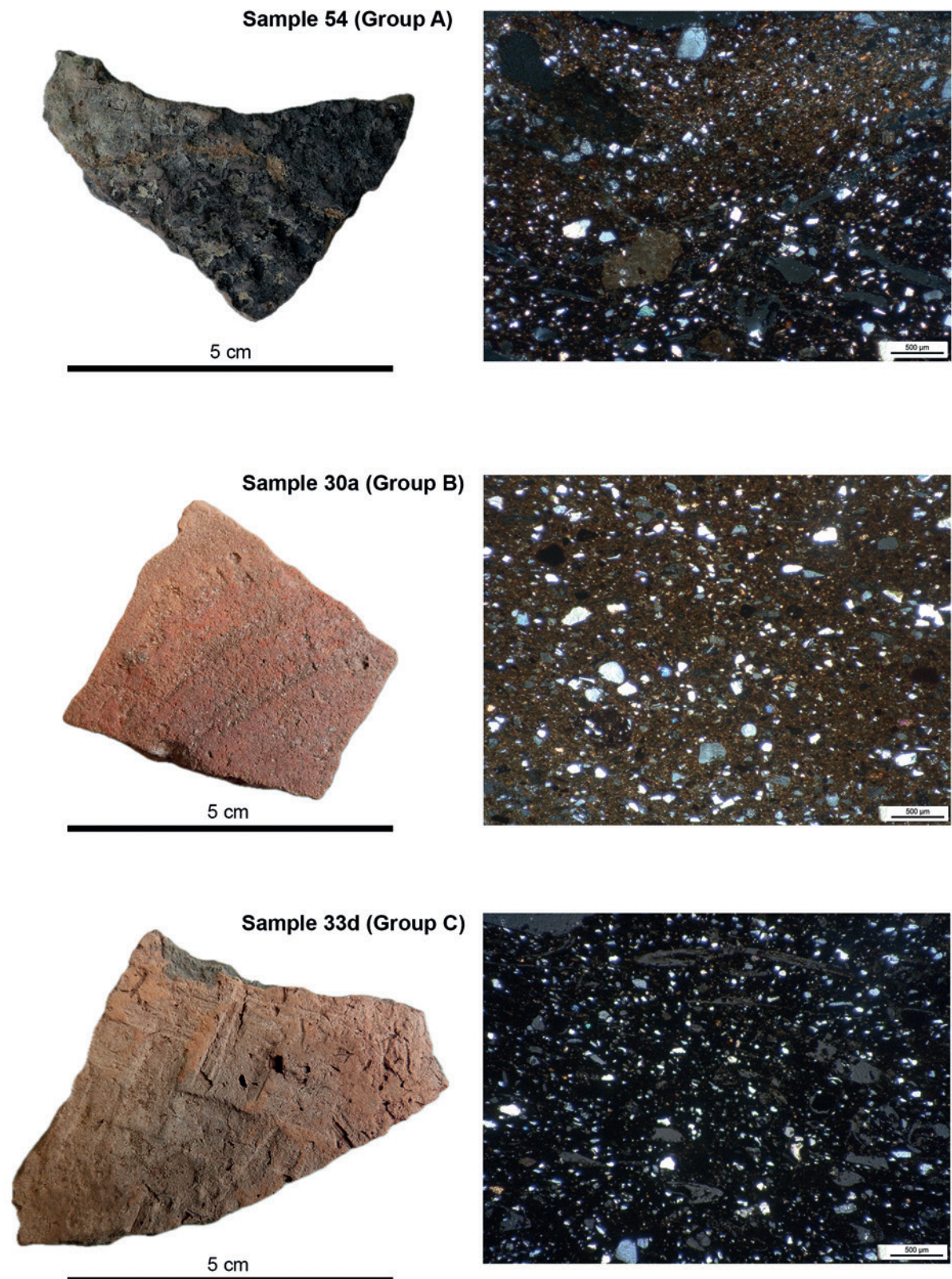


Fig. 6 Macro- and microphotos of representative samples analysed by optical microscopy.

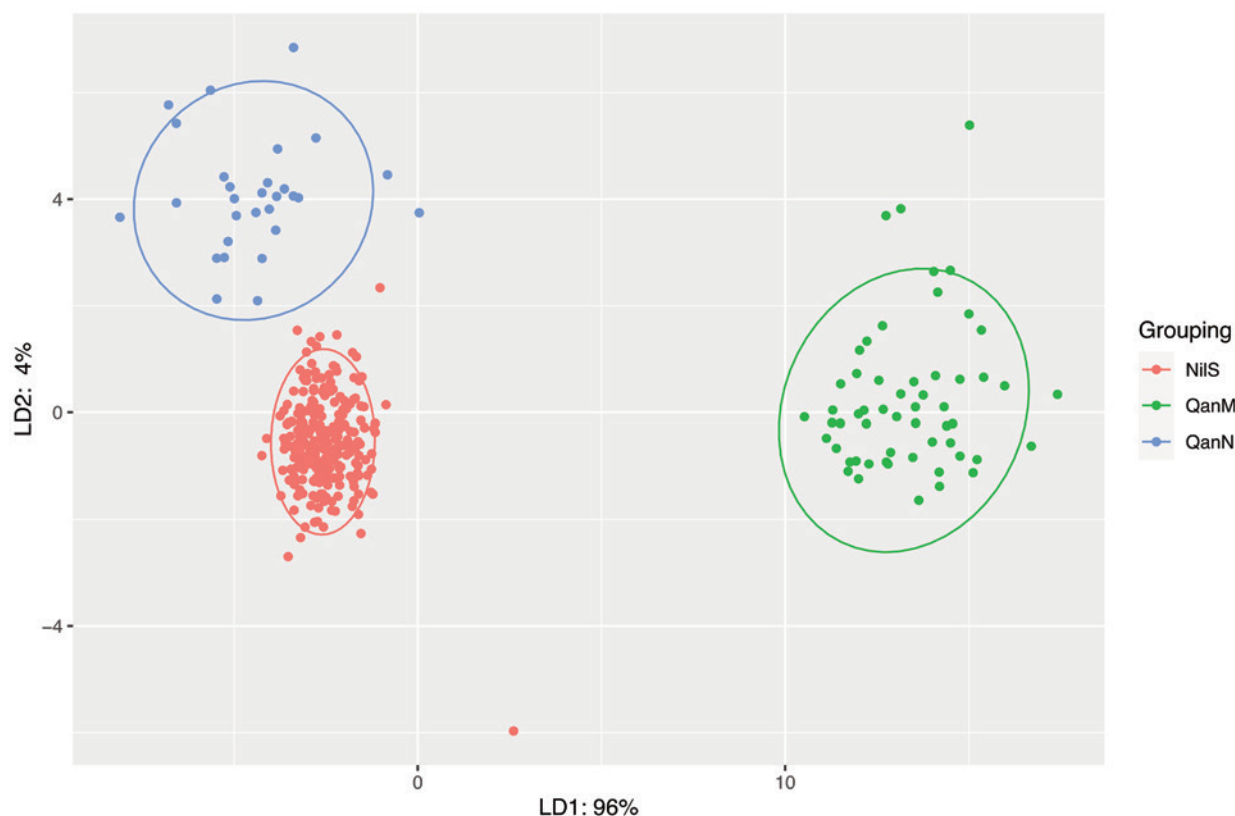


Fig. 7 Discriminant analysis of the three established chemical groups of Nile clay (QanN, QanM and NilS) from the Bonn/Vienna database, including the samples from the current dataset. Ellipses drawn are the 2σ boundaries of the groups. Discriminant analysis is used for visualisation only, grouping is done according to a modified Mahalanobis distance filter.

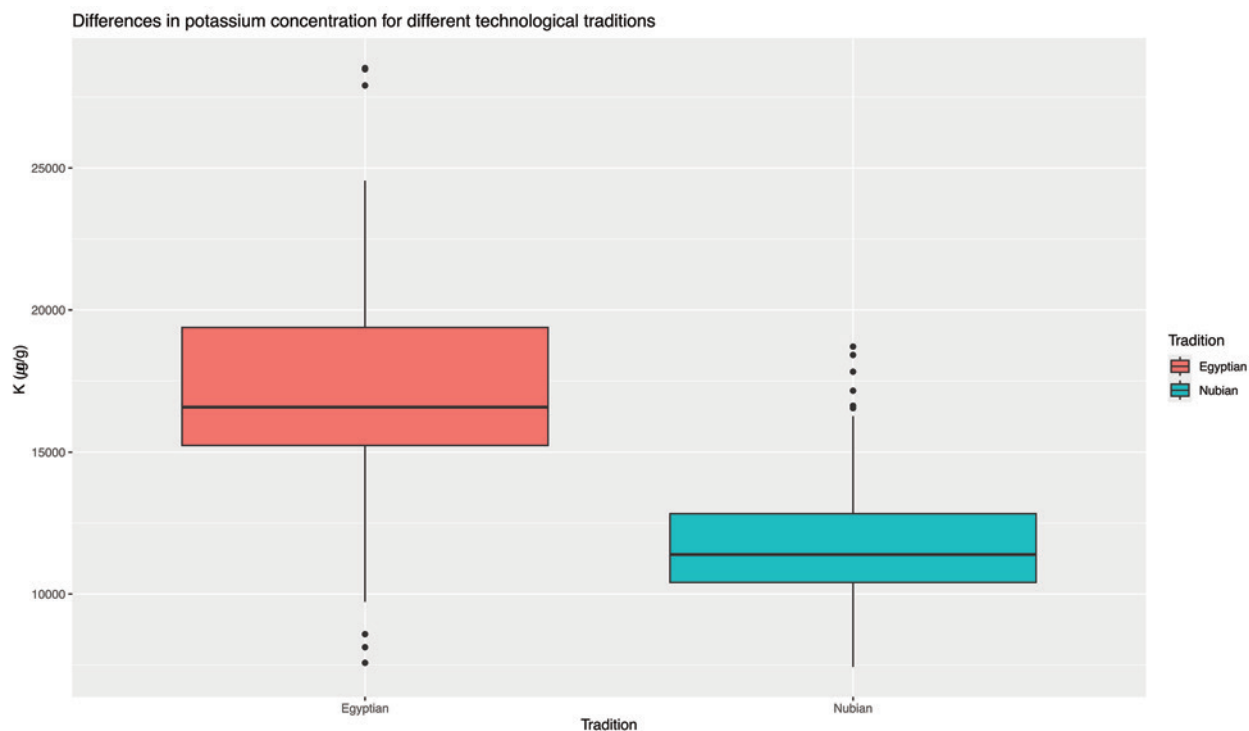


Fig. 8 Comparison of the potassium concentration in Nile clay ceramics, related to their technological and typological tradition.

and 88e) traditions. According to their morphology, they are either cooking pots (33d, 41, 88d and 88e), storage vessels (47b), jars (46, 87b), bowls (56, 65, 66p), zirs (30e, 34d) or dishes (33a). The Nubian-style samples have higher ilmenite and calcite but lower hematite contents compared to the Egyptian-style samples of this group. The absence of chlorite and smectite is noteworthy and might indicate a distinct preparation of the paste (without the need to temper the clay with the addition of coarse sand) or a different raw material source (see below in Discussion).

3.3 Chemical characterisation of Nile clay ceramics

Ceramics produced with Nile clay are very commonly found in archaeological excavations along the Nile River, the MUAFS project and its ceramic material being no exception. Application of Neutron Activation Analysis as a bulk chemical method to establish provenance is, while usually quite successful, severely challenged with this type of samples. Ceramics made of Nile clay are usually characterised by a very homogeneous groundmass with a very similar framework of inclusions that is hardly differentiated along the river bed.⁵²

The 237 samples from the MUAFS concession area measured for this project were compared to the Vienna/Bonn Database of over 20000 ceramic samples and ~1500 chemical groups, including a set of 43 samples from Dukki Gel as well as over 300 samples from Sai Island. Grouping was done following established statistical procedures⁵³ including a modified Mahalanobis distance filter. Comparison to the established groups in the database shows that a total of 126 samples corresponds to one of the three chemical groups of Nile clay. 84 samples belong to the chemical group “NilS”, containing a total of 302 samples; 37 samples belong to the chemical group “QanM” (90 samples in the database) and five more samples belong to the chemical group “QanN” (35 samples in the database). Group “NilS” was established mostly with samples from Sai Island⁵⁴ and can be divided into smaller subgroups. Chemical groups QanM and

QanN were formed following samples of Nile clay ceramics found at Naukratis, Egypt.⁵⁵ The three groups can be separated chemically (see Fig. 7) by their concentration in potassium and several lanthanides. They most likely represent sedimentations of Nile clay that contain a slightly different mineralogical composition. It can be noted that more than half of the samples from the MUAFS dataset that can be correlated with one of the three chemical groups belong to the “NilS” group, which could indicate that the “NilS” group represents Nile clay from the Middle Nile and the southern parts of the Lower Nile, whereas QanM and QanN correlate more with Nile clay from the Egyptian Delta.

While for the Nile clay samples there is no clear chemical separation possible between the Egyptian and Nubian traditions, however, on average, the potassium concentration of the Egyptian tradition is higher than for the samples of Nubian tradition (see Fig. 8). It is doubtful that this indicates the use of different raw materials, however it could indicate different preparations of the clay paste.

3.4 Differentiation of Nubian- and Egyptian-style ceramics using Raman spectroscopy

The firing techniques of a set of Nubian- and Egyptian-style ceramics were investigated via Raman spectroscopy (Figs. 6, 9) to identify the relative maximum firing temperatures.⁵⁶ Both manufacturing traditions (hand-made and wheel-made) used Nile silt clay with organic temper additives, such as herbivore dung, chaff or straw, to strengthen the ceramic material. This leaves characteristic carbonised residues that provide insights into the firing temperature. Organic inclusions within the ceramic samples were first identified via reflected and polarised light microscopy (Fig. 9c, d) and subsequently measured using Raman spectroscopy (Fig. 9d-f).

Our preliminary results, based on average higher HD/HG ratios, show that Egyptian-style ceramics (see XRD group B and Egyptian-style in group C with > hematite; Fig. 9a) reach slightly higher firing temperatures than Nubian-style ceramics (see XRD group A; Fig. 9b, f). The difference in the range of firing temperatures could be that Egyptian-style

⁵² See CARRANO et al. 2009 and SPATARO et al. 2015; for a partly successful assessment of the provenance of clayey sediments along various parts of the Nile, including the Blue and White Nile using chemical, mineralogical and strontium isotope analysis, see MARITAN et al. 2023.

⁵³ See BEIER and MOMMSEN 1994; MOMMSEN and SLÄRBERG 2007.

⁵⁴ D'ERCOLE et al. 2017.

⁵⁵ SPATARO et al. 2019.

⁵⁶ DELLEFANT et al. 2023.

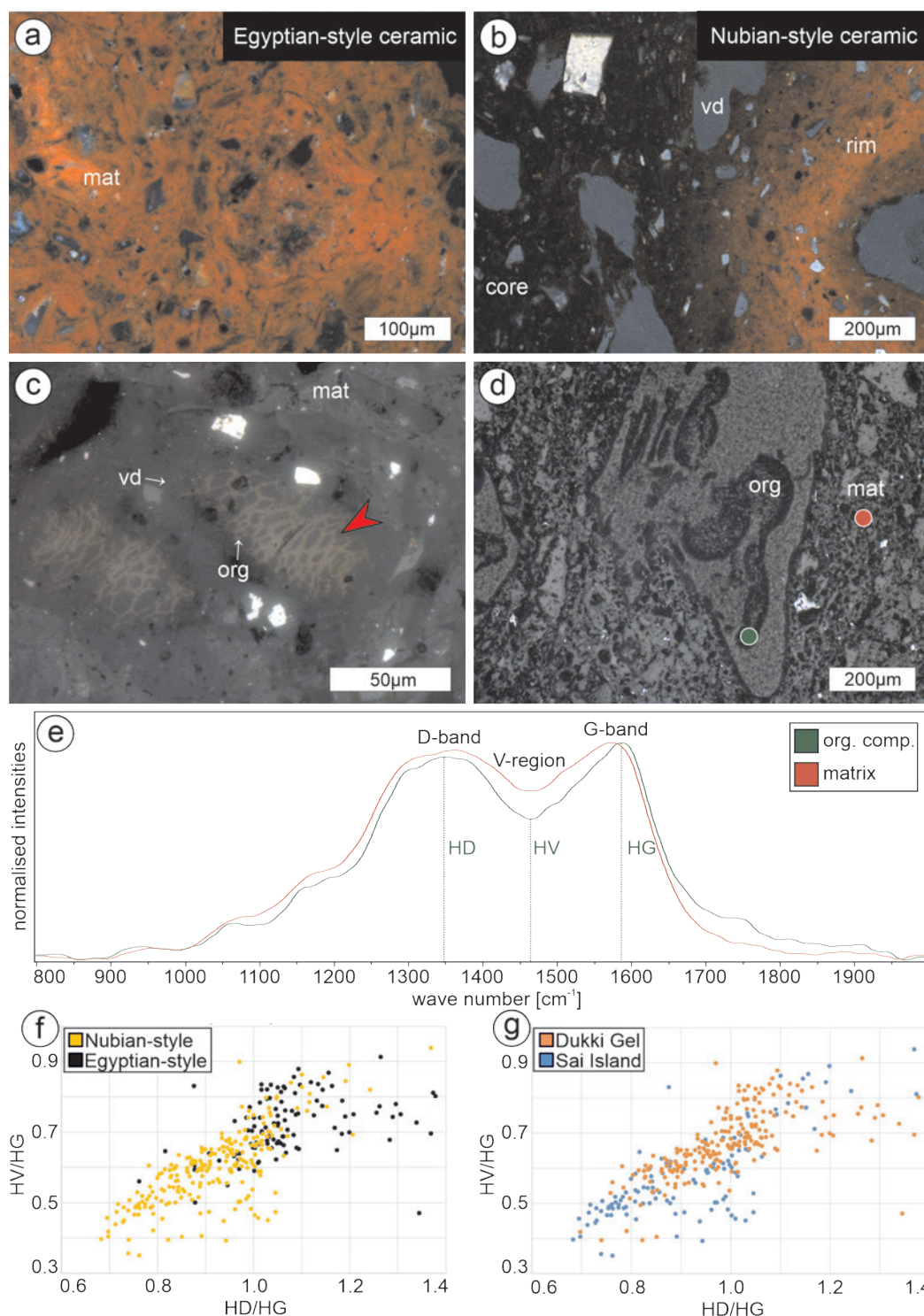


Fig. 9 Photomicrographs (a-d) and Raman spectroscopy investigation (e-f) of Egyptian- and Nubian-style ceramics. a) Oxidised reddish matrix of Egyptian-style ceramic; sample DG-35. b) Reduced blackish core displaying voids (vd) and oxidised reddish rim of Nubian-style ceramic; sample DG-23. (a, b) taken with a reflected polarised light and crossed polarisers. c) Preserved cell structure (red arrow) of organic component (org) within void (vd) in blackish matrix (mat); sample DG-18. d) Organic component (org) within matrix (mat) with respective Raman measurement positions (green and red dots) of data displayed in (e); sample SAV/S 009 taken with reflected polarised light. (c-d) taken with reflected polarised light. e) Raman spectra of organic component (green) and matrix (red) represented by the correspondingly coloured dots shown in (d). Note the heights of the G-band (GD), V-region (HV), and D-band (DG). f, g) All Raman measurements from Dellefant et al. (2023) with ratio of the V-region and G-region heights (HV/HG) plotted against the ratio of the D-band and G-band heights (HD/HG) of Nubian- and Egyptian-style ceramics from Dukki Gel and Sai Island. Note that Egyptian-style samples have higher HD/HG from higher production temperatures and samples from Dukki Gel have higher HV/HG and more scattering than Sai Island samples, indicating more oxidative weathering.

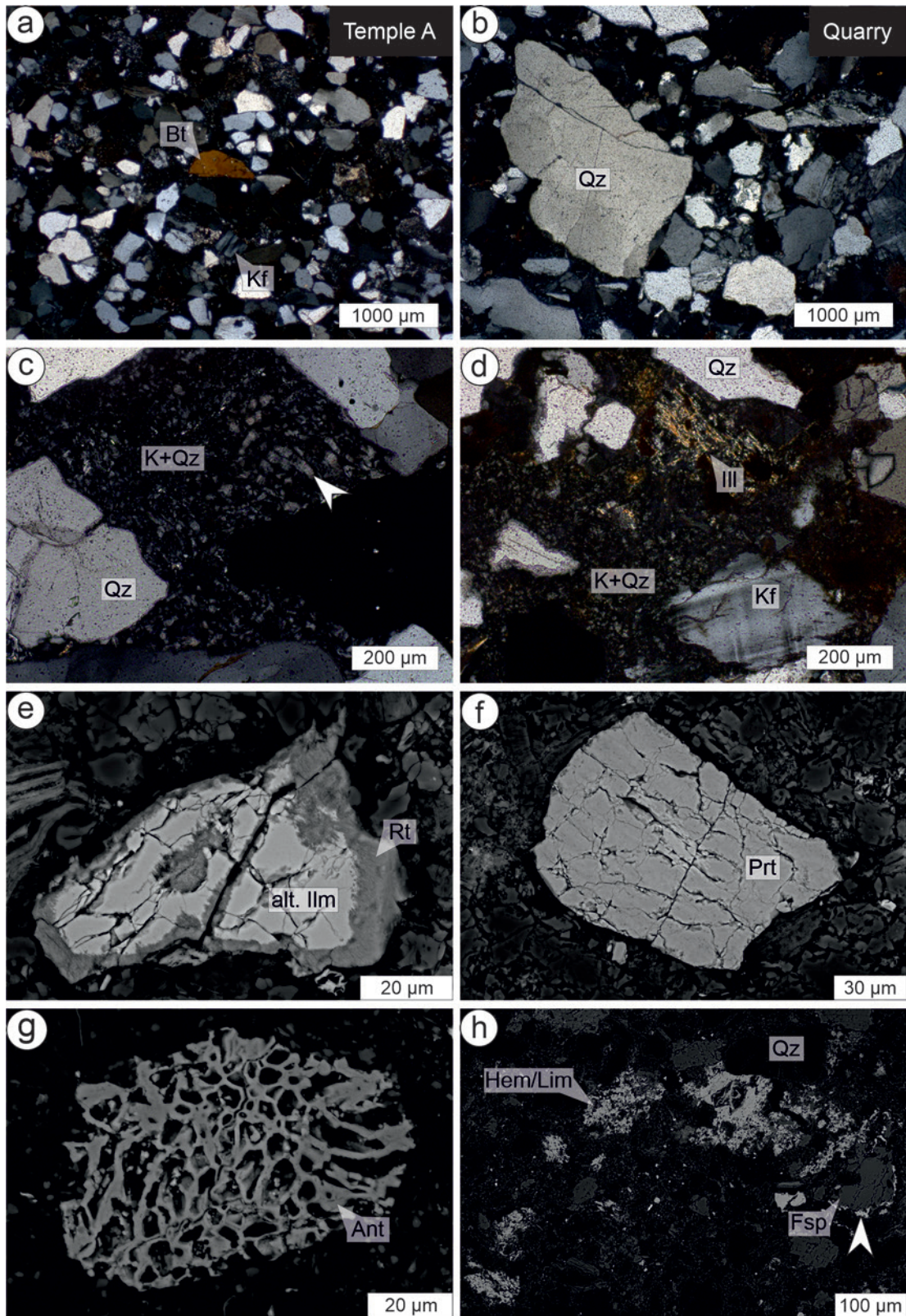


Fig. 10 Overview of Nubian sandstone constituents with major component quartz (qz) and minor K-feldspar (Kf) and phyllosilicates, such as biotite (Bt). Samples from Temple A exhibit a) moderate sorting (sample 15), whereas samples from ancient quarries have b) poor to very poor sorting (sample 6). The matrix is comprised of c) few μm -sized up to tens of μm -log vermicular aggregates of kaolinite (K, white arrow, sample 2) together with c) minor (sub-) μm -sized illite (Ill). Ilmenite alteration products occur throughout all samples and are e) altered ilmenite (alt. Ilm) and rutile (Rt) as well as f) pseudorutile (Prt), and g) anatase (Ant). Upon alteration, iron leaching occurs, which results in the precipitation of h) hematite (Hem) and iron hydroxide minerals (Lim) within vesicles and along grain boundaries (white arrow).

pottery is often oxidised (red surfaces; Fig. 9a), indicating firing in oxygen-rich environments. In contrast, Nubian-style pottery typically has reduced, blackened cores (Fig. 9b), meaning they were fired in lower oxygen environments, resulting in lower maximum firing temperatures overall. Moreover, the study discovered that organic materials were likely ash or plant residue added to the clay paste before firing, based on the findings that the matrix shows distinct HD/HG ratios of amorphous carbon (with the best signal-to-noise ratios) although no organic inclusion could be observed with optical microscopy. Therefore, the respective particle sizes have been interpreted to be in the sub- μm scale.

To quantify absolute temperatures, an ongoing project, discussed in the outlook (5.), will calibrate the measuring conditions of Dellefant and colleagues⁵⁷ to offer a new calibrated methodological approach for archaeology.

3.5 Analysis of Nubian sandstone from Sai Island

For the analysis of the Nubian sandstone samples, OM was applied first, followed by chemical measurements and imaging using SEM and structural investigations using Raman spectroscopy. The sandstones from all the sites on Sai Island are primarily composed of quartz (90–95%), with lesser amounts of feldspar (up to 10%) and lithoclasts (less than 5%) with grain sizes of 250 μm to 1150 μm (Fig. 10a, b). The amount of matrix varies significantly in proportion, ranging from 5% to 50%, and consists of minerals such as kaolinite, illite, and minor amounts of hematite, iron hydroxide minerals and calcite (Fig. 10c, d). The sandstones are classified into two types based on matrix content:⁵⁸ quartz arenites (matrix amount below 15%) and quartz wackes (matrix amount between 15% and 50%). The Fe-Ti-oxide mineral phases of all samples are altered ilmenite and rutile (Fig. 10e), pseudorutile (Fig. 10f), and anatase (Fig. 10g), resembling alteration products that indicate the progressive transformation of ilmenite.⁵⁹ Ilmenite alteration is accompanied by iron leaching,⁶⁰ which resulted in the formation of hematite and iron hydroxide minerals, often along grain boundaries and vesicles (Fig. 10h). Locally, hematite and rutile occur as monocrystalline tens of μm -sized grains in contrast

to the generally (sub-) μm -sized hematite and rutile, which are ilmenite alteration products, implying that the larger grains are not a secondary product of ilmenite but were present before alteration started. The sandstones from Temple A have distinct characteristics compared to those from the quarries. The Temple A samples (Fig. 10a) exhibit moderate sorting, smaller grain sizes (mostly between 250 μm to 310 μm), and lighter colours (ranging from pinkish-gray to very pale orange). In contrast, the samples from the quarries (Fig. 10b) are (very) poorly sorted, with larger grains (up to 750 μm), and often darker colours (reddish-brown and grayish-red).

4. Discussion

In this article, some case studies and their results were presented in the context of the contact space biography approach applied by the DiverseNile project in the MUAFS concession in northern Sudan. From a variety of possible discussion points, some are presented below.

Section 4.1 discusses possible conclusions about Bronze Age contact areas in the MUAFS concession area based on remote sensing, GIS mapping, excavations and the evaluation of the material culture. One focus is on the diachronic development during the Bronze Age in the Attab to Ferka region, as there are major changes between the Kerma period, New Kingdom and later periods.

Section 4.2 reinforces what was discussed in Section 4.1 in relation to dynamic contact spaces, focusing on the importance of our multidisciplinary collaborative study on ceramics for ceramic production and technology in the MUAFS concession area. In addition to trends within the MUAFS region as a rural setting compared to urban contexts in Sai, we discuss possible evidence for co-option and co-operation between Egyptians and Nubians in ceramic production during the colonial New Kingdom.

Section 4.3 discusses the quarrying of Nubian sandstone on Sai Island, which is fundamental to our landscape biography and taskscape approach in the MUAFS region, as Sai represents the main source of quarried sandstone for an extensive area of the Middle Nile Valley during the Bronze Age.

⁵⁷ DELLEFANT et al. 2023.

⁵⁸ DOTT 1964; PETTIJOHN et al. 1987.

⁵⁹ TEMPLE 1966; ANAND and GIKKES 1984; DELLEFANT et al. 2024.

⁶⁰ MÜCKE and BHADRA CHAUDHURI 1991.

Again, the aim is to underline the added value of archaeometric analyses for the cultural understanding of human-environment relationships.

4.1 Bronze Age contact spaces in the MUAFS concession area

Overall, based on the material culture from Attab West 001, its general characteristics and especially its location within the ancient landscape, the site was most likely a control post for trade, gold transport and possibly for communication between hinterland communities and the newly established Egyptian centre on Sai Island.⁶¹ With its mix of material culture, including large amounts of Nubian-style ceramics as well as in-between vessels (combining both the Egyptian and the Nubian traditions), Attab West 001 seems to have functioned as a seasonal market and meeting place for various groups, including mobile communities. When discussing the exchange of commodities, the importance of semi-nomadic and nomadic groups is sometimes neglected in archaeology. Furthermore, the location of Attab West 001 on a former island and the past riverscape both need to be considered — it is possible that the site was only accessible during certain periods, increasing the likelihood of either short-term or seasonal use. To fully assess this, the immediate surroundings of the site still need to be further investigated, especially for the presence of other Bronze Age remains. The possible correlation between what seems to be a sudden abandonment of the site and changes in the waterscape caused by increased aridity (and the possible drying up of the Nile channels around Attab West 001) also needs to be investigated in more detail. A similar interpretation has already been proposed for a later phase at Amara West. This would contribute to discussions on the so-called Northern paleochannel of the region.⁶²

In addition to Attab West 001, the mapping of numerous dry-stone walls similar to the one south-east of the excavation at Attab West 001 adds new information to the ancient use of the district of Attab.⁶³ The features, which are not a complete record

of all the stone walls present, already show a clustering in three main areas: along the west bank of the modern Nile, in the main paleochannel west of site Attab West 002⁶⁴ and in a wadi running north-east to south-west between Attab West 001 and Attab West 002. This could be related to the function of the walls and the former riverscape during the Bronze Age.⁶⁵

The sites excavated and the dry-stone walls mapped so far in Attab West reveal the spatial and temporal dimensions of the landscape⁶⁶ for the Bronze Age communities living in this district. The environmental conditions of this region have changed significantly over time. Woodward and his team have already shown that the New Kingdom was a time of significant environmental change, in particular with the water channels in the region drying up.⁶⁷ In the MUAFS concession, this will be further investigated along the large paleochannel in the districts of Attab and Ginis. For the time being, it is important to visualise the landscape during the period of use of sites like 2-R-18 and Attab West 001 and 002 as crisscrossed by old Nile channels and the aforementioned sites being located on islands — possibly seasonal islands during the flooding season.⁶⁸

Our investigation of the spatial structure and function of the dry-stone walls in Attab is still preliminary but can be placed in the context of recent research.⁶⁹ The recently published analysis of river walls, known as groynes, in the Amara West region was an attempt to reconstruct the long-term landscape history and practice of hydraulic engineering in the region.⁷⁰ Similar to that study, we also observed a wide variety of building materials, techniques, forms and orientations in the landscape, including flat and upright stone stacking, as well as coursing with and without rubble interiors. These particular architectural dry-stone techniques appear to have been used by Nubians across many time periods⁷¹ and are also present at gold working sites such as Duweishat.⁷² In the MUAFS concession area, the arrangement of the walls associated with Kerma sites along, and within, the paleochannels

⁶¹ BUDKA 2022.

⁶² See WOODWARD et al. 2017; DALTON et al. 2023.

⁶³ For a map of these walls in the Attab West district see BUDKA et al. 2023, 33, fig. 20.

⁶⁴ BUDKA et al. 2023, 24–26.

⁶⁵ See, most recently, BUDKA et al. 2025.

⁶⁶ Cf. INGOLD 1993.

⁶⁷ WOODWARD et al. 2017; see also STEVENS and GARNETT 2017.

⁶⁸ STEVENS and GARNETT 2017, 303.

⁶⁹ See also BUDKA et al. 2025.

⁷⁰ DALTON et al. 2023.

⁷¹ LISZKA 2017, 41.

⁷² EDWARDS and MILLS 2020, 406–407.

suggests that they may have served as wadi flood walls linked to activities such as agriculture and gold mining.⁷³

Since we have material evidence to suggest that several sites in the MUAFS concession, including Attab West 001, were connected to the ancient gold mining industry (based on the findings of quartz flakes, stone hammers and grinding stones on the sites), the area is well suited to reconsider past approaches to gold mining in the Middle Nile. We suggest that we need to imagine well-established concepts of co-option and cooperation between Egyptians and Nubians for gold mining through the centuries, both in the Nile Valley and in the desert.⁷⁴ Similar concepts have been proposed for other technologies such as faience production⁷⁵ or copper production,⁷⁶ emphasising the need to focus on taskscapes and contact space biographies rather than studying Egyptian mining and quarrying activities or metallurgy in Kerma in isolation.

The diachronic distribution of sites in the MUAFS concession allows a preliminary reconstruction of a dynamic hinterland of Sai Island during the Bronze Age. The periphery of Sai during the 18th Dynasty, when the island was not only the administrative centre of the region but also the main sandstone quarry of the region and a gold distribution hub,⁷⁷ is similar to the situation in Kerma times. Major changes are evident in the Ramesside period when the new urban site of Amara West was built and the peripheral riverine system modified — in particular along the large paleochannel in the district of Attab, where at present no New Kingdom sites later than the mid-18th Dynasty are attested. This confirms a fluid notion of centre and periphery in the Middle Nile during the Bronze Age, which was influenced as much by the changing landscape as by political changes.

4.2 Ceramic production and technology in the MUAFS concession area

The results of our multidisciplinary collaborative study of ceramics and their complete chaînes opératoires presented herein, although still in a preliminary phase, allow the formulation of a comprehensive understanding of the technology of ceramic production in this region. One which is historically,

environmentally and culturally complex and which presents several challenges to the conventional archaeological theoretical approaches to the study of materiality.

As previously observed in the study of ceramic assemblages from Sai Island and Dukki Gel,⁷⁸ there is typically no notable distinction between Egyptian-style and Nubian-style productions in the selection of raw materials. Indeed, bulk chemical analysis reveals that these ceramics are rather homogeneous, reflecting the general compositional uniformity of alluvial Nile clays. Additionally, this evidence suggests a profound familiarity with the region's geography and a reliance on locally available and relatively timeserving raw materials, rather than culturally specific expertise or an adherence to traditional clay selection practices.

Our initial XRD data from the MUAFS area further corroborates this picture. Group C indicates that the same clay was likely used across a diverse range of traditions as well as for producing various shapes and wares, such as wheel-made, hand-made, coiling, basketry and black-topped vessels. This may be indicative of an open and rather permeable technological and social context of collaborative efforts, connections and shared tasks among multiple individuals, possibly of both Egyptian and Nubian backgrounds, living, making and using their pottery side by side — resulting, among others, in new hybrid versions. It is particularly noteworthy that this trend appears more accentuated in a rural and marginal region, such as the area under investigation between the districts of Attab and Ferka, than in an urban context like Sai Island.

Furthermore, it is interesting to observe that exceptions to this general rule are primarily cooking wares, both of Nubian (XRD group A) and Egyptian (XRD group B) tradition, as well as a few specimens referring to specific bread plate and bread mould fabrics, and a small number of Pan-Grave types. These samples tend to cluster together and differ from the broader and more heterogeneous ceramics from group C.

Overall, the differences found in the mineral composition of these groups (in particular the presence/absence of chlorite and smectite) could be due to a different origin of the raw material (possibly

⁷³ BUDKA et al. 2023, 31.

⁷⁴ BUDKA 2024c.

⁷⁵ See MINOR 2023.

⁷⁶ See RADEMAKERS et al. 2022.

⁷⁷ See BUDKA 2020b, 403–404, 407.

⁷⁸ Cf. D'ERCOLE 2024, 216–217.

local for the majority of ceramics belonging to group C, and otherwise allochthonous for the Nubian cooking ware and some Pan-Grave types from group A, as well as for the Egyptian cooking ware from group B).

Another explanation for the presence/absence of chlorite could be that chlorite only occurs in coarse fractions in the raw material. Finally, it is possible that the firing temperatures for the various ceramics were not the same and thus this affected the incidence of certain mineral phases, i.e., most likely higher temperatures for the Egyptian-style pottery from groups B and C than for the Nubian-style cooking ware from group A.

Similarly, preliminary results from Raman spectroscopy indicated that there is a difference in the firing temperatures between Egyptian-style (typically higher temperatures due to the oxidative atmosphere in kilns) and Nubian-style (lower temperatures due to the reducing firing environment, most likely in open fires) vessels.⁷⁹

Other differences relate to the use of tempering agents. Nubian-style pots, in particular, appear rich in organic tempers. These were added both in the form of herbivore dung and vegetable ash (fine ware) and as straw or chaff (coarse ware).⁸⁰ The addition of feldspathic sand, on the other hand, seems to be exclusive to the manufacture of specific Egyptian-style cooking pots. Finally, as observed at Sai Island, many Nubian potsherds contain micrite or carbonate mudstone, which may have been added to improve the performance of the coarse cooking ware.

Despite these differences, our current proposal, based on our multidisciplinary study of ceramics and their complete chaînes opératoires as well as archaeological evidence, is that during the New Kingdom — the colonial era of cultural entanglement with differing regional responses — there were no culturally specific pottery workshops especially in rural contexts such as the region of Attab to Ferka. Rather, there would have been a single local workshop in which different styles and types of pottery were produced, likely together, of Egyptian-style, hybrid and Nubian-style pottery (as reflected in the heterogeneity of styles/traditions of the ceramics of

our XRD group C). As a result, it is possible that certain stages of the manufacturing sequence took place simultaneously without a significant distinction between the Egyptian and Nubian traditions. In such an ‘open’ and shared production context, Egyptian and Nubian potters would easily have been able to copy and positively influence each other.⁸¹ This could include the replication of key decisions such as the choice of raw materials and preparation or production techniques where these seemed appropriate to the functionality of the vessels (or were simply visually appealing).⁸² This eventually led to the simultaneous production of pottery in both Egyptian-style (wheel-made) and Nubian-style (hand-made) during the Napatan period in the Middle Nile Valley.

4.3 Nubian sandstone quarrying on Sai Island

Mineralogically, all samples of Nubian sandstone from Sai Island show significant similarities, such as mineralogical matrix composition (Fig. 10c, d) and Fe-Ti-oxide assemblage (Fig. 10e-h), which implies that they may have been sourced from similar or identical stratigraphic units. The comparably small amount of feldspar is interpreted as a result of extensive weathering before or during deposition. The matrix in the sandstone samples, dominated by kaolinite and illite, provides insights into the diagenetic history of the rocks. The formation of kaolinite (Fig. 10c, d) is typically associated with feldspar alteration, which occurs during weathering or early diagenesis.⁸³ The presence of illite (Fig. 10d), a secondary clay mineral, likely formed under more advanced diagenetic conditions, suggests that the sandstones experienced moderate to deep burial diagenesis.⁸⁴ Fe-Ti-oxides can generally be used to estimate the temperature and oxygen fugacity conditions during their genesis in the later stages of their magmatic origins in depth⁸⁵ and can thus serve as provenance proxy. The presence of only ilmenite and its alteration products (Fig. 10e-g) as well as primary rutile and hematite throughout the examined Nubian sandstones (from Temple A and the ancient quarries) suggests that the sediments could be derived from a single magmatic source⁸⁶ and, therefore, from the same sedimentary unit.

⁷⁹ DELLEFANT et al. 2023.

⁸⁰ DELLEFANT et al. 2023; D’ERCOLE forthcoming.

⁸¹ For Nubian pottery as integral part of the New Kingdom pottery corpus from Sai see most recently BUDKA 2025b.

⁸² Cf. D’ERCOLE 2024, 217.

⁸³ HUERTAS et al. 1999; LANSON et al. 2002; DILL 2016.

⁸⁴ EHRENBURG et al. 1993.

⁸⁵ HOU et al. 2021.

⁸⁶ LINDSLEY 1991.

However unlikely, it might also be possible that multiple magmatic sources — which experienced similar late-stage temperatures and oxygen fugacity conditions — contributed to the composition of the sediment.

In terms of provenance analysis, we conclude that, although the sandstones from Temple A and the quarries are mineralogically similar, precise matching of quarries to specific temple blocks remains inconclusive. This might be due to the homogeneity of the sandstone compositions across different locations on Sai Island. The difference between samples from Temple A and the quarries regarding grain sizes and colours suggests that the ancient Egyptian builders likely engaged in selective quarrying to obtain more uniform (moderate sorting and grain sizes ranging from 250µm to 310µm [cf., Figure 10a, b]) and visually appealing stones for Temple A's construction. They may have followed a reference standard to ensure the aesthetic consistency of the building materials. Since there are hieroglyphic texts on 'white stone' from Sai that are associated with other New Kingdom temples further north in Nubia,⁸⁷ it is likely that the sandstone from Sai Island was well known and might have been widely exploited as a building material.

5. Conclusions and outlook

Through the DiverseNile project's bottom-up approach of 'contact space biographies', the established categorisation of sites and activities as 'Egyptian' or 'Nubian' can be challenged, and the study of intercultural encounters in the Middle Nile Valley, but also elsewhere, can be revisited. This paper's case studies from recent investigation of landscape properties within the MUAFS concession area and their associated material remains, enhances our understanding of the significant ecological and social transformations in the Middle Nile. Aspects of acceptance, appropriation and ignorance/rejection of Egyptian cultural symbols are traceable for all the indigenous groups in the region, the so-called Kerma culture, the C-group and

the Pan-Grave.⁸⁸ The in-depth study of sites such as Attab West 001, particularly a detailed analysis of their material culture, can help us to better understand the complex networks of rural communities in the Middle Nile Valley and their relationships with the inhabitants of more central sites such as Sai or Amara West, also reflecting the fluid notion of centre and periphery in the Middle Nile of the Bronze Age.⁸⁹

It is, therefore, time to conduct archaeological research in the Nile Valley in a truly interdisciplinary framework, taking advantage of a combination of methods and approaches. With the DiverseNile project, we want to illustrate the fundamental necessity of including social practices, communities and the subsistence strategies of marginal regions in Egyptian and Sudanese archaeology, in order to understand the complexity of cultural processes and encounters. The analytical approach used in this case study of the Attab to Ferka region is applicable to other regions of the world.

The concept of an 'archaeology of interaction'⁹⁰ appears in many respects to be crucial for understanding the social aspects of the Middle Nile — for example of gold mining, but also of many other activities. The already culturally diverse communities living along the Nile, which included both Nubians and Egyptians especially during the Bronze Age, were also in close exchange and contact with nomads and semi-nomads, and the gold business was probably a cooperative activity involving different groups for thousands of years. Similar cooperations are to be expected for agriculture and farming, on which the use of dry-stone walls as wadi flood walls in the MUAFS region may shed light.

As a novel methodological approach in archaeology, Raman spectroscopy facilitates understanding the effects of temperature conditions on ceramics,⁹¹ which allows conclusions to be drawn on technologies, raw materials and more. However, there are currently major problems with the use of Raman spectroscopy on charcoal to assess maximum firing temperatures, especially with the laser calibration. Various Raman laser calibrations and methods exist for reconstructing the maximum heating temperature

⁸⁷ For details including the specific hieroglyphic texts see ULLMANN 2020.

⁸⁸ See, e.g., NÄSER 2013; WILLIAMS 2014; BUDKA 2020a and most recently DE SOUZA and SCHRÖDER 2025.

⁸⁹ Cf. STEIN 2002, also BUDKA et al. 2025 with references on an updated assessment of the outdated model of core and periphery.

⁹⁰ KNAPPETT 2011; see also NÄSER 2012.

⁹¹ DELLEFANT et al. 2023.

of charcoal,⁹² consistently showing an increase in HD/HG ratios and a corresponding decrease in HV/HD and HV/HG ratios. However, no calibration is available for the 532nm wavelength, which provides the best signal-to-noise ratio compared to 638nm and 785nm.⁹³ Additionally, Deldicque and colleagues recently documented that oxidative weathering can alter charcoal, potentially leading to inaccurate firing temperature interpretations.⁹⁴ Weathering typically begins at surfaces and along fractures, likely causing the data scattering observed by Dellefant and colleagues⁹⁵ (Fig. 6f, g), which we aim to statistically characterise as a weathering indicator. To determine absolute maximum firing conditions using the 532nm Raman wavelength, we will produce synthetic charcoal samples at temperatures from 400°C to 1200°C and quantify their HD/HG ratios to create a calibration.

We, moreover, plan to publish an automated data processing tool to check for weathering and interpret maximum firing temperatures from unweathered Raman data. As a result, the novel method will be more accessible, especially for those inexperienced with Raman data processing, and therefore contribute to the archaeological understanding of ceramic production in its broader social and environmental context.

Further results from the DiverseNile project are expected in the near future. For example, XRD will be applied to additional samples and both INAA and Raman investigations on the pottery from the MUAFS concession are still in progress. It can al-

ready be said that the human-environment interactions such as quarry activities, wadi flood walls, gold mining and the reconstruction of the ancient landscape in the area between Attab and Ferka can be better understood thanks to our methodological approach of contact space biography and a range of archaeometric investigations. Above all, it is clear that such human-environment interactions developed dynamically during the Bronze Age.

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⁹² McDONALD-WHARRY et al. 2013; GUIZANI et al. 2017a, 2017b; DELDICQUE et al. 2023.

⁹³ DELLEFANT et al. 2023.

⁹⁴ DELDICQUE et al. 2023.

⁹⁵ DELLEFANT et al. 2023.

Bibliography

- ANAND, R.R. and GILKES, R.J.
1984 Weathering of ilmenite in a lateritic pallid zone, *Clays and Clay Minerals* 32, 363–374, <https://doi.org/10.1346/CCMN.1984.0320504>.
- BEIER, T. and MOMMSEN, H.
1994 Modified Mahalanobis filters for grouping pottery by chemical composition*, *Archaeometry* 36, 287–306, <https://doi.org/10.1111/j.1475-4754.1994.tb00971.x>.
- BRINDLEY, G.W. and ALI, S.C.
1950 X-ray study of thermal transformations in some mag-nesian chlorite minerals, *Acta Crystallographica* 3, 25–30, <https://doi.org/10.1107/S0365110X50000069>.
- BUDKA, J.
2017 Pottery from SAV1North, 119–156, in: J. BUDKA (ed.), *AcrossBorders I. The New Kingdom Town of Sai Island, Sector SAV1 North*, CAENL 4, Vienna.
2019 Towards Middle Nile biographies: The Munich University Attab to Ferka survey project 2018/2019, *Sudan & Nubia* 23, 1–15.
2020a Kerma presence at Ginis East: The 2020 season of the Munich University Attab to Ferka Survey Project, *Sudan & Nubia* 24, 57–71.
2020b *AcrossBorders 2: Living in New Kingdom Sai. With contributions by Johannes Auenmüller; Annette M. Hansen, Frits Heinrich, Veronica Hinterhuber; Ptolemaios Paxinos, Nadja Pöllath, Helmut Sattmann, Sara Schnedl and Martina Ullmann*, AESL 1, Vienna.
2022 Early New Kingdom settlement activities in the periph-ery of Sai Island: towards a contextualisation of fresh evidence from Attab West, *MittSAG – Der Antike Su-dan* 33, 45–61.
2024a Processing reused pottery from settlement contexts in Egypt and Nubia: Challenges & Potential, 83–124, in: A. KILIAN, A. PRUSS and M. ZÖLLER-ENGELHAR-DT (eds.), *Proceedings of the international workshop Excating the extra-ordinary 2: Challenges & merits of working with small finds*, Heidelberg, <https://doi.org/10.11588/propylaeum.1382.c19771>.
2024b Introduction: Foodways in ancient Sudan, 103–112, in: J. BUDKA and R. LEMOS (eds.) 2024.
2024c Introduction: Regionality of resource management in Bronze Age Sudan: an overview and case studies, 19–33, in: J. BUDKA and R. LEMOS (eds.) 2024.
- 2025a The untold tale of a holy mountain. Update on site 3-K-10 located on Jebel Umm Rowag, MUAFS concession area, *MittSAG – Der Antike Sudan* 36, 91–101.
2025b Nubian style pottery from the New Kingdom town of Sai Island, *Old World: Journal of Ancient Africa and Eurasia (Special Issue)* 5, 1–81, <https://doi.org/10.1163/26670755-04020011>.
- BUDKA, J. and DOYEN, F.
2013 Life in New Kingdom towns in Upper Nubia – New evidence from recent excavations on Sai Island, *Egypt and the Levant* 22/23 (2012–2013), 167–208.
- BUDKA, J. and LEMOS, R. (eds.)
2024 *Landscape and resource management in Bronze Age Nubia: Archaeological perspectives on the exploitation of natural resources and the circulation of commodities in the Middle Nile*, CAENL 17, Wiesbaden.
- BUDKA, J., ROSE, K. and WARD, C.
2023 Cultural diversity in the Bronze Age in the Attab to Ferka region: new results based on excavations in 2023, *MittSAG – Der Antike Sudan* 34, 19–35.
- BUDKA, J., AGLAN, H. and WARD, C.
2025 Reconstructing Contact Space Biographies in Sudan During the Bronze Age, *Humans* 5(1), 1, <https://doi.org/10.3390/humans5010001>.
- CARRANO, J.L., FERGUSON, J.R., GIRTY, G.H., SMITH, S.T. and CARRANO, C.J.
2008 A chemical and mineralogical comparison of Nubian and Egyptian style ceramics and the implications for culture contact: preliminary report, *Sudan & Nubia* 12, 90–98.
- CARRANO, J.L., GIRTY, G.H. and CARRANO, C.J.
2009 Re-examining the Egyptian colonial encounter in Nu-bia through a compositional, mineralogical, and tex-tural comparison of ceramics, *Journal of Archaeolo-gical Science* 36, 785–797, <https://doi.org/10.1016/j.jas.2008.11.002>.
- DALTON, M., SPENCER, N., MACKLIN, M.G., WOODWARD, J.C. and RYAN, P.
2023 Three thousand years of river channel engineering in the Nile valley, *Geoarchaeology* 38, 565–587, <https://doi.org/10.1002/gea.21965>.
- DELDICQUE, D., ROUZAUD, J.N. and VELDE, B.
2016 A Raman - HRTEM study of the carbonization of wood: A new Raman-based paleothermometer dedicated to archaeometry, *Carbon N. Y.* 102, 319–329, <https://doi.org/10.1016/j.carbon.2016.02.042>.

- DELDICQUE, D., ROUZAUD, J.N., VANDEVELDE, S., MEDINA-ALCAIDE, M.Á., FERRIER, C., PERRENOUD, C., POZZI, J. and CABANIS, M.
- 2023 Effects of oxidative weathering on Raman spectra of charcoal and bone chars: consequences in archaeology and paleothermometry, *Comptes Rendus. Géoscience* 355, 1–22, <https://doi.org/10.5802/crgeos.186>.
- DELLEFANT, F., D'ERCOLE, G., BUDKA, J. and KALIWODA, M.
- 2023 Differentiation of Late Bronze Age Nubian- and Egyptian-style ceramics from northern Sudan by manufacturing firing temperatures using Raman spectroscopy, *Journal of Archaeological Sciences Reports* 52, 104233, <https://doi.org/10.1016/j.jasrep.2023.104233>.
- DELLEFANT, F., TREPMANN, C.A., SCHMAHL, W.W., GILDER S.A., SLEPTSOVA, I.V. and KALIWODA, M.
- 2024 Ilmenite phase transformations in suevite from the Ries impact structure (Germany) record evolution in pressure, temperature, and oxygen fugacity conditions, *American Mineralogist* 109, 1005–1023, <https://doi.org/10.2138/am-2023-8985>.
- DELLEFANT, F., KLEMM, R., BUDKA, J. and KALIWODA, M.
- 2025 Provenance and selective quarrying of New Kingdom Nubian sandstones on Sai Island, Sudan: Insights from ilmenite alterations and matrix compositions, *Journal of Archaeological Science: Reports* 67, 105370, <https://doi.org/10.1016/j.jasrep.2025.105370>.
- D'ERCOLE, G.
- 2024 Material meanings, technology and cultural choices: Pottery production in Late Bronze Age Nubia, 207–221, in: J. BUDKA and R. LEMOS (eds.) 2024.
- Forthcoming Petrography of the pottery from the New Kingdom town of Sai, in: J. BUDKA, *AcrossBorders 3: Vessels for the home away from Egypt. The pottery corpus from the New Kingdom town of Sai Island*, AESL, Vienna.
- D'ERCOLE, G., BUDKA, J., STERBA, J.H., GARCEA, E.A.A. and MADER, D.
- 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, 24–42, <https://doi.org/10.15184/aqy.2016.262>.
- DE SOUZA, A.M.
- 2019 *New Horizons: The Pan-Grave ceramic tradition in context*, London.
- 2023 The "Bronze Age" concept and Nubia during the second Millennium BCE: does one size fit all?, *Old World: Journal of Ancient Africa and Eurasia* 3 (1), <https://doi.org/10.1163/26670755-20230005>.
- 2024 Blurring boundaries: towards a more integrative view of Nubian-Egyptian interactions, 117–145, in: S. ASHBY and A.J. BRODY (eds.), *New perspectives on ancient Nubia*, Piscataway, NJ.
- DE SOUZA, A.M. and OWNBY, M.F.
- 2022 Re-assessing Middle Nubian cultural constructs through ceramic petrography, *African Archaeological Review* 39, 35–58, <https://doi.org/10.1007/s10437-022-09473-x>.
- DE SOUZA, A.M. and SCHRÖDER, M.-K.
- 2025 De-constructing Nubia: a critical look at cultural divisions in the Nubian Nile Valley, *Old World: Journal of Ancient Africa and Eurasia* 5 (1), 1–25, <https://doi.org/10.1163/26670755-04020003>.
- DILL, H.G.
- 2016 Kaolin: Soil, rock and ore: From the mineral to the magmatic, sedimentary and metamorphic environments, *Earth-Science Reviews* 161, 16–129, <https://doi.org/10.1016/j.earscirev.2016.07.003>.
- DOTT, R.H.J.
- 1964 Wacke, graywacke and matrix; what approach to immature sandstone classification?, *Journal of Sedimentary Research* 34, 625–632, <https://doi.org/10.1306/74D71109-2B21-11D7-8648000102C1865D>.
- DRAGANITS, E.
- 2014 Geoarchaeological investigations on Sai Island (Sudan), *Rapp. AcrossBorders Geoarchaeological Fieldwork*, 11 pages, <https://doi.org/10.13140/RG.2.2.24775.70563>.
- DRITS, V.A., BESSON, G. and MULLER, F.
- 1995 An improved model for structural transformations of heat-treated aluminous dioctahedral 2:1 layer silicates, *Clays and Clay Minerals* 43, 718–731, <https://doi.org/10.1346/CCMN.1995.0430608>.
- EDWARDS, D.N. and MILLS, A.J. (eds.)
- 2020 *The archaeological survey of Sudanese Nubia, 1963–69: The pharaonic sites*, Sudan Archaeological Research Society Publication 23, Oxford.
- EGER, J., and KARBERG, T.
- 2020 Nord-Kordofan im Satellitenbild: Vorbericht über die Forschungen des InterLINK-Projektes 2020, *MittSAG – Der Antike Sudan* 31, 87–98.
- EHRENBERG, S.N., AAGAARD, P., WILSON, M.J., FRASER, A.R. and DUTHIE, D.M.L.
- 1993 Depth-dependent transformation of kaolinite to dickite in sandstones of the Norwegian continental shelf, *Clay*

- Minerals* 28, 325–352, <https://doi.org/10.1180/clay-min.1993.028.3.01>.
- FRANCIGNY, V.
2024 Saï: recherches récentes et projet patrimonial à grande échelle, *Bulletin de la Société Française d'Égyptologie* 211, 3–38.
- GARZANTI, E., ANDÒ, S., PADOAN, M., VEZZOLI, G. and EL KAMMAR, A.
2015 The modern Nile sediment system: Processes and products, *Quaternary Science Reviews* 130, 9–56, <https://doi.org/10.1016/j.quascirev.2015.07.011>.
- GEIGER, C.
2019 Drone aerial photography, in: J. BUDKA 2019, 22.
- GRATIEN, B.
2014 Kerma north of the Third Cataract, in: J.R. ANDERSON and D. A. WELSBY (eds.), *The Fourth Cataract and beyond: proceedings of the 12th International Conference for Nubian Studies*, Leuven; Paris; Walpole, MA, 95–101.
- GUIZANI, C., JEGUIRIM, M., VALIN, S., LIMOUSY, L. and SALVADOR, S.
2017a Biomass chars: The effects of pyrolysis conditions on their morphology, structure, chemical properties and reactivity, *Energies* 10, <https://doi.org/10.3390/en10060796>.
- GUIZANI, C., HADDAD, K., LIMOUSY, L. and JEGUIRIM, M.
2017b New insights on the structural evolution of biomass char upon pyrolysis as revealed by the Raman spectroscopy and elemental analysis, *Carbon N. Y.* 119, 519–521. <https://doi.org/10.1016/j.carbon.2017.04.078>.
- HEIMANN, R.B., MAGGETTI, M., HEIMANN, G. and MAGGETTI, J.
2014 *Ancient and historical ceramics: materials, technology, art and culinary traditions*, Stuttgart.
- HOU, T., BOTCHARNIKOV, R., MOULAS, E., JUST, T., BERNDT, J., KOEPKE, J., ZHANG, Z., WANG, M., YANG, Z. and HOLTZ, F.
2021 Kinetics of Fe-Ti oxide re-equilibration in magmatic systems: Implications for thermo-oxybarometry, *Journal of Petrology* 61, 1–24, <https://doi.org/10.1093/peetrology/egaa116>.
- HUERTAS, F.J., FIORE, S. HUERTAS, F. and LINARES, J.
1999 Experimental study of the hydrothermal formation of kaolinite, *Chemical Geology* 156, 171–190, [https://doi.org/10.1016/S0009-2541\(98\)00180-6](https://doi.org/10.1016/S0009-2541(98)00180-6).
- INGOLD, T.
1993 The temporality of the landscape, *World Archaeology* 25, 152–174, <https://doi.org/10.1080/00438243.1993.9980235>.
- JESSE, F.
2025 Bronze Age as a term in northeast African archaeology? A plea for regional chronologies, *Old World: Journal of Ancient Africa and Eurasia* 5 (1), <https://doi.org/10.1163/26670755-04020006>.
- KNAPPETT, C.
2011 *An archaeology of interaction*, Oxford.
- KOLEN, J. and RENES, H.
2015 Landscape Biographies: Key Issues, 21–47, in: J. KOLEN, H. RENES and R. HERMANS (eds.), *Landscape biographies: Geographical, historical and archaeological perspectives on the production and transmission of landscapes*, Amsterdam.
- LAMBRECHT, G., RODRÍGUEZ DE VERA, C., JAMBRINA-ENRÍQUEZ, M., CREVECOEUR, I., GONZALEZ-URQUIJO, J. LAZUEN, T., MONNIER, G., PAJOVIĆ, G., TOSTEVIN, G. and MALLOL, C.
2021 Characterisation of charred or, ganic matter in micro-morphological thin sections by means of Raman spectroscopy, *Archaeological and Anthropological Sciences* 13, <https://doi.org/10.1007/s12520-020-01263-3>.
- LANSON, B., BEAUFORT, D., BERGER, G., BAUER, A., CASSAGNABÈRE, A. and MEUNIER, A.
2002 Authigenic kaolin and illitic minerals during burial diagenesis of sandstones: a review, *Clay Minerals* 37, 1–22, <https://doi.org/10.1180/0009855023710014>.
- LINCK, R., BUSCHE, T., BUCKREUSS, S., FASSBINDER, J.W.E. and SEREN, S.
2013 Possibilities of archaeological prospection by high-resolution X-band satellite radar – a case study from Syria, *Archaeological Prospection* 20, 97–108, <https://doi.org/10.1002/arp.1444>.
- LINDSLEY, D.H.
1991 Experimental studies of oxide minerals, 69–106, in: D.H. LINDSLEY (ed.), *Oxide Minerals: Petrologic and Magnetic Significance*, Berlin/Boston, <https://doi.org/10.1515/9781501508684-006>.
- LISZKA, K.
2017 Egyptian or Nubian? Dry-stone architecture at Wadi el-Hudi, Wadi es-Sebua, and the Eastern Desert, *Journal of Egyptian Archaeology* 103, 35–51, <https://doi.org/10.1177/0307513317714407>.
- MAGGETTI, M.
1982 Phase analysis and its significance for technology and origin, 121–133, in: J.S. OLIN and A.D. FRANKLIN (eds.), *Archaeological Ceramics*, Washington.

- MARITAN, L., GRAVAGNA, E., CAVAZZINI, G. ZERBONI, A., MAZZOLI, C., GRIFA, C., MERCURIO, M., MOHAMED, A.A., USAI, D. and SALVATORI, S.
- 2023 Nile River clayey materials in Sudan: Chemical and isotope analysis as reference data for ancient pottery provenance studies, *Quaternary International* 657, 50–66, <https://doi.org/10.1016/j.quaint.2021.05.009>.
- MCDONALD-WHARRY, J., MANLEY-HARRIS, M. and PICKERING, K.
- 2013 Carbonisation of biomass-derived chars and the thermal reduction of a graphene oxide sample studied using Raman spectroscopy, *Carbon N. Y.* 59, 383–405, <https://doi.org/10.1016/j.carbon.2013.03.033>.
- MINOR, E.J.
- 2023 Faience Tiles from Deir el-Ballas and Kerma: New evidence of Egyptian-Nubian relations at the foundation of the New Kingdom, 103–116, in: D. KISER-GO and C.A. REDMOUNT (eds.), *Weseretskau “mighty of kas”: papers in memory of Cathleen A. Keller*, Columbus.
- MOHAMMEDNOOR, M., BIBI, F., EISAWI, A., TSUKAMOTO, S. and BUSSERT, R.
- 2024 Quaternary alluvial paleosols of the Atbara River, eastern Sudan: description and paleoenvironments, *Journal of Quaternary Science* 39, 102–118, <https://doi.org/10.1002/jqs.3574>.
- MOMMSEN, H. and SLÄRBERG, B.L.
- 2007 The Importance of the ‘Best Relative Fit Factor’ when evaluating elemental concentration data of pottery demonstrated with Mycenaean sherds from Sinda, Cyprus, *Archaeometry* 49, 359–371, <https://doi.org/10.1111/j.1475-4754.2007.00306.x>.
- MOORE, D.M. and REYNOLDS, R.C. Jr.
- 1997 *X-ray diffraction and the identification and analysis of clay minerals*, Oxford, New York, <https://doi.org/10.1346/CCMN.1990.0380416>.
- MORRIS, E.
- 2018 *Ancient Egyptian Imperialism*, Hoboken.
- MÜCKE, A. and BHADRA CHAUDHURI, J.N.
- 1991 The continuous alteration of ilmenite through pseudomorph to leucosene, *Ore Geological Review* 6, 25–44, [https://doi.org/10.1016/0169-1368\(91\)90030-B](https://doi.org/10.1016/0169-1368(91)90030-B).
- NÄSER, C.
- 2012 Nomads at the Nile: towards and archaeology of interaction, 80–89, in: H. BARNARD and K. DUISTERMAAT (eds.), *The history of the peoples of the Eastern Desert*, Los Angeles.
- 2013 Die C-Gruppe: Unternubien im 3. und 2. Jahrtausend v. Chr., 105–120, in: S. WENIG and K. ZIBELIUS-CHEN (eds.), *Die Kulturen Nubiens – ein afrikanisches Vermächtnis*, Dettelbach.
- PETTJOHN, F.J., POTTER, P.E. and SIEVER, R.
- 1987 *Sand and sandstone*, 2nd ed., New York.
- RADEMAKERS, F.W., VERLY, G., DEGRYSE, P., VANHAECKE, F., MARCHI, S. and BONNET, C.
- 2022 Copper at ancient Kerma: A diachronic investigation of alloys and raw materials, *Advances in Archaeomaterials* 3, 1–18, <https://doi.org/10.1016/j.aia.2022.01.001>.
- RETZMANN, A., BUDKA, J., ZIMMERMANN, T., IRRGEHER, J., PRÖFROCK, D. and PROHASKA, T.
- 2019 *Sr and Pb isotope ratio analyses and its application to investigate cultural interactions in ancient Nubia (c. 1539–1077 BC)*, Poster, European Winter Conference on Plasma Spectrochemistry EWCPs-2019, Pau, France, 3–8 February 2019.
- RICE, P.M.
- 1987 *Pottery analysis. A sourcebook*, Chicago.
- SALISBURY, R.B.
- 2016 *Soils in archaeology: Settlement and social organization in the Neolithic of the great Hungarian Plain*, Budapest.
- SHOVAL, S., BECK, P., KIRSH, Y., LEVY, D., GAFT, M. and YADIN, E.
- 1991 Rehydroxylation of clay minerals and hydration in ancient pottery from the ‘Land of Geshur,’ *Journal of Thermal Analysis and Calorimetry* 37, 1579–1592, <https://doi.org/10.1007/BF01913490>.
- SMITH, S.T.
- 2003 *Wretched Kush: Ethnic identities and boundaries in Egypt’s Nubian Empire*, London.
- 2024 Foodways and cultural entanglements in New Kingdom Nubia, 173–197, in: J. BUDKA and R. LEMOS (eds.) 2024.
- SPATARO, M., MILLET, M. and SPENCER, N.
- 2015 The New Kingdom settlement of Amara West (Nubia, Sudan): mineralogical and chemical investigation of the ceramics, *Archaeological and Anthropological Sciences* 7(4), 399–421, <https://doi.org/10.1007/s12520-014-0199-y>.
- SPATARO, M., MOMMSEN, H. and VILLING, A.
- 2019 Making pottery in the Nile Delta: ceramic provenance and technology at Naukratis, 6th–3rd centuries BC, *Archaeological and Anthropological Sciences* 11, 1059–1087, <https://doi.org/10.1007/s12520-017-0584-4>.

- SPENCER, N.
- 2014 Creating and Re-Shaping Egypt in Kush: Responses at Amara West, *Journal of Ancient Egyptian Interconnections* 6, 42–61, https://doi.org/10.2458/azu_jaei_v06i1_spencer.
- 2017 Building on new ground: the foundation of a colonial town at Amara West, 323–355, in: N. SPENCER, A. STEVENS and M. BINDER (eds.), *Nubia in the New Kingdom. Lived experience, pharaonic control and indigenous traditions*, British Museum Publications on Egypt and Sudan 3, Leuven.
- STEIN, G.J.
- 2002 From passive periphery to active agents: Emerging perspectives in the archaeology of interregional interaction, *American Anthropologist* 104, 903–916, <https://doi.org/10.1525/aa.2002.104.3.903>.
- STERBA, J.H.
- 2018 A workflow for Neutron Activation Analysis of archaeological ceramics at the Atominstitut in Vienna, Austria; *Journal of Radioanalytical and Nuclear Chemistry* 316(2): 753–759; <https://doi.org/10.1007/s10967-018-5803-7>.
- STERBA, J.H. and D'ERCOLE, G.
- 2018 From macro wares to micro fabrics and INAA compositional groups: the pottery corpus of the New Kingdom town on Sai Island (northern Sudan), 171–183, in: J. BUDKA and J. AUENMÜLLER (eds.), *From microcosm to macrocosm: Individual households and cities in ancient Egypt and Nubia*, Leiden.
- Forthcoming Chemical analysis of the pottery from the New Kingdom town of Sai, in: J. BUDKA, *AcrossBorders 3: Vessels for the home away from Egypt. The pottery corpus from the New Kingdom town of Sai Island*, AESL, Vienna.
- STEVENS, A. and GARNETT, A.
- 2017 Surveying the Pharaonic Desert Hinterland of Amara West, 227–306, in: N. SPENCER, A. STEVENS and M. BINDER (eds.), *Nubia in the New Kingdom: Lived experience, pharaonic control and indigenous traditions*, British Museum Publications on Egypt and Sudan 3, Leuven.
- STOCKHAMMER, P. and ATHANASSOV, B.
- 2018 Conceptualising contact zones and contact spaces: An archaeological perspective, 93–112, in: S. GIMATZIDIS, M. PIENIAŻEK and S. MANGALOĞLU-VOTRUBA (eds.), *Archaeology across frontiers and borderlands. Fragmentation and connectivity in the North Aegean and the Central Balkans from the Bronze Age to the Iron Age*, Vienna.
- TEMPLE, A.K.
- 1966 Alteration of ilmenite, *Economic Geology* 61, 695–714, <https://doi.org/10.2113/gsecongeo.61.4.695>.
- ULLMANN, M.
- 2020 2.4 Textual sources for sandstone from Sai, 52–58, in: J. BUDKA 2020b.
- VILA, A.
- 1976a *La prospection archéologique de la Vallée du Nil, au Sud de la Cataracte de Dal (Nubie Soudanaise). Fascicule 3: District de Ferka (Est et Ouest)*, Paris.
- 1976b *La prospection archéologique de la Vallée du Nil, au Sud de la Cataracte de Dal (Nubie Soudanaise). Fascicule 4: District de Mograkka (Est et Ouest), District de Kosha (Est et Ouest)*, Paris.
- 1977a *La prospection archéologique de la Vallée du Nil, au Sud de la Cataracte de Dal (Nubie Soudanaise). Fascicule 5: District de Ginis (Est et Ouest)*, Paris.
- 1977b *La prospection archéologique de la Vallée du Nil, au Sud de la Cataracte de Dal (Nubie Soudanaise). Fascicule 6: District de Attab (Est et Ouest)*, Paris.
- WARD, C., KRATIMENOS, P., AGLAN, H. and BUDKA, J.
- 2025 Establishing a dialogue – settlement and funerary archaeology in northern Sudan, *World Archaeology*, 1–26, <https://doi.org/10.1080/00438243.2025.2567057>
- WILLIAMS, B.B.
- 2014 Some geographical and political aspects to relations between Egypt and Nubia in C-Group and Kerma times, ca. 2500–1500 B.C., *Journal of Ancient Egyptian Interconnections* 6, 62–75, https://doi.org/10.2458/azu_jaei_v06i1_williams.
- WOODWARD, J., MACKLIN, M., FIELDING, L., MILLAR, I., SPENCER, N., WELSBY, D. and WILLIAMS, M.
- 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., MACKLIN, M., SPENCER, N., BINDER, M., DALTON, M., HAY, S. and HARDY, A.
- 2017 Living with a changing river and desert landscape at Amara West, 227–257, in: N. SPENCER, A. STEVENS and M. BINDER (eds.), *Nubia in the New Kingdom: Lived*

experience, pharaonic control and indigenous traditions, British Museum Publications on Egypt and Sudan 3, Leuven.

ZIMMERMANN, T., RETZMANN, A., SCHÖBER, M., PRÖFROCK, D., PROHASKA, T. and IRRGEHER, J.

2019 Matrix separation of Sr and Pb for isotopic ratio analysis of Ca-rich samples via an automated simultaneous separation procedure, *Spectrochimica Acta Part B: Atomic Spectroscopy* 151, 54–64.

